Analysis of Soil Vapor Extraction Expenses to Estimate Bioventing Expenses

Steven M. Loken

ANALYSIS OF SOIL VAPOR
EXTRACTION EXPENSES TO ESTIMATE
BIOVENTING EXPENSES

THESIS

Steven M. Loken, Captain, USAF

AFIT/GEE/ENV/95D-11

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

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Presented to the Faculty of the School of Engineering

of the Air Force Institute of Technology

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In Partial Fulfillment of the

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Master of Science in Engineering and Environmental

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Captain, USAF

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Joseph P. Cain, Ph.D.

John Glaser by CAB

John A. Glaser, Ph.D.

Charles A. Bleckmann, Ph.D.

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Steven M. Loken

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Abstract

An in-depth analysis of the expenses incurred with five soil venting petroleum remediation projects was accomplished. The data was obtained from receipts provided by a major United States petroleum refiner and distributor. Cost categories were designed that incorporated all costs and provided a method to analyze the data. The five cost categories used were: permits, equipment, management, utilities, and analysis.

Further analysis showed trends and described the behavior of the costs related to remediation events. The relative percentile for each cost category was found to be consistent among the projects. Many costs were also found to be very linear through out the life of the project from discovery to final cleanup. These linear costs for each cost category were also found to have similar slopes when comparing different projects.

The last analysis performed was to create a simplified equation to use to predict soil vapor extraction and bioventing expenses. The apparent linearities of the costs made this a relatively simple equation.

ANALYSIS OF SOIL VAPOR EXTRACTION

EXPENSES TO ESTIMATE BIOVENTING EXPENSES

I. Introduction

General Issue

As long as petroleum is relied upon as a major source of energy in the world, there will be oil spills. Daily operations from producing, refining, distributing and consuming oil products will eventually produce spillage. Therefore it is extremely important to find easy and economical ways to clean up petroleum that has been released into the environment. Excavation costs can run above $110 per cubic yard of soil cleaned up, while bioremediating with bioventing can cost less than $10 per cubic yard of soil cleaned up (AFCEE, 1994:12). When comparing cleanup technique costs, it is easy to see that the best way to clean up contamination in soils is in-situ bioremediation. This technique involves cleaning up the petroleum by microorganisms while the petroleum remains in the ground.

Biodegradation of petroleum is an intricate process that is not yet fully understood by scientists. The structure of petroleum is complex and varied, but it is, after all, a natural product of the degradation of natural substances. Therefore it can be inferred that there are natural biologically mediated processes that can break it down into carbon dioxide and water. It is our job to find these processes and help them along when necessary. Oxygen has been proven to be the most common limiting factor for biodegradation in the soil. Other factors may come into play, but for *in-situ* bioremediation, oxygen availability seems to be the controlling variable.

A new and innovative technology that has come to the forefront of bioremediation techniques is bioventing. Bioventing is the introduction of air into the unsaturated soil zone by mechanical means to aid the destruction of petroleum hydrocarbons. In this method oxygen is more readily available to microorganisms so that aerobic degradation of petroleum can occur at very high rates. Bioventing is very similar to soil vapor extraction treatment in which air containing volatilized petroleum hydrocarbons is removed from the ground and treated to remove these hydrocarbons. The main objective of soil vapor extraction is the removal of the volatile hydrocarbons, but the introduction of air into the ground has been found to assist bioremediation rates. The two treatments use very similar construction and operation methods. The main difference is that bioventing is designed to produce no off-gas that requires treatment because it moves the gas phase through the contaminated zone at a rate that minimizes air stripping of the contaminant hydrocarbon. The primary advantages of soil vapor extraction and bioventing are the relatively low cost of cleanup and minimal public exposure. The disadvantages include the need for accurate monitoring and the current inability to predict cleanup time (Long, 1992: 345).

Specific Problem

In order for bioventing to be considered a valuable remediation technique to be used by environmental engineers and managers, the full scope of cost for any bioventing remediation project must be understood before a project should be considered for funding. The extensive literature search required for this thesis has not uncovered a detailed cost analysis procedure or cost evaluation for any existing bioventing project. Many articles and books discuss the effectiveness and limitations of bioventing and air sparging, but very little on cost analysis. There have been many studies that have identified costs as lump sums for projects with certain time periods (AFCEE, 1994:12, Hinchee, 1987). Other studies have concentrated on individual aspects of the bioventing process such as minimizing costs (Downey, 1995). Research is required to identify each component of the cost associated with the successful application of bioventing a contaminated site.

Research Objectives

The purpose of this research is to review, analyze, compare, and predict costs associated with soil vapor extraction and bioventing remediation projects. Very detailed cost data on existing soil vapor extraction projects will be obtained. The data will be analyzed to produce a framework for estimating costs for future projects. A cost framework for bioventing will then be produced for estimating bioventing projects using the similarities between bioventing and soil vapor extraction. An important part of this understanding is predicting expenses as they will occur.

Research Questions

Research questions answered by this research include:

1. What are the major cost constituents incurred during a soil vapor extraction remediation project?

2. During what time frame are most of the costs incurred for each phase of cleanup?

3. Are there costs that are independent of level/area of contamination?

4. Can a simple cost model be developed for estimating bioventing remediation projects?

Scope

The scope of this research will only include petroleum hydrocarbon soil vapor extraction and bioventing projects conducted in the continental United States. Two very important factors about bioventing will not be addressed, how effective is bioventing or how long does a bioventing project take to obtain cleanup. Others are spending considerable time on qualitative analysis of soil venting projects (Johnson, Paul, 1990). Due the infinite variety of soil conditions, the underlying assumption that a soil vapor extraction or bioventing project has been deemed feasible by other methods is necessary. This research is intended only to facilitate a detailed cost estimate.

Thesis Organization

The thesis is organized into four separate parts: literature review, methodology, conclusions, and recommendations. A literature review of all relevant subjects is accomplished first. Then the methodology for the thesis is discussed. Next the data is described and analyzed. The conclusions and recommendations are at the close of this thesis. Appendices are included which show the database from the five soil venting projects used for analysis.

II. LITERATURE REVIEW

Overview

A working and in-depth knowledge about the subject is a basic requisite to the development of a detailed cost analysis framework.

This thesis is focussed on petroleum hydrocarbon treatment by the process of bioventing. The literature review will include information on the following subjects: the natural process that must be understood involves the petroleum constituents and the specifics of petroleum biodegradation, and current bioremediation technologies including soil vapor extraction (SVE), air sparging, and bioventing. To do the final analysis, cost estimating will also be reviewed.

Petroleum Constituents

How can gasoline remain in the ground for millions of years before being recovered by man, and yet rapidly disappear from the ground when it is spilled? The answer to this question is that biodegradation of oil is for the most part an aerobic process. Petroleum is the result of anaerobic conversion of biomass under temperature and pressure. Geologic and environmental evidence has shown that these formations persist for a long time. Once the oil is exposed to an aerobic environment with petroleum degrading microorganisms, the oil is quickly, in geological terms, mineralized through both biotic and abiotic processes.

Crude oil, as it is taken from the ground, can be broken down into two distinct categories: polars and hydrocarbons. Polars, sometimes called NSO, are compounds containing nitrogen (N), sulfur (S), or oxygen (O) molecules in addition to the carbon (C) and hydrogen (H) molecules. Hydrocarbons are further classified into saturates and aromatics. The saturates include cyclics and straight and branched chained alkanes. Aromatics can be broken down into mononuclear and polynuclear aromatics. Figure 1 shows the hydrocarbon components (Huesemann, 1994:303).

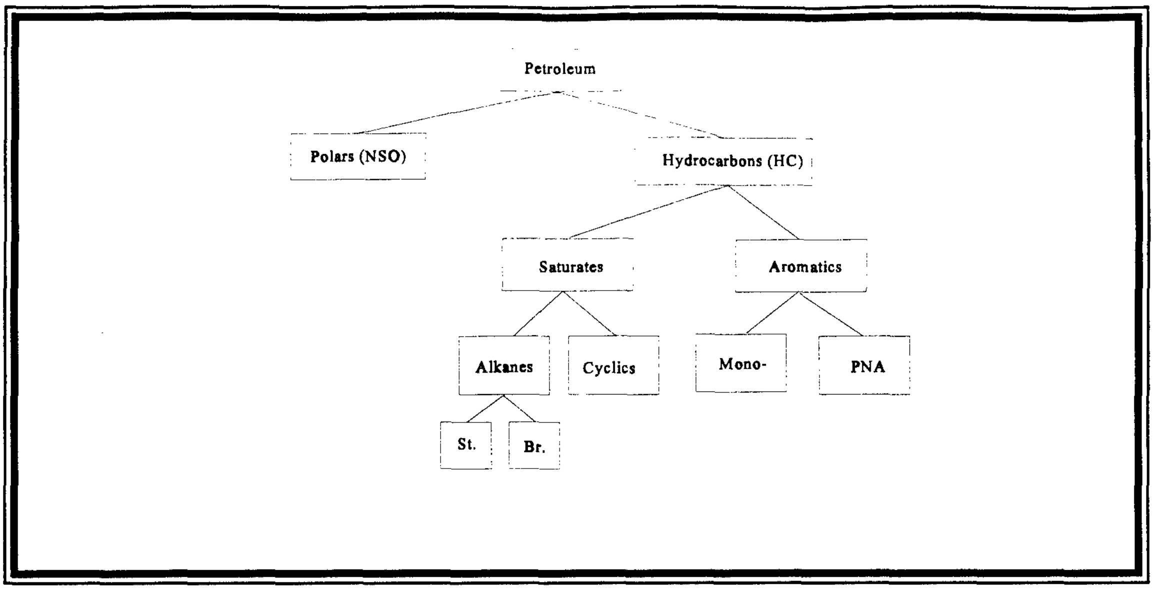

FIGURE 1: PETROLEUM CATEGORIES (Huesemann, 1994)

Petroleum Biodegradation

In an article entitled "Guidelines for Land-Treating Petroleum Hydrocarbon-contaminated Soils," Michael H. Huesemann suggests the following relative biodegradation potential for particular hydrocarbon compounds, shown in Figure 2.

Mono-Aromatics

Straight-Chain Alkanes

Branched Alkanes

Saturated Cyclics

(Naphthenes)

Polynuclear Aromatics

Polars

Decreased Potential

Increasing Ring # or Molecular Weight

FIGURE 2: PETROLEUM BIODEGRADATION RATES (Heusemann, 1994)

The mono-aromatics are the most easily degraded because of their high solubility in water. The degree of biodegradability of the branched and straight-chain alkanes is highly dependent on molecular weight (carbon chain length) and the degree of branching.

The book "Microbial Ecology: Fundamentals and Applications" discusses in great detail the chemical processes that are involved in the degradation of petroleum hydrocarbons (Atlas 1993). It has been inferred that the initial degradation is aerobic because of the existence of relatively stable geologic formations of crude oil that have existed deep underground in anaerobic conditions. The book suggests that alkane biodegradation begins with enzymes that have a requirement for molecular oxygen, and that once this step takes place, a Beta-oxidation sequence can occur under anaerobic conditions. The more interesting and apparently biologically difficult biodegradations involve complex aromatic rings. The actual degradation process is beyond the scope of this paper, but with condensed polynuclear aromatic ring structures, it has been shown that in order for enzymes to be induced for the aromatic ring biodegradation, there must first be the presence of lower-molecular-weight aromatics (Heitkamp and Cerniglia 1988). The "Microbial Ecology" book also points out, on page 397, an interesting occurrence in the degradations of aromatic hydrocarbons. Eukaryotic microorganisms, much like mammalian liver systems, oxidize the hydrocarbons to *trans* diols, "whereas most bacteria oxidize aromatic hydrocarbons to *cis* diols. ... *Trans* diols of various polynuclear aromatic hydrocarbons are carcinogenic, whereas *cis* diols are not." (Atlas and Bartha, 1993:397)

In order to estimate the biodegradation potential of a pollutant, many factors must be evaluated. Conditions affecting biodegradation rates include: chemical structure, availability to microorganisms, levels of populations of appropriate microorganisms, concentration of waste, oxygen availability, water availability, temperature, pH, and nutrient availability.

- Chemical structure of the waste was discussed in the previous paragraph, but the basic concept is the higher the molecular weight of the hydrocarbon and the more complex the aromatic structure, the less easily biodegraded.

- The mass transport of the pollutant, processes of desorption, diffusion, and convection, can have a major influence in biodegradation rates. Where the pollutant is absorbed into the pores of the soil and unavailable to the microorganisms, not much degradation will take place.

- The microbial populations of soils vary greatly, but it has been estimated that most natural soils contain large numbers (about 10^6 cells per gram of soil) of native petroleum hydrocarbon biodegrading microorganisms (Huesemann, 1994:307). The numbers of microorganisms do not appear to be a major factor in the degradation rates because of their high reproductive rates, but if there are no required organisms present, no biodegradation will occur.

- The more concentrated a waste, the higher the degradation rate to a point. Biodegradation is inhibited at relatively high concentrations because the pollutant interferes with the microorganism cell functions and for aerobic processes it requires large quantities of oxygen to support respiration. At extremely low levels it appears that degradation stops at some point and microorganisms will not degrade the product further. These low and high level points vary among different hydrocarbon compounds and different microorganisms.

- Although molecular oxygen is not essential for all petroleum degradations, higher concentrations of oxygen are very conducive to biodegradation. Benzene, toluene, and xylene (BTX) are petroleum constituents that are often studied. Many experiments have shown that all three are readily degradable in aerobic environments, but anoxic environments greatly slow the degradation (Barker and others 1987:70)

- Soil moisture content has an effect on the biodegradation rate. Low water levels do not allow microorganisms to function properly while high concentrations of water reduce oxygen transfer rates.

- Low temperature reduces biodegradation rates because of slowed cell functions. Low temperatures do not kill most microorganisms. Inversely, biodegradation rates increase with higher temperatures to a point around 40°C. There are some microorganisms that can function above this temperature, but most die at the higher temperatures.

- The prime pH conditions appear to be between 6 and 8, but there are many organisms that can function outside this range.

- The biodegradation rate in most contaminated soils is limited by available nutrients. Nitrogen (N) and phosphorous (P) are the most common nutrients that are required for biodegradation but are often present in insufficient quantities for maximum biodegradation.

There are other factors that control the rate of biodegradation, but these factors are dominant. All of these factors vary from soil to soil and there will even be significant variation within seemingly homogenous soils. A petroleum biodegradation study in Denmark has demonstrated that water and soil samples in close proximity to each other, 10 meters or less, showed significant variations in biodegradation rates. Some hydrocarbon contaminants showed no variation in degradation rates among sites, but some contaminants showed a slowed degradation rate by as much as half compared to adjacent areas. Over the run of the experiment, two years, all hydrocarbon contaminants were biodegraded (Nielsen and Christensen, 1994:319).

Biodegradation Remediation

A relatively uncomplicated form of remediating wastes in soils is through the use of landfarming. Landfarming is the application of organic wastes to soils, or use of previously contaminated soils, for the purpose of biodegradation. The waste soil is spread out and worked as needed. This form of bioremediation has been studied extensively because many of the variables of biodegradation can be easily monitored and controlled. In an article by Huddleston and others, they state that landfarming has some noteworthy features including: metabolism of waste puts minerals into natural elemental cycles, the biodegradation converts wastes into safe forms, it is a treatment and a disposal process, and it sometimes upgrades the soil quality. All bioremediation techniques share these advantages.

In landfarming, pH can be controlled through the use of lime to increase pH or with elemental sulfur or ammonium/aluminum sulfate to lower the pH. Soil moisture content is characterized by the following graph (Huesemann 1994:311).

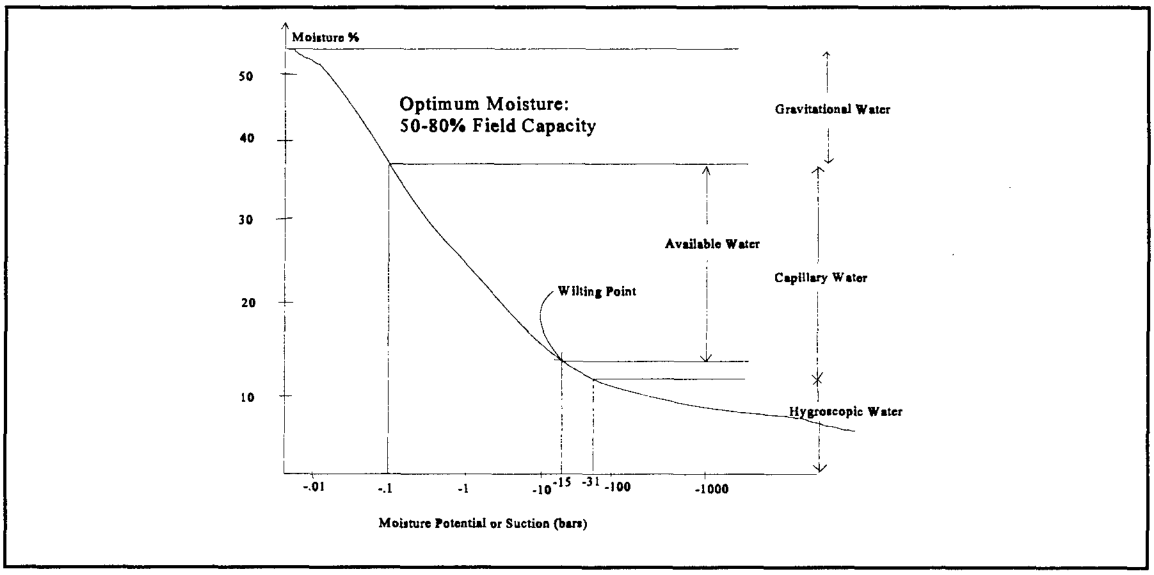

FIGURE 3: SOIL MOISTURE CONTENT VS. MOISTURE SUCTION (Huesemann, 1994)

The moisture content at the field capacity is the maximum amount of water that can be held in the soil after drainage. Irrigation can help to increase moisture content, and bulking agents may be added for better drainage. Nutrient fertilizer addition to supplement soil nutrients is another site condition that may be adjusted for maximum biodegradation. The carbon:nitrogen:phosphate ratios in bacterial cells are about 100:20:1 (Huesemann, 1994:313). The C:N:P ratio in the soil is regulated to match the bacterial needs by adding fertilizer. Although the ratios needed in the soil vary for different contaminants, care must be taken not to add too much nitrogen or phosphorus to create toxicity problems. These factors can be monitored and adjusted to make land treatment a very effective bioremediation technique.

By understanding the biodegradation factors involved in land treatment, it is possible to evaluate biodegradation with other techniques to see how biodegradation rates are controlled. The more we learn about the factors controlling biodegradation of the targeted contaminants, the easier spills in the ground can be controlled and remediated. Current research into natural attenuation of soluble hydrocarbons, especially BTEX, in ground water suggests (Salanitro, 1993:156):

a) plumes tend to reach a stable shape and size even when a source is present.

b) plumes shrink because of higher groundwater dissolved oxygen concentrations and lower BTEX concentrations at the edges when a source is reduced or removed.

c) biodegradation is responsible for overall mass reduction of 80-100 percent.

d) there is an inverse relation between DO and BTEX

e) plume hydrocarbon degradation is limited by available oxygen transport into the aquifer.

The same report also states that there is no apparent added benefit, and maybe a decrease in biodegradation rates, by adding nitrogen or phosphorus to enhance the soil. All this information suggests that oxygen is the major limiting factor.

An interesting variant to biodegradation in soils is brought up by Gersberg and others in their article entitled "Biodegradation of Dissolved Aromatic Hydrocarbons in Gasoline-Contaminated Groundwaters using Denitrification." As the title implies, they proposed and proved with data that biodegradation of BTX compounds can occur in anoxic conditions with denitrification. Hydrogen peroxide application was used to provide a comparison with aerobic conditions. Experiments were performed with and without nitrogen and phosphorus additions, and they found that biodegradation under aerobic conditions with nutrients added was significantly better than without.

Soil Vapor Extraction

The clean-up of petroleum contaminated soils has evolved very rapidly over the last 20 years. Remediators are always looking for ways to remove the contaminants from the soil without having to excavate the soil, for obvious cost reasons. Soil vapor extraction has come to the forefront as an established technology to remove contaminants from the soil. The precursor technology to soil vapor extraction was the use of vapor extraction to control contaminant vapor migration into structures located next to contaminated soils (Johnson, P., 1991:254). The purpose of the vapor extraction was to prevent the contaminant vapors from entering structures. When it was discovered that this sometimes highly contaminated vapor was removing a lot of contaminant, remediators started to investigate it as a remediation action. Soil vapor extraction(SVE), or soil venting, is the removal of contaminants in the vadose zone by removing the contaminant in the vapor phase. "Soil venting" has also been described as low vacuum, blower system used initially to describe the passive venting of landfill gasses (Malot, 1989:287). SVE as a remediation technique began appearing in conference proceedings and peer-reviewed journals in the beginning of the 1980's. Soil vapor extraction "is based on the principle that volatile organic compounds vaporize to a state of equilibrium in the air spaces surrounding the soil particles" (Kostecki, 1992:86).

A basic components of a remediation system using SVE technology is a blower extracting air containing volatilized contaminants from a well in the contaminated soil. The off gas is then treated, if necessary, for emission into the atmosphere. Figure 4 shows a simplified model used for SVE.

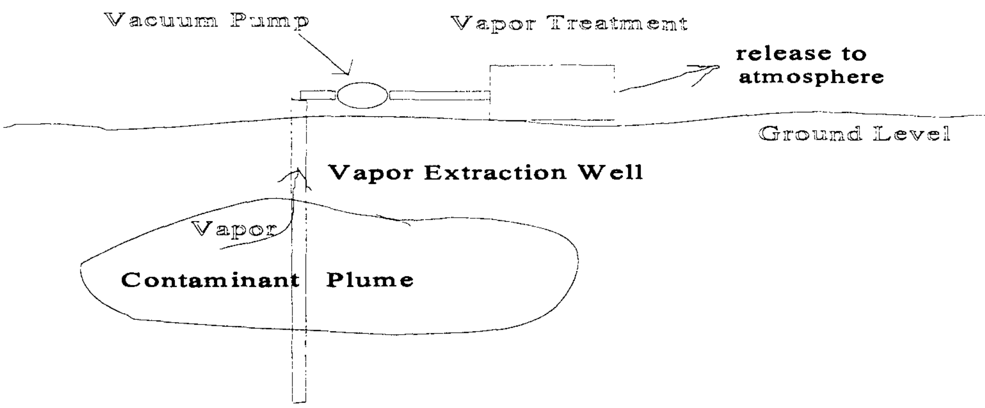

FIGURE 4: SOIL VAPOR EXTRACTION SYSTEM

In order for the SVE system to work, the ground must be permeable and the contaminant must be able to volatilize. Air permeability is of the utmost importance in order to allow the air to flow through the contaminated soil. The contaminant must also be able to be volatilized and carried out in the air when the vapor extraction system is in operation. Paul Johnson and others, have suggested guidelines for the design of SVE systems that are based on: contaminant type, location of the contaminant in the soil, site geology, soil characteristics, and depth to water table

(Johnson, P., 1990). There are many researchers working on the exact way to determine the feasibility and effectiveness of soil venting with models. Because of the variability in soil conditions and geography, it will be very difficult to accurately predict how SVE systems will operate under specific conditions.

There are ways to increase the effectiveness of soil vapor extraction. Some improvements are drilling more extraction wells, using bigger vacuum pumps (although this may cause channelization), and pumping air into the ground. In order to facilitate the removal of air, air injection wells can be installed to pump air into the soil. The installation of the air injection wells may also make it easier to control the vapor flow in the subsurface geological structure.

An important part of the remediation process that was most likely not even considered in the beginning of SVE was the biodegradation of the contaminants. As mentioned before, the greatest limiting factor in the biodegradation of petroleum in soils is the absence of oxygen. Oxygen for biodegradation can be supplied to anoxic regions of contaminated soil by the movement of air in the soil, thereby allowing biodegradation to occur at higher levels than without air flow. It has even been postulated that by slowing down the air flow enough to prevent the vapors from escaping the soil, but fast enough to keep the soil in aerobic conditions, the contamination may be entirely remediated by biodegradation. Bioventing, described later, is this process.

Air Sparging

Robert Hinchee describes air sparging as the introduction of air beneath the water table for the purpose of volatilization and/or biodegradation (Hinchee, 1994:2). There are two distinct techniques of air sparging described by Hinchee: in-well aeration and air injection into the aquifer. The in-well aeration method involves using air pumped into the ground water. It is contained usually within a well, causing an air lift pumping effect. It is important to recognize that the injected air is not intended to enter the surrounding aquifer/soil except in the dissolved form. The injected air, recovered in the well, is removed, treated if necessary, and then either reused or released. Figure 5 shows a typical layout. The overall effect is the introduction of air into the water assisting with volatization and providing oxygen to the groundwater. The other important effect is the movement of groundwater within the aquifer, thereby assisting with the transport of oxygen to adjacent areas for biodegradation. This technology is often called a vacuum vaporizer well or "UVB", short for the German *Unterdruck-Verdampfer-Brunnen* (Hinchee, 1995:1).

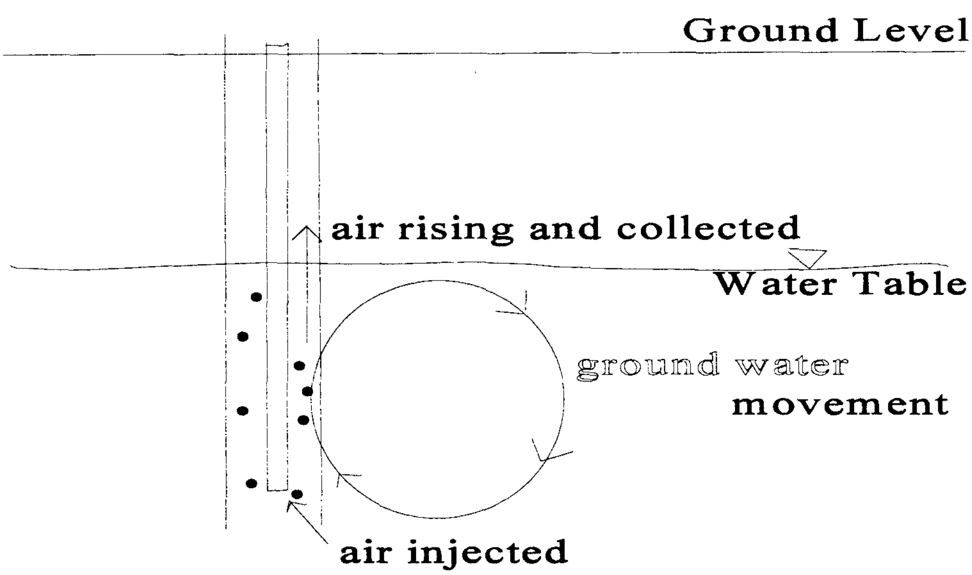

FIGURE 5 - IN-WELL AERATION AIR SPARGING SYSTEM

Air injection, the other type of air sparging, is injecting air into the aquifer, letting it migrate up into the vadose zone. The air and volatiles can be captured with vacuum extraction wells, but this is not always required or necessary. The purpose of injecting the air is again to provide oxygen for bioremediation and volatilize contaminants for removal.

Bioventing

A promising form of bioremediation for petroleum hydrocarbons is bioventing. The basic design of the system is either a set of wells that injects air into or pulls air out of a contaminated zone. Air injection is usually set at a low air flow rate as to avoid vapors to escape into the atmosphere or be pushed off site. Air removal rates are also usually set low enough as to not extract contaminant vapors, although off gases may be treated or pumped back into the ground to be bioremediated. The main difference between soil vapor extraction and vacuum bioventing is that the purpose of SVE is to remove contaminant by vapor, while the basic premise of bioventing is to increase the availability of molecular oxygen to microorganisms in the soil.

The system has been shown to be highly effective in some porous soils. The low cost of equipment and no requirement for off gas treatment makes bioventing a prime candidate when looking at capital cost and maintenance. This low cost, simplistic design, and ease of operation will make it the bioremediation technique of choice in many future circumstances as it is proven effective in the field.

Cost Analysis

As a design engineer, one of the most asked questions is how much will something cost. Any cost estimate is based on past experience in projects of similar design or function. A standard approach for many cost estimates are books that contain line item breakdowns for individual items and tasks. A standard in the engineering community are the Means cost estimating books (Means, 1995). The books contain task descriptions along with the "average" cost for material and equipment, and total hours to accomplish the task.

The problem with estimating the cost for soil vapor extraction and bioventing project is not that there are not books available showing line item costs. An excellent cost book used in helping to validate data in this thesis is the Environmental Restoration Unit Cost Book, published by

Environmental Cost Handling Options and Solutions (ECHOS, 1995). The real problem is that there have been relatively few comparable remediation projects, so even with good line item costs, the actual cost estimates may not be accurate. There is a lack of understanding of the total breadth of the remediation project and all the associated costs.

The United States Environmental Protection Agency (EPA) has established a program to help share technology with potential remediators. The EPA's Superfund Innovative Technology Evaluation (SITE) program has sought to help understand the cost of potential remediation technologies. Cost estimating for the SITE program is broken into twelve cost categories (Evans, 1990:1048). The categories are shown in Table 1.

TABLE 1: SITE PROGRAM COST CATEGORIES (EVANS, 1990:1048)

1. Site Preparation
2. Permitting and Regulatory Requirements
3. Capital Equipment
4. Start-up
5. Remediation Labor
6. Consumables and Supplies
7. Utilities
8. Effluent Treatment and Disposal
9. Residuals/Waste Shipping and Handling
10. Analytical Services
11. Maintenance and Modifications
12. Demobilization

The purpose of these standardized cost categories was to make more consistent cost estimates so technologies could be compared to each other.

Conclusion

Any analysis of cost for new remediation techniques will add to understanding of the technologies. This literature review has shown how bioremediation of petroleum in soil occurs and some of the potential remediation systems currently in use. Because bioventing is such a new technology for remediation projects, an analysis of a method very similar, soil vapor extraction, may help to predict costs for future bioventing projects.

The next chapter will focus on the methodology used to perform an analysis of soil vapor extraction projects to better understand potential costs associated with the remediation technology. It will also try to create a limited cost estimate framework for future bioventing projects.

III. Methodology

Overview

This chapter discusses the methodology used in selecting data for analysis. Also discussed are the methods used to gather and categorize data, and perform an analysis of costs associated with soil vapor extraction as a remediation method for petroleum contamination in soils. In general, the chapter describes the approaches used to answer the following questions:

1. What are the major cost constituents incurred during a SVE remediation?
2. During what time frame are most of the costs incurred for each phase of clean-up?
3. Are there costs that are independent of level/area of contamination?
4. Can a simple cost model be developed for estimating bioventing remediation costs?

Specific Problem

In the literature search performed for this thesis, I have found very little information on actual costs incurred during the remediation of petroleum contaminated soils. An in-depth analysis of costs would aid greatly in the understanding and usefulness of remediation/bioremediation projects in the future.

Target Population

In order to perform an analysis of SVE remediation costs, it was necessary to collect actual cost data from SVE remediation projects. The scope of the data was to be limited to remediation projects in the continental United States for purpose of constraining overall cost variables.

Validation

Most future project cost estimates are taken from historical cost data bases. In the engineering community, the Means cost data books are invaluable in estimating cost and man hours for known project scopes. A new entry into the engineering cost estimating books is from Environmental Cost Handling Options and Solutions (ECHOS, 1995). The estimating format is given a unit, then a labor cost, equipment cost, and man hour cost can be estimated.

I intend to validate the data I collect against the

ECHOS costs, and fill in data gaps from the collected field data with data from the ECHOS cost book.

Data Collection

After contacting many individuals in the Air Force concerning collecting cost data from Air Force remediation sites, I determined that the cost tracking and collection would not be suitable for my analysis. For this reason I started to contact civilian agencies that have performed petroleum remediation projects with soil vapor extraction and/or bioventing. With the help of my advisor, Dr. Bleckmann, one petroleum company agreed to open their files to me for the purpose of gathering data for my thesis. The data were files of receipts and invoices from various petroleum contaminated soil remediation projects they had conducted over the last 15 years. The company did not conduct any part of the remediation projects in-house, but rather contracted out the entire clean-up processes and used only limited in-house resources to manage the project. They agreed to let me peruse the files of the projects and consult with the project managers for these projects.

There were two databases from which to draw data. An electronic database contained cost information for individual remediation sites. The only thesis-relevant details contained in this database were cost incurred, invoice date, and invoice number. I decided that this database could be used as a verification of receipts and invoices contained in the files. The actual project files consisted of copies of invoices, project reports, correspondence, and copies of relevant state regulations. Copies of all invoices and receipts were made so that the costs could be incorporated and interpreted with as much detail as possible. All selected project reports were reviewed and important information about site characteristics, remediation details, and any information that seemed relevant to analysis of the cost were copied and incorporated into my thesis data files.

Over fifty soil venting remediation projects were initially identified as possible sources of cost data. When a screening factor of over 50% completion was applied to the sites, the list was narrowed down to twenty sites. This factor was applied to get try to get as many phases of costs as possible for each individual project. Next, any project over $1.5 million was eliminated from the list. Projects over this cost limit had complexities beyond the limited scope of this thesis. The list was narrowed to twelve projects. The next step was to research the twelve project files and determine if they contained enough detail for appropriate evaluation.

Only five projects in the company files were found to meet all the criteria established for use in the thesis. The relevant data were then obtained from each file. Of the five, two were projects that had been completed in the last 2 years, and almost all of the cost data was available for the duration of the projects. The other three projects were not yet completed, so costs are available only up until the time of data collection (June 1995). Limited data about site conditions, effluent levels, and other site information was gathered from contractor progress reports. Table 2 shows the system configurations and the total cost for the five sites, and following is a brief description of each project used in this thesis.

TABLE 2: REMEDIATION SYSTEMS AND TOTAL EXPENSE

Site	System	Cost ($)
CA #1	SVE, 7 vapor wells, thermal off gas treatment	450k
MN	SVE w/sparging, 9 wells, no offgas treatment	275k
NE	SVE w/sparging, 2 vapor and 2 spaging wells, no offgas treatment	130k
LA	GW, SVE, 3 vapor wells, no offgas treatment	375k*
CA #2	GW, SVE, 5 vapor wells, thermal off gas treatment	1,400k*

*=not representative of total project expense

#1 - Site number one is in California. Petroleum contamination was found in the soil in April 1985 when checking the soil during a property transfer of an old gasoline filling station. The groundwater, over one hundred feet below ground level was unaffected. It is estimated that 2000 gallons of petroleum was spilled. A soil venting study was conducted in 1987 and it was determined that a soil venting system was feasible. The construction for a soil vapor extraction system with a three horsepower blower, seven extraction wells, and a thermal oxidation unit began in May 1989. The remediation unit was started in June 1990. The soil vapor extraction with offgas incineration is still in operation today. Table 3 presents this information is a summary form.

TABLE 3: CALIFORNIA #1 EVENTS

1985	- Contamination discovered; estimate 2000 gallons
1987	- Soil vent study performed
1989	- Construction of SVE system started
1990	-System operational

#2 - Site number two is in Minnesota. The site was an old gasoline filling station. Hydrocarbon contamination was discovered in 1984. Clean-up of the tanks and surrounding soil was immediately started. A soil vent system was installed and started in 1987. An upgrade in September 1990 increased the flow rate. The new system consisted of nine soil vapor vents and a 1.5 horsepower motor. No vapor control system is used. An air sparging study completed in July 1992 showed system needed upgrade to complete remediation. System upgrade, started in November 1992 and completed in September 1993, modified system into air sparging and soil vent system with no off gas treatment. The system was restarted in October 1993 and is still in operation. Table 4 presents this information is a summary form.

