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THESIS

ANALYSIS OF THE HAZARDOUS MATERIAL
REUTILIZATION FACILITIES AT
SUBASE BANGOR AND NS SAN DIEGO

by

Michael G. Berkin

December, 1990

Thesis Co-Advisors: David R. Henderson
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This thesis is an analysis of the hazardous material reutilization facilities at SUBASE Bangor and NS San Diego. The operations at both sites are described and a forecasting analysis is applied to determine future levels of incoming supply amounts, outgoing sales amounts, and predicted levels of hazardous material within the SUBASE Bangor facility. Cost benefit analyses are presented to determine which of three options is the most economical on-base activity for operating the facility and which of three options is the most economical for operating a hazardous waste minimization program. Using base supply personnel in a renovated building was found to be the most economical solution. Furthermore, a general eleven-step hazardous waste and material management model is applied to the military.

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Analysis of the Hazardous Material Reutilization Facilities at SUBASE Bangor and NS San Diego

by

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Submitted in partial fulfillment
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ABSTRACT

This thesis is an analysis of the hazardous material reutilization facilities at SUBASE Bangor and NS San Diego. The operations at both sites are described and a forecasting analysis is applied to determine future levels of incoming supply amounts, outgoing sales amounts, and predicted levels of hazardous material within the SUBASE Bangor facility. Cost-benefit analyses are presented to determine which of three options is the most economical on-base activity for operating the facility and which of three options is the most economical for operating a hazardous waste minimization program. Using base supply personnel in a renovated building was found to be the most economical solution. Furthermore, a general eleven-step hazardous waste and material management model is applied to the military.

TABLE OF CONTENTS

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I. INTRODUCTION

A. THESIS PURPOSE

The purpose of this thesis is to develop a general model of an ideal hazardous material reutilization facility that the Naval Supply Systems Command can use to help solve hazardous material (HAZMAT) and hazardous waste (HAZWASTE) management problems. Such a model is intended to serve as the basis for establishing reutilization facilities at various naval bases. The thesis analyzes the operations at two already established facilities: 1) SUBASE Bangor, Washington, which serves as a mature facility example, and
2) Naval Station (NS) San Diego, California, which serves as an example of an infant program.

B. THESIS OVERVIEW

The thesis is divided into seven chapters and one appendix. Chapter I presents the scope of the study, research questions and methodology, and identifies the benefits that can be derived from the study. Chapter II discusses the background of hazardous material and hazardous waste management, in general, and specifically within the Department of Defense and Department of the Navy. Previous studies in this area are also reviewed.

Chapter III describes the facility layout and operation at the mature SUBASE Bangor facility. Chapter IV presents the facility layout and operation of the infant hazardous material reutilization facility at Naval Station San Diego. A comparison of this facility is made against the operation at SUBASE Bangor to determine which factors are inherent to all hazardous material reutilization facilities and which factors tend to be different due to a facility's specific location or due to customer supply and demand. The final section in the chapter presents a short list based on lessons learned from the SUBASE Bangor and Naval Station San Diego facilities and is intended to direct the operator in formulating a viable program which includes a mature, self-sustaining reutilization facility.

Chapter V examines the mature facility at SUBASE Bangor from a regression analysis and forecasting perspective to determine expected HAZMAT supply and sales quantities and to determine predicted hazardous material levels within the facility. Chapter VI presents an economic analysis to determine whether implementation of a reutilization facility at a U.S. Naval base would be cost effective and to determine at what level such a facility should be supported.

The final chapter gives a summary of the work and recommendations for future work in this area. Appendix A is a copy of the questionnaire used to interview facility workers and tenant commands on HAZMAT handling procedures.

C. SCOPE OF THE STUDY

The thesis focuses on the operations already in place at SUBASE Bangor and Naval Station San Diego. The study is limited to observing the flow of hazardous materials in and out of the HAZMAT "store" and the various tenant commands and assessing the efficiency of their material handling and administrative procedures. Using a regression and forecasting analysis, the predicted future HAZMAT supply and sales rates for the SUBASE Bangor facility are determined. Predicted levels of HAZMAT are then calculated. An economic analysis is subsequently made of the SUBASE Bangor facility using various cost benefit analyses.

D. RESEARCH QUESTIONS

This study addresses the following seven questions:

1. What are the various steps involved in hazardous waste minimization? How effectively is the U.S. Navy currently performing in this area?
2. How is material collected, catalogued, warehoused and distributed at the prototype SUBASE Bangor facility?
3. What hazardous material handling procedures are used at the Naval Station San Diego facility and how do they compare with the SUBASE Bangor operation?
4. Is the current flow of hazardous material through the SUBASE Bangor facility being efficiently managed?

5. How effective and cost-effective is the current SUBASE Bangor operation? Will changes in administrative policies, number of workers employed, location of facility, or types of material carried effect the efficiency of the operation?
6. What are the requirements of tenant commands?
7. Can a facility model, based on forecasting and economic methods, be formulated to aid in the establishment of like facilities at various other U.S. Navy bases?

E. METHODOLOGY

Actual observation of the material flow; interviews with supervisors, workers, and tenant commands; and a review of administrative records were used to assess the material handling and administrative procedures being used at each facility. A review of current literature was used to formulate a comprehensive background on hazardous material management procedures in the United States Navy. Regression and forecasting analyses of the supply and sales of hazardous material were made and a sensitivity analysis using simulated sales levels was used to determine the effect current operating trends had on the SUBASE Bangor facility. The cost-benefit analyses methods presented in the U.S. Navy Civil Engineering Corps' Economic Analysis Handbook were used to determine the cost effectiveness of the SUBASE Bangor hazardous material reutilization facility.

F. BENEFITS OF THE STUDY

This study will directly benefit the Naval Supply and Naval Air Systems Commands with their implementation of a viable hazardous material handling program and possible establishment of subsequent HAZMAT "stores" at various other naval bases around the country. The study will also provide cost-saving recommendations and options for efficient hazardous material handling procedures within the United States Navy.

II. HAZARDOUS MATERIAL/WASTE MANAGEMENT PROGRAMS

To better understand the process of hazardous material (HAZMAT) reutilization, a basic understanding of the hazardous material handling/waste process is necessary. The purpose of this chapter is to provide the reader with an overview of hazardous material/waste management, in general, and provide specifics of the Department of Defense's (DoD) and Department of the Navy's (DoN) Hazardous Material Control and Management (HMC&M) programs.

A. THE PROBLEM OF HAZARDOUS WASTE GENERATION

Hazardous materials and subsequent waste are problems for the military- big problems. Although accurate estimates are hard to come by, during 1989, Department of Defense installations and components generated over 300,000 tons of hazardous waste annually, while Department of the Navy components contributed 89,000 tons to that total. [Ref. 1] After years of either lack of guidance, neglect, or recklessness, the military is realizing that yesterday's absence of HAZMAT management must be replaced by a vigorous program for careful and proper hazardous material storage and handling and hazardous waste (HAZWASTE) disposal. Particularly in light of anticipated budget cuts, a changing political world, and a renewed nation-wide emphasis on environmental awareness, interest in domestic hazardous material and waste management in the military will continue to grow.

B. HAZARDOUS MATERIAL IDENTIFICATION

Hazardous material differs from hazardous waste. The military uses the following definition as set forth by 49 CFR 173 (Code of Federal Regulations) to identify hazardous material: Any element, chemical, or substance that, because of its quantity, concentration, or hazardous properties, may pose a substantial hazard to human health or the environment when purposely released or accidently spilled [Ref. 2:p. 434]. Hazardous waste is that hazardous material which cannot be reutilized or reclaimed, and which is no longer needed, thus requiring special disposal through landfill, deep well, storage tank or incineration methods [Ref. 3:p. 1(Encl.1)].

The Federal Emergency Management Agency has identified over 100 common chemicals, used throughout the federal government and the military, which can be considered hazardous substances [Ref. 4:p. C-2]. Hazardous materials are divided into 18 subgroups that are compatible enough within each group such that they can be stored together in a general close proximity. However, within each group, substances should remain in separate containers since mixtures between chemicals could result in explosion, combustion, toxic gas or rupture.

Table 1 has been annotated, by asterisk, those materials carried by the SUBASE Bangor Hazardous Material Reutilization facility.

C. A MODEL FOR HAZARDOUS MATERIAL/WASTE MANAGEMENT

Wayne C. Turner of Oklahoma State University has developed a ranked sequential process for handling hazardous material and hazardous waste as outlined in Table 2. Each step of the process is less desirable and particularly more costly than the preceding one. The objective of the process is threefold: first, to comply with federal, state, and local directives; second, to reduce the volume and toxicity of waste to such a point that hazardous waste handling becomes manageable and cost effective; and third, to dispose of any remaining hazardous waste so as to limit one's liability and make the problem less politically-sensitive. [Ref. 5:p. 48] The process is applied to the military in this study as a method to better examine the hazardous material/waste management process within the Department of Defense and, specifically, the U.S. Navy.

1. COMPLIANCE

Whenever a military activity initiates a hazardous material and waste program, its first concern should be compliance with Department of Transportation (DOT), Environmental Protection Agency (EPA), Occupational Safety and Health Administration (OSHA), DoD, and service-related rules,

TABLE 1 - COMMON HAZARDOUS MATERIALS USED BY U.S. NAVY

GROUP I: HYDROCARBONS	
a) Gases	**b) Liquids**
hydrogen	pentane
methane	hexane
ethane	cyclohexane
natural gas	heptane
ethylene	octane
*acetylene	benzene
*propane	toluene
propylene	xylene
*butane	mesitylene
isobutane	ethylbenzene
	gasoline
	*kerosene
c) Solid	*fuel oils and lubricants
*naphthalene	*gasoline (aviation grade)
	*paints (oil & water based)
	*epoxies, sealant, glues, and adhesives
	*hydraulic fluid
	*hydroquinone
GROUP II: HALOGENATED COMPOUNDS	
a) Gases	b) Liquids
methly chloride	methylene chloride
methyl bromide	*chloroform
ethyl chloride	carbon tetrachloride
	ethylene dichloride
	*trichloroethane
	*trichloroethylene
	*trichlorotrifluoroethane
	chlorobenzene
	dichlorobenzene
GROUP III: SELF-POLYMERIZING COMPOUNDS	
a) Gases	**b) Liquids**
vinyl chloride	*formaldehyde-water solvent
vinyl bromide	acetaldehyde
butadiene	acrolein
formaldehyde	acrylonitrile
	*sodium acetate
	isoprene
	*styrene
	methyl acrylate
	methyl methacrylate
	*turpentine, varnish

GROUP IV: OXIDES AND PEROXIDE-FORMING COMPOUNDS

a) Gases
- ethylene oxide
- dimethyl ether

b) Liquids
- propylene oxide
- diethyl ether
- tetrahydrofuran
- dioxane
- dimethoxy ethane
- diisopropyl ether

GROUP V: COMBUSTIBLE COMPOUNDS

a) Non-toxic liquids
- *methanol
- *ethanol
- *acetone
- *methyl ethyl ketone
- ethyl scotate
- dimethyl sulfoxide
- propyl alcohol
- *isopropyl alcohol
- *butanol

b) Liquids
- methyl mercaptan
- acetonitrile
- *dimethyl sulfate
- *photo fixer, toner, and developer

c) Solid
- *phenol

GROUP VI: BASES

a) Gases
- ammonia anhydrous
- methylamine

b) Liquids
- ethanolamine
- ethylenimine
- aniline
- pyridine

c) Solids
- *sodium hydroxide
- *potassium hydroxide
- *ammonium hydroxide

GROUP VII: ACIDS A
- *acetic acid
- *phosphoric acid

GROUP VIII: ACIDS B - OXIDIZERS

a) Gases
- nitrogen tetroxide

b) Liquids
- *nitric acid
- *perchloric acid

GROUP IX: ACIDS C
- *chlorosulfonic acid

GROUP X: ACIDS D
- *sulfuric acid
- *boric acid

GROUP XI: POISON A

a) Gases
- hydrogen chloride
- hydrogen fluoride
- *carbon monoxide
- hydrogen sulfide

b) Liquids
- hydrogen cyanide
- carbon disulfide
- *hydrochloric acid
- *acetone cyanahydrin

GROUP XII: POISON B - MISCELLANEOUS

a) Gases
- sulfur dioxide
- chlorine
- boron trifluoride

b) Liquids
- bromine
- *chlorine

GROUP XIII: POISON C

a) Liquid
- tetraethyl lead

GROUP XIV: POISON D

a) Gas
- fluorine

GROUP XV: POISON E

a) Solid
- phosphorus red
- phosphorus white/yellow

GROUP XVI: OXIDIZERS

a) Solid
- ammonium nitrate
- ammonium perchlorate

GROUP XVII: METALS AND DERIVATIVES

a) Solid
- lithium
- sodium
- potassium
- magnesium
- calcium hydride

GROUP XVIII: NON-METALS DERIVATIVES

a) Liquids
- sulfur trioxide, oleum
- sulfuryl chloride
- thionyl chloride
- phosphorus trichloride
- phosphorus oxychloride
- titanium tetrachloride

b) Solids
- phosphorus pentoxide
- phosphorus pentasulfide

***= Hazardous materials carried by the SUBASE Bangor HAZMAT Reutilization Facility**

TABLE 2 - HAZARDOUS MATERIALS MANAGEMENT STAGES

		STEP:
********************Dispose Off Site		11
******************Transport - Treat Destroy Off Site		10
****************Dispose on Site		9
**************Destroy or Treat on Site		8
************Reclaim		7
**********Reuse		6
********Minimize		5
******Eliminate		4
****Hazardous Communication	OSHA & state	3
**Hazardous Material Transportation	Act DOT	2
Resource Conservation & Recovery Act	EPA & state	1

instructions and guidance. Inactivity and noncompliance has been costly in the past because the EPA has the power to fine activities up to $25,000/day. Several commanding officers of shore establishments have been fined or relieved for compliance infractions. Non-compliance has resulted in skyrocketing costs for cleanup. Currently, the DoD's annual waste cleanup and management program totals more than $1 billion. [Ref. 6:p. 82] The confusing, seemingly contradictory instructions can be divided into three areas, or the first three steps of Dr. Turner's model.

The <u>Resource Conservation and Recovery Act</u> and "Community Right to Know" are EPA-controlled programs which require industry to strictly control the storage, handling, and identification of hazardous material and waste [Ref. 7:p. 3]. The Transportation Safety Act of 1974 (Public Law 93-633) provides direction for the Department of Transportation to control the quantity and form of hazardous material/waste being transported along public thoroughfares [Ref. 8]. Hazard Communication is an OSHA-sponsored program intended to ensure that the hazards of all chemicals produced or imported are evaluated, and that information concerning their hazards is transmitted to employers and employees [Ref. 9:p. 356]. Such a program includes proper container labeling and other forms of warning, employee training, and the use of material safety data sheets (MSDS) as depicted in Figures 1a and 1b.

2. WASTE REDUCTION

Once a military installation is in full compliance with all applicable guidance and instructions, it can concentrate on the second area of proper hazardous material/waste management: waste reduction. The fourth step of the process (and the first of waste reduction) is to Eliminate. An often overlooked process, this step is extremely important and is usually accomplished by changes in engineering and testing procedures. Its objective is to ensure the hazardous material is truly required. Through product redesign, a rustless product material may be used to eliminate the need for painting or surface treatment. The use of mechanical instead

MSDS
000702

MATERIAL SAFETY DATA SHEET

FOR COATINGS RESINS AND RELATED MATERIALS

Approved by U.S. Department of Labor Essentially Similar to Form OSHA 20

DATE OF PREP November 1985

Section I

MANUFACTURER'S NAME GLYPTAL, INC.

