GENERATION AND MANAGEMENT OF WASTES AND SECONDARY MATERIALS

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Petroleum Refining Performance

Generation and Management of Wastes and Secondary Materials

Petroleum Refining Performance 1989 Survey

AMERICAN PETROLEUM INSTITUTE

HEALTH AND ENVIRONMENTAL AFFAIRS DEPARTMENT

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FORWARD

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Each year, U.S. petroleum refineries process 650 million tons of crude oil as they create fuels and other petroleum products vital to the U.S. economy and way of life. Not much waste results -- less than 1 percent of those 650 million tons. Still, that amount of waste is a big number in its own right.

This is the third annual survey of wastes generated by U.S. petroleum refineries -- and how they handle those wastes. Conducted by the American Petroleum Institute, it is the only ongoing industry-wide effort of its kind. It is also the first to track "source reduction" in refineries -- preventing pollution by avoiding the creation of waste.

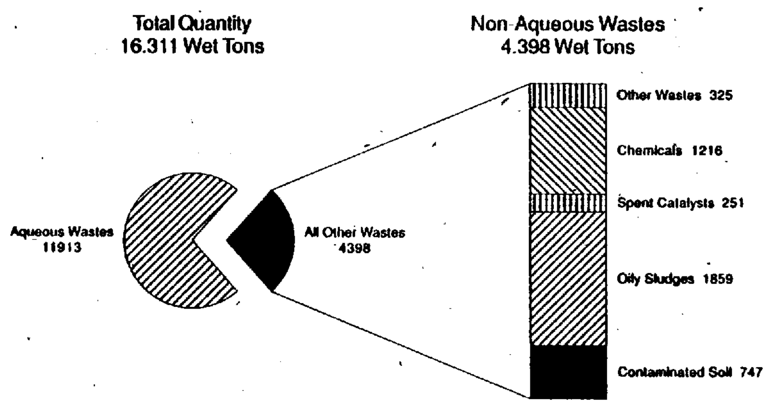
For this survey, *Generation and Management of Wastes and Secondary Materials: Petroleum Refining Performance,* API mailed questionnaires to 183 operating U. S. refineries. The 117 refineries that responded represent 74 percent of domestic refining capacity. This high response rate enabled API to develop industry-wide estimates with a high degree of confidence and statistical accuracy.

Wastes Generated

U.S. refineries generated roughly 16.3 million wet tons of wastes and secondary materials in 1989 -- about the same as in 1987 and 1988. The total includes non-hazardous and hazardous wastes (as classified under RCRA, the federal Resource Conservation and Recovery Act), byproducts, and other secondary materials.

The survey obtained information on 28 waste streams, grouped in six categories. As shown below, aqueous wastes constitute about two-thirds of the total. Four facilities (treated as outliers in the statistical analysis) generate nearly all of these wastes and dispose of them by injecting them into underground wells. In diminishing order of volume, the remaining wastes are oily sludges, chemicals, contaminated soils, "other," and spent catalysts.

Types of Wastes Generated
(millions of wet tons)



With the exception of contaminated soil, the amount of each type of waste has remained about the same since 1987. It appears that the amount of contaminated soil is on the rise -- most likely, a result of new construction at refineries and stepped-up efforts to clean up and remediate contamination from past releases.

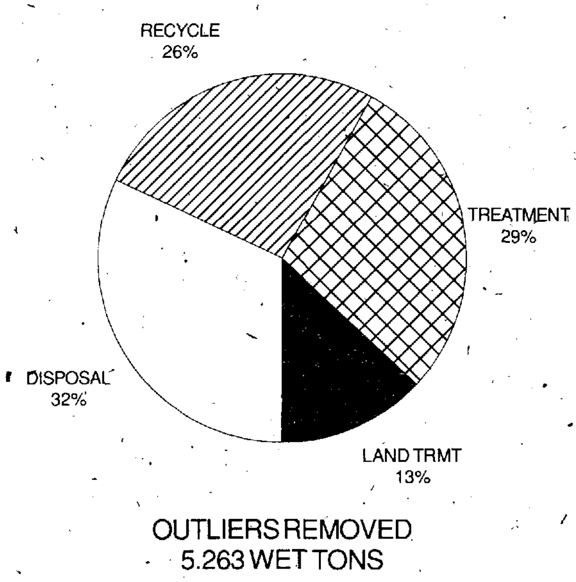
Waste Management

The U.S. Environmental Protection Agency has created a waste management hierarchy that reflects the growing emphasis on reducing the amount of waste generated rather than than treating and disposing of it. The ranking (in general order of preference) is source reduction, recycling, treatment, and disposal.

Trends in handling petroleum refining wastes reflect the shift in emphasis in the waste management community at large. Of the 117 refineries that participated in the 1989 survey, 55 reported progress in source reduction. Their activities included technical and procedural modifications, in-process recycling, and improved housekeeping practices. Economic incentives such as lower treatment and disposal costs were the main reasons they undertook such source reduction activities.

Recycling of refinery wastes is also on the rise. Twenty-six percent of refineries' wastes were recycled in 1989, compared to 21 percent in 1987. In contrast, land farminsg has declined dramatically. It was used to dispose of 66 percent of refinery wastes in 1981 and 17 percent in 1987, but just 13 percent in 1989. As the illustration below shows, refineries use other waste management methods as well. In 1989, they eliminated 29 percent of their wastes through treatment and 32 percent through disposal -- about the same proportions as in 1987 and 1988.

Methods of Managing Wastes
(millions of wet tons)



Implications

API's waste management survey is a tool that quantifies the wastes petroleum refineries generate. It helps individual refineries assess their performance and monitor progress, while providing an overview of the industry's performance as a whole.

Now that three successive years of data are available, it is also possible to compare the performance of individual refineries and the industry as a whole over time. Here, "within facility" variations in amounts of wastes generated suggest that the industry-wide aggregated data give a false sense of stability.

Annual variations in generation quantities for specific waste streams at individual refineries are up to seven times greater than those of the industry as a whole. If additional observations validate this trend, it could lend support to the view that site-specific factors merit consideration -- especially, in regulatory decisions.

Introduction

Four years ago, API began chronicling the generation and management of wastes and secondary materials in the petroleum refining industry. Recognizing that one-time data collection would provide a snapshot that could not be used to reliably assess progress, API committed to analyzing at least four consecutive years of data.

In February 1991, the first two years of data were compiled and published in *The Generation and Management of Wastes and Secondary Materials in the Petroleum Refining Industry 1987-1988* (API publication number 849-30000). This report on 1989 data continues the series. Data for 1990 are now being collected and will be published separately.

The scope of the survey is broader than the Resource Conservation and Recovery Act (RCRA) regulatory definition of solid waste. API has collected data on a variety of materials, including hazardous and non-hazardous wastes *and* secondary materials sometimes considered byproducts or recyclable materials. The rationale for including both wastes and secondary materials in the survey is to characterize -- and quantify -- the non-fuel materials the refining industry generates and manages. Previous data collection efforts -- by regulatory agencies and the industry itself -- focused only on certain wastes; the resulting lack of comprehensive information impaired advocacy efforts and slowed the planning of pollution prevention initiatives.

The primary goal of the survey is to track the management of wastes and secondary materials from the point of generation. API has incorporated an integrated waste management hierarchy in the data collection forms -- classifying waste handling practices as source reduction, recycling, treatment or disposal. This conceptual framework acknowledges that a range of practices is needed to handle wastes, and that some practices are more desirable than others. It may also help the industry and individual refineries assess progress over time both in reducing the amount of waste generated and in handling those that remain in an environmentally sound manner.

The survey is an ambitious undertaking. In the area of waste -- where conventional wisdom holds that smaller is better -- a large industry essentially asked, "How much?" Petroleum refineries process some 15.7 million barrels of crude oil per per day -- 5.7 billion barrels or 650 million tons per year. Even if the waste from each barrel is small, the sheer volume results in a large number.

By amassing several years of data in an effort to create a reliable baseline, the industry risks being asked a second question, "How much less?" Here, the variability inherent in refineries' operating practices works against early detection of incremental progress in reducing wastes. One-time events such as turnarounds or shutting down surface impoundments create peaks in waste volumes that can mask the progress better management practices and source reduction activities achieve.

Simply by conducting the survey, API invites a third question, "What does it mean?" While many quantitative observations can be explained -- particularly where there are strong trends -- the reasons why other numbers increase or decrease are more elusive. Though some may never be entirely clear, additional measures over an extended period of time may identify more factors that influence generation rates and the magnitude of their effects.

Individual refineries have already reported that they find the survey a useful accounting tool for classifying and quantifying wastes. Having characterized their wastes, they may go on to compare themselves to the industry as a whole and target areas where change is needed. The aggregated survey data also provide a context for evaluating the impact of new regulations and reporting requirements. Though it takes two to three years to amass the data, API's information is more current and comprehensive than any other waste management database. Thus, the survey can also provide more reliable estimates of the impact of proposed regulatory changes.

Methodology

Since the 1989 survey largely replicates the 1987-1988 survey, the following discussion focuses on changes made to improve the quality of the data. For detailed information on general survey procedures, see *The Generation and Management of Wastes and Secondary Materials in the Petroleum Refining Industry: 1987-1988* (API publication number 849-30000).

Survey Design

This survey, like its predecessors, took a census approach. Using the Department of Energy's *1989 Petroleum Supply Annual* and API's *Entry and Exit in U.S. Petroleum Refining, 1948-1989,* the Institute updated its list of 176 operational refineries. The resulting population of 183 refineries used for the 1989 survey reflect the opening (under new ownership) of some refineries and the closing of others. Ninety-five companies owned the refineries; roughly a third were API members.

Data Collection

The survey questionnaire had two parts: 12 short-answer questions about the age, size and complexity of the refinery, the types of source reduction activities performed, and "data sheets" that captured quantitative information on generation of 28 types of wastes and secondary materials, and methods of managing them (see Appendix A).

The 1989 survey used the same list of 28 waste streams used in the 1987-1988 survey. As Table 1 on the next page shows, these waste streams are divided into six broad categories that reflect the typical grouping of wastes and secondary materials in a refinery (see Appendix A for the subcategories of each waste stream).

As a quality control measure, the data sheets balanced waste "inputs" and "outputs." As the illustration below shows, the inputs are quantity generated, treatment additives, and net from storage (the total amount of waste removed from storage minus the amount placed into storage). The outputs are quantity recycled, quantity treated, and quantity diposed.

Quantity Generated + Treatment Additives + Net From Storage = ***Total Quantity Managed***

Total Quantity Managed *= Quantity Recycled + Quantity Treated + Quantity Disposed*

To improve the consistency of the data collected, API made several changes in the data sheets. Respondents were asked to indicate whether wastes were generated on a routine or one-time basis and whether they had been dewatered. In addition, each data sheet included a simplified source reduction question that served largely as a consistency check with the source reduction questions in the short-answer section.

Table 1
Refining Waste Streams

Category	Constituents
Aqueous wastes	Biomass High pH/low pH waters Oil contaminated waters (not wastewaters)* Spent Stretford solution Spent sulfide solution Other aqueous wastes NOS**
Chemicals/inorganic wastes	Spent acids Spent caustics Waste amines Other inorganic wastes NOS**
Contaminated soils/solids	Contaminated soils/solids Heat exchanger bundle cleaning sludge*** Waste coke/carbon/charcoal Waste sulfur Other contaminated solids NOS**
Oily sludges/other organic wastes	API separator sludge*** DAF float*** Leaded tank bottoms*** Nonleaded tank bottoms Other separator sludges Pond sediments Slop oil emulsion solids*** Waste oils/spent solvents Other oily sludges/organic wastes NOS**
Spent catalysts	Fluid cracking catalyst Hydroprocessing catalyst Other spent catalysts NOS**
Other wastes	Other wastes NOS**

* Does not include NPDES or POTW wastewaters.
** Not otherwise specified.
*** RCRA-listed hazardous wastes for petroleum refining.

Waste Minimization

Congress mandated a waste minimization policy in 1984 amendments to RCRA, applying the term "waste minimization" to a variety of activities that reduce the amount of waste requiring disposal. The waste management hierarchy -- source reduction, recycling, treatment, and disposal -- illustrates how different activities at different points in the continuum work in concert to achieve this goal.

In the 1987-1988 survey, waste minimization questions focused on source reduction activities -- changes in practices that prevent generating wastes in the first place. Quality control edits of the data received, coupled with follow-up calls to respondents, indicated a need to clarify the meaning of "source reduction" and ways of calculating reductions in the quantities of waste managed (see Appendix D, summary of questionnaire development issues, 1987-1988 survey).

Some of the confusion regarding source reduction stems from the difficulty of measuring an unknown -- successfully preventing waste means that what is being measured no longer exists. Early instructional materials clouded the concept by suggesting that year-to-year reductions in wastes can be construed as source reduction. This is not necessarily the case: the reduction may simply be a normal fluctuation. For example, a refinery could have a major turnaround that creates peak quantities of waste. When wastes decline in subsequent years, the reason is not source reduction, but a return to usual operating conditions.

Another reason source reduction can be hard to measure is that refineries sometimes undertake activities that reduce wastes for reasons other than waste management -- to improve products or increase efficiency. Such practices include modifying equipment, technology or procedures, recycling within a process, and streamlining housekeeping practices. Although the main goal is to make a product more efficiently, a secondary benefit may be that wastes are also reduced.

In light of these considerations, the source reduction questions on the 1989 survey had implicit goals beyond the obvious objective of developing a quantitative profile of progress. Specifically, those goals were to:

- Promote understanding of the source reduction concept -- in particular, how activities other than feedstock substitution can reduce waste.

- Give respondents latitude in measuring progress so as not to arbitrarily influence their responses, yet enable quality control measures to ensure the comparability of data from year-to-year.

- Facilitate technology transfer and innovation by collecting descriptive information on the steps that resulted in waste reduction.

- Create a linkage with federal efforts to identify incentives for source reduction and eliminate barriers to innovation.

API met these goals by including a fairly long introductory passage; by asking respondents to use a six-point classification framework for source reduction activities and provide a narrative description of innovations made and methods used to measure the reduction; and by including questions drafted by EPA on incentives for -- and barriers to -- source reduction activities (see Appendix A, questions 9-12).

Automated Questionnaire

The automated version of the questionnaire was redesigned for the 1989 survey. To make the program faster and simpler to use, it was rewritten in Clipper™, a commercially available compiler for dBase™. The revised version had five menu-driven parts with quality control checks and "help" screens. API sent survey participants diskettes with their 1987 and 1988 data, and instructions on retrieving them for analysis; this allowed survey participants to create their own databases for site-specific analysis.

Survey Administration

API assured survey participants that the data for individual refineries would remain confidential, mailing survey materials to the headquarters of the refining branch of each company, which then distributed them to the refineries themselves. All materials were mailed by mid-October; eight weeks were allowed for response. About a month after the mailing of the materials, API made follow-up calls to refineries that had not previously participated in the survey. The purpose of these calls was to confirm receipt of the survey materials and to ascertain whether the refineries intended to complete them.

API retained the consulting services of an expert in refining practices, who staffed a "helpline" for survey-related questions. Survey participants were advised to contact the consultant to clarify technical issues. In addition, the consultant reviewed questionnaire items that automated edit checks identified as potentially out-of-range or inconsistent. The consultant resolved such problems with the contact person at the refinery in question.

Data Analysis

The 1989 survey used essentially the same data verification, non-respondent estimation, and extrapolation procedures as the 1987-1988 survey (see Appendix B). A summary of the main differences between the 1989 survey and the earlier survey follows.

With regard to data verification, the most substantive change was reducing the number of questionable data elements. The improved quality of the data was probably due to increased reliance on the automated questionnaire -- with its internal consistency checks -- and the "learning" effect generally associated with a second administration. In addition:

- Special efforts were made to verify generation quantities for four facilities identified as statistical "outliers" in the 1987 and 1988 surveys. Though three of these facilities were unable to participate in the 1989 survey, API telephoned them and verified that they were still following practices that resulted in the generation of comparable quantities of **aqueous wastes NOS**. Accordingly, the 1988 data for these refineries were used for the 1989 survey.

- Problems detected through edit checks -- for example, patterns of inconsistent reponses to questions about hazardous wastes and source reduction -- identified several questions that needed structural revision.

- Edit checks of the consistency in generation quantities between survey years were made both across and within facilities. They helped identify reasons for annual fluctuations in generation rates for various waste streams.

API used statistical models to estimate generation quantities for refineries that did not participate in the survey. The models developed for the 1987-1988 data were tested to determine their reliability, including a separate linear regression model for estimating waste generation as a function of capacity for refineries with less than 200,000 barrels per stream day (B/SD). A non-linear relationship between waste generation and capacity held true for refineries with more than 200,000 B/SD.

Although there were some differences between the 1987-1988 and 1989 surveys -- notably, 183 active refineries and 117 participants in 1989 versus 176 refineries and 115 participants in 1987-1988 -- the modeling procedures retained their validity. The R^2 for smaller refineries indicated that the model accounted for 43 percent of the variability in generation quantities, while the model for larger refineries accounted for 60 percent of the variability. An approximate 2 percent margin of error was estimated for the total waste generation quantity and an approximate 15 percent margin of error was estimated for the individual waste streams.

The extrapolation procedures used to calculate the amount of waste generated by the entire population of refineries was the same as that used in the 1987-1988 survey. API added estimates for the 66 non-responding facilities to the responses of the 117 participating facilities, performing successive calculations to create generation estimates for each waste stream and for each waste handling method. Unless otherwise specified, all data reported for the 1989 survey are estimates of wastes for all 183 refineries.

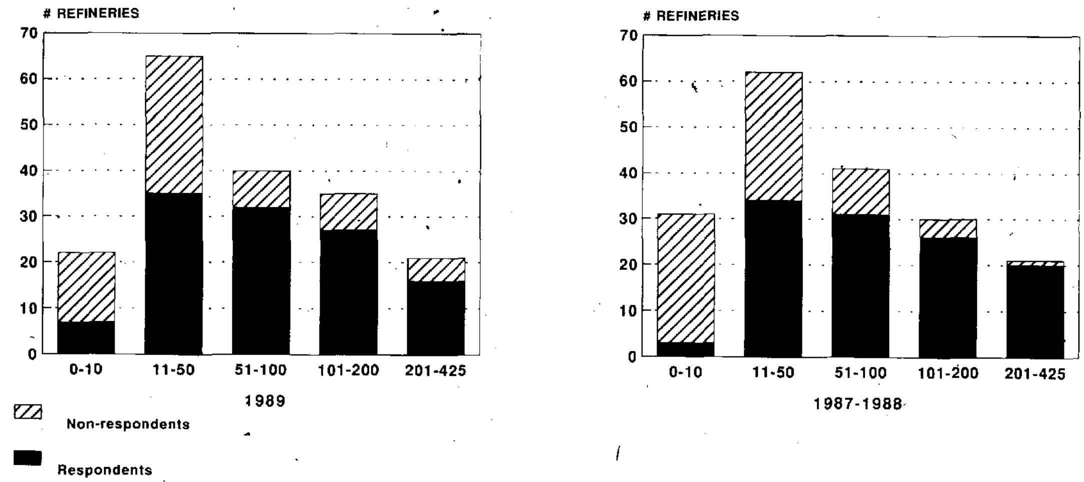
Results

Response Rate

The 1989 survey response rate was comparable to the 1987-1988 survey: 117 refineries. They reported operating capacity of 12,659,939 barrels per day. In 1989, they processed 3.9 billion barrels of oil. These refineries represent 64 percent of the population of 183 active refineries, and 74 percent of domestic crude refining capacity. This is somewhat less than the 80 percent of capacity represented by 1987-1988 survey participants.

There was some turnover in participants: 19 refineries that participated in 1989 had not done so previously and 18 refineries that participated in the 1987-1988 survey did not do so in 1989. This did not change the overall profile of participants (see Figure A below). In 1989, representation of 101,000 to 200,000 B/SD refineries remained constant, several refineries of less than 100,000 B/SD joined the survey, and three of the largest refineries dropped out of the survey.

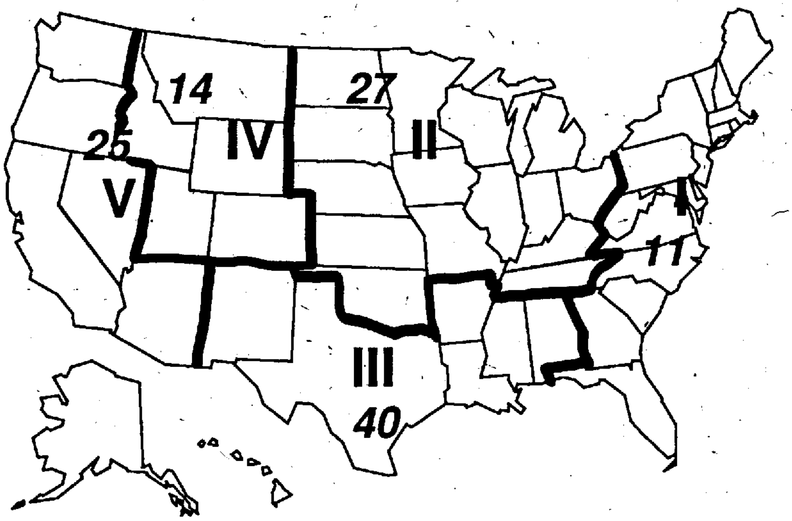
Figure A
Number of Respondents by Capacity Group
(thousand barrels per stream per day)



Respondent Characteristics

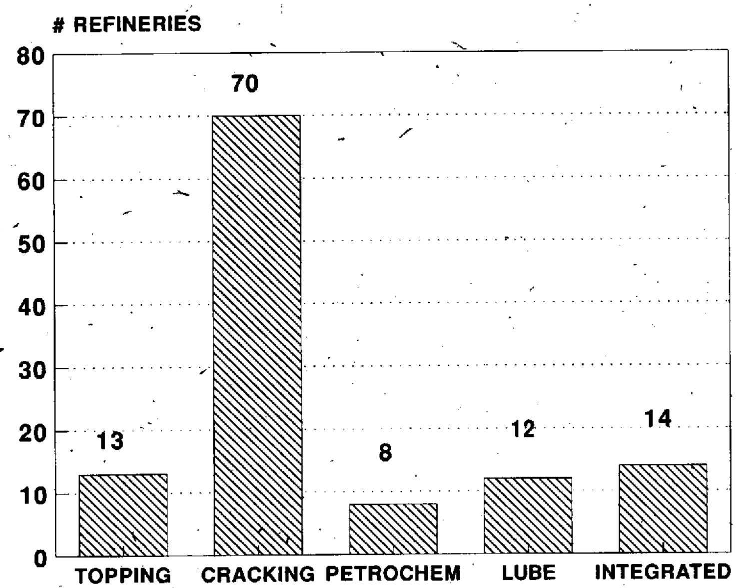
The survey elicited information about the refinery's *location, complexity, age, type of sewer system* and *RCRA permitting status.* As Figure B (following page) shows, the U.S. Department of Energy's Petroleum Administration for Defense (PAD) III, the Texas/Louisiana region, had 40 respondents (of 64 refineries). PAD II had 27 respondents (of 39 refineries), PAD V had 25 respondents (of 45 refineries), PAD IV had 14 respondents (of 17 refineries), and PAD I had 11 respondents (of 19 refineries).

Figure B
Distribution of Respondents by Location



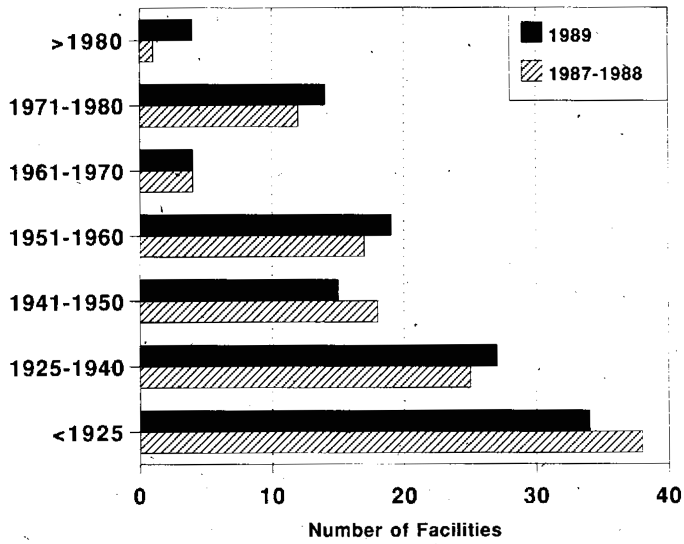
The second descriptive variable -- complexity -- used NPDES permit classifications (see Appendix A, question 2). The overwhelming majority of participants were "cracking" class refineries (see Figure C below). Though the actual distribution of complexity among refineries is unknown, the observed distribution is probably representative. Given that complexity tends to increase with size -- and that larger refineries are well represented in the survey -- it follows that most non-responding refineries would be smaller, less complex facilities of the "cracking" class.

Figure C
Distribution of Respondents by Complexity



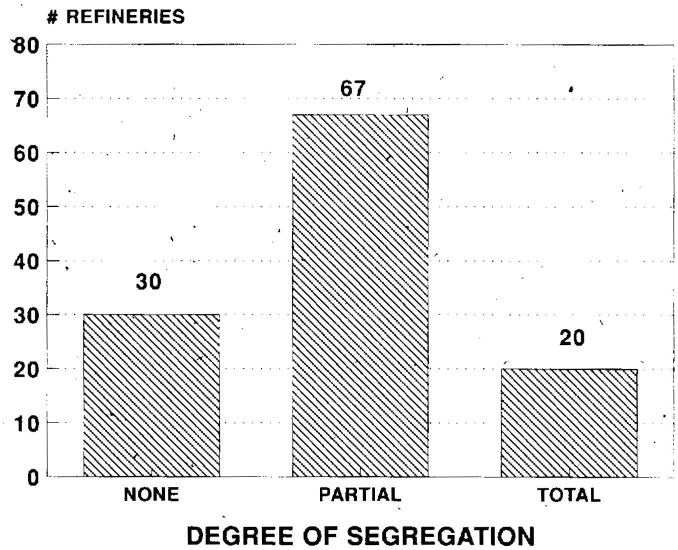
The age distribution of respondents was similar to that in the 1987-1988 survey. More than half the refineries were built before 1940, making them at least 50 years old (see Figure D below). The number of participants in the 30-40 age group (began operating between 1951 and 1960) rose slightly, as did the number in the youngest age group.

Figure D
Distribution of Respondents by Age
(year operations began)



The survey also gathered information about the degree of segregation of storm and process water sewer systems in refineries (see Figure E below). Sixty-seven refineries -- 57 percent of the respondents -- had partially segregated sewers.

Figure E
Distribution of Respondents by Sewer Type



The last descriptive variable was RCRA permitting status. Forty-five refineries -- 39 percent of the respondents -- did not require permits because they are "generators" (as defined by RCRA) who neither treat, store nor dispose of hazardous wastes on-site. Of the remaining 72 refineries, 37 facilities -- 32 percent -- are involved in the permitting process (have filed Part A) and 35 facilities -- 30 percent -- have already obtained a permit.

RCRA permitting status seems to correlate loosely with size. Twenty-five of the 45 refineries that were only generators process less than 50,000 B/SD, while 21 of the 35 refineries that have permits process more than 100,000 B/SD. Refineries that process 50,000 to 100,000 B/SD were evenly distributed: 11 generators, 11 with interim status, and 10 with permits. Thirteen of the larger and 13 of the smaller refineries had filed for permits (Part A).

Total Waste Management Quantity

The term "total waste management quantity" (illustrated below) is defined as generation quantities plus initial waste handling practices that contribute to the amount of waste subsequently managed during the survey year.

***Total Quantity Managed** = Quantity Generated + Treatment Additives + Net From Storage*

Waste Generation

As in the 1987-1988 survey, the instruction manual did not explicitly define "wastes" and "secondary materials." The manual said:

> *Although denominated as a "solid waste" survey, it should be understood that neither this title nor the references herein (e.g., "wastes" and "residuals") are used in a statutory or regulatory sense. Whereas EPA regulations implementing RCRA have given these terms special meaning, our usage here is in a broader, more generic sense. API wants survey participants to report the management of all residual type materials (e.g., materials that are byproducts or residuals of petroleum refining operations). This includes residuals that are beneficially recycled or reclaimed, as well as material that is discarded. This will allow reporting of industry data, wherever appropriate, according to the waste management hierarchy of source reduction, recycling, treatment, and disposal.*

The aim was to encourage reporting of actual practices and to avoid the potential bias of experimental or survey effects -- for example, arbitrary definitions of the point of generation. As a quality control measure, the data sheets distinguished between wastes generated on an ongoing, routine basis; wastes relating to a one-time event; and materials that had received some dewatering prior to classification as wastes. This allowed respondents to use their own operational definitions and quality control checks on data comparability.

Using the extrapolation procedures already described, API estimated that the 183 operating U.S. petroleum refineries generated 16.3 million wet tons of waste in 1989 -- slightly more than the 16.1 million wet tons refineries reported in 1987 and the 16.0 million wet tons reported in 1988. But when the waste generation rate is standardized by the 1989 crude throughput (657 million wet tons[1]), the ratio of waste to throughput is 0.0248 -- less than the 0.0256 observed in 1987 and virtually the same as the 0.0247 observed in 1988.

Aqueous wastes NOS remained the highest volume stream, representing close to 70 percent of all waste generated. As already noted, four facilities whose practices differ from the industry norm -- statistical outliers -- reported nearly all this waste. When waste to crude throughput is calculated without the outliers, the ratio is 0.0076.

During the survey years, increases and decreases in individual waste streams were fairly evenly distributed: quantities fell in 8 streams and rose in 10 streams. In the remaining 10 streams, the 1989 quantity fell somewhere between the 1987 and 1988 quantities.

The 1989 survey showed substantial percentage reductions in the quantities of **biomass, DAF float, high pH/low pH waters, spent acids** and **spent sulfite solution.** While the latter two dropped more than 80 percent, they accounted for relatively small quantities and thus had little impact on the aggregate. Overall, the rise in the quantity of waste generated in 1989 resulted from increases in **contaminated soils/solids, other inorganic wastes NOS,** and **waste coke/carbon/charcoal.**

As previously noted, one-time generation quantities were identified for the first time in 1989. Reasons included unit closure, new construction, soil remediation activities, and change-outs without a planned cycle. These data helped clarify the changes. For example, **contaminated soils/solids** had the most one-time generators (21 refineries), who accounted for a quarter of the total quantity (see Table 2, following page).

[1]U.S. Department of Energy *Petroleum Supply Annual* figures on total crude input were converted from barrels to wet tons by dividing by 5.94.

Table 2
Estimated Wastes from the U.S. Refining Industry
(thousands of wet tons)

Waste Stream	1989	1988	1987
Aqueous wastes NOS	11,100	11,076	11,296
Spent caustics	716	656	675
Biomass	642	786	757
DAF float	496	655	652
Contaminated soils/solids	512	240	165
Other inorganic wastes NOS	440	213	325
API separator sludge	419	355	400
Other wastes NOS	325	412	203
Pond sediments	313	266	337
Slop oil emulsion solids	272	224	208
FCC catalyst or equivalent	182	193	173
Nonleaded tank bottoms	161	129	216
Waste coke/carbon/charcoal	129	67	43
Other separator sludges	114	104	79
High pH/low pH waters	91	138	144
Other contaminated soils NOS	53	68	82
Waste sulfur	52	22	17
Waste amines	51	14	13
Other oily sludges/organic wastes NOS	47	61	38
Spent Stretford solution	42	49	5
Hydroprocessing catalysts	36	36	40
Other spent catalysts NOS	33	37	33
Waste oils/spent solvents	31	7	4
Oil contaminated waters (not wastewaters)	29	36	28
Spent acids	8	149	126
Spent sulfite solution	8	40	42
Leaded tank bottoms	4	8	9
Heat exchanger bundle cleaning sludge	2	5	3
Total	16,311	16,044	16,144

Another stream that rose significantly was **waste oils/spent solvents,** which went from 5,000 to 7,000 wet tons per year to more than 30,000 wet tons in 1989. This was mainly due to a single refinery with a large, one-time generation quantity. In contrast, **other inorganic wastes NOS** had few one-time generators, but a single routine generator reported 25 percent of the total: 111,000 wet tons. Similarly, a single refinery reported close to half the routinely generated quantity of waste coke/carbon/charcoal.