TABLE 4: MINNESOTA EVENTS

1984	- Contamination discovered
1987	- SVE system installed and operational
1990	- Blower upgrade
1992	- Air sparging study
1993	- Sparging system startup

#3 - Site number three is in Nebraska. Petroleum contamination was discovered June 1989 when old underground tanks and dispenser lines were removed from an old gasoline filling station. Due to other owners of the land and possible other off-site contaminants, a remediation access plan was not completed until 1992. A soil venting pilot study was completed in June 1993. Construction of a soil vapor extraction remediation system, consisting of two soil vapor vents and two air sparging vents, was started in May 1994. The system was completed and started up in July 1994. Emission of the off gas is straight into the atmosphere without treatment. The remediation unit still in operation today. Table 5 presents this information is a summary form.

TABLE 5: NEBRASKA #1 EVENTS

1989 - Contamination discovered
1993 - Soil vent study performed
1994 - Construction and startup of SVE and sparging system

#4 - Site number four is in Louisiana. An environmental assessment performed in November 1986 for an old gasoline filling station discovered hydrocarbon contamination. An air diffuser system was installed in August 1987. The system was dismantled in 1988 when no free product remained. It was discovered in 1990 that waste oil was poured down a monitoring well from a used car operation using the lot. Ground water treatment was started in September 1990 and continued until August 1992 when a soil vapor extraction system was placed in operation. Soil vapor remediation system continued operation until September 1994. Monitoring of wells is continuing. Table 6 presents this information is a summary form.

TABLE 6: LOUISIANA EVENTS

1986	Contamination discovered
1987	Air diffuser installed and operational
1990	Oil poured down monitoring well, Ground water treatment started
1992	SVE system installed and operational
1994	System shutdown

#5 - Site number five is in California. Contamination was discovered in 1985 from underground tanks from an old gasoline filling station. An estimated 8000 gallons of gasoline are in the vadose and saturated zones. A ground water recovery and treatment system was installed and operational by April 1987. Treatment of removed ground water is an air stripper. Various upgrades with monitoring wells and recovery wells continued until 1993. Soil vapor extraction with thermal incineration and air injection wells were installed and operational by 1992. Groundwater treatment and soil vapor extraction systems are still in operation today. Table 7 presents this information is a summary form.

TABLE 7: CALIFORNIA #2 EVENTS

1985	Contamination discovered; estimate 8000 gallons
1987	Ground water treatment started
1992	SVE system installed and started

Cost Categorization

The most important step in the analysis of the cost data is its incorporation in defined cost categories. The costs from the receipts and invoices available are to be input into a database, broken down by date and cost categories.

The easiest breakdown of costs is the phase the project is in. For this thesis, the following remediation phases were distinguished and identified:

#1 Investigation

#2 Construction

#3 Operation

#4 Shutdown/Monitoring

It is not always possible to clearly identify the phases because of periodic upgrades, system restarts, and other factors.

Because of the lack of details in the actual invoices, there are only five cost categories that can be accurately delineated from the descriptions. The basic cost categories, a modified version of the SITE cost categories described in Chapter 2, are as follows:

#2 **Permitting and Regulatory Requirements** - These costs are payment to government agencies that require permits for system installation or operation.

#3 **Equipment** - costs for purchasing capital equipment, renting of equipment, and any parts required for the remediation system installation and operation.

#5 **Management** - Charges for remediation management required for accomplishment of all phases of the remediation project.

#7 **Utilities** - Utility charges for the remediation site including gas and electricity.

#10 **Laboratory Analytical Services** - Charges for laboratory analysis of air, water, or soil samples.

Cost Analysis

The cost analysis can begin once the data is put into a computerized relational database. For comparison of data between sites, the data will be normalized using area cost factors obtained from ECHOS *Unit Cost Book* described in Chapter 2 (ECHOS, 1995). The normalization takes into account differences in costs caused because of regional cost differences, such as cost of living. The actual cost will be divided by the cost normalizer to obtain a cost that can be compared between sites. The normalizing numbers for each site are shown in Table 8.

Table 8: AREA COST NORMALIZERS (ECHOS, 1995)

Site#	Cost normalizer
1-CA#1	1.34
2-NE	0.86
3-LA	0.84
4-MN	1.07
5-CA#2	1.20

Because of the relatively short term of the projects, under ten years, and the low inflation rates in the United States over the last ten years, the expenses were not be converted to present or future costs. In effect this is forcing an inflation rate of 0% over the range of the project. It is very important to note that the use of the word "cost", in this thesis, is the same as "expense" because of the 0% inflation factor. All expenses are actual dollars paid at the time of the invoice, no time scaling was applied.

The data for this thesis was input into Borland Paradox and analyzed with Paradox for Windows and Borland Quattro Pro Version 5.0.

Analysis by Time

This portion of the analysis describes the methodology employed to answer the question of how much is spent at what time along the remediation process. Each project will be analyzed along the entire time frame of data available. Correlations to known events can be shown at this time as well as identifying any possible missing data. An analysis of overall cost along a time line will be presented for each project, and also compared to the other four projects.

Analysis by Phase

The purpose of the analysis by this section is to try and identify the trends associated within definable phases for each project site along a time line. If there are linearities or other identifiable characteristics for cost categories, this analysis by phase should be able to pick them up. The three phases for each project will be analyzed, and each phase for the five projects will be analyzed will be compared side by side to help identify overall similarities and differences.

Analysis by Cost Category

This is probably the most important analysis because it answers questions about the behavior of the total cost based on the sum of the five cost categories. Using the analysis of total costs and phase costs to help understand the analysis by cost category, a very thorough analysis can be accomplished The five cost categories for each project will be analyzed, and each cost category for the five projects will be compared with the other sites.

Simplified Bioventing Model

Based on a simplified cost model for estimating SVE systems, a simplistic bioventing cost model is established. The similarities for equipment make bioventing essentially equivalent to a soil vapor extraction system with no off-gas treatment. Characteristic costs for the soil vapor extraction systems were estimated to provide a cost per unit time that could be applied to a bioventing project. Management costs are expected to be equivalent for equivalent projects, as are laboratory analysis costs. The difference for bioventing permit, equipment, and utility costs will be addressed.

Cost per Unit Analysis

Total cost means relatively little without some comparison to how effective the clean-up action is. One commonly used method of evaluating this is through the use of dollars spent per gallon of product removed. A problem with using only this information to evaluate the effectiveness of the cleanup is that this method only evaluates on actual product pulled out of the ground and does not evaluate the product removal by bioremediation.

Despite this downfall of this analysis method, the result of this analysis will be discussed.

Conclusion

The next chapter is the heart of the research. Chapter IV will report the findings of the analysis.

IV. Data Description and Analysis

Overview

This chapter presents the findings obtained from the analysis of cost data from five air venting petroleum remediation projects. The information was gathered from project files from a major United States petroleum refiner and marketer that has numerous petroleum impacted remediation sites across the United States.

Data Description

The original data for each site, obtained from the company project files, was in two somewhat redundant forms. The first form was the actual invoices paid to vendors and contractors. There were a variety of kinds of invoices ranging from one line item lump sums to very detailed item by item descriptions. The five projects chosen for analysis had the most detailed receipts of all the projects available. The second form, containing the cost data, was a computer database of invoices paid. The parts of the computer database used in this thesis are invoice date, vendor, and amount. The database is the cost accounting way to keep track of the invoices in a database for management use.

The first place to begin the data analysis is to compare the two forms of databases to validate each against the other. There were mistakes, discrepancies, and missing invoices that were found for all projects. Data included in the computer database, but not in the invoices, was included in the data for the thesis. Based on the vendor name, an estimate based on past and future invoices was made of the cost constituents of the total invoice amount. This kind of discrepancy did not occur often, about 1% of the invoices were unaccounted for in the project files.

Comparing the receipts to the computer database was a lot easier. The computer database lacked data from invoices prior to 1989. This was not an error in the database, but rather a choice by the company not to research into the files prior to 1989 when the computer invoice system was put together and on-line in the 1990's. There were relatively few problems with inconsistencies between the receipts and the computer database. There was occasional mistyping of information into the computer database, but the error was apparent when looking at the invoice, and the invoice data was used in the thesis database. Less than .5% of the invoices did not agree with the numbers put into the computer database.

This process of checking the receipts against the computer database has made the data used in this thesis a very accurate account of money paid by the petroleum company for the remediation projects. The data used in this thesis for the five sites in Minnesota, Nebraska, Louisiana, and California is shown in Appendix A.

Cost Categorization

The most involved step in the analysis of the cost data is the categorization into the five cost categories used in this thesis. The description of the cost categories is included in Chapter 3, Methodology. The receipts, as mentioned before, varied widely in description depth.

The most straight forward cost categorizations were utility and laboratory analysis costs. The only problem with utility data was that the Nebraska project was missing all utility data. The other receipts in the file were fairly descriptive and did not include utility charges. The most probable cause of the missing data was that the utility bills were paid as a lump sum with other projects or facilities, and the utility cost for this remediation project was not broken out. For the rest of the projects, the data was very good. Regular monthly payments to utility companies showed that all receipts were available.

The laboratory analysis costs were also very easy to identify. Commercial laboratory invoices showed actual costs in most cases. Where analysis invoices were not available, the contractor provided line items stating laboratory expenses.

Permit costs were also fairly straight forward to identify. By digging through contractor line item costs, any cost paid to government organizations was considered a permit cost.

The management costs and equipment costs were the only costs remaining to identify. Hours identified by the main contractor as personnel hours were considered management costs. Equipment costs were what was remaining. Capital equipment, rentals, and parts were very easy to identify. The only uncertainty in identifying the two costs where subcontractor billing. This did not happen often, but some subcontractor billing was in a lump sum. In this case it was impossible to separate management costs from equipment costs, so when costs were in doubt, the entire lump sum was put into equipment costs.

Specific Site Data

The next sections describe each site and some specific problems with invoices and any major cost category identifications.

California #1 Invoices

Invoices were available starting September 1985. The receipts covered the period from discovery of contamination to clean-up operations today. I was unable to verify invoices before November 1988 because of lack of data in computer database. All invoices are fairly descriptive despite cycling through five different management contractors in nine years.

Minnesota Invoices

Invoices were available starting September 1987. The receipts cover the period from initial site investigation and clean-up until continued operation in April 1995.

Again, I was unable to verify receipts prior to November 1988 because of lack of information in computer database. The initial contractor did not itemize utility costs, therefore utility costs are unavailable until 1995 data. The system was operating, starting in November 1987, so there was a utility cost, but it was not identifiable.

Nebraska Invoices

Invoices were available starting in July 1990, but the computer database started with invoices dated October 1992. Invoices covered from site investigation until continued operation in February 1995. The use of only one contractor made identifying costs much easier than other project files.

Louisiana Invoices

Invoices were available starting March 1987, but the computer database started in July 1989. In addition, all invoices before June 1991 were only lump sum payments. Individual costs were not identified, so all data prior to June 1991 was not utilized in this thesis. It is important to realize that the total cost for this project is not accurate, but the soil vapor extraction installation and operation costs are accurate. All costs prior to June 1991 were for groundwater treatment operations.

California #2 Invoices

The invoices for this project were not as easily interpreted as those from the other projects. The contractor in this project submitted lump sum invoices for all equipment, materials, and man hours. Other invoices for laboratory testing, permits, and utilities were paid directly to the utility companies, government offices, and testing laboratories, so these costs were easily to distinguish. I was unable to verify if other costs, such as permits or testing, were included in the contractor lump sum, but judging by the regularities of the other than contractor invoices, I am reasonably sure these cost are not included in the contractor's lump sums.

Cost Graphing and Analysis

The data is graphed in two forms. The first form presented is total cost verses date incurred. The numbers and dates are directly from the invoice. The second form presented normalized cost verses day number. The normalized cost, as discussed in the methodology, is to adjust the cost for area cost-of-living which is done to make the costs between projects comparable. The day number is not an absolute day number from the date the project started, but rather just a reference day from one of the first invoices. The linear regression line is not forced to pass through the zero point for this reason. The line is intended to find the slope of the data points.

California #1 Analysis

Figure 6 shows a graph of total cost for the project, and the total costs for each cost category. The total cost for the project up until June 1995 was $466,569.30.

The costs seem fairly linear except for large costs jumps at three time periods. Looking at the time line of the project, these cost are associated with a soil vent feasibility study conducted in August 1987 and construction of the SVE system and a thermal oxidizer in September 1989. The most striking feature of the graph is straight line increase in total cost, this can be addressed later as each cost category is analyzed.

The permit costs were relatively unexciting as seen if

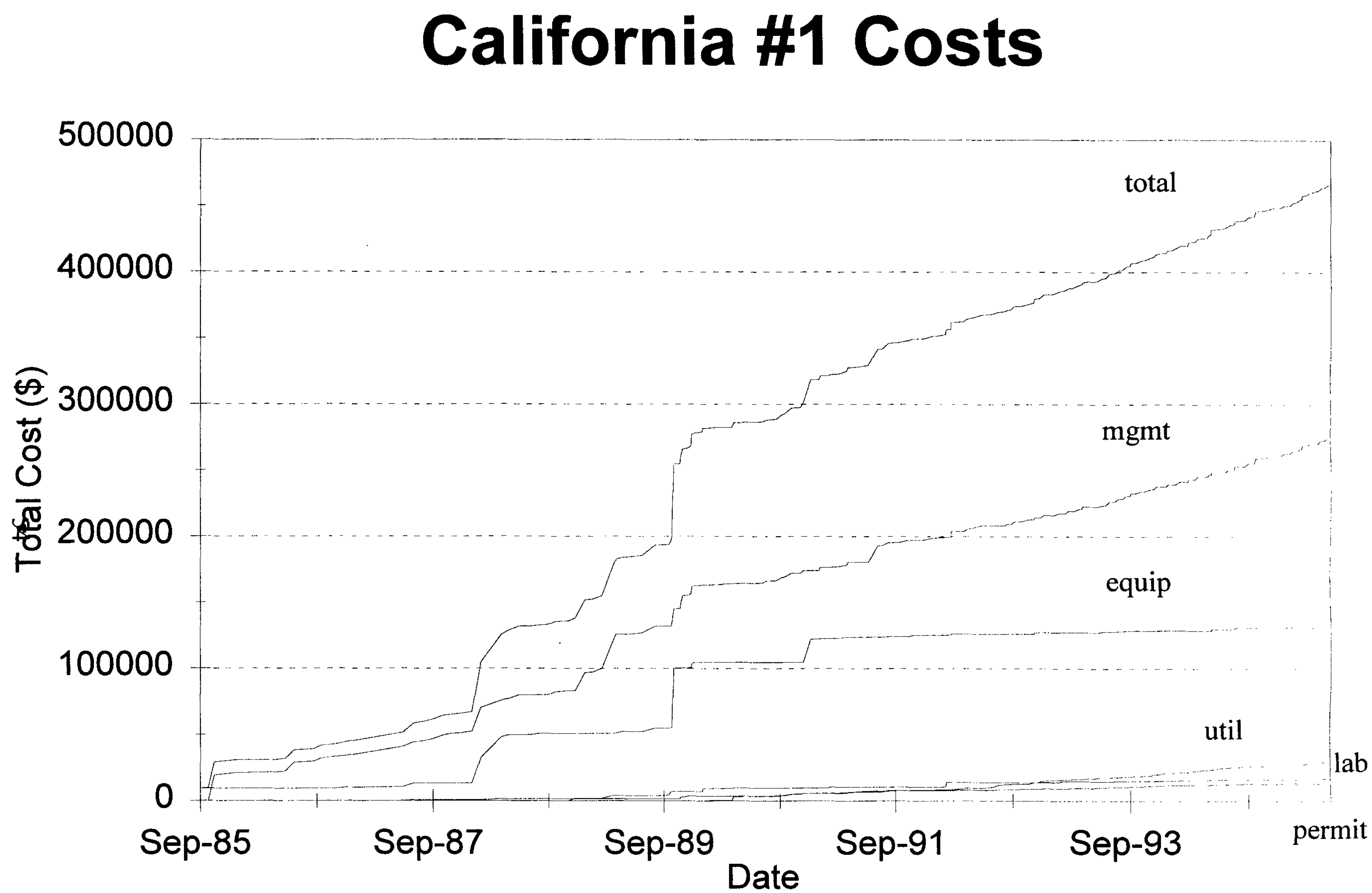

FIGURE 6: CALIFORNIA TOTAL COSTS

Figure 7, total permit costs. The total cost for permits was $16,863.87. The permit costs were not normalized.

The total of equipment costs is shown in Figure 8. The equipment total was $132,622.40. The large costs from the soil vent study and the construction of the system are very evident. It is interesting to note the relatively linear increase in cost after the construction of the system is complete. Figure 9 shows the cost normalized for location along with a linear regression line with a slope of $4.43 dollars per day, and a R-squared factor of 0.982. The system has been operating at this approximately straight line cost for over four years. The importance of this linearity will be discussed when the other projects have been analyzed.

The actual total management costs for the California #1 site are shown in Figure 10. With a total cost of $274,802.90, the management costs seem fairly constant except during the two periods of activity mentioned before, the soil vent study and the construction. Figure 11 shows the normalized cost, and a linear regression line covering the entire project length. The slope for the line is $57.97 per day with a R-squared value of 0.966. The apparent

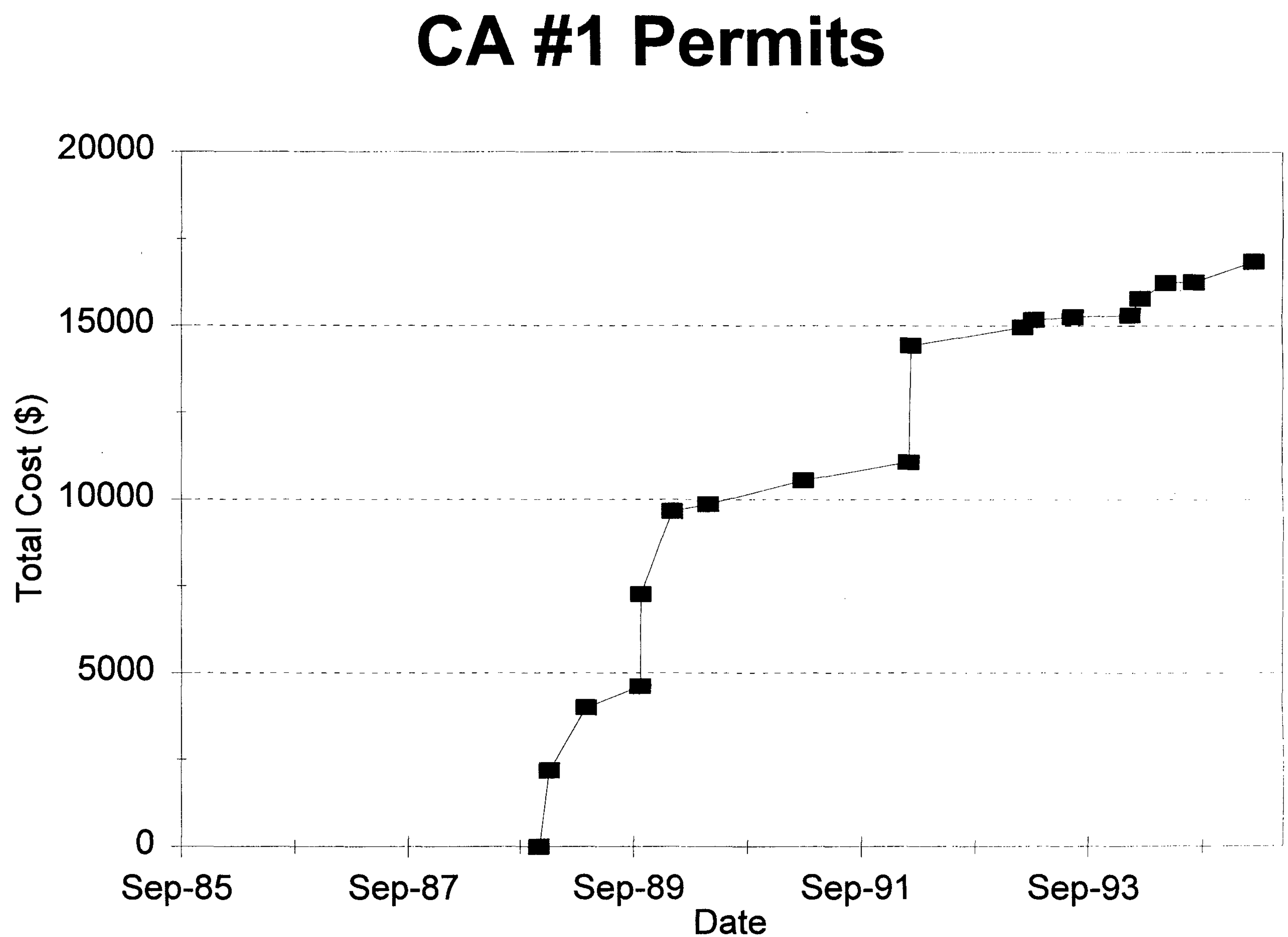

FIGURE 7: CALIFORNIA #1 PERMITS

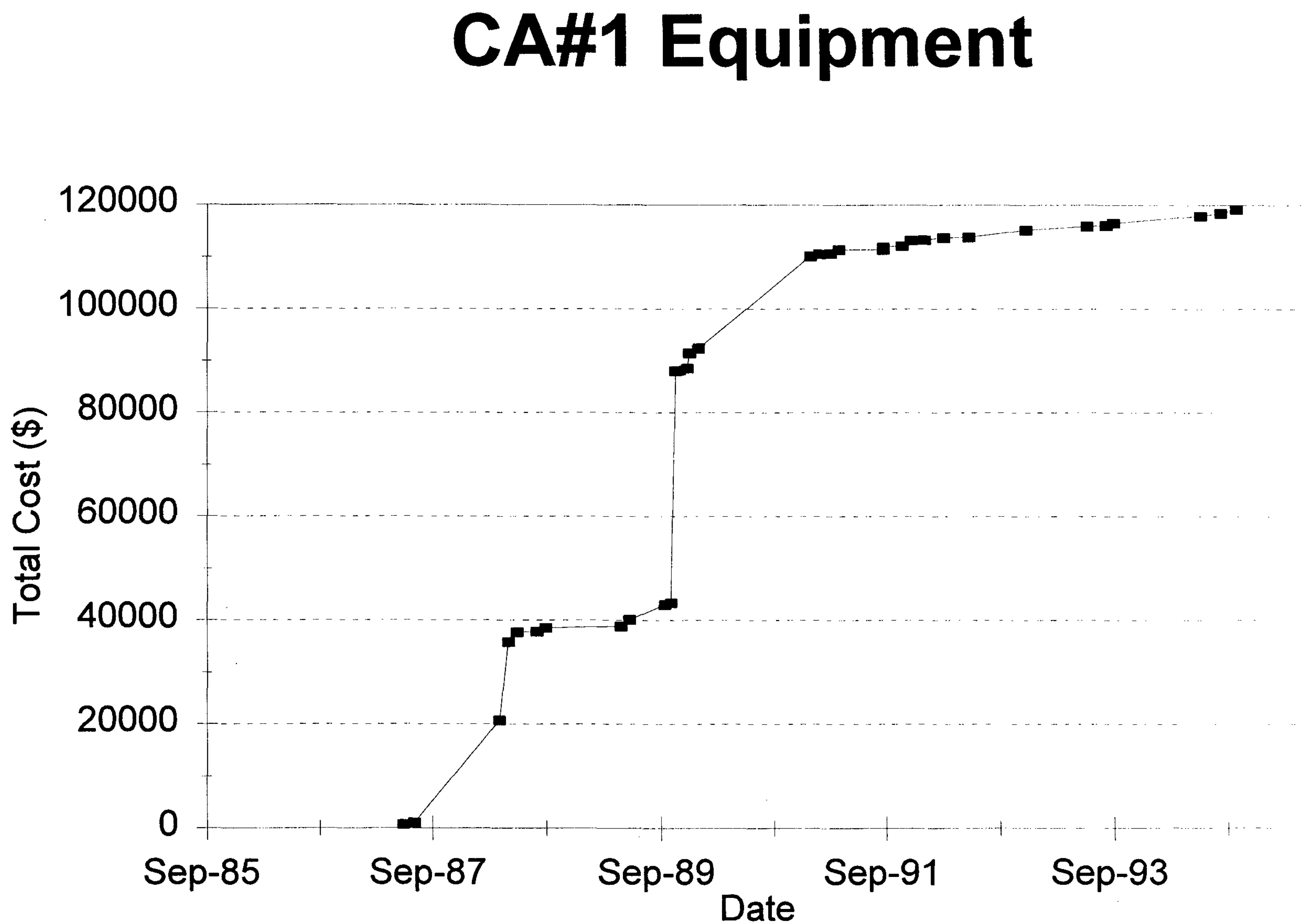

FIGURE 8: CALIFORNIA #1 EQUIPMENT

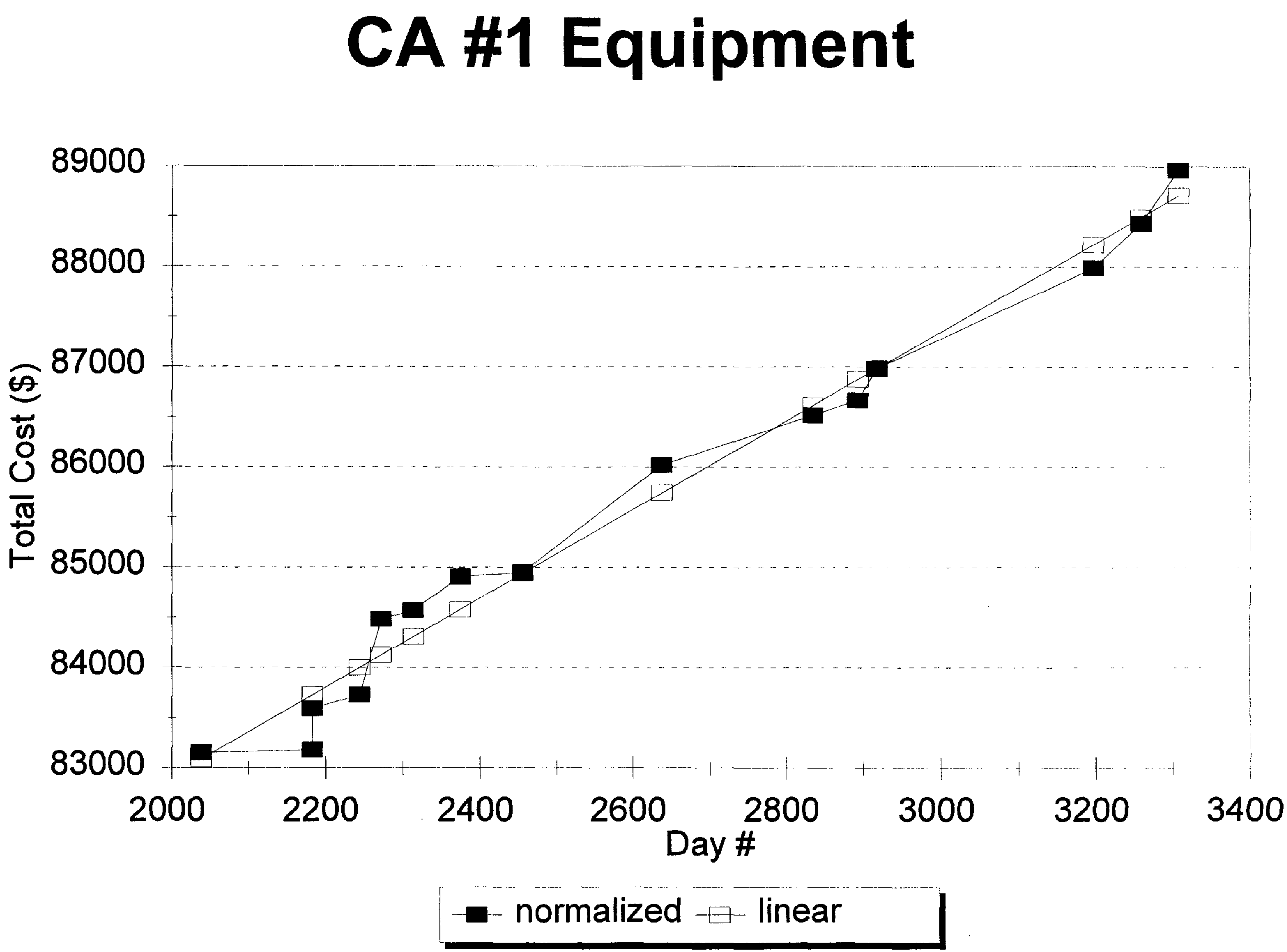

FIGURE 9: CALIFORNIA #1 EQUIPMENT - NORMALIZED AND LINEAR

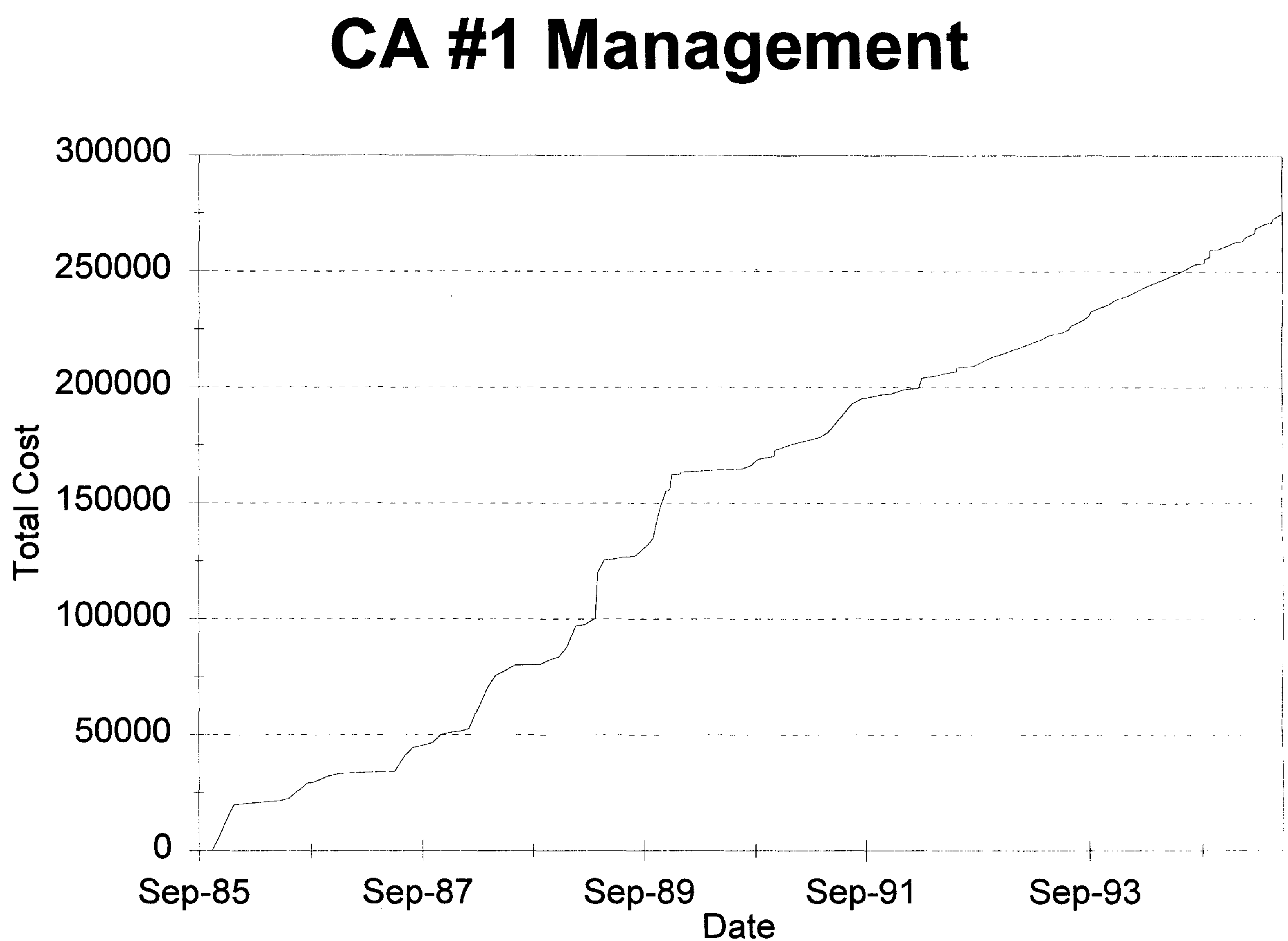

FIGURE 10: CALIFORNIA #1 MANAGEMENT

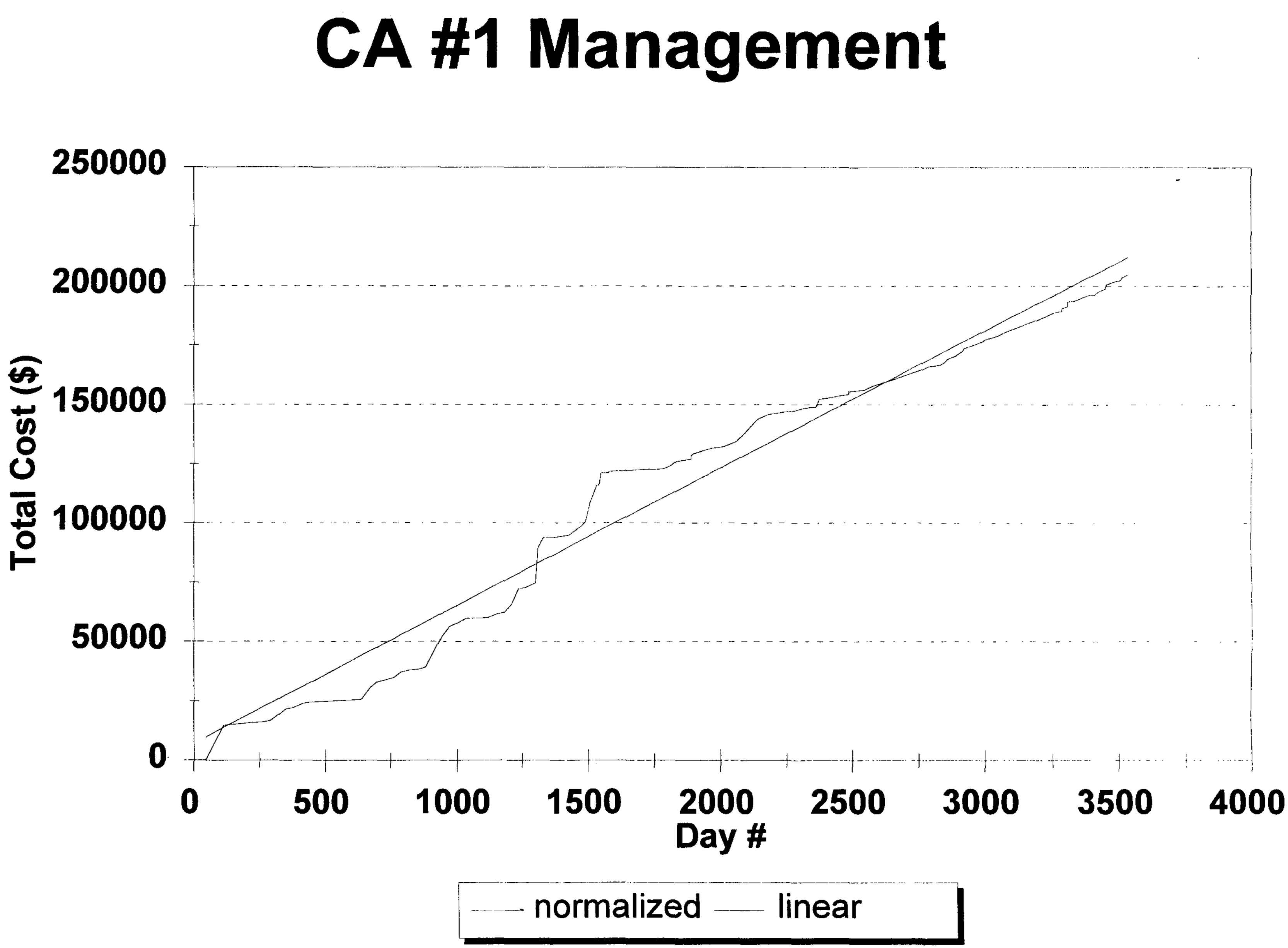

FIGURE 11: CALIFORNIA #1 MANAGEMENT - NORMALIZED AND LINEAR

linearity over the entire project surprised me. This data will be compared with the other sites later in this chapter.