STREET ADDRESS 305 Eastern Avenue

CITY STATE AND ZIP CODE Chelsea MA 02150

EMERGENCY TELEPHONE NO (617)884-6918

PRODUCT CLASS Paint ALKYD

MANUFACTURERS CODE IDENTIFICATION 1201

TRADE NAME GLYPTAL

HAZARD INDEX
0-MINIMAL Hazard
1-SLIGHT Hazard
2-MODERATE Hazard
3-SERIOUS Hazard
4-SEVERE Hazard

HEALTH 2
FLAMMABILITY 3
REACTIVITY 0

Section II — HAZARDOUS INGREDIENTS

INGREDIENT	CAS #	PERCENT	TLV PPM	TLV mg/m³	LEL	VAPOR PRESSURE
XYLENE	1330-20-7	34.4	100	435	1.0	9.5
V M & P NAPHTHA	84742-89-8	5.6	300	1300	1.0	45.0
TALC	14807-96-6	17.0	--	2*	--	--

*For Pigment Dust

Section III — PHYSICAL DATA

BOILING RANGE 242-287°F

VAPOR DENSITY [XX] HEAVIER [ ] LIGHTER THAN AIR

EVAPORATION RATE [ ] FASTER [XX] SLOWER THAN ETHER

PERCENT VOLATILE BY VOLUME 56.1

WEIGHT PER GALLON 9.95

Section IV — FIRE AND EXPLOSION HAZARD DATA

DOT CATEGORY PAINT, FLAMMABLE LIQUID UN 1263 RED LABEL

FLASH POINT 72°F

LEL 1.0

EXTINGUISHING MEDIA CARBON DIOXIDE, DRY CHEMICAL, FOAM OR WATER SPRAY

UNUSUAL FIRE AND EXPLOSION HAZARDS EXPLOSION HAZARD IN CONTAINERS DUE TO PRESSURE BUILD-UP DUE TO HEAT. USE WATER TO KEEP CONTAINERS COOL.

SPECIAL FIRE FIGHTING PROCEDURES SELF-CONTAINED BREATHING APPARATUS WITH POSITIVE PRESSURE MODE SHOULD BE WORN. WATER SHOULD BE USED TO KEEP FIRE CONTAINERS COOL TO REDUCE PRESSURE.

702 A

741-5 745(2)

Figure 1a. Material Safety Data Sheet (MSDS)- (Front)

Section V — HEALTH HAZARD DATA

See Section II

INHALATION: Anesthetic. Respiratory irritation, dizziness, headache, unconsciousness.

ACUTE: Skin and eye contact: Primary irritation.

CHRONIC: XYLENE contained in this material has been found to cause the following effects in laboratory animals: amenia, liver abnormalities, kidney damage, eye damage.

EMERGENCY AND FIRST AID PROCEDURES
INGESTION: Consult a Physician IMMEDIATELY!
INHALATION: Remove from exposure. UNCONSCIOUS BUT BREATHING: administer oxygen.
NOT BREATHING: artificial resusitation.
EYE CONTACT: Flush with copious amounts of water, SEE PHYSICIAN.
SKIN CONTACT: Wash thoroughly with soap and water. Use hand lotion.

Section VI — REACTIVITY DATA

STABILITY ☐ UNSTABLE ☒ STABLE — CONDITIONS TO AVOID Excessive heat, sparks and open flames.

INCOMPATIBILITY (Materials to avoid) Strong oxidizers

HAZARDOUS DECOMPOSITION PRODUCTS Carbon Monoxide may be formed by incomplete combustion.

HAZARDOUS POLYMERIZATION ☐ MAY OCCUR ☒ WILL NOT OCCUR

CONDITIONS TO AVOID Excessive heat, sparks and open flame.

Section VII — SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED Use an absorbent material such as Vermiculite to remove spilled materials. Provide adequate ventilation. Avoid excessive heat, sparks and open flames.

WASTE DISPOSAL METHOD Solvents may be distilled off and removed. Dispose of waste paint and still residue as ignitible material D001, following all Local, State and Federal regulations.

Section VIII — SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION In confined areas use: Approved self-contained respirators.

VENTILATION Keep vapors below LEL (Section IV) and TLV (Section II). Solvent vapors should be removed by dilution ventilation from lower levels. Eliminate all ignition sources (open motors, switches, etc.).

PROTECTIVE GLOVES Impervious gloves

EYE PROTECTION Chemical goggles

OTHER PROTECTIVE EQUIPMENT As required to avoid skin contact.

Section IX — SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING Store in a cool, well-ventilated area. Avoid excessive heat, sparks, and open flames. Ground containers and transfer vessels. Keep free fall of liquid to a few inches to avoid build-up of static electricity.

Do not take internally. Avoid prolonged breathing of vapors. Avoid prolonged contact with skin.

7451 (M7)

7020

Figure 1b. Material Safety Data Sheet (MSDS) - (Back) of chemical cleaning, non-toxic soaps instead of hazardous solvents, water-based glues and paints instead of oil-based coverings, and recycling and reutilization of hazardous material to eliminate hazardous waste generation are all examples of process redesign. Subsequent chapters of this study will concentrate upon this aspect of reutilization of hazardous material.

Another aspect of the Eliminate step is hazard testing, where products are tested carefully to determine their true toxicity and whether delisting is possible. Finally, subcontracting, where a local, civilian activity can perform cleaning and painting functions for the military installation can be considered. Although this does not eliminate the problem of hazardous waste, it can shift the primary responsibility for its disposal. However, in the case of some chlorinated substances, the military may still retain primary responsibility for waste disposal even if it is subcontracted to a commercial vendor.

The fifth step is to Minimize. The objective of this step is to reduce volume and toxicity of hazardous waste when it cannot be eliminated. Aspects of this step include stricter usage guidelines, where less hazardous material is authorized to be used for a particular process; and separating the effluent, where hazardous effluent is mixed in with other, non-hazardous wastes, thus greatly multiplying the volume of the waste problem. For example, Navy shipyards have implemented a process of recycling waste water from hard chrome plating operations into collection tanks and allowing evaporation to separate effluent [Ref. 7:p. 9].

Disposal of acute waste, and the subsequent higher level of regulation that comes with that, can be dramatically reduced if <u>less hazardous material</u> is used. Table 3 lists several recommendations for solvent substitutions which can be used in minimizing military's HAZWASTE [Ref. 10:p. 12]. Finally, by <u>standardizing</u> the solvent or cleaner used, the

Table 3 - RECOMMENDATIONS FOR SOLVENT SUBSTITUTION

Solvents Currently in Use	Recommended Solvent Substitute	Reason for Recommendation
Methyl Ethyl Ketone	1. Acetone 2. Ethyl Acetate 3. Methylene Chloride 4. Trichloroethane	1. 5 x less toxic. Less expensive. 2. 1.5 x less toxic 3. Less toxic. 4. Less toxic.
Toluene	Acetone	10 x less toxic. Less expensive.
Low Boiling Ketone	Acetone	Less toxic.
Trichloroethylene	None. Do not use.	Carcinogenic.
Methanol	Isopropanol	Less flammable. Non toxic. Not absorbed through skin.
Lacquer Thinner	1. Acetone 2. Aliphatic Naphtha	1. Less toxic. 2. Less toxic.
Solvent Naphtha	1. Acetone 2. Aliphatic Naphtha	1. Less toxic. 2. Less toxic.
Xylene	Varsol PD-680	Less toxic. Less expensive.

volume of hazardous material subject to disposal can be reduced significantly.

Step six is to reuse. In this step, the effluent is reused directly with little or no treatment. This can be accomplished by separation and reuse in a dirtier operation (ie., counter flow rinses), or using a filter to separate dirt (ie., alcohols and paint). Perhaps even collecting the waste and reusing it can be accomplished for operations not requiring pure solvents during a process (ie., some plating operations). Reclaiming (Step seven) takes place when significant treatment is required to recycle effluent. Recycling can be accomplished by the military activity, on- or off-site , on-site by a vendor, or off-site by a vendor.

3. **WASTE DISPOSAL**

When compliance with directives and reduction of waste have been properly completed, the military activity will find itself entering into the third and final area of hazardous material and waste management: waste disposal. Compared to the previous two areas, waste disposal is particularly more costly and administratively more complex. Military managers are quickly realizing that the responsibility for hazardous waste often lasts forever for the activity involved and that regulatory commissions are often holding individuals personally liable. This underscores the importance of hazardous waste reduction and the subsequent reutilization of hazardous material, the primary concern of this study.

Step eight of Dr. Turner's model (and first step of waste disposal) is to Destroy or Treat on Site. Although this requires special permits, equipment, and careful coordination with the EPA, state and local authorities, it can be done by the military activity itself, treated through a vendor, or destroyed through incineration. The use of traveling incinerators may also be considered. Destroying or treating on site are extremely popular solutions to HAZWASTE elimination and are the methods of choice for SUBASE Bangor. A treatment plant on base separates waste into water (which is eliminated through the sewer) and a residual (which is eliminated as true waste). The base then either coordinates a delivery order to a vendor through the Defense Resource Management Regional (DRMR) office in Ogden, Utah or contracts its own vendor to eliminate the waste. SUBASE Bangor off-station waste is normally incinerated at Rollins, Texas.

Land fills, deep well injection, and land forming are examples of Disposing on Site (step nine). However, this is quickly becoming a politically sensitive issue and likely will someday cease to be an option. According to the Department of Defense's Inspector General, there are 14,401 hazardous waste sites at 1,579 bases, with only 287 sites having been cleaned up. [Ref. 11:p. 42] Recently, numerous military bases (e.g., Robbins Air Force Base, GA and Fort Lewis, WA) have been the targets of criticism concerning the intrusion of hazardous waste into nearby local community groundwater. Many bases are heavily involved with Superfund cleanup operations, thus making disposal of hazardous waste on base politically infeasible.

Step ten, <u>Destroy or Treat Off Site</u>, is also a commonly used option of military installations. Although the transportation of hazardous material off base is potentially dangerous, the military often finds this an attractive solution since its liability ends once the waste is either sold to a vendor or correctly destroyed. At SUBASE Bangor, after hazardous waste which is untreatable on base is collected in sufficient quantities, it is transferred to the Defense Resource Management Office (DRMO), Ft. Lewis, WA via commercial trucks or sold directly to a vendor. DRMO either sells the waste to a vendor, ships it to a landfill in Oregon, or incinerates it.

The final step of hazardous material and waste management is to <u>Dispose of Waste Off Site</u> (Step 11). As previously mentioned, landfills, storage tanks, or deep well insertion are the primary methods for disposal of waste at this stage. However, this is the least desirable option since, in this instance, the military's liability usually does not end.

D. DEPARTMENT OF DEFENSE (DoD) GUIDANCE

Defense Secretary Richard Cheney has stated that he wants his department to become "the federal leader" in complying with federal environmental laws and protecting the environment [Ref. 11:p. 42]. Subsequently, there are numerous DoD directives and instructions concerning hazardous material packaging, storing, transportation and management. The two most important are DoD Instruction 6050.5/M and DoD 4145.19-R-1. The first deals with the operation procedures of the DoD Hazardous Materials Information System (HMIS). The system provides reference data in three primary areas: safety, environmental control, and transportation. Direction is given to each of the services on how to manage certain hazardous material. The second instruction provides direction on the storage and handling of certain hazardous materials.

E. VARIOUS HAZMAT MANAGEMENT SYSTEMS WITHIN THE MILITARY

To implement DoD Instruction 6050.5/M, the different military services have developed various hazardous material and waste tracking systems designed specifically to the needs of their particular service.

The Army's Hazardous Material Management System (HMMS) provides that service information on identifying and handling of hazardous materials. It is able to search for materials via national stock number (NSN), manufacturer's number (FSCM), chemical name, trade name, generic name, specification or item manager. [Ref. 12:p. 7] The system is able to generate the information found on an MSDS by providing the physical and chemical properties of an item, fire and explosion data, health information, and handling and spill procedures. Recently, many Navy and Air Force installations have begun using the HMMS system to track and identify their hazardous materials.

The Army's TRACKER system identifies the types and volumes of HAZMAT issued to each Army unit on post during the previous month by interfacing the post procurement records with a data base of known hazardous materials [Ref. 13:p. 5]. Finally, the Army's Trade Name Translator (TNT) system works in conjunction with the HMMS system to correlate national stock numbers of chemical materials with an item name description and identifies less dangerous substitutes for certain HAZMAT [Ref. 14:p. 5].

F. HAZMAT CONTROL AND MANAGEMENT (HMC&M) PROGRAM

The Hazardous Material Control and Management (HMC&M) program is the Navy's life cycle material and equipment direction for the research, development, acquisition, production, operation and final disposition of substances considered hazardous as per 49 CFR 173.2 [Ref. 3:p. 1]. The program is outlined in Chief of Naval Operations directive OPNAVINST 4110.2. Through this program, the Navy intends to greatly reduce its use of hazardous material (HM) and generation of hazardous waste (HW).

The directive assigns the Commander, Naval Supply Systems Command (COMNAVSUPSYSCOM) the responsibility of serving as the overall program manager for the supply aspects of the Navy HMC&M Program. This includes formulating HM logistics requirements, manual and automated warehousing and material information systems, marking and labeling of HM containers passing through Naval Supply Centers and distribution points, and storage compatibility information. [Ref. 3:p. 6] All other naval systems commands, echelon II major commands, and designated program managers are directed to assist NAVSUPSYSCOM in developing and maintaining a centralized list of HM as a database for the Navy's HMMS system [Ref. 3:p. 9].

G. CNO'S HAZARDOUS MATERIAL AND WASTE (HAZMIN) GOAL

The Chief of Naval Operations has issued an aggressive Navy HAZMIN goal of 50 percent HW reduction, by weight, by the end of CY 1992 [Ref. 3:p. 9]. But what does this really mean and how does the Navy determine whether it is meeting that goal? According to Mr. Robert Woods of the Navy Environmental and Engineering Services Administration (NEESA), Port Hueneme, CA there was initial confusion over how waste generation measurements were going to be made and what items were to be included. Initially, both 1987 and 1988 were used as baseline periods and oily waste water was included in determining the amount of HAZWASTE generated. Now only 1987 is considered as the baseline. Oily waste water amounts are no longer included in calculating HAZWASTE volume since new treatment methods reduce massive amounts of contaminated water to sewer water, leaving only minimal sludge residue. [Ref. 1]

In determining U.S. Navy HAZWASTE quantities, NEESA collects data on amount generated, amount treated, amount recovered, amount disposed of, and the amount stored during the measurement period and the amount backlogged from the previous year. The last two measurements are made to eliminate double counting at the end of the year. Table 4 presents data for HAZWASTE generation and disposal within the Navy since 1987 (base year). The quantity generated indicates the amount of waste collected prior to any HAZMIN process such as reclamation, reuse or recycling. Quantity disposed is the amount actually eliminated as waste through either landfill, storage tank, deep well, or incineration method. [Ref. 1]

Table 4 - U.S. NAVY'S HAZWASTE MINIMIZATION

YEAR	HAZWASTE GENERATED	HAZWASTE DISPOSED
1987	145,000 tons	46,000 tons
1988	107,000 tons	52,000 tons
1989	89,000 tons	38,000 tons

The rise in the quantity of HAZWASTE disposed of during 1988 is attributable to the increased awareness of HAZMAT liability of many users as warehouses of old material were being cleaned out due to expired shelf-lives and confusion on what items really constituted an hazardous material. The table shows that the Navy is making a concerted effort to limit its generation of HAZWASTE and that minimization efforts appear to be working as indicated by a substantial drop in HAZWASTE actually disposed.

Due to an aggressive HAZMIN program at SUBASE Bangor, hazardous waste generation there has dropped from 1,664 tons in 1987 to 976 tons in 1989, with a projection of only 400 tons generated during 1990. [Ref. 15] With this goal of hazardous waste minimization in mind, the operation of the SUBASE Bangor, WA and Naval Station San Diego, CA HAZMAT reutilization programs are examined in the remaining chapters of this study.