The number of refineries reporting each waste stream has remained fairly constant The five most common waste streams have also remained constant, though the order has varied somewhat. For example, **API separator sludge** was the second most frequently cited stream in 1987, reported by 91 refineries; in 1988 and 1989, it was the most frequently cited stream (see Table 3, following page).

Table 3
Number of Refineries Reporting Wastes

Waste Stream	1989	1988	1987
Other wastes NOS	89	85	92
API separator sludge	93	94	91
FCC catalyst or equivalent	84	86	85
Spent caustics	70	77	79
Contaminated soils/solids	88	77	77
Other inorganic wastes NOS	73	73	77
Nonleaded tank bottoms	72	75	72
Other contaminated soils NOS	61	71	70
Other spent catalysts NOS	60	60	62
Hydroprocessing catalysts	65	60	57
DAF float	47	50	53
Waste oils/spent solvents	56	61	52
Heat exchanger bundle cleaning sludge	49	48	49
Other oily sludges/organic wastes NOS	49	47	49
Waste coke/carbon/charcoal	51	47	48
Biomass	44	45	47
Slop oil emulsion solids	38	43	47
Waste sulfur	42	47	41
Leaded tank bottoms	31	37	38
Waste amines	38	36	32
Pond sediments	31	29	26
Spent acids	18	23	20
Other separator sludges	22	20	15
High pH/low pH waters	11	12	14
Oil contaminated waters (not wastewaters)	14	10	14
Other aqueous wastes NOS	14	12	13
Spent Stretford solution	11	13	12
Spent sulfite solution	2	1	1

Treatment Additives

Always low, use of treatment additives (chemicals that facilitate subsequent handling of wastes) declined from 55,000 and 72,000 wet tons in 1987 and 1988, to 35,000 wet tons in 1989 -- 0.2 percent of the total. Additives were used with 18 streams in 1989, 1 less than before. **Biomass, API separator sludge, DAF float, slop oil emulsion solids, other separator sludges** and **pond sediments** continued to require the most additives.

Storage

Instead of using positive and negative values to distinguish between wastes "removed from storage" and wastes "placed into storage," the 1989 data sheets had separate spaces for them. According to survey participants, **FCC catalyst or equivalent** had the most wastes removed from storage, followed by **DAF float** and **waste coke/carbon/charcoal.** In other streams, the amount removed from storage was 1 percent or less of the total waste generated (see Table 4, following page).

Table 4
Top-five Waste Streams Removed from Storage
(thousands of wet tons)

Waste Stream	Total Managed	From Storage	Percent of Total
FCC catalyst or equivalent	5	31	17
DAF float	521	19	4
Waste coke/carbon/charcoal	137	8	6
Nonleaded tank bottoms	164	2	1
Other inorganic wastes NOS	441	<1	<1

During the survey years, there has been a complete turnover in the streams with high volumes of waste removed from storage. None of the high-volume streams in the 1987-1988 survey -- **API separator sludge, pond sediments, contaminated soils/solids, other contaminated soil NOS** and **other catalysts NOS** -- were among the top-five in 1989. Three streams -- **DAF float, FCC catalyst or equivalent** and **other inorganic wastes NOS** -- had high volumes put in storage in 1987-1988 that were removed for final disposition in 1989.

The five streams with the most wastes put in storage in 1989 were **pond sediments, contaminated soils/solids** (with the highest one-time generation rate), **slop oil emulsion solids** and **biomass** (where high volumes were also reported in the 1987-1988 survey), and **API separator sludge** (see Table 5 below).

Table 5
Top-five Waste Streams Placed into Storage
(thousands of wet tons)

Waste Stream	Total Managed	From Storage	Percent of Total
Pond sediments	273	41	15.0
Contaminated soils/solids	496	17	3.0
Slop oil emulsion solids	262	12	5.0
Biomass	655	2	<1.0
API separator sludge	425	1	<1

Total Quantity of Waste Managed

As noted above, the total quantity of waste managed (input) is the sum of the estimated quantity of waste generated, treatment additives used, and net waste from storage. Table 6 (following page) presents these data for 1989 and compares the totals for the survey years. The amount of waste put in storage was greater than the amount of additives used, so the total amount of waste managed in 1989 was less than the amount of waste generated. The data also illustrate some of the fluctuations within individual waste streams noted above.

Table 6
Estimated Waste Quantities
(wet tons)

Waste Stream	1989 Input			Total Amount Managed		
	Amount Generated	Treatment Additives	From Storage	1989	1988	1987
Aqueous wastes NOS	11,100,221	0	0	11,100,221	11,076,251	11,296,230
Spent caustics	715,502	20	18	715,540	655,528	674,522
Biomass	642,466	14,146	(1,615)	654,977	748,589	720,355
DAF float	495,790	6,403	18,605	520,798	660,514	653,899
Contaminated soils/solids	511,666	657	(16,812)	495,511	242,074	185,819
Inorganic wastes NOS	440,442	21	346	440,809	220,503	322,702
API separator sludge	419,176	6,679	(1,354)	424,501	430,042	563,733
Other wastes NOS	325,227	0	(15)	325,212	412,380	202,645
Pond sediments	312,892	1,479	(41,154)	273,217	311,268	359,996
Slop oil emulsion solids	272,164	2,322	(12,137)	262,349	213,551	211,854
FCC catalyst/equivalent	182,220	12	3,148	185,380	189,191	170,853
Nonleaded tank bottoms	161,095	375	2,230	163,700	130,851	217,869
Waste coke/carbon/ charcoal	129,218	0	7,885	137,103	66,549	42,712
Other separator sludges	114,948	2,091	(94)	116,945	110,251	82,797
High pH/low pH waters	91,261	252	0	91,513	138,269	144,015
Contaminated soils NOS	53,294	0	(28)	53,266	76,698	88,002
Waste sulfur	51,706	0	(1)	51,705	22,714	17,299
Waste amines	51,052	0	1	51,053	13,798	13,107
Oily sludges/organic wastes NOS	47,108	101	10	47,219	61,336	40,024
Spent Stretford solution	42,449	0	0	42,449	49,264	34,881
Hydroprocessing catalysts	35,532	0	255	35,787	36,630	39,415
Other spent catalysts	33,032	522	(158)	33,396	37,904	38,238
Waste oils/spent solvents	30,858	18	20	30,896	7,346	4,453
Oil contaminated waters (not wastewaters)	28,861	43	3	28,907	35,867	28,156
Spent acids	8,424	0	0	8,424	160,399	130,436
Spent sulfite solution	7,937	0	0	7,937	40,274	42,262
Leaded tank bottoms	4,347	13	111	4,471	9,615	9,264
Heat exchanger bundle cleaning sludge	2,450	6	(1)	2,455	4,643	2,977
Total	16,311,318	35,160	(40,737)	16,305,741	16,162,299	16,338,555

Source Reduction

The 1989 survey tested several new questions to elicit information on source reduction -- about activities specifically undertaken to prevent waste generation, methods of measuring progress, and factors influencing progress. Responses to the survey indicated that while not all facilities have implemented source reduction activities, the activities undertaken affect nearly all waste streams.

In 1989, 55 refineries initiated source reduction activities involving all but four streams: **waste coke/carbon/charcoal, hydroprocessing catalysts, spent acids** and **spent sulfite solution.** Table 7 (below) presents the quantitative data for the waste streams with the largest reductions (for detailed data on all 24 waste streams with source reduction activities, see Appendix C).

The single largest reduction -- 56,000 wet tons for **slop oil emulsion solids** -- included a reduction of 41,900 wet tons in one refinery. The three streams with the most responses were RCRA-listed hazardous wastes: **API separator sludge, DAF float** and **slop oil emulsion solids.** More refineries -- 25 -- indicated source reduction for **API separator sludge** than any other stream.

Table 7
Summary of Source Reduction Achievements

Waste Stream	Tons Reduced (thousands)	Number of Refineries
Slop oil emulsion solids	56	11
Other inorganic wastes NOS	26	5
DAF float	17	11
API separator sludge	13	25
Biomass	15	5
Nonleaded tank bottoms	11	7
Other separator sludges	10	7
All others	21	NA
Total	169	NA

The statistical validity of these estimates is unclear. While there probably was some under-reporting of potential source reduction practices (for example, housekeeping improvements), the methods used to quantify reductions suggest variation in the precision of the estimates.

Descriptions of methods used to estimate reductions were divided into six categories (see Table 8, following page). The most common method was comparing successive years (36 percent), followed by engineering (23 percent), waste managment records (16 percent), and mass balance and other data based methods (each 3 percent).

Table 8
Methods of Calculating Source Reduction Achievements

Estimation Method	Number of Responses	Percent of Total
Subtract 1989 from 1988	16	36
Engineering estimate	10	23
Waste management records	7	16
Mass balance	3	7
Other data based method	3	7
Other	5	11

The pattern of targeting hazardous waste streams for source reduction is repeated in Table 9 (following page). The 25 facilities that reported reducing generation of **API separator sludge** used all 6 source reduction methods; some facilities used several of them. **DAF float,** cited by 13 facilities, ranked second and included all source reduction methods except product reformulation. Refineries also performed a variety of source reduction activities for oily sludges, a category that includes the first nine streams listed in Table 9, and for **other wastes NOS.**

Source reduction activities (described in detail in Appendix C) included *equipment and technology modifications* for 15 streams -- for example, installing more efficient dewatering equipment, improving containment methods to reduce sewer infiltration, and improving individual process units such as sulfur recovery units. *In-process recycling* also occurred in 15 streams -- most often, recovering hydrocarbons from centrifuge or filter presses and the use of oily materials as feedstreams for cokers.

Refineries reported *improved housekeeping, employee training or inventory control* for 12 streams. With the exception of **aqueous wastes NOS**, those streams were subject to other source reduction methods as well. The most frequently cited were controlling coke fines and debris that wash into sewers, and removing obsolete chemicals.

Refineries attributed reductions in wastes generated in 10 streams to *procedure modifications.* While many reported discontinuing the use of sand to cover sewers for hot work, other procedural changes seemed tailored to individual facilities -- for example, closing storm water ponds and performing equipment change-outs less frequently.

Table 9
Summary of Source Reduction Activities

Waste Stream	Number of Responses	Method of Source Reduction					
		1	2	3	4	5	6
API separator sludge	39	✓	✓	✓	✓	✓	✓
DAF float	13	✓	✓		✓	✓	✓
Slop oil emulsion solids	11	✓	✓			✓	✓
Leaded tank bottoms	5			✓	✓	✓	
Other separator sludges	7		✓			✓	✓
Pond sediments	4	✓	✓				✓
Nonleaded tank bottoms	8	✓	✓			✓	
Waste oils/spent solvents	6		✓		✓	✓	✓
Other oily sludges/organic wastes	4					✓	
Heat exchanger bundle cleaning sludge	2					✓	
Contaminated soils/solids	3	✓					✓
Waste sulfur	1		✓				
Other contaminated soils NOS	4	✓			✓	✓	
FCC catalyst or equivalent	3	✓					✓
Other spent catalysts	1				✓		
Biomass	3	✓				✓	✓
Oil contaminated waters	2	✓				✓	
High pH/low pH waters	2	✓	✓				
Spent Stretford solution	1	✓					
Aqueous wastes NOS	1						✓
Spent caustics	2	✓				✓	
Waste amines	1		✓				
Other inorganic wastes NOS	3	✓				✓	✓
Other wastes NOS	6	✓	✓		✓	✓	✓

Methods of Source Reduction
1 = equipment or technology modifications
2 = procedure modifications
3 = reformulation or design of products
4 = substitution of raw materials
5 = recycling within a process
6 = improved housekeeping, employee training or inventory control

Seven refineries reported *substitution of raw materials* and two reported *reformulation or design of products.* Given the lack of feed substitutes for crude oil -- and the performance characteristics petroleum fuels must meet -- these low frequencies were not surprising.

The substitutions cited most often were using phosphate instead of chromium in cooling towers and using less toxic degreasing agents. The phase-out of leaded gasoline, which had affected the lead in **API separator sludge** and **leaded tank bottoms,** was characterized as product reformulation.

Refineries that reported source reduction activities were asked their reasons for undertaking them (see Table 10 below). The most common motive was reducing treatment and disposal costs (cited by 84 percent of survey participants), followed by self-initiated review (67 percent), and regulatory requirements (44 percent).

Source reduction does not seem to be a reactive tactic; few refineries undertook it as a result of pressure from the public or environmental groups. Rather, it appears to be a proactive stance to allay public concern (cited by 31 percent of survey participants), and to reduce occupational liabilities and process costs.

Table 10
Incentives for Source Reduction Activities

Reasons	Number of Responses	Percent of Total
Reduction of treatment/disposal cost	46	84
Self-initiated review	37	67
Regulatory requirement for waste	24	44
Occupational safety	18	33
Concern over public reactions	17	31
Other process cost reduction	25	26
Pressure from public or environmental groups	5	9
Other	4	7

Waste Management

The term "waste management" applies to a range of practices that "eliminate" wastes, residuals and secondary materials after they have been treated with additives or moved into -- or out of -- storage. For purposes of this survey, these practices are classified as *recycling, treatment, land treatment,* and *disposal.*

Recycling

When waste has been created, the preferential method to eliminate it is through recycling. Such reuse of materials obviates the need for further handling, treatment, and disposal. Petroleum refineries have long used their oil recovery systems to recycle oily materials. Much of this recycling occurs in-process before the materials are considered wastes. For example, oil is routinely skimmed from the surface of water in wastewater treatment systems -- before the water is treated, discharged or considered a waste. As a result, many of these routine practices are not captured by this survey. Like the 1987-1988 survey, it documented a broader range of recycling activities -- in particular, the industry's extensive reuse of chemicals and spent catalysts.

In 1989, petroleum refineries recycled 1.4 million wet tons of waste -- about 9 percent of the total amount of waste managed. After adjustment to correct for the outliers, the proportion of recycled wastes is 26 percent -- slightly more than the 21 percent observed in 1987 and the 23 percent observed in 1988.

To some degree, petroleum refineries recycle all 28 waste streams (see Appendix D, Table D-1). The recycled quantity ranges from negligible for **aqueous wastes NOS** (the outlier category) to a high of nearly 600,000 wet tons -- 84 percent -- for **spent caustics**. In addition, survey participants reported recycling more than 78 percent of **spent sulfite solution, hydroprocessing catalysts, waste oils and spent solvents,** and **waste coke/carbon/charcoal.** In 14 streams, recycling eliminated 20 percent or more of the wastes managed.

Table 11 (below) summarizes the recycling practices used during the survey years. In 1989, refineries used cokers and crude units for slightly more than one-quarter of their recyclable materials. Over time, there has been a small -- but consistent -- increase in recycling via cokers and crude units. Though reclamation/regeneration was used for some 150,000 additional wet tons of waste in 1989, it accounted for 44 percent of total recycling activity -- a comparable level to prior years. Use of recycling devices in the "other" category -- desalters, sour water strippers and industrial furnaces -- seemed to dip slightly in 1989.

Table 11
Summary of Recycling Practices
(thousands of wet tons)

Method of Recycling	**1989 Tons**	**Percent**	**1988 Tons**	**Percent**	**1987 Tons**	**Percent**
Coker	231	17	186	16	148	14
Crude unit	125	9	85	7	68	6
Reclamation/regeneration	611	44	434	38	447	42
Other	408	30	474	41	410	38
Total	1,376	100	1,179	100	1,073	100

Table 12 (page 24) shows the recycling methods reported for different waste streams (for detailed data, see Appendix D, Table D-2). *Cokers* and *crude units* received oily materials from several streams: **DAF float, API separator sludge, nonleaded tank bottoms** and **slop oil emulsion solids**. In 1989, cokers also received substantial amounts of **biomass** and **nonleaded tank bottoms** that were not high volume recycling streams in earlier years. Similarly, crude units received **other separator sludges** not previously identified as significant sources of recyclable materials.

Spent caustics, waste coke/carbon/charcoal, hydroprocessing catalysts and **FCC catalyst or equivalent** remained high volume streams for *reclamation/regeneration.* **Waste oils/spent solvents** was a new high volume stream for this recycling method in 1989. (By contrast, spent acids, slop oil emulsion solids and DAF float were high volume streams for this method in 1987-1988, but not in 1989.)

Use of *other* recycling methods increased in several streams in 1989. In descending order, they were **spent caustics, slop oil emulsion solids,** and **waste coke/carbon/charcoal** (used in industrial furnaces).

These aggregate statistics do not take into account that the proportion of waste recycled by a particular method is a potentially biased measure -- for example, large refineries create more waste and may manage it differently. In other words, the proportion of waste handled in a certain way may not reflect how frequently the industry as a whole uses that method.

Thus, a second analysis of the frequency of responses was undertaken in 1989. These frequency counts (see Appendix D, Table D-3) are the actual number of refineries using each method; no attempt was made to extrapolate them for the entire population. Thus, they differ substantially from the extrapolations used to estimate the amount of wastes generated and how they are managed industry-wide.

The number of practices cited less than 10 times suggests considerable variation in recycling methods among refineries. There were just 8 streams where the recycling practices appear somewhat standardized, including reclamation of **hydroprocessing catalysts** (54 responses), **spent caustics** (23 responses), **other spent catalysts** (22 responses), and **FCC catalysts** (15 responses). Twenty-seven refineries reported reclamation of **waste oils/spent solvents,** but the remaining refineries reported quite diverse recycling practices: 10 returned them to crude units, 4 used them in industrial furnaces, 5 undertook regeneration, and 3 employed other methods.

Table 12
Estimated Quantities of Recycled Wastes
(thousands of wet tons)

Recycling Method/ Waste Stream	1989	1988	1987
Coker			
DAF float	79	45	82
Biomass	59	27	25
API separator sludge	55	73	14
Nonleaded tank bottoms	23	7	-
Slop oil emulsion solids	9	23	19
All others	6	11	8
Total	231	186	148
Crude unit			
DAF float	34	19	16
Other separator sludges	26	13	8
API separator sludge	24	13	18
Nonleaded tank bottoms	18	13	11
Slop oil emulsion solids	17	27	12
All others	6	-	3
Total	125	85	68
Reclamation/regeneration			
Spent caustics	459	243	262
Waste coke/carbon/charcoal	40	43	27
Hydroprocessing catalysts	32	21	26
FCC catalyst or equivalent	27	7	11
Waste oils/spent solvents	18	-	-
All others	35	120	212
Total	611	434	447
Other*			
Spent caustics	138	254	232
Slop oil emulsion solids	63	-	-
Waste coke/carbon/charcoal	67	-	-
All others	141	220	178
Total	409	474	410
Grand total	1,376	1,179	1,073

* Includes materials sent to desalters, industrial furnaces, sour water strippers, and unspecified practices.

API separator sludge and **DAF float** -- two streams with constellations of responses for cokers and crude units -- show the difficulty of interpreting the relationship between frequency and quantity. For **API separator sludge,** 15 refineries reported recycling via cokers and 22 reported recycling via crude units. A comparison of actual quantities of waste recycled (see Appendix D) shows that cokers accounted for 55,000 tons (about 65 percent) and crude units 24,000 tons. Conversely, 17 refineries sent 79,000 tons of **DAF float** to cokers while 9 refineries sent 34,000 tons to crude units.

The final recycling variable was *location*. Table 13 (below) shows the distribution of on-site and off-site activities for streams where recycling eliminated more than 10,000 wet tons of waste. **Spent caustics** -- the highest volume stream -- was the only stream in which roughly equivalent amounts were handled on-site and off-site. Seven streams containing usable hydrocarbons -- **DAF float, slop oil emulsion solids, API separator sludge, nonleaded tank bottoms, other separator sludges, contaminated soils/solids** and **other oily sludges/organic wastes NOS** -- were recycled on-site almost exclusively, as was **biomass**. Five streams -- consisting of spent chemicals, chemical mixtures, and catalysts -- were mostly recycled off-site.

Table 13
Location of Recycling Activities
(thousands of wet tons)

Waste Stream	Quantity	Percent On-Site	Percent Off-site
Spent caustics	598	55%	45%
DAF float	132	100	0
Waste coke/carbon/charcoal	107	0	100
Slop oil emulsion solids	93	95	5
API separator sludge	84	99	1
Biomass	61	100	0
FCC catalyst or equivalent	51	6	94
Nonleaded tank bottoms	43	100	0
Hydroprocessing catalysts	32	0	100
Waste sulfur	30	0	100
Other separator sludges	27	100	0
Waste oils/spent solvents	24	11	89
Contaminated soils/solids	23	95	5
Other oily sludges/organic wastes NOS	11	100	0

Treatment

In the waste management hierarchy, treatment is a tertiary choice for the handling of wastes. The treatment methods refineries use include separation procedures -- to concentrate dilute wastes and other chemicals -- and physical, thermal, and stabilization techniques. (Incineration is classified as a treatment method; the ash that remains is designated a residue for disposal.) Though land treatment was classified as a treament method during the data collection phase of the survey, findings on it are presented separately in a later section of this report -- reflecting its unique status as a means of both treatment and disposal.

In 1989, petroleum refineries reported treatment of 1.51 million tons of waste (for a breakdown by waste stream, see Appendix D, Table D-4). This was more than the 1.45 million tons reported in 1988 and less than the 1.58 million tons treated in 1987. After adjusting for the outliers who generated large amounts of **aqueous wastes NOS,** the proportion of waste eliminated by treatment was 28 percent of the 1989 total -- the same share as in 1988 and a slightly smaller share than the 31 percent in 1987.

Table 14 summarizes the data on methods used to treat refining wastes during the survey years. *Wastewater* treatment -- a series of neutralization, chemical and physical processes refineries employ in their wastewater treatment systems -- was used for 78 percent of the wastes treated in 1989. Though the number of tons of wastes eliminated by *incineration* has increased consistently over time, the total amount of waste treated by this method is just 9 percent -- comparable to the amount eliminated by *chemical/physical* treatment. The use of *other* treatment methods dropped to 3 percent in 1989.

Table 14
Summary of Treatment Methods
(thousands of wet tons)

Method of Treatment	1989 Tons	Percent	1988 Tons	Percent	1987 Tons	Percent
Wastewater	1,176	78	1,045	72	1,167	74
Incineration	143	9	131	9	107	7
Chemical/physical	143	9	148	10	117	7
Other	49	3	122	8	186	12
Total	1,511	100	1,446	100	1,577	100

Table 15 (page 28) presents 1989 treatment data for the highest volume streams (for detailed data, see Appendix D, Table D-5). Streams in the wastewater treatment category -- the largest -- are divided into two groups: *wastewaters from oily materials,* which are dewatered[2] (in some cases, deoiled) to reduce the volume of sludge created, and *aqueous chemical wastes/inorganics,* which are more dilute with fewer solids.

In the oily materials group, the ranking of **DAF float** and **API separator sludge** were consistent with the 1987-1988 survey, as were the amounts treated. While the ranking of other streams in this group varied more over the survey years, their 1989 quantities were in the range previously observed.

The pattern was similar for aqueous chemical wastes/inorganics. The 249,000 wet tons of **biomass** and 93,000 wet tons of **spent caustics** were comparable to the amounts for previous years. Amounts of treated **high pH/low pH waters** and **waste amines** rose in 1989, but other streams in the group were fairly consistent over time.

As noted above, the total amount of waste treated by *incineration* has steadily increased. In 1989, **biomass** was the highest volume stream treated by this method of thermal destruction, followed by **DAF float.**

[2]A separate step that precedes wastewater treatment.

In the *chemical/physical* category, the overall quantity has hovered in the 10 percent range despite a nearly complete turnover in high volume streams. **Spent caustics** was the only stream mentioned in all three survey years. **Other inorganic wastes NOS**, whose generation quantity rose more than 100,000 tons in 1989, was the highest volume stream; it included 63,000 tons undergoing chemical treatment (see Appendix D, Table D-5). **API separator sludge** was second highest in volume, followed by **pond sediments.**

In the *weathering/other* category, **other inorganic wastes NOS** remained a high volume stream in 1989.

The frequency of refineries reporting each treatment method was also reviewed. These actual counts -- of the number of times a refinery pairs a waste stream and a treatment method -- were not weighted to correspond with the extrapolated quantities of wastes generated by the population as a whole.

The most frequently reported treatment method was incineration of **other wastes NOS** (see Appendix D, Table D-6). But just over 500,000 tons of were treated this way. Thus, while more than 25 percent of the survey participants reported incineration of miscellaneous wastes such as used drums, batteries, and lab wastes, the total amount incinerated was insignificant.

Frequency counts were more reliable for dewatered streams and streams undergoing wastewater treatment. These methods were cited 197 times by at least 10 refineries for at least 10 streams. (This reporting can be considered more reliable because the greater frequency of method citations per waste stream tends to reflect the relative quantity of waste eliminated.) The number of pairings of other waste streams and treatment methods was low. Again, this suggests that refineries tailor their waste treatment patterns to circumstances unique to each facility.

Table 15
Estimated Quantities of Wastes Treated*
(thousands of wet tons)

Treatment Method/ Waste Stream	1989	1988	1987
Wastewater treatment			
From dewatered oily materials			
DAF float	248	236	263
API separator sludge	149	136	146
Slop oil emulsion solids	98	57	98
Other separator sludges	53	48	32
Pond sediments	48	22	74
Nonleaded tank bottoms	37	30	87
Aqueous chemical wastes/inorganics			
Biomass	249	222	234
Spent caustics	93	74	87
High pH/low pH waters	53	40	33
Waste amines	46	2	2
Spent Stretford solution	29	39	17
Other inorganic wastes NOS	23	39	33
Oil contaminated waters (not wastewaters)	19	35	26
All others	31	594	735
Total	1,176	1,045	1,167
Incineration			
Biomass	103	73	64
DAF float	26	47	35
All others	14	11	8
Total	143	131	107
Chemical/physical			
Other inorganic wastes	63	-	-
API separator sludge	35	10	2
Pond sediments	11	0	-
DAF float	9	0	-
Spent caustics	8	18	17
All others	17	120	98
Total	143	148	117
Weathering/other			
Other inorganic wastes NOS	23	23	22
Pond sediments	16	21	88
All others	10	78	76
Total	49	122	186
Grand total	1,511	1,446	1,577

* Does not include land treatment.

Table 16 (below) shows the location of treatment to eliminate 10,000 or more wet tons. Virtually all of the 11 waste streams were treated on-site. Only 2 streams had substantial off-site treatment: **other inorganic wastes** and **spent Stretford solution.**

Table 16
Location of Treatment Activities
(thousands of wet tons)

Waste Stream	Quantity	Percent On-Site	Percent Off-site
Biomass	355	82	18
DAF float	283	98	2
API separator sludge	195	100	0
Other inorganic wastes	112	45	55
Slop oil emulsion solids	103	100	0
Spent caustics	103	96	4
Pond sediments	69	100	0
High pH/low pH water	58	99	1
Other separator sludges	53	100	0
Waste amines	47	99	1
Nonleaded tank bottoms	38	98	2
Spent Stretford solution	30	56	44
Oil contaminated waters (not wastewaters)	19	100	0
Other spent catalysts NOS	12	100	0

Land Treatment

This technology, also known as "land farming," uses organisms that naturally exist in soil for biodegradation of organic materials. The mixture of soil and wastes is tilled to oxygenate it, then fertilized and watered. The nutrients and moisture encourage the growth of biological organisms that feed on organic materials. The residue from the process remains in the ground and must be properly managed when the land farm closes.

As Table 17 (following page) shows, 709,000 wet tons of waste were land treated in 1989 -- some 100,000 wet tons less than the 832,000 wet tons reported in 1988 and the 850,000 wet tons reported in 1987. This dropped the percentage of land treated wastes from the 16 to 17 percent range to 13 percent (after adjusting to control for the outliers). Although land treatment of wastes appears to be declining, it was used in 23 of the 28 waste streams in 1989 (see Appendix D, Table D-7).

Table 17
Estimated Quantities of Land Treated Wastes
(thousands of wet tons)

Waste Stream	1989	1988	1987
Biomass	187	259	236
Contaminated soils/solids	132	28	22
Pond sediments	127	64	67
DAF float	72	203	159
API separator sludge	61	85	211
Nonleaded tank bottoms	36	34	58
Other separator sludges	30	22	12
Slop oil emulsion solids	27	57	35
Other inorganic wastes NOS	16	30	25
Other contaminated soils	10	28	22
Other oily sludges/organic wastes	6	6	11
All others	5	11	14
Total	709	832	850

The high volume streams were essentially the same during the survey years. Heading the list was **biomass** (a dilute stream containing up to 98 percent water -- necessary for the land treatment process -- and decayed biological organisms from the activated sludge process). The 187,000 wet tons of biomass reported in 1989 was less than the 259,000 wet tons and 236,000 wet tons reported previously. Similarly, the amount of land treated **DAF float** and **API separator sludge** declined during the survey years, though they remained among the five highest volume streams.

More **contaminated soils/solids** and **pond sediments** were land treated in 1989. This probably reflects the pending listing of primary sludges as hazardous wastes under RCRA and the imminent ban on land treatment.

No true pattern emerged from a comparison of the frequency of land treatment in each stream (see Appendix D, Table D-8) and the extrapolated quantities shown above. The streams cited most often, **API separator sludge** (26 refineries) and **nonleaded tank bottoms** (24 refineries), were intermediate in quantity. Conversely, just 10 facilities reported land treatment of 187,000 wet tons of **biomass. Contaminated soils,** cited by 20 refineries, may be the only stream where the amount of land treated waste seems to comport with the number of facilities reporting this treatment method.

Review of the data on the location of land treatment showed that it is almost always performed on-site. Thus, it was surprising to find that 34 percent of **DAF float** and 17 percent of **slop oil emulsion solids** were sent to off-site facilities for land treatment.

Disposal

Disposal is the least preferred method of handling waste, yet it is a critical and essential part of all waste management scenarios. After valuable materials have been recycled and treatment diminishes the amount of waste, some residual materials inevitably remain. Because they have little intrinsic value, they are discarded -- disposed of in impoundments, landfills, injection wells or by landspreading.

Though disposal is the least preferred method of handling wastes, it is an essential part of waste management. Table 18 (below) summarizes refineries' disposal practices during the survey years (for a breakdown by waste stream, see Appendix D, Table D-9). In 1989, the refining industry disposed of 12.710 million wet tons of waste -- comparable to the 12.703 million wet tons in 1988 and the 12.829 million wet tons in 1987.

The 12.710 million wet tons disposed of in 1989 was 78 percent of the waste the industry managed that year, including the 11 million tons of injected **aqueous wastes NOS** from the outlier facilities. When the disposal rate is calculated without the outliers, the amount disposed of is 32 percent of the wastes managed in 1989 -- comparable to the 31 percent and 33 percent in prior years.

Table 18
Summary of Disposal Practices
(thousands of wet tons)

Method of Disposal	1989 Tons	Percent	1988 Tons	Percent	1987 Tons	Percent
Disposal impoundments	113	1	245	2	280	2
Landfills	1,375	11	1,200	9	1,070	8
Landspread	95	1	160	1	109	1
Injection	11,106	87	11,097	87	11,329	88
Other	21	<1	1	<1	41	<1
Total	12,710	100	12,703	100	12,829	100

The overall amount of waste requiring disposal has remained stable over the years. Disposal methods also seem consistent, since the large amounts the outliers inject mask changes in other categories. But while the percentage in each category has remained constant, the amount in landfills has increased and the amount in impoundments has decreased. Not counting the outliers, 80 percent of the wastes disposed of in 1989 went to landfills -- 26 percent of the total amount managed.