The total utility costs, which started in November 1989 and are shown in Figure 12, summed up to $29,650.84. The normalized and linear regression estimate are shown in Figure 13. The gas is the highest cost with a linear estimated slope of $8.73 per day with a R-squared of 0.987, and the electric costs are $2.52 per day with a R-squared of 0.944. The system was shutdown for about ninety days starting near day 3300 of the project. This period of no utility cost can easily be seen in the graph.

The total laboratory analysis costs are shown in Figure 14. The total cost summed up to $13,629.29. Figure 15 shows the normalized data along with the linear regression line with a slope of $3.73 per day and a R-squared value of 0.984.

The realization that many of these cost categories seem linear is an important point, but only in relation to other projects and their corresponding costs.

Minnesota Analysis

This project did not have a long design period or soil

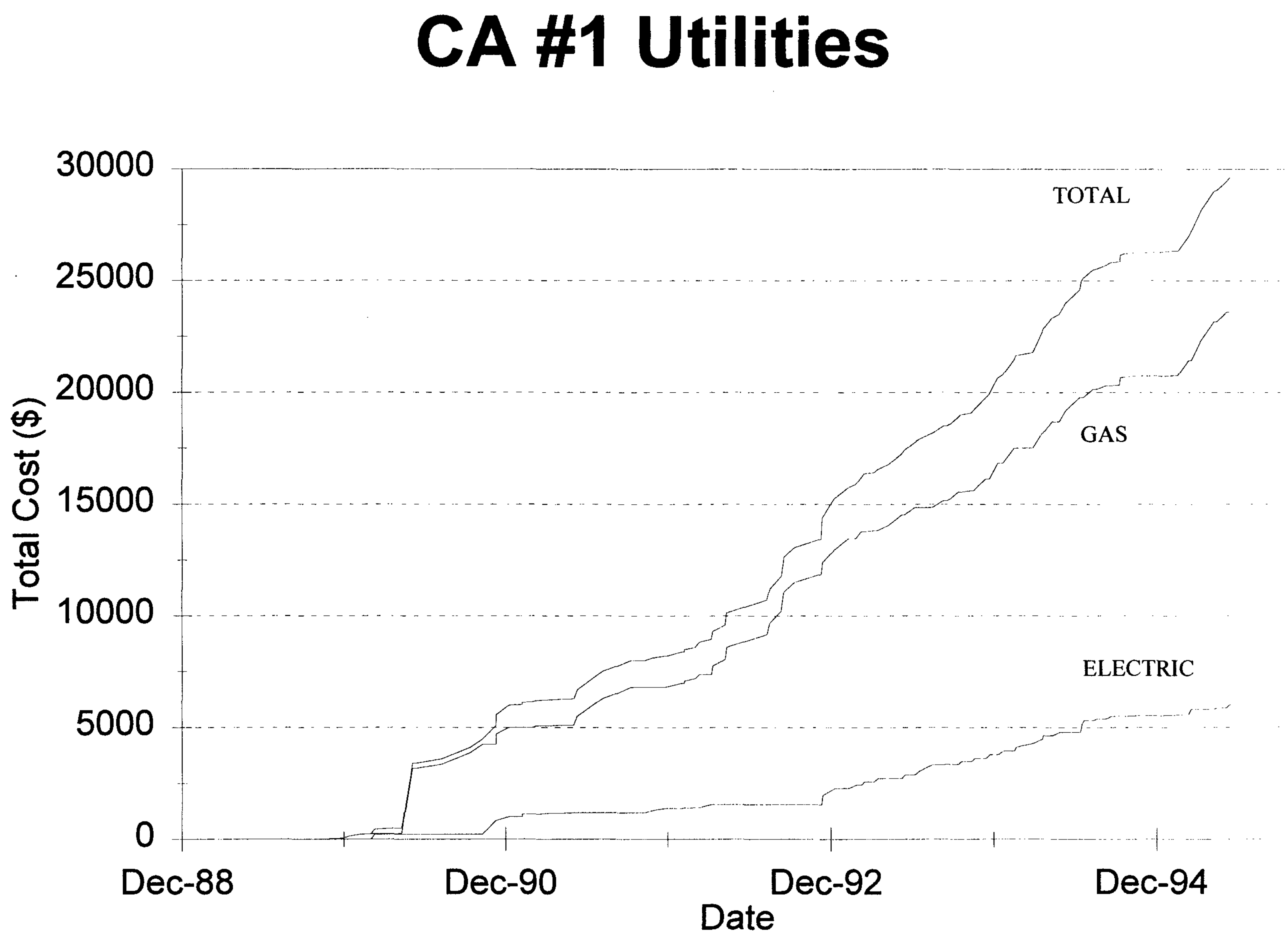

FIGURE 12: CALIFORNIA #1 UTILITIES

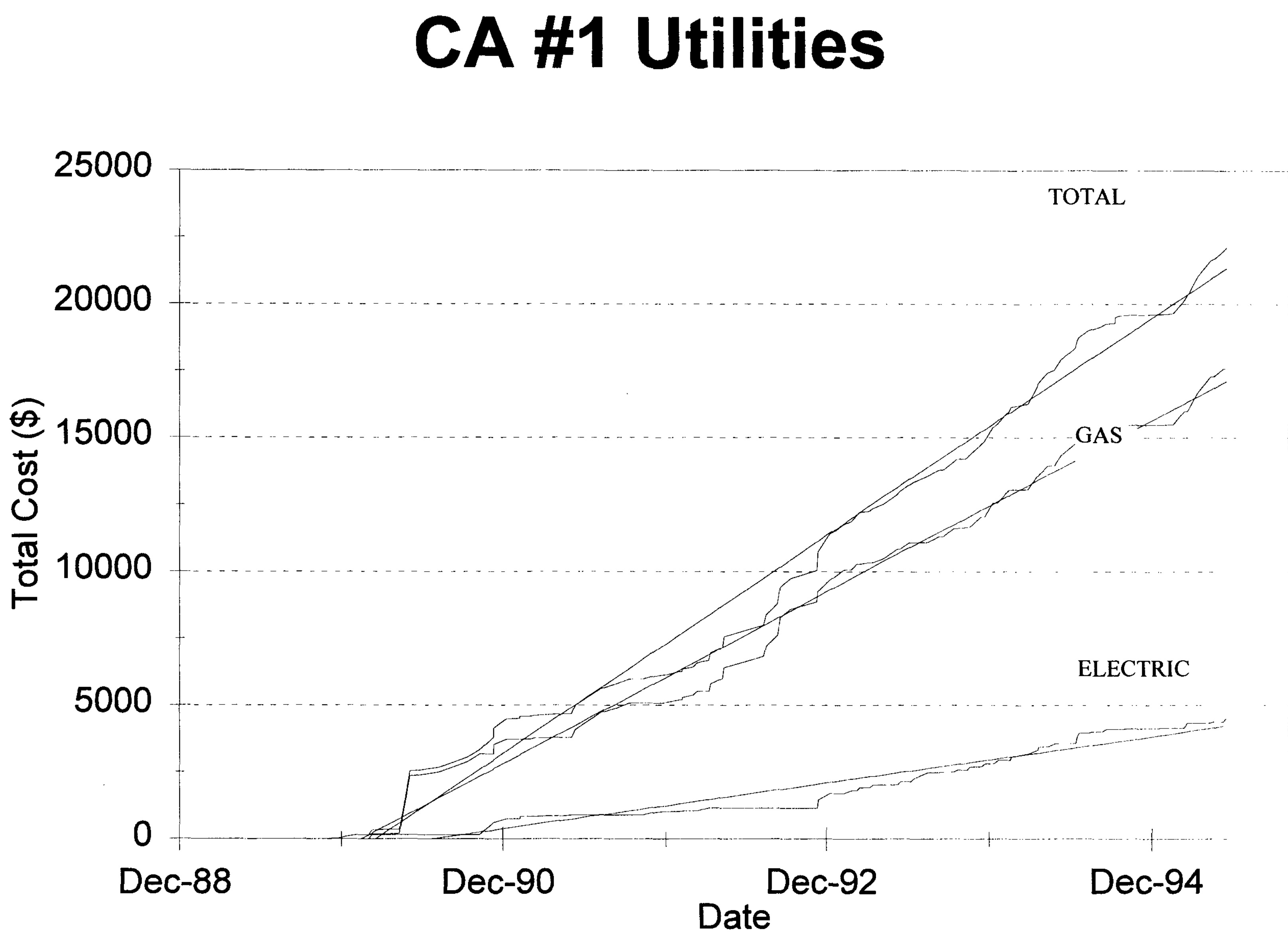

FIGURE 13: CALIFORNIA #1 UTILITIES - NORMALIZED AND LINEAR

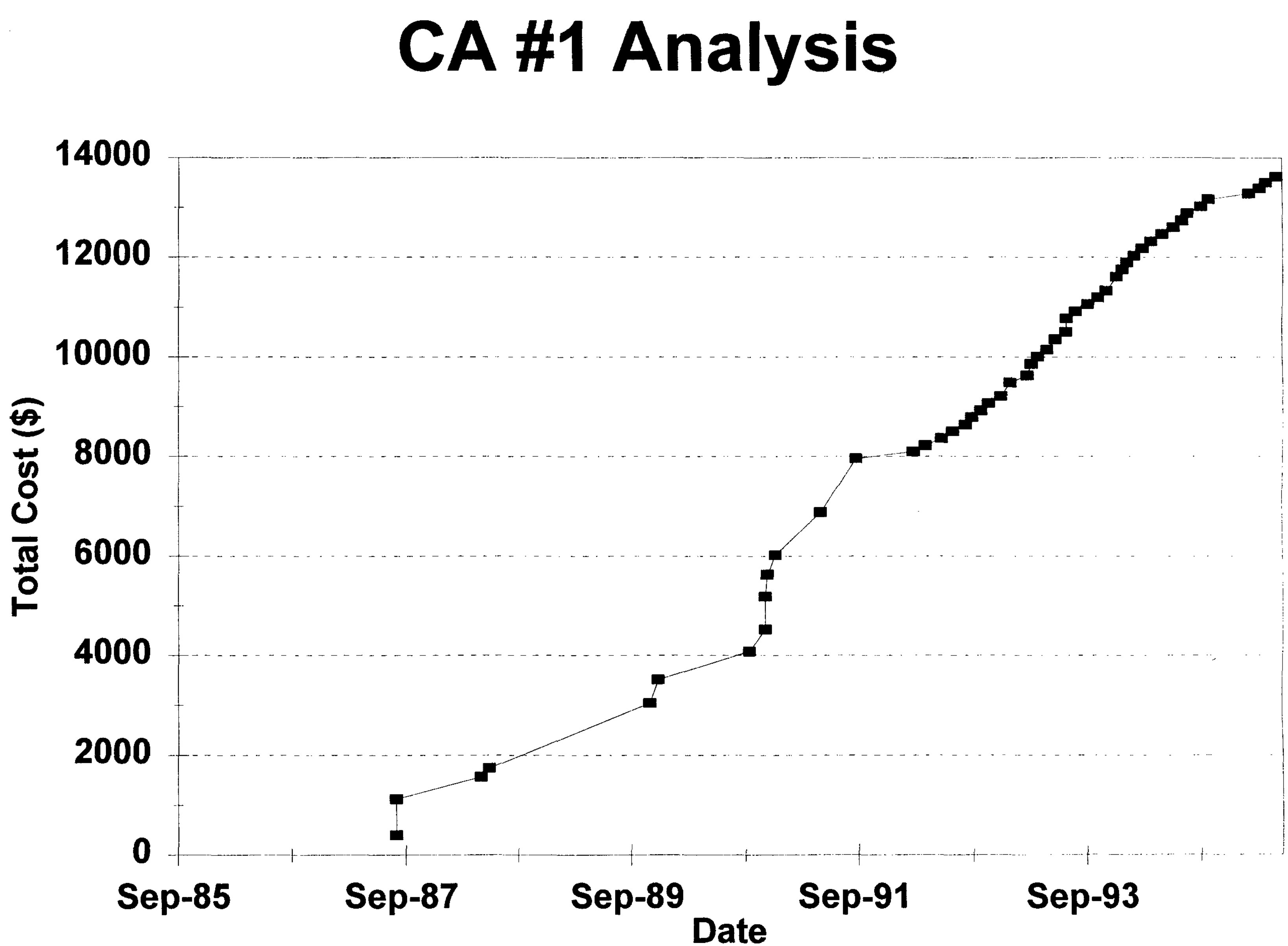

FIGURE 14: CALIFORNIA #1 ANALYSIS

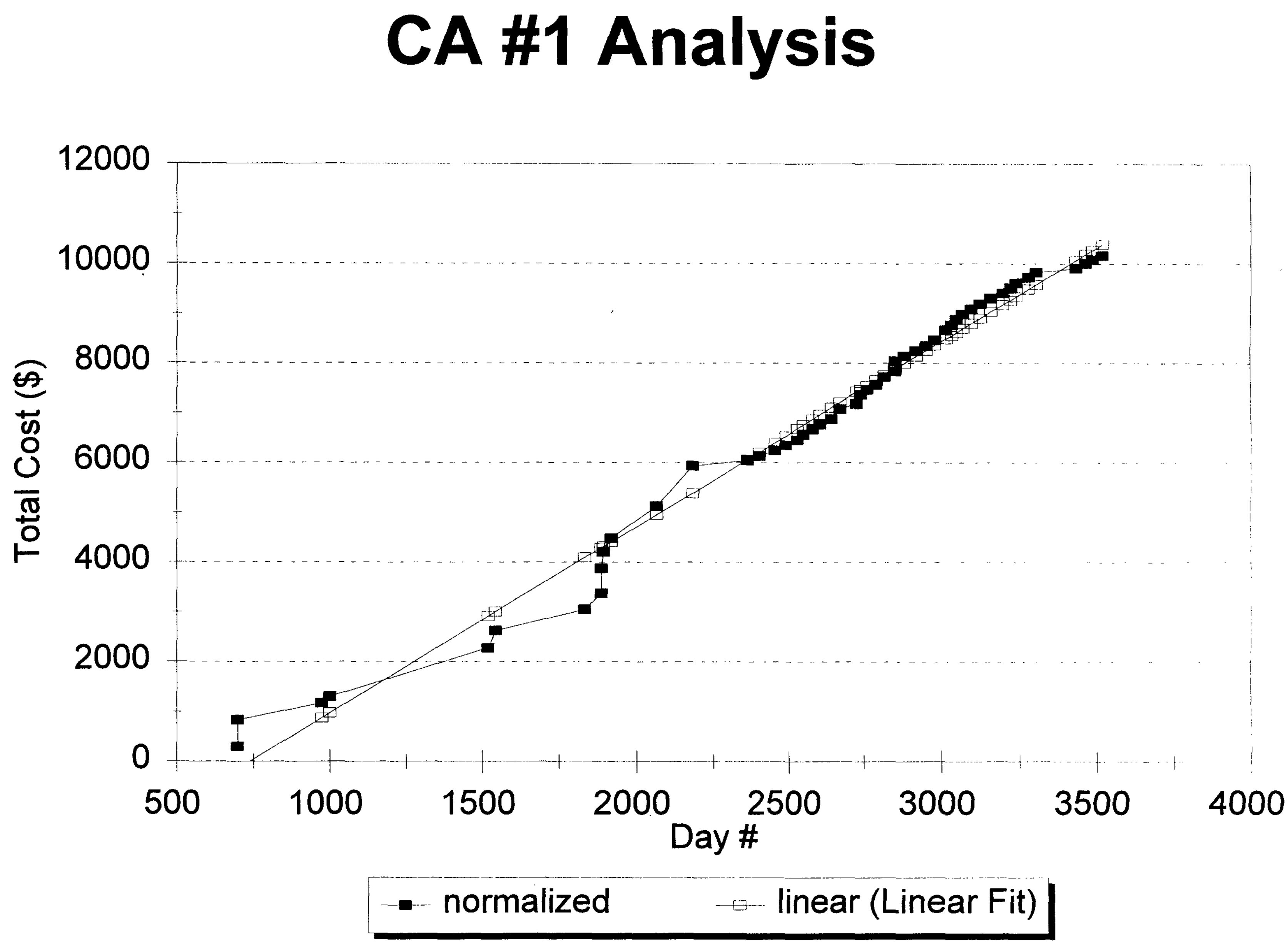

FIGURE 15: CALIFORNIA #1 ANALYSIS - NORMALIZED AND LINEAR

vent study. The system upgrades and redesign of the remediation system also factors into the understanding of this project.

Figure 16 shows the actual costs incurred during the run, so far, of the project. The total project cost as of April 18, 1995 was $280,892.30. As mentioned before, the utility data prior to 1995 was not definable. The big steps are easily identified with major accomplishments. The big step at the beginning is the installation of the initial venting system in September 1987. In September 1990, a new blower motor was installed to increase the air flow from about 10 cfm to about 45 cfm. The biggest lump sum increases occurred March 1992 until September 1993 when a new sparging and vent system was designed and installed.

This site in Minnesota ended up having a total cost of $426.90 in permit fees. This cost was associated only with well permits. No further analysis was done on this cost element.

The three project construction periods mentioned before show up very well in the equipment total cost breakdown shown in Figure 17. The total cost for equipment is $95,163.68. There are several areas after each period of

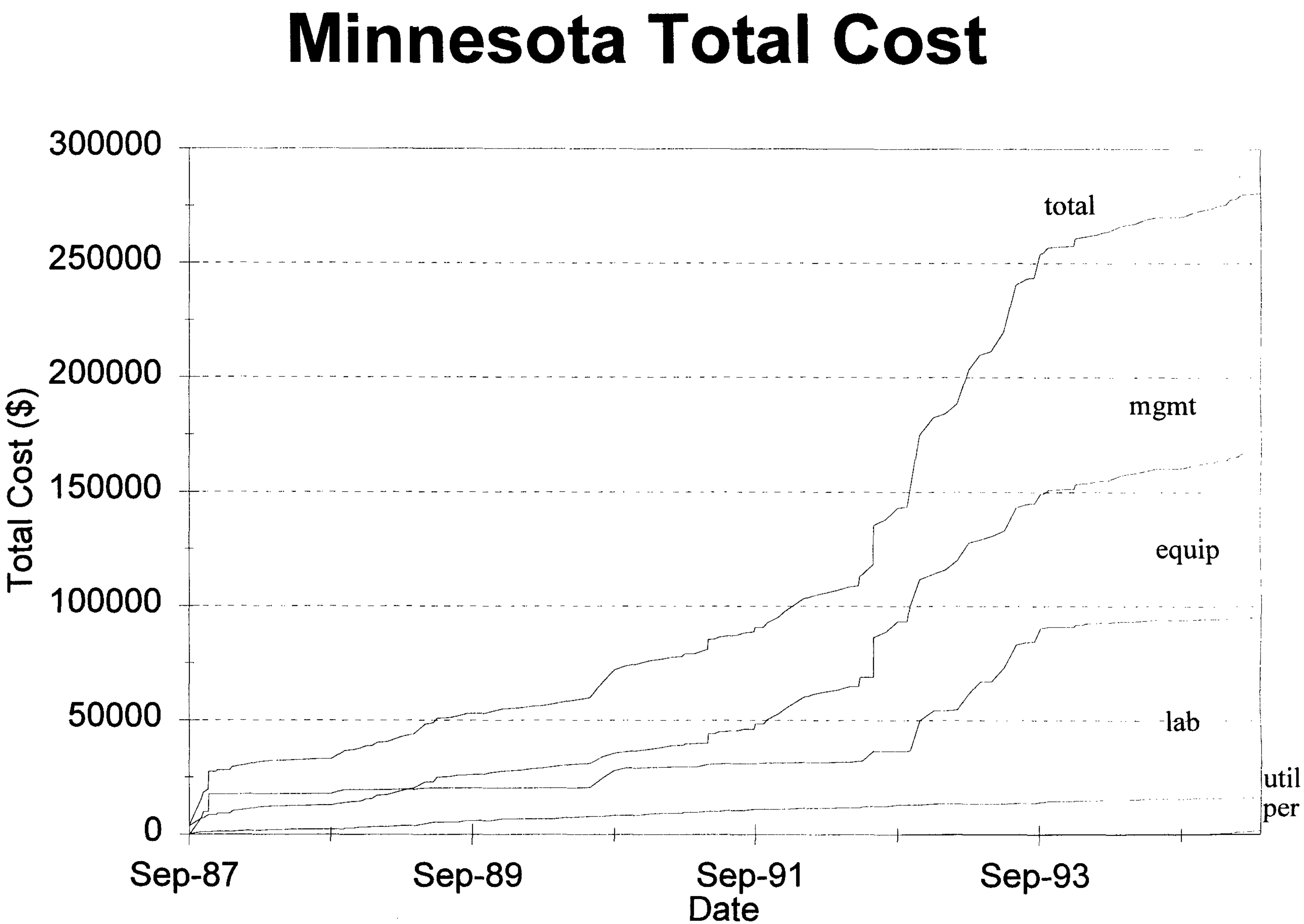

FIGURE 16: MINNESOTA TOTAL COSTS

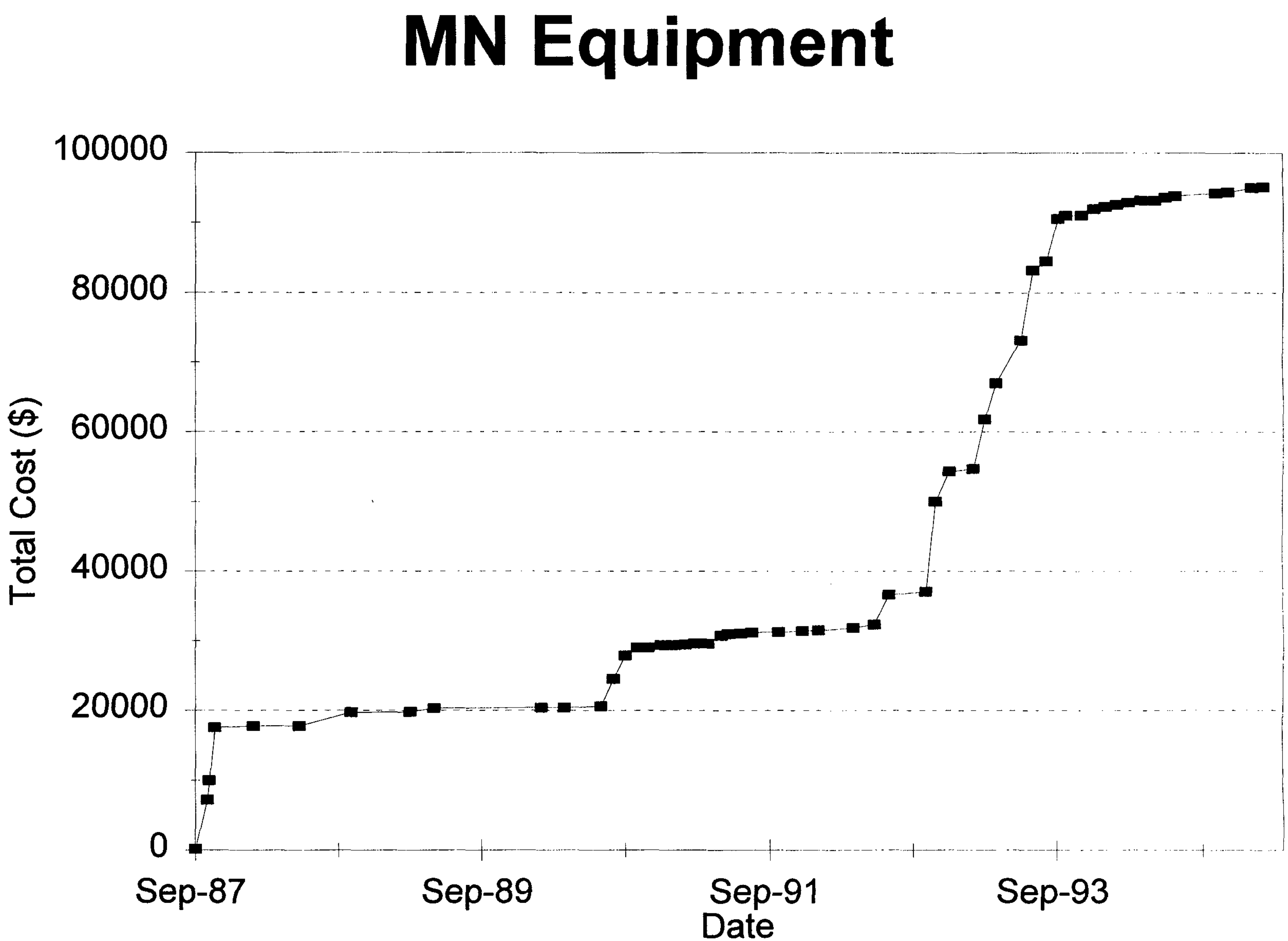

FIGURE 17: MINNESOTA EQUIPMENT

construction that appear to be linear increases with low cost slopes, but analysis of these was not pursued because of their short time spans, less than two years.

Management costs incurred for the project are shown in Figure 18. There is a definite higher cost around the time of the design and construction of the sparging system. Applying a linear regression for the period of the whole project normalized management costs produces a line with a slope of $62.39 per day with a R-squared of 0.899, as shown in Figure 19. The slopes, before and after the construction, appear to be similar, and with linear regression they are found to be close. Figure 20 show the pre-July 1990 management costs with a slope of $24.18, with a R-squared of 0.965. Figure 21 shows the post October 1993 management costs with a slope of $28.85 and a R-squared of 0.985.

Utility costs, with a total of $1,821.66 was not analyzed because only four months of data was available. The cost can be expected to be very consistent with the last few months data of about $350 per month.

Laboratory Analysis costs, shown in Figure 22, seem to occur at a relatively consistent rate. The total cost for