III. SUBASE BANGOR FACILITY LAYOUT AND OPERATION

A. BACKGROUND

The SUBASE Bangor Hazardous Material Reutilization facility (store) is a clearinghouse operation that allows tenant SUBASE commands to turn in old, half-used HAZMAT for reuse instead of disposing it as hazardous waste. Those commands requiring quantities of hazardous material can draw from the facility's turned-in resources, thus eliminating the need to requisition new HAZMAT from the Navy Supply system. The objectives of the store are to allow the U.S. Navy to save money by having its commands reutilize materials already purchased and to cut down on the quantity and cost of disposing hazardous materials as HAZWASTE.

In mid-1984, Mr. Rick Comfort, a SUBASE Bangor Public Works Command (PWC) employee, decided to solve the growing problem of hazardous material and its subsequent disposal as waste. Since the base was already deeply committed to recycling in such other areas as paper, computer paper, corrugated containers, and scrap metal, he was able to obtain base-wide command support to establish a prototype HAZMAT reutilization facility. Section 2577 of Title 10 Public Law (1 Oct 1982) provided an increased incentive for military installations to establish and operate recycling programs to reduce waste flow, conserve natural resources and prevent pollution. The HAZMAT store was established adjacent to the hazardous waste operation, due to the size and safety features of the industrial waste building.

B. ORGANIZATION

The organization of the HAZMAT reutilization facility is depicted in Figure 2. Presently, the reutilization facility is the responsibility of PWC, which monitors its operation. Since 1987, the responsibility for actually running the store has been contracted out to Pan American Corporation, which also operates the base's hazardous waste facility, base security, and some transportation services.

Public Works Center Officer
|
Engineering Director
|
Environmental Director
|
Hazardous Substance Manager
|
Hazardous Materials Coordinator
|
Hazardous Materials/Waste Supervisor
| |
Clerk (1) **Material Handlers (3)**

Figure 2. SUBASE Bangor Operation Organization

The store is run by one contractor employee (storekeeper) who has additional responsibilities in the hazardous waste disposal operation. He uses one or two hazardous waste disposal employees on an as-needed basis for the transportation of material to, from and within the facility. The storekeeper works for a supervisor who oversees both the HAZMAT reutilization and hazardous waste operations.

C. DESCRIPTION OF MATERIAL FLOW

The HAZMAT reutilization facility encourages tenant commands to deliver its own material, particularly if the amount or size of the material is small. However, the store offers delivery assistance for large amounts of hazardous material (ie., 55-gallon drums of oil, hydraulic fluid, etc.). When a tenant command has material to be delivered to the HAZMAT reutilization facility, it either telephones the store for pickup or deposits it next to its hazardous waste to be picked up on an automatic, twice-a-day pickup schedule.

Large amounts of material are normally staged on pallets outside each tenant's Material Control office or hazardous material storage locker. The HAZMAT store operates a 2-ton Navy pickup truck. At least two people are required for transporting large quantities of hazardous material and waste.

Once material arrives at the facility, it is staged in a palletized area for check-in. A handling clerk ensures hazardous material is separated from hazardous waste, sending the latter to waste receptacles and the former to either small storage (less than 10-gallon containers) or large storage (10-gallon drums or more). Hazardous material is defined as unopened and/or opened but uncontaminated material which can be reutilized before disposal as waste.

The internal inventory system is simple and manual. As depicted in Figure 3, local form (M1348-I) is filled out with the following information: type and amount of material being inducted, anticipated storage location, shelf life and disposal information, and the unit price of the material when it was issued new. Later, at the end of each work day, incoming and outgoing items are entered into an IBM PC spreadsheet program at Public Works by the Hazardous Materials Manager. An HMMS system is currently being installed at Public Works to aid in material tracking and identification.

M1348-I

****
****

M1348 NUMBER______	NUMB CONTAINERS______
MIS NUMBER______	TYPE CONTAINERS______
TURN-IN COMMAND______	SIZE CONTAINERS______
	MEASURE______
FINAL DISPOSAL______	STORAGE LOCATION______
DISPOSAL DATE______	UNIT PRICE______
DATE CLOSED______	

Figure 3. Local inventory form (M1348-I)

Identification of incoming material tends to be very labor intensive. The reutilization store personnel find it imperative to handle only material that they can positively identify. A new OSHA directive requires all material coming through the reutilization store to be accompanied by a proper MSDS identification sheet. Consequently, almost all material handled by the store must be in its original container with proper federal stock number (FSN), Navy Inventory Identification Number (NIIN) or Navy stock number (NSN). The store uses a stock number cross-check (HMMS-generated) list to identify commercially available items and to determine their stock numbers if the container is not so labeled.

All opened material receive a visual inspection to determine the extent of contamination, whether what is in the container is the original material, and whether it is of the quality and amount necessary to be offered for reutilization. Containers filled with oxidized, dirty, dried out, or spoiled material are not accepted by the store and are disposed of as hazardous waste. There are two distillers on base which are used to separate good from bad material and are normally used to purify solvents and freon.

Containers must also be in satisfactory condition to be accepted by the reutilization facility. Hazardous material in severely dented or rusted containers is usually either not accepted and disposed of as waste or the container is discarded and the material is transferred into a brand new, substitute container.

The store usually prefers not to mix material from half-filled containers with similar material, even if both are positively identified. Like material can have different shelf lives which would make mixing of the two unwise. Occasionally, however, paints are mixed together to produce a generic, multi-purpose paint called SUBASE gray which has been deemed acceptable to tenant commands for use in self-help projects not requiring MILSPEC conditions.

Samples from opened material in which an uncontaminated state is deemed imperative (particularly some oils and hydraulic fluids) are taken and delivered to a laboratory on base for content analysis. The analysis can take up to a week for completion and the material will not be released until positive identification is made. If material can not be identified, it is rejected by the store and disposed of as hazardous waste.

D. LAYOUT OF SMALL STORAGE

Once material is accepted by the facility and checked-in, it is stored in either the large (bulk) or small storage depending on its size (greater or less than 10 gallons). Small storage is a 20'x 30' alcove within SUBASE Bangor's brand new, $1.7 million dollar state-of-the-art hazardous waste facility as depicted in Figure 4.

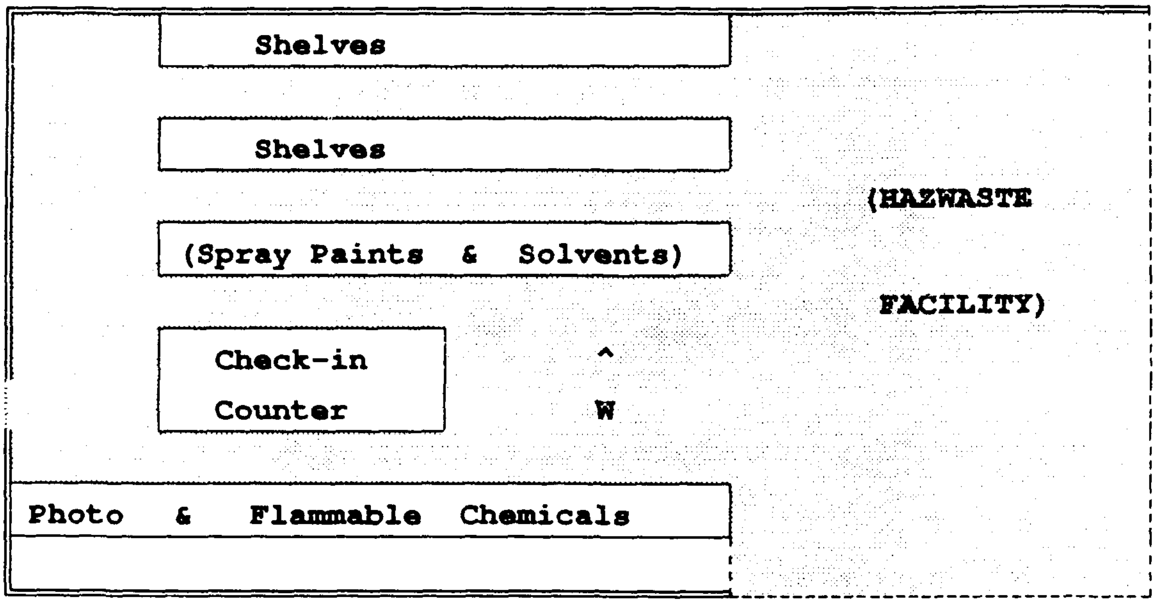

Figure 4. Small HAZMAT storage at SUBASE Bangor facility

Items are stored on double-tiered shelves with smaller, unbreakable containers stowed high while larger, glass containers are stowed on bottom shelves. The shelves are arranged as in Figure 4 with three rows of shelving on the west side of the room and one row of shelves on the east side, with the check-in counter separating the two areas. Common items handled in small storage include highly inflammable items such as alcohols, paints, glues and epoxy, greases, aerosol spray paints, cleaners, and photographic supplies.

The store is particularly careful in separating chemicals whose mixing could lead to combustible or toxic consequences by stowing incompatible materials away from each other. Acids are separated from oils, greases, and cyanides; oxidizers are separated from phenols and strong reducers; and epoxides are separated from caustics. The store does not accept or handle ammunition, explosives or nuclear/radioactive items.

Due to the large quantities of hazardous waste stored in the same building, the small storage reutilization facility is able to benefit from the many safety features and climate control conditions available for the safe storage of the hazardous waste. The air conditioned facility maintains an average temperature of 70 degrees. The store has two ventilation systems: a large wall- mounted fan located near the ceiling to vent out hot air, and a smaller wall-mounted emergency fan to vent out accidently-released fumes. The store is equipped with a ceiling-mounted dry agent fire extinguishing system and uses explosion-proof lighting fixtures. The floor of the facility is a cement slab with numerous drains located at low spots for convenient clean up of accidental spillage. If a spill occurs, it is washed down the drain which empties into a receiving reservoir outside the building. From this pool, the hazardous material is cleaned up, deposited as hazardous waste and disposed of properly.

E. LAYOUT OF LARGE STORAGE

Large (bulk) storage is located a quarter mile north of the HAZMAT/Hazardous Waste facility in an old supply warehouse. The size of the facility is approximately 30'x 50'. The 1950s-vintage warehouse has not been refitted with any special ventilation or drainage systems and is suitable only for the storage of less inflammable hazardous materials. There are no shelves and all full drums sit on wooden pallets on the floor.

The facility is divided into four sections as per Figure 5. Full 55-gallon containers of oils and hydraulic fluid which have been tested for purity are located along the west wall. Drums still waiting for laboratory work sit in front of the tested drums in the middle of the storeroom next to the sliding door. Smaller containers of material are stored along the north wall. Empty, brand-new 55-, 10- and 5-gallon drums and containers are stowed along the south wall.

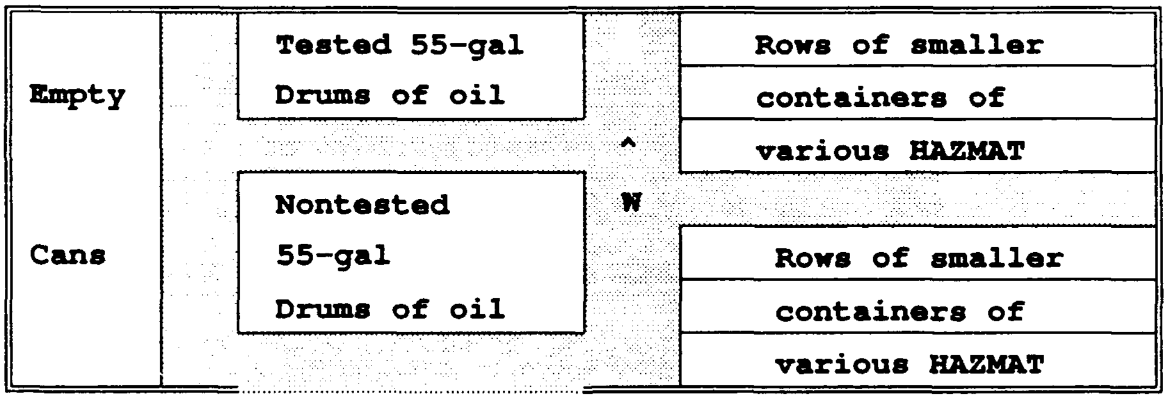

Figure 5. Large HAZMAT storage at SUBASE Bangor facility

F. REUTILIZATION STORE/TENANT COMMAND RELATIONSHIP

The HAZMAT reutilization Facility/Hazardous Waste Deposit complex is located rather centrally on the civilian side of SUBASE Bangor, on an unobtrusive side road just off a main thoroughfare. (The base has another, operational, side which is restricted to submariners and other military personnel.) The store serves seven major permanent commands (COMSUBGRU NINE, SUBASE BANGOR, COMSUBRON 17, TRIREFFAC, SWFPAC, TRITRAFAC, and the Base Operating Support Contractor); various support units (EODMU NINE DET, Construction Battalion Unit 418, Photo Lab, Medical/Dental Clinics); and any of the submarines (SSBNs) which may be in from deployment. Base regulations allow outside commands to draw hazardous material from the store but limits depositing old material at the store only to tenant commands.

A telephone survey (Appendix A, Section XII) of four of the seven major permanent commands and one support unit was made to assess customer service and the rapport between the reutilization store and various tenant commands. A survey involving the submarines was not possible due to security reasons and their unwillingness to discuss logistics issues. In each positive survey, a worker at the user command's material handling department was interviewed. In each case, the workers were well aware of the existence of the reutilization store and had either deposited to or drawn material from the facility within the last month. Each activity was aware of the store's working hours and had the latest copy of the store's monthly inventory catalog.

Most activities were very pleased with the service received by facility workers. Two tenant commands mentioned how store workers were so familiar with the needs of user commands that they would call the users when they received an item which store workers thought a particular user command might need. The only real complaint from users was that often, whenever a new, highly desirable item appeared in a new month's catalog, the item would be already gone when the user called the reutilization store to place it on hold. Most user commands stated that, to preclude that from occurring, they would often visit the store several times a week to survey new inventory.

One particularly convenient aspect of the reutilization store operation is the ease of ordering material and the lack of paperwork involved in picking up or dropping off material. Only a signature, command name, date, and item name are required on item receipts. Simplicity and user convenience are central to the store's customer policy. They realize that to ensure tenant commands continue using the store rather than dispose of half used material or requisition new material from Base Supply, they must accommodate the customer fully.

IV. NS SAN DIEGO FACILITY OPERATION AND COMPARISON

A. PURPOSE

This chapter describes the HAZMAT reutilization operation at Naval Station (NS) San Diego, California and compares it to the operation at SUBASE Bangor. While SUBASE Bangor serves as an example of a relatively mature (six years old) operation with many of its programs in place and running smoothly, the NS San Diego HAZMAT reutilization is an example of an infant program (less than a year old) with several objectives not yet met. A comparison of the two above facilities is useful to the military manager to determine which factors are inherent to all HAZMAT reutilization facilities and which factors are different due to geographical location or customer supply and demand. It also gives the manager a sense of how long it might take to solve inherent problems.

B. ORGANIZATION

NS San Diego's HAZMAT reutilization operation organization is depicted in Figure 6. Like the SUBASE Bangor facility, HAZMAT reutilization primarily is the responsibility of the PWC's Environmental Support Branch. However, unlike Bangor, the operation is run by PWC employees at the HAZWASTE facility and is hardly distinguishable from the HAZWASTE operation. One handling supervisor (government paygrade WG-7) and four other handlers (WG-5/6) deliver material to the facility, sort and store it, and dispatch it to various user commands. One WG-7 administers all necessary recordkeeping and paperwork. PWC's Environmental Protection Specialist (640) monitors the operation and provides guidance.

Public Works Center Officer

Naval Utilities Department Director

Environmental Director

Hazardous Waste Minimization Coordinator

Hazardous Waste/Materials Foreman

Clerk (1) | Handler (3)

Figure 6. NS San Diego facility organization

C. DESCRIPTION OF MATERIAL FLOW

A major difference between the reutilization operation at NS San Diego and the unit at SUBASE Bangor is the different set of base, city, county, and state regulations and ordinances under which each base has to operate. SUBASE Bangor permits its own hazardous material to be transferred to other bases but does not allow the transfer of HAZMAT from other bases onto its base. NS San Diego does not have such restrictions and will allow the transfer of hazardous material to and from its base subject to special transportation and handling specifications as set forth by 49 CFR 175. This freedom to accept material from other bases gives the San Diego operation a far greater opportunity than Bangor has to search for a particular material a tenant command may need.