Table 19 (following page) shows the disposal of large quantities of waste in different streams. (See Table D-10 in Appendix D for information on all waste streams.) In the *disposal impoundment* category, it appears that quantities dropped because of changes in the contributing streams. The amount of **other inorganic wastes NOS, high pH/low pH waters** and **FCC catalyst or equivalent** remained constant during the survey years. But in 1989, refineries did not use disposal impoundments for **biomass, API separator sludge, pond sediments,** and **DAF float.**

Table 19
Estimated Quantities of Wastes Eliminated by Disposal
(thousands of wet tons)

Disposal Method/ Waste Stream	1989	1988	1987
Disposal impoundment			
Other inorganic wastes NOS	65	25	56
High ph/low Ph waters	24	16	25
FCC catalyst or equivalent	14	13	11
All others	10	191	188
Total	113	245	280
Landfill			
Contaminated soils/solids	317	189	141
Other wastes NOS	315	384	195
Other inorganic wastes NOS	227	77	155
FCC catalyst or equivalent	104	115	123
API separator sludge	77	51	54
Pond sediments	60	50	77
Nonleaded tank bottoms	45	42	53
Other contaminated soils NOS	38	69	82
Biomass	37	48	41
DAF float	29	51	31
Waste coke/carbon/charcoal	28	13	13
Other oily sludges/organic wastes NOS	22	14	8
Waste sulfur	20	19	16
Slop oil emulsion solids	19	22	25
All others	37	56	56
Total	1,375	1,200	1,070
Landspread			
Slop oil emulsion solids	20	2	4
Contaminated soils/solids	16	11	4
Biomass	15	48	51
Other inorganic wastes NOS	14	10	11
FCC catalyst or equivalent	13	-	5
All others	17	89	33
Total	95	160	109
Injection			
Aqueous wastes NOS	11,091	11,067	11,289
Spent caustics	14	24	33
All others	1	6	7
Total	11,106	11,097	11,329
Other methods			
Pond sediments	9	-	-
All others	12	-	-
Total	21	-	-
Grand total	12,710	12,703	12,829

The increase in the amount of waste in *landfills* appears to relate to the reported increase in generation of **contaminated soils/solids** and **other inorganic wastes NOS**. In addition, it appears that more **DAF float, waste coke/carbon/charcoal** and **waste sulfur** went to landfills in 1989.

While use of *landspreading* has remained stable, it appears that in 1989 this method of disposal was used for a greater variety of wastes. In 1987 and 1988, most landspread wastes were **biomass** and **pond sediments**; in 1989, there were five streams.

A comparison of the frequency of refineries reporting use of landfills for specific streams and the quantities of waste thus disposed of reveals a fairly direct relationship (see Appendix D, Table D-11). Landfills were most frequently used for **other wastes NOS** (93 refineries) and **contaminated soils/solids** (71 refineries). A relatively small number sent **pond sediments** (14 refineries) and **biomass** (17 refineries) to landfills, though they ranked high in total quantity -- sixth and ninth, respectively.

Table 20 (below) shows the disposal *location* for the 18 streams with wastes of 10,000 or more wet tons. In contrast to recycled and treated wastes -- where an "all or none" pattern prevailed -- on-site and off-site disposal were mixed for most streams.

Table 20
Location of Disposal Activities
(thousands of wet tons)

Waste Stream	Quantity	Percent On-Site	Percent Off-site
Aqueous wastes NOS	11,091	100	0
Contaminated soils/solids	336	30	70
Other wastes NOS	316	40	60
Other inorganic wastes NOS	305	85	15
FCC catalyst or equivalent	133	38	62
API separator sludge	85	6	94
Pond sediments	72	8	92
Biomass	52	55	45
Nonleaded tank bottoms	47	19	81
Other contaminated soils NOS	40	10	90
Slop oil emulsion solids	39	52	48
DAF float	34	17	83
Waste coke/carbon/charcoal	29	37	63
High pH/low pH waters	25	100	0
Other oily sludges/organic wastes NOS	23	32	68
Waste sulfur	22	8	92
Spent caustics	15	2	98
Other spent catalysts NOS	12	33	67

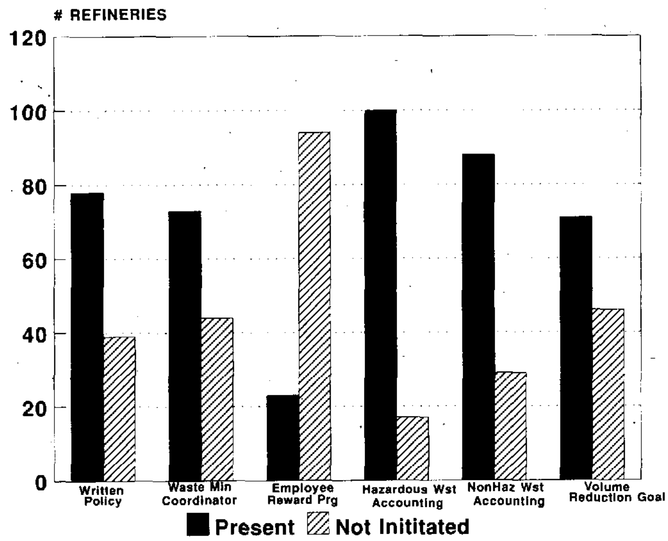
Aqueous wastes NOS and **high pH/low pH waters** were disposed of exclusively on-site. Another stream also relied heavily on on-site disposal capacity: **other inorganic wastes NOS**. In contrast, 90 percent or more of five streams were sent off-site for *disposal:* **API separator sludge, pond sediments, other contaminated soils NOS, waste sulfur,** and **spent caustics.** The remaining 10 streams were handled both on-site and off-site.

Waste Minimization Programs

Section 3002(b)(1) of RCRA requires hazardous waste generators to have "a program in place to reduce the volume or quantity and toxicity of such waste to the degree determined by the generator to be economically practicable." Instead of prescriptive standards defining what constitutes a waste minimization program, EPA has issued technical assistance and guidance documents.

The components of a waste minimization program include management commitment, waste characterization, and volume reduction goals. Accordingly, the survey asked about a written policy, personnel dedicated to it, employee awards for waste minimization, accounting for hazardous and non-hazardous wastes, and waste reduction goals (see Appendix A, question 8). Figure F (below) shows that most survey participants have most of these elements except employee awards (16 percent). Eighty-three percent compile quantitative data on generation of hazardous wastes and 75 percent on generation of non-hazardous wastes.

Figure F
Waste Minimization Program Components



Two categories are shown above: "present" and "not inititated." When the data were collected, there were four possible responses: company-wide, refinery-specific, at both the corporate and facility level, and not initiated. This four-category scheme yielded inconsistent data for companies with several refineries. Before using this question again, the response categories will be revised to eliminate the possibility of inconsistencies.

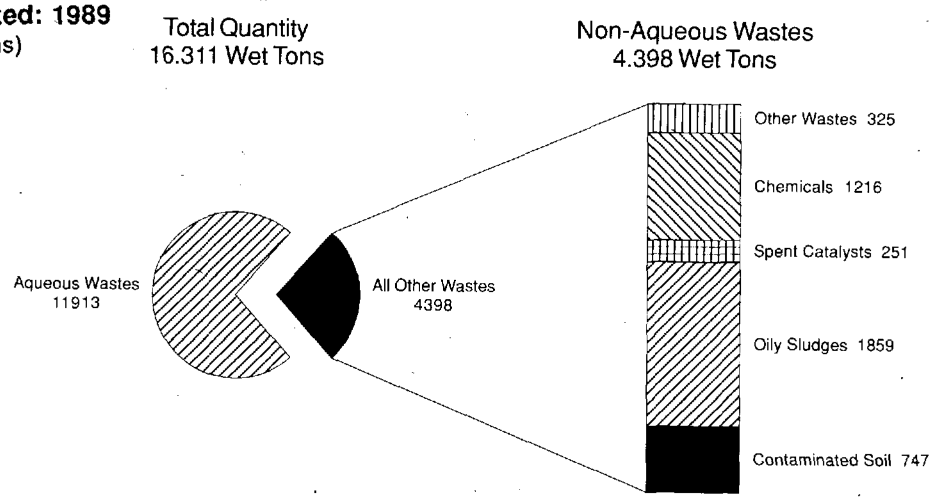
Discussion

Waste Generation

In 1989, the petroleum refining industry generated about 16.3 million wet tons of waste -- slightly more than the 16.0 million wet tons generated in 1988 and the 16.1 million wet tons generated in 1987. Standardizing this by crude throughput for the year -- 657 million wet tons -- results in a 0.0248 ratio of waste to throughput. This is virtually the same as the 0.0247 ratio for 1988 and less than the 0.0256 ratio for 1987.

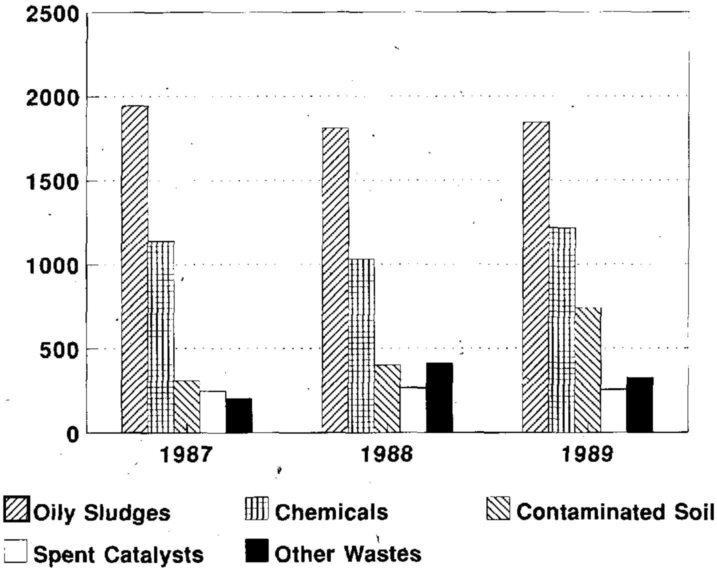
Figure G (below) shows the composition of wastes generated in 1989. About two-thirds were **aqueous wastes** (including the outliers). The other five categories of waste comprised the remaining third.

Figure G
Wastes Generated: 1989
(millions of wet tons)



Ordered by quantity, **oily sludges** ranked first, followed by **chemicals, contaminated soils, spent catalysts** and **other wastes NOS** -- similar to other survey years. The amounts of **oily sludges, chemicals** and **spent catalysts** have also remained steady. But the amount of **contaminated soil** has increased over time and the amount of **other wastes** has fluctuated (see Figure H, following page).

Figure H
Wastes Generated: 1987-1989



The consistency of the amount of waste in most categories seemed counter to the variations in specific streams observed while "cleaning" the data -- identifying potentially out-of-range responses. Thus, data from refineries that participated in the survey in all three years, generated at least 1,000 wet tons of waste per stream, and reported a change of 50 percent or more in the amount of waste generated (either an increase or decrease) were reviewed.

In the *oily sludges* category, there was substantial variation in four of the nine streams: **API separator sludge, other separator sludges, slop oil emulsion solids,** and **other separator sludges.** Three streams -- **DAF float, pond sediments** and **waste oils/spent solvents** -- were relatively stable, in contrast to the category as a whole (see Figure H).

More than half the survey participants reported a change of 50 percent or more in three waste streams: **biomass** (19 of 29 refineries), **contaminated soils** (34 of 57 refineries), and **nonleaded tank bottoms** (25 of 38 refineries). At least 40 percent of the refineries reported a change of 50 percent or more in four streams: **API separator sludge, other separator sludges, other inorganic wastes NOS,** and **slop oil emulsion solids**. The variations were not entirely surprising: unit change-outs and new construction cause periodic peaks in the amounts of these wastes.

At the other end of the spectrum, less than 10 percent of the refineries reported a 50 percent change in seven waste streams: **waste oils/spent solvents, DAF float, hydroprocessing catalysts, waste sulfur, pond sediments,** and **waste coke/carbon/charcoal.**

To determine the sources of variability in waste generation rates, the performance of refineries that participated in the survey in all three years was closely examined. Streams with three-year industry-wide means of at least 100,000 wet tons -- reported by at least 10 refineries -- were chosen for further study. There were 12 such streams, representing about 87 percent of the non-aqueous wastes the industry generated. For these streams, coefficients of variation (the standard deviation expressed as a percentage of the mean) were determined for the entire industry and for each refinery reporting each waste stream. Table 21 (below) presents this data.

Table 21
Sources of Variability in Waste Generation Rates 1987-1989

Waste Stream	Number of Refineries Reporting the Stream	Mean Amount of Waste Managed (in wet tons)	Mean Coefficient of Variation for the Industry	Median Coefficient of Variation for Refineries
Spent caustics	54	681,863	4	31
FCC catalyst or equivalent	65	181,808	5	37
Biomass	29	707,974	7	37
Slop oil emulsion solids	35	229,251	13	60
DAF float	35	611,737	13	41
Pond sediments	13	314,827	14	70
API separator sludge	68	472,769	17	60
Other separator sludges	11	103,331	18	61
Nonleaded tank bottoms	38	170,807	26	80
Other inorganic wastes NOS	48	328,005	34	52
Other wastes NOS	19	313,412	34	65
Contaminated soils/solids	34	307,801	54	71

The mean coefficient of variation for the industry ranges from 4 to 54 percent. Waste streams with lower coefficients of variation tend to be generated continually -- for example, **spent caustics** (4 percent) and **FCC catalyst or equivalent** (5 percent). Waste streams with higher coefficients of variation tend to be generated periodically -- for example, **pond sediments** (14 percent), **API separator sludge** (17 percent), and **contaminated soils** (54 percent).

The median coefficients of variation for refineries are consistently higher than the mean coefficients of variation for the industry. The refinery figures -- ranging from 31 percent to 71 percent -- are three to seven times higher. This indicates that from year to year, waste generation rates vary much more within facilities than industry-wide statistics suggest. Since they vacillate more for individual refineries than for the industry as a whole, assessments of progress should be refinery-specific.

This observation raises the concern that although industry-wide measures are good indicators of national trends, they may be less reliable when it comes to individual refineries. It also suggests that for the industry as a whole, meaningful progress may be difficult to detect. Industry-wide measures of change have to be quite substantial to overcome the background "noise" of individual refinery variations. Indeed, this is the case for **contaminated soils,** which more than doubled during the survey years.

Source Reduction

In 1989, 55 refineries -- close to half the survey participants -- reported source reduction activities related to 24 of the 28 waste streams. To our knowledge, the collection and publication of such industry-wide data is a first. Some individual companies have publicized their accomplishments, but this is the first national effort to track progress on source reduction as a pollution prevention indicator. As a result, API can more readily provide technical assistance to the industry and help promote source reduction activities.

The 1989 survey data show that economic considerations are an impetus for -- and impediment to -- source reduction activities. Eighty-four percent of the refineries that conducted source reduction activities identified reducing treatment and disposal costs as an incentive. Conversely, inability to recover capital costs was the leading reason refineries did not implement source reduction activities (see Table 22 below).

Table 22
Barriers to Source Reduction

Reason	Number of Responses	Percent of Total
Not economically feasible; capital investment not recoverable	22	37
Lack of technical information on applicable reduction techniques	14	23
Technical limitations of production process	14	23
Other	12	20
Permitting burdens	6	10
Concern with product quality	4	7

Though API cannot lessen economic constraints on source reduction, publishing this report can address conceptual misunderstandings about source reduction. For example, many of the reported changes in housekeeping and inventory control procedures were not expensive. And more street sweeping, dike reinforcement, and paving -- which help reduce sludge formation -- have probably been performed than reported (for detailed descriptions, see Appendix C). The hope is that this information will help refineries recognize the activities that contribute to preventing waste generation -- even if those activities are undertaken for other reasons.

Misunderstandings about what constitutes source reduction are widespread. The inconsistencies and errors in reporting source reduction activities attest to this -- though they were understandable given that the 1989 survey tested new questions on the subject.

While "cleaning" the 1989 data, it became clear that source reduction had been defined in a way that excluded certain beneficial practices. For example, a number of facilities reported improvements in dewatering operations and reuse or recovery of secondary materials at off-site facilities. As a result, the 1990 survey includes a new question on "resource recovery" activities, which comes before the source reduction section. The hope is that this order -- giving respondents a chance to report such waste minimization activities first -- will improve the quality of answers to source reduction questions later in the survey.

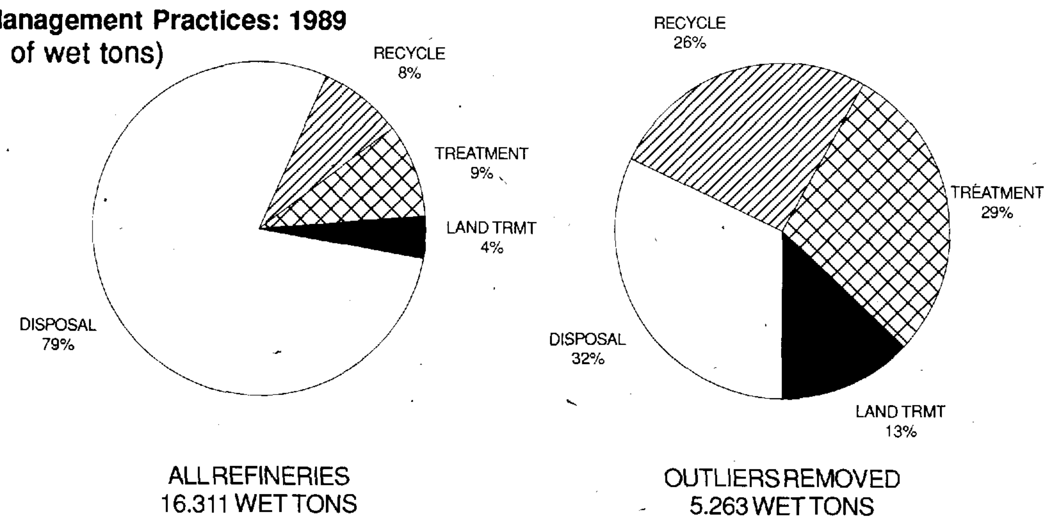
The 1989 survey provided insight into the confusion surrounding source reduction. The hope is that the 1990 survey will help API plan additional technical assistance activities and further promote the implementation of source reduction activities.

Waste Management

The petroleum refining industry managed 16.306 million wet tons of waste in 1989 -- slightly less than the 16.311 million wet tons generated (largely due to putting **pond sediments** in storage). The amount managed was more than the 16.162 million wet tons managed in 1988 and less than the 16.338 million wet tons managed in 1987.

Figure I shows how the industry managed its 1989 wastes according to the waste management heirarchy. The figure on the left includes the outliers, while the figure on the right illustrates the more normative pattern of recycling, treatment, land treatment, and disposal.

Figure I
Waste Management Practices: 1989
(millions of wet tons)



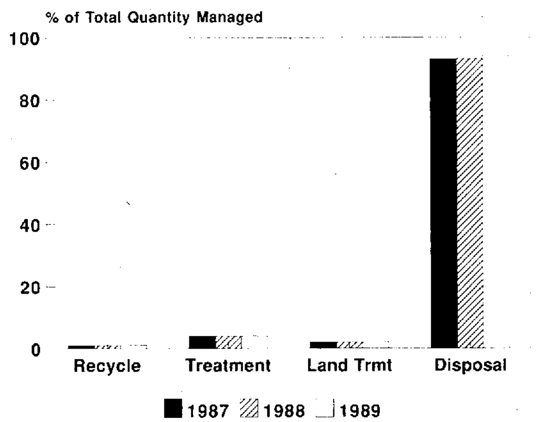
The waste management practices reported in 1989 were virtually the same as those in 1987 and 1988. While there were no significant differences in consecutive years, there appear to be some shifts during the three-year survey period. The amount of *recycled* waste rose from 21 percent in 1987 to 23 percent in 1988 to 26 percent in 1989. The amount of *land treated* waste declined from 17 percent in 1987 to 16 percent in 1988 to 13 percent in 1989. *Treatment* and *disposal* quantities for 1989 were between those observed in 1987 and 1988 (31 and 28 percent for treatment, and 31 and 33 percent for disposal).

Figure J (following page) summarizes the survey data for all six broad categories of waste. The bulk of *recycling* involves **chemicals/inorganic wastes**; recycling is also used for substantial amounts of **spent catalysts, oily sludges/other organic wastes,** and **contaminated soils.** *Treatment* eliminates about 40 percent of **oily sludges/other inorganic wastes** and about 20 percent of **chemicals/inorganic wastes.** *Land treatment* is used for **oily sludges/other inorganic wastes** and a small share of **contaminated soils/solids.** While *disposal* is used for significant shares of **contaminated soils/solids, aqueous wastes, other wastes,** and **spent catalysts,** the actual amount of waste in three of these categories is among the smallest of any stream.

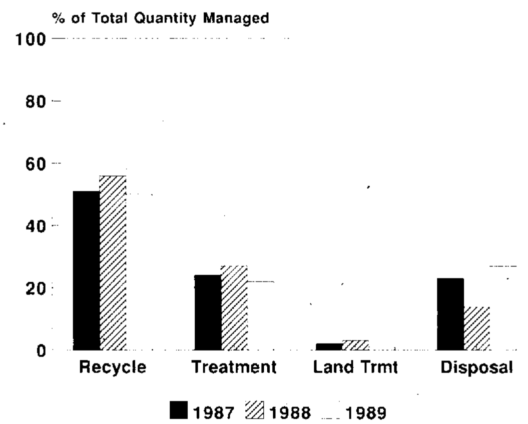
Management profiles for individual waste streams vary more than might be expected (see the bar graphs in Appendix E). The profiles of several streams appear static -- for example, **biomass, spent caustics,** and **other inorganic wastes.** Nonetheless, there have been changes in how they are handled -- for example, treatment and land treatment of **other separator sludges** have increased while disposal of them has declined.

Figure J
Waste Management Practices: 1987-1989

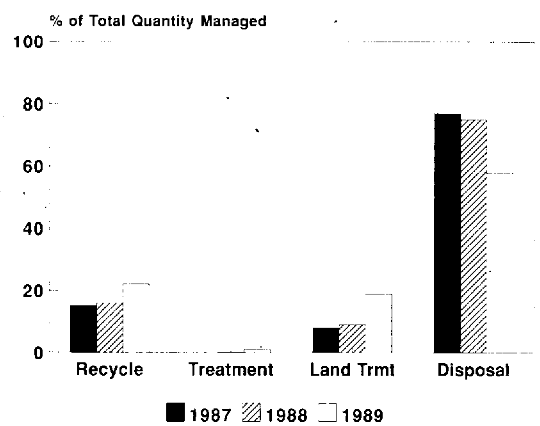
AQUEOUS WASTES



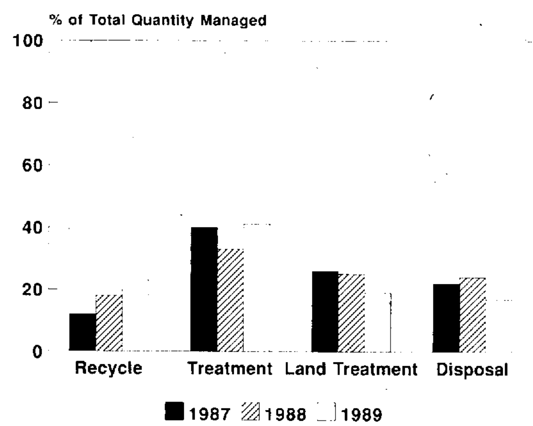
CHEMICALS/INORGANIC WASTES



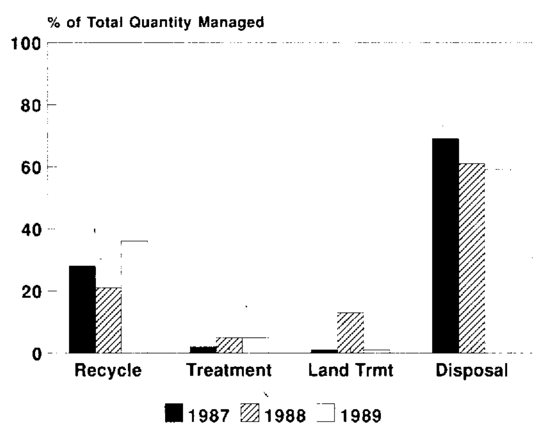
CONTAMINATED SOILS/SOLIDS



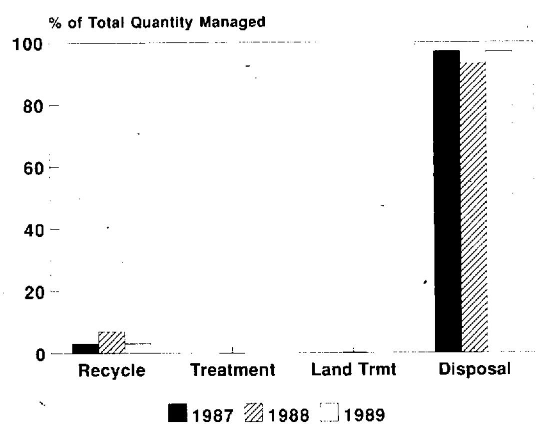
OILY SLUDGES/OTHER ORGANIC WASTES



SPENT CATALYSTS

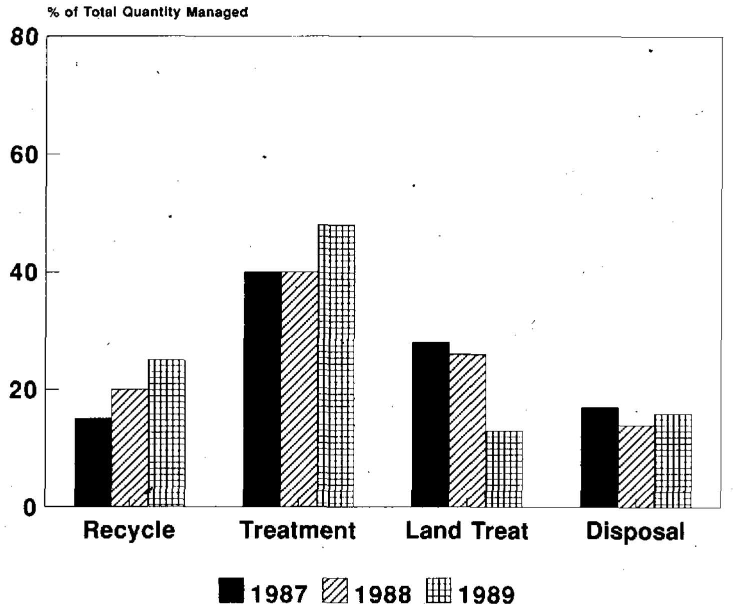


OTHER WASTES



Methods of handling RCRA-listed hazardous wastes further illustrate the interplay of waste management techniques (see Figure K below).

Figure K
Management Practices for RCRA Hazardous Wastes



Petroleum refineries are relying more on methods higher in the waste management hierarchy to deal with RCRA-listed hazardous wastes -- specifically, recycling and treatment. Over the last eight years, the amount of RCRA-listed hazardous wastes the eliminated by land treatment, incineration and disposal has declined 66 percent per unit of throughout.

In 1981, according to an API survey, the industry land treated or incinerated 850,000 wet tons of K048-K052 wastes; participants in the 1989 API survey reported using these methods for just 358,000 wet tons. In 1981, crude throughout was 575 million wet tons; in 1989, it was 657 million wet tons. Thus, the ratio of waste to throughout has declined from 0.15 to 0.05 percent between 1981 and 1989.

The consistency in methods of managing RCRA-listed hazardous wastes is not the norm for managing other refinery waste streams, however. As illustrated by the earlier discussion of how often survey participants cite various recycling, treatment and disposal methods, relationships between the number of refineries using each method and the amount of waste eliminated are not always clear. (Recall that the number of refineries sending **API separator sludge** to cokers was less than the number of refineries returning material to crude units, though substantially more waste went to cokers than to crude units.)

Further analysis is needed to determine the sources of such variability. Before it can be done, there must be sufficient annual data to overcome the dispersion of data points across handling practices. With 8 recycling methods, 10 treatment methods, and 5 disposal methods, there are not yet enough data points to make meaningful comparisons -- especially when other factors such as refinery size must be taken into account. As more data is collected, such analyses will be attempted.

Even though the database is not amenable to multivariate analysis, one factor was explored to determine its effect on waste management practices. In 1989, a data element was added that identifies dewatering performed before materials are considered wastes and reported on the survey (see the data sheet in Appendix A). The theory was that prior dewatering would result in the generation of less waste and fewer opportunities for recycling and treatment. Thus, the reported point of generation could influence the management profile of the waste stream.

The data were arrayed by waste stream, dewatering status, and refinery size. It was found that 6 of the 28 streams did not undergo prior dewatering: **hydroprocessing catalysts, high pH/low pH waters, spent sulfite solution, spent Stretford solution, spent caustics,** and **spent acids**. Overall, the rate of prior dewatering was low: 161 reports from a total of 1,146 data sheets. (While the frequency of prior dewatering seemed high, the amount of waste involved was less than 15 percent of the total managed in 1989.)

Reports of prior dewatering clustered consistently in RCRA-listed hazardous waste streams -- or candidates for listing such as **pond sediments** and **other inorganic wastes** (streams subject to F037 and F038 primary sludge listings). Half the survey participants who generated **API separator sludge** and **slop oil emulsion solids** reported prior dewatering. Survey participants also reported prior dewatering of **DAF float** and **pond sediments**.

While dewatering minimizes hazardous wastes, it also prevents reporting waste minimization as EPA defines it. Refineries that perform prior dewatering dispose of more wastes -- leaving less to recycle and treat. Refineries that do not perform dewatering have more wastes to manage -- and more to recycle and treat.

This analysis does not take into account all the complexities of waste management: waste composition; refinery configuration and location; the availability of on-site treatment capacity such as filter presses, centrifuges and cokers; the proximity of disposal capacity; and regulatory constraints. As more data accumulate -- and further analyses are performed -- understanding of variations will grow. A cautionary note is warranted, however. It is unreasonable to expect that even with time, the survey will explain all the variations. In the end, waste management decisions will continue to reflect a dynamic balancing of economic, environmental, and regulatory factors.

APPENDIX A - QUESTIONNAIRE

1989 API Solid Waste Survey-Refining

API ID ______
Leave Blank

1) What was the approximate year this facility began operations?

Check the appropriate box.

- ☐ Before 1925
- ☐ 1925 - 1940
- ☐ 1941 - 1950
- ☐ 1951 - 1960
- ☐ 1961 - 1970
- ☐ 1971 - 1980
- ☐ After 1980

2) Which of the following USEPA National Pollutant Discharge Elimination System (NPDES) - Permit Fact Sheet Classifications best describes this refinery?

Check the appropriate box

- ☐ **Topping**
  Refinery uses topping and catalytic reforming, but <u>not</u> thermal processes or cracking.
- ☐ **Cracking**
  Refinery uses topping and cracking, but none of the operations designated in the categories below.
- ☐ **Petrochemical**
  Refinery uses topping and cracking, and 1) <u>at least 15%</u> of refinery production is first-generation petrochemicals and isomerization products (e.g., BTX, olefins), or
  2) the refinery produces second-generation petrochemicals (e.g., alcohols, cumene), and 3) there is <u>no</u> lube oil manufacturing.
- ☐ **Lube**
  Refinery uses topping, cracking, and lube oil manufacturing processes, but <u>not</u> petrochemical operations.
- ☐ **Integrated**
  Refinery uses topping, cracking, lube oil, and petrochemical manufacturing processes.

(NOTE: If your facility does <u>not</u> fit one of these categories, please call Wendall Clark at (914) 227-5769 to clarify the types of operations performed at your facility.)

3) What type of sewer system does this facility have?