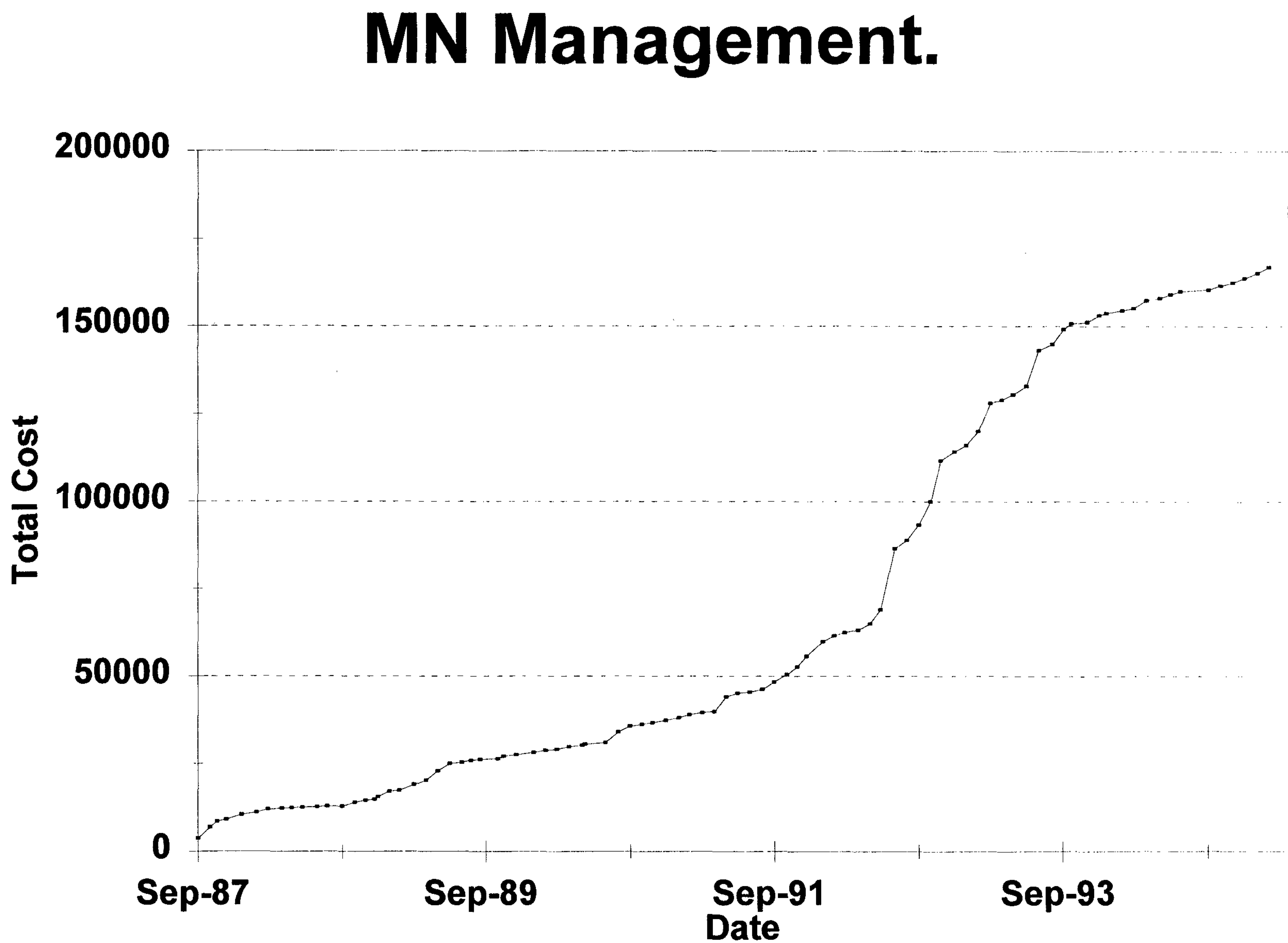

FIGURE 18: MINNESOTA MANAGEMENT

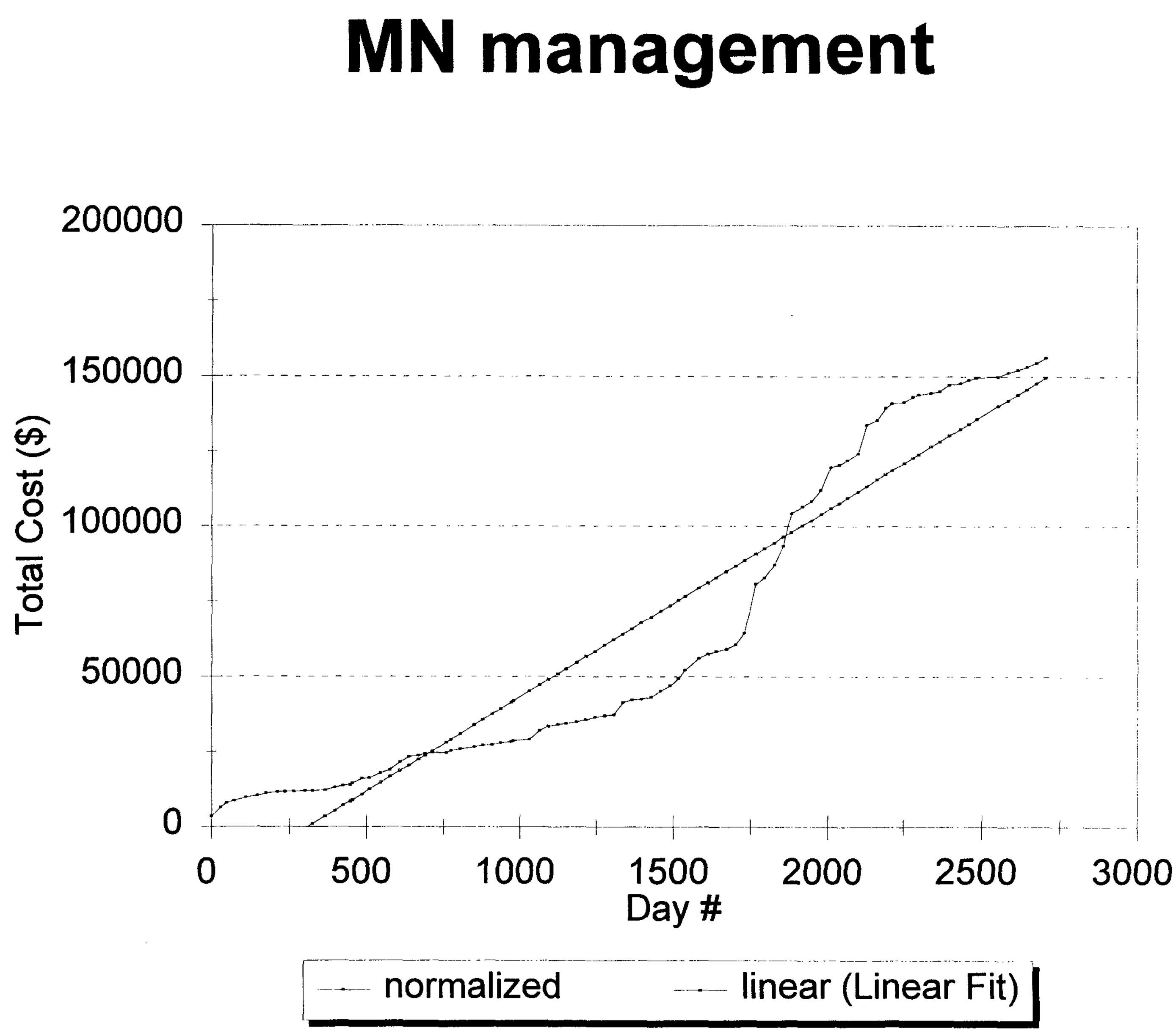

FIGURE 19: MINNESOTA MANAGEMENT - NORMALIZED AND LINEAR

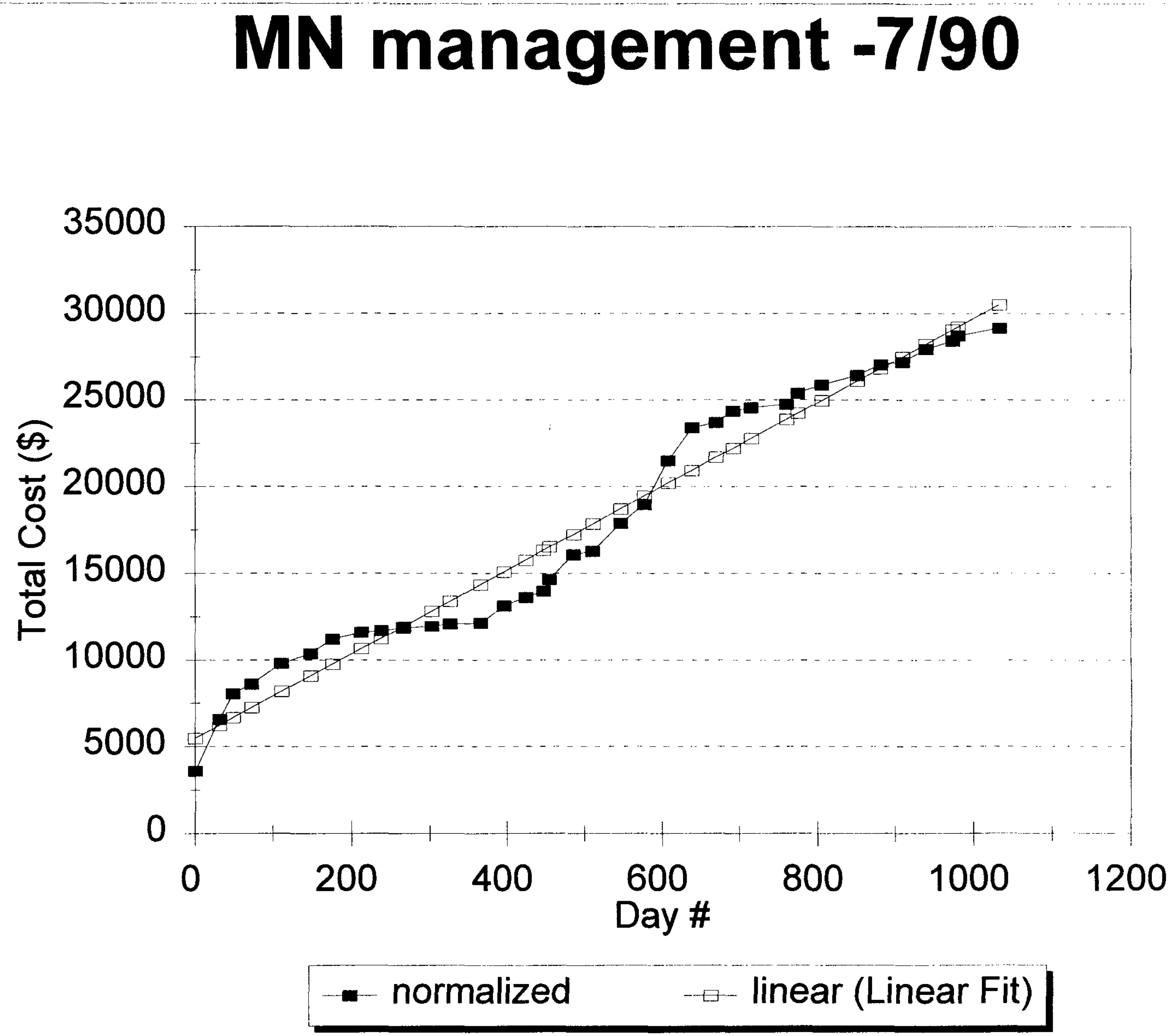

FIGURE 20: MINNESOTA MANAGEMENT -7/90 NORMALIZED AND LINEAR

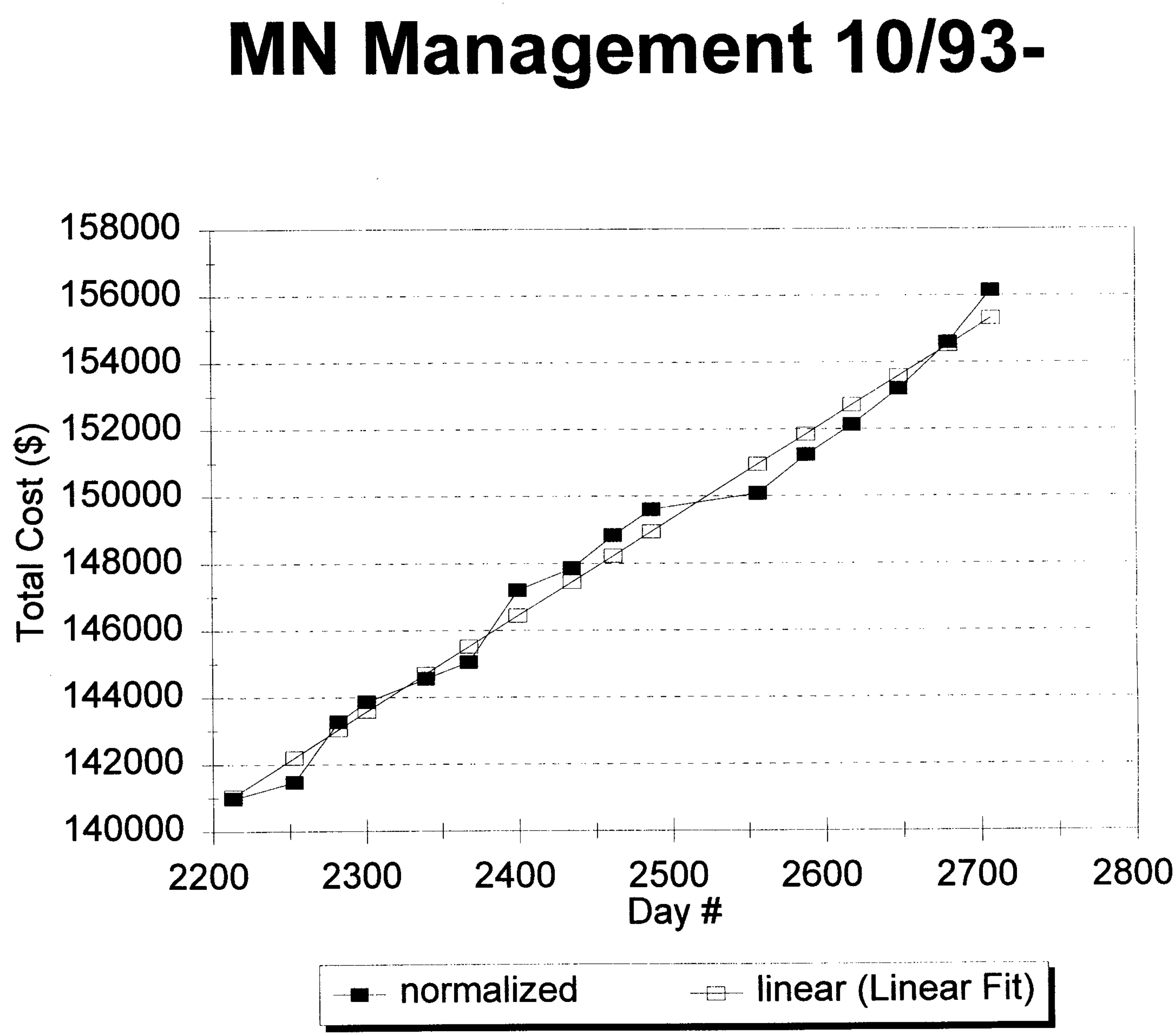

FIGURE 21: MINNESOTA MANAGEMENT 10/91- NOMALIZED AND LINEAR

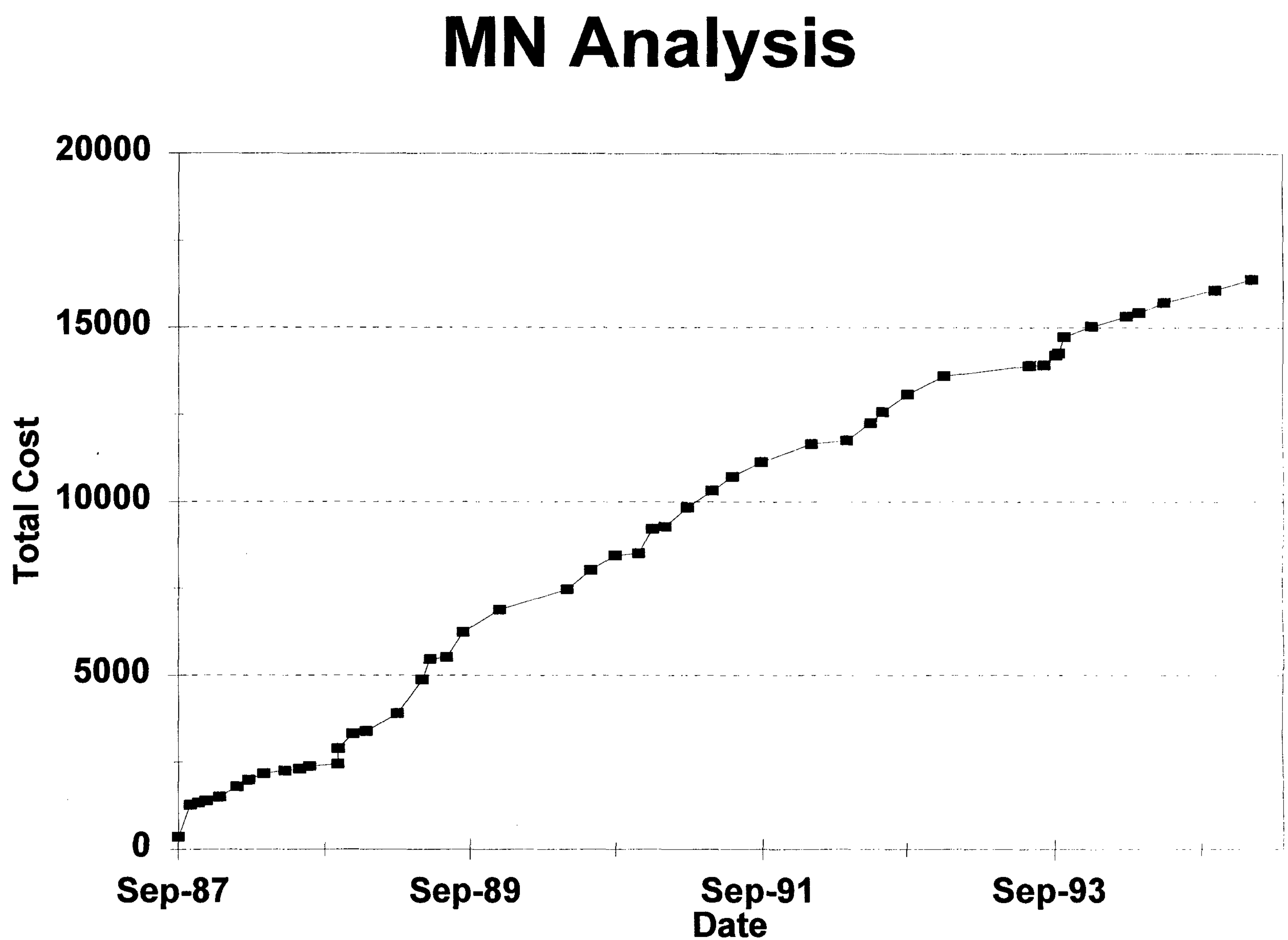

FIGURE 22: MINNESOTA ANALYSIS

analysis, until April 1995 is $16,385.91. The normalized cost, Figure 23, analyzed with linear regression shows a line with a slope of $5.79 per day, with a R-squared of 0.986.

Apparently with this project, a lot of the costs occurred very linearly as evidenced by the very high R-squared numbers. These costs will be compared with the other projects to see if they are any similarities among different projects.

Nebraska Analysis

This project has one of the less complex time lines of the projects. A pilot study was done, and the system was installed.

The total costs, shown in Figure 24, were $130,034.30. The costs before January 1992 are not shown on the graph to produce more detail in the later stages. The pilot study completed in June 1993 and the construction in June of 1994 are easily seen by the large increases in cost.

The total cost for permits is $233.45. The only permits required for this project were well permits for the drilling of the monitoring wells. The costs are not

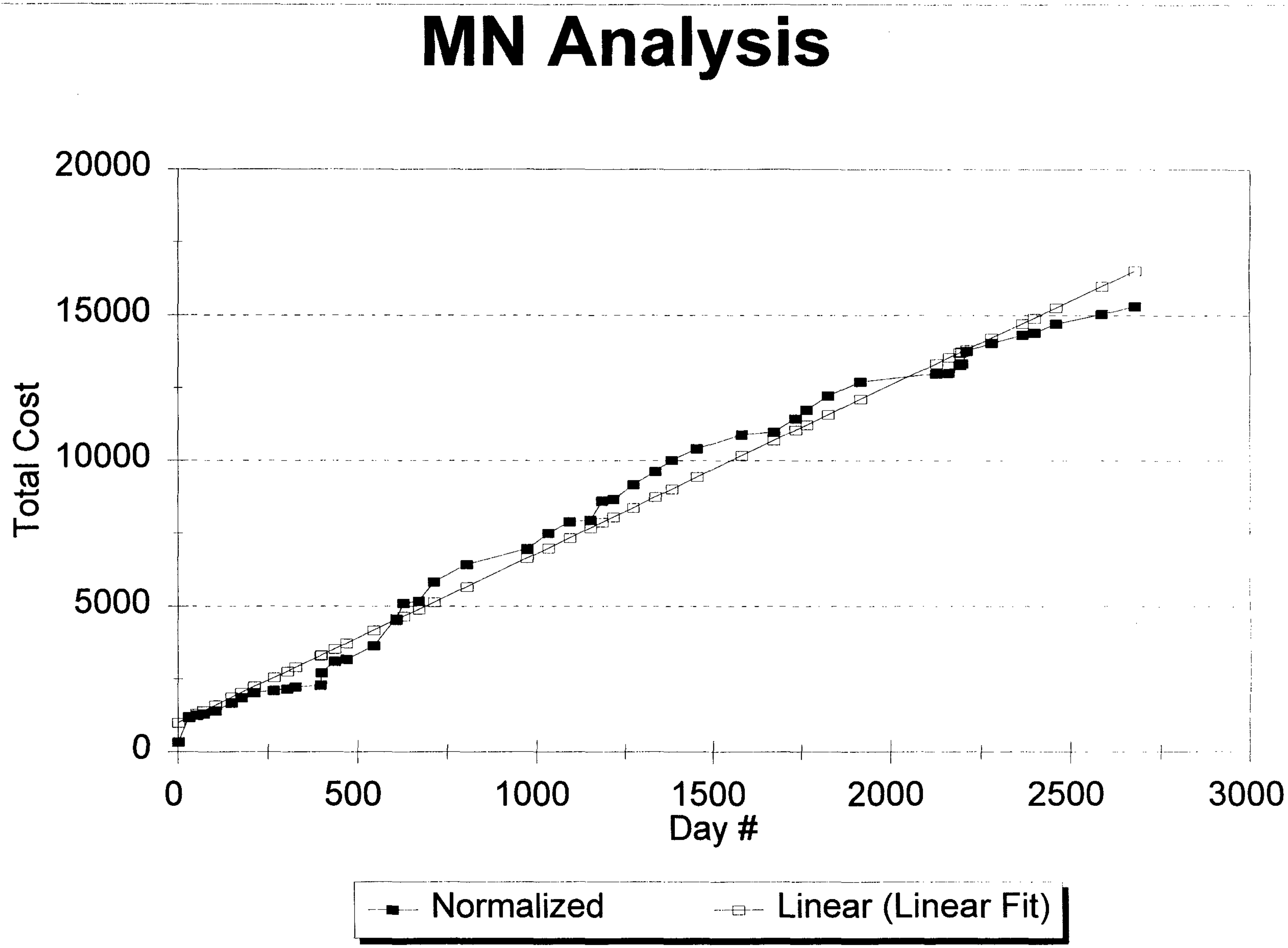

FIGURE 22: MINNESOTA ANALYSIS - NORMALIZED AND LINEAR

Nebraska Total Costs

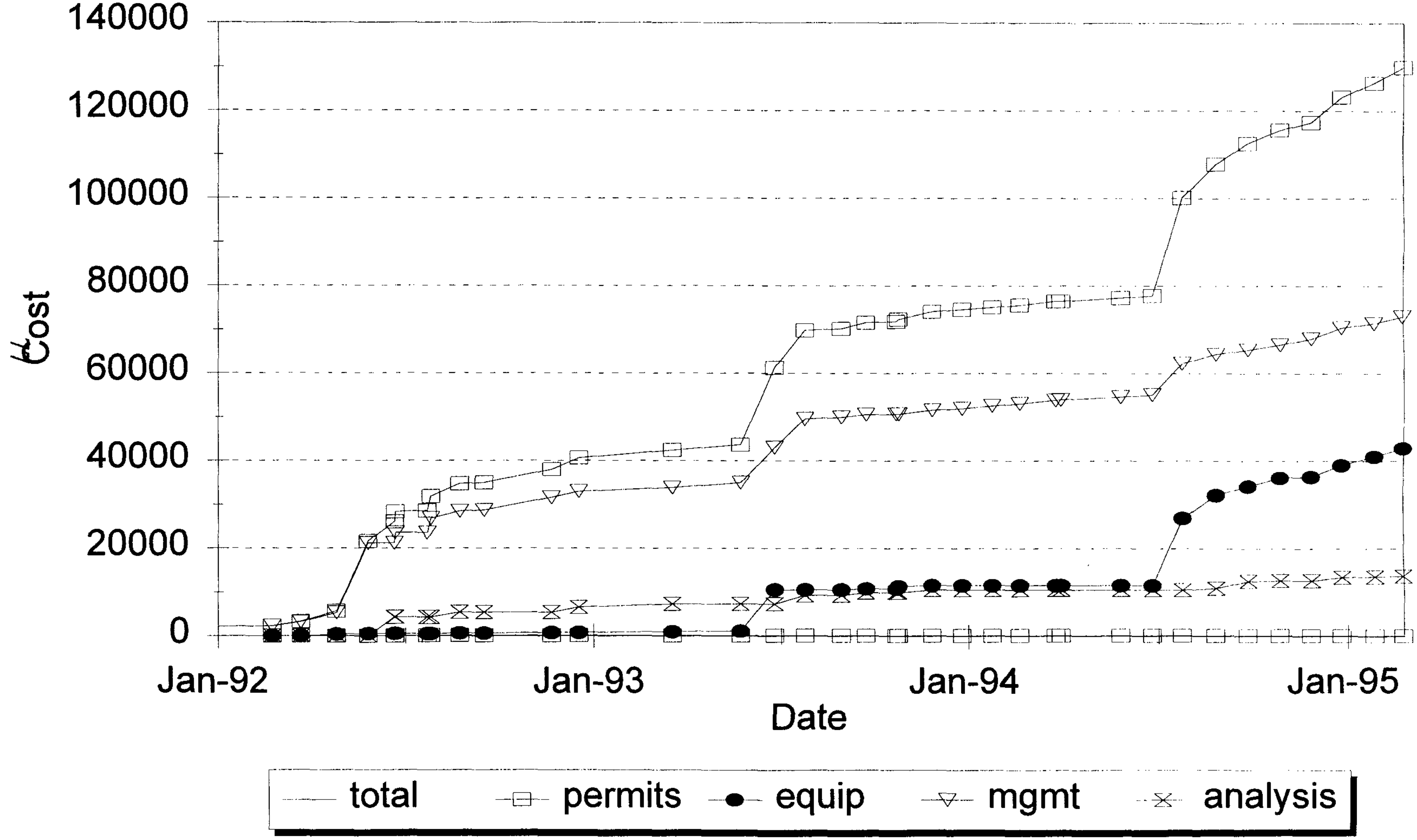

FIGURE 24: NEBRASKA TOTAL COSTS

analyzed by time.

The equipment costs for the project are shown in Figure 25. The total for equipment is $43,009.29. There is almost no cost before the pilot study, and once the construction costs in June 1994 are complete, there appears to be a constant slope. It is important to note that there are only seven data points after the construction period, so the linear regression analysis of the normalized cost, shown in Figure 26, may not be characteristic for an extended period of time. The linear regression shows a slope of $67.00 per day, with a R-squared of 0.983.

The management costs are shown in Figure 27. The total cost for management is $73,004.51. The two major events are again very apparent as high cost times. Figure 28 shows the normalized costs and the result of the linear regression with a slope of $65.49 per day, with a R-squared of 0.943. The data from the operation of the system seems especially consistent with the linear regression line.

The utility data is conspicuously missing for reasons stated in the description of the site data in previous pages.

The actual costs for laboratory analysis are shown in

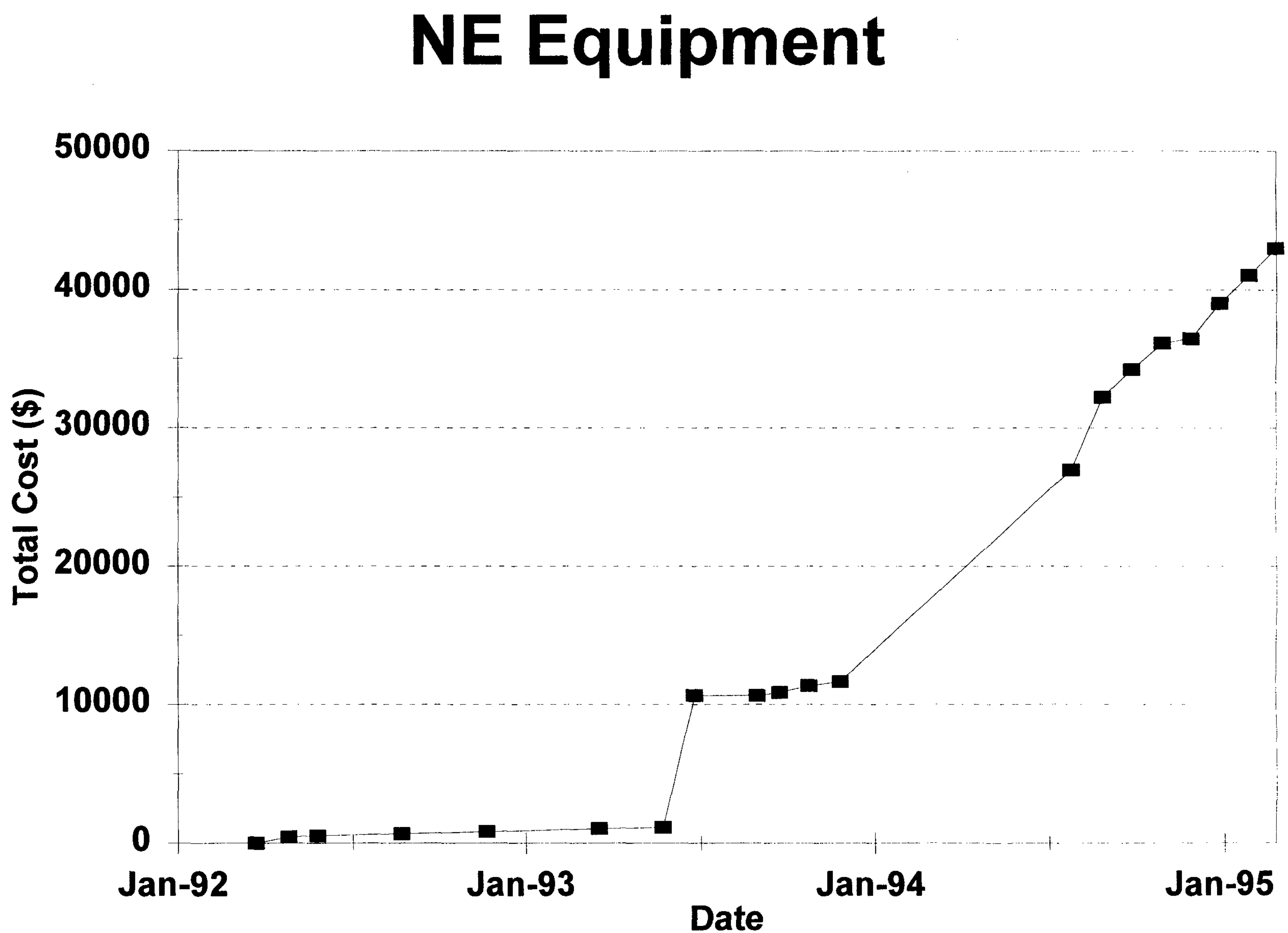

FIGURE 25: NEBRASKA EQUIPMENT

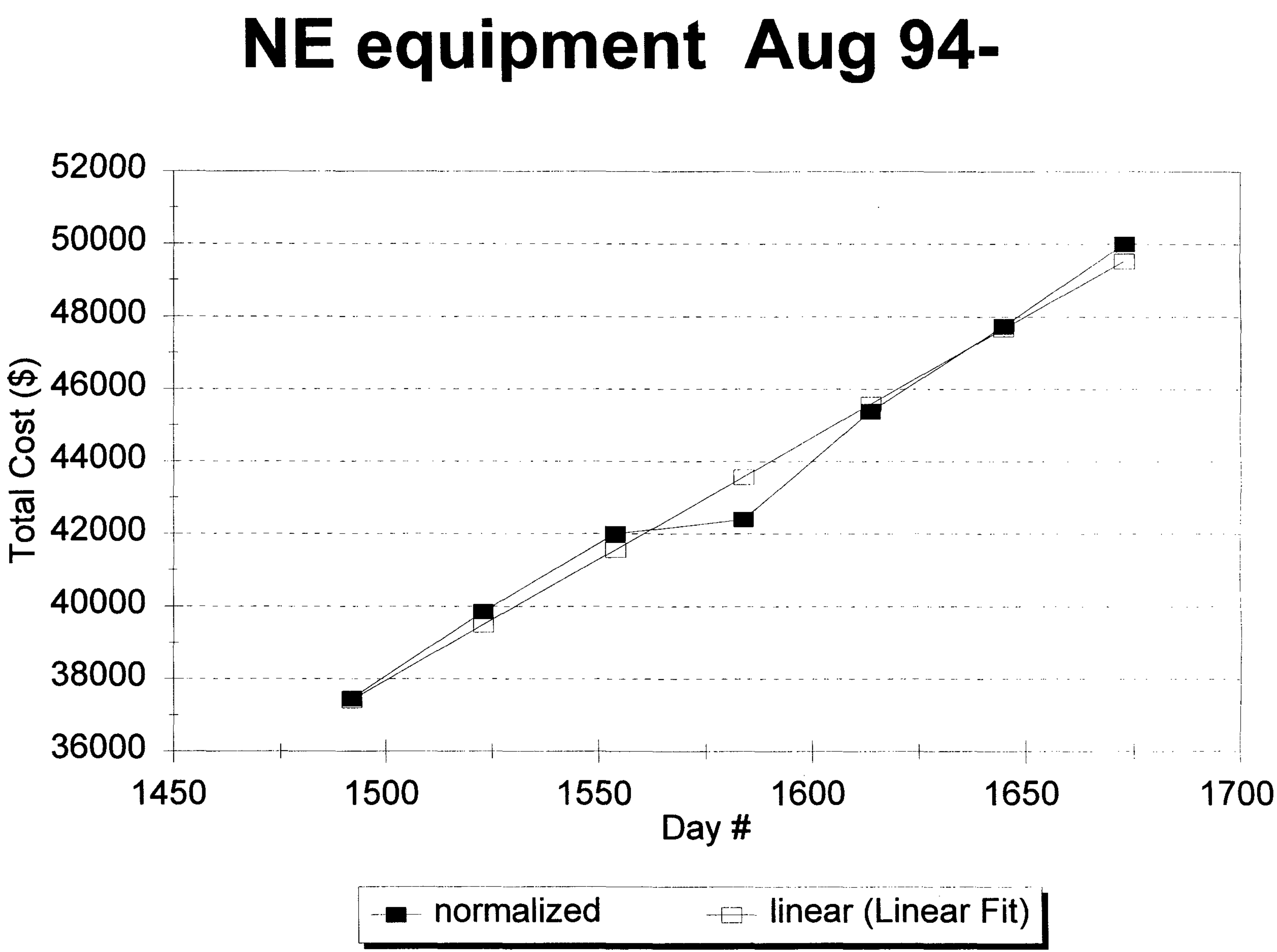

FIGURE 26: NEBRASKA EQUIPMENT - NORMALIZED AND LINEAR

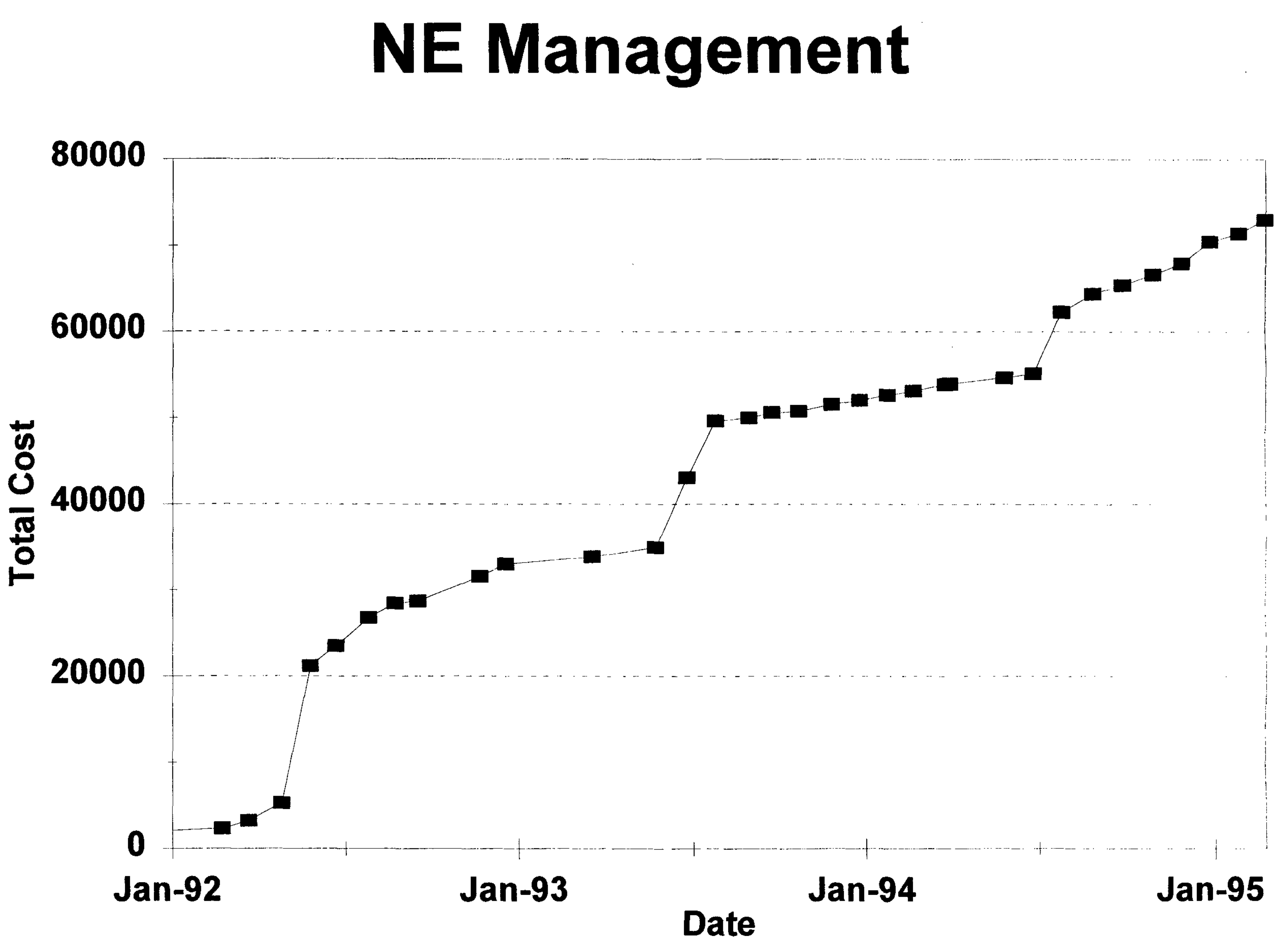

FIGURE 27: NEBRASKA MANAGEMENT

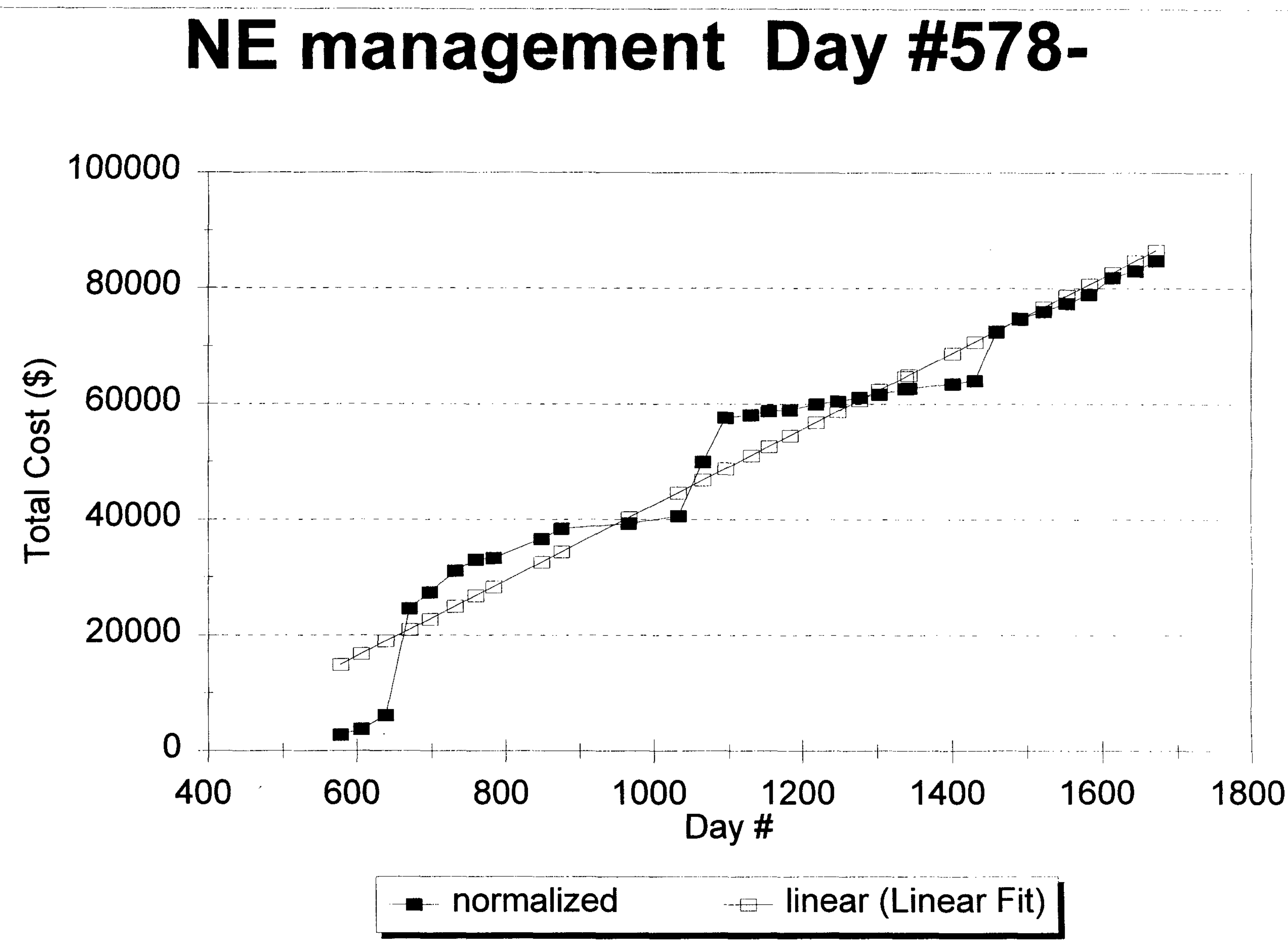

FIGURE 28: NEBRASKA MANAGEMENT - NORMALIZED AND LINEAR

Figure 29. Figure 30 shows the normalized total cost along with the linear regression line. The data is very linear with a R-squared of 0.968 and a slope of $10.49 per day.

Except for the feasibility study and the construction periods, all data seems to be very linear for this site.

Louisiana

It is important to remember that all the data prior to June 1991 could not be used in the thesis, so total amounts are not representative of the actual total amounts. It is also very important to remember that data after June 1991 are accurate, so the actual costs and any trends recognized are accurate.

The total cost for the period of June 1991 until December 1994, when it is shut down, is shown in Figure 31. The most important time line events are the installation of the SVE system in August 1992 and the system shutdown in September 1994.

There is only one permit cost during this time period of the project for $352. This cost is associated with a sewer permit for the ground water discharge unit.