Procedures for check-in of HAZMAT at San Diego are similar to those at Bangor. Normally, when an activity has excess material that merits reutilization, it telephones the HAZWASTE facility for a screening of its material. Facility personnel separate useable material from waste and deliver both to the HAZWASTE/HAZMAT facility. Since most hazardous material comes from incoming ships, facility workers are usually aware of their deployment schedules and coordinate with crewmembers the offload of hazardous waste and material from their boats.

Upon delivery to the facility, the material is staged for identification and stored according to its physical properties. Like Bangor, the San Diego facility personnel believe that ease of transaction and customer service are the two keys for successfully operating the store. Consequently, they do not require any paperwork to be filled out by the delivering customer and require only that a user command provide his signature and command name when "buying" material. All other necessary data (date, material name, amount used) is recorded by the facility worker after the "sale."

An area which needs to be addressed at the NS San Diego facility is the practice of charging those commands which supply the store with unused material. This is done to offset possible HAZWASTE handling costs, but appears to be a great disincentive to use the facility for HAZMAT reutilization and may tend to demotivate commands from separating their HAZMAT from their HAZWASTE. Although a user command has a great incentive to use material from the San Diego facility since it is "free," a command sending its excess HAZMAT material to the store may think twice before turning material in. Such a policy encourages commands to just dispose of usable HAZMAT, ultimately contributing to an ever-increasing HAZWASTE disposal problem. This policy of charging suppliers is counterproductive to the idea of HAZMIN and should be discontinued.

At the end of each day, sheets containing a description of delivered material name, amounts used, and user command name are forwarded to PWC's Environmental Programs Branch (Code 640) for compilation. Unlike the Bangor facility, the San Diego operation does not maintain a computer data base of incoming and outgoing hazardous material. Such a system is unaffordable at this time.

D. LAYOUT OF THE FACILITY

While the Bangor operation is divided into two facilities (small and large storage), the San Diego operation is located in only one area. In fact, hazardous material and hazardous waste are stored beside each other under the same roof. Unlike the brand-new, totally-enclosed facility at Bangor, the San Diego facility is a 1,200 square foot fenced-in open air area with a twenty foot high ceiling and canvas sheets upon the fence to keep out the weather as depicted in Figure 7. Only the most reactive hazardous materials are housed in this section. Adjacent to this area is a 3,500 square foot fenced but uncovered area which houses more stable HAZMAT. A small enclosed building next to the covered area acts as an office.

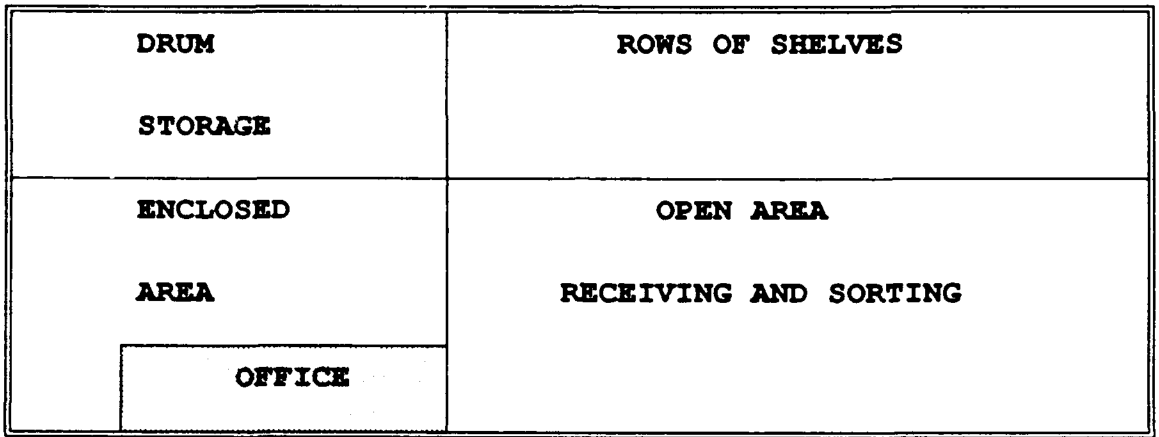

Figure 7. NS San Diego HAZMAT Reutilization Facility Layout

The floor of the covered area is concrete and is divided into sections using raised berms. This keeps any spills from reacting with other, possibly non-compatible material. Numerous sump drains are located at low points in the floors. The sumps are checked and emptied periodically for accumulation. Although the facility does not have a ceiling-mounted chemical sprinkler like Bangor, it does have several wall-mounted, hand-held chemical extinguishers. Since it is a partially covered, open-air facility, it has no ventilation systems.

Keeping track of material within the facility is not difficult. The entire area is cordoned-off using an alphanumeric grid system. Using a plexiglass layout board and grease pencil, facility workers can add or delete material from the grid location on the board as material is transferred in and out. The Bangor facility does not use a grid system but relies on the expertise of its material facility handlers to locate material.

E. REUTILIZATION STORE/TENANT COMMAND RELATIONSHIP

A major difference between the reutilization operation at NS San Diego and the unit at SUBASE Bangor is the number of potential customers that can use the facility. While the Bangor operation is limited to only seven major commands, various subcommands and a handful of submarines, the San Diego operation has the potential to serve 13 San Diego-area bases, including all of their base commands and accompanying ships. This totals to well over 220 commands, of which 90 are ships.

Since no real HAZMAT transportation restrictions exist, the NS San Diego facility can be used by any user command in the area. This thesis, however, does not advocate that only one single reutilization store be used as a clearinghouse for HAZMAT reutilization over such a large area as San Diego.

Separate reutilization facilities should be established at each of these bases, thus allowing each to easily handle its own base's material and transfer material only on an as needed basis.

The HAZMAT reutilization operation at NS San Diego is still a new concept at the base and it has yet to establish a full reputation among all tenant commands. Although the store has enjoyed a brisk business recently, users of the facility tend to be the same few customers, indicating that the demand for reusable material exists but that only a few commands are aware of the benefits available to them. Since the facility keeps no computer data base, a monthly inventory catalog to tenant commands similar to Bangor's catalog is not yet possible. Currently, the facility and its contents are advertised to various commands only by word of mouth.

F. RECYCLING, REPACKAGING, AND SHELF-LIFE CONCERNS

A hallmark of the SUBASE Bangor reutilization facility is its ability to process and distill used hazardous material to remove contaminants and then repackage it for reuse by tenant commands. The NS San Diego facility has not yet developed its program to such a degree, but has just purchased a 5-gallon still through which it intends to run used solvents. The local DRMO at Imperial Beach, CA has very stringent standards on the condition of hazardous material containers and will not accept severely dented, rusted, or torn cans and boxes. Also, all containers must be clearly marked with proper labels. This has been a problem for the reutilization facility since they are left with material which they cannot move. Like the Bangor facility, the San Diego operation intends to requisition new cans and boxes for repackaging purposes and will even relabel material for proper identification.

The NS San Diego facility normally holds material for sixty days, with periodic extensions to ninety days while SUBASE Bangor will usually hold material for ninety days with extensions up to 120 days. Of particular concern to both the Bangor and San Diego facilities is the extension of shelf-lives on materials, since occasionally a material will reach its shelf-life at the facility before its sixty or ninety day limit is reached.

To minimize the disposal of functional material, the reutilization facilities are authorized by FED-STD-793 to extend the shelf-life of the material if the end user of the material determines that the material will perform satisfactorily for the user's need. [Ref. 16:p. 2] This is normally accomplished by visual inspection of the container's condition and of the consistency of the hazardous material. Such extensions will be done only for those materials whose jobs do not require MILSPEC conditions (ie., self-help painting or cleaning projects). Each extension should not exceed a period of one-half the stated normal shelf-life of the material.

G. OTHER LIMITATIONS

Local restrictions account for another difference between the Bangor unit and the San Diego operation. San Diego County restricts the use, or even handling, of any hazardous material with a VOC (Volatile Organic Compound) content of more than 350 grams per liter of material, within the county limits. This restriction limits the use of a large number of U.S. Navy supply system products (particularly paint) and necessitates the open purchase of numerous locally procured paint products whose VOC content is within standards.

Due to these strict limitations on the use and handling of certain hazardous materials, some bases (e.g., NAS North Island) prefer to screen every request for hazardous material made by its tenant commands. They intend to promulgate an acceptable products list which limits their tenant users from drawing certain hazardous material from the NS San Diego facility.

H. LESSONS LEARNED FOR ESTABLISHING A HAZMAT FACILITY

Although each U.S. Naval base has its share of unique situations and potential problems, the following short list of lessons learned from the SUBASE Bangor and NS San Diego HAZMAT reutilization facilities may aid the Navy manager in establishing a similar facility on his or her base:

1) Establish the program first.

- It is very important to get key players on board with the program first; do not go it alone. Sell the idea of a HAZMAT reutilization facility to the base Commanding Officer, Public Works Officer, base Supply Officer, the commanding officers of the major tenant commands, and to the Environmental and Safety offices.

- Unless you get extraordinary help from key players, do all the legwork planning yourself. This includes looking into regulations (local, state, government), determining costs, and possible location for a facility.

2) Appropriate a building.

- A medium-sized base normally requires 1500 to 2000 square feet of space for its facility.

- In warmer climates (e.g., San Diego), the facility does not have to be totally enclosed. However, HAZMAT should be adequately covered from the elements and some type of security restraint (e.g., fence) may be necessary to separate HAZMAT from the general public.

- Regular (2 feet deep) and bulk shelves are necessary for display and storage of HAZMAT.

- Obtain a fire department and Safety Office check-out before moving into a certain building. Normally, a facility must have proper ventilation, sprinkler/fire extinguisher, and spill washdown systems before it is acceptable to house large quantities of HAZMAT.

3) Standardize storage procedures.

- All HAZMAT should be stored according to its hazard class. Label shelves according to hazard class using large, easy-to-read placards.

- Use an alphanumeric grid system (on shelves or walls) to keep track on HAZMAT location. Either a manual card or computer spreadsheet program can aid in documenting item location and quantity.

- Keep paperwork to a minimum.

4) Be innovative with HAZMAT reutilization efforts.

- Laboratory work should be done on all recycled solvents to analyze its contents.

- Repackage HAZMAT in dented, rusted containers.

- Large quantities of HAZMAT can be repackaged into smaller containers, often making them more appealing and convenient to potential customers.

- Ensure customers that unused quantities of large containers obtained from the facility can always be returned for re-reuse.

- Obtain a still to separate contaminated solvents.

- Always separate HAZWASTE from acceptable HAZMAT. Do not accept HAZWASTE.

- Ensure Base Supply checks facility stock before ordering new HAZMAT from the supply system. SUBASE Bangor will shortly have a computer system in place which allows Base Supply to electronically check facility stock availability prior to ordering new HAZMAT.

5) Customer service is key to facility success.

- Advertise your services to all tenant commands. The program will not work unless people know about the advantages of using the facility. In addition to word-of-mouth advertising reaped from superior customer service, the facility services should be advertised through Plan-of-the-Day statements, base newspaper articles, and even a monthly or weekly newsletter.

- Ensure users know that the material is "free" and of usable quality. Never charge users for supplying HAZMAT to the facility.

- Pickup and deliver HAZMAT, if possible.

- Again, keep paperwork to a minimum.

V. FORECAST ANALYSIS OF THE SUBASE BANGOR FACILITY

A. BACKGROUND

This chapter presents a forecast analysis of the SUBASE Bangor HAZMAT Reutilization Facility to determine whether there is a need to expand or decrease the facility size. The purpose of operating a HAZMAT reutilization facility is twofold:

- 1) It facilitates the reutilization of old, half-used material to keep it from becoming hazardous waste before it needs to be disposed. Such a program would significantly reduce the amount of hazardous waste needing to be disposed (HAZMIN) and, consequently, greatly reduce the Navy's disposal costs.

- 2) It allows DoD and DoD-related activities to first use half-used material of acceptable quality from the reutilization store rather than requisition new material from the Navy Supply system. Such a program would significantly reduce the cost of the procurement of new materials, reduce the amount of new hazardous material brought into the usage pipeline (thus exacerbating the eventual hazardous waste problem), and keep the Navy from paying twice for using its hazardous materials (once for the initial material and another time for disposal).

The objective of the facility is to provide the customer with the type of material he/she wants, at the time that he/she wants it. The meeting of this demand by the facility to the user is referred to as a "sale." Only met demand will be considered in this study. By providing complete customer service, the facility operator can be assured that the right customer gets the right material (and thus the reutilized material does not get wasted or disposed of) and that he generates an ever-increasing group of satisfied customers.

The following general assumptions are made concerning the facility operation:

- Although the facility recycles other than hazardous materials (e.g., empty containers and barrels, building supplies, etc.) the study will be limited to HAZMAT. To simplify the analysis, material was divided into four groups: petroleum/oil/lubricants (POL), solvents, toxins, and pesticides.
- Determining material amounts is a difficult and non-exact endeavor. Since hazardous material comes in a multitude of sizes and shapes, careful estimates from unit issue reports have been made to determine HAZMAT amounts. For ease in calculation, all material is measured in gallons, to the nearest whole unit.
- Although various hazardous materials have different specific weights and volumes, for purposes of this study, a gallon of material is assumed to weigh 10 pounds.

B. FORECAST ANALYSIS

To determine whether the HAZMAT reutilization facility at SUBASE Bangor needs to be enlarged or decreased, two forecasts are made: 1) the predicted outgoing sales of HAZMAT for the upcoming year, and 2) the predicted incoming supply of HAZMAT for the same upcoming year. An assumption is made that no shelf-life expirations occur and that the facility has enough extra capacity to hold large inventories. Typically, end users may extend the shelf-life as long as the item performs satisfactorily for that user's needs [Ref. 16:p. 2]. Once supply and sales values are calculated, the predicted amount of HAZMAT to be warehoused can be determined using the following equation:

$$H_p = H_c + S - D$$

where:

H_p=Predicted amount of HAZMAT

H_c=Current amount of HAZMAT

S=Incoming HAZMAT supply amount

D=Outgoing HAZMAT demand amount

Based on past historical data, a time series forecasting model is used to predict future supply and sales amounts. Often supply and sales tend to follow a time series composed of cyclical patterns, with general, seasonal and/or random trends. At a U.S. Naval base, ship deployments, construction work, and self-help projects often follow various cyclical schedules. The requirement for, or generation of, HAZMAT tends to vary cyclically in a corresponding manner.

Before supply and sales amounts can be forecasted, the time series of both the supply amounts and sales amounts must be decomposed into their separate components. An assumption is made that the supply and sales amounts of HAZMAT at SUBASE

Bangor fall about a straight line and that they follow general, seasonal, and random trends. A linear regression analysis is performed on each to fit a line through amount values and a residual analysis is made to determine the validity of the assumption.

1. Supply Forecast

Twenty-four months of historical incoming HAZMAT supply data from SUBASE Bangor is outlined in Table 5.

TABLE 5 - INCOMING HAZMAT SUPPLY DATA (IN GALLONS)

MONTH & YEAR	SUPPLY (GALS)	MONTH & YEAR	SUPPLY (GALS)
JUL88	528	JUL89	694
AUG88	675	AUG89	637
SEP88	732	SEP89	696
OCT88	826	OCT89	781
NOV88	902	NOV89	767
DEC88	439	DEC89	683
JAN89	136	JAN90	312
FEB89	317	FEB90	332
MAR89	473	MAR90	531
APR89	441	APR90	473
MAY89	166	MAY90	358
JUN89	576	JUN90	696

The first step in decomposing the time series is to determine the seasonal factor. Monthly data is grouped into the four seasons: summer (JUL/AUG/SEP), fall (OCT/NOV/DEC), winter (JAN/FEB/MAR), and spring (APR/MAY/JUN) as shown in Table 6. Average supply per season is then determined. A seasonal factor for each quarter is determined by taking the ratio of the quarter average to the average for all the seasons of one year. The results of these calculations indicate that summer and fall are the busiest times for incoming HAZMAT supply with the two seasons being 27% and 19%, respectively, more than the trend component. Winter and spring are the slowest seasons at only 67% and 87%, respectively, of the trend component.