Check the appropriate box.

- ☐ Non-segregated between process water & storm water
- ☐ Partially segregated between process water & storm water
- ☐ Totally segregated between process water & storm water

4) Indicate your facility's RCRA permitting status and the regulatory authority for the permit.

In each column, check the **ONE** category that best describes this facility.

Before 9/25/90	After 9/25/90	
☐	☐	Generator only; no RCRA permit required. (Hazardous waste is NOT treated, stored or disposed of on-site.)
☐	☐	Part A filed (interim status).
☐	☐	RCRA permit issued.

5) For 1989, what was this facility's operable crude oil capacity in BARRELS PER STREAM DAY as reported in the Oil & Gas Journal?

__________ Barrels per <u>Stream</u> Day

6) What was the **TOTAL AMOUNT** of crude processed (throughput) in 1989?

__________ Million Barrels

7) In 1989, on how many days was crude charged? __________ Days

1989 API Solid Waste Survey-Refining

API ID ______
Leave Blank

8) Have any of the following activities been instituted on a company wide basis and/or at your refinery?

Check the appropriate boxes to indicate the organizational level where these activities have been initiated.

■ Prepared a written policy directive on waste minimization.

☐ Company wide ☐ Refinery Specific ☐ Both

■ Designated a waste minimization coordinator at each facility.

☐ Company wide ☐ Refinery Specific ☐ Both

■ Initiated a program to reward employees that identify/implement waste minimization activities.

☐ Company wide ☐ Refinery Specific ☐ Both

■ Set specific goals for reducing the volume or toxicity of wastes.

☐ Company wide ☐ Refinery Specific ☐ Both

■ Developed quantitative data on the generation of **hazardous** waste to measure progress on waste minimization.

☐ Company wide ☐ Refinery Specific ☐ Both

■ Developed quantitative data on the generation of **non-hazardous** waste to measure progress on waste minimization.

☐ Company wide ☐ Refinery Specific ☐ Both

9) **SOURCE REDUCTION** refers to a variety of activities that **prevent or decrease** the amount of waste created or the toxicity of waste generated. Source reduction activities include:

1) equipment and technology modifications;
2) procedure modifications;
3) reformulation or design of products;
4) substitution of raw materials;
5) recycling within a process; and
6) improved housekeeping, training or inventory control.

Generally, these changes are implemented in the process, before the "end of the pipe." Source reduction activities range from dust suppression measures and covering sewers, to the installation of vapor recovery systems.

In the spaces provided below, summarize each activity that prevented the generation of waste by coding the activity performed according to the enumeration of source reduction activities given above. Then provide the requested information on the amount of waste and/or toxicity reduced and the streams affected (use the code numbers from the coding sheet to indicate waste streams.) Finally, because source reduction activities are likely to be so variable between refineries, please provide a brief narrative description of the actual activities performed. (Space for the narrative summaries is provided on the following page.)

IF YOU DID NOT IMPLEMENT ANY SOURCE REDUCTION ACTIVITIES, SKIP ON TO QUESTION 12

	ACTIVITY (Circle only one)	AMOUNT REDUCED (Wet Tons)	TOXICITY REDUCED (Circle one)	WASTE STREAMS AFFECTED (List up to 5 Streams)
1.	1 2 3 4 5 6 Other	______	YES NO	___ ___ ___ ___ ___
2.	1 2 3 4 5 6 Other	______	YES NO	___ ___ ___ ___ ___
3.	1 2 3 4 5 6 Other	______	YES NO	___ ___ ___ ___ ___
4.	1 2 3 4 5 6 Other	______	YES NO	___ ___ ___ ___ ___
5.	1 2 3 4 5 6 Other	______	YES NO	___ ___ ___ ___ ___

1989 API Solid Waste Survey-Refining

API ID ______
Leave Blank

DESCRIPTION OF SOURCE REDUCTION ACTIVITIES

1. ______________________

2. ______________________

3. ______________________

4. ______________________

5. ______________________

10) What method did you use to calculate the quantity of waste that was prevented by your source reduction activities?

____

11) Listed below are several reasons why source reduction activities might be undertaken. Check all that apply.

- ☐ Regulatory requirement for waste.
- ☐ Reduction of treatment or disposal cost.
- ☐ Other process cost reduction.
- ☐ Self-initiated review.
- ☐ Occupational safety.
- ☐ Concern over public reaction to release amounts.
- ☐ Actual pressure from public or environmental groups.
- ☐ Other. Describe: ______________________

BECAUSE YOUR FACILITY HAS ALREADY IMPLEMENTED SOURCE REDUCTION ACTIVITIES, PLEASE GO ON TO THE DATA SHEETS. (SKIP QUESTION 12)

12) If you did not initiate any source reduction activities, identify those factors listed below that limited your ability to implement source reduction activities.

Check all that apply.

- ☐ Insufficient capital to install new source reduction equipment or source reduction practices.
- ☐ Lack of technical information on source reduction techniques applicable to specific production processes.
- ☐ Source reduction not economically feasible; cost savings in waste management or production will not recover the capital investment.
- ☐ Concern that product quality will decline as a result of source reduction.
- ☐ Technical limitations of the production processes.
- ☐ Permitting burdens.
- ☐ Other. Describe: ______________________

WASTE CODES FOR 1987-1988 API SOLID WASTE SURVEY

OILY SLUDGES AND OTHER ORGANIC WASTES

101 API SEPARATOR SLUDGE (K051)

102 DISSOLVED AIR FLOTATION FLOAT (K048)

103 SLOP OIL EMULSION SOLIDS (K049)

104 LEADED TANK BOTTOMS (K052)

105 OTHER SEPARATOR SLUDGES
- Induced Air Flotation (IAF) Float
- Separator Sludge, Other

106 POND SEDIMENTS
- Stormwater pond sludge
- Evaporation pond sludge
- Equalization pond sludge
- Secondary Wastewater Treatment Sludge
- Polishing pond sludge

107 NONLEADED TANK BOTTOMS
- Tank asphalt sludge
- Tank basic sediment sludge (muck/scale)
- Tank cat tar sludge
- Tank clarified oil sludge
- Tank crude sludge (muck/scale)
- Tank product sludge (muck/scale)
- Tank other sludge

108 WASTE OILS/SPENT SOLVENTS
- Benzene
- Naphtha
- Specialty oil, waste
- Toluene
- Waste oil (not used)
- Waste oil, used

109 OTHER OILY SLUDGES & ORGANIC WASTES NOS
- Desalter Sludge
- HF acid tars
- Pretreatment sludge
- Scraper trap waste (PL pigging sludge)
- Other organic sludges, NOS above
- Tetraethyl lead
- Spent additive (gasoline)
- Other organic liquids, NOS

CONTAMINATED SOIL/SOLIDS

201 HEAT EXCHANGER BUNDLE CLEANING SLUDGE (K050)

202 CONTAMINATED SOIL/SOLIDS
- Soil (crude) contaminated
- Soil (product) contaminated
- Debris, contaminated
- Used Sand Blasting Grit

203 WASTE COKE/CARBON/CHARCOAL
- Activated carbon
- Carbon Black
- Charcoal
- Coke Chunks
- Filter media, activated carbon
- VRU charcoal

204 WASTE SULFUR
- Claus unit waste
- Contaminated sulfur
- Sulfur with Stretford contamination

205 OTHER CONTAMINATED SOILS NOS
- Activated alky alumina
- Activated alumina
- Asphalt spill
- Catacarb filter media
- Stretford solution
- Filter sand
- Filter clay
- Grit trap waste
- Oil (crude) spill, non-soil
- Oil (product) spill debris, non-soil
- Tank bottoms, absorbent materials
- Waste oil absorbents
- Wax, contaminated
- Other contaminated solids, NOS above

SPENT CATALYSTS

301 FLUID CRACKING CATALYST OR EQUIVALENT
- FCCU cat dust
- Spent FCCU cat
- Contaminated FCCU cat

302 HYDROPROCESSING CATALYSTS
- Metallic Catalysts

303 OTHER SPENT CATALYSTS NOS
- Reformer catalysts
- Shift converter catalysts
- Other Metallic catalysts NOS
- Other Spent Catalysts, NOS

AQUEOUS WASTES

401 BIOMASS
- Biox Sludge

402 OIL CONTAMINATED WATERS OTHER THAN WASTEWATER
- Miscellaneous aqueous liquids
- Water, contaminated - oil, gasoline, etc.
- Bilge water

403 HIGH PH/LOW PH WATERS
- Ammonia & Water

404 SPENT SULFITE SOLUTION

405 SPENT STRETFORD SOLUTION
- Stretford slurry froth

406 OTHER AQUEOUS WASTE NOS
- (Do not include refinery process and/or storm wastewater)

CHEMICALS/INORGANIC WASTES

501 SPENT CAUSTICS
- Caustic, cresylic
- Caustic, sulfidic

502 SPENT ACIDS
- Acids, spent
- Sulfuric acid (excluding that exempted under C.F.R. 261.4(a)(7))

503 WASTE AMINES
- Amine Sludges
- Amine Reclaimer Sludges
- Spent Amines
- Other Amine Wastes NOS

504 OTHER INORGANIC WASTES NOS
- Boiler feed treatment sludge
- Caustic Tank Sludge
- Cleaners, acid
- Cleaners, caustic
- Cooling tower sludge
- Ion exchange resin
- Iron sulfide rust sludge
- Lime sludge, water treatment
- Lime sludge, alky
- Inorganic liquids, not specified above
- Inorganic sludges, not specified above

OTHER WASTES

601 OTHER WASTES NOS
- Asbestos insulation
- Drums, empty
- Lab/sample container, empty
- Laboratory wastes
- Batteries
- Butyl mercaptan
- Cement
- Desiccant, air drier
- Fiberglass
- Filter cartridges
- Filter, turbo fuel
- Oily rags
- Paint waste
- PCB capacitors
- PCB transformers
- PCB liquid
- Other listed wastes, not specified above
- Other organic gases, not specified above

SEPARATION TECHNIQUES, RECYCLE, TREATMENT, DISPOSAL CODES

SEPARATION TECHNIQUES	On-Site	Off-Site
Decanting	S100	S101
Thickening	S120	S121
Centrifugal	S150	S151
Filtration	S160	S161

RECYCLE METHOD	On-Site	Off-Site	Sold
Coker	R200	R201	R203
Crude Unit	R210	R211	R213
Desalter	R220	R221	R223
Sour Water Stripper	R230	R231	R233
Industrial Furnace	R240	R241	R243
Reclamation	R250	R251	R253
Regeneration	R260	R261	R263
Other *	R920	R921	R923

TREATMENT METHOD	On-Site	Off-Site
Weathering	T310	T311
Chemical	T330	T331
Heat	T340	T341
Impoundment	T370	T371
Physical	T380	T381
Wastewater Treatment	T390	T391
Incineration	T400	T401
Land Treatment	T410	T411
Stabilization/Fixation	T420	T421
Other *	T940	T941

DISPOSAL METHODS	On-Site	Off-Site
Disposal Impoundment	D500	D501
Landfill	D510	D511
Landspread	D520	D521
Injection	D530	D531
Other *	D950	D951

* Describe method in Comment section of data sheet

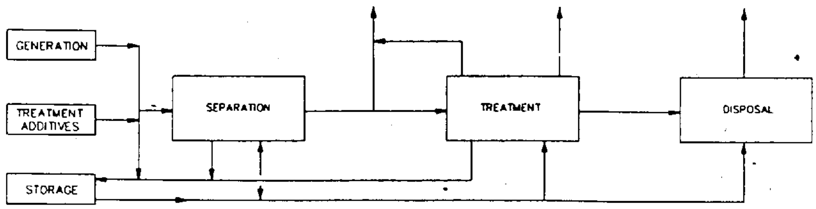
1989

API ID# ____________ (LEAVE BLANK)

DID YOUR FACILITY GENERATE AND/OR MANAGE **CODE 101 API SEPARATOR SLUDGE (K051)** IN 1989? ____________ (YES/NO)

WASTE MANAGEMENT

INPUTS		OUTPUTS						
GENERATION	WET TONS	**SEPARATION TECHNIQUES**	**ELIMINATED BY RECYCLE**		**ELIMINATED BY TREATMENT**		**DISPOSAL**	
		CODE	WET TONS	CODE	WET TONS	CODE	WET TONS	CODE
ROUTINE	______							
ONE-TIME ★	______	S ______	______	R ______	______	T ______	______	D ______
HAVE THESE GENERATION QUANTITIES HAD PRIOR DEWATERING? ☐ YES ☐ NO		S ______	______	R ______	______	T ______	______	D ______
TREATMENT ADDITIVES	______	S ______	______	R ______	______	T ______	______	D ______
STORAGE		S ______	______	R ______	______	T ______	______	D ______
REMOVED FROM	______							
PLACED INTO	-(______)		______	R ______	______	T ______	______	D ______
TOTALS	☐ =		☐ +		☐ +		☐	



WASTE REPORTED TO AGENCY

FEDERAL HAZARDOUS ____________ WET TONS + ADDITIONAL STATE HAZARDOUS NA WET TONS

SOURCE REDUCTION PRACTICES

DID YOUR REFINERY INITIATE ANY ACTIVITIES, CHANGE ANY PRACTICES OR FEEDSTOCKS, OR MODIFY ANY EQUIPMENT THAT DECREASED THE AMOUNT OF THIS WASTE GENERATED IN 1989? ☐ NO ☐ YES IF YES, ENTER AMOUNT REDUCED ________ WET TONS

PLEASE CHECK TO MAKE SURE YOU HAVE ENTERED THIS INFORMATION ON QUESTION 9.

COMMENTS/CALCULATIONS:

★DESCRIBE ONE-TIME EVENT:

APPENDIX B - STATISTICAL PROCEDURES

DATA ANALYSIS PROCEDURES DEVELOPED FOR THE 1987-1988 API SURVEY

Data Verification

Programs to verify the internal consistency of responses were written using the Statistical Analysis System (SAS). Errors such as waste input and management quantities that did not balance, invalid responses, and missing but required data elements, were identified. All errors along with any responses that appeared to be aberrant values were corrected and/or verified by phone calls to the respondents. Nearly every respondent was contacted to verify some part of their response; approximately 3000 corrections were made during this extensive data cleaning effort.

A second phase of data verification occurred during development of the estimation models. Estimation models were developed to extrapolate the quantities generated by the entire U.S. refining industry from the responses received. When the data were plotted, six cases with outlying values were identified and calls were placed to the respective refineries to verify that these were actual values. In all of these cases, the respondents confirmed the accuracy of the responses.

Because these extreme values skewed the extrapolation, they were considered to be "outliers" and treated differentially during the model development.

The six outliers included two refineries which generated no waste in 1987 nor 1988. The four other refineries generated large quantities of Other Aqueous Waste and utilized deep well injection to dispose of these dilute wastes. Unlike other refineries that discharge waste under NPDES permits or to POTWs, facilities that inject wastes remove only the solids that could block the well pores prior to disposal (i.e., they do not perform additional treatment to diminish the water content).

A brief table of the affected streams and quantities follows:

Table B - I. Summary of Outlier Values

WASTE STREAM	# of Facilities	87 Generation (Wet Tons)*	88 Generation (Wet Tons)*
Other Aqueous Wastes	4	11,267	11,048
All Streams	2	0	0

*Thousan

(It should be noted that the facilities with large quantities of **"Other Aqueous Wastes NOS"** reported quantities of the other waste streams that were in the normal range.)

Non-Respondent Estimation Procedures

To estimate the total amount of waste generated for all (176) of the U.S. refineries, the data obtained from the 115 survey participants had to be combined with estimates for the 61 refineries that did not participate in the study. A regression model approach (with the implicit assumption that non-respondents do not differ from respondents) was selected to develop the generation quantities for these non-respondents.

After calculating the total waste generated by each responding refinery, correlation coefficients were calculated for the refinery characteristics (e.g., capacity, age, sewer system) with total waste generation. In addition, scatterplots were made to help explore any relationships which could lead to development of models to estimate total waste generation.

The strongest correlation was between operable crude capacity (Question 3) and waste generation, with quantity of waste increasing as refinery capacity increased.

Simple linear, multiple regression and nonlinear models were considered. After examining all the model results for levels of significance, mean squared error, R-squared, and model complexity, the simple regression model using capacity as the independent variable was chosen.

Further examination of plots and sample statistics indicated that improvement in the regression results could be made by separately modeling refineries having capacities below 200,000 barrels per stream day (B/SD) and those with capacities above 200,000 B/SD. The plots showed that unlike the smaller facilities, the relationship between total waste generation and capacity at large facilities was not linear. Consequently, separate regression models were developed for these two groups of data.

For the less than 200,000 B/SD facilities, waste generated was modeled as being directly related to capacity:

$$\text{Total Waste} = a_1(\text{capacity}) \qquad (1)$$

At refineries with capacities greater than 200,000 B/SD, however, the increase in waste was modeled as a function of the square of the capacity:

$$\text{Total waste} = a_2(\text{capacity}^2) \qquad (2)$$

Both a_1 and a_2 were estimated based on the data from 109 refineries[1].

[1] The six outliers discussed in Section 2.4.1 were not included in any of the calculations performed to derive values for non-respondents.

To determine how well the models explained the variability in the data, R^2 was calculated. For 1987, R^2 values were 0.55 and 0.79 for the smaller and large facilities, respectively. For 1988 the R^2 values were 0.58 and 0.79. (The corresponding correlation coefficients were 0.75 and 0.89, respectively.) For this type of data, these R^2 values reflect a reasonably good fit.

Estimation of Waste Generation Quantities

The models were used to estimate the total quantity of waste generated for each of the 61 non-responding refineries (based on their crude capacities) for both 1987 and 1988. To calculate the total amount of waste generated by all refineries, the estimate for the non-respondents was added to the responses from the 115 survey participants. All data shown in this report are estimates of waste for all 176 refineries.

After deriving the total waste generation quantity, calculations were performed to estimate the generation quantity for each of the 28 waste streams. As with the calculation of the total quantity of waste, the first step was to estimate the values for the non-respondents. A step by step summary of the procedure used follows:

1) The total waste generation quantity for each of the 109 non-outlier respondents was calculated.

2) The percentage contribution of each waste stream to the total quantity of wastes was calculated by dividing the individual waste stream generation quantity calculated in (1) by the summation of all 28 waste generation quantities.

3) These percentages were applied to the total waste generation quantity estimated for the 61 non-respondents.

To obtain a total generation quantity for each of the 28 waste streams, the individual waste stream estimates for the non-respondents were added to the actual quantities reported for each waste stream by the 115 participants.

The margin of error (for sampling and modeling) for the total waste generation quantity and for the individual stream estimates were calculated. An approximate 2 percent margin of error was estimated for the total waste generation quantity. An approximate 10 percent margin of error value was estimated for the individual waste streams. These error estimates confirmed the expected high precision of the estimates which, in turn, reflect the excellent response rate.

APPENDIX C - SUMMARY OF SOURCE REDUCTION ACTIVITIES

Total Source Reduction Quantities Reported on Data Sheets by Waste Stream

OBS	Waste Stream	Total Reduced	# of Refineries	Average	Smallest >0	Largest
1	101	12879	25	515.16	1	5597
2	102	17239	11	1567.18	13	8500
3	103	56238	11	5112.55	1	41890
4	104	61	3	20.33	1	50
5	105	9626	7	1375.14	6	5120
6	106	374	4	93.50	24	200
7	107	11231	7	1604.43	30	6600
8	108	1695	2	847.50	4	1691
9	109	466	4	116.50	6	400
10	201	2	2	1.00	1	1
11	202	1837	4	459.25	1	1000
12	204	537	3	179.00	13	274
13	205	85	2	42.50	1	84
14	301	1343	6	223.83	24	400
15	302	19	1	19.00	19	19
16	303	120	1	120.00	120	120
17	401	15001	5	3000.20	50	13100
18	402	164	2	82.00	20	144
19	403	6006	1	6006.00	6006	6006
20	405	2432	1	2432.00	2432	2432
21	406	41	1	41.00	41	41
22	501	4973	5	994.60	7	2757
23	502	223	1	223.00	223	223
24	503	68	1	68.00	68	68
25	504	26405	5	5281.00	75	25000
26	601	405	8	50.63	1	350

Table C - 2. Summary of Equipment and Technology Modifications

WASTE STREAM	# RESPONSES	DESCRIPTION OF SOURCE REDUCTION ACTIVITIES
API Separator Sludge	5	-Sewers upgraded to prevent bedding/sand infiltration in sewer system -New tanks installed in improve oil/water/solids separation -Gravity dewatering + improved precipitator operations for FCC cat fines -Install filtration sumps
DAF Float	3	-More efficient dewatering equipment installed; solids entering sewer system controlled. -Install filtration sumps
Slop Oil Emulsion Solids	2	-Install filtration sumps
Pond Sediments	1	-Install wet air regeneration unit in wastewater treatment plant
Nonleaded Tank Bottoms	1	-Install filtration sumps
Contaminated Soils/Solids	1	-Install contaminment to eliminate soil contamination by drips & spills
Waste Sulfur	2	-New sulfur tanks installed -Sulfur recovery pit facilities upgraded
FCC Catalyst or Equivalent	2	-Regenerator repair -Improved cyclones, ski jump & air grid
Biomass	1	-Installed new Biomass piping; replumged generation basin -Replaced impoundment with storage tank
High pH/Low pH Waters	1	-Unspecified
Spent Stretford Solution	1	-Install new Sulfur Recovery Unit that does not use Stretford Solutiion
Spent Caustics	1	-Install new VRU; caustic use down despite addition of second caustic wash tower
Other Inorganic Wastes NOS	1	-Design work to replace boiler feed water treatment system to eliminate lime sludges
Other Wastes NOS	1	-Installed bulk feed systems to reduce drum disposal by 400 drums/year

Table C - 3. Summary of Procedure Modifications

WASTE STREAM	# RESPONSES	DESCRIPTION OF SOURCE REDUCTION ACTIVITIES
API Separator Sludge	6	-Discontinue use of sand when covering sewers for hot work. -Modify tank cleaning procedures to include chemical cleaning when appropriate. -Improved operating/separation procedures for wastewater treatment. -Increased efficiency of equipment w/ high quality catalyst; decreased disposal frequency. -Change dredging operations by centrifuging (dewatering) materials prior to disposal.
DAF Float	4	-Discontinue use of sand when covering sewers for hot work -Increased efficiency of equipment w/ high quality catalyst; decreased disposal frequency. -Confidential process
Slop Oil Emulsion Solids	2	-Discontinue use of sand when covering sewers for hot work -Improved operating/separation procedures for wastewater treatment
Other Separator Sludges	2	-Discontinue use of sand when covering sewers for hot work -Increased efficiency of equipment w/ high quality catalyst; decreased disposal frequency.
Pond Sediments	2	-Close stormwater pond & sludge pit -Unspecified
Nonleaded Tank Bottoms	1	-Discontinue use of sand when covering sewers for hot work
Waste Sulfur	1	-Procedures changed that reduced hydrocarbon carryover to sulfur plant
High pH/Low pH Waters	1	-Change out of demineralization resin; use more resin in process to increase run times between resin regenerations
Waste Amines	1	-Change out frequency reduced to once a year
Other Wastes NOS	1	-Desiccant tower operations & regeneration practices corrected

Table C - 4. Summary of Activities to Reformulate or Design Products

WASTE STREAM	# RESPONSES	DESCRIPTION OF SOURCE REDUCTION ACTIVITIES
API Separator Sludge	2	-Reduction in lead usage reduced toxicity of waste.
Leaded Tank Bottoms	3	-Reduced volume of TEL in leaded gasoline. -Leaded tanks were cleaned & put back into service as non-leaded tanks. -Discontinued production of leaded gasoline.

Table C - 5. Summary of Activities to Substitute Materials

WASTE STREAM	# RESPONSES	DESCRIPTION OF SOURCE REDUCTION ACTIVITIES
API Separator Sludge	2	-Chromium anti-rust/scale agents in cooling towers replaced by less toxic chemicals (phosphate).
DAF Float	1	-Substitute phosphate treatment for chromate treatment in cooling towers
Leaded Tank Bottoms	1	-Unspecified
Waste Oils/Spent Solvents	2	-Use less toxic/biodegradable degreasers instead of solvents
Other Contaminated Soils NOS	1	-Feedstock change eliminated use of clay treatment & spent clay waste
Other Spent Catalysts NOS	1	-Used high quality catalyst
Other Wastes NOS	1	-Replace chlorinated cleaning solvent w/ non-chlorinated solvent

Table C - 6. Summary of Within Process Recycling Activities

WASTE STREAM	# RESPONSES	DESCRIPTION OF SOURCE REDUCTION ACTIVITIES
API Separator Sludge	14	-Recover/Recycle hydrocarbon from sludge -Coker feed stream -Recycle wastewater
DAF Float	3	-Recover/recycle hydrocarbons from centrifuge or filter press -Coker feed stream
Slop Oil Emulsion Solids	5	-Recover/recycle hydrocarbons from centrifuge or filter press -Reuse of caustic as pH control for water treatment
Leaded Tank Bottoms	1	-Decanted oil from tank sludge recycled
Other Separator Sludges	3	-Recover/recycle hydrocarbons from centrifuge or filter press
Nonleaded Tank Bottoms	6	-In situ cleaning of crude tanks -Recover/recycle hydrocarbons from centrifuge or filter press -Resuspension of tank bottoms by mixing nozzle w/ subsequent charging of feed to appropriate process unit
Waste Oils/Spent Solvents	2	-Recover/recycle hydrocarbons from centrifuge or filter press -Unspecified
Other Oily Sludges & Organic Wastes NOS	4	-Recover/recycle hydrocarbons from centrifuge or filter press
Heat Exchanger Bundle Cleaning Sludge	2	-Recycle hydrocarbons from centrifuge
Other Contaminated Soils NOS	1	-Unspecified
Biomass	1	-Recycle oil from filter press operations
Oil Contaminated Waters Other than Wastewater	1	-Recovery & reuse of phenolic compounds in contaminated water -High pressure plate & frame filter press installed
Spent Caustics	1	-Recovery of hydrocarbons entrained in caustic solution
Other Inorganic Wastes NOS	1	-Unspecified
Other Wastes NOS	1	-Unspecified

Table C - 7. Summary of Improved Housekeeping, Training or Inventory Control Activities

WASTE STREAM	# RESPONSES	DESCRIPTION OF SOURCE REDUCTION ACTIVITIES
API Separator Sludge	10	-Improve gravity settling by increasing sewer sump cleaning. -Control coke fines from entering sewer system; total elimination of coke fines. -Reduce soil/solids washed into drains & sewer grates by dike stabilization, asphalt paving &/or lining of sewer pipes.
DAF Float	2	-Eliminate coke piles
Slop Oil Emulsion Solids	2	-Eliminate coke piles
Other Separator Sludges	2	-Eliminate coke piles -Obsolete chemicals disposed (inventory control) -Reduce debris entering sewer system
Pond Sediments	1	-Removed contaminated soil from plant to improve quality of runoff
Waste Oils/Spent Solvents	1	-Unspecified
Contaminated Soils/Solids	2	-Dike stabilization to prevent erosion & entry of bulk into wastewater system -Concrete paving
FCC Catalyst or Equivalent	1	-Improvement in general operating practice
Biomass	1	-Emphasized in training that disposal of Bio or Lime sludge should be last resort
Other Aqueous Waste NOS	1	-Obsolete chemicals disposed (inventory control) -Reduce debris entering sewer system
Other Inorganic Wastes NOS	1	-Obsolete chemicals disposed (inventory control) -Reduce debris entering sewer system
Other Wastes NOS	2	-Street sweeping -Use of bulk chemicals

APPENDIX D - WASTE MANAGEMENT SUMMARY TABLES

Estimated Quantities of Waste Recycled and Percentage of Total Amount Managed
By Waste Stream for 1989

Waste Stream	Quantity Recycled (Tons)	% of Total Managed (Tons)
API Separator Sludge	83,600	19.69
Dissolved Air Flotation Float	132,147	25.37
Slop Oil Emulsion Solids	93,015	35.45
Leaded Tank Bottoms	24	0.54
Other Separator Sludges	26,991	23.08
Pond Sediments	5,883	2.15
Nonleaded Tank Bottoms	42,640	26.05
Waste Oils/Spent Solvents	6,885	50.58
Other Oily Sludges & Organic Wastes	11,182	23.68
Heat Exchanger Cleaning Bundle Sludge	97	3.95
Contaminated Soil/Solids	22,899	4.62
Waste Coke/Carbon/Charcoal	106,871	77.95
Waste Sulfur	30,154	58.32
Other Contaminated Soils NOS	2,575	4.83
Fluid Cracking Catalyst or Equivalent	50,963	27.49
Hydroprocessing Catalysts	32,158	89.86
Other Spent Catalysts NOS	8,864	26.54
Biomass	60,805	9.28
Oil Contaminated Water NOT Wastewater	4,038	13.97
High pH/Low pH Waters	8,410	9.19
Spent Sulfite Solution	7,657	96.47
Spent Stretford Solution	5,865	13.82
Other Aqueous Wastes NOS	123	0.00
Spent Caustics	597,742	83.54
Spent Acids	836	9.93
Waste Amines	429	0.84
Other Inorganic Wastes NOS	6,608	1.50
Other Wastes NOS	8,052	2.47
	==========	
	1,357,513	

Estimated 1989 Tonnage Eliminated by Recycle Techniques for Each Waste Stream

Waste Stream	Coker	Crude Unit	Desalter	Sour Water Stripper	Industrial Furnace	Reclamation	Regeneration	Other	Sold
API Separator Sludge	54,582	23,821	0	9	502	859	0	3,827	0
Dissolved Air Flotation Float	78,982	34,037	0	0	0	533	0	18,595	0
Slop Oil Emulsion Solids	9,259	17,283	0	0	861	2,955	0	62,657	0
Leaded Tank Bottoms	0	24	0	0	0	0	0	0	0
Other Separator Sludges	0	26,168	0	0	0	0	0	823	0
Pond Sediments	4,923	798	0	0	0	162	0	0	0
Nonleaded Tank Bottoms	22,583	17,940	0	0	0	1,619	0	498	0
Waste Oils/Spent Solvents	0	77	0	0	91	6,116	5	596	0
Other Oily Sludges & Organic Wastes	35	655	1,189	0	6,845	2,436	22	0	0
Heat Exchanger Cleaning Bundle Sludge	28	68	0	0	0	0	0	1	0
Contaminated Soil/Solids	0	0	0	0	0	0	0	22,899	0
Waste Coke/Carbon/Charcoal	0	0	0	0	66,428	39,613	214	25	591
Waste Sulfur	0	0	0	0	15	35	0	0	30,104
Other Contaminated Soils NOS	118	0	0	0	0	2,457	0	0	0
Fluid Cracking Catalyst or Equivalent	0	0	0	0	263	22,012	5,320	9,791	13,577
Hydroprocessing Catalysts	0	0	0	0	0	31,188	970	0	0
Other Spent Catalysts NOS	0	0	0	0	0	8,067	546	41	210
Biomass	59,330	70	0	0	0	1,265	0	140	0
Oil Contaminated Water NOT Wastewater	137	3,300	0	0	0	601	0	0	0
High pH/Low pH Waters	0	0	5,531	0	0	5	0	2,874	0
Spent Sulfite Solution	0	0	0	0	0	0	0	7,657	0
Spent Stretford Solution	737	0	0	0	0	5,128	0	0	0
Other Aqueous Wastes NOS	0	0	0	0	0	123	0	0	0
Spent Caustics	0	13	3,068	0	0	172,974	286,277	99,543	35,867
Spent Acids	0	0	0	0	0	0	18	734	84
Waste Amines	198	0	0	0	0	0	0	0	231
Other Inorganic Wastes NOS	105	75	0	0	0	636	0	4,654	1,138
Other Wastes NOS	11	11	0	0	4	7,701	0	325	0
	=======	=======	========	==========	==========	===========	============	=======	=======
	231,028	124,340	9,788	9	75,009	306,485	293,372	235,680	81,802