Figure 32 shows the incurred equipment costs and Figure

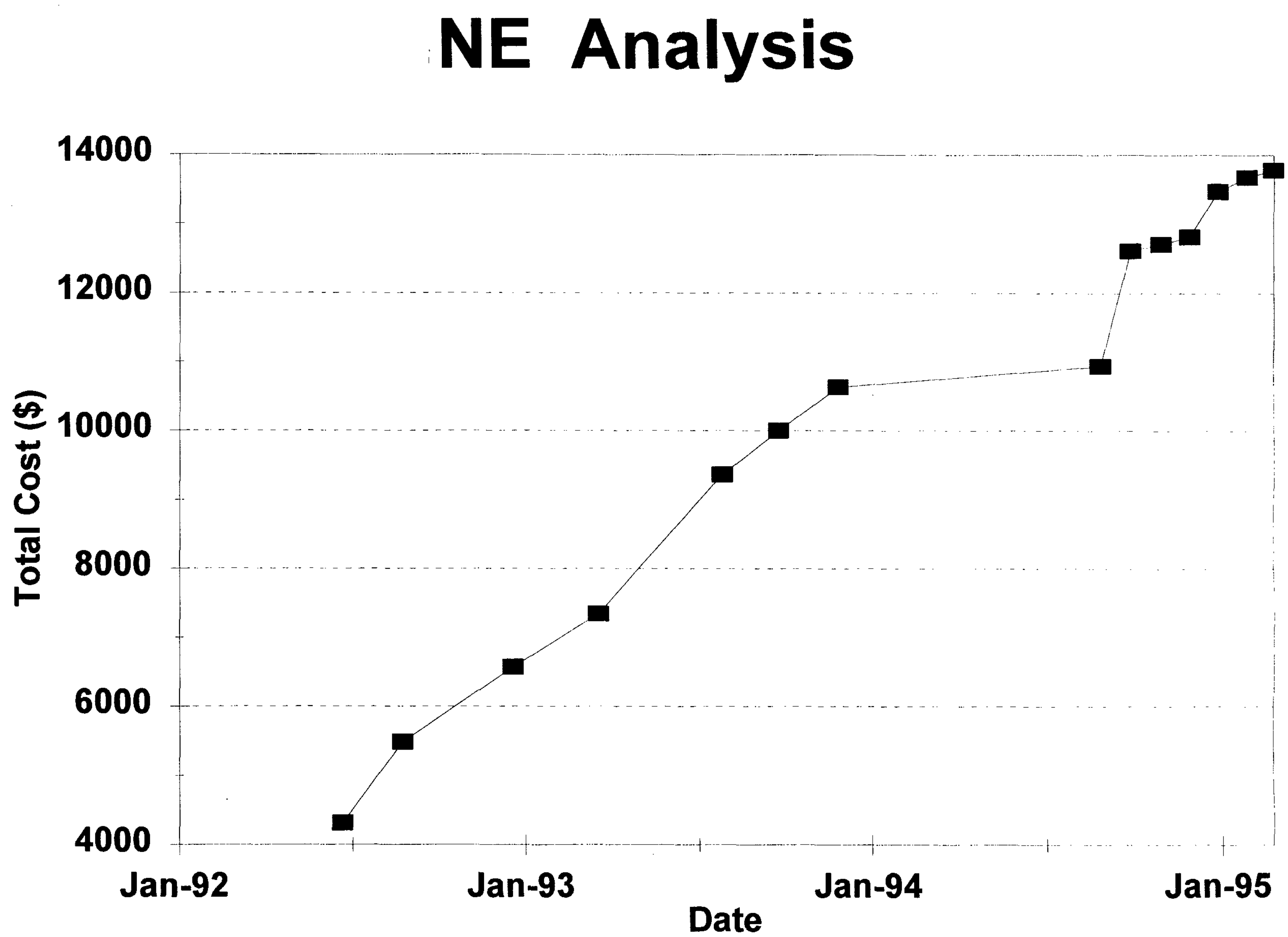

FIGURE 29: NEBRASKA ANALSYIS

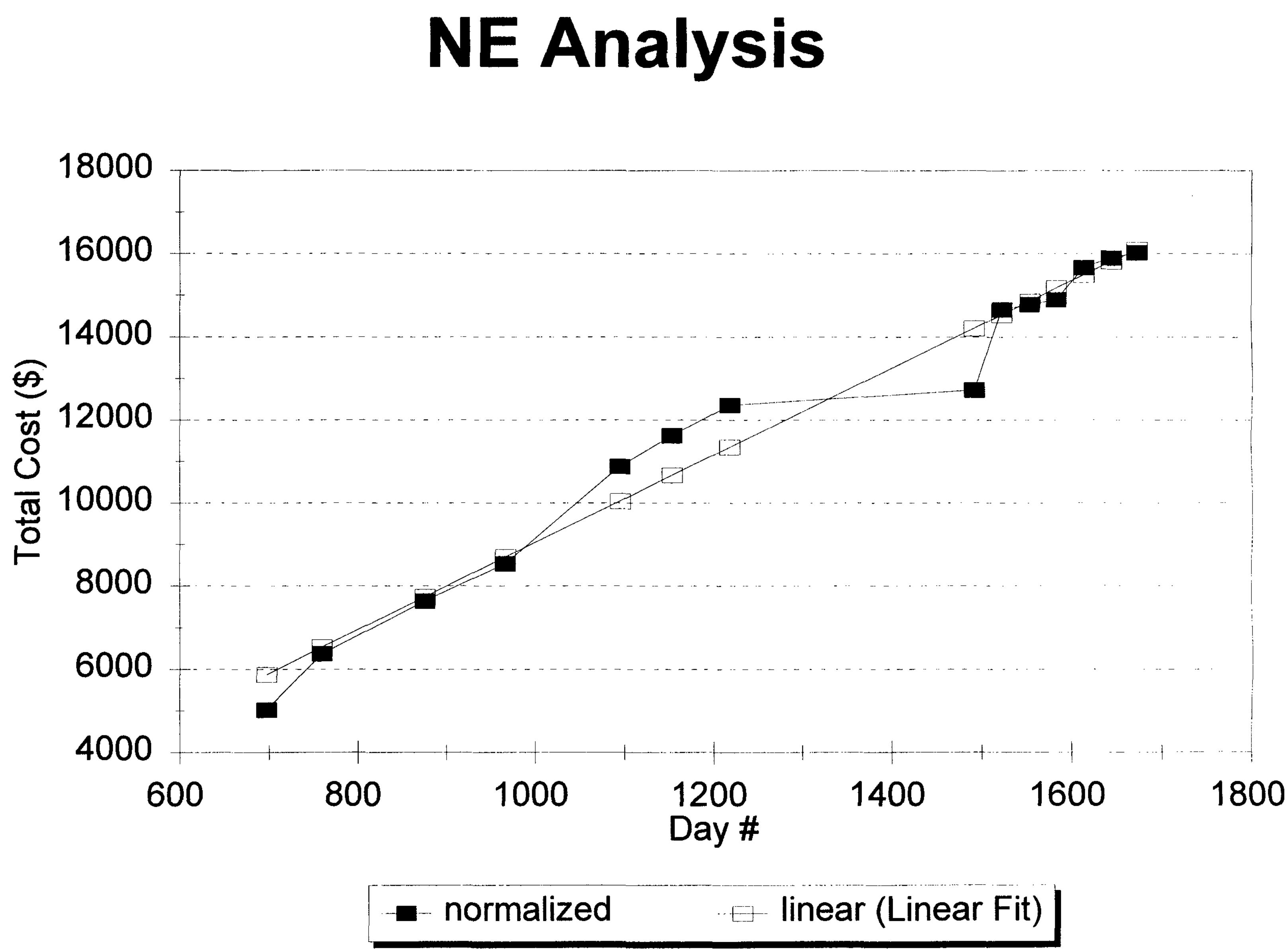

FIGURE 30: NEBRASKA ANALSYIS - NORMALIZED AND LINEAR

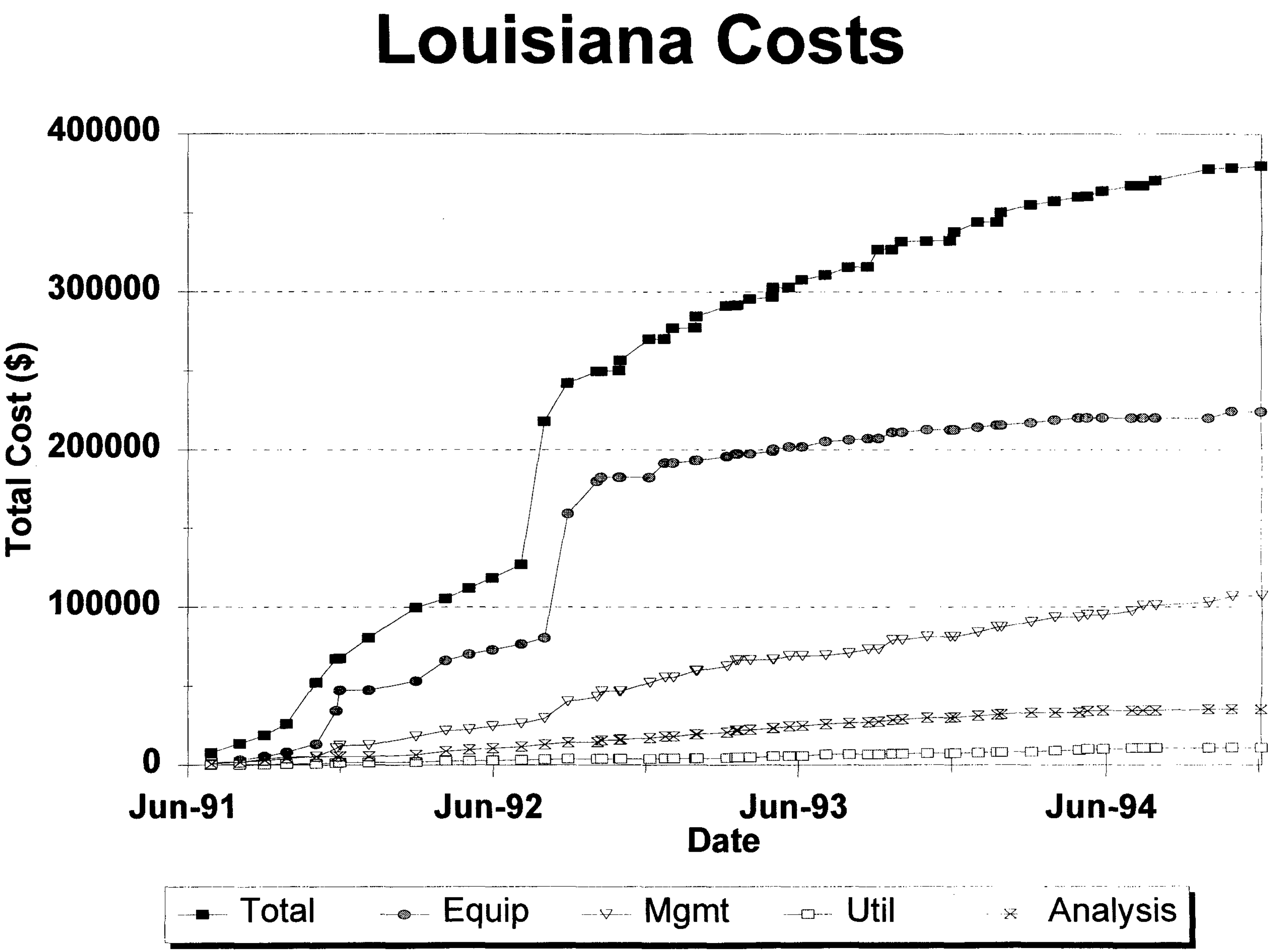

FIGURE 31: LOUISIANA TOTAL COSTS

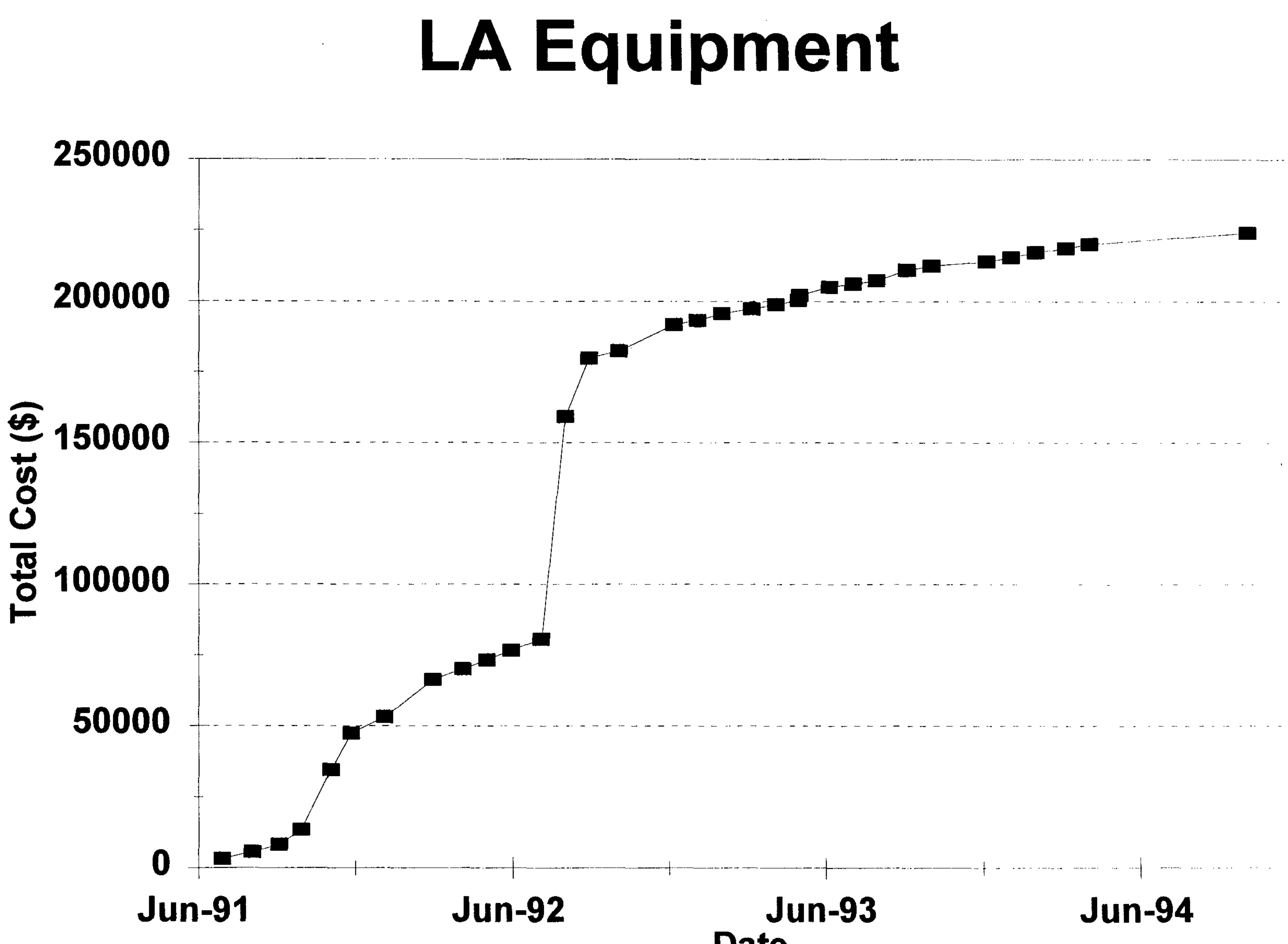

FIGURE 32: LOUISIANA EQUIPMENT

33 shows the normalized equipment cost and a linear regression line for the data after the construction in September 1992. The line has a slope of $68.45 and a R-squared of 0.951.

The management costs are shown in Figure 34. The costs appear very linear, as evidenced by Figure 35 which is the normalized cost and the linear regression line with a slope of $109.82 and a R-squared of 0.985.

The utility costs for from June 1991 until the end of the project are shown in Figure 36. Figure 37 shows the normalized cost and the linear regression line with a slope of $10.99 and a R-squared value of 0.985. The small dips in the cost occur when the system is shut down for various reasons.

The laboratory analysis costs occur very regularly. Figure 38 shows the actual costs and Figure 39 shows the normalized cost along with the linear regression line with a slope of $38.72 and a R-squared of 0.990.

Although all the data prior to June 1991 is missing, the rest of the data shows trends and event occurrences very well. When interpreting total costs for this project, it must be understood that it is not for the entire length of