TABLE 6 - DECOMPOSITION OF THE SUPPLY TIME SERIES

SEASON	ACTUAL SUPPLY	SEASON AVERAGE	SEASONAL FACTOR	DESEASON SUPPLY (Y)	PERIOD (X)
SUMM88	1,935	1,981	1.27	1,524	1
FALL88	1,477	1,854	1.19	1,241	2
WINT89	926	1,050	0.67	1,382	3
SPRNG89	1,183	1,355	0.87	1,360	4
SUMM89	2,027	*******	1.27	1,596	5
FALL89	2,231	*******	1.19	1,875	6
WINT90	1,175	*******	0.67	1,754	7
SPRNG90	1,527	*******	0.87	1,755	8
TOTAL	**12,481**	**6,241**	**8.00**	**12,487**	**36**
AVERAGE	1,560	1,560	1.00	1,561	4.5

Once the seasonal factor is determined, the supply amounts are deseasonalized by dividing the actual supply amount by the seasonal factor. This allows the new amounts to be analyzed through regression analysis as in Figure 8.

```
The regression equation is
gallons = 1245 + 70.2 period

Predictor        Coef        Stdev      t-ratio        p
Constant       1245.0        120.7        10.32    0.000
period          70.20        23.90         2.94    0.026

s = 154.9       R-sq = 59.0%     R-sq(adj) = 52.2%

Analysis of Variance

SOURCE       DF         SS          MS         F        p
Regression    1     206992      206992      8.63    0.026
Error         6     143925       23988
Total         7     350917

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Figure 8. Regression analysis of incoming HAZMAT supply

The linear model equation from the regression analysis is $Y = 1245 + 70.2X$. The relative strength of the linear relationship between the independent variable, X, and the dependent variable, Y, is indicated by the coefficient of determination, r^2. From the regression analysis readout in Figure 8, a 59% proportion of the variability in the sample Y variable is explained by the X variable through the fitting of the regression line. This is not a particularly strong indication that the regression line explains the variability.

The fitted regression line is plotted against a scatter diagram for the incoming HAZMAT supply data as in Figure 9.

To determine whether using a simple linear regression model is valid, a residual analysis is made to test the assumption. The *ith* residual, denoted by e_i, is the difference between the observed value y_i and the corresponding fitted value $\hat{y}_i$:

$$e_i = y_i - \hat{y}_i$$

The residual can be standardized by subtracting the mean of the residuals (which should be zero apart from numerical roundoff) and dividing by the standard error of the estimate, $s_{Y/x}$:

$$i\text{th standardized residual} = \frac{e_i}{s_{Y/x}}$$

where

$$s^2_{Y/x} = \sum_{i=1}^{n} \frac{(y_i - \hat{y}_i)^2}{n-2}$$

For the incoming HAZMAT supply, the calculated residuals and standardized residuals are displayed in Table 7. The residuals or standarized residuals are used to assess the assumptions concerning the error term, ε_i, in the regression model where:

$$\varepsilon_i = Y_i - E(Y_i), \; i = 1, 2, \ldots, n$$

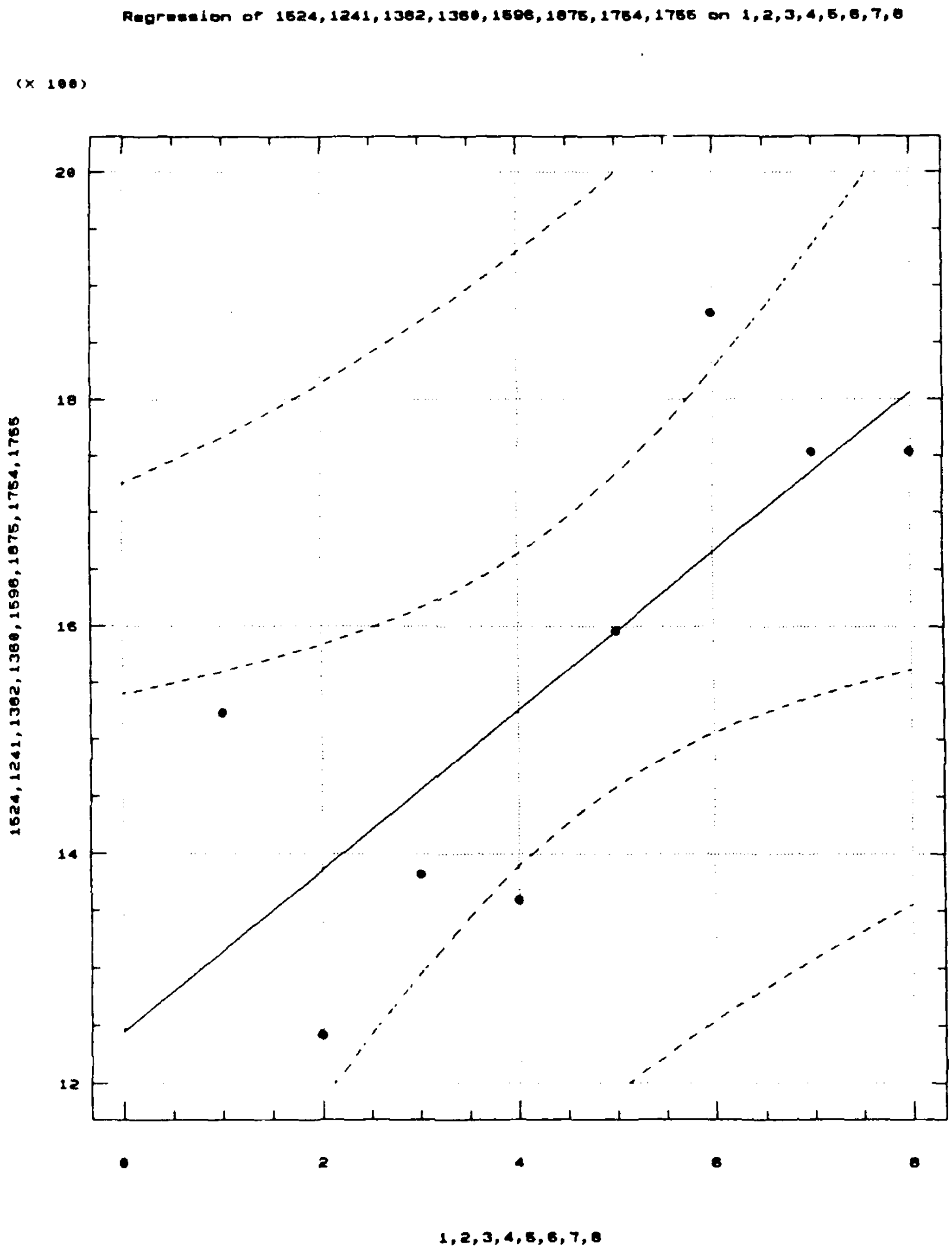

Figure 9. Fitted regression line against scatter dots of actual incoming HAZMAT supply data

TABLE 7 - CALCULATED RESIDUALS FOR INCOMING HAZMAT SUPPLY

x (Period)	y (Gallons)	$e = y - \hat{y}$ (residuals)	Standardized residuals
1.00	1524.00	208.8	1.77
2.00	1241.00	-144.4	-1.09
3.00	1382.00	-73.6	-0.52
4.00	1360.00	-165.8	-1.15
5.00	1596.00	0.0	0.00
6.00	1875.00	208.8	1.49
7.00	1754.00	17.6	0.13
8.00	1755.00	-51.6	-0.44

The following three assumptions need to be initially met if a regression model is to be considered a valid representation between the dependent and independent variable:

1. The ε_i's are normally distributed.
2. The ε_i's are independent, or uncorrelated.
3. The ε_i's are homoscedastic, or have the same variance.

If the fitted line is an appropriate model to fit the sample data, the observed residuals e_i should reflect the three above assumptions on the error term ε_i. [Ref. 17:pp. 671-672]

Using the calculated standardized residuals, the first assumption can be checked. If error terms are normally distributed, the standardized error terms will be distributed as standard normal (Z) variables. Therefore, about 68% of the standardized residuals would fall between -1 and +1, about 95% would fall between -2 and +2, and 100% would fall between -3 and +3. [Ref. 17:p. 674] For the incoming HAZMAT supply, for the sample size of n = 8, 50% of the standardized residuals fall between -1 and +1, 100% between -2 and +2, and 100% between -3 and +3. Although not following a perfectly normal distribution, the values are fairly close to the expected percentages and the first assumption is validated.

A useful method for analyzing the second and third error term assumptions is the residual plot as depicted in Figure 10 for the incoming HAZMAT supply. In the second assumption, the error terms must be uncorrelated. Thus, there should be no pattern in the residual plot. The plot in Figure 10 appears scattered, with no pattern, but there does not appear to be enough data points to be conclusive. The third assumption requires variability to be approximately constant. There appears to be some variability with the residuals but they do not appear to be increasing as the values of x increases. Once again, the results are inconclusive and the third assumption cannot be stated as positively valid.

Since the residual plot does not positively satisfy the error term assumptions, the assumption that the incoming HAZMAT supply can be represented by a fitted regression line is considered questionable and open to further testing, using more data points. However, if the model does follow a normal distribution, before using the model for prediction purposes, a statistical test of the usefulness of the model developed should initially be made.

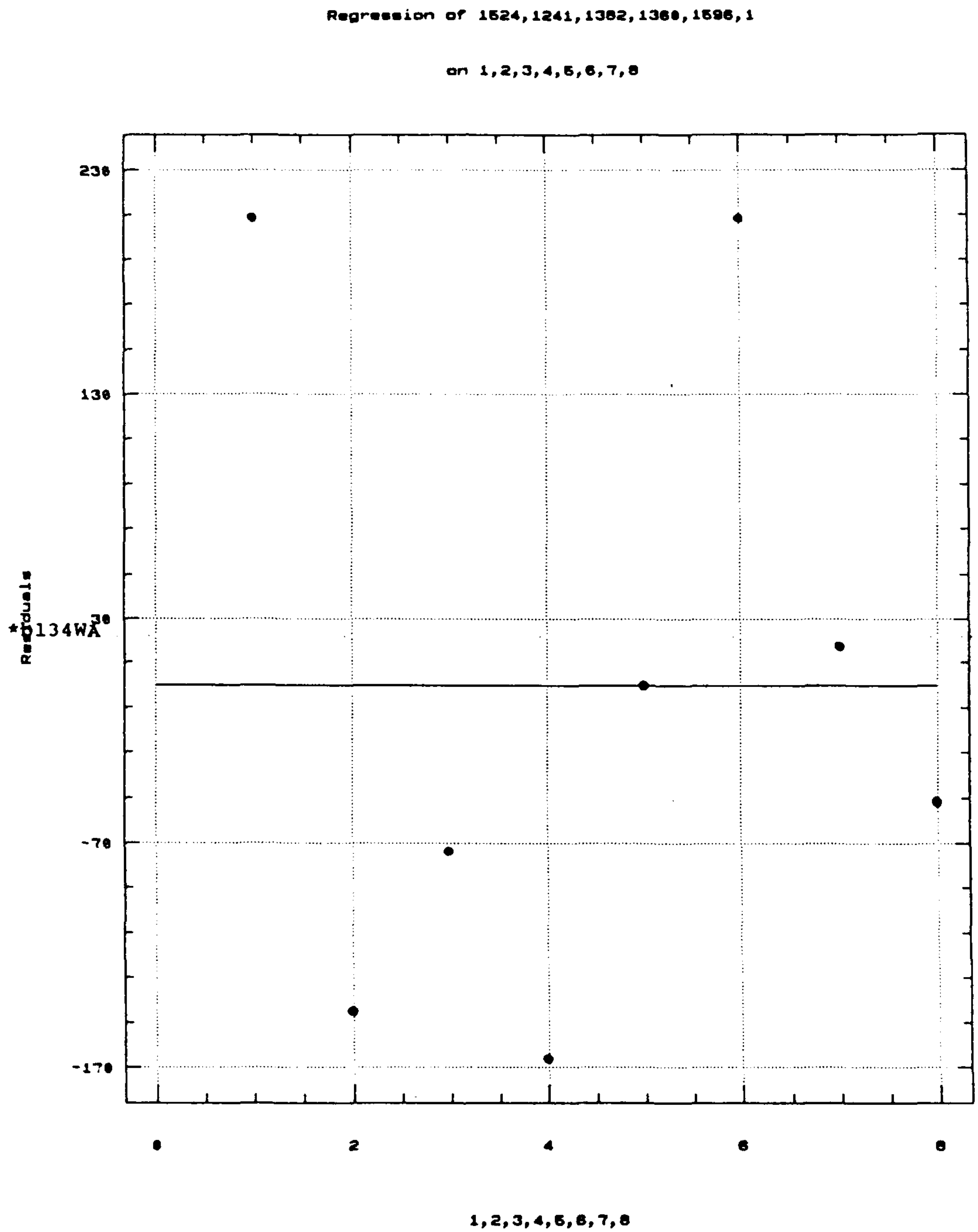

Figure 10. Residual plot for the incoming HAZMAT supply

The slope of the regression line is important in that it can indicate whether the model is useful for prediction. If an inference can be made that the slope is equal to zero, then it can be stated that the model ($E(Y) = \beta_0 + \beta_1 x$) is of no value, since a zero slope ($\beta_1 = 0$) would indicate that for every value of x, the predicted value of the dependent variable would be equal to the y-axis intercept, β_0.

A confidence interval estimate for β_1 is given by the following equation [Ref. 18:p. 711]:

$$b_1 - t_{a/2:n-2} s_{b1} \leq \beta_1 \leq b_1 + t_{a/2:n-2} s_{b1}$$

where t_{n-2} is the test statistic:

$$t_{n-2} = \frac{b_1 - \beta_1}{s_{b1}}$$

s_{b1} is the square root of the point estimator of the variance:

$$s_{b1} = \sqrt{\frac{s^2{}_{Y/x}}{\sum x^2{}_i} - \frac{(\sum x_i)^2}{n}}$$

where $s^2{}_{Y/x} = SSE/(n-2)$

For the incoming HAZMAT supply data, the point estimate of β_1 is $b_1 = 70.2$. For a 95% confidence interval, $(1-\alpha) = 0.95$. Thus, $\alpha = 0.05$ and $\alpha/2 = 0.025$. The test statistic for a sample, n = 8, at this level is $t_{0.025:8-2} = 2.447$ [Ref. 17:p. 1156]. Using the above equations, $s_{b1} = 23.8984$. The resulting confidence interval is:

$$70.2 - (2.447)(23.8984) \le \beta_1 \le 70.2 + (2.447)(23.8984)$$

$$11.7 \le \beta_1 \le 128.7$$

Therefore, with 95% confidence, it can be concluded that the true slope β_1 lies between 11.7 and 128.7 and since the interval does not contain zero, the sample regression line, Y=1245+70.2X, could be a useful predictor of incoming HAZMAT supply during the next eight periods.

Future incoming HAZMAT supply amount trend can now be forecasted. Since a linear regression analysis is accurate only for a linear relationship, the future forecast should not be made for much more than a year ahead since, beyond that, the prediction interval can become too large as trend lines diverge. A supply trend is made for eight quarters in Table 8 and then adjusted using the seasonal factor from Table 6.

TABLE 8 - FUTURE FORECAST OF INCOMING HAZMAT SUPPLY

SEASON	PERIOD (X)	TREND (Y)	SEASONAL FACTOR	FORECAST
Summer 90	9	1,877	1.27	2,384
Fall 90	10	1,947	1.19	2,317
Winter 91	11	2,017	0.67	1,351
Spring 91	12	2,087	0.87	1,816
Summer 91	13	2,158	1.27	2,741
Fall 91	14	2,228	1.19	2,651
Winter 92	15	2,298	0.67	1,540
Spring 92	16	2,368	0.87	2,060

2. Sales Forecast

A similar analysis is made of the historical outgoing HAZMAT sales data. Table 9 outlines this data, which includes both HAZMAT reutilized locally at SUBASE Bangor and HAZMAT reclaimed by the local DRMO for sale to commercial vendors. The HAZMAT reclaimed by DRMO makes up nearly 65% of the outgoing sales.

TABLE 9 - OUTGOING HAZMAT SALES DATA (IN GALLONS)

MONTH & YEAR	SALES (GALS)	MONTH & YEAR	SALES (GALS)
JUL88	576	JUL89	559
AUG88	456	AUG89	565
SEP88	460	SEP89	497
OCT88	430	OCT89	474
NOV88	493	NOV89	510
DEC88	687	DEC89	766
JAN89	642	JAN90	643
FEB89	624	FEB90	659
MAR89	492	MAR90	504
APR89	441	APR90	402
MAY89	527	MAY90	584
JUN89	601	JUN90	668

The decomposition of the sales time series is outlined in Table 10. Once again, the seasonal factor is determined first, followed by the deseasonalization of sales. The results of the seasonal factor calculations indicate that the sales amounts tend to follow their trend component much more closely than the supply amounts followed their trend. Interestingly, the fall and winter seasons tend to be slightly busier seasons than the other two. This is not unreasonable since these are the times when the facility is receiving new material and also when commands tend to prepare for spring with many self-help projects in late winter.

TABLE 10 - DECOMPOSITION OF THE SALES TIME SERIES

SEASON	ACTUAL SALES	SEASON AVERAGE	SEASONAL FACTOR	DESEASON SALES (Y)	PERIOD (X)
SUMM88	1,492	1,556	0.94	1,587	1
FALL88	1,610	1,680	1.01	1,594	2
WINT89	1,758	1,782	1.08	1,628	3
SPRNG89	1,569	1,612	0.97	1,618	4
SUMM89	1,621	*******	0.94	1,724	5
FALL89	1,750	*******	1.01	1,733	6
WINT90	1,806	*******	1.08	1,672	7
SPRNG90	1,654	*******	0.97	1,705	8
TOTAL	**13,260**	**6,630**	**8.00**	**13,261**	**36**
AVERAGE	1,658	1,658	1.00	1,658	4.5

After deseasonalized outgoing HAZMAT sales amounts are found, a linear regression analysis can be applied. The output in Figure 11 indicates that the regression equation is

$Y = 1570 + 19.5X$ and the fitted regression line is plotted against the scatter dots of the actual data in Figure 12. The r^2 value of 66.4% indicates that there is probably a stronger linear relationship to the sample outgoing sales data points than there was to the incoming supply data but that it is still not particularly strong. Another residual analysis is made to determine whether the assumptions of the simple linear regression model have been met.