Respondent Frequencies for 1989 Recycle Techniques for Each Waste Stream

Waste Stream	Coker	Crude Unit	Desalter	Sour Water Stripper	Industrial Furnace	Reclamation	Regeneration	Other	Sold
API Separator Sludge	15	22	0	1	1	3	0	3	1
Dissolved Air Flotation Float	17	9	0	0	0	2	0	4	1
Slop Oil Emulsion Solids	5	9	0	0	2	1	0	2	1
Leaded Tank Bottoms	0	1	0	0	1	0	0	0	0
Other Separator Sludges	0	6	0	0	0	0	0	1	0
Pond Sediments	4	3	0	0	0	1	0	0	0
Nonleaded Tank Bottoms	5	12	0	0	0	3	0	1	0
Waste Oils/Spent Solvents	3	10	0	0	4	27	5	3	0
Other Oily Sludges & Organic Wastes	1	5	1	0	7	2	2	2	0
Heat Exchanger Cleaning Bundle Sludge	2	2	0	0	0	0	0	1	0
Contaminated Soil/Solids	0	0	0	0	0	0	0	7	0
Waste Coke/Carbon/Charcoal	1	0	0	0	2	1	6	1	2
Waste Sulfur	0	0	0	0	1	1	0	0	1
Other Contaminated Soils NOS	1	0	0	0	0	2	0	0	0
Fluid Cracking Catalyst or Equivalent	0	0	0	0	1	15	4	13	9
Hydroprocessing Catalysts	0	0	0	0	0	54	4	0	0
Other Spent Catalysts NOS	0	0	0	0	0	22	5	1	1
Biomass	5	1	0	0	0	1	0	1	0
Oil Contaminated Water NOT Wastewater	1	2	0	0	0	3	0	0	0
High pH/Low pH Waters	0	0	1	0	0	1	0	1	0
Spent Sulfite Solution	0	0	0	0	0	0	0	2	0
Spent Stretford Solution	1	0	0	0	0	2	0	0	0
Other Aqueous Wastes NOS	0	0	0	0	0	1	0	0	0
Spent Caustics	1	1	1	0	0	23	3	9	7
Spent Acids	0	0	0	0	0	2	6	3	2
Waste Amines	1	0	0	0	0	0	0	0	1
Other Inorganic Wastes NOS	1	2	0	0	0	1	0	1	3
Other Wastes NOS	3	1	0	0	1	19	0	6	0
	=====	=====	========	==========	==========	===========	============	=====	====
	67	86	3	1	20	187	35	62	29

Estimated Quantities of Waste Treated and Percentage of Total Amount Managed
By Waste Stream for 1989

Waste Stream	Quantity Treated (Tons)	% of Total Managed (Tons)
API Separator Sludge	195,177	45.98
Dissolved Air Flotation Float	282,565	54.26
Slop Oil Emulsion Solids	102,876	39.21
Leaded Tank Bottoms	337	7.54
Other Separator Sludges	52,753	45.11
Pond Sediments	69,307	25.37
Nonleaded Tank Bottoms	37,968	23.19
Waste Oils/Spent Solvents	5,680	41.73
Other Oily Sludges & Organic Wastes	7,039	14.91
Heat Exchanger Cleaning Bundle Sludge	692	28.19
Contaminated Soil/Solids	4,599	0.93
Waste Coke/Carbon/Charcoal	0	0.00
Waste Sulfur	4	0.01
Other Contaminated Soils NOS	971	1.82
Fluid Cracking Catalyst or Equivalent	0	0.00
Hydroprocessing Catalysts	93	0.26
Other Spent Catalysts NOS	11,564	34.63
Biomass	354,671	54.15
Oil Contaminated Water NOT Wastewater	18,893	65.36
High pH/Low pH Waters	58,221	63.62
Spent Sulfite Solution	0	0.00
Spent Stretford Solution	29,759	70.11
Other Aqueous Wastes NOS	7,714	0.07
Spent Caustics	103,170	14.42
Spent Acids	7,109	84.40
Waste Amines	47,196	92.44
Other Inorganic Wastes NOS	112,406	25.50
Other Wastes NOS	923	0.28
	==========	
	1,511,687	

Estimated 1989 Tonnage Eliminated by Treatment Techniques for Each Waste Stream

Waste Stream	Weathering	Chemical	Heat	Impoundment	Physical	Waste H20 Treatment	Incineration	Stabilization and/or Fixation	Other
API Separator Sludge	0	1,299	0	3,280	33,848	149,190	7,417	143	0
Dissolved Air Flotation Float	0	2,309	0	0	6,949	247,735	25,572	0	0
Slop Oil Emulsion Solids	0	3,788	0	0	387	98,347	354	0	0
Leaded Tank Bottoms	69	0	0	0	0	268	0	0	0
Other Separator Sludges	0	0	0	0	55	52,698	0	0	0
Pond Sediments	16	3,760	0	0	7,095	48,433	0	0	10,003
Nonleaded Tank Bottoms	0	0	0	0	692	37,237	39	0	0
Waste Oils/Spent Solvents	0	0	4,266	0	0	1,161	253	0	0
Other Oily Sludges & Organic Wastes	0	2,114	0	0	32	4,890	3	0	0
Heat Exchanger Cleaning Bundle Sludge	0	0	0	0	0	602	89	0	1
Contaminated Soil/Solids	1	0	0	0	207	0	219	4,172	0
Waste Coke/Carbon/Charcoal	0	0	0	0	0	0	0	0	0
Waste Sulfur	0	0	0	0	0	0	0	0	4
Other Contaminated Soils NOS	0	0	0	0	3	953	15	0	0
Fluid Cracking Catalyst or Equivalent	0	0	0	0	0	0	0	0	0
Hydroprocessing Catalysts	0	0	0	0	0	0	93	0	0
Other Spent Catalysts NOS	0	462	0	0	0	11,095	0	0	7
Biomass	0	0	1,868	0	0	249,423	103,380	0	0
Oil Contaminated Water NOT Wastewater	0	0	0	0	21	18,872	0	0	0
High pH/Low pH Waters	0	4,811	0	0	0	52,585	0	0	825
Spent Sulfite Solution	0	0	0	0	0	0	0	0	0
Spent Stretford Solution	270	0	0	0	0	29,489	0	0	0
Other Aqueous Wastes NOS	95	4	0	0	0	7,614	1	0	0
Spent Caustics	1,241	8,024	0	0	0	93,823	82	0	0
Spent Acids	0	4,776	0	0	0	2,333	0	0	0
Waste Amines	0	6	0	0	0	46,355	835	0	0
Other Inorganic Wastes NOS	22,796	62,556	0	0	0	23,311	3,743	0	0
Other Wastes NOS	0	81	0	0	0	264	553	0	25
	==========	=======	======	===========	========	========	===========	============	========
	24,488	93,990	6,134	3,280	49,289	1,176,678	142,648	4,315	10,865

Respondent Frequencies for 1989 Treatment Techniques for Each Waste Stream

Waste Stream	Weathering	Chemical	Heat	Impoundment	Physical	Waste H2O Treatment	Incineration	Stabilization and/or Fixation	Other
API Separator Sludge	0	1	1	1	3	25	5	2	1
Dissolved Air Flotation Float	0	1	1	0	1	19	5	0	1
Slop Oil Emulsion Solids	0	1	1	0	1	10	1	0	1
Leaded Tank Bottoms	1	0	0	0	0	2	0	0	0
Other Separator Sludges	0	0	0	0	1	5	0	0	0
Pond Sediments	1	1	2	0	2	6	0	0	1
Nonleaded Tank Bottoms	0	0	0	0	2	11	3	0	0
Waste Oils/Spent Solvents	0	0	1	0	0	6	10	0	0
Other Oily Sludges & Organic Wastes	0	3	1	0	1	8	3	0	0
Heat Exchanger Cleaning Bundle Sludge	0	0	0	0	0	13	3	1	1
Contaminated Soil/Solids	1	0	0	0	1	0	3	2	0
Waste Coke/Carbon/Charcoal	0	0	0	0	0	0	0	0	0
Waste Sulfur	0	0	0	0	0	0	0	0	1
Other Contaminated Soils NOS	0	0	0	0	1	1	2	0	0
Fluid Cracking Catalyst or Equivalent	0	0	0	0	0	0	0	0	0
Hydroprocessing Catalysts	0	0	0	0	0	0	1	0	1
Other Spent Catalysts NOS	0	1	0	0	0	1	0	0	1
Biomass	1	0	1	0	1	11	4	0	0
Oil Contaminated Water NOT Wastewater	0	0	0	0	1	5	0	0	0
High pH/Low pH Waters	0	2	0	0	0	7	0	0	1
Spent Sulfite Solution	0	0	0	0	0	0	0	0	0
Spent Stretford Solution	1	0	0	0	0	5	0	1	0
Other Aqueous Wastes NOS	1	1	0	0	1	2	1	0	1
Spent Caustics	2	5	0	0	0	20	1	0	0
Spent Acids	0	5	0	0	0	10	0	0	0
Waste Amines	0	1	0	0	1	15	1	0	0
Other Inorganic Wastes NOS	3	6	0	0	0	12	3	0	0
Other Wastes NOS	0	2	0	0	0	3	31	0	2
	==========	========	====	===========	========	=========	============	============	=====
	11	30	8	1	17	197	77	6	12

Estimated Quantities of Waste Land Treated and Percentage of Total Amount Managed
By Waste Stream for 1989

Waste Stream	Quantity Land Treated (Tons)	% of Total Managed (Tons)
API Separator Sludge	60,562	14.27
Dissolved Air Flotation Float	71,637	13.76
Slop Oil Emulsion Solids	27,143	10.35
Leaded Tank Bottoms	265	5.93
Other Separator Sludges	29,694	25.39
Pond Sediments	126,520	46.31
Nonleaded Tank Bottoms	36,319	22.19
Waste Oils/Spent Solvents	483	3.55
Other Oily Sludges & Organic Wastes	6,443	13.64
Heat Exchanger Cleaning Bundle Sludge	317	12.91
Contaminated Soil/Solids	131,562	26.55
Waste Coke/Carbon/Charcoal	1,092	0.80
Waste Sulfur	4	0.01
Other Contaminated Soils NOS	9,656	18.13
Fluid Cracking Catalyst or Equivalent	932	0.50
Hydroprocessing Catalysts	35	0.10
Other Spent Catalysts NOS	829	2.48
Biomass	187,395	28.61
Oil Contaminated Water NOT Wastewater	482	1.67
High pH/Low pH Waters	0	0.00
Spent Sulfite Solution	0	0.00
Spent Stretford Solution	0	0.00
Other Aqueous Wastes NOS	1,118	0.01
Spent Caustics	0	0.00
Spent Acids	0	0.00
Waste Amines	70	0.14
Other Inorganic Wastes NOS	16,394	3.72
Other Wastes NOS	210	0.06
	==========	
	709,162	

Respondent Frequencies for 1989 Land Treatment for Each Waste Stream

Waste Stream	Land Treatment
API Separator Sludge	26
Dissolved Air Flotation Float	16
Slop Oil Emulsion Solids	17
Leaded Tank Bottoms	4
Other Separator Sludges	9
Pond Sediments	11
Nonleaded Tank Bottoms	24
Waste Oils/Spent Solvents	5
Other Oily Sludges & Organic Wastes	6
Heat Exchanger Cleaning Bundle Sludge	9
Contaminated Soil/Solids	20
Waste Coke/Carbon/Charcoal	6
Waste Sulfur	3
Other Contaminated Soils NOS	15
Fluid Cracking Catalyst or Equivalent	1
Hydroprocessing Catalysts	1
Other Spent Catalysts NOS	4
Biomass	10
Oil Contaminated Water NOT Wastewater	1
High pH/Low pH Waters	0
Spent Sulfite Solution	0
Spent Stretford Solution	0
Other Aqueous Wastes NOS	2
Spent Caustics	1
Spent Acids	0
Waste Amines	4
Other Inorganic Wastes NOS	13
Other Wastes NOS	1
	=========
	209

Estimated Quantities of Waste Disposed and Percentage of Total Amount Managed
By Waste Stream for 1989

Waste Stream	Quantity Disposed (Tons)	% of Total Managed (Tons)
API Separator Sludge	85,160	20.06
Dissolved Air Flotation Float	34,448	6.61
Slop Oil Emulsion Solids	39,315	14.99
Leaded Tank Bottoms	3,846	86.00
Other Separator Sludges	7,509	6.42
Pond Sediments	71,506	26.17
Nonleaded Tank Bottoms	46,773	28.57
Waste Oils/Spent Solvents	564	4.14
Other Oily Sludges & Organic Wastes	22,556	47.77
Heat Exchanger Cleaning Bundle Sludge	1,349	54.95
Contaminated Soil/Solids	336,457	67.90
Waste Coke/Carbon/Charcoal	29,140	21.25
Waste Sulfur	21,542	41.66
Other Contaminated Soils NOS	40,062	75.21
Fluid Cracking Catalyst or Equivalent	133,485	72.01
Hydroprocessing Catalysts	3,501	9.78
Other Spent Catalysts NOS	12,139	36.35
Biomass	52,106	7.96
Oil Contaminated Water NOT Wastewater	5,494	19.01
High pH/Low pH Waters	24,883	27.19
Spent Sulfite Solution	280	3.53
Spent Stretford Solution	6,824	16.08
Other Aqueous Wastes NOS	11,091,266	99.92
Spent Caustics	14,629	2.04
Spent Acids	478	5.67
Waste Amines	3,360	6.58
Other Inorganic Wastes NOS	305,401	69.28
Other Wastes NOS	316,288	97.18
	==========	
	12,710,361	

Estimated 1989 Tonnage Eliminated by Disposal Techniques for Each Waste Stream

Waste Stream	Disposal Impoundment	Landfill	Landspread	Injection	Other
API Separator Sludge	4	76,598	4,554	0	4,004
Dissolved Air Flotation Float	0	29,014	4,228	0	1,206
Slop Oil Emulsion Solids	0	18,927	20,388	0	0
Leaded Tank Bottoms	0	3,815	20	0	11
Other Separator Sludges	0	5,845	1,664	0	0
Pond Sediments	1,348	59,842	906	0	9,410
Nonleaded Tank Bottoms	917	45,290	528	0	38
Waste Oils/Spent Solvents	58	122	49	268	67
Other Oily Sludges & Organic Wastes	58	22,003	495	0	0
Heat Exchanger Cleaning Bundle Sludge	4	1,082	263	0	0
Contaminated Soil/Solids	34	316,862	16,463	0	3,098
Waste Coke/Carbon/Charcoal	267	28,368	505	0	0
Waste Sulfur	1,238	20,304	0	0	0
Other Contaminated Soils NOS	0	38,264	1,798	0	0
Fluid Cracking Catalyst or Equivalent	13,582	103,891	13,188	0	2,824
Hydroprocessing Catalysts	4	3,497	0	0	0
Other Spent Catalysts NOS	0	11,034	1,105	0	0
Biomass	281	37,185	14,640	0	0
Oil Contaminated Water NOT Wastewater	4,154	280	0	826	234
High pH/Low pH Waters	24,265	605	13	0	0
Spent Sulfite Solution	280	0	0	0	0
Spent Stretford Solution	790	6,034	0	0	0
Other Aqueous Wastes NOS	1	52	62	11,091,151	0
Spent Caustics	248	409	0	13,664	308
Spent Acids	1	477	0	0	0
Waste Amines	17	2,965	64	310	4
Other Inorganic Wastes NOS	64,886	226,893	13,622	0	0
Other Wastes NOS	918	315,362	0	0	8
	===========	==========	==========	==========	==========
	113,355	1,375,020	94,555	11,106,219	21,212

Respondent Frequencies for 1989 Disposal Techniques for Each Waste Stream

Waste Stream	Disposal Impoundment	Landfill	Landspread	Injection	Other
API Separator Sludge	2	61	9	0	2
Dissolved Air Flotation Float	0	24	5	0	3
Slop Oil Emulsion Solids	0	24	3	0	0
Leaded Tank Bottoms	0	25	1	0	1
Other Separator Sludges	0	12	2	0	0
Pond Sediments	2	14	3	0	1
Nonleaded Tank Bottoms	1	50	5	0	2
Waste Oils/Spent Solvents	1	1	1	1	3
Other Oily Sludges & Organic Wastes	1	28	1	0	0
Heat Exchanger Cleaning Bundle Sludge	2	30	2	0	0
Contaminated Soil/Solids	2	71	4	0	1
Waste Coke/Carbon/Charcoal	3	40	2	0	0
Waste Sulfur	2	36	0	0	0
Other Contaminated Soils NOS	0	54	3	0	0
Fluid Cracking Catalyst or Equivalent	3	63	3	0	4
Hydroprocessing Catalysts	1	22	0	0	0
Other Spent Catalysts NOS	0	54	1	0	0
Biomass	2	17	4	0	0
Oil Contaminated Water NOT Wastewater	1	1	0	1	1
High pH/Low pH Waters	1	1	1	0	0
Spent Sulfite Solution	1	0	0	0	0
Spent Stretford Solution	1	3	0	0	0
Other Aqueous Wastes NOS	1	2	1	1	0
Spent Caustics	3	6	0	8	1
Spent Acids	1	2	0	0	0
Waste Amines	1	11	3	4	3
Other Inorganic Wastes NOS	8	54	7	0	0
Other Wastes NOS	3	93	0	0	3
	===========	========	==========	=========	=====
	43	799	61	15	25

Estimated 1989 Tonnage Eliminated by Techniques for Each Waste Stream

Waste Stream	Managed (Tons)	Recycled (Tons)	Treated (Tons)	Land Treated (Tons)	Disposed (Tons)
API Separator Sludge	424,499	83,600	195,177	60,562	85,160
Dissolved Air Flotation Float	520,797	132,147	282,565	71,637	34,448
Slop Oil Emulsion Solids	262,349	93,015	102,876	27,143	39,315
Leaded Tank Bottoms	4,472	24	337	265	3,846
Other Separator Sludges	116,947	26,991	52,753	29,694	7,509
Pond Sediments	273,216	5,883	69,307	126,520	71,506
Nonleaded Tank Bottoms	163,700	42,640	37,968	36,319	46,773
Waste Oils/Spent Solvents	13,612	6,885	5,680	483	564
Other Oily Sludges & Organic Wastes	47,220	11,182	7,039	6,443	22,556
Heat Exchanger Cleaning Bundle Sludge	2,455	97	692	317	1,349
Contaminated Soil/Solids	495,517	22,899	4,599	131,562	336,457
Waste Coke/Carbon/Charcoal	137,103	106,871	0	1,092	29,140
Waste Sulfur	51,704	30,154	4	4	21,542
Other Contaminated Soils NOS	53,264	2,575	971	9,656	40,062
Fluid Cracking Catalyst or Equivalent	185,380	50,963	0	932	133,485
Hydroprocessing Catalysts	35,787	32,158	93	35	3,501
Other Spent Catalysts NOS	33,396	8,864	11,564	829	12,139
Biomass	654,977	60,805	354,671	187,395	52,106
Oil Contaminated Water NOT Wastewater	28,907	4,038	18,893	482	5,494
High pH/Low pH Waters	91,514	8,410	58,221	0	24,883
Spent Sulfite Solution	7,937	7,657	0	0	280
Spent Stretford Solution	42,448	5,865	29,759	0	6,824
Other Aqueous Wastes NOS	11,100,221	123	7,714	1,118	11,091,266
Spent Caustics	715,541	597,742	103,170	0	14,629
Spent Acids	8,423	836	7,109	0	478
Waste Amines	51,055	429	47,196	70	3,360
Other Inorganic Wastes NOS	440,809	6,608	112,406	16,394	305,401
Other Wastes NOS	325,473	8,052	923	210	316,288
	==========	==========	==========	==========	==========
	16,288,723	1,357,513	1,511,687	709,162	12,710,361

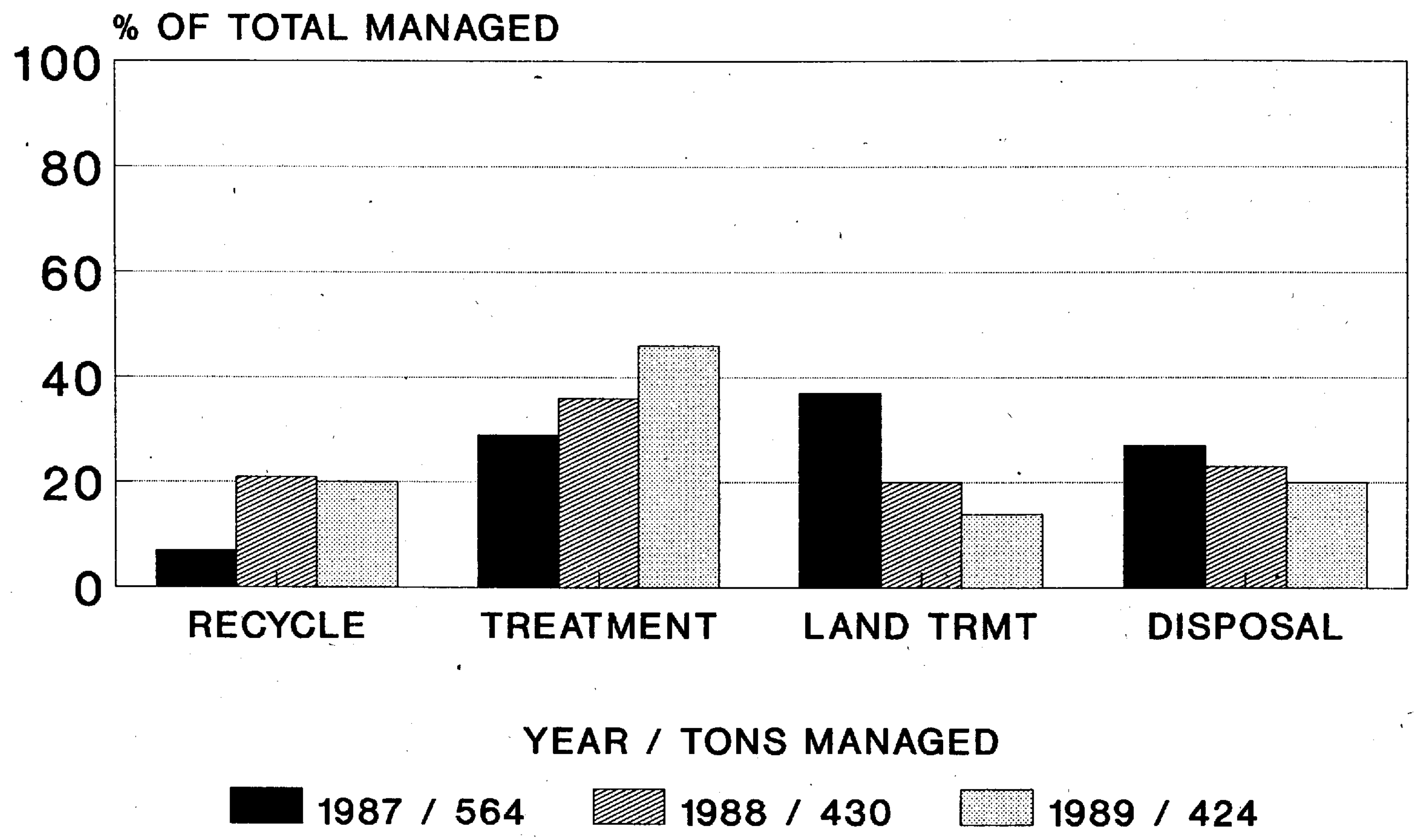
1989 Tonnage Elimination by Land Management Activities

Total Land Managed Tons = Disposed + Incinerated + Land Treated
Estimated

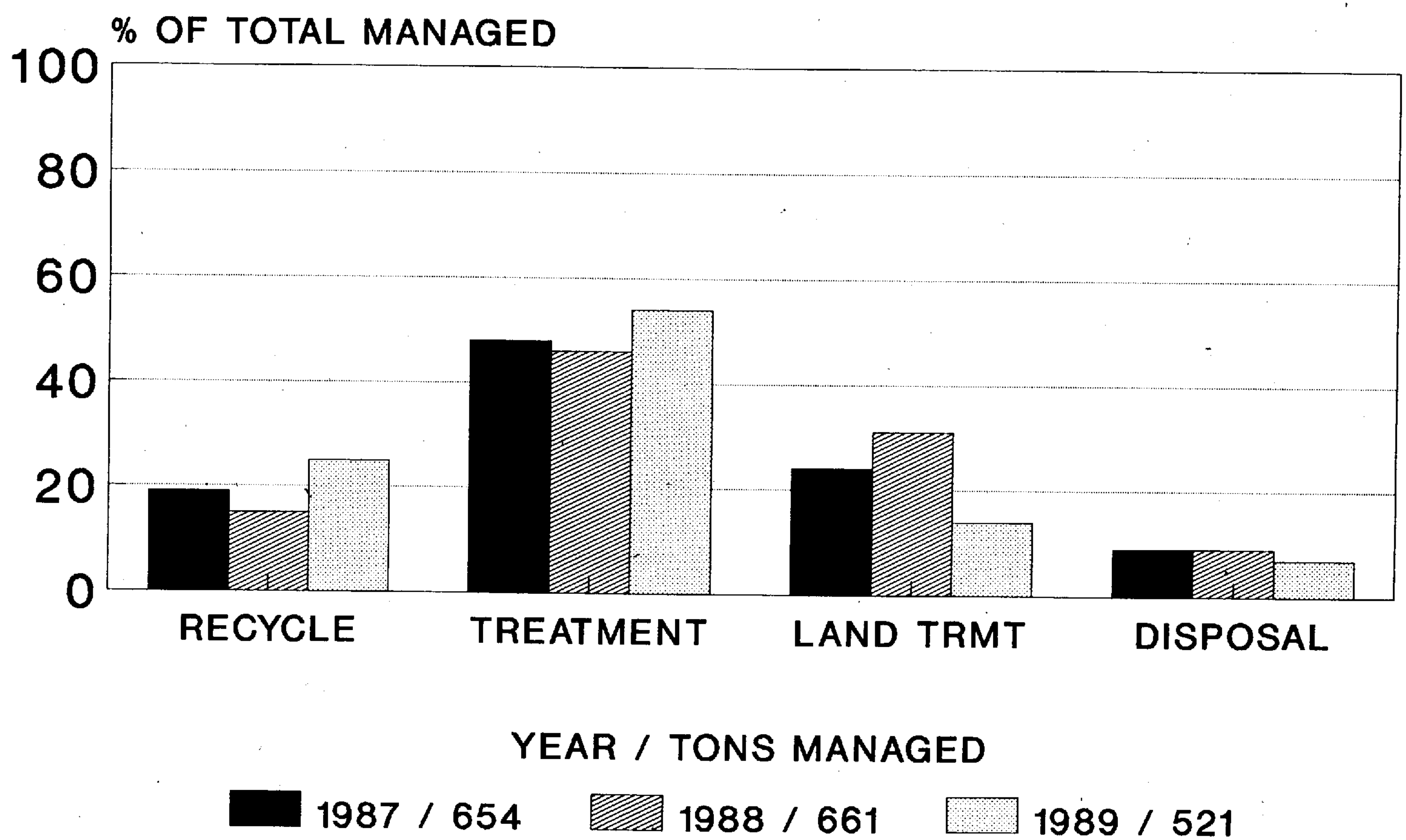
Waste Stream	Total Land Managed	Total Disposed	Total Incinerated	Total Land Treated
API Separator Sludge	153,139	85,160	7,417	60,562
Dissolved Air Flotation Float	131,657	34,448	25,572	71,637
Slop Oil Emulsion Solids	66,812	39,315	354	27,143
Leaded Tank Bottoms	4,111	3,846	0	265
Heat Exchanger Cleaning Bundle Sludge	1,755	1,349	89	317
	========	========	===========	========
	357,474	164,118	33,432	159,924