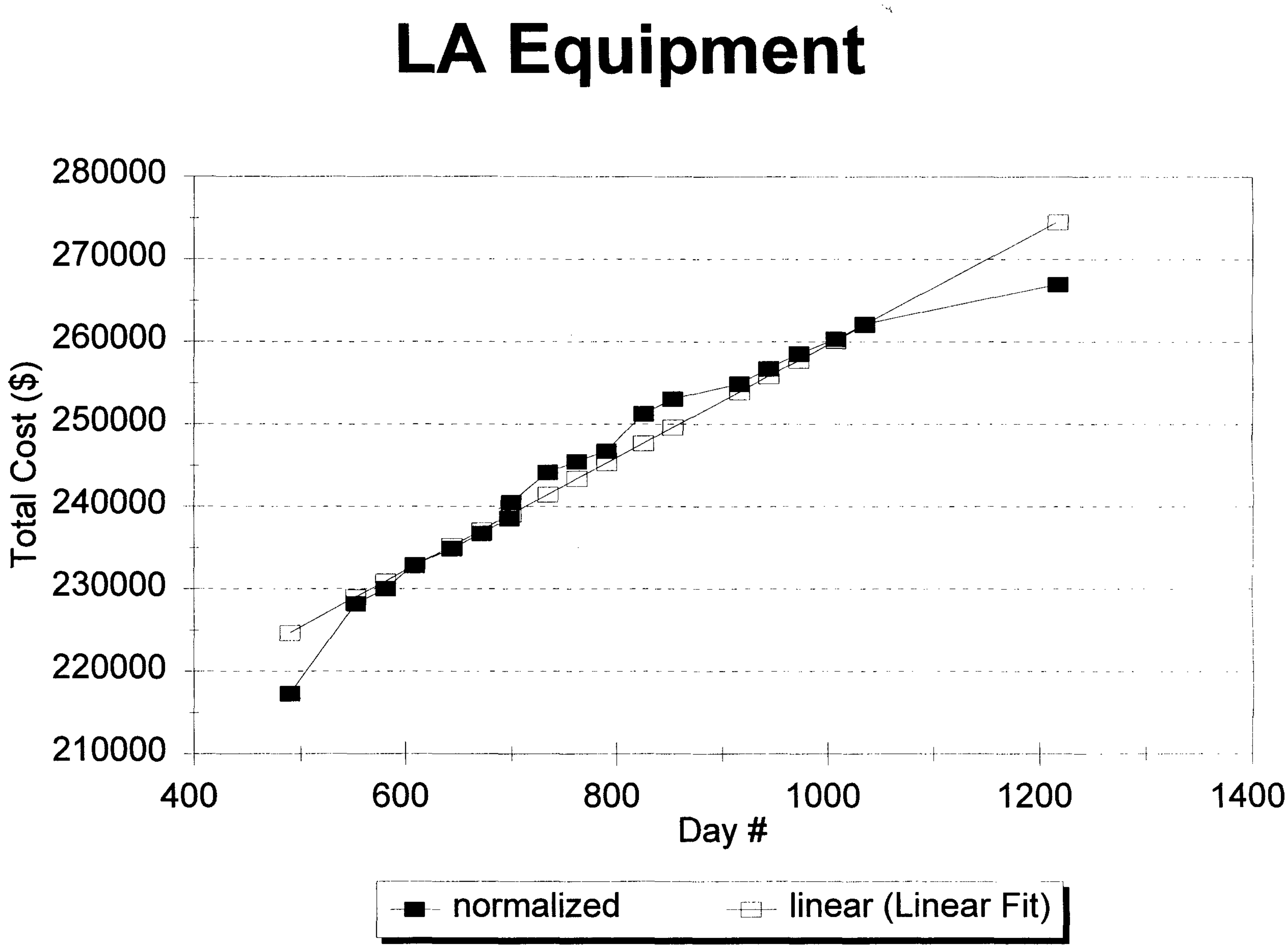

FIGURE 33: LOUISIANA EQUIPMENT - NORMALIZED AND LINEAR

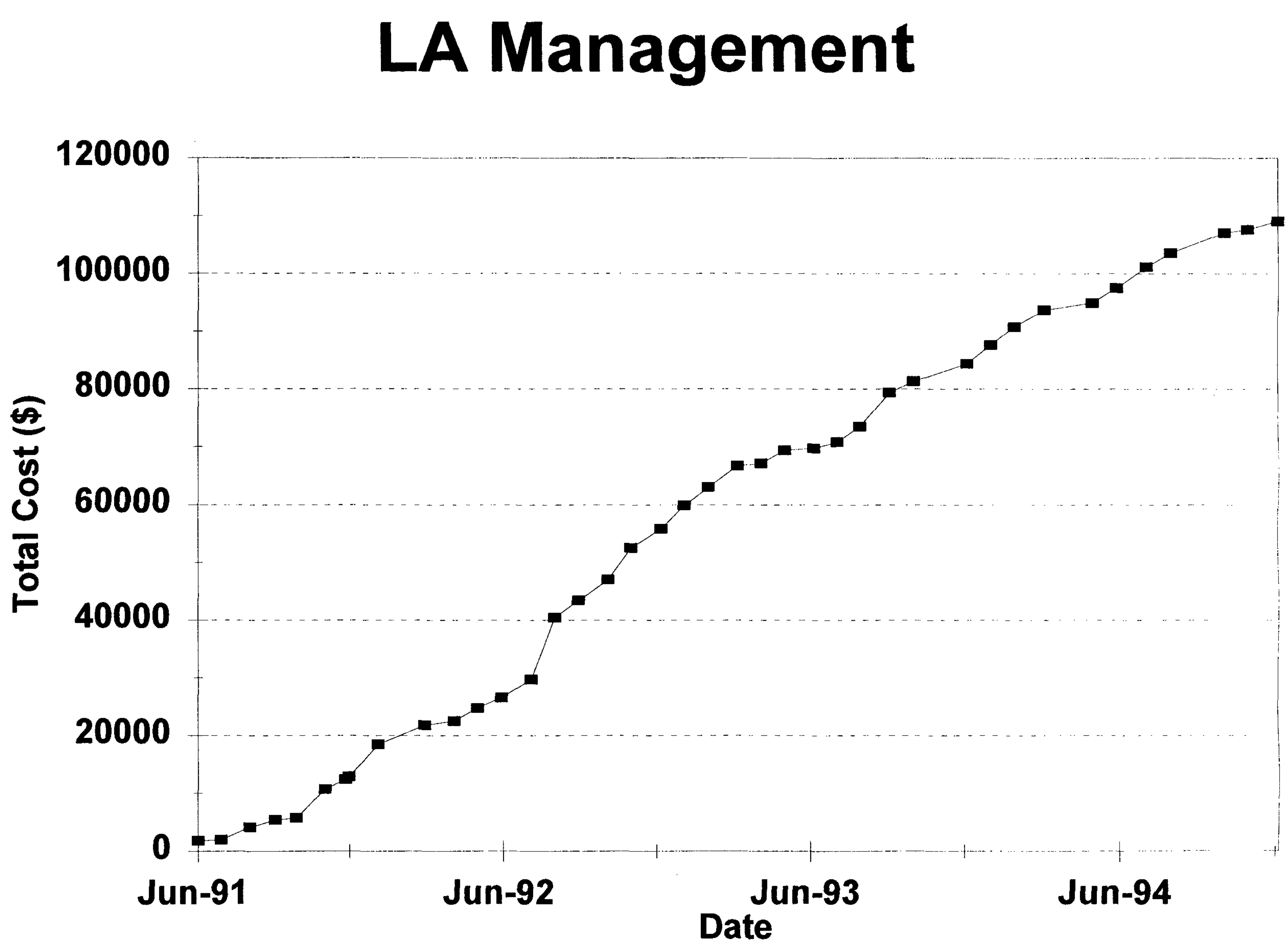

FIGURE 34: LOUISIANA MANAGEMENT

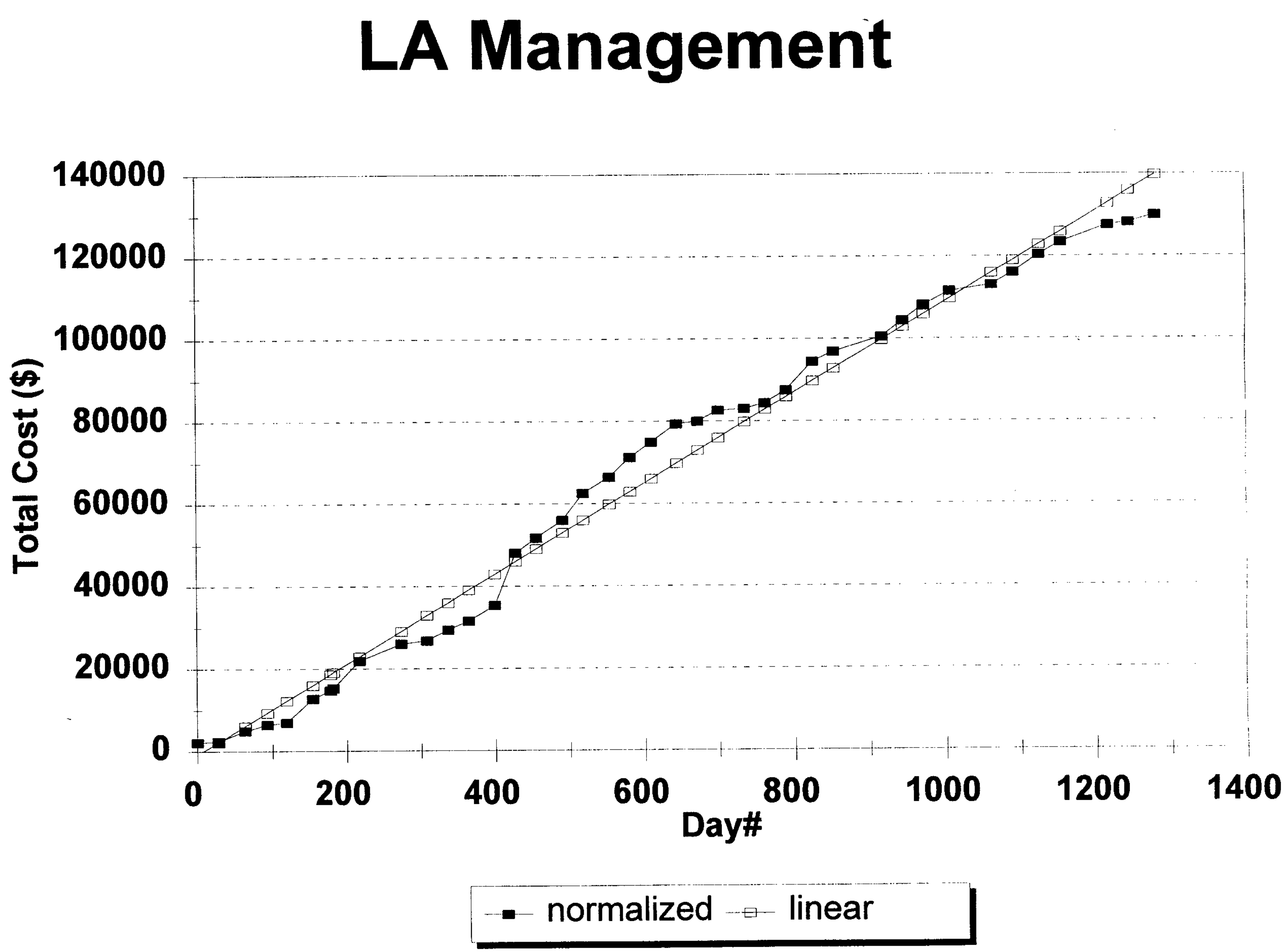

FIGURE 35: LOUISIANA MANAGEMENT-NORMALIZED AND LINEAR

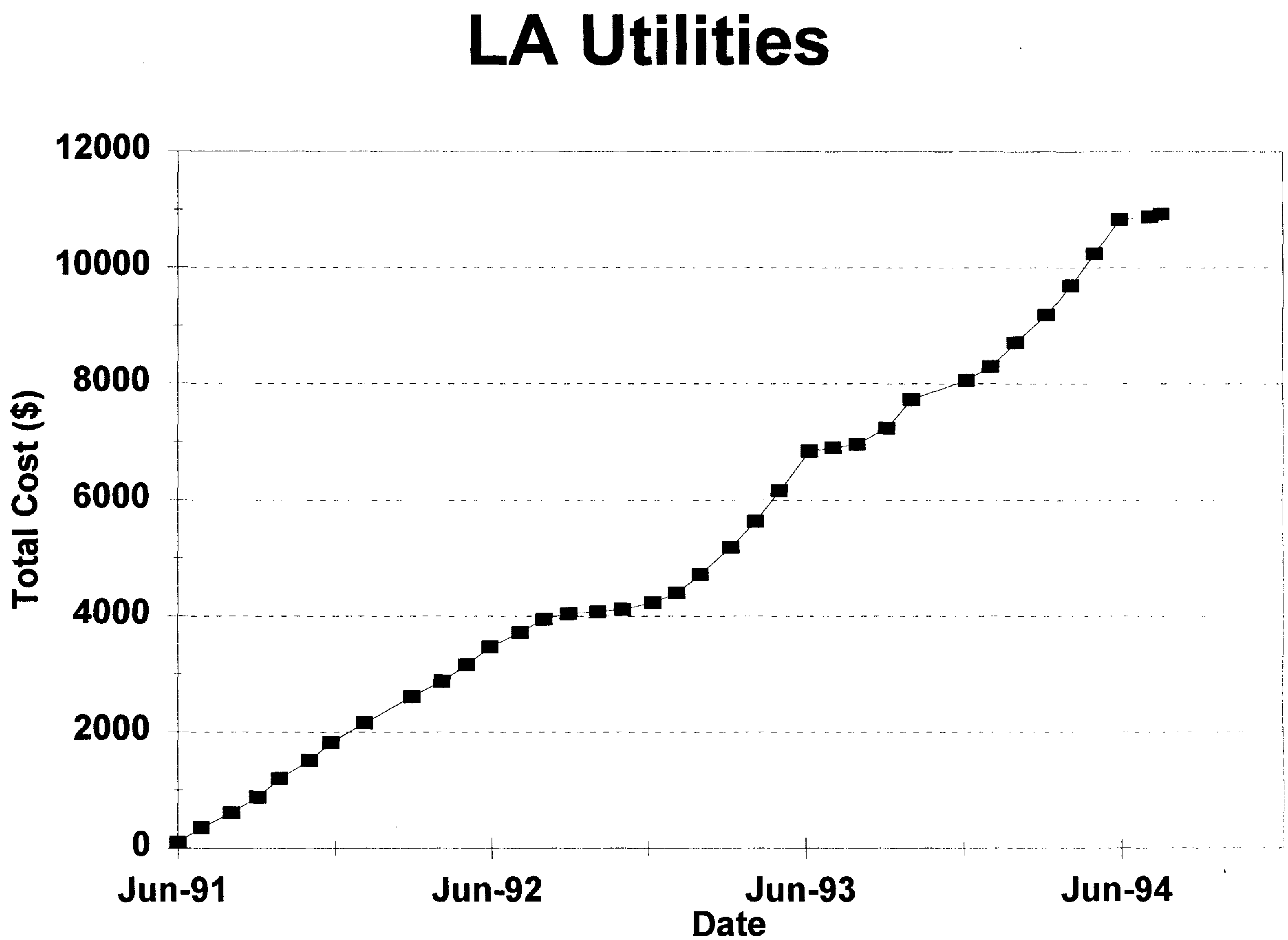

FIGURE 36: LOUISIANA UTILITIES

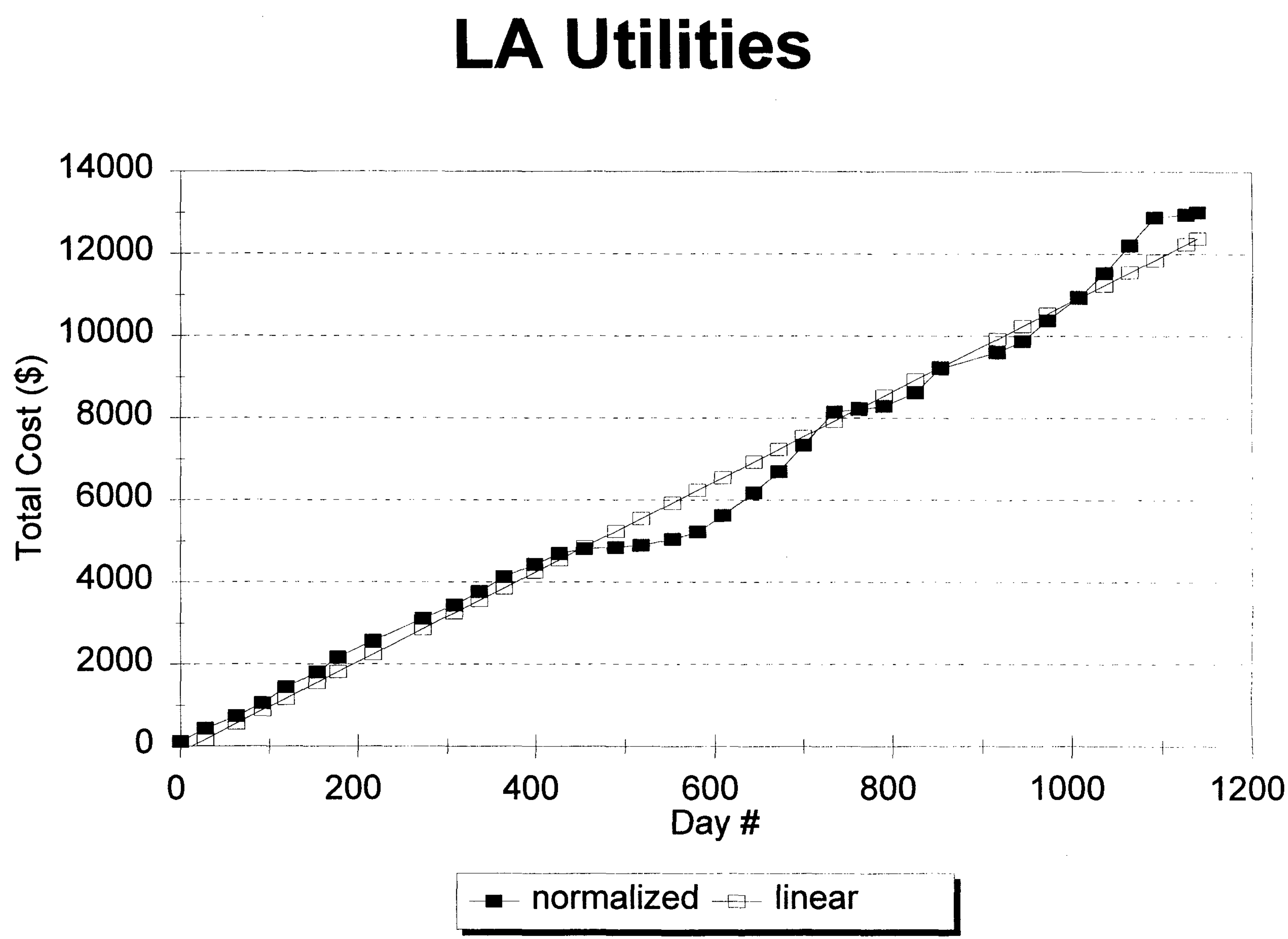

FIGURE 37: LOUISIANA UTILITIES - NORMALIZED AND LINEAR

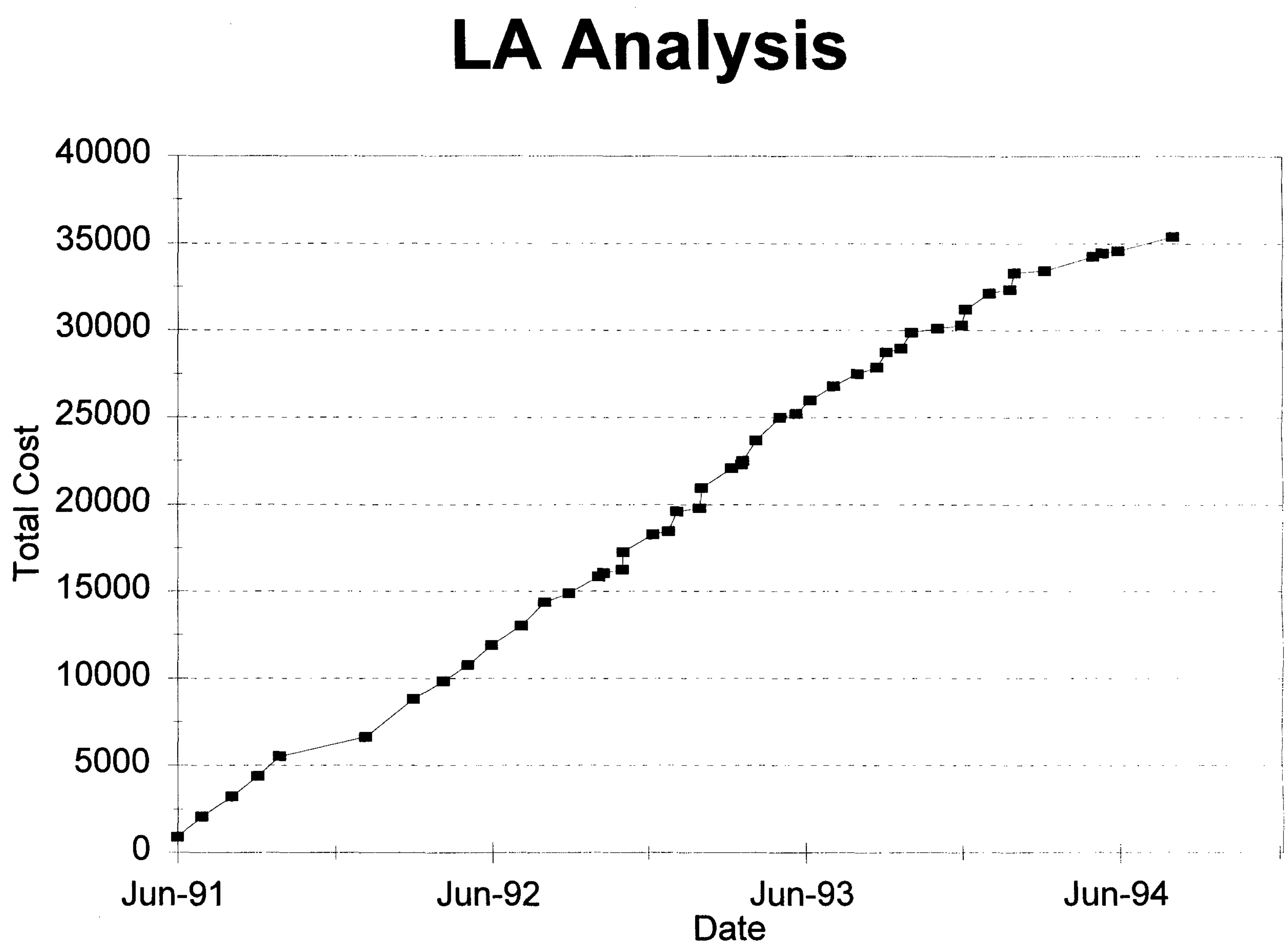

FIGURE 38: LOUISIANA ANALYSIS

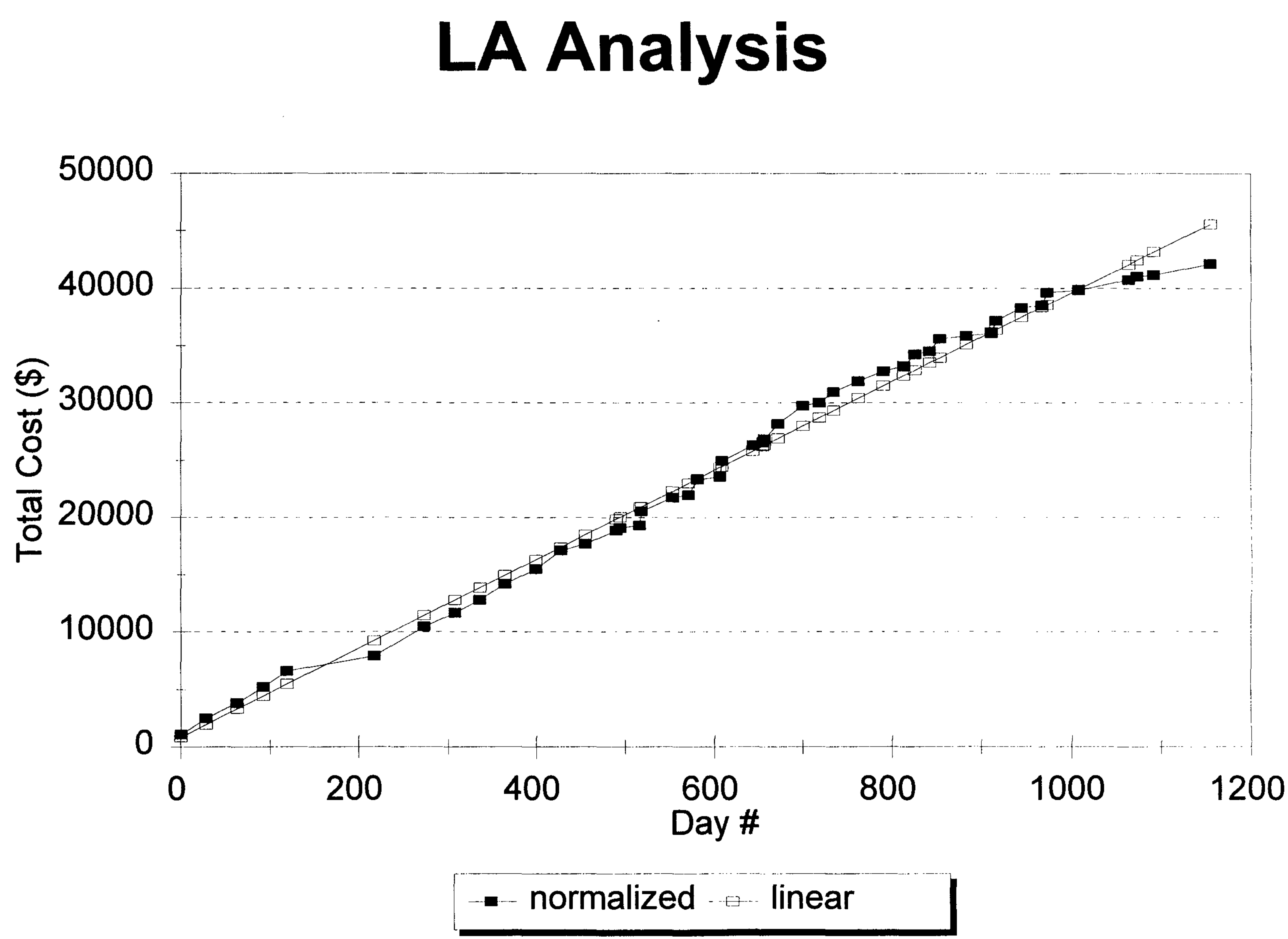

FIGURE 39: LOUISIANA ANALYSIS - NORMALIZED AND LINEAR

the project, but rather just for the time period after June 1991.

California #2 Analysis

This project has the highest total cost of all the projects analyzed. The system includes soil vapor extraction and ground water treatment. The data for equipment and management costs could not be distinguished from each other, as explained earlier, so they are lumped together.

The total cost for this project is $1,410,876. Figure 40 shows the total cost breakdowns. The line has no major distinguishing features that correspond to site events.

Permit costs, totaling $9,197.34, are shown in Figure 41. The linear regression line is also shown in the figure. It has a slope of $4.65 per day with a R-squared of 0.895. The permit costs are for the SVE and incinerator system.

The equipment and management costs are shown in Figure 42. This is the bulk of the total cost as can be expected. The total cost is $1,178,774.80. The bulk of the cost occurring between November 1990 and November 1992 are for monitoring wells and the installation of the SVE system with

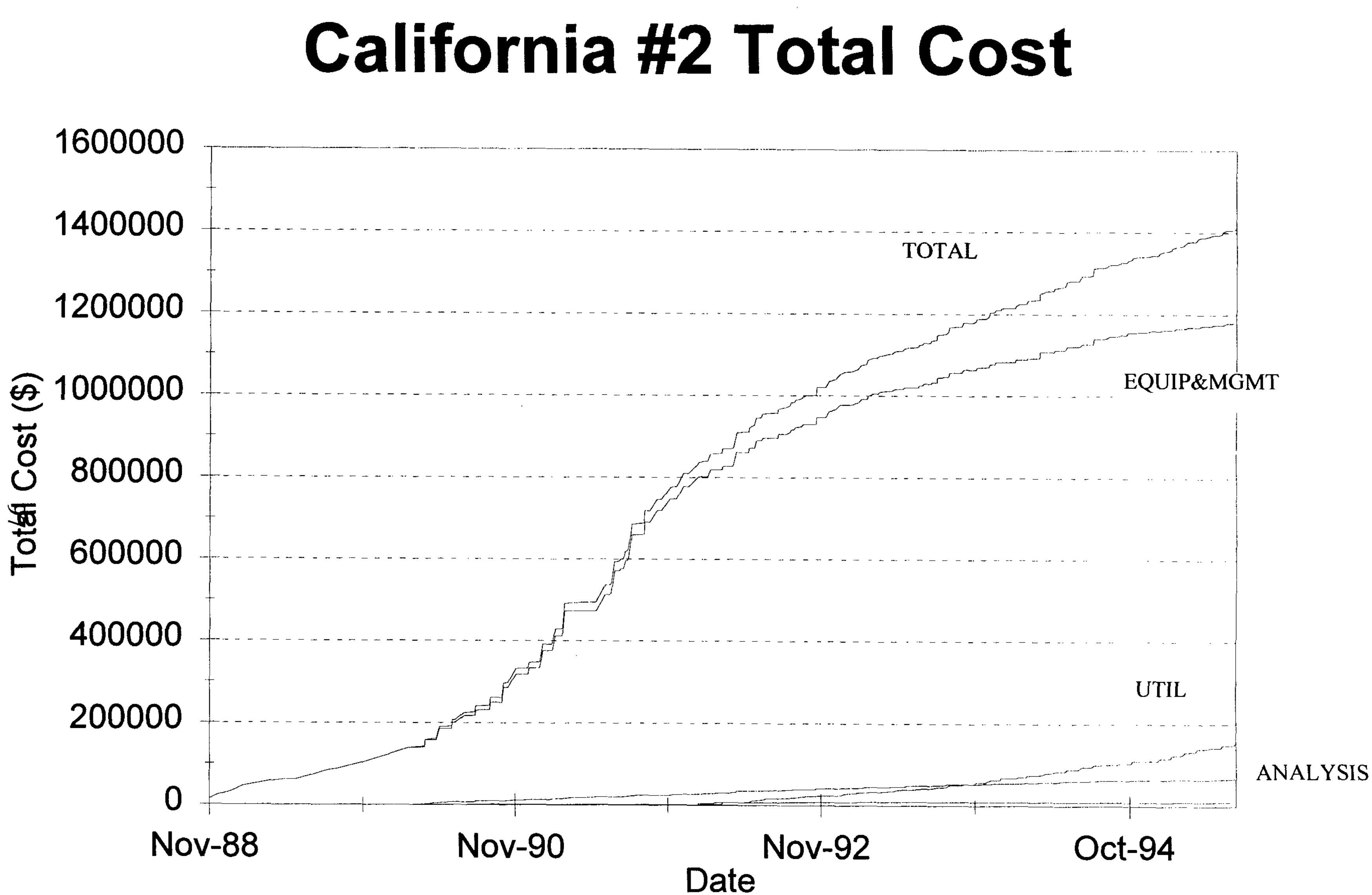

FIGURE 40: CALIFORNIA #2 TOTAL COSTS

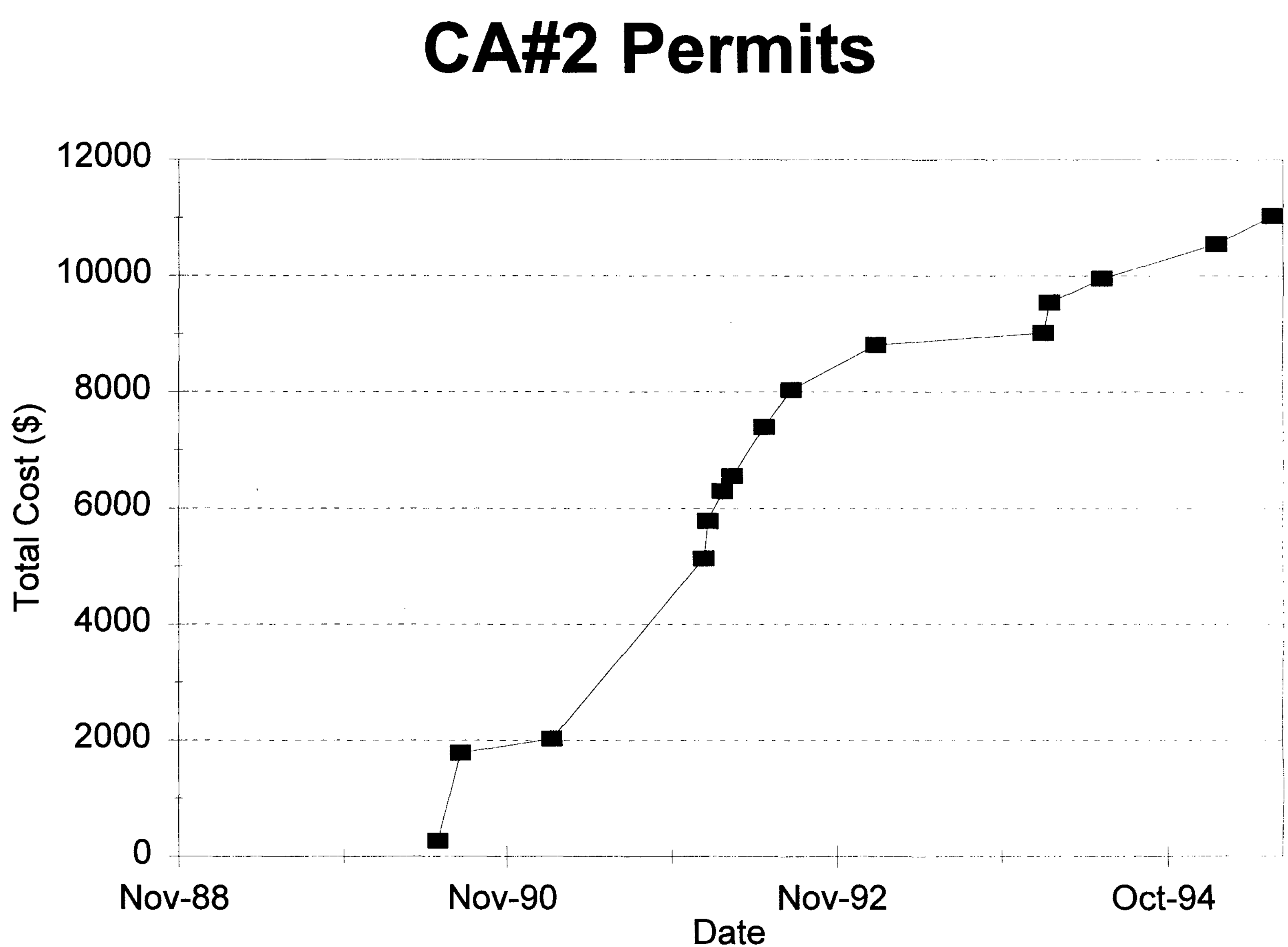

FIGURE 41: CALIFORNIA #2 PERMITS

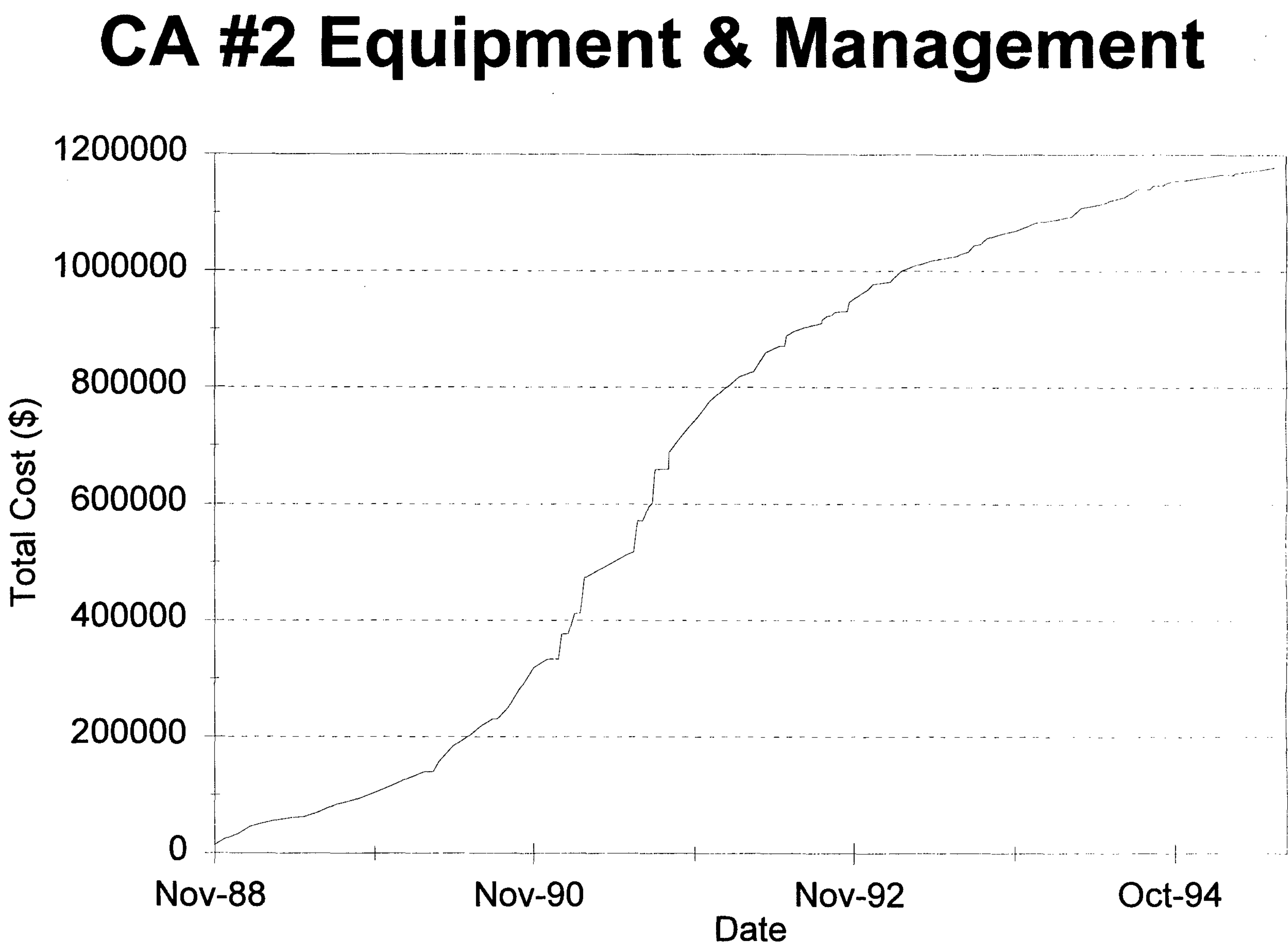

FIGURE 42: CALIFORNIA #2 EQUIPMENT AND MANAGEMENT

thermal incineration.

The total cost for utilities is shown in Figure 43. It seems to continue to rise rapidly. The constituents of the total utility cost are shown in Figure 44. The linear regression for each (with R-squared value) is : electric $10.41 per day (0.986), sewer $48.74 per day (0.983), telephone $1.17 per day (0.991), and natural gas $44.41 per day (.816).

Figure 45 shows the total cost for laboratory analysis. The normalized and linear regression estimates are shown in Figure 46. The regression has a slope of $30.12 per day with a R-squared of 0.991.

Cost Category Percentages

Figure 47 shows the percentage of total cost that each cost category entails. The California #1, Minnesota, and Nebraska project all have amazing similarities among the cost percentages. All three have management costs at the highest at about 55 percent of the total cost. The next highest cost is equipment at about 30 to 35 percent of the total cost. The reason that the Louisiana costs do not match the other three is that the project costs during the

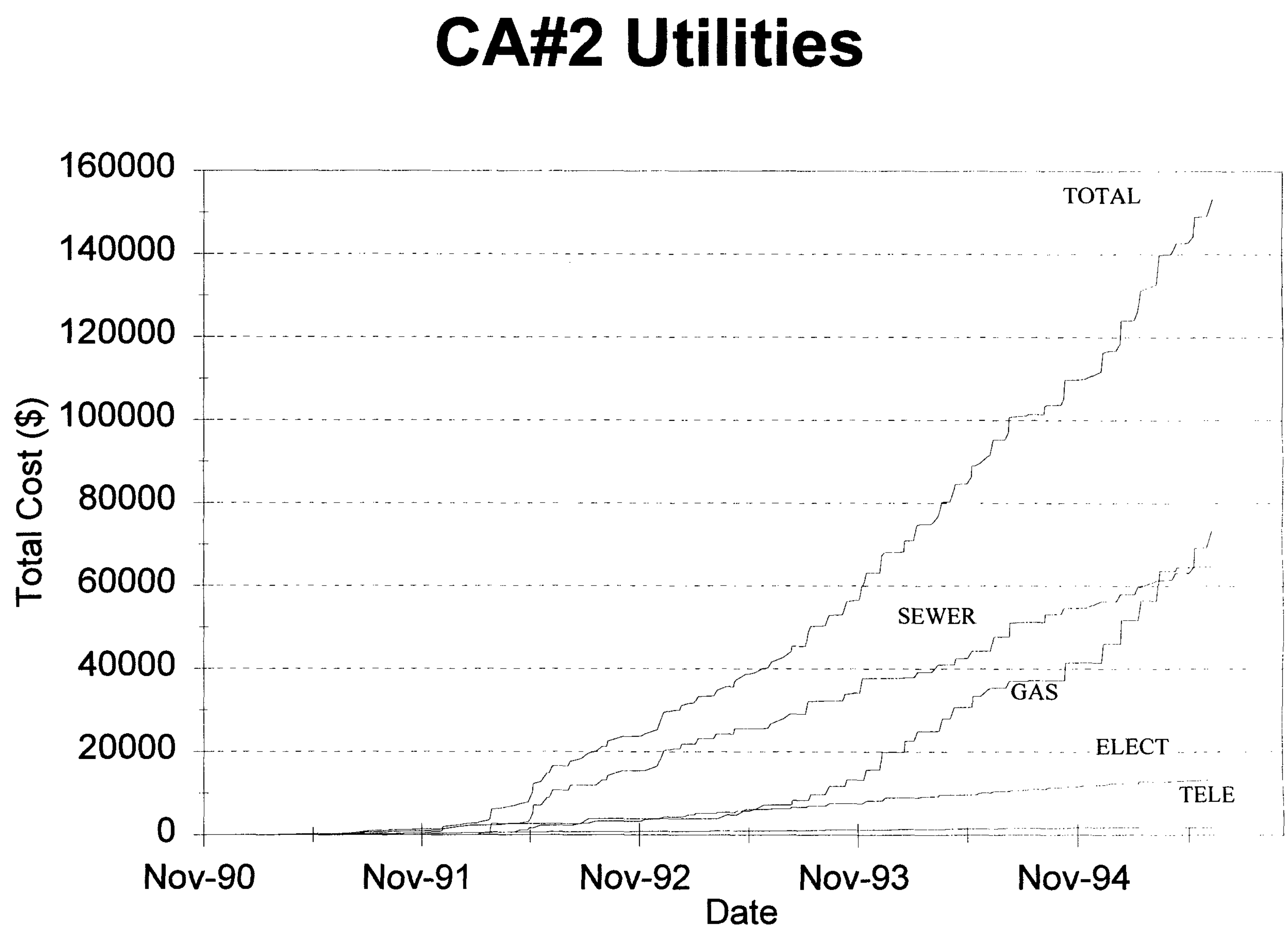

FIGURE 43: CALIFORNIA #2 UTILITIES

CA#2 Utilities

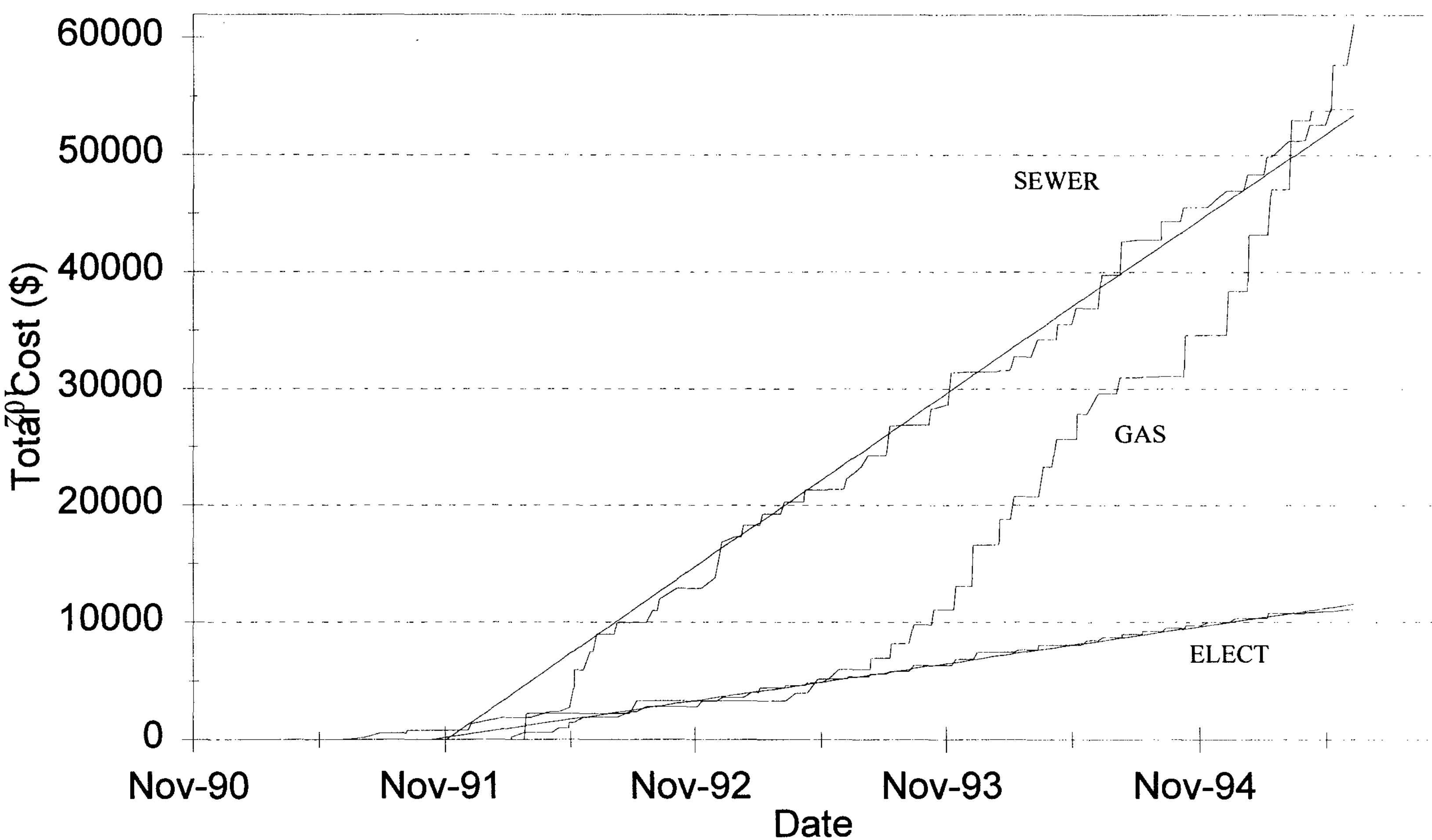

FIGURE 44: CALIFORNIA #2 UTILITIES NORMALIZED

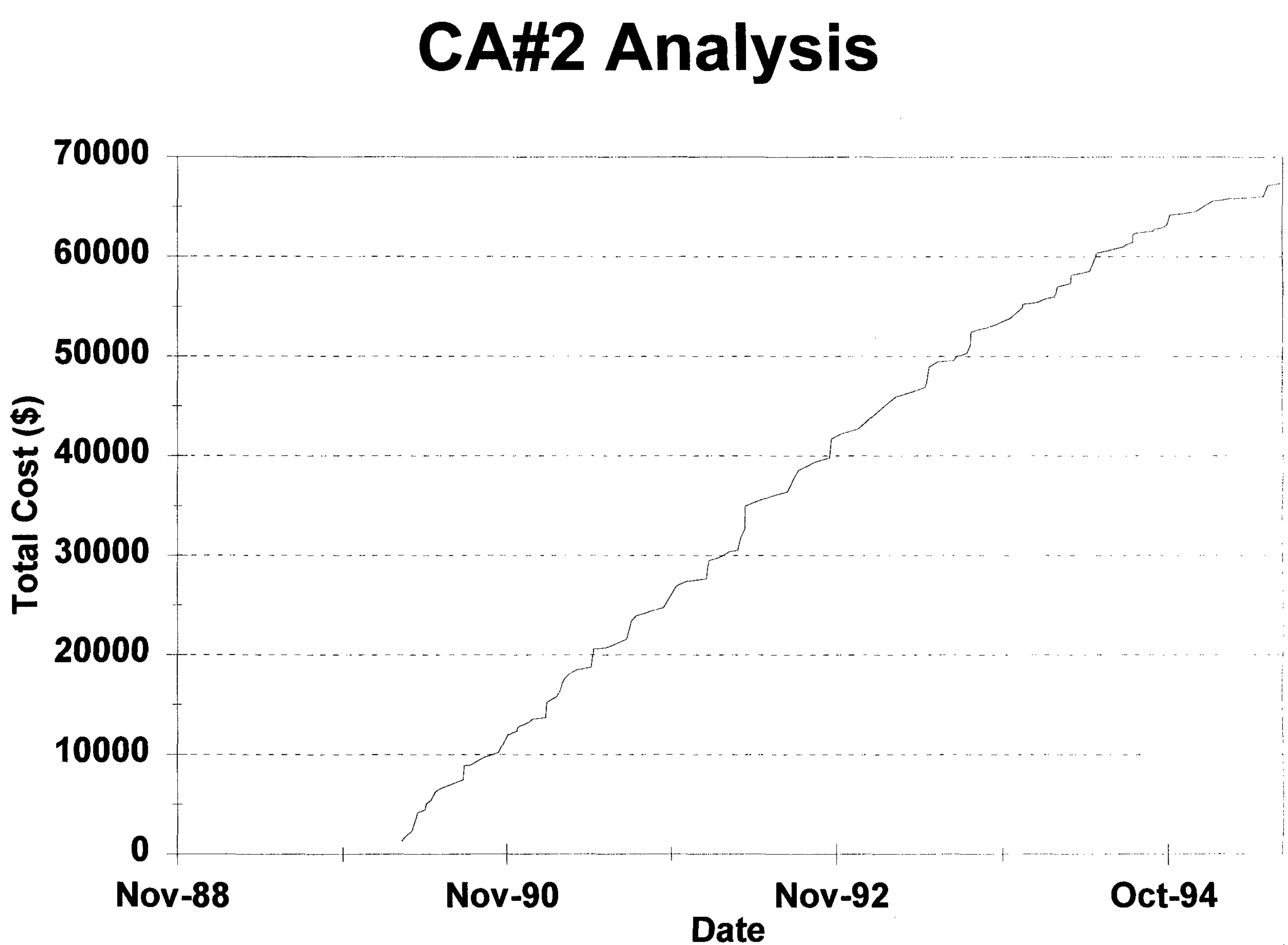

FIGURE 45: CALIFORNIA #2 ANALYSIS

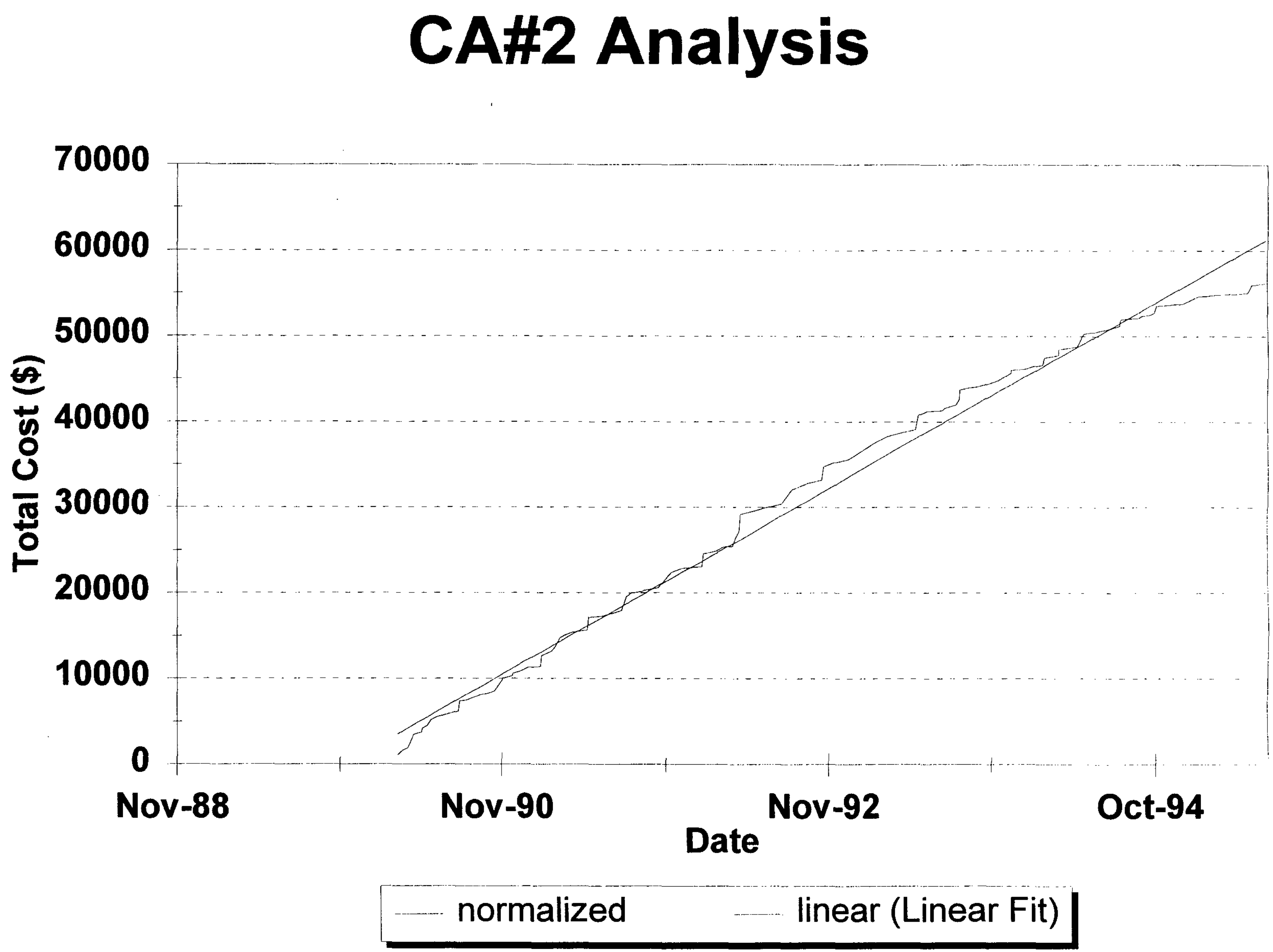

FIGURE 46: CALIFORNIA #2 ANALYSIS - NORMALIZED AND LINEAR

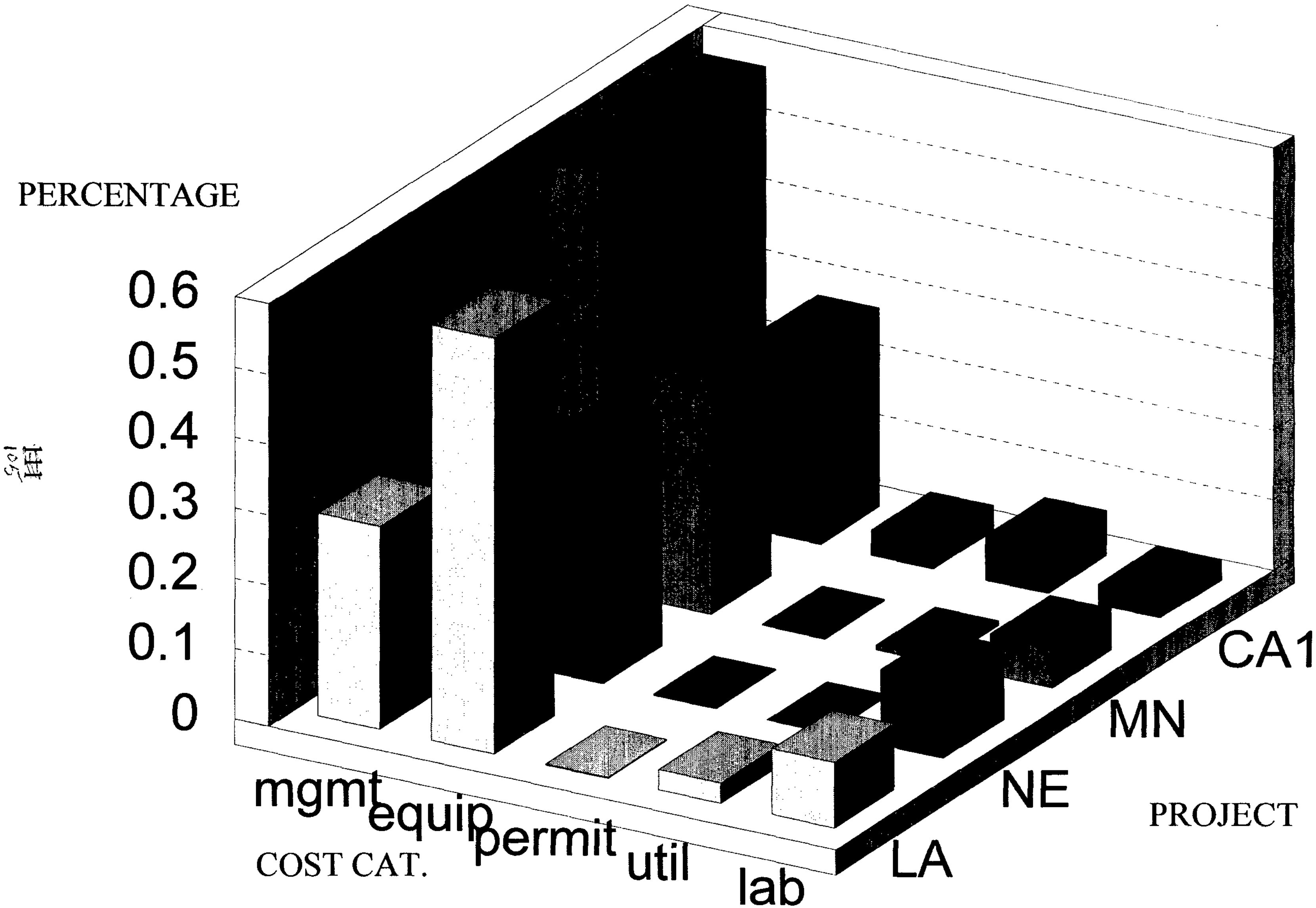

FIGURE 47: ALL PROJECTS PERCENTAGE COSTS BY COST CATEGORY

time frame of site investigation and project planning and coordinating are not included in the database. I would expect the percentages to be more like the other three projects had this data been available for use in this thesis.