```
The regression equation is
gallons = 1570 + 19.5 period

Predictor       Coef          Stdev     t-ratio         p
Constant     1569.93          28.58       54.94     0.000
period        19.488          5.659        3.44     0.014

s = 36.68       R-sq = 66.4%      R-sq(adj) = 60.8%

Analysis of Variance

SOURCE        DF          SS          MS          F          p
Regression     1       15951       15951      11.86      0.014
Error          6        8071        1345
Total          7       24022

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Figure 11. Regression analysis of outgoing HAZMAT demand

The residuals and standardized residuals for the outgoing HAZMAT sales data are calculated and displayed in Table 11. Using the standardized residuals, the first error term assumption is checked. Of the eight sample data points, 62.5% lie between -1 and +1, 100% lie between -2 and +2, and 100% lie between -3 and +3. These data points follow a normal

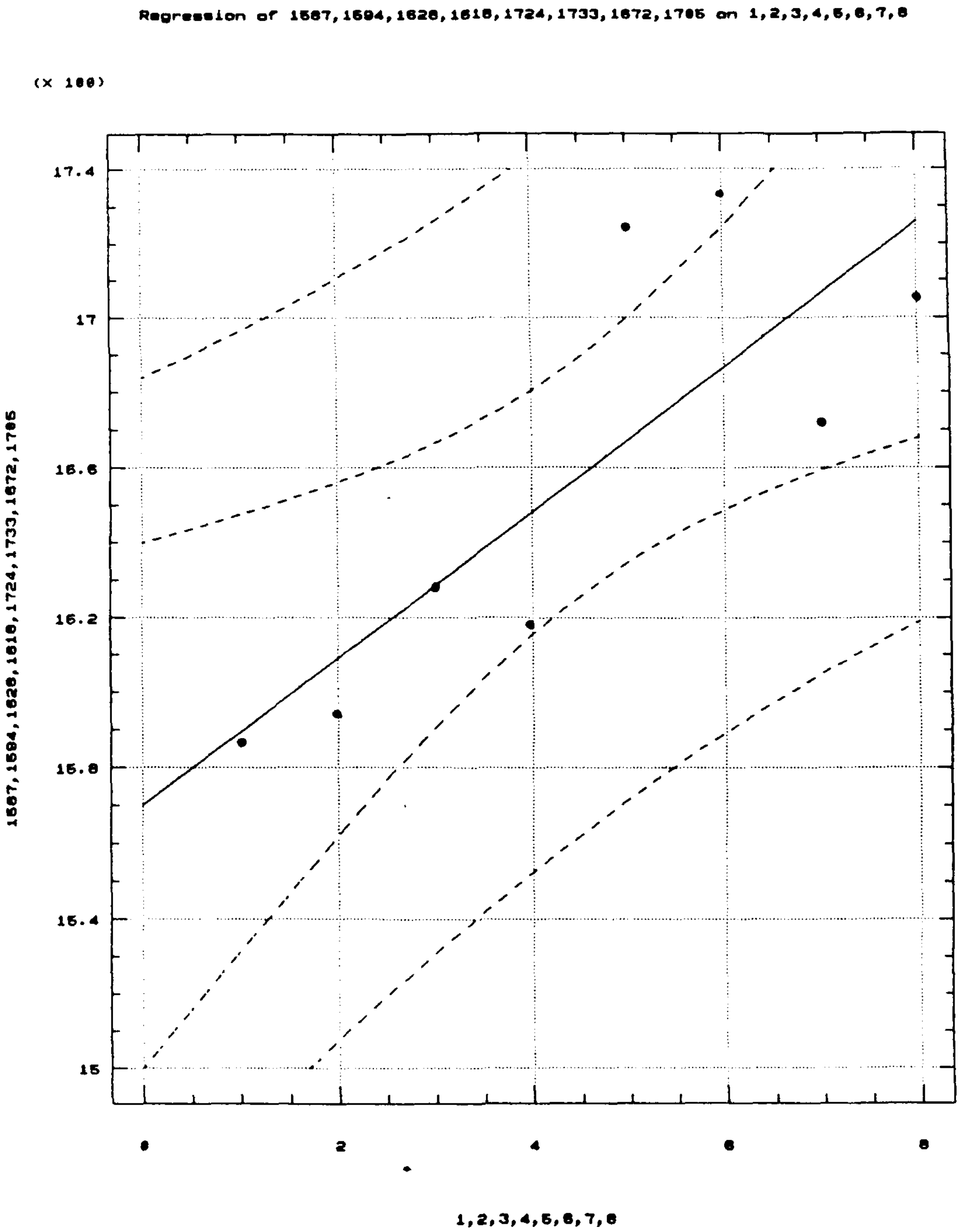

Figure 12. Fitted regression line against scatter dots of actual outgoing HAZMAT sales data

TABLE 11 - CALCULATED RESIDUALS FOR OUTGOING HAZMAT SALES

X (Period)	Y (Gallons)	$e = y - \hat{y}$ (residuals)	Standardized residuals
1.00	1587.00	-2.4	-0.09
2.00	1594.00	-14.9	-0.48
3.00	1628.00	-0.4	-0.01
4.00	1618.00	-29.9	-0.87
5.00	1724.00	56.6	1.66
6.00	1733.00	46.1	1.39
7.00	1672.00	-34.3	-1.10
8.00	1705.00	-20.8	-0.74

distribution much more closely than the incoming HAZMAT supply data. Therefore, the first error term assumption appears to be more valid but is still inconclusive.

The residual plot for the outgoing HAZMAT sales data points is depicted in Figure 13 and is used to determine whether the second and third error term assumptions are satisfied. Once again, the dots are scattered with no particular pattern, but more data points are necessary to ensure an uncorrelated condition. The variability of the residuals appears to be less volatile in this group than in the incoming supply but the test is still inconclusive.

Once again, a statistical test is performed to determine the usefulness of the regression model developed, should it indeed follow a normal distribution. For the outgoing HAZMAT sales data, the point estimate of β_1 is b_1=19.488. For a 95%

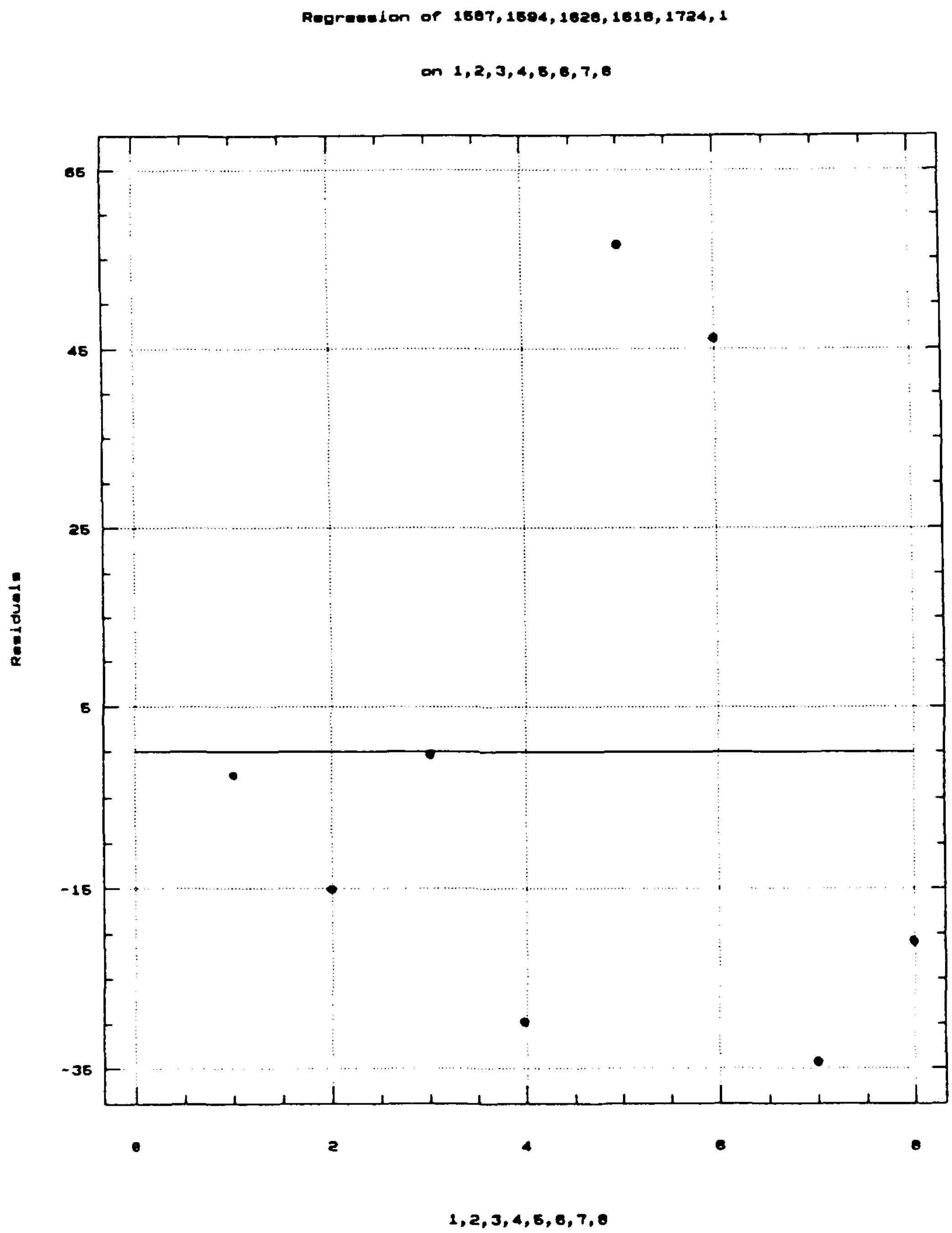

Figure 13. Residual plot for outgoing HAZMAT sales data

confidence interval, the test statistic is once again $t_{0.025;8-2} = 2.447$. The square root of the point estimate of the variance is $S_{b1} = 5.659$. The resulting confidence interval is:

$$19.488 - (2.447)(5.659) \le \beta_1 \le 19.488 + (2.447)(5.659)$$

$$5.6 \le \beta_1 \le 33.3$$

It can therefore be concluded, with 95% confidence, that the true slope β_1 lies between 5.6 and 33.3. Since this interval does not contain zero, the sample regression line, Y=1569.93 + 19.488X, could be a useful predictor of outgoing HAZMAT sales for the next eight periods.

The final steps are the trend projection and seasonal adjustment (from Table 10) of each trend amount to determine the forecasted sales amounts. This is outlined in Table 12.

TABLE 12 - FUTURE FORECAST OF OUTGOING HAZMAT SALES

SEASON	PERIOD (X)	TREND (Y)	SEASONAL FACTOR	FORECAST
Summer 90	9	1,746	0.94	1,641
Fall 90	10	1,765	1.01	1,783
Winter 91	11	1,784	1.08	1,927
Spring 91	12	1,804	0.97	1,750
Summer 91	13	1,824	0.94	1,715
Fall 91	14	1,843	1.01	1,861
Winter 92	15	1,862	1.08	2,011
Spring 92	16	1,882	0.97	1,826

3. Predicted Level of HAZMAT (H_p)

At the baseline period (July 1990), the current content (H_c) of the SUBASE Bangor facility (including both large and small storage), was determined to be approximately 1025 gallons of HAZMAT. Under the aforementioned assumptions of no shelf-life expirations and enough warehouse capacity, and assuming the regression model is valid, the forecasted values of incoming supply and outgoing sales can be used in the equation [$H_p=H_c+S-D$] to calculate the predicted value of HAZMAT (H_p) for the next eight periods, as indicated in Table 13.

TABLE 13 - PREDICTED VALUE OF HAZMAT (H_p)

SEASON	H_c (gallons)	SUPPLY (gallons)	SALES (gallons)	H_p (gallons)
Summer 90	1,025	2,384	1,641	1,768
Fall 90	1,768	2,317	1,783	2,302
Winter 91	2,302	1,351	1,927	1,726
Spring 91	1,726	1,816	1,750	1,792
Summer 91	1,792	2,741	1,715	2,818
Fall 91	2,818	2,651	1,861	3,608
Winter 92	3,608	1,540	2,011	3,137
Spring 92	3,137	2,060	1,826	3,371

The results of the projection indicate that at current trends, the level of HAZMAT could nearly triple within two years. This is obviously unacceptable and indicative that either changes in outgoing HAZMAT demand amounts need to be made or that the reutilization facility needs to be greatly increased in size.

C. SIMULATION OF OUTGOING HAZMAT SALES AMOUNTS

The HAZMAT reutilization operation can be viewed in terms of a waiting line, with the rate of incoming supply similar to an arrival rate and the rate of outgoing sales as a service rate. Since as much HAZMAT as possible should be reutilized, the flow of incoming supply should not be impeded. However, to keep the queue from stacking up with excess HAZMAT, the service rate (rate of outgoing sales) needs to be increased. Sensitivity analyses are performed in Tables 14, 15, and 16, where 5%, 10%, and 15% increases, respectively, in outgoing sales are simulated and applied to the forecasted incoming supply amounts to recalculate predicted levels of HAZMAT.