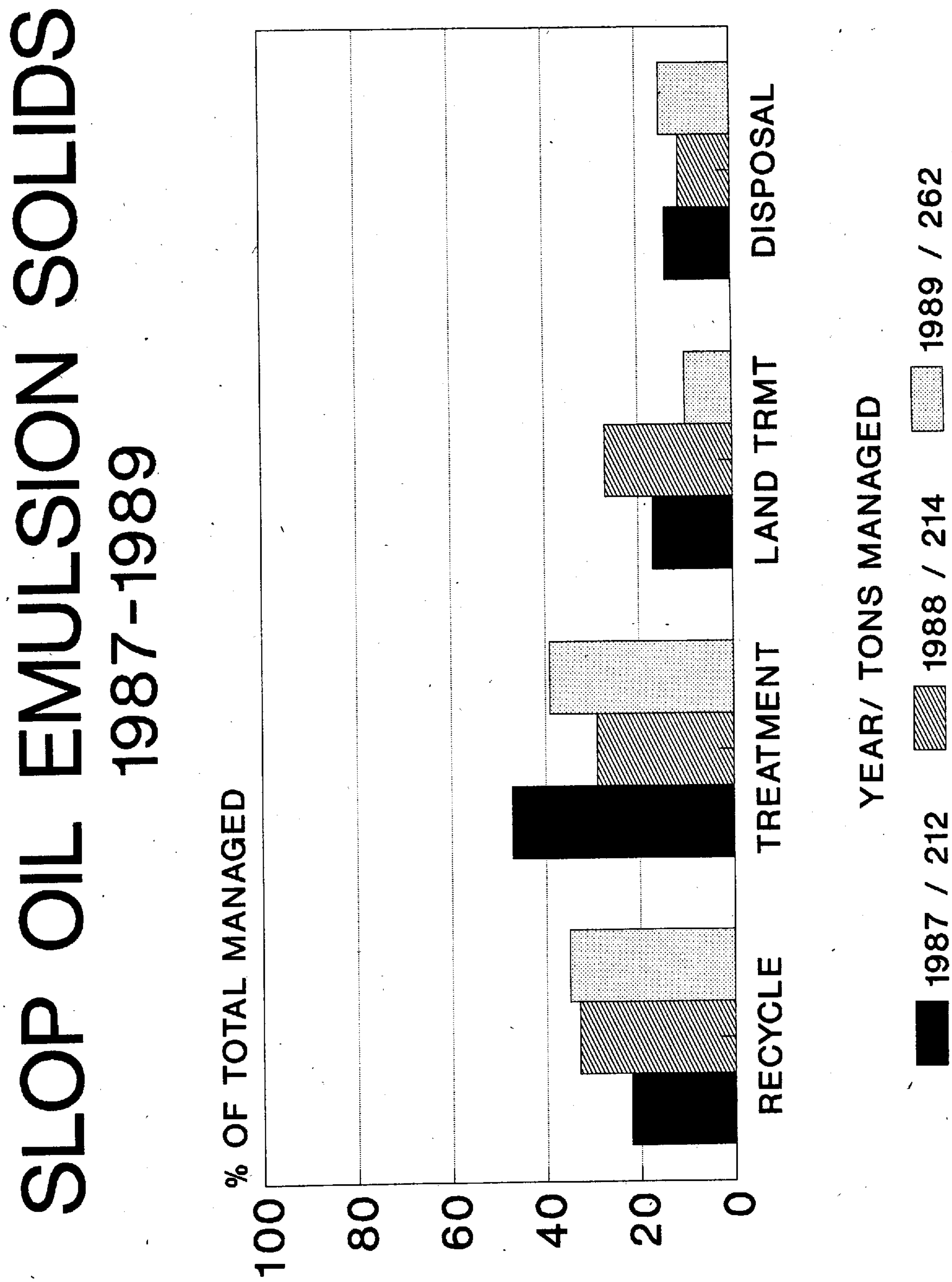
APPENDIX E - SUMMARY OF WASTE MANAGEMENT PRACTICES FOR INDIVIDUAL WASTE STREAMS

API SEPARATOR SLUDGE
1987-1989

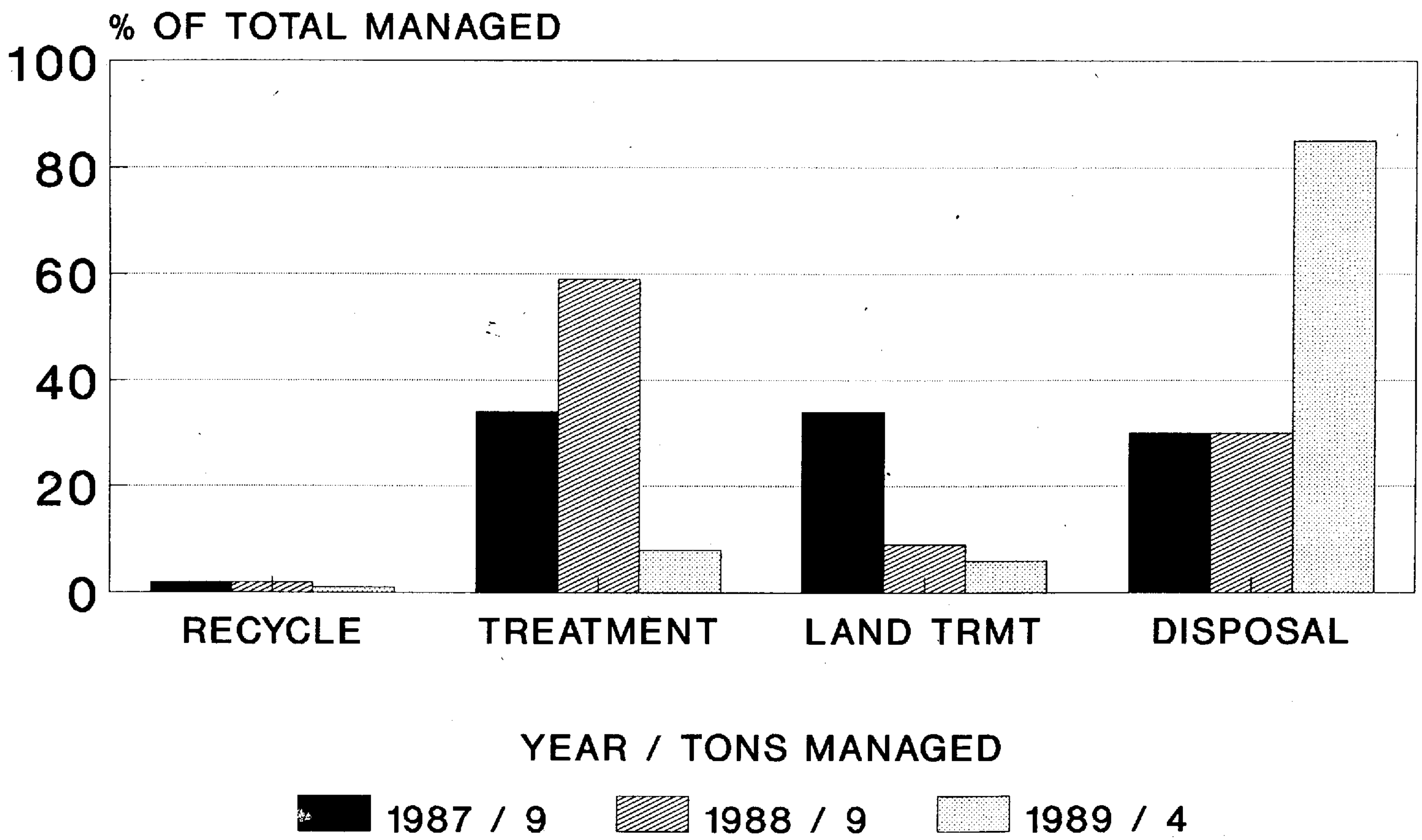


DAF FLOAT
1987-1989

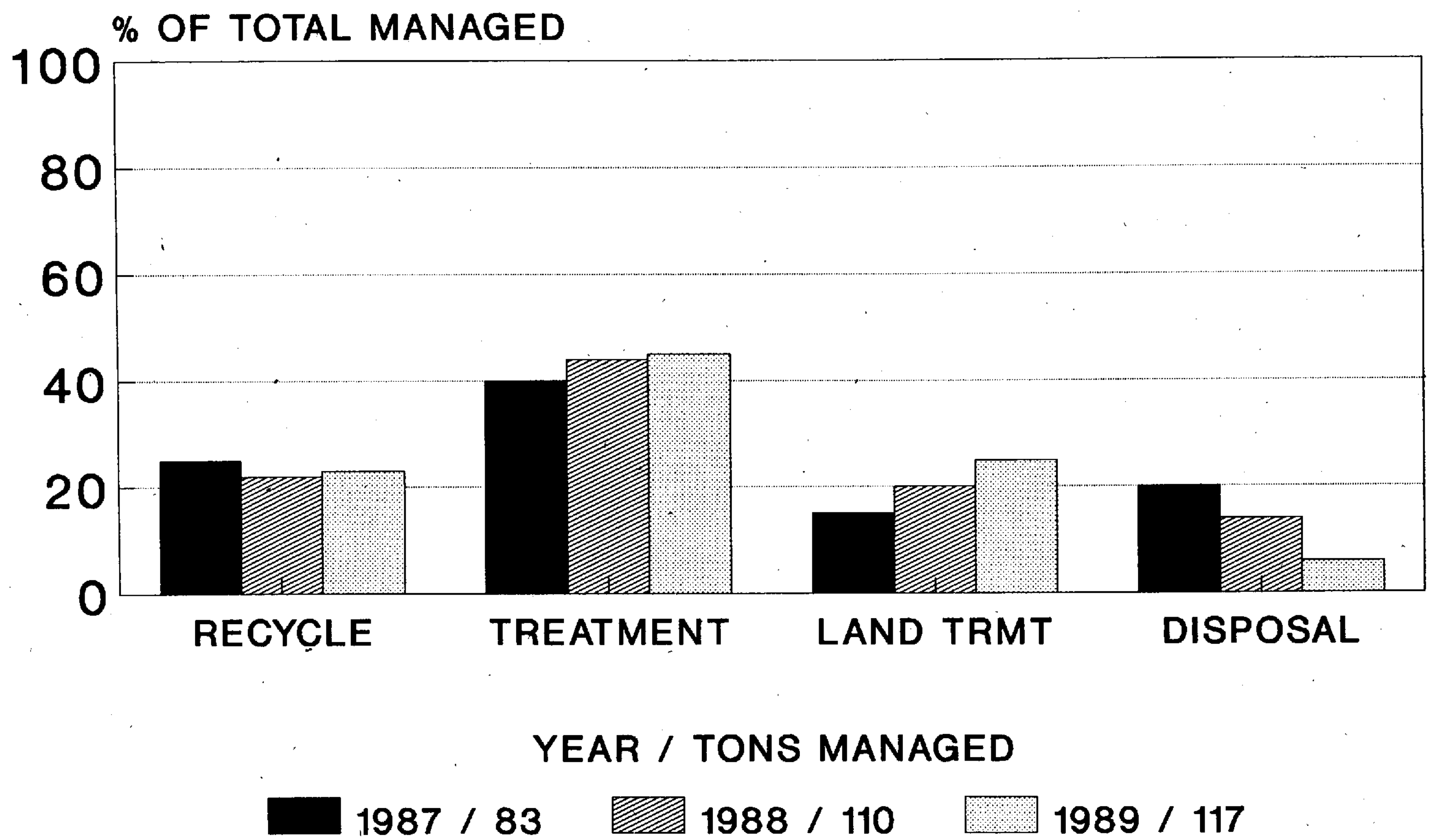



SLOP OIL EMULSION SOLIDS
1987-1989
% OF TOTAL MANAGED
100
80
60
40
20
0
RECYCLE
TREATMENT
LAND TRMT
DISPOSAL
YEAR/ TONS MANAGED
1987 / 212
1988 / 214
1989 / 262

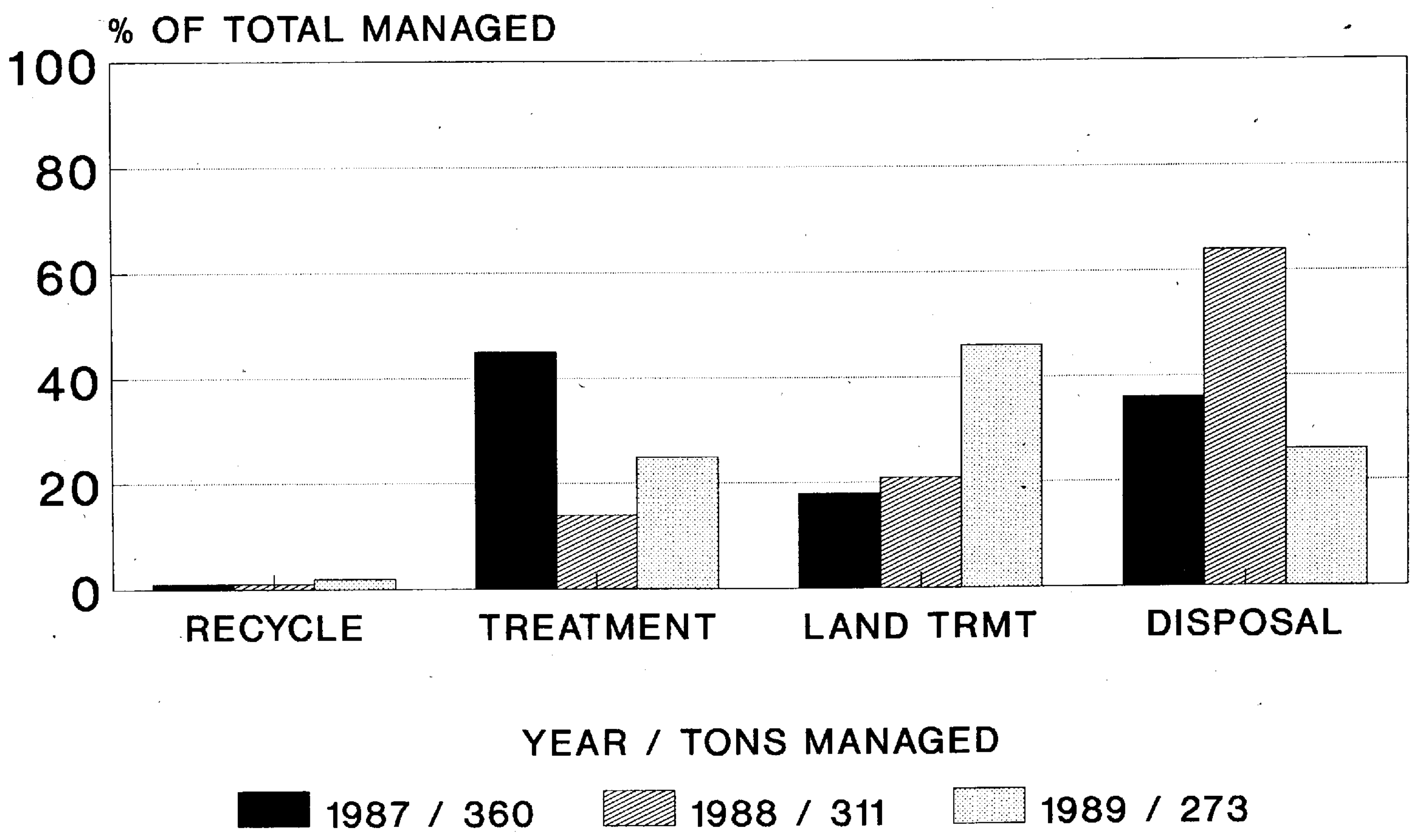
LEADED TANK BOTTOMS
1987-1989



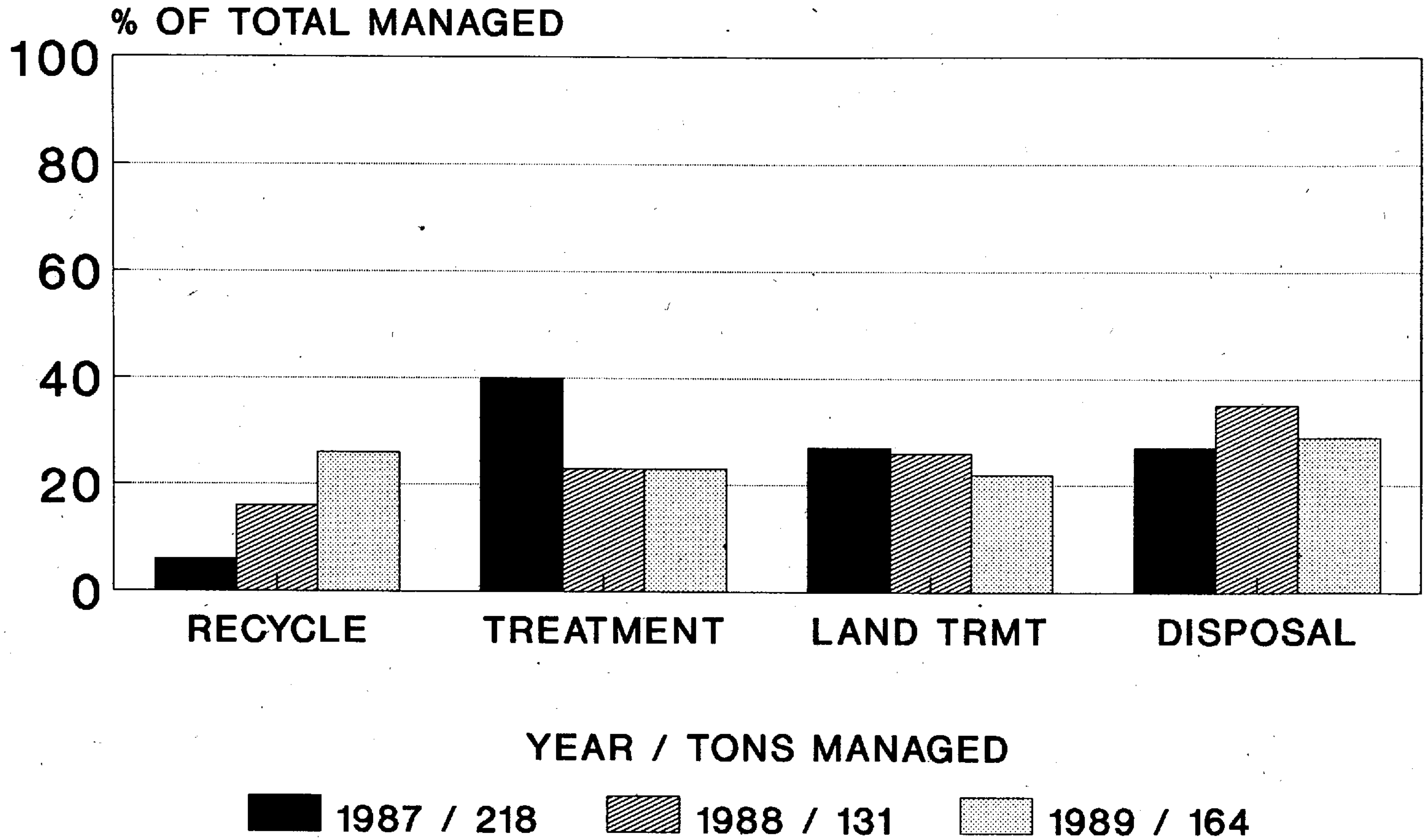
OTHER SEPARATOR SLUDGES
1987-1989



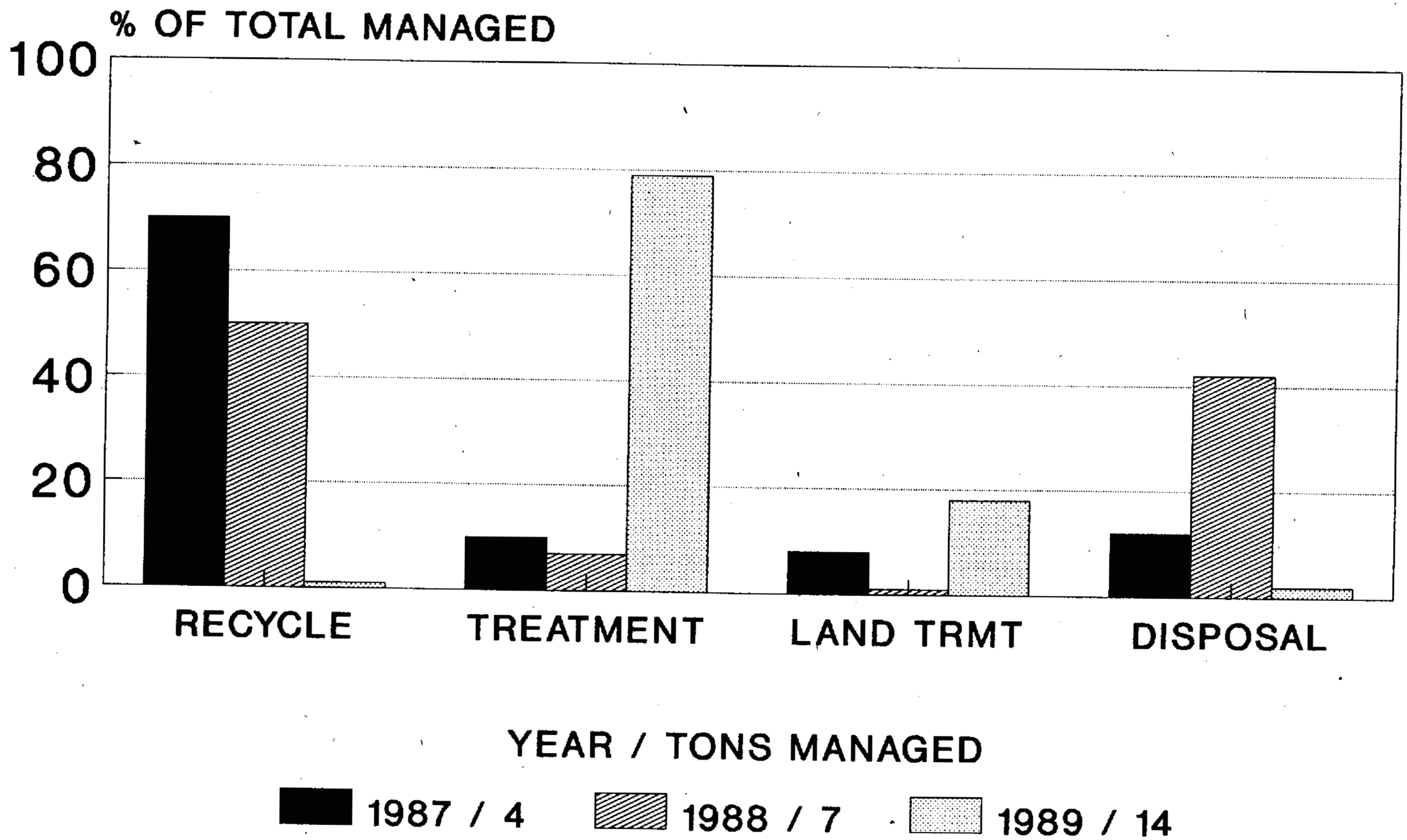
POND SEDIMENTS
1987-1989



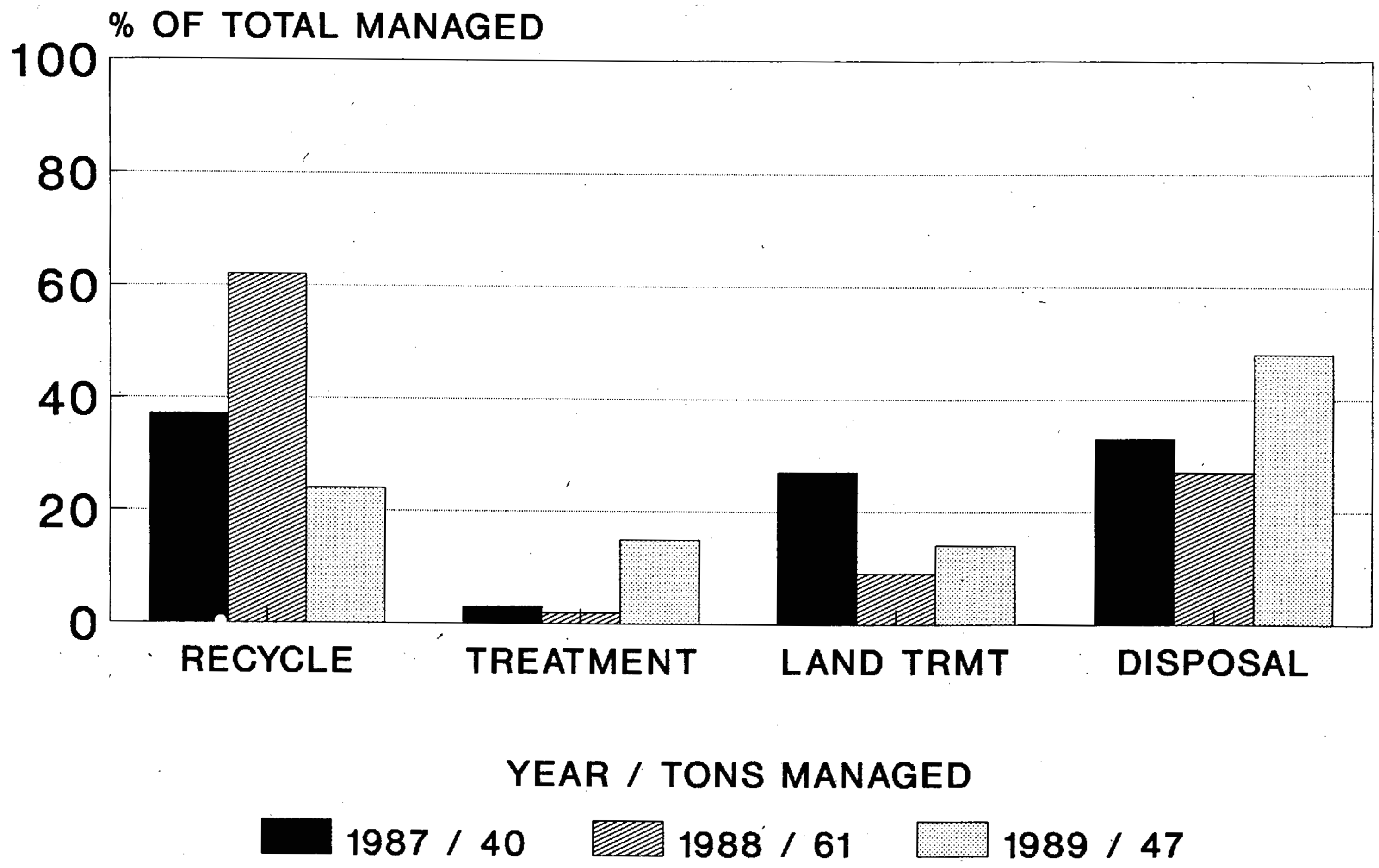
NONLEADED TANK BOTTOMS
1987-1989



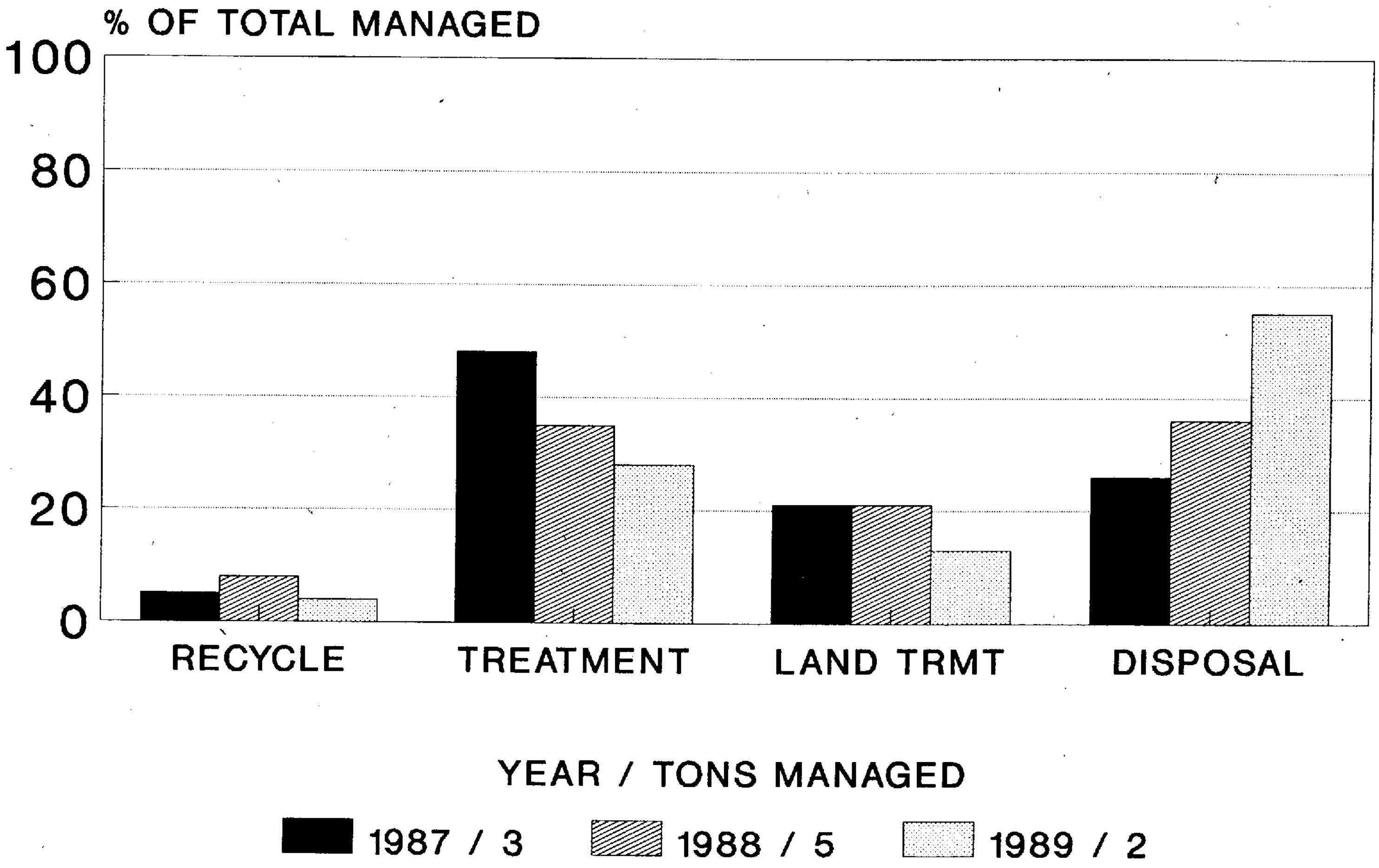
WASTE OILS/SPENT SOLVENT
1987-1989



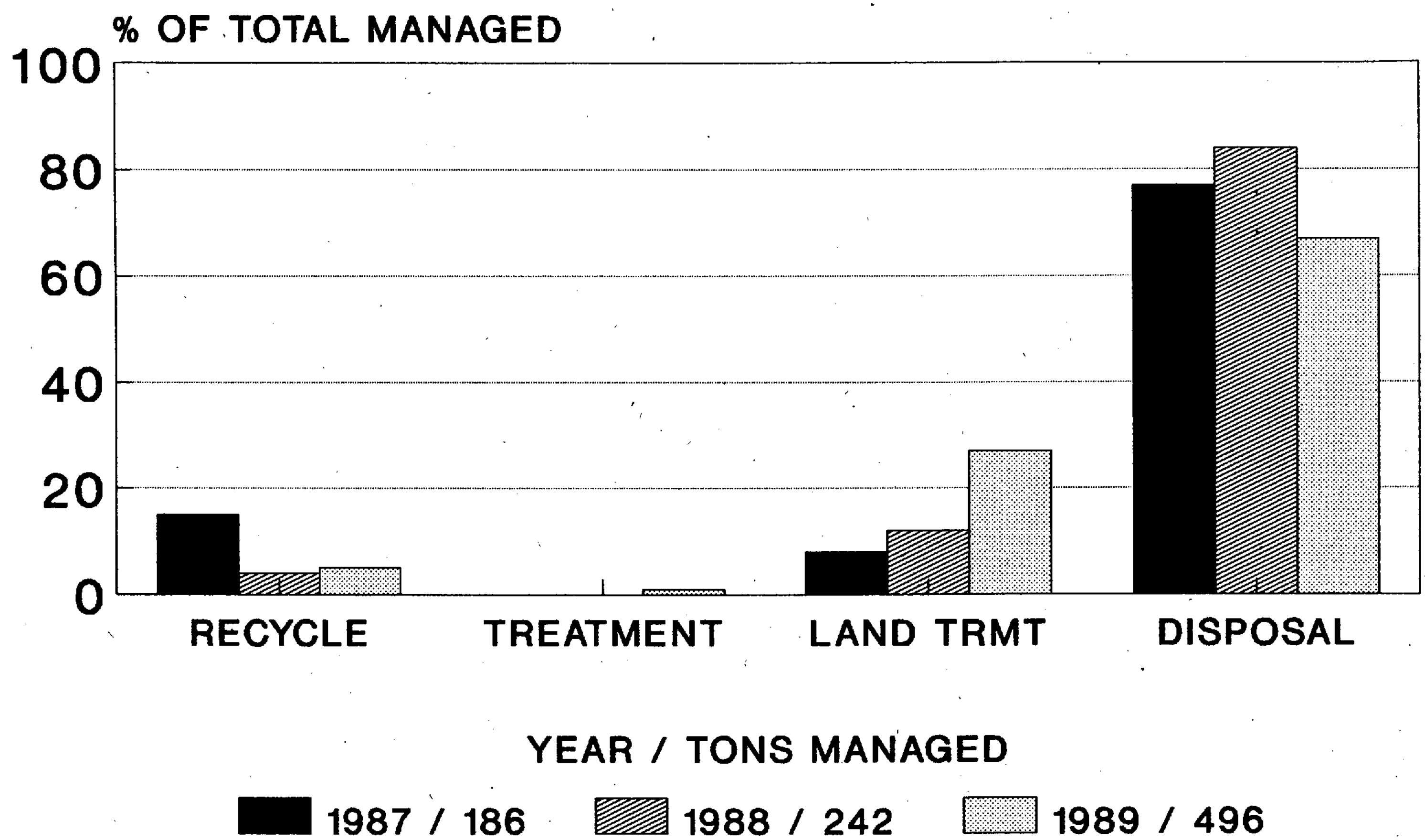
OTHER OILY SLUDGES & ORGANIC WASTES 1987-1989