The two other costs that seem to be the next highest are the laboratory analysis and utility costs. The reason for the Nebraska utilities being low is that the utility data wasn't in the database, and the reason the Minnesota utility cost is low is because the project remediation stage has just begun.

Analysis of Linear Regression Estimates

The linear regression estimates do not have much meaning when viewed alone, but when the information is put side by side, a lot of new insight can be gleaned. Table 9 shows all the regression data from the individual site analysis. The easiest way to approach interpreting the data is to find out why there are similarities and differences.

TABLE 9: LINEAR REGRESSION SLOPES

($/day)	NE	MN	LA	CA#1	CA#2
Equipment	$67.00	-	$68.26	$4.43	-
Management	$65.49	$62.39	$109.82	$57.97	-
Util- Elect **Gas**	- -	- -	$10.99 -	$2.52 $8.73	$10.41 $44.41
Analysis	$10.49	$5.79	$38.72	$3.73	$30.12

The equipment costs are a good place to start. The Nebraska and the Louisiana costs are very close to each other, but the California #1 is under one-fifteenth the cost of the other two. The California #1 data, at $4.43 per day, is over the last four years. The cost is minimal because little maintenance is required for the system. The Louisiana cost, at $68.26 per day, includes a flat $1525 per month maintenance charge for personnel costs, all materials are extra. If you subtract this from the total, it comes down to $18.00 per day. The Nebraska equipment includes an enclosed trailer at $1450 per month, and about $350 per month for sampling equipment. When these two costs are subtracted from the $67.00 per day, the total cost per day is reduced down to $6.00.

The management costs for all four projects are very similar. The Nebraska, Minnesota, and California projects hover around $60 per day, while the Louisiana project is almost $110 per day. I have no explanation for this other than the project involved more management man hours.

The utility costs are somewhat different. The California #1 site uses SVE with off gas treatment. The gas and electric are low compared to other sites. The Louisiana site used ground water treatment and soil vapor extraction, therefore it has a higher electric rate for pumping air and water. The California #2 site uses soil vapor extraction with thermal oxidation of the off-gas. It is a very large system as evidenced by the high gas and electric costs.

The analysis costs range from $3.73 per day, for the California #1 site, up to $38.72 per day, for the Louisiana site. Effluent monitoring is about the same for all the sites, but the major difference causing the cost range is the testing of monitoring wells to monitor the plume.

These costs can help us to predict future costs associated with projects similar in design, as seen in the bioventing estimation model.

Bioventing Cost Model

To create the simplified cost predicting model, all it takes is to gather and filter the data presented in this chapter. The total cost of the project will be the sum of all its parts. The phases of projects covered include initial clean-up, site investigation, construction, and operation. Monitoring after shutdown is not included because there was no data for this from the five projects used in this thesis. The parts in this model are permits, equipment, management, utility, and analysis costs.

Permitting costs for a bioventing system are minimal. The only permits required are building, well drilling, and soil venting. The exact cost varies from state to state, but because the costs are so low compared to the total cost (typically less than one percent) the cost for this will not be included in the model.

Equipment costs can be expected to occur in the order of magnitude shown in Figure 48.

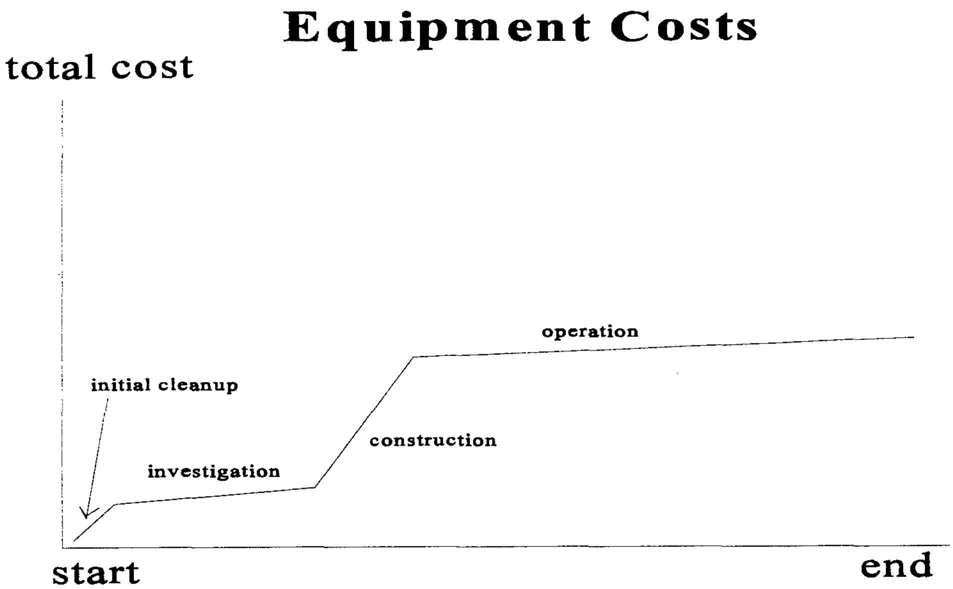

Figure 48: Projected Equipment Costs

The initial clean-up costs are very dependent on the site conditions. If the spill is new, excavation may be able to remove a lot of surface soil, but if the spill is deep, then little may be able to be done without spending a lot of money. The site investigation equipment costs are for monitoring/vent wells drilled to characterize the site. Construction equipment costs are very dependent on the system used, it is usually a very simple item with a relatively high one time price. There will be variations because of upgrades, catastrophic failure, and other site specific requirements. The operation equipment costs have been between $4 and $18 per day for the projects analyzed in this thesis.

Management costs can be expected to be relatively stable throughout the span of the project. There are periods of higher and lower activity, but in the five projects used in this thesis, the range of costs was from $57.97 to $109.82 per day, with the average of $73.92 per day.

Utility costs occur mainly during the period of system operation. Electric costs for the soil vapor extraction systems in this thesis ranged from $2.52 to $11.14 per day. A bioventing system requires slightly less energy because it moves less air. Therefore, it can be assumed the cost will be below $3.00 per day for the bioventing system.

Analysis costs had the widest variation among the systems studied in this thesis. The range encountered was from $3.73 to $38.72 per day. The reason for the wide variation depends on how closely the system in monitored. The $3.73 is for mainly only for monitoring off gas concentrations. The $38.72 includes off gas concentration testing and a lot of soil and groundwater tests. The actual cost for a bioventing project is dependent upon the sampling plan for the site.

The time for each phase is the only thing needed to complete this expense estimate/model. The initial clean-up is very short. The site characterization time can be expected to be at least a year, based on the timeline of the five projects used in this thesis. Construction time is not very long, typically much less than a year. Operation time is the biggest unknown. Models can be used to predict this, but the operation time usually goes a lot longer than expected.

A general equation could be:

Total Cost = Equipment + Management + Utilities + Analysis

where:
Equipment = IC + SI + RS + 5*OT
Management = 74 * (IT + CT + OT)
Utility = 3 * OT
Analysis = AC * (IT + CT + OT)

Per day Costs:
AC = Analysis ($/day)

Lump Sum Equipment Costs:
IC = Initial Cleanup ($)
SI = Site Investigation ($)
RS = Remediation System ($)

Periods of Time:
IT = Investigation Time (days)
CT = Construction Time (days)

OT = Operation Time (days)

Giving the final equation of :

Total ($)= IC + SI + RS + (86+AC)*OT + (74+AC)*(IT+CT)

This is a very simplistic and unproven equation, but I believe it is a good estimator of total expenses. As the expenses are fine tuned for specific site conditions, the estimating equation/model gets more and more accurate.

<u>Cost per Unit Analysis</u>

Of the five projects analyzed, only two sites had estimates of product removed, California #1 and Nebraska.

Figure 49 shows the estimate of product removed fro the California #1 site. The last estimate, in July of 1994, put the total product removed at about 75,000 pounds of gasoline removed, this is about 10,000 gallons. The cost in July 1994 is about $4 per pound. Figure 50 shows how the cost per unit has been going down since the removal has started, and over the past year-and-a-half, it has remained relatively constant at about four to five dollars. Soil vent effluent is still high enough to require catalytic

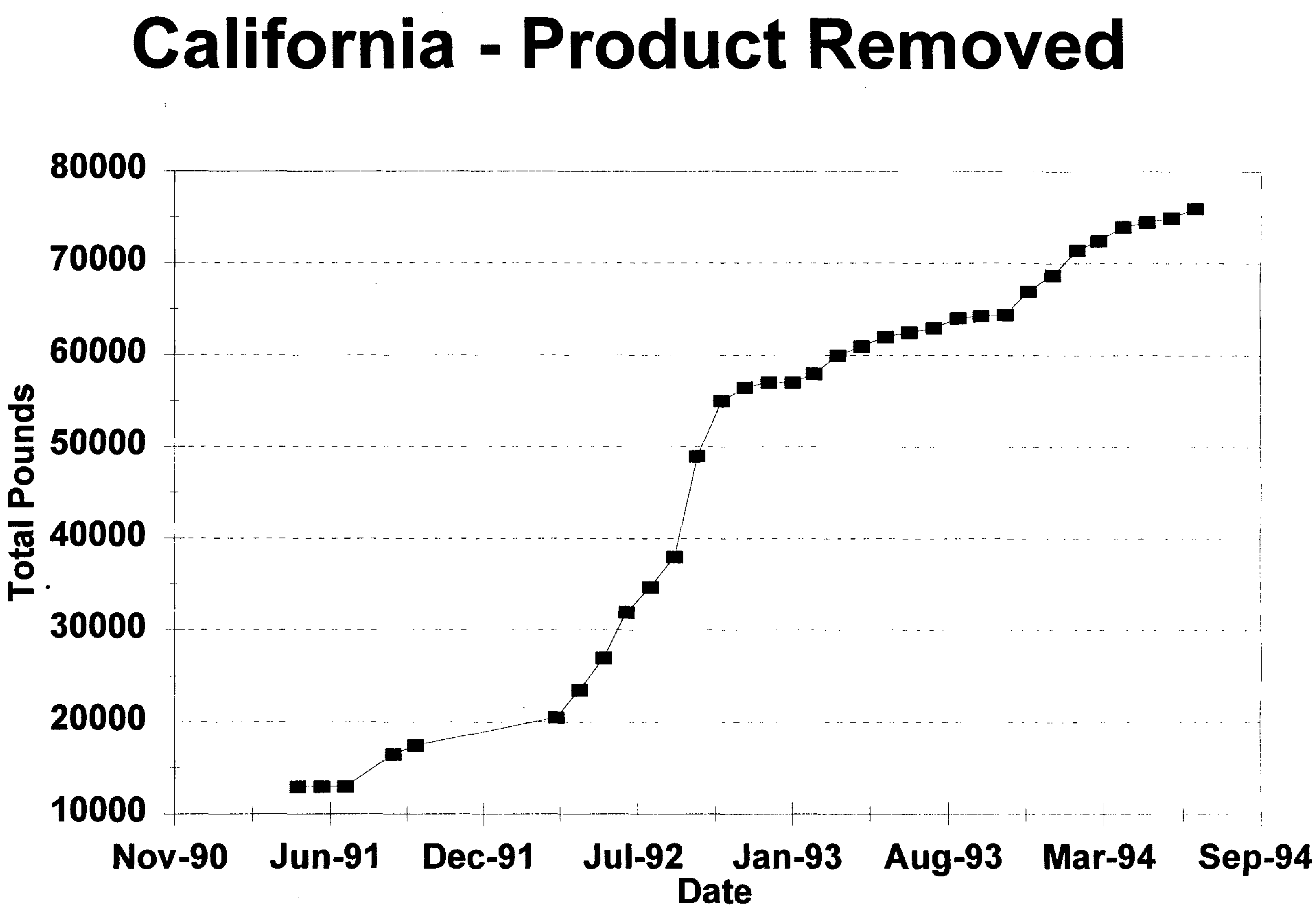

FIGURE 49: CALIFORNIA #1 PRODUCT REMOVED IN POUNDS

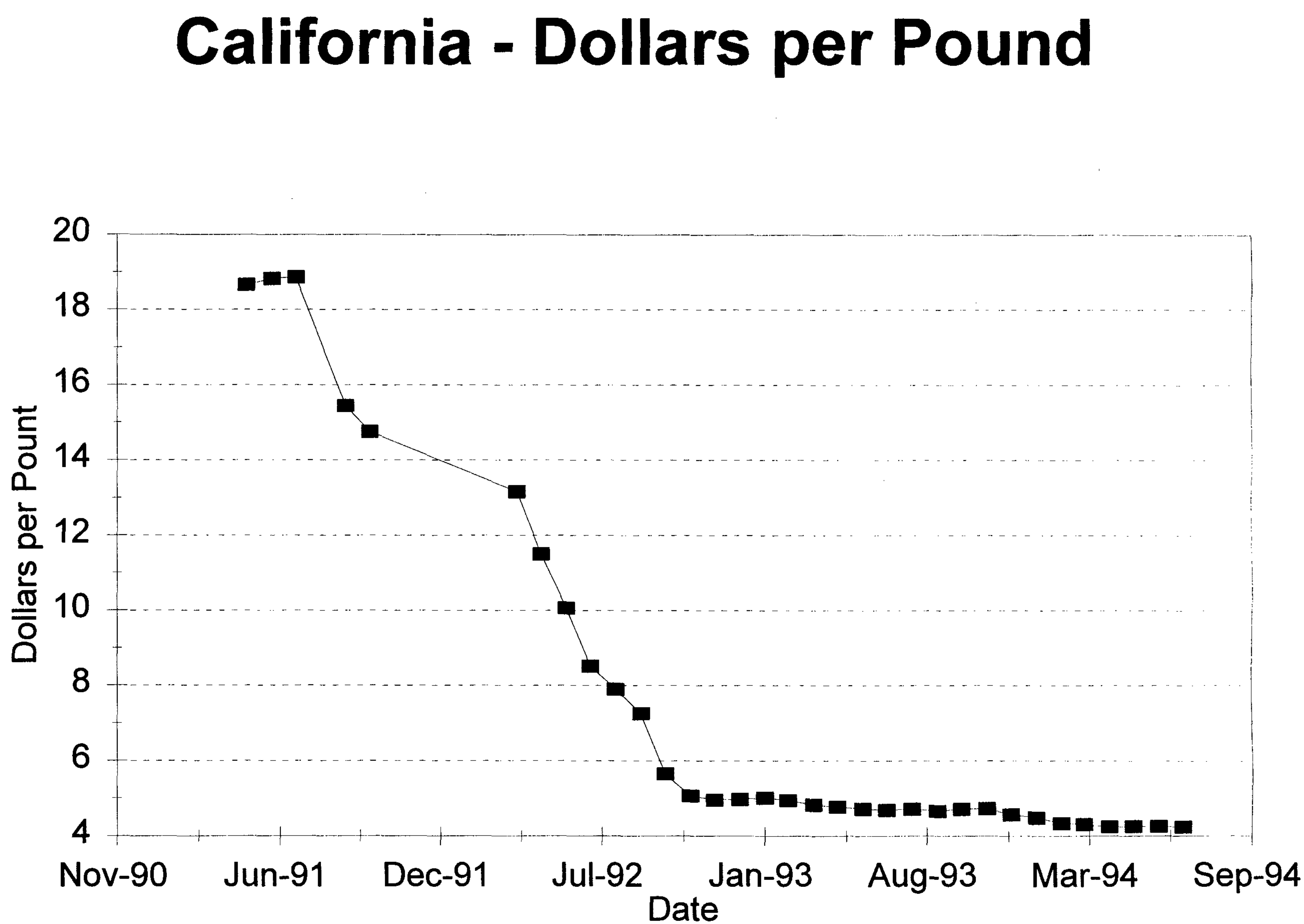

FIGURE 50: CALIFORNIA #1 DOLLARS PER POUND

oxidation, so the remediation should be going on for a while. It will be interesting to see what this cost goes to as the project gets near the end.

The Minnesota project is removing a lot less quantity of product. They estimate that, as of March 1994, 1730 gallons of product have been removed by the extraction system, as shown if Figure 51. Figure 52 shows that the cost per gallon removed is starting to settle down near $140 per gallon, or about $18 per pound of contaminant removed. This is much higher than the California #1 cost.

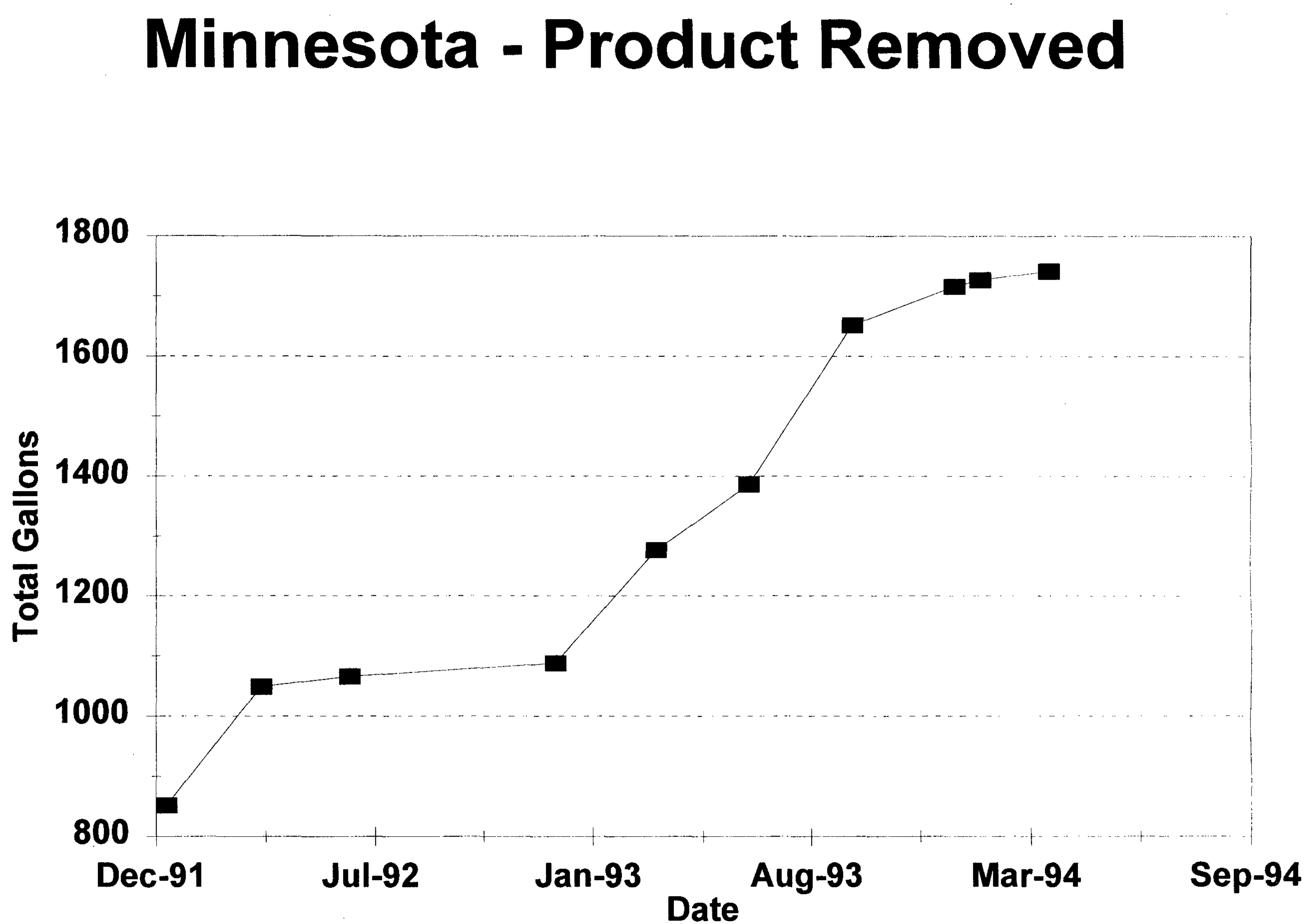

FIGURE 51: MINNESOTA PRODUCT REMOVED IN GALLONS

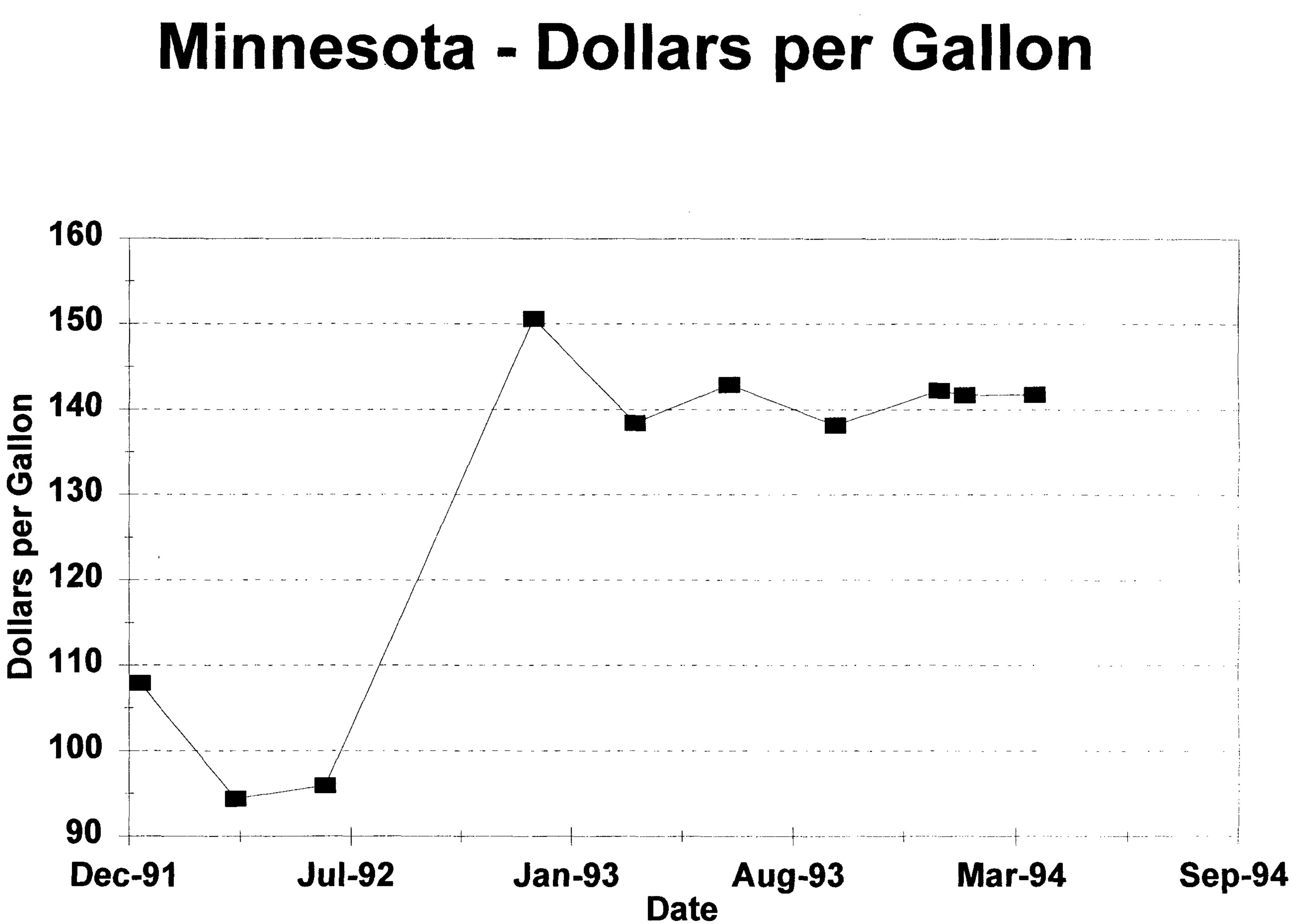

FIGURE 52: MINNESOTA DOLLARS PER GALLON

V. Conclusions and Recommendations

Overview

The objective of this research is to review, analyze, and predict costs associated with soil vapor extraction and bioventing remediation projects. Understanding how the costs are functions of time and other factors can increase our understanding of estimating future costs. The initial research questions to be answered were:

1. What are the major cost constituents incurred during a soil vapor extraction remediation project?
2. During what time frame are most of the costs incurred for each phase of cleanup?
3. Are there costs that are independent of level/area of contamination?
4. Can a simple cost model be developed for estimating bioventing remediation projects?

Conclusions

Question 1. The first question, what are the major cost constituents, was answered by the overall cost graphs for all the projects. Well over half the cost is for project management by the contractor. The second highest cost is for equipment, and utilities and analysis are very low in percentage of total cost.

Question 2. The second question to be answered is during what time frame are most of these costs incurred? It is easiest to give an answer for each cost category. The equipment costs are mostly during site investigations and construction/upgrade times. During other times, the cost increases relatively linear at a slow rate.

Management costs occur at surprisingly regular rate during the entire life of the project. There are some slightly higher rates around site investigations and construction, but for the most part, the cost is very linear. Utility costs are another cost that is very linear, as it should be. The only exceptions to this are upgrades or system shutdowns. Analysis costs are also surprisingly linear throughout the project.

Question 3. Are there costs that are independent of level/area of contamination? The answer to this question is that costs are not solely a function of level/area of contamination. High levels with large areas generally cost more to cleanup, but sometimes seemingly small areas can cost a lot because of management problems, which is the highest cost. Complexities in management can add a lot to the total cost of the project. Another way to look at the cost of the system is to analyze the cost per unit of product removed. In this case, the smaller projects usually have the higher cost per unit product removed, while the higher cost and larger projects seem more efficient.

Question 4. The final research question is whether or not a simplified cost model for bioventing can be made. I believe that understanding how the five cost categories (permits, equipment, management, utilities, and analysis) are a function of time can make estimating the total cost much easier. The model I have presented seems to follow all the "rules" defined by the projects analyzed, but the data I have cannot evaluate the equation for other projects. It will take using the equation in the real world to answer this question.

Recommendations

The original scope of this thesis was to provide an in depth analysis into the costs associated with bioventing projects. Due to the lack of data from actual bioventing projects, soil vapor extraction projects were used because of the similarities of the two systems. Performing the same analysis as done in this thesis applied to bioventing systems would be an excellent way to show the similarities between the two systems.

The lack of detail in the invoices lead to the use of only five cost categories. The petroleum company has instituted a more detailed cost database, but the newness of the system and the so far incomplete data prevented its use in this thesis. The actual costs may be documented in some files somewhere, but I was unable to get access to them, or they just weren't there. It would be a great service to the cost analysis of remediating system if this cost data could be used for analysis.

The models for estimating soil venting cleanup times are progressing rapidly. It would be of great value to use the efforts of this thesis and the output of those models to obtain the predicted actual costs for soil vapor extraction, air sparging, or bioventing systems.

Bioremediation Future

In my opinion, the future is very bright for bioremediation. California, as an example, is one of the first states to begin pushing for bioremediation of petroleum contaminated soils. Some regions even now require that bioremediation be explored first, before any other technologies for remediation are adopted (Gersberg and others, 1990:231).

There are many scientific discoveries that are waiting to be found that will enable bioremediation to be the best choice among remediation techniques. Some areas that I believe should be concentrated on are: improving site characterization and modeling, improving data on specific microorganisms and their degradation potentials, the effects of adding nutrients. Something else that I did not mention in this paper, but I believe needs additional attention, is the governments attitude towards allowing low level concentrations to remain in soils with low potential for risk exposure and the acceptance of new technologies. All these subjects are being investigated in some way as I write this, and I believe that biodegradation will be the only approved method of waste disposal in the future.