TABLE 14 - PREDICTED HAZMAT LEVEL W/ 5% INCREASE IN SALES

SEASON	H_c (gallons)	SUPPLY (gallons)	SALES (gallons)	H_p (gallons)
Summer 90	1,025	2,384	1,723	1,686
Fall 90	1,686	2,317	1,872	2,131
Winter 91	2,131	1,351	2,023	1,459
Spring 91	1,459	1,816	1,838	1,437
Summer 91	1,437	2,741	1,801	2,377
Fall 91	2,377	2,651	1,954	3,074
Winter 92	3,074	1,540	2,112	2,502
Spring 92	2,502	2,060	1,917	2,645

TABLE 15 - PREDICTED HAZMAT LEVEL W/ 10% INCREASE IN SALES

SEASON	H_c (gallons)	SUPPLY (gallons)	SALES (gallons)	H_p (gallons)
Summer 90	1,025	2,384	1,805	1,604
Fall 90	1,604	2,317	1,961	1,960
Winter 91	1,960	1,351	2,120	1,191
Spring 91	1,191	1,816	1,925	1,082
Summer 91	1,082	2,741	1,886	1,937
Fall 91	1,937	2,651	2,047	2,541
Winter 92	2,541	1,540	2,212	1,869
Spring 92	1,869	2,060	2,009	1,920

The results of the sensitivity analysis with simulated sales indicate with just a 5% increase in HAZMAT demand, the predicted level of HAZMAT after two years drops nearly 22%. With a 10% and 15% increase, the predicted level of HAZMAT

TABLE 16 - PREDICTED HAZMAT LEVEL W/ 15% INCREASE IN SALES

SEASON	H_c (gallons)	SUPPLY (gallons)	SALES (gallons)	H_p (gallons)
Summer 90	1,025	2,384	1,887	1,522
Fall 90	1,522	2,317	2,050	1,789
Winter 91	1,789	1,351	2,216	924
Spring 91	924	1,816	2,012	728
Summer 91	728	2,741	1,972	1,497
Fall 91	1,497	2,651	2,140	2,008
Winter 92	2,008	1,540	2,313	1,235
Spring 92	1,235	2,060	2,100	1,195

falls by 43% and 65%, respectively. The increase of 170 gallons in HAZMAT level after two years (using a 15% increase in sales amount) should be quite manageable. Figure 14 shows these effects.

The implications of this analysis indicate that with a slight increase in the service rate of the outgoing HAZMAT sales, a great decrease in awaiting HAZMAT level can occur. Increasing outgoing HAZMAT sales can be done in two main ways:

1) First, a concerted effort should take place to match certain HAZMAT with potential customers through newsletters, advertisements, telephone calls, and effective customer service. Although DoD facilities should be offered new incoming HAZMAT first, civilian firms should be allowed to obtain unwanted HAZMAT.

2) Second, HAZMAT should not be allowed to stay within the facility for more than one season (60 days) and, preferably, less than that period. Although there are already established rules for storage time limits (usually 60 days), they are often ignored or extended to 120 or more days. Such extensions usually only contribute to increasing HAZMAT levels within the facility. However, inventory levels for each item should be calculated so that approximately 70 days worth of item inventory exists to preclude stockout. Otherwise, excess HAZMAT should be passed to DRMO for recycling and sale to commercial vendors. If it is not moving, get rid of it!

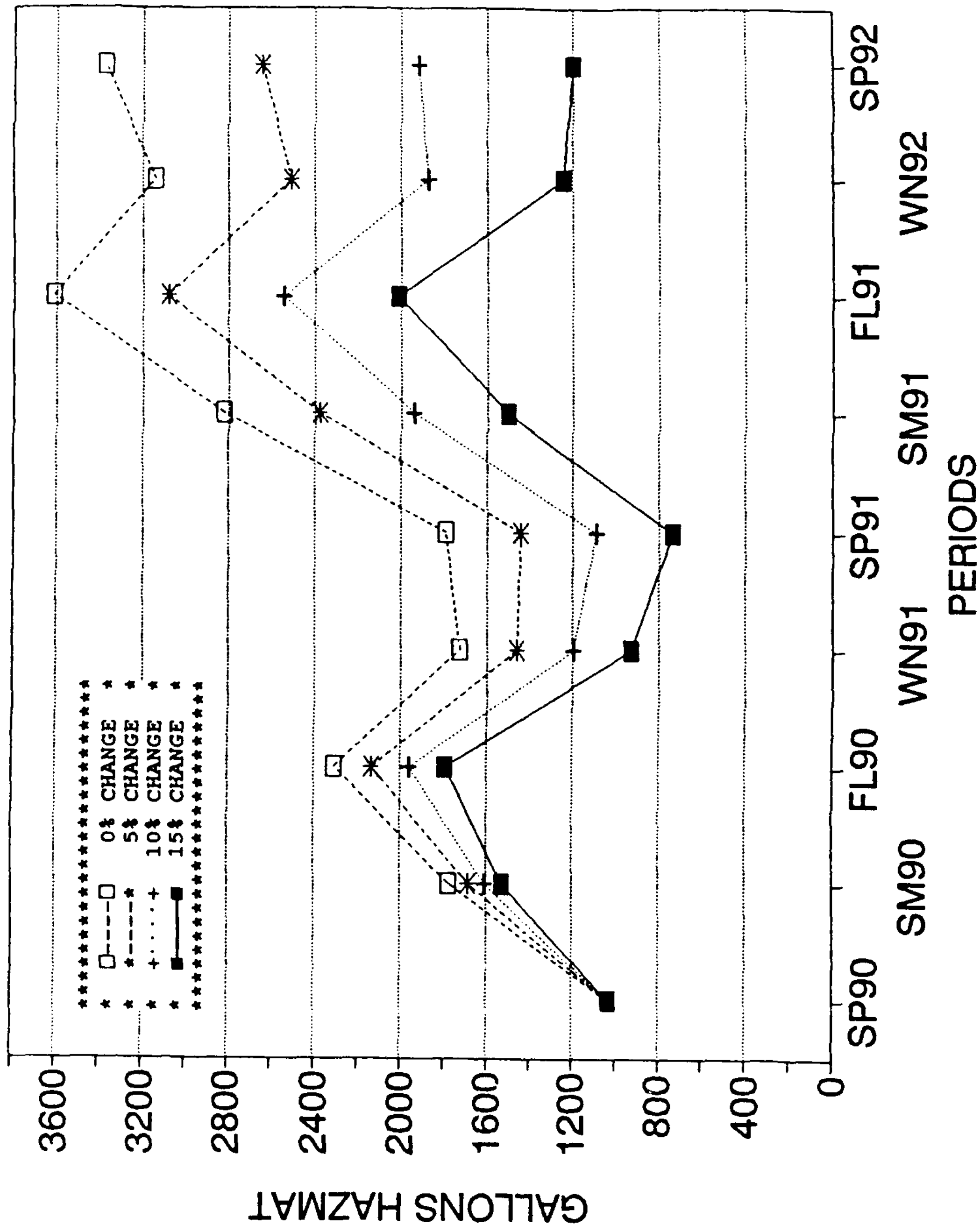

Figure 14. Predicted HAZMAT level w/ 0%, 5%, 10%, and 15% increases in outgoing HAZMAT sales

VI. ECONOMIC ANALYSIS OF THE SUBASE BANGOR FACILITY

A. BACKGROUND

This chapter presents economic analyses on HAZMAT reutilization facility options. Its purpose is to aid U.S. Navy managers in determining whether establishment of such facilities is a viable approach to alleviating current HAZWASTE problems by aiding HAZMIN reduction efforts. Data from the SUBASE Bangor operation and government cost estimation tables are use to focus on two specific areas:

1) First, assuming that a reutilization facility is to be established on base, a Type II (or secondary) economic analysis is performed to determine which on-base activity is preferable in operating the facility. A Type II analysis refers to the method of selection of the most economical alternative from a group of satisfactory alternatives designed to perform a function which is not justified on the basis of dollar savings. It is used to justify investments which <u>initiate</u> an expense stream [Ref. 18:p. 12].

2) Second, once cost data from the Type II decision is known, a Type I (or primary) economic analysis is made to determine whether the normal, status quo situation of having no reutilization facility available on base and the subsequent disposing of half-used hazardous materials as hazardous waste

should be changed. Two alternative solutions are compared against each other and the status quo alternative to determine which of the three is the most cost effective. A Type I economic analysis involves alternatives with a proposed savings over an existing mode of operation. It is used to justify investments intended to reduce an <u>already existent</u> cash flow [Ref. 18:p. 12].

B. METHODOLOGY

To ensure a systematic, iterative evaluation of all reasonable alternatives for satisfying the above objectives, the economic analysis takes the following six step approach:

a) Define the objective.

b) Generate alternatives.

c) Formulate assumptions.

d) Determine costs and benefits.

e) Compare costs and benefits and rank alternatives.

f) Perform sensitivity analysis.

Each alternative is considered in terms of its implications for full life cycle funding and benefits. Also, life cycle costs and benefits are expressed in present values.

C. OBJECTIVE (TYPE II ECONOMIC ANALYSIS)

The objective of this analysis is to determine which of the following activities is preferable in operating an HAZMAT reutilization facility, assuming that such a facility is to be built on base: Base Supply (using U.S. Naval personnel), Public Works (using government-employed civilians), or a private commercial vendor (using private civilians).

D. ALTERNATIVES (TYPE II ECONOMIC ANALYSIS)

1. Base Supply

The first alternative (ALT 1) is to employ U.S. Naval storekeepers at Base Supply to operate the facility.

2. Public Works Department

The next alternative (ALT 2) is to use government-employed civilians at the base's Public Works Department to operate the facility. NS San Diego currently runs its operation this way.

3. Private Commercial Vendor

The third alternative (ALT 3) of the Type II decision analysis is to employ a private vendor. SUBASE Bangor currently operates in this manner. A contract is bid out to the least cost vendor who can acceptably perform.

E. ASSUMPTIONS (TYPE II ECONOMIC ANALYSIS)

- From statements made at both the Bangor and San Diego operations, only two persons are necessary to run the HAZMAT facility, with only one working full time (100%) while the other working part time (33%). His job would include handling materials and administration work. Only occasionally would he require extra help to move some materials. Consequently, labor cost calculations in these cost benefit analyses will be for two persons.
- Although dollar amounts in the enclosed calculations appear to be very exact, they should only be viewed as general representations of actual cost relationships, since activity time limits are only estimates.

- Government economic analyses use wage rates at Step 5 level when calculating personnel labor costs.

- Establishing an HAZMAT operation at Base Supply (ALT 1) will require transferring a person in from another duty station. Permanent Change of Station (PCS) costs are calculated at $815 per person. ALT 2 would use personnel from the local area, thus not requiring PCS transfers.

- A competitive bidding process take place among vendors. The winning bid defrays all recurring and nonrecurring costs incurred by the vendor. Only the estimated winning bid will be considered when calculating ALT 3's costs.

- All costs and salaries reflect those in effect during FY91. No provision is made for inflation.

- Cost elements are anticipated to escalate at the same rate as the general price level.

- Initial present value analysis computations are made using the standard Government 10% discount rate (DoDI 7041.3 and OMB Circular A-94). P.V. analyses using lower discount factors are computed later.

- Instead of end-of-year factors, an average factor for the year is used since costs are usually dispersed throughout the year.

- Since nonrecurring (NRECUR) costs are a one time expense, the discount factor for the first year is applied to determine its discounted cost. If recurring (RECUR) costs are uniform each year, a cumulative factor is applied to determine its discounted cost. If recurring costs vary each year, a single discount factor is applied and the sum of all discounted costs is used to determine total discounted costs (TDC).

- As recommended in the NAVFAC P-442 manual, the economic life of the operation is 25 years from the point of full implementation.

F. COST ANALYSIS (TYPE II ECONOMIC ANALYSIS)

Nonrecurring and recurring costs were determined for each alternative. Nonrecurring costs are costs incurred on a one-time basis. They include initial planning and investment costs. Recurring costs are those which occur on a periodic basis throughout the life cycle of the project and include operations and maintenance (O&M,N) and personnel labor (military, government, and civilian) costs.

Since this Type II economic analysis is only examining already existing activities to run a reutilization program, the only nonrecurring costs will be initial set up costs to establish this operation at the activity. The only recurring costs of interest will be in personnel labor costs. A more diverse set of nonrecurring and recurring costs is found when performing the Type I economic analysis.

1. Nonrecurring Costs

To establish a reutilization operation at each of the alternative activities requires initial set up costs. For ALT 1, the U.S. Navy would have to transfer two people into the area at a cost of $1630 to fill the required job billets. For ALT 2, a set up cost of $1500 is the administrative cost of advertising the two new job billets. This figure includes the costs of classification, writing, distribution, rating, ranking, certification, and interviewing. ALT 3 would require $2000 in contract bidding costs. [Ref. 19]

2. Recurring Costs

The only significant recurring costs in determining who should run the facility are personnel labor costs and supply costs. Annual costs for administrative and repackaging supplies for ALTs 1 and 2 are approximately $1000 each. Military personnel costs are based on the composite military pay rates identified in the NAVCOMPT manual (035750). Civilian government employee labor costs are based on current annual salaries defined by the General Schedule pay rates. Private vendor personnel costs are based on SUBASE Bangor commercial vendor historical data.

a. Alternative 1

If Base Supply was to run the facility, they would assign two storekeepers as outlined in Table 17. Annual personnel costs are approximately $32,737 and will remain constant throughout the entire life cycle.

TABLE 17 - ALTERNATIVE 1 PERSONNEL COSTS

Grade	# Persons	Ann.Salary	% of Year	LaborCost
E-4	01	$25,530	100%	$25,530
E-3	01	$21,621	33%	$7,207
Total	**02**	*******	****	**$32,737**

b. Alternative 2

If Public Works was to run the facility, a wage grade leader (WG-7) and handler (WG-5) would be employed. As indicated in Table 18, Government-civilian labor cost is $53,268, based on 2080 hours for one man-year of work. The NAVCOMPT manual uses a 52.8% acceleration rate to account for retirement and disability, health and life insurance, Medicare, leave and absences, and other employee benefit costs. [Ref. 20:p. 20]

Table 18 - ALTERNATIVE 2 PERSONNEL COSTS

Grade	#Pers (%Yr)	Ann.Salary	W/Benefits	LaborCost
WG-7	01 (100%)	$26,832	$41,000	$41,000
WG-5	01 (33%)	$24,087	$36,805	$12,268
Total	**02** ****	*******	*******	**$53,268**

c. *Alternative 3*

The only recurring cost in Alternative 3 that the Navy manager should consider is annual contract cost. Using the SUBASE Bangor contract as a standard, the Navy can expect to spend $46,500 for such a contract employing one supervisor and one administration clerk/material handler.

G. BENEFIT ANALYSIS (TYPE II ECONOMIC ANALYSIS)

Although not always quantifiable, some benefits and disadvantages are nevertheless important in determining the desirability of certain alternatives. The following are a number of benefits and disadvantages for each of the alternatives.

1. Alternative 1

a. Benefits

- This option allows hazardous material recycling to be handled at the source of newly-procured material. This may significantly reduce the amount of new material entering the system since this same supply activity has great incentive to issue old, reused material before it issues new material to user commands.

b. Disadvantages

- Adding this responsibility to the military, who feel they are already undermanned and overworked, may be demoralizing.

2. Alternative 2

a. Benefits

- This frees the military up to perform other supply responsibilities.

- The non-military government tenants (of which Public Works is the biggest) may feel freer to use the facility under this option. Public Works usually already operates the hazardous waste facility on base.

b. Disadvantages

- The military activities on base become more isolated from using the reutilization facility since it is being run by a non-military organization.

3. Alternative 3

a. Benefits

- If the contractor is already performing services in other areas of the base, they might offer a substantially-reduced contract price to operate the HAZMAT reutilization facility also, and then divert some of their personnel to help run the operation. This is the case at Bangor where Pan Am Services charges only an additional $19,000/year to run the HAZMAT store in addition to running the HAZWASTE facility.

b. Disadvantages

- Using a commercial vendor may require finding a building on base from which the vendor can operate. This may require moving other activities to other facilities, thus inconveniencing them.