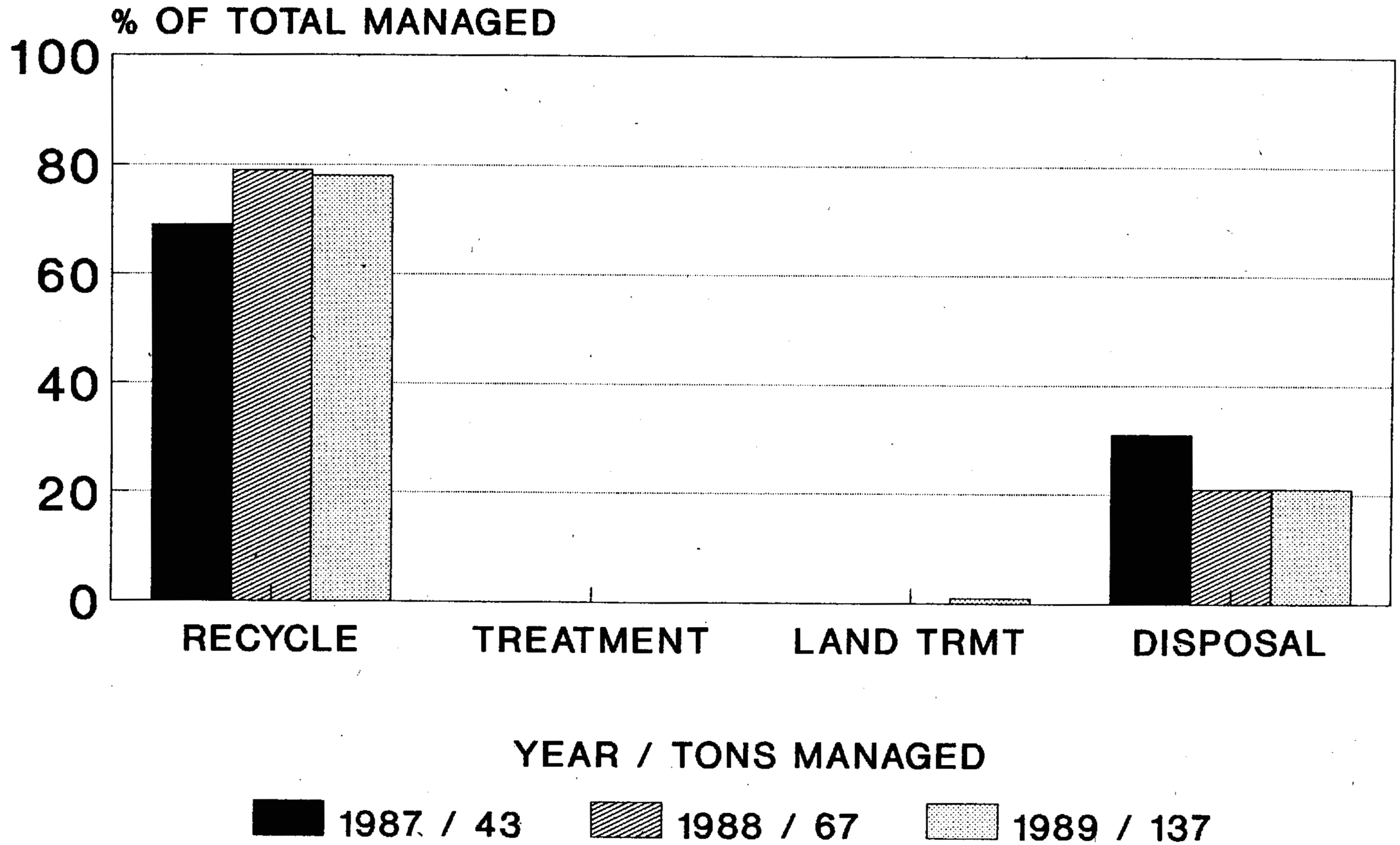
HEAT EXCHANGER CLEANING BUNDLE SLUDGE 1987-1989



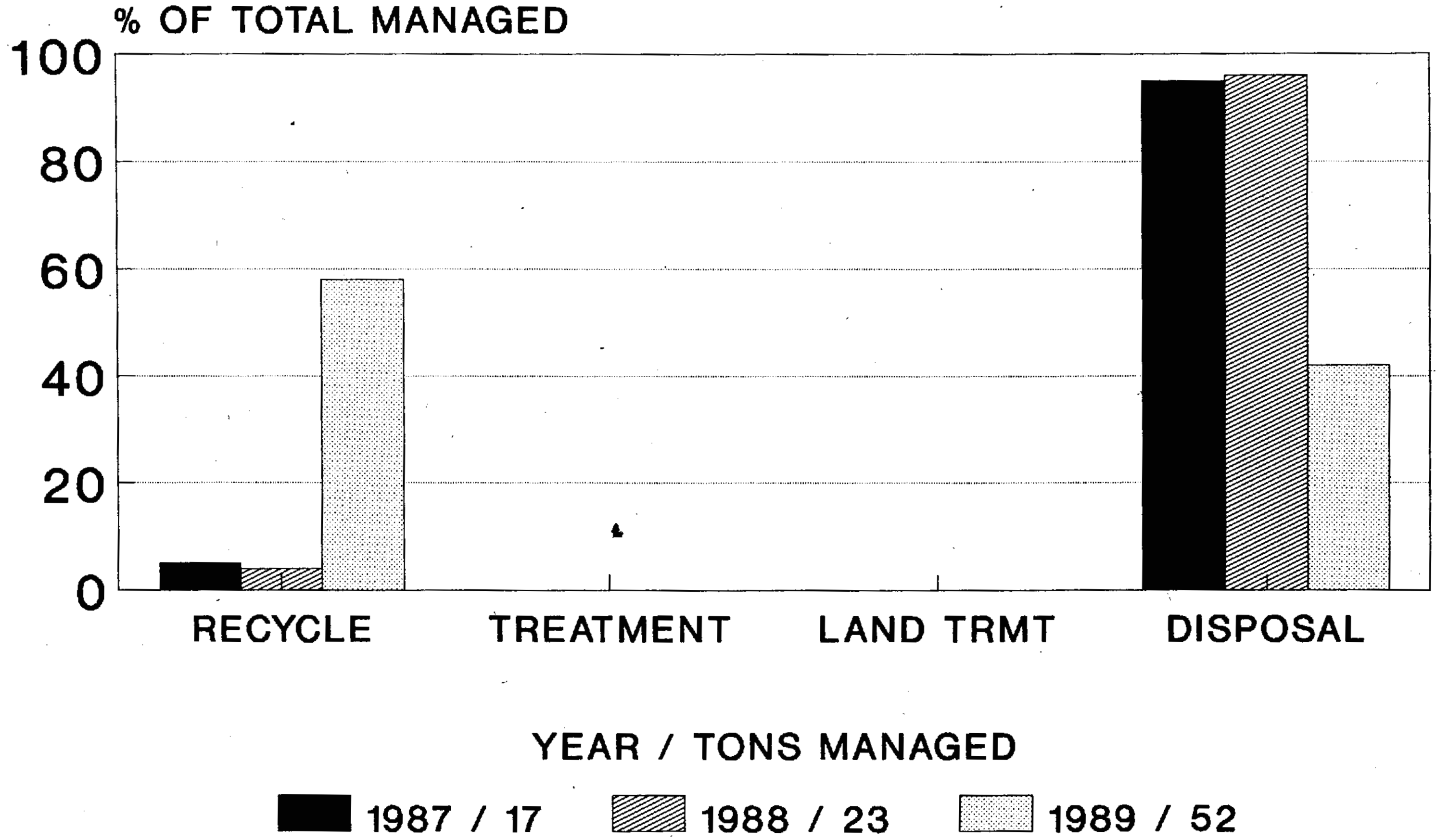
CONTAMINATED SOIL/SOLIDS
1987-1989



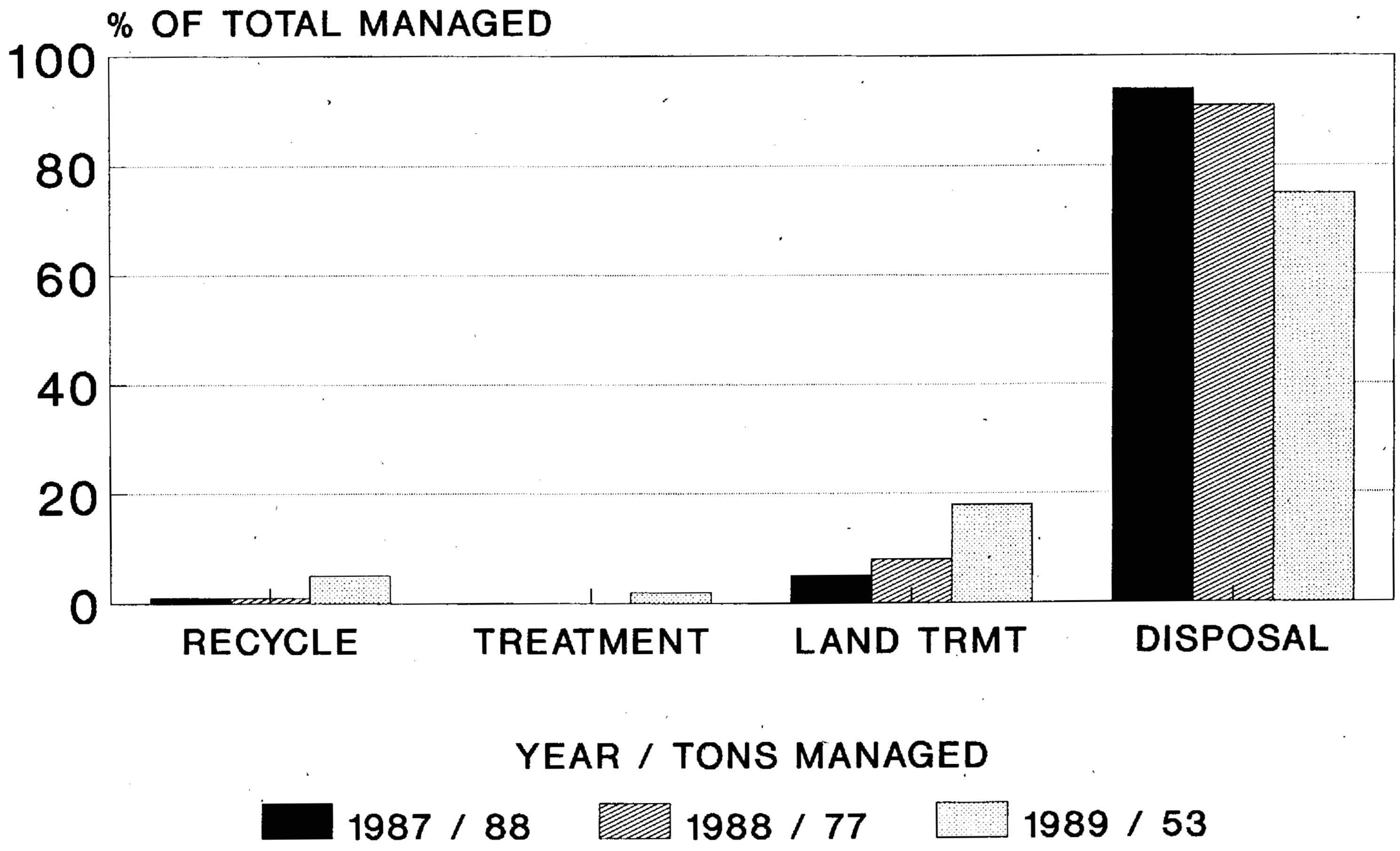
WASTE COKE/CARBON/CHARCOAL 1987-1989



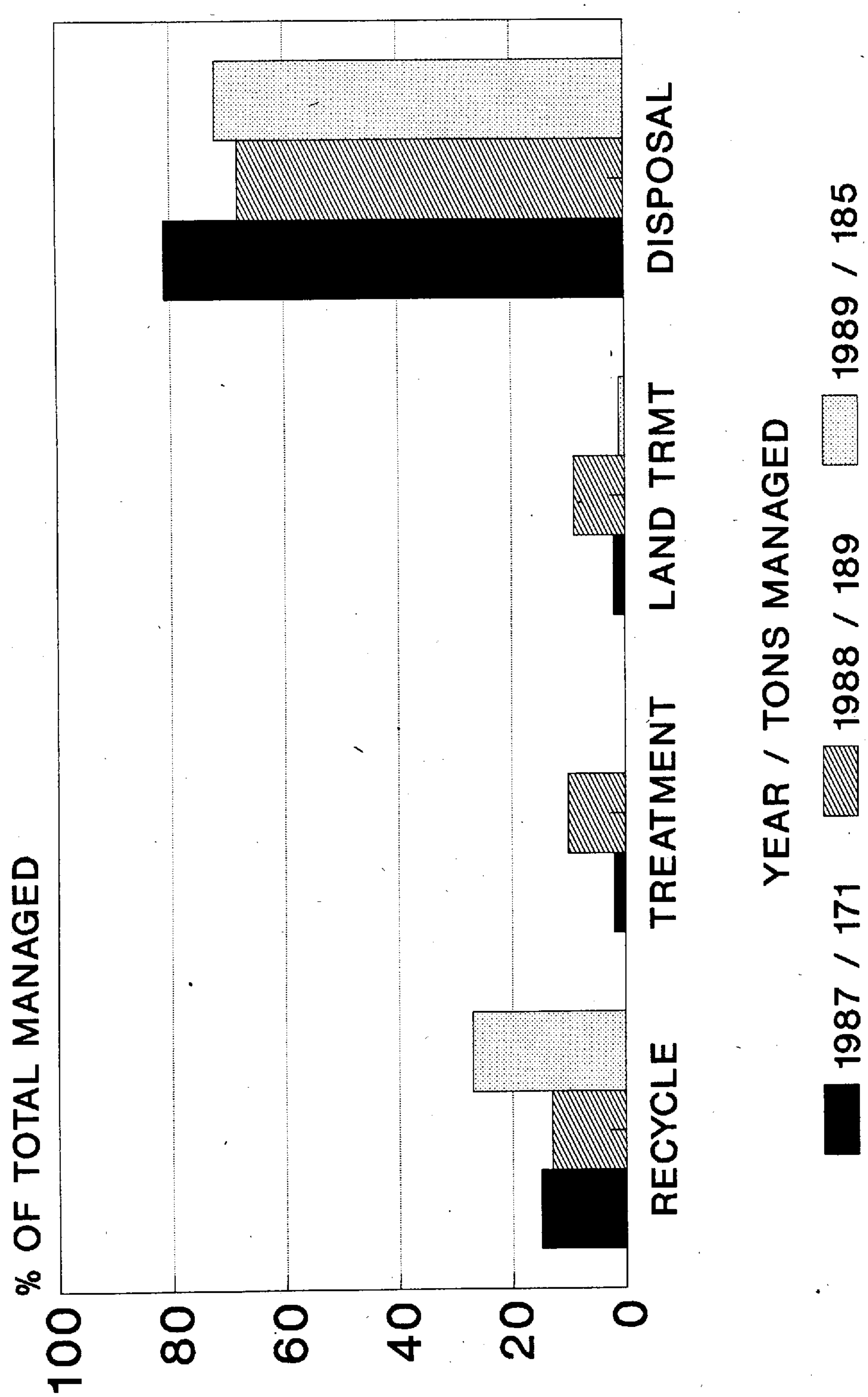
WASTE SULFUR
1987-1989



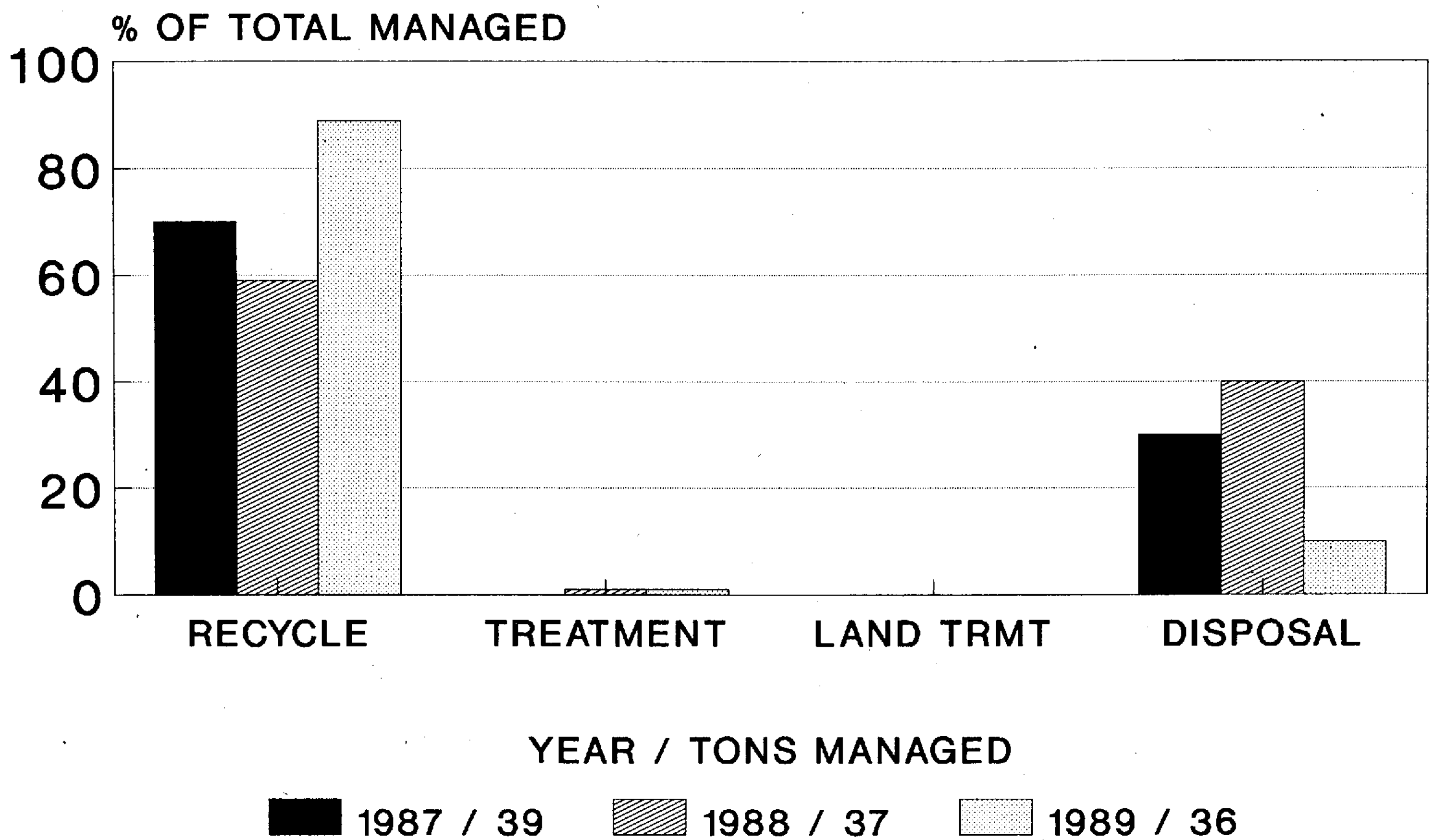
OTHER CONTAMINATED SOILS NOS 1987-1989



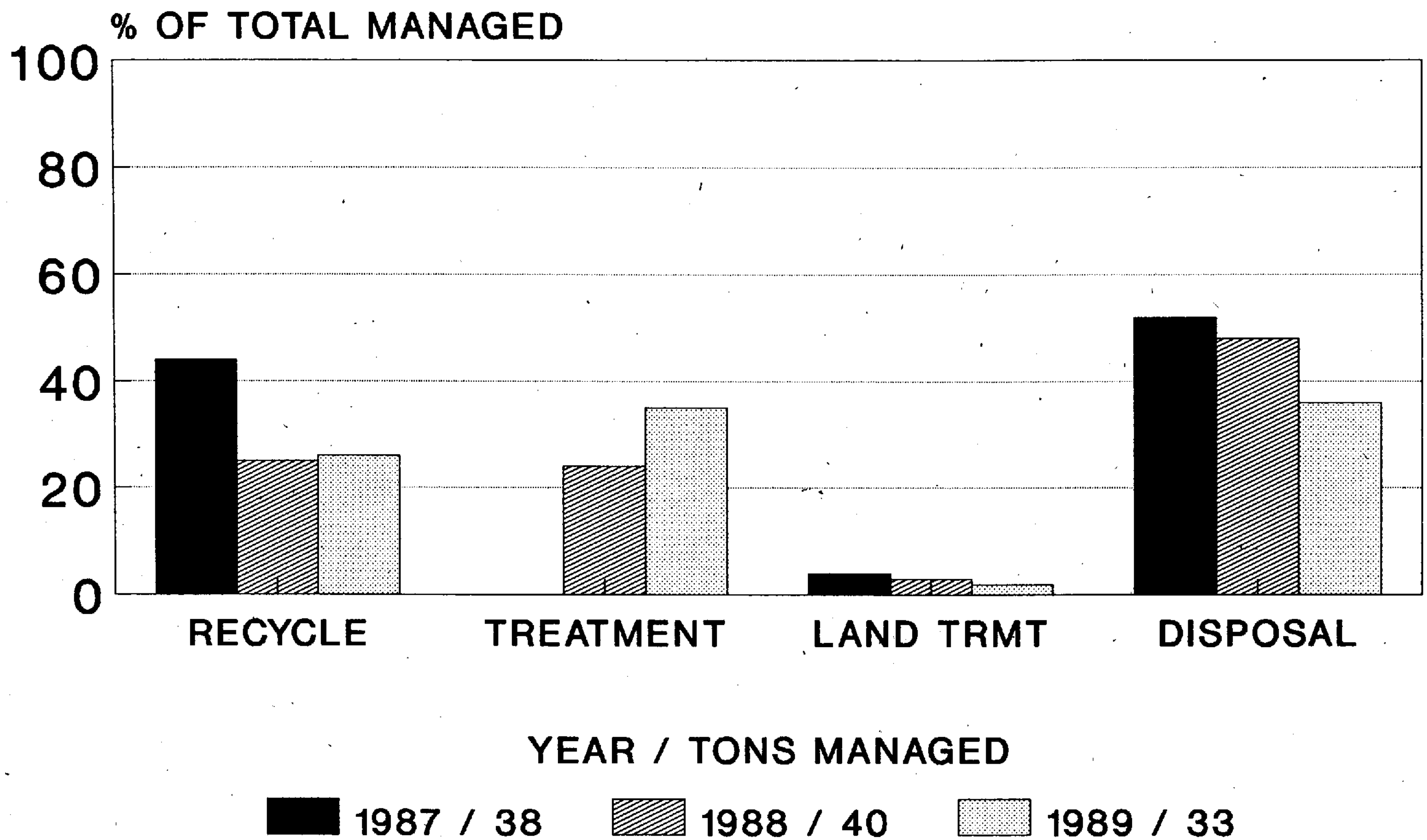
FLUID CRACKING CATALYST OR EQUIVALENT 1987-1989