Appendix A: California #1 Data

Date	Cost Cat	Amount
9/28/85	3	$1,327.50
10/24/85	3	$8,224.60
11/12/85	5	$358.38
1/20/86	5	$19,496.48
5/9/86	5	$1,472.64
6/19/86	5	$306.08
7/17/86	5	$889.87
9/16/86	5	$6,568.80
10/9/86	5	$700.00
11/21/86	5	$2,589.08
12/29/86	5	$974.10
6/27/87	3	$815.00
6/27/87	5	$943.00
8/1/87	3	$309.88
8/1/87	5	$6,795.61
8/29/87	10	$1,124.50
8/29/87	3	$2,853.00
8/29/87	5	$3,470.65
9/26/87	5	$825.41
10/31/87	5	$1,365.00
11/28/87	5	$3,207.48
12/26/87	5	$962.25
1/30/88	5	$530.50
2/27/88	5	$1,150.00
4/30/88	3	$19,643.14
4/30/88	5	$17,934.03
5/28/88	10	$450.70
5/28/88	3	$15,066.20
5/28/88	5	$5,260.55
6/25/88	10	$175.00
6/25/88	3	$1,910.86
6/25/88	5	$1,818.50
7/30/88	5	$2,601.12
8/27/88	3	$132.24
9/24/88	3	$705.50
10/19/88	5	$248.56
11/28/88	2	$14.48
11/28/88	5	$2,332.07
12/20/88	5	$666.00
12/31/88	2	$2,182.50
1/20/89	5	$4,570.53
2/16/89	5	$9,060.51
3/16/89	5	$450.00
4/20/89	5	$2,612.56
4/30/89	2	$1,811.56
4/30/89	5	$19,864.85
5/22/89	3	$277.60
5/22/89	5	$5,772.50
6/20/89	3	$1,315.96
6/20/89	5	$96.00
7/20/89	5	$643.00
8/30/89	5	$752.00
10/12/89	3	$2,861.89
10/12/89	5	$4,876.90
10/20/89	2	$604.00
10/22/89	2	$2,652.10
10/29/89	3	$399.86
10/29/89	5	$2,794.60
11/16/89	3	$44,722.10
11/16/89	5	$10,503.02
11/20/89	7	$25.20
11/26/89	10	$1,302.38
11/26/89	3	$24.73
11/26/89	5	$3,889.19
12/12/89	5	$6,086.23
12/21/89	10	$467.36
12/21/89	5	$158.70
12/21/89	7	$44.00
12/24/89	3	$492.07
12/24/89	5	$1,095.00
12/29/89	3	$2,942.10
12/29/89	5	$5,712.50
1/3/90	7	$80.60
1/27/90	3	$832.65
1/27/90	5	$150.00
1/28/90	3	$81.41
1/28/90	5	$854.27
1/28/90	7	$65.00
1/31/90	2	$2,400.00
2/22/90	7	$24.21
3/2/90	5	$220.00
3/2/90	7	$232.50
3/5/90	7	$0.99
3/31/90	5	$260.00
3/31/90	5	$41.25
4/1/90	7	$14.11
4/30/90	5	$193.75
5/3/90	7	$16.36
5/27/90	2	$193.20
5/27/90	5	$333.33
5/27/90	7	$2,901.45
6/4/90	7	$13.62
8/1/90	7	$185.58
8/17/90	5	$390.00
9/14/90	5	$1,657.50
10/2/90	7	$505.79
10/8/90	10	$569.25
10/8/90	5	$2,730.60
10/31/90	7	$376.03
11/30/90	10	$1,106.88
11/30/90	5	$3,102.45
11/30/90	7	$601.53
12/3/90	7	$480.65
12/7/90	10	$442.75
12/7/90	5	$954.60
12/31/90	10	$379.50
12/31/90	5	$1,166.00
12/31/90	7	$263.37
12/31/90	7	$187.68
1/28/91	3	$17,701.01
1/30/91	7	$12.11
1/31/91	5	$1,192.50
1/31/91	7	$106.22
2/24/91	3	$348.78
2/24/91	5	$996.50
2/24/91	7	$12.11
3/4/91	7	$62.97
3/28/91	2	$336.00
3/28/91	2	$364.00
3/31/91	3	$159.07
3/31/91	5	$711.55
3/31/91	7	$28.43
4/25/91	7	$20.87

4/28/91	3	$687.95
4/28/91	5	$1,304.35
5/26/91	10	$863.25
5/26/91	5	$1,873.85
5/26/91	7	$31.17
6/3/91	7	$405.78
7/1/91	7	$396.29
8/1/91	7	$431.74
8/13/91	5	$12,502.03
9/3/91	7	$233.40
9/20/91	10	$1,081.00
9/20/91	3	$33.01
9/20/91	3	$554.11
9/20/91	5	$2,508.45
10/2/91	7	$245.46
11/2/91	7	$12.06
11/20/91	3	$183.14
11/20/91	5	$1,439.00
11/20/91	7	$105.28
12/18/91	3	$1,006.25
12/18/91	5	$382.30
12/18/91	7	$91.59
12/23/91	7	$13.03
1/23/92	7	$154.98
1/29/92	3	$122.00
1/29/92	5	$1,683.90
1/29/92	7	$11.50
1/31/92	7	$107.70
2/24/92	7	$107.70
2/25/92	5	$449.77
3/2/92	2	$384.00
3/2/92	2	$132.00
3/3/92	7	$197.80
3/9/92	2	$3,373.69
3/9/92	5	$75.00
3/9/92	7	$48.56
3/19/92	10	$140.80
3/20/92	5	$200.00
3/30/92	3	$449.77
3/30/92	5	$4,311.30
3/30/92	7	$97.19
4/2/92	7	$359.35
4/27/92	10	$128.00
4/30/92	7	$285.47
5/3/92	7	$548.75
5/22/92	5	$1,281.00
6/19/92	10	$140.80
6/19/92	3	$59.03
6/19/92	5	$981.50
7/24/92	10	$140.80
7/24/92	5	$2,175.00
8/1/92	7	$567.24
8/7/92	7	$506.96
9/2/92	10	$140.80
9/2/92	7	$557.24
9/8/92	7	$865.00
9/18/92	5	$877.35
9/22/92	10	$140.80
10/2/92	7	$422.51
10/23/92	10	$140.80
10/23/92	5	$2,293.98
11/17/92	10	$140.80
11/20/92	5	$1,434.00
12/1/92	7	$378.79
12/4/92	7	$524.77
12/4/92	7	$425.36
12/18/92	3	$1,434.00
12/18/92	5	$1,297.50
12/24/92	10	$140.80
1/1/93	7	$555.72
1/1/93	7	$315.50
1/22/93	10	$275.00
1/22/93	5	$1,660.00
2/1/93	7	$506.72
2/18/93	7	$140.56
2/25/93	5	$1,725.00
3/3/93	2	$384.00
3/3/93	2	$132.00
3/3/93	7	$302.10
3/9/93	7	$154.97
3/19/93	10	$140.80
3/24/93	5	$1,450.00
3/31/93	10	$236.80
4/1/93	7	$64.40
4/8/93	2	$212.60
4/8/93	7	$137.55
4/21/93	10	$140.80
4/28/93	5	$1,725.00
5/3/93	7	$207.59
5/21/93	10	$140.80
5/21/93	5	$1,725.00
6/2/93	7	$479.63
6/9/93	7	$165.61
6/16/93	10	$211.12
7/1/93	7	$325.79
7/3/93	3	$666.00
7/3/93	5	$1,017.00
7/9/93	7	$147.50
7/19/93	10	$140.80
7/23/93	10	$275.00
7/23/93	5	$1,450.00
7/31/93	5	$1,670.00
8/9/93	7	$293.03
8/10/93	2	$86.25
8/20/93	10	$140.80
8/31/93	3	$199.00
8/31/93	5	$1,882.00
9/3/93	7	$299.40
9/13/93	7	$24.61
9/24/93	3	$425.00
9/24/93	5	$2,154.05
9/27/93	10	$140.80
9/30/93	5	$2,023.39
10/5/93	7	$396.29
10/12/93	7	$119.14
10/29/93	10	$140.80
10/31/93	5	$1,494.50
11/3/93	7	$70.95
11/10/93	7	$139.55
11/26/93	10	$140.80
11/30/93	5	$1,764.50
12/6/93	7	$516.00
12/13/93	7	$172.58
12/17/93	5	$1,832.00
12/30/93	10	$281.60
1/1/94	7	$707.26
1/13/94	7	$172.13
1/17/94	10	$140.80
1/31/94	5	$1,832.00
2/2/94	10	$140.80

2/7/94	2	$54.73
2/8/94	7	$674.21
2/11/94	7	$169.58
2/24/94	10	$140.80
2/25/94	5	$1,742.00
3/11/94	2	$384.00
3/11/94	2	$96.00
3/21/94	7	$159.54
3/22/94	10	$140.80
3/25/94	5	$1,818.00
4/12/94	7	$666.89
4/12/94	7	$194.94
4/13/94	7	$156.91
4/20/94	10	$140.80
4/30/94	5	$1,953.25
5/4/94	7	$530.64
5/20/94	7	$160.01
5/24/94	10	$140.80
5/29/94	5	$1,877.00
6/1/94	2	$438.21
6/3/94	7	$499.49
6/30/94	10	$140.80
6/30/94	3	$1,348.77
6/30/94	5	$1,847.00
7/5/94	7	$588.66
7/8/94	7	$347.60
7/13/94	7	$174.69
7/26/94	10	$140.80
7/31/94	5	$1,891.25
8/4/94	7	$351.91
8/11/94	7	$65.15
8/12/94	10	$140.80
8/31/94	2	$37.55
8/31/94	3	$587.21
8/31/94	5	$2,246.00
9/2/94	7	$159.70
9/12/94	7	$122.94
9/23/94	10	$140.80
9/30/94	5	$1,849.00
9/30/94	5	$545.45
10/2/94	7	$36.71
10/4/94	7	$298.73
10/11/94	7	$59.11
10/18/94	10	$140.80
10/20/94	3	$720.00
10/20/94	5	$786.00
10/20/94	5	$3,040.47
11/9/94	7	$36.71
11/9/94	7	$14.39
11/15/94	5	$374.00
12/12/94	7	$10.80
12/16/94	5	$1,698.00
1/4/95	7	$18.54
1/12/95	7	$18.54
1/13/95	5	$1,698.00
1/31/95	5	$50.00
2/2/95	7	$13.76
2/10/95	7	$17.02
2/11/95	5	$1,698.00
2/24/95	10	$114.40
3/6/95	7	$657.70
3/10/95	2	$481.00
3/10/95	2	$110.00
3/10/95	5	$1,698.00
3/13/95	7	$241.84
3/15/95	5	$2,224.25
3/29/95	10	$114.40
4/4/95	7	$934.52
4/13/95	5	$1,698.00
4/19/95	10	$114.40
5/3/95	7	$813.14
5/5/95	5	$840.00
5/10/95	7	$47.86
5/12/95	5	$1,698.00
5/22/95	10	$114.40
6/2/95	7	$424.53
6/6/95	5	$1,698.00
6/9/95	7	$175.45

Appendix B: Minnesota Invoices

Date	Cost Cat	Amount
9/30/87	10	$375.00
9/30/87	3	$220.75
9/30/87	5	$3,854.00
10/31/87	10	$910.00
10/31/87	3	$7,022.19
10/31/87	5	$3,191.25
11/5/87	3	$2,794.86
11/18/87	5	$1,585.25
11/20/87	10	$60.00
11/20/87	3	$7,569.07
12/10/87	10	$60.00
12/12/87	5	$599.50
1/12/88	10	$110.00
1/19/88	5	$1,279.25
2/26/88	10	$288.00
2/26/88	3	$196.75
2/26/88	5	$602.00
3/25/88	10	$194.06
3/25/88	5	$902.25
4/30/88	10	$190.00
4/30/88	5	$414.00
5/25/88	5	$87.50
6/22/88	10	$67.25
6/22/88	3	$10.25
6/22/88	5	$181.50
7/29/88	10	$67.50
7/29/88	5	$99.00
8/22/88	10	$67.50
8/22/88	5	$128.00
9/30/88	5	$75.00
10/31/88	10	$70.50
10/31/88	3	$1,987.25
10/31/88	5	$1,059.50
11/3/88	10	$445.00
11/28/88	5	$543.00
12/9/88	10	$416.00
12/21/88	5	$377.17
12/29/88	5	$718.00
1/12/89	10	$80.00
1/28/89	5	$1,537.00
2/22/89	5	$215.00
3/30/89	10	$503.00
3/30/89	3	$62.50
3/30/89	5	$1,723.25
4/30/89	5	$1,153.25
5/31/89	10	$985.00
5/31/89	3	$480.00
5/31/89	5	$2,721.75
6/20/89	10	$581.60
6/30/89	5	$2,023.60
7/31/89	5	$291.25
8/1/89	10	$65.00
8/22/89	5	$734.00
9/13/89	10	$713.00
9/14/89	5	$214.72
10/30/89	5	$184.75
11/13/89	5	$696.86
12/14/89	10	$648.00
12/14/89	5	$521.75
1/29/90	5	$594.25
2/28/90	3	$65.00
2/28/90	5	$628.25
3/28/90	5	$173.00
4/27/90	3	$65.00
4/27/90	5	$816.00
5/31/90	10	$580.00
5/31/90	5	$504.00
6/7/90	5	$292.00
7/30/90	10	$560.00
7/30/90	3	$198.00
7/30/90	5	$476.50
8/31/90	3	$3,868.41
8/31/90	5	$2,997.75
9/30/90	10	$420.00
9/30/90	3	$3,438.10
9/30/90	5	$1,548.50
10/31/90	3	$1,069.50
10/31/90	5	$650.25
11/27/90	10	$60.00
11/27/90	3	$58.00
11/27/90	5	$488.50
12/31/90	10	$700.00
12/31/90	3	$334.50
12/31/90	5	$562.50
1/31/91	10	$60.00
1/31/91	3	$39.00
1/31/91	5	$690.00
2/28/91	3	$40.40
2/28/91	5	$938.25
3/25/91	3	$144.00
3/28/91	10	$560.00
3/31/91	5	$547.75
4/25/91	3	$39.00
4/30/91	5	$349.25
5/29/91	10	$477.25
5/29/91	3	$1,082.50
5/31/91	5	$4,278.00
6/17/91	3	$231.45
6/28/91	5	$916.00
7/16/91	10	$414.00
7/16/91	3	$86.50
7/30/91	5	$310.00
8/15/91	3	$177.80
8/30/91	5	$788.50
9/26/91	10	$414.00
9/30/91	5	$2,130.30
10/22/91	3	$52.55
10/31/91	5	$2,048.00
11/27/91	5	$2,271.25
12/20/91	3	$121.71
12/20/91	5	$3,075.75
1/31/92	10	$523.25
1/31/92	3	$121.90
1/31/92	5	$4,221.50
2/28/92	5	$1,513.75
3/27/92	5	$937.50
4/30/92	10	$89.70
4/30/92	3	$342.54
4/30/92	5	$842.50
5/29/92	5	$1,681.00
6/22/92	3	$424.10
6/26/92	5	$4,090.25
6/30/92	10	$503.70
7/30/92	10	$322.00
7/30/92	3	$4,290.88

7/31/92	5	$17,360.25
8/30/92	5	$2,443.37
9/30/92	10	$517.50
9/30/92	5	$4,416.76
10/23/92	2	$351.90
10/30/92	3	$489.74
10/30/92	5	$6,672.50
11/25/92	3	$12,878.11
11/25/92	5	$11,671.50
12/31/92	10	$517.50
12/31/92	3	$4,380.99
12/31/92	5	$2,611.50
1/29/93	5	$1,872.25
2/28/93	3	$334.34
2/28/93	5	$3,975.75
4/1/93	3	$7,119.30
4/1/93	5	$7,910.00
4/29/93	3	$5,210.61
4/29/93	5	$1,035.25
5/27/93	5	$1,634.00
7/1/93	3	$6,116.05
7/1/93	5	$2,356.00
7/30/93	10	$296.70
7/30/93	3	$10,051.63
7/30/93	5	$10,105.50
9/3/93	10	$25.00
9/3/93	3	$1,299.47
9/3/93	5	$1,819.50
9/16/93	7	$94.90
10/1/93	10	$276.00
10/1/93	3	$6,038.16
10/1/93	5	$4,313.50
10/8/93	10	$57.50
10/21/93	10	$466.90
10/21/93	3	$514.80
10/21/93	5	$1,579.50
11/30/93	3	$45.17
11/30/93	5	$526.50
12/26/93	2	$75.00
12/29/93	10	$310.50
12/29/93	3	$908.73
12/29/93	5	$1,930.50
1/17/94	5	$627.25
1/27/94	3	$313.00
2/25/94	3	$274.32
2/25/94	5	$747.75
3/25/94	10	$276.00
3/25/94	3	$318.80
3/25/94	5	$538.25
4/26/94	10	$103.50
4/26/94	3	$264.70
4/26/94	5	$2,282.75
5/31/94	3	$41.32
5/31/94	5	$723.00
6/27/94	10	$310.50
6/27/94	3	$428.44
6/27/94	5	$1,037.50
7/22/94	3	$189.44
7/22/94	5	$828.50
9/30/94	5	$503.00
10/31/94	10	$356.40
10/31/94	3	$398.72
10/31/94	5	$1,253.51
11/30/94	3	$175.00
11/30/94	5	$939.40
12/15/94	7	$383.46
12/30/94	5	$1,159.23
1/18/95	7	$349.44
1/31/95	10	$291.60
1/31/95	3	$558.38
1/31/95	5	$1,476.62
2/16/95	7	$358.87
2/28/95	3	$180.00
2/28/95	5	$1,668.90
3/17/95	7	$346.71
4/18/95	7	$288.28

Appendix C: Nebraska Data

Date	Cost Cat	Amount
7/30/90	5	$776.25
10/9/90	5	$107.50
4/4/91	5	$63.75
2/28/92	5	$1,437.50
3/27/92	3	$16.00
3/27/92	5	$879.75
4/30/92	3	$451.03
4/30/92	5	$2,045.50
5/31/92	3	$58.45
5/31/92	5	$15,917.05
6/26/92	10	$4,320.55
6/27/92	5	$2,338.96
7/28/92	2	$170.20
7/31/92	5	$3,249.25
8/28/92	10	$1,167.25
8/28/92	2	$5.75
8/28/92	3	$161.59
8/28/92	5	$1,668.25
9/21/92	5	$240.25
11/25/92	3	$153.23
11/25/92	5	$2,849.50
12/22/92	10	$1,087.50
12/22/92	5	$1,477.25
3/23/93	10	$776.25
3/23/93	3	$225.12
3/23/93	5	$802.00
5/28/93	3	$92.83
5/28/93	5	$1,125.50
6/30/93	3	$9,504.71
6/30/93	5	$8,090.75
7/30/93	10	$2,018.25
7/30/93	5	$6,591.50
9/3/93	3	$25.00
9/3/93	5	$364.75
9/27/93	10	$632.50
9/27/93	2	$23.00
9/27/93	3	$198.75
9/27/93	5	$572.75
10/26/93	5	$192.75
10/28/93	3	$509.55
11/30/93	10	$632.50
11/30/93	2	$34.50
11/30/93	3	$294.13
11/30/93	5	$805.25
12/30/93	5	$454.00
1/28/94	5	$594.50
2/24/94	5	$470.50
3/30/94	5	$832.00
4/4/94	5	$18.75
5/31/94	5	$709.25
6/30/94	5	$507.75
7/29/94	3	$15,285.12
7/29/94	5	$7,148.25
8/30/94	10	$310.50
8/30/94	3	$5,246.36
8/30/94	5	$2,087.00
9/30/94	10	$1,667.50
9/30/94	3	$2,054.38
9/30/94	5	$1,039.25
10/31/94	10	$102.60
10/31/94	3	$1,852.48
10/31/94	5	$1,168.00
11/30/94	10	$102.60
11/30/94	3	$337.76
11/30/94	5	$1,318.25
12/30/94	10	$661.20
12/30/94	3	$2,568.60
12/30/94	5	$2,515.00
1/30/95	10	$205.20
1/30/95	3	$2,021.32
1/30/95	5	$995.25
2/27/95	10	$102.60
2/27/95	3	$1,952.88
2/27/95	5	$1,550.75

Appendix D: Louisiana Data

Date	Cost Cat	Amount
6/29/91	10	$929.00
6/29/91	5	$1,871.60
6/29/91	7	$103.65
7/27/91	10	$1,155.00
7/27/91	3	$3,375.68
7/27/91	5	$148.94
7/27/91	7	$259.47
8/31/91	10	$1,155.00
8/31/91	3	$2,434.26
8/31/91	5	$2,146.75
8/31/91	7	$254.81
9/30/91	10	$1,155.00
9/30/91	3	$2,484.26
9/30/91	5	$1,320.50
9/30/91	7	$269.27
10/26/91	10	$1,155.00
10/26/91	3	$5,255.96
10/26/91	5	$325.19
10/26/91	7	$322.18
11/30/91	3	$21,054.63
11/30/91	5	$4,956.51
11/30/91	7	$308.91
12/24/91	3	$13,028.14
12/24/91	5	$1,667.98
12/24/91	7	$308.95
12/28/91	5	$437.59
2/1/92	10	$1,105.50
2/1/92	3	$5,657.57
2/1/92	5	$5,607.10
2/1/92	7	$336.13
3/28/92	10	$2,172.60
3/28/92	3	$13,213.95
3/28/92	5	$3,393.23
3/28/92	7	$449.26
5/2/92	10	$1,017.50
5/2/92	3	$3,818.09
5/2/92	5	$717.50
5/2/92	7	$272.49
5/30/92	10	$929.50
5/30/92	3	$3,068.86
5/30/92	5	$2,203.05
5/30/92	7	$277.50
6/27/92	10	$1,155.00
6/27/92	3	$3,452.73
6/27/92	5	$1,803.00
6/27/92	7	$309.36
8/1/92	10	$1,105.50
8/1/92	3	$3,865.23
8/1/92	5	$3,119.40
8/1/92	7	$250.55
8/29/92	10	$1,353.00
8/29/92	3	$78,518.00
8/29/92	5	$10,704.55
8/29/92	7	$226.63
9/26/92	10	$506.00
9/26/92	3	$20,637.54
9/26/92	5	$3,013.90
9/26/92	7	$97.00
10/31/92	10	$968.00
10/31/92	3	$2,696.07
10/31/92	5	$3,644.71
10/31/92	7	$30.45
11/5/92	10	$210.00
11/27/92	10	$180.00
11/28/92	10	$1,017.50
11/28/92	5	$5,468.00
11/28/92	7	$40.33
1/2/93	10	$1,017.50
1/2/93	3	$9,123.71
1/2/93	5	$3,326.75
1/2/93	7	$120.65
1/20/93	10	$180.00
1/30/93	10	$1,155.00
1/30/93	3	$1,525.00
1/30/93	5	$3,991.79
1/30/93	7	$156.65
2/25/93	10	$180.00
2/27/93	10	$1,155.00
2/27/93	3	$2,454.45
2/27/93	5	$3,167.30
2/27/93	7	$330.90
4/3/93	10	$1,155.00
4/3/93	3	$1,678.41
4/3/93	5	$3,673.23
4/3/93	7	$469.00
4/14/93	10	$210.00
4/16/93	10	$210.00
5/1/93	10	$1,155.00
5/1/93	3	$1,525.00
5/1/93	5	$534.85
5/1/93	7	$436.50
5/28/93	3	$1,525.00
5/29/93	10	$1,320.00
5/29/93	3	$1,655.75
5/29/93	5	$2,215.40
5/29/93	7	$534.67
6/17/93	10	$210.00
7/3/93	10	$790.99
7/3/93	3	$3,088.24
7/3/93	5	$322.65
7/3/93	7	$684.12
7/31/93	10	$801.30
7/31/93	3	$1,062.63
7/31/93	5	$1,116.70
7/31/93	7	$56.62
8/28/93	10	$733.98
8/28/93	2	$352.23
8/28/93	3	$1,099.16
8/28/93	5	$2,732.69
8/28/93	7	$58.33
9/20/93	10	$360.00
10/2/93	10	$869.56
10/2/93	3	$3,789.53
10/2/93	5	$5,819.51
10/2/93	7	$277.45
10/19/93	10	$210.00
10/30/93	10	$929.39
10/30/93	3	$1,525.00
10/30/93	5	$1,984.29
10/30/93	7	$499.02
11/29/93	10	$195.00
12/27/93	10	$210.00
1/1/94	10	$916.80

1/1/94	3	$1,525.00
1/1/94	5	$3,008.23
1/1/94	7	$327.62
1/29/94	10	$929.39
1/29/94	3	$1,525.00
1/29/94	5	$3,262.61
1/29/94	7	$235.97
2/21/94	10	$210.00
2/26/94	10	$936.88
2/26/94	3	$1,525.00
2/26/94	5	$3,205.43
2/26/94	7	$415.36
4/2/94	10	$135.58
4/2/94	3	$1,525.00
4/2/94	5	$2,856.40
4/2/94	7	$472.68
4/30/94	3	$1,525.00
4/30/94	7	$506.53
5/28/94	10	$801.30
5/28/94	5	$1,293.06
5/28/94	7	$553.58
6/7/94	10	$210.00
6/25/94	10	$135.58
6/25/94	5	$2,557.75
6/25/94	7	$577.93
7/30/94	5	$3,590.00
7/30/94	7	$53.87
8/12/94	7	$49.50
8/27/94	10	$810.30
8/27/94	5	$2,446.53
10/29/94	3	$4,063.33
10/29/94	5	$3,515.24
11/26/94	5	$583.82
12/31/94	5	$1,415.50

Appendix E: California #2 Data

Date	Cost Cat	Amount
11/28/88	5	$14,795.90
12/19/88	5	$10,133.88
1/20/89	5	$8,407.62
2/16/89	5	$12,980.75
3/16/89	5	$5,088.37
4/20/89	5	$6,441.00
5/22/89	5	$4,059.17
6/19/89	5	$300.00
7/20/89	5	$8,018.81
8/30/89	5	$13,945.60
9/23/89	5	$4,319.59
10/22/89	5	$6,757.13
11/20/89	5	$7,872.31
12/21/89	5	$9,853.25
1/23/90	5	$10,486.15
1/27/90	5	$2,048.84
2/19/90	5	$7,223.23
3/16/90	5	$6,954.77
4/1/90	10	$1,324.80
4/5/90	5	$567.00
4/12/90	10	$648.00
4/17/90	10	$172.80
4/18/90	5	$16,954.27
4/23/90	10	$172.80
5/7/90	10	$1,900.80
5/15/90	10	$115.20
5/22/90	5	$27,832.12
5/23/90	10	$172.80
5/25/90	10	$576.00
6/5/90	10	$340.80
6/15/90	10	$864.00
6/19/90	2	$276.00
6/20/90	10	$172.80
6/21/90	5	$14,742.32
6/27/90	10	$172.80
7/20/90	5	$18,269.01
8/8/90	2	$1,515.43
8/14/90	10	$840.00
8/17/90	10	$1,411.20
8/17/90	5	$12,422.42
8/28/90	5	$290.00
8/31/90	10	$86.40
9/17/90	10	$477.60
9/20/90	5	$19,039.96
9/24/90	10	$158.56
10/2/90	10	$172.80
10/16/90	10	$172.80
10/21/90	5	$36,247.69
11/1/90	10	$276.32
11/19/90	10	$1,633.20
11/19/90	5	$32,999.38
11/20/90	10	$158.40
11/28/90	10	$158.40
12/11/90	10	$198.00
12/12/90	10	$364.56
12/17/90	10	$140.80
12/20/90	5	$14,130.75
12/26/90	10	$140.80
1/7/91	10	$281.60
1/8/91	5	$355.71
1/14/91	10	$281.60
1/14/91	5	$140.80
1/22/91	5	$42,830.12
2/5/91	5	$624.00
2/11/91	10	$140.80
2/14/91	10	$1,548.80
2/20/91	5	$35,019.26
2/26/91	5	$140.80
2/27/91	2	$240.00
3/5/91	5	$128.00
3/8/91	10	$576.00
3/15/91	10	$563.20
3/15/91	5	$60,903.50
3/21/91	10	$704.00
3/26/91	10	$573.12
3/27/91	7	$196.80
4/5/91	10	$400.80
4/12/91	7	$24.08
4/22/91	10	$422.40
5/24/91	10	$281.60
5/25/91	7	$51.53
5/28/91	10	$1,831.00
6/19/91	5	$40,333.65
6/26/91	10	$140.80
6/27/91	7	$54.66
7/2/91	10	$128.00
7/2/91	5	$3,253.03
7/11/91	5	$54,430.33
7/16/91	7	$127.91
7/18/91	10	$281.60
7/22/91	5	$37.50
7/25/91	5	$5,477.20
7/26/91	5	$165.15
7/31/91	7	$91.42
8/5/91	5	$18,311.46
8/8/91	10	$432.00
8/12/91	5	$6,500.00
8/19/91	10	$1,914.60
8/19/91	5	$52,891.17
8/20/91	5	$4,370.00
8/20/91	7	$455.15
8/23/91	10	$140.80
8/27/91	7	$22.18
8/29/91	10	$288.00
9/1/91	5	$300.00
9/18/91	5	$790.00
9/19/91	5	$30,182.41
9/23/91	10	$352.00
9/27/91	10	$80.00
9/27/91	7	$50.83
9/30/91	7	$252.07
10/18/91	5	$28,302.12
10/28/91	10	$352.00
10/29/91	7	$43.00
11/18/91	5	$28,582.83
11/25/91	10	$2,182.40
11/26/91	7	$36.57
12/2/91	10	$169.60
12/19/91	5	$30,727.67
12/20/91	10	$352.00
12/26/91	7	$40.43
12/30/91	7	$675.10
1/22/92	5	$22,890.23

1/23/92	2	$3,108.16
1/28/92	5	$1,264.10
1/28/92	7	$406.54
1/30/92	10	$281.60
1/30/92	7	$26.80
1/31/92	2	$641.03
2/3/92	10	$1,804.80
2/14/92	7	$257.36
2/20/92	5	$16,353.07
2/24/92	10	$281.60
2/27/92	7	$55.87
2/28/92	7	$290.17
3/2/92	2	$516.00
3/4/92	10	$140.80
3/5/92	10	$70.40
3/17/92	7	$425.37
3/19/92	10	$422.40
3/20/92	5	$8,248.81
3/20/92	7	$2,669.89
3/23/92	2	$265.53
3/23/92	5	$300.00
3/26/92	7	$57.28
4/6/92	10	$80.00
4/13/92	10	$1,267.20
4/21/92	5	$33,910.99
4/21/92	7	$571.95
4/22/92	10	$909.92
4/22/92	5	$92.58
4/23/92	5	$300.00
4/24/92	10	$2,323.20
4/27/92	7	$85.88
5/6/92	7	$506.75
5/21/92	7	$404.12
5/22/92	10	$492.80
5/22/92	5	$10,410.68
5/22/92	7	$512.17
5/27/92	7	$1,945.15
5/28/92	7	$28.17
5/29/92	7	$1,922.91
6/1/92	2	$840.00
6/3/92	5	$92.58
6/8/92	5	$18,000.00
6/11/92	7	$601.19
6/19/92	10	$492.00
6/21/92	5	$6,596.37
6/21/92	7	$1,922.91
6/25/92	7	$26.45
7/1/92	7	$1,782.27
7/24/92	10	$422.70
7/27/92	7	$24.53
7/29/92	5	$10,079.50
7/30/92	7	$1,151.93
7/31/92	2	$641.03
8/1/92	7	$24.43
8/17/92	10	$2,147.20
8/17/92	7	$545.50
8/26/92	5	$4,271.67
8/28/92	5	$5,995.00
8/28/92	7	$1,286.09
9/4/92	10	$422.40
9/8/92	5	$6,542.85
9/11/92	7	$493.92
9/14/92	5	$640.00
9/18/92	5	$1,000.00
9/21/92	7	$1,217.14
9/22/92	10	$422.40
9/25/92	5	$4,116.40
9/28/92	7	$25.74
9/30/92	5	$1,082.10
10/1/92	7	$1,172.84
10/23/92	10	$422.40
10/24/92	5	$1,080.00
10/26/92	7	$1,124.62
10/28/92	10	$1,900.80
10/28/92	5	$15,390.19
10/30/92	7	$58.08
11/18/92	10	$492.80
11/25/92	5	$14,885.68
11/25/92	7	$58.44
12/1/92	7	$514.50
12/11/92	5	$6,273.00
12/22/92	5	$10,164.26
12/22/92	7	$1,120.54
12/24/92	10	$492.80
1/1/93	7	$4,124.44
1/19/93	7	$487.32
1/28/93	5	$3,948.91
1/28/93	7	$26.10
1/30/93	5	$40.00
1/31/93	7	$1,184.42
2/1/93	2	$774.00
2/10/93	5	$9,740.94
2/11/93	7	$500.39
2/19/93	10	$2,257.20
2/21/93	7	$24.50
2/23/93	7	$447.74
2/25/93	5	$9,633.06
2/28/93	7	$1,174.16
3/8/93	5	$3,005.00
3/15/93	7	$26.95
3/19/93	10	$968.00
3/24/93	5	$5,274.00
3/26/93	5	$610.00
3/26/93	7	$58.37
3/31/93	7	$1,185.41
4/1/93	7	$236.58
4/8/93	5	$2,047.88
4/16/93	7	$857.85
4/21/93	10	$492.00
4/28/93	5	$4,240.00
4/28/93	7	$33.51
4/30/93	7	$1,273.97
5/3/93	7	$337.65
5/18/93	7	$1,397.24
5/21/93	10	$493.00
5/21/93	5	$4,592.53
5/24/93	7	$27.82
5/28/93	10	$2,041.60
6/2/93	7	$324.72
6/3/93	7	$24.50
6/16/93	10	$492.80
6/17/93	7	$1,032.65
6/22/93	7	$25.37
6/23/93	5	$4,337.00
6/25/93	7	$26.39
6/27/93	5	$40.00
6/30/93	7	$1,133.79
7/1/93	7	$238.55
7/5/93	5	$4,116.30
7/19/93	10	$140.80

7/21/93	7	$1,217.94
7/23/93	5	$4,155.88
7/26/93	10	$352.00
7/31/93	7	$1,142.35
8/2/93	7	$283.64
8/4/93	7	$1,162.33
8/5/93	5	$10,549.72
8/10/93	5	$1,734.03
8/18/93	10	$422.40
8/20/93	5	$418.61
8/25/93	10	$774.40
8/26/93	7	$89.24
8/27/93	10	$1,337.60
8/31/93	7	$3,361.98
9/3/93	5	$10,227.80
9/3/93	7	$1,467.15
9/16/93	10	$281.60
9/27/93	7	$25.52
9/28/93	7	$68.92
9/30/93	10	$128.00
10/5/93	5	$7,601.31
10/5/93	7	$2,534.03
10/22/93	10	$352.00
10/28/93	7	$38.47
10/29/93	10	$140.80
10/31/93	7	$1,700.35
11/3/93	7	$1,532.79
11/5/93	5	$5,917.63
11/19/93	10	$422.40
11/21/93	7	$410.03
11/25/93	7	$43.48
11/30/93	7	$3,344.72
12/2/93	7	$287.92
12/5/93	5	$8,026.85
12/6/93	7	$2,810.00
12/16/93	10	$1,126.40
12/17/93	10	$325.60
12/18/93	5	$4,783.60
12/21/93	7	$25.52
12/29/93	7	$32.38
1/1/94	7	$4,226.45
1/6/94	7	$693.52
1/17/94	10	$140.80
1/31/94	2	$211.63
2/1/94	7	$70.17
2/2/94	10	$352.00
2/4/94	5	$5,948.50
2/7/94	7	$85.13
2/8/94	7	$2,566.21
2/9/94	7	$27.07
2/14/94	2	$516.00
2/23/94	10	$211.20
2/23/94	7	$36.29
2/28/94	10	$1,046.00
3/1/94	7	$3,764.90
3/3/94	5	$3,943.00
3/8/94	7	$252.94
3/10/94	5	$40.00
3/22/94	10	$211.20
3/25/94	7	$56.01
3/30/94	10	$140.80
3/31/94	10	$828.80
3/31/94	5	$15,376.68
4/4/94	7	$1,788.30
4/6/94	7	$421.24

4/12/94	7	$3,040.13
4/20/94	10	$140.80
4/25/94	7	$39.55
5/1/94	7	$2,819.35
5/3/94	5	$4,620.47
5/4/94	7	$1,558.14
5/10/94	10	$211.20
5/23/94	10	$1,619.20
5/24/94	10	$140.80
5/24/94	7	$46.81
5/27/94	10	$70.40
5/31/94	5	$6,392.23
5/31/94	7	$1,680.39
6/1/94	5	$2,126.38
6/1/94	7	$2,615.80
6/6/94	7	$27.37
6/7/94	2	$420.00
6/14/94	7	$577.07
6/17/94	10	$211.20
6/30/94	10	$180.80
7/1/94	7	$2,092.77
7/6/94	5	$6,243.76
7/6/94	7	$3,642.16
7/22/94	10	$281.60
7/26/94	10	$140.80
7/27/94	7	$79.31
8/1/94	7	$1,660.99
8/3/94	5	$12,929.81
8/3/94	7	$3,433.53
8/4/94	7	$279.54
8/11/94	10	$281.60
8/12/94	10	$774.40
8/17/94	10	$140.80
8/26/94	7	$214.07
8/31/94	5	$608.21
9/1/94	7	$28.39
9/2/94	7	$398.74
9/9/94	5	$5,876.65
9/23/94	10	$140.80
9/29/94	7	$54.85
9/30/94	10	$281.60
9/30/94	5	$545.45
9/30/94	7	$1,857.91
10/4/94	7	$317.40
10/5/94	5	$3,228.78
10/18/94	10	$140.80
10/21/94	5	$4,260.77
10/25/94	10	$352.00
10/25/94	7	$28.39
10/26/94	7	$36.21
10/31/94	10	$915.20
10/31/94	7	$1,479.44
11/2/94	7	$4,552.21
11/15/94	5	$1,573.00
11/23/94	7	$27.91
11/28/94	10	$114.40
12/5/94	7	$317.48
12/16/94	5	$3,146.00
12/28/94	10	$228.80
12/31/94	7	$1,664.28
1/4/95	7	$4,554.13
1/13/95	5	$3,146.00
1/13/95	7	$412.38
1/25/95	7	$33.54
1/31/95	10	$1,029.60

1/31/95	7	$1,644.98
2/2/95	7	$5,716.27
2/8/95	2	$591.00
2/11/95	5	$3,146.00
2/21/95	7	$28.39
2/22/95	10	$114.40
2/23/95	7	$30.93
2/28/95	10	$35.00
2/28/95	7	$1,803.59
3/1/95	7	$528.74
3/6/95	7	$4,684.05
3/8/95	5	$40.00
3/10/95	5	$3,146.00
3/13/95	10	$114.40
3/31/95	7	$1,593.19
4/4/95	7	$7,152.86
4/13/95	5	$3,146.00
4/21/95	7	$128.39
4/24/95	10	$114.40
4/24/95	7	$145.71
4/30/95	7	$1,593.17
5/3/95	7	$915.64
5/12/95	5	$3,146.00
5/22/95	10	$114.40
5/23/95	7	$42.26
5/31/95	10	$1,086.80
5/31/95	7	$1,576.23
6/2/95	7	$4,695.50
6/9/95	2	$481.00
6/9/95	5	$3,146.00
6/22/95	7	$153.28
6/27/95	10	$228.80
6/29/95	10	$104.00
7/3/95	7	$4,323.88

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<u>Vita</u>

Captain Steven M. Loken [redacted] He graduated from North Senior High School located in Eau Claire, Wisconsin in 1985. He immediately entered Rose-Hulman Institute of Technology, in Terre Haute, Indiana and enrolled in the Reserve Officer Training Corps. In 1989 he graduated with a Bachelor of Science Degree in Electrical Engineering and was also commissioned. Captain Loken has been assigned to Malmstrom Air Force Base, Osan Air Base, and Cheyenne Mountain Air Force Base. He has served as Base Electrical Engineer, Chief of Mechanical and Electrical Design Section, A/E Program Manager, Chief of Resources and Logistics, and Chief of Maintenance Engineering. Captain Loken's next assignment is Aviano Air Base, Italy.

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