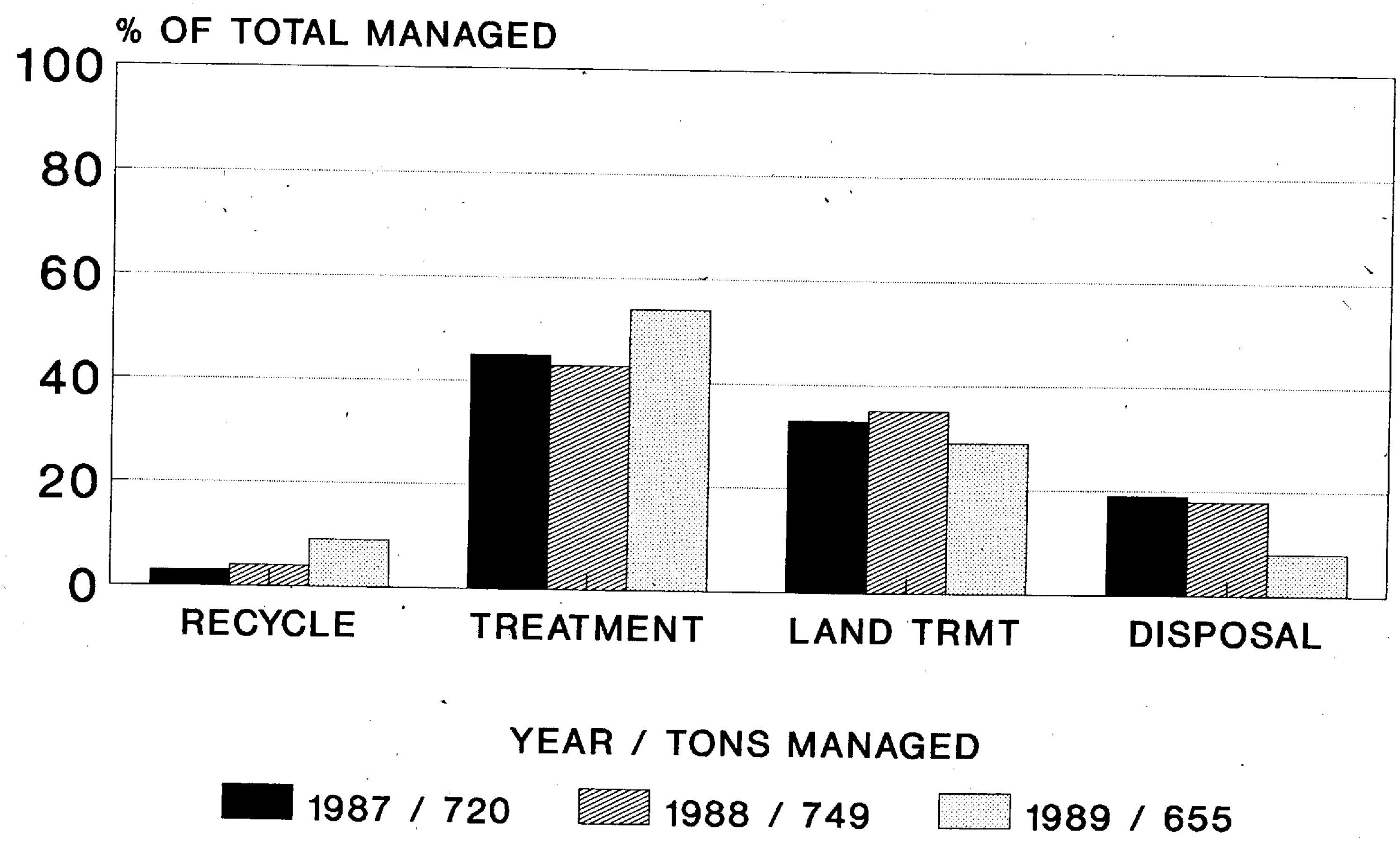
HYDROPROCESSING CATALYST
1987-1989



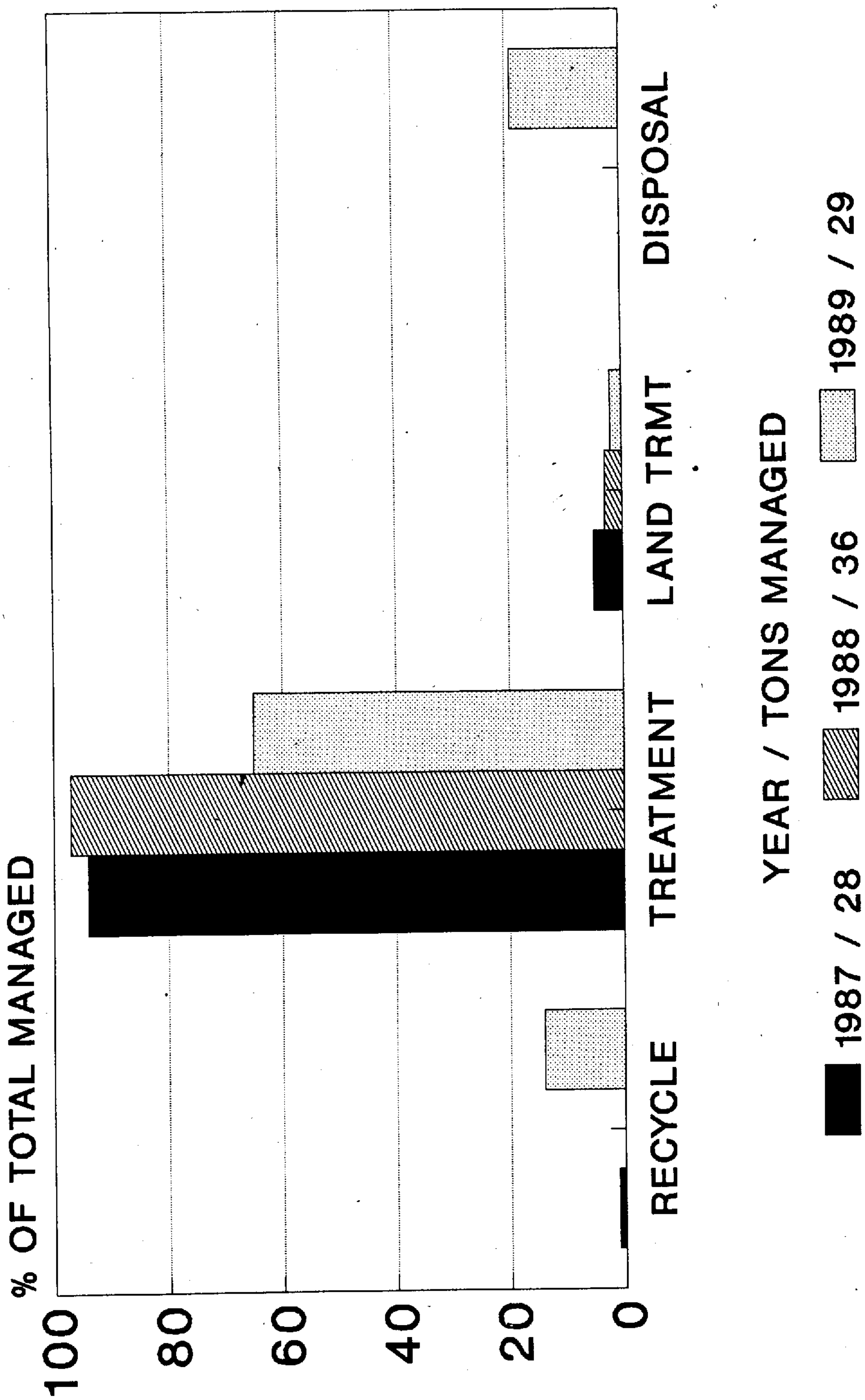
OTHER SPENT CATALYST NOS
1987-1989



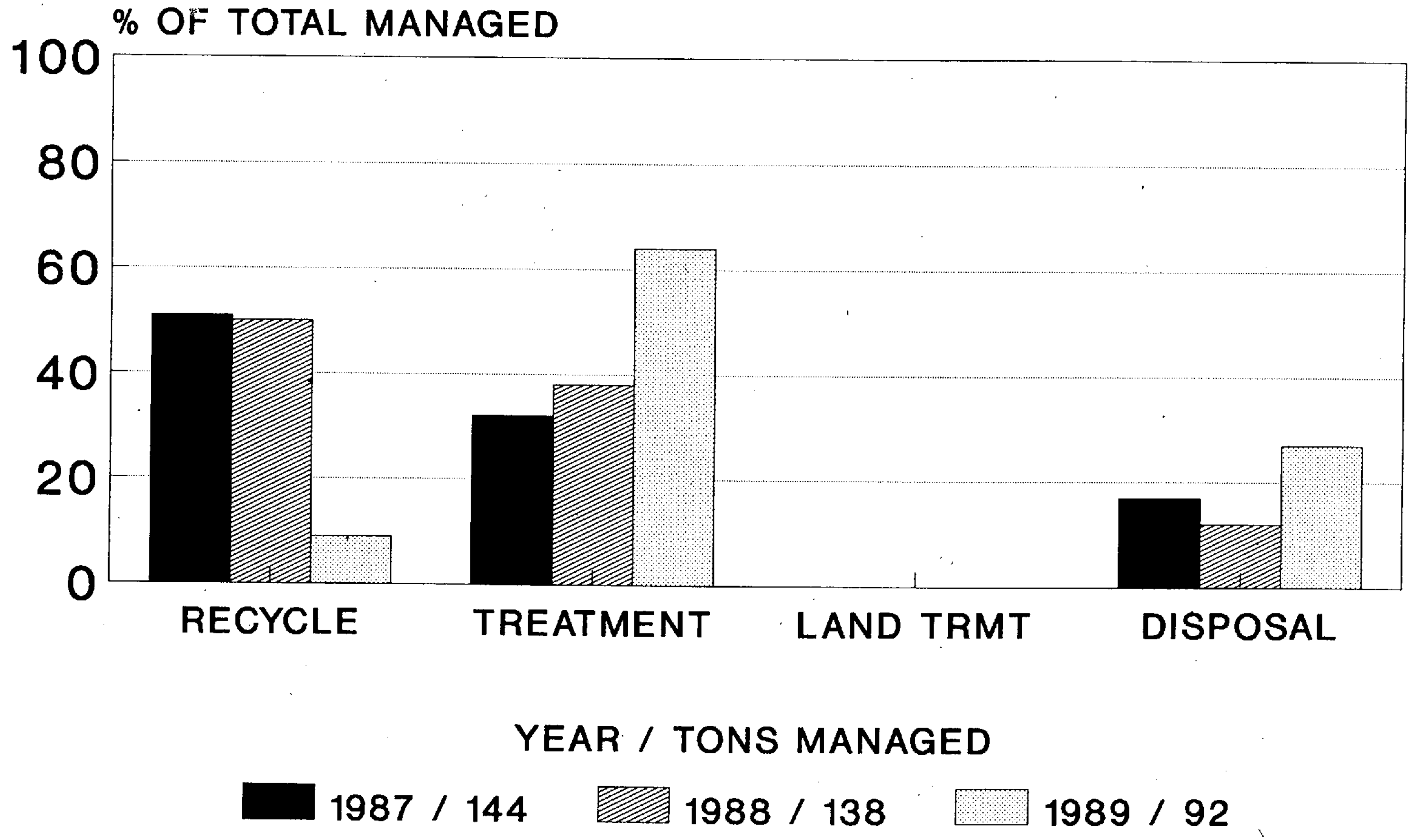
BIOMASS
1987-1989



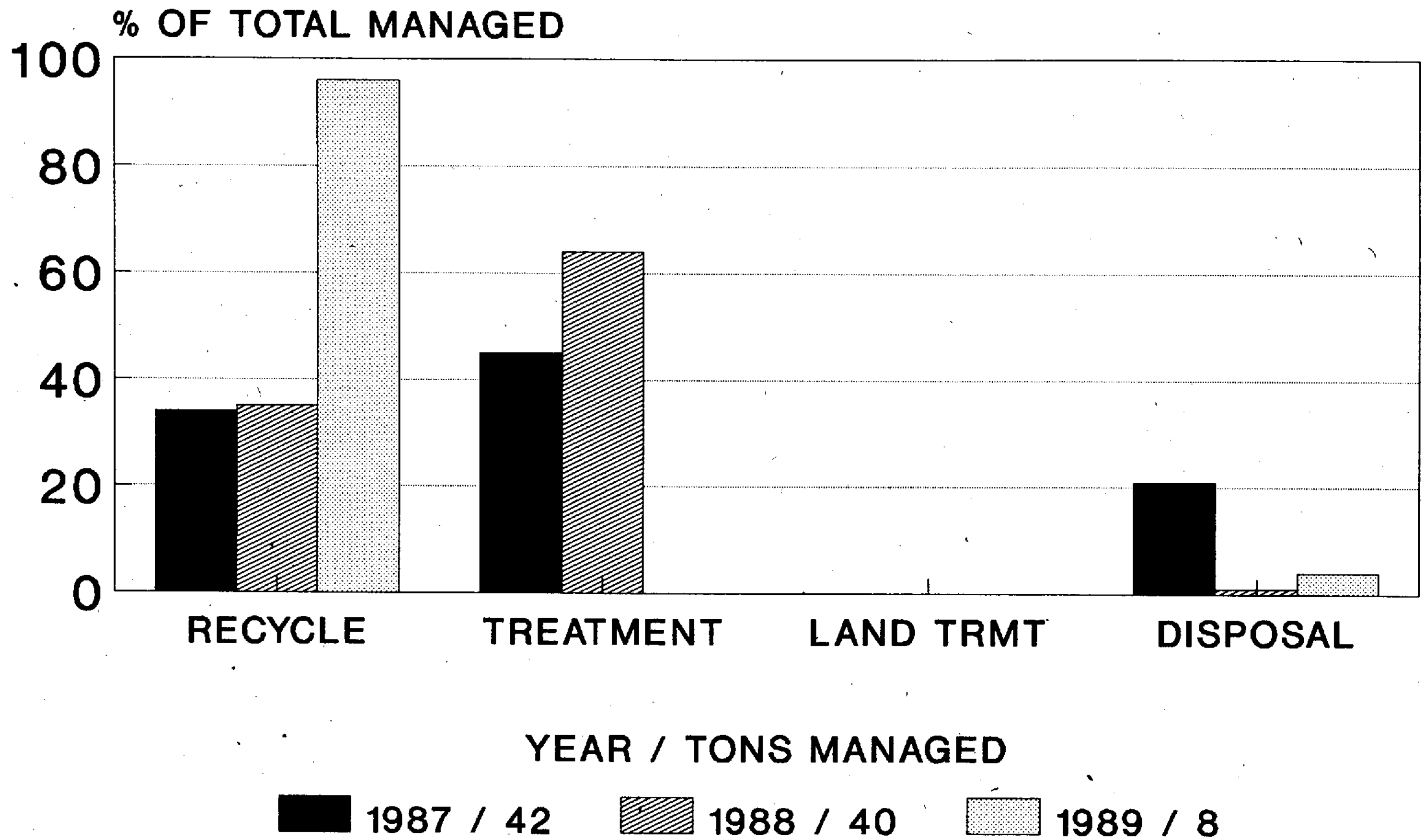
OIL CONTAMINATED WATER NOT WASTEWATER 1987-1989



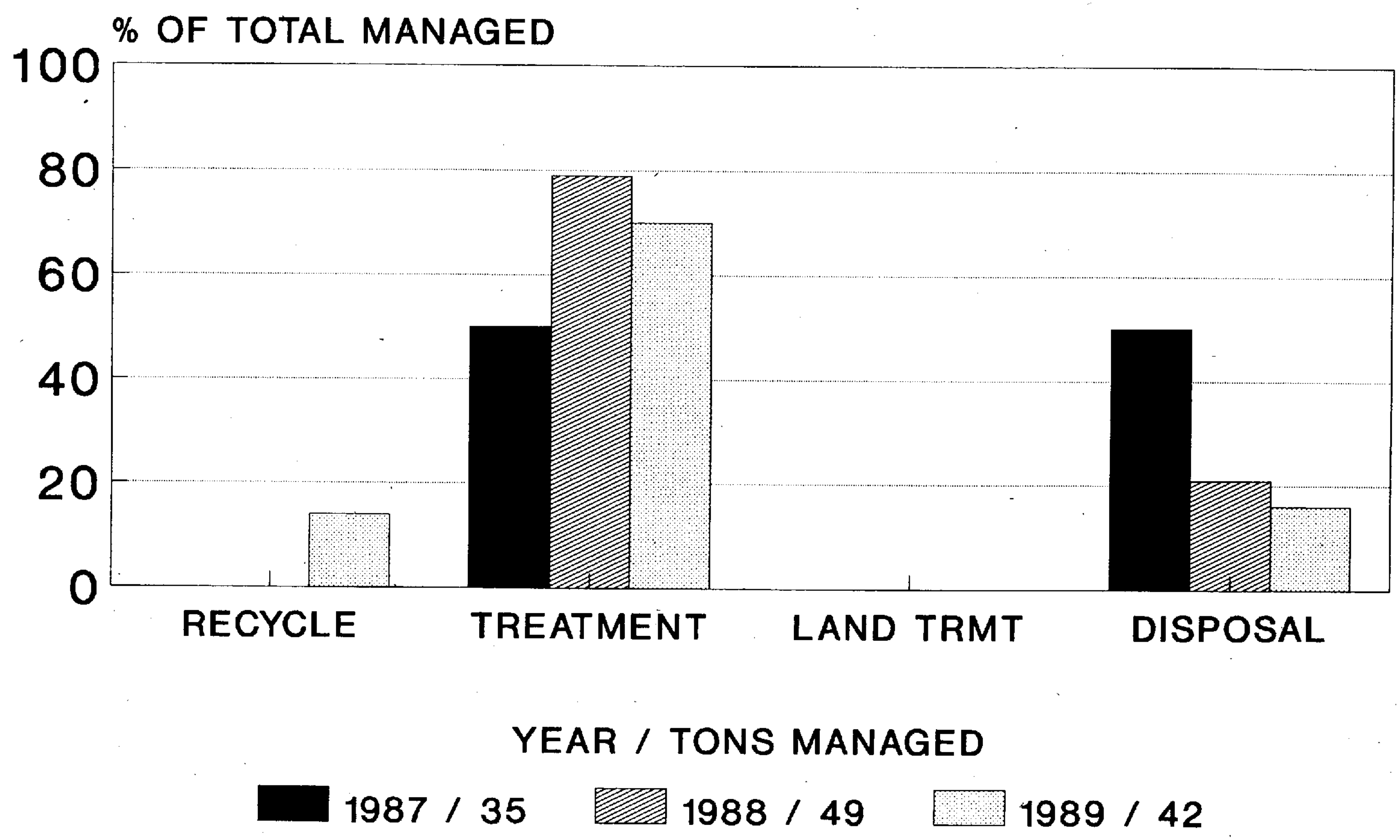
HIGH PH/LOW PH WATERS
1987-1989



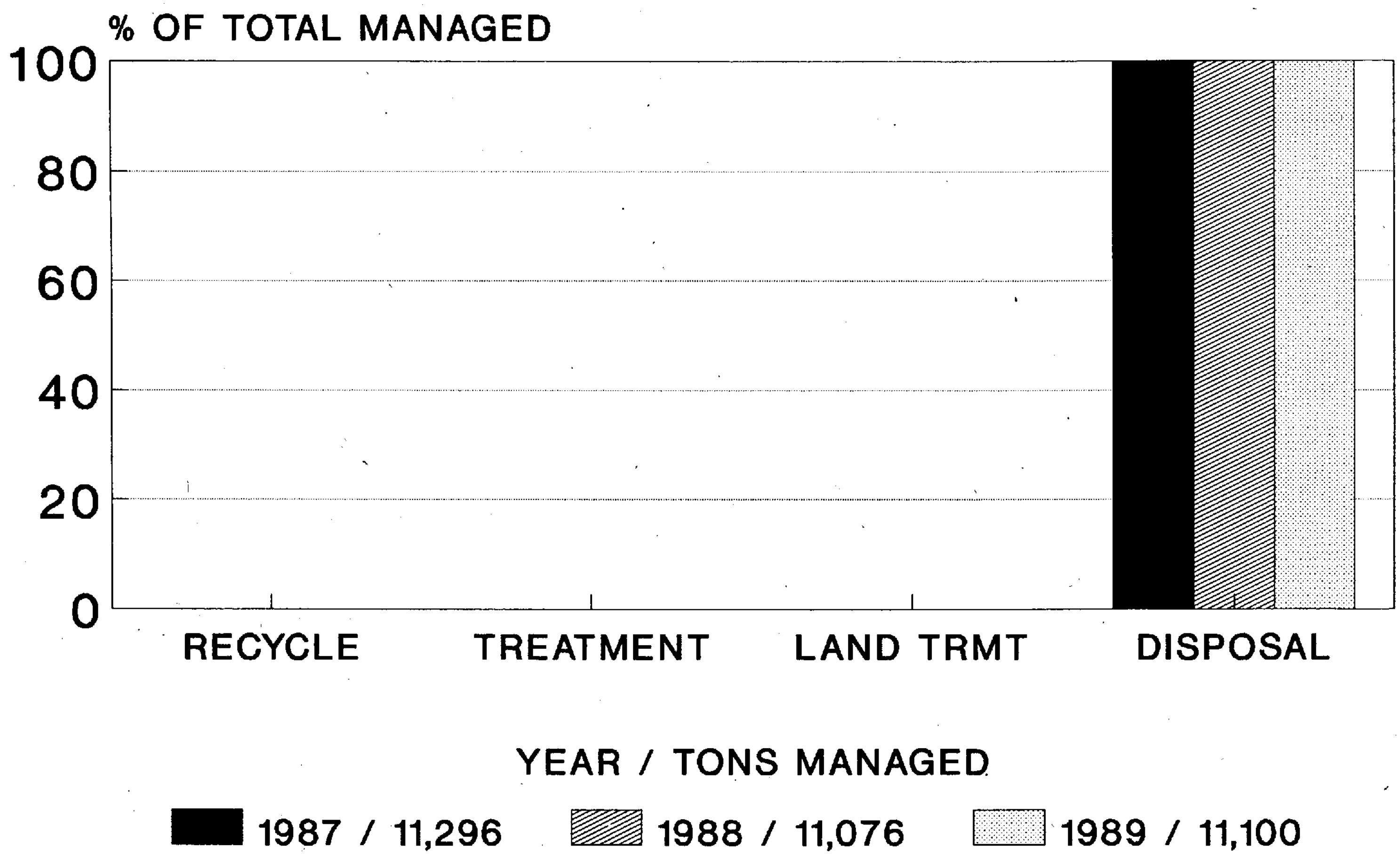
SPENT SULFITE SOLUTION
1987-1989



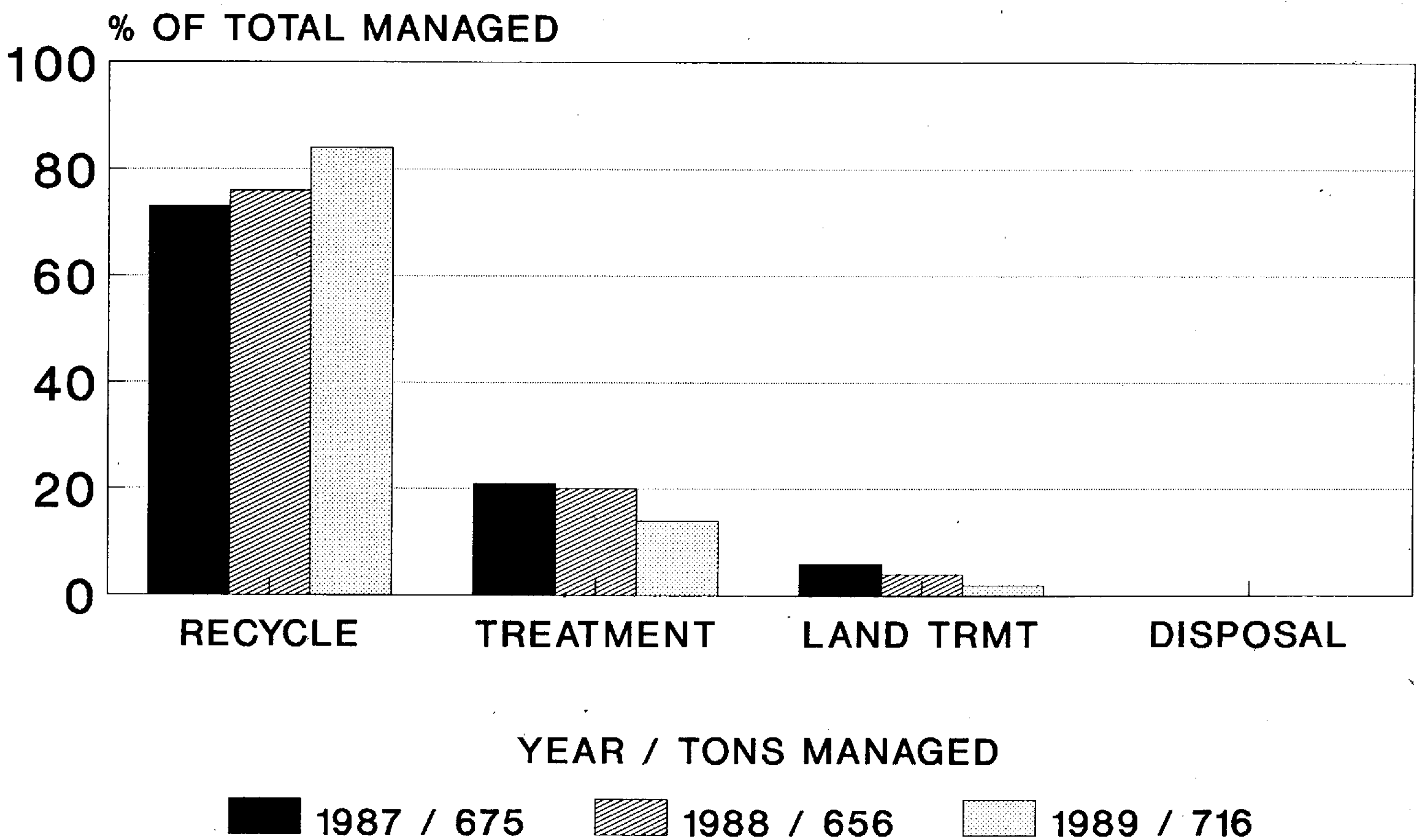
SPENT STRETFORD SOLUTION
1987-1989



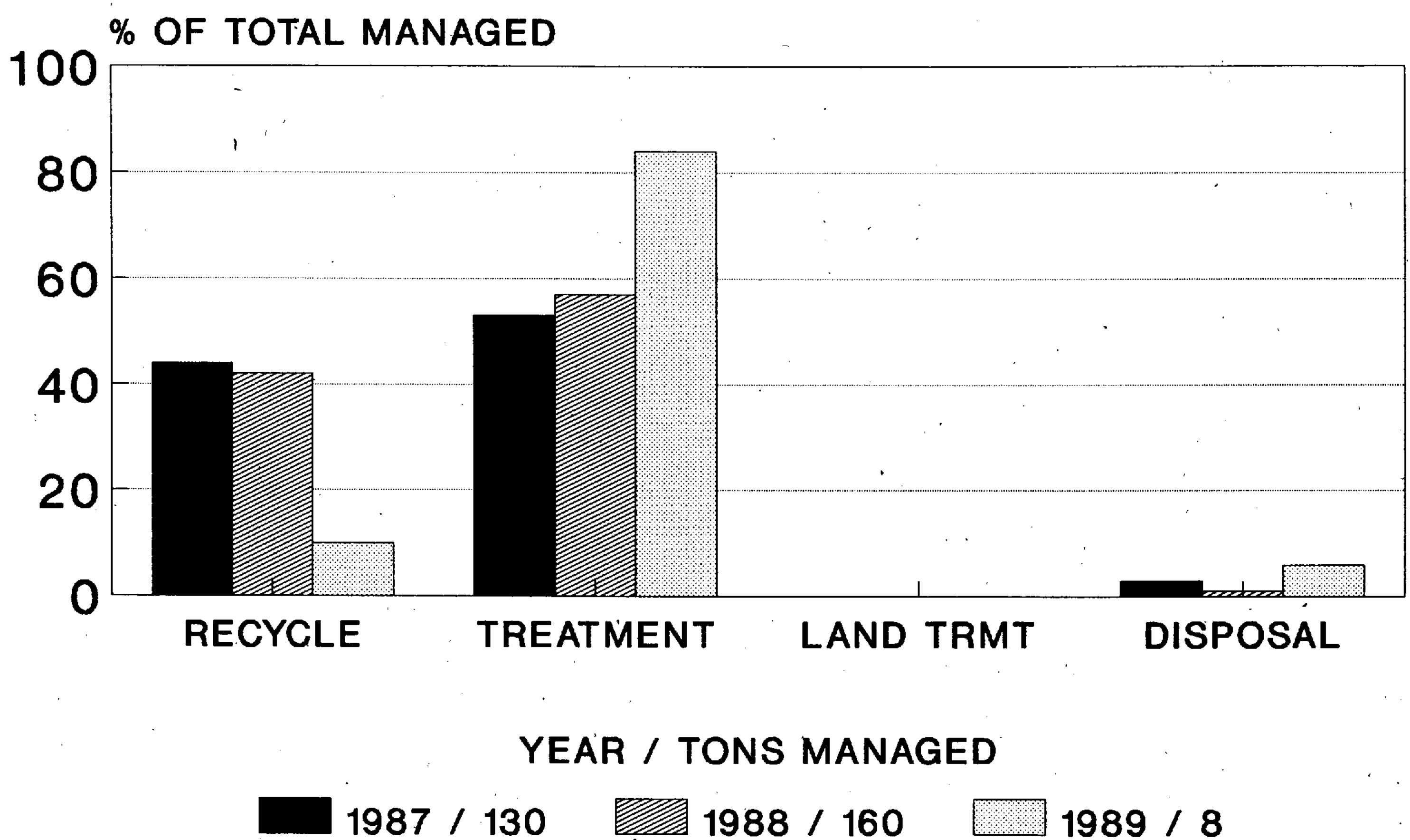
OTHER AQUEOUS WASTES NOS 1987-1989

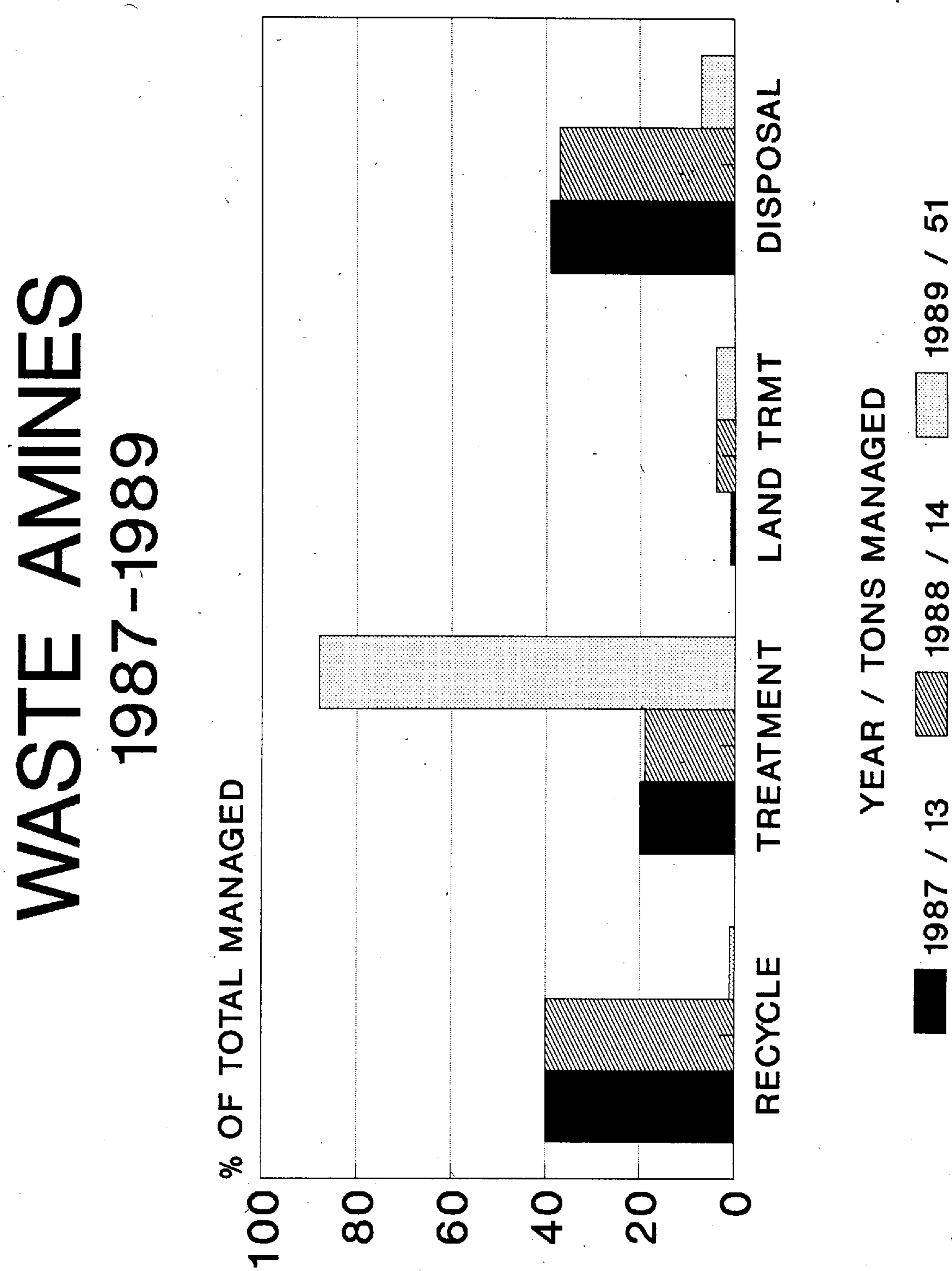


SPENT CAUSTICS
1987-1989

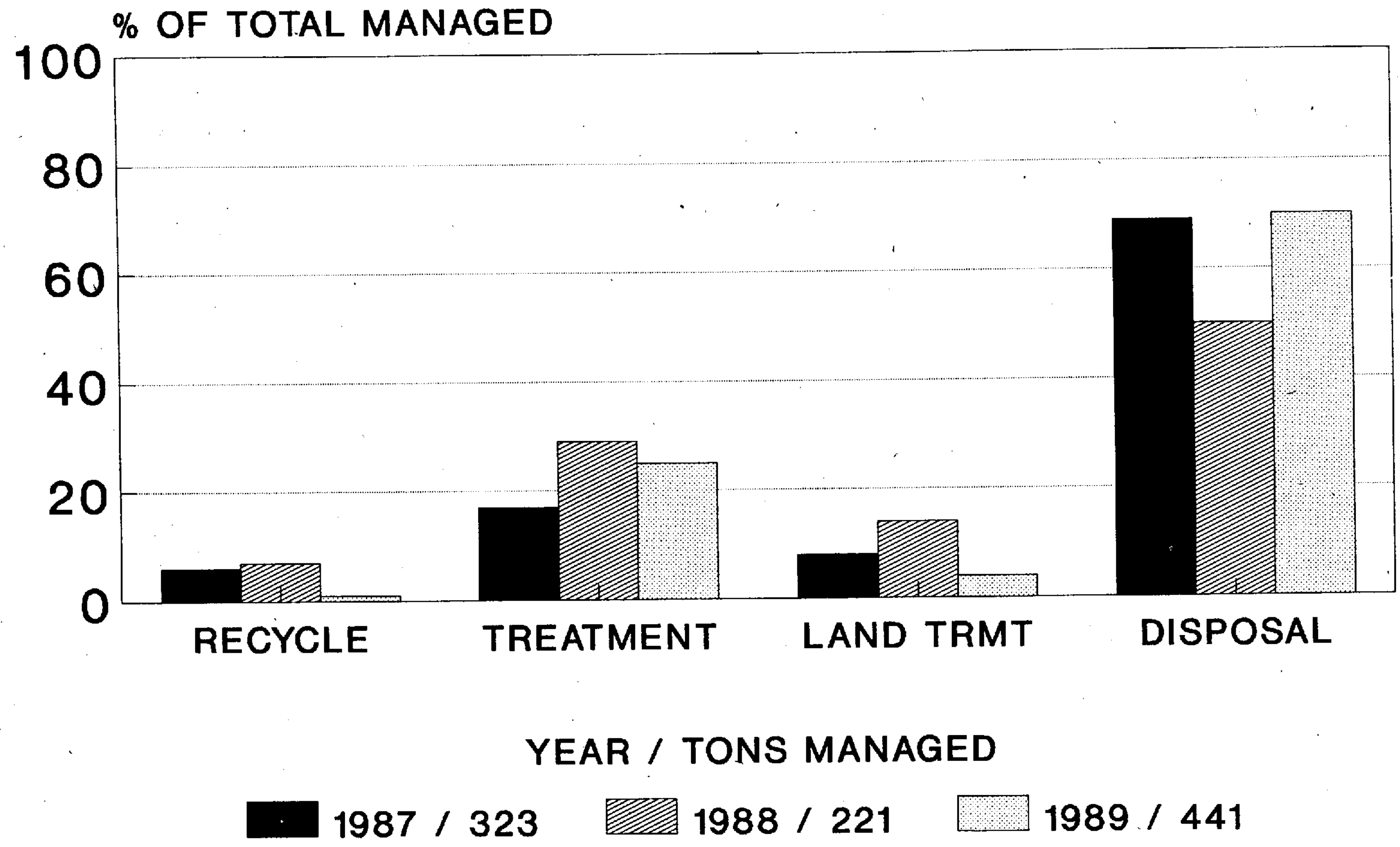


SPENT ACIDS
1987-1989

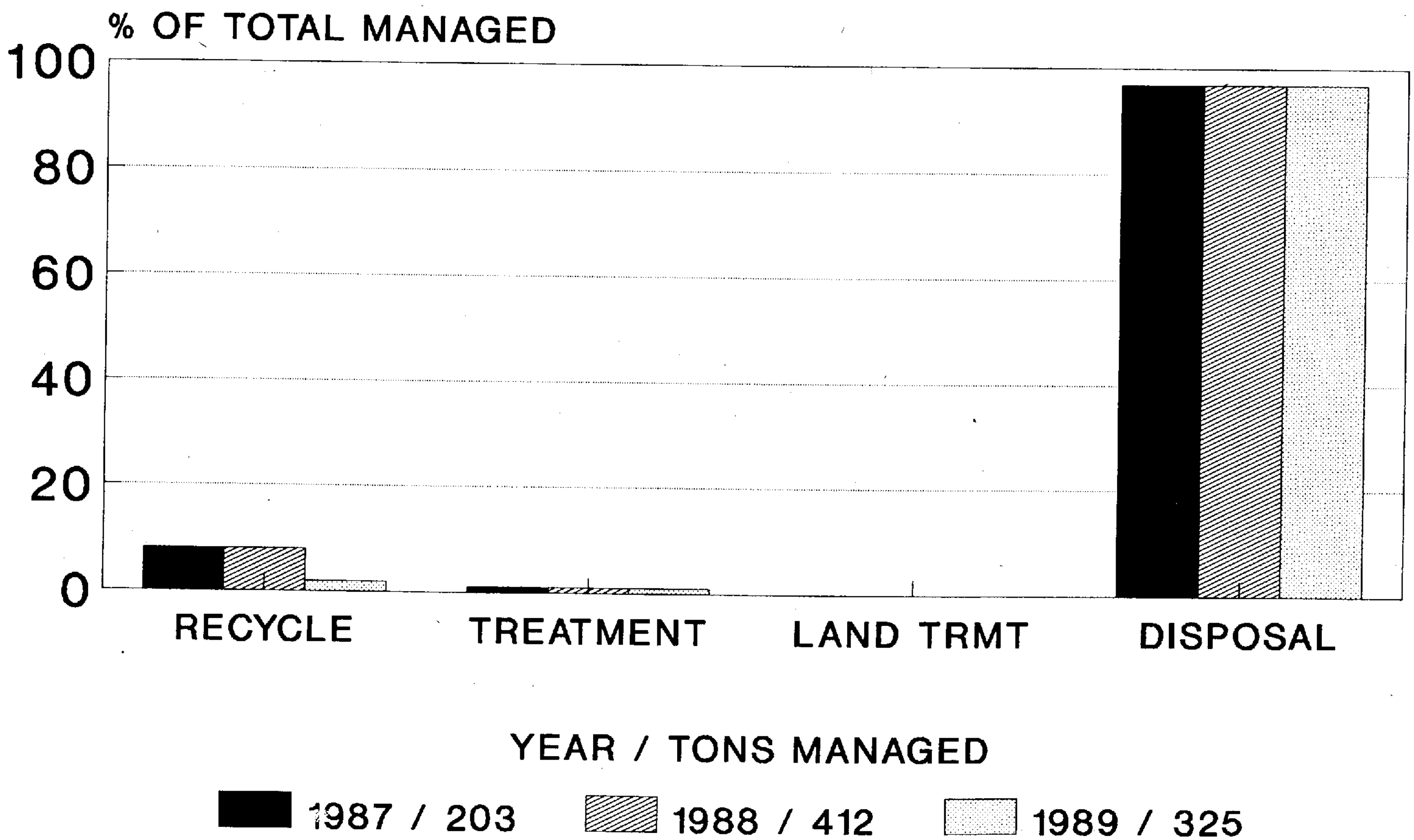



WASTE AMINES
1987-1989
% OF TOTAL MANAGED
100
80
60
40
20
0
RECYCLE
TREATMENT
LAND TRMT
DISPOSAL
YEAR / TONS MANAGED
1987 / 13
1988 / 14
1989 / 51

OTHER INORGANIC WASTES NOS 1987-1989



OTHER WASTES NOS
1987-1989



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