H. COMPARISON OF ALTERNATIVES (TYPE II ANALYSIS)

1. Present Value Analysis

Present value analysis was performed on Alternatives 1, 2, and 3 and is presented in Table 19. Nonrecurring costs were discounted for 1 year while a cumulative discount factor was applied to the recurring cost for the entire 25 year life of the alternative. The results show that the discounted life-cycle costs for Alternatives 1, 2, and 3 are $322,866, $518,279, and $444,774, respectively. Operating the facility at Base Supply is the most economical alternative, yielding

TABLE 19 - TYPE II PRESENT VALUE ANALYSIS

Option	Type	#Yrs	Annual Cost	Discount	Total Cost
ALT 1	N/Rec	1	$1,630	0.954	$1,555
	Recur	25	$33,737	9.524	$321,311
				Total:	$322,866
ALT 2	N/Rec	1	$1,500	0.954	$1,431
	Recur	25	$54,268	9.524	$516,848
				Total:	$518,279
ALT 3	N/Rec	1	$2,000	0.954	$1,908
	Recur	25	$46,500	9.524	$442,866
				Total:	$444,774

net discounted savings of $121,908 over the next least expensive option, Alternative 3.

I. OBJECTIVE (TYPE I ECONOMIC ANALYSIS)

The objective of this analysis is to determine the economic feasibility of building either a brand new HAZMAT reutilization facility or renovating an existing building on a naval base which normally does not house such a facility for HAZMAT recycling and hazardous waste minimization.

J. ALTERNATIVES (TYPE I ECONOMIC ANALYSIS)

1. Continue to Operate Without Facility (Status Quo)

With this option, the base continues to operate without a reutilization facility. Only limited recycling, storage and transfer of excess hazardous material is realized since commands are unwilling to hold onto their excess hazardous material and tend to mix useable material with unusable items, disposing of both as hazardous waste. Without an available clearinghouse facility, the base is unable to efficiently direct useable HAZMAT to those commands which need material. Consequently, commands continue to spend precious Operations & Maintenance, Navy (O&M,N) needlessly and duplicate hazardous material enters the system.

2. Build a Brand New Reutilization Facility

With a brand new reutilization facility, the base can operate a clearinghouse operation for excess hazardous material. This would allow tenant commands a place to turn in their excess hazardous material separately from their hazardous waste. By drawing "free" material from the reutilization facility rather than Base Supply, commands can save O&M,N funds and keep duplicate material from entering the system.

3. Renovate an Already Established Building

A third option is to renovate an already established facility for use as a reutilization facility. This might necessitate the transfer of merchandise from the established building to another area to make room for the reutilized HAZMAT. Renovation would include establishing a chemical sprinkler, drainage/sump system, berms for separating materials and minimizing spills, and an adequate ventilation system.

K. ASSUMPTIONS (TYPE I ECONOMIC ANALYSIS)

- In addition to the assumptions presented in the Type II analysis, the following assumptions are made:

- The type of structure used for housing the HAZMAT reutilization operation could be different for different geographical locations and climates (e.g., totally enclosed for Bangor, covered open-air facility for San Diego). This cost analysis determines the cost for a totally enclosed facility.

- Using Bangor and San Diego as guides, costs for a 1200 SF facility will be determined.

- MILCON funding will be available for construction and renovation of buildings.

- Land is available to build a new facility.

- Cost totals were established by consolidating estimates from various separate work segments and using historical data for workload, size and operation of similar facilities.

- Hazardous materials used at Naval bases tend to be particularly potent and difficult to dispose. Thus, high range limits in disposal costs per item are used to determine total disposal costs.

- According to historical records at SUBASE Bangor, available HAZMAT input has increased at an 8-10% rate each year. Since such a growth rate may be unrealistic over the entire 25 year life cycle of the reutilization program, a conservative 5% growth rate is applied to the disposal/procurement costs when determining total discounted costs (TDC).

L. COST ANALYSIS (TYPE I ECONOMIC ANALYSIS)

1. Nonrecurring Costs

a. Initial Construction Planning

Before construction of a new reutilization facility can begin, initial construction planning is conducted to provide a site study, draw up construction blueprints, and coordinate miscellaneous other tasks in preparation for construction. According to a PWC spokesman, such planning can be accomplished by a two person team: a GS-12, Step 5 Engineer (10 days of work), and a GS-9, Step 5 Draftsman (21 days of work). [Ref. 21] Table 20 outlines the cost breakdown for this planning phase. Labor costs include salary and fringe benefits. Travel costs are estimated at two trips at a transportation cost of $1000 per person and per diem for 31 days at $50 per day.

TABLE 20 - INITIAL CONSTRUCTION PLANNING COSTS

CostElement	**Unit Cost**	**Frequency**	**Total Cost**
GS-12/S5	$156.16/day	10 Days	$1,562
GS-9/S5	$107.70/day	21 Days	$2,262
Travel	$1,000/person	4 Trips	$4,000
Per Diem	$50/day	31 Days	$1,550
Total	**********	**********	**$9,374**

b. Initial Renovation Planning

Renovation of an already-established facility would also require initial planning. This could be done by the same two person team as in section F.1.a. but with less labor time expended: Engineer (3 days) and Draftsman (7 days). Travel costs are estimated at one trip at $1000 per person and per diem for 10 days at $50 per day [Ref. 21]. Table 21 outlines these costs.

TABLE 21 - INITIAL RENOVATION PLANNING COSTS

CostElement	**Unit Cost**	**Frequency**	**Total Cost**
GS-12/S5	$156.16/day	3 Days	$469
GS-9/S5	$107.70/day	7 Days	$754
Travel	$1,000/person	2 Trips	$2,000
Per diem	$50/day	10 Days	$500
Total	*********	**********	**$3,723**

c. *Construction of a New Facility*

The construction of a new reutilization facility would be contracted out for an estimated cost of $100,980. A cost breakdown of the facility is outlined in Table 22. The facility would be a 1200 SF storage area with concrete walls, roof system and bermed concrete slab for spillage containment. Air conditioning and ventilation systems would be wall-mounted near the ceiling. Explosion-proof lighting and dry chemical sprinkler system would be ceiling-mounted.

TABLE 22 - FACILITY CONSTRUCTION COSTS

Cost Element	Total Cost
Primary Structure	$51,810
Perimeter Fence	$2,000
Electrical Utilities Hook-Up	$9,600
Mechanical Utilities Hook-Up	$17,100
Electrical Lighting and Equipment	$8,100
Vents, Sprinkler, A/C & Heater	$12,370
Total	**$100,980**

d. *Renovation Costs*

Alternative 3 would require the renovation of an already established building. This can be done at a cost of $37,070, as outlined in Table 23. Such a facility would require ventilation, air conditioning, sprinkler, and berming systems similar to the facility in Alternative 2.

TABLE 23 - FACILITY RENOVATION COSTS

Cost Element	Total Cost
Primary Structure Renovation & Berms	$2,200
Perimeter Fence	$2,000
Electrical Utilities Hook-Up	$1,000
Mechanical Utilities Hook-Up	$10,500
Electrical Lighting & Equipment	$4,000
Vents, Sprinkler, A/C & Heater	$12,370
Total	**$32,070**

e. *Initial Warehouse Plant Property*

Alternatives 2 and 3 would both require initial warehouse plant property, including shelving (90 LF), lockers, safety eye/face deluge bath, and fire extinguishers. The total sum for these items is $2850.

f. *Migration/Transfer Costs*

If Alternative 3 was to be considered, the transfer of people and equipment to another facility might very well be likely. A total of 72 manhours, at a cost of $12.25 per hour, for a total of $882, is needed to effect such a move.

2. Recurring Costs

a. *Hazardous Waste Disposal Costs*

In Alternative 1, the high range annual cost of disposing unreutilized hazardous materials as hazardous waste at SUBASE Bangor is $2,359.41. This is calculated by applying standard disposal costs supplied by the Defense Logistics

Agency (DLA) to the various categories of materials being reutilized at the SUBASE Bangor facility. Table 24 outlines this cost breakdown.

TABLE 24 - HAZWASTE DISPOSAL COSTS

HAZMAT Group	Amnt Reused	Price Range	Total Cost
Petrol,Oils	1528.7 GAL	Lo: .10/GAL	$152.87
& Lubes	1528.7 GAL	Hi: .38/GAL	$580.91
Solvents	511.5 GAL	Lo: .10/GAL	$51.15
	511.5 GAL	Hi: 1.00/GAL	$511.50
Toxins	247.4 GAL	Lo: .10/GAL	$24.74
	247.4 GAL	Hi: 5.00/GAL	$1237.00
Pesticide	30.0 GAL	1.00/GAL	$30.00
Total	**2317.6 GAL**	**Low Range**	**$258.76**
	2317.6 GAL	**High Range**	**$2,359.41**

b. Cost of Procuring New Hazardous Material

If old HAZMAT is not being reutilized, Alternative 1 also incurs the cost of user activities bringing new hazardous material into the system. This total equals the sum of the new procurement cost of items being reutilized by user commands and is equal to $25,321.34 for the period 01 July 1989-30 June 1990 at the SUBASE Bangor facility.

c. Utilities

Alternatives 2 and 3 would incur recurring utility costs of $4,813. Utilities include electrical/heating/air conditioning costs and water/sewage costs. Table 25 outlines this cost breakdown.

TABLE 25 - FACILITY UTILITY COSTS

Cost Element	Usage/Yr.	Unit Cost	Total Cost
Electrical(A/C) cost	20,000KWH	$.152/KWH	$3,040
Heating Cost	144MBTU	$10/MBTU	$1,440
Water/Sewage cost	260,000GL	1.28/KGAL	$333
Total	*********	********	**$4,813**

d. Maintenance and Janitorial Costs

Alternatives 2 and 3 would also incur recurring maintenance and janitorial costs, but at different rates. Table 26 outlines this cost breakdown.

TABLE 26 - FACILITY MAINTENANCE & JANITORIAL COSTS

Cost	Element	Size	Unit Cost	Total Cost
Maintenance Costs	ALT 2	1200SF	1.0/SF/Yr	$1200
	ALT 3	1200SF	1.5/SF/Yr	$1800
Janitorial Costs	ALT 2	1200SF	1.2/SF/Yr	$1440
	ALT 3	1200SF	1.5/SF/Yr	$1800
Total Costs	**Alternative 2**			**$2640**
	Alternative 3			**$3600**

M. BENEFIT ANALYSIS (TYPE I ECONOMIC ANALYSIS)

1. Alternative 1

a. Benefits

Continuing status quo is convenient and easy.

b. Disadvantages

It is environmentally and politically unacceptable to continue massive HAZWASTE disposal. Aside from the actual disposal and procurement costs of hazardous material that continuing with Alternative 1 incurs, there exists a qualitative cost of perception that the U.S. Navy and its sister services are not actively pursuing aggressive hazardous waste minimization on their bases. Avoiding such a perception may even override other economic considerations (i.e., net discounted savings) when determining whether operating a HAZMIN reutilization facility on a U.S. Navy base is a feasible and desirable activity.

2. Alternative 2

a. Benefits

A new facility is easier to maintain, usually safer and can be built in an area which will service the most customers.

b. Disadvantages

A new facility is usually expensive and may take some time to build and come on line.

3. Alternative 3

a. Benefits

A modified building is usually less expensive and easier to come on line than building a new building. Unused storage warehouses are often available.

b. Disadvantages

Using a renovated building can mean transferring personnel and equipment from the building to another location. The building may not be in the optimal place for use as a HAZMAT reutilization facility.

N. COMPARISON OF ALTERNATIVES (TYPE I ANALYSIS)

1. Present Value Analysis

Present value analyses were performed on Alternatives 1, 2, and 3 for the Type I economic analysis and are presented in Tables 27 and 28. Since using a 10% discount factor is standard in Government economic analyses, such a factor is initially applied in this analysis. A 6% discount factor is used in the sensitivity analysis.

The results show that the discounted life-cycle costs for Alternatives 1, 2, and 3 are $399,458; $501,750; and $445,469; respectively. Under the stated conditions and cost element inputs, Alternative 1 is the most economical alternative, yielding a net discounted savings of $46,011 over the next least expensive option, Alternative 3.

Table 27 - ALTERNATIVE 1 P.V. ANALYSIS (10% DISCOUNT)

YR	DISPOSAL COST	PROCURE COST	TOTAL COST	DISCOUNT FACTOR	DISCOUNT COST
01	2,360	25,321	27,681	0.954	26,408
02	2,477	26,588	29,065	0.867	25,199
03	2,601	27,917	30,518	0.788	24,048
04	2,731	29,313	32,044	0.717	22,976
05	2,868	30,778	33,646	0.652	21,937
06	3,011	32,317	35,328	0.592	20,914
07	3,162	33,933	37,095	0.538	19,957
08	3,320	35,630	38,950	0.489	19,047
09	3,486	37,411	40,897	0.445	18,199
10	3,660	39,282	42,942	0.405	17,391
11	3,843	41,246	45,089	0.369	16,638
12	4,035	43,308	47,343	0.334	15,813
13	4,237	45,474	49,711	0.304	15,112
14	4,449	47,747	52,196	0.276	14,406
15	4,671	50,135	54,806	0.251	13,756
16	4,905	52,641	57,546	0.228	13,120
17	5,150	55,273	60,423	0.208	12,568
18	5,408	58,037	63,445	0.189	11,991
19	5,678	60,939	66,617	0.172	11,458
20	5,962	63,986	69,948	0.156	10,912
21	6,260	67,185	73,445	0.142	10,429
22	6,573	70,544	77,117	0.129	9,948
23	6,902	74,071	80,973	0.117	9,474
24	7,247	77,775	85,022	0.107	9,097
25	7,610	81,664	89,274	0.097	8,660
	10%	TOTAL	DISCOUNT	COST:	$399,458

TABLE 28 - ALTS 2 & 3 P.V. ANALYSES (10% DISCOUNT)

TYPE COST	TOTAL ANNUAL COST	#YRS	DISCOUNT FACTOR	DISCOUNT COST
NONRECUR	$114,834	01	0.954	$109,552
RECUR	$41,180	25	9.524	$392,198
	ALT 2 TOTAL	**DISCOUNTED**	**COST**	$501,750
NONRECUR	$46,155	01	0.954	$44,032
RECUR	$42,150	25	9.524	$401,437
	ALT 3 TOTAL	**DISCOUNTED**	**COST**	$501,750

O. SENSITIVITY ANALYSIS

Since neither of the reutilization alternatives under the stated input conditions were found to be more economical than the status quo alternative, a sensitivity analysis was conducted by changing the disposal and procurement cost variables. The original estimate was changed by 25%, 50%, and 100% while holding all other parameters constant. This is not an unreasonable approach since SUBASE Bangor (the basis of the original estimates) is only a medium-sized base and may not be totally representative of larger bases like NS San Diego.

The outcome of the sensitivity analysis reveals that the total discounted costs (TDC) (discount rate 10%) for a 25%, 50%, and 100% increase in HAZMAT input would be $499,267, $599,118, and $798,826, respectively. Interestingly, such increases in available HAZMAT input would make Alternatives 2 and 3 more economically feasible.

As indicated in Table 29, with a 25% increase in amount of available HAZMAT input, the net discounted cost of Alternative 2 against Alternative 1 is now only $(2,483) and Alternative 3 against Alternative 1 is a positive savings of $53,798. As available HAZMAT input is increased, the net discounted cost savings increase dramatically.

TABLE 29 - S/A (10% DSCNT) CHANGING DISPOSAL/PROCURE COSTS

	25% CHANGE	50% CHANGE	100% CHANGE
ALT 1	499,267	599,118	798,826
ALT 2	501,750	501,750	501,750
DIFFERENCE	$(2,483)	$97,368	$297,076
ALT 3	445,469	445,469	445,469
DIFFERENCE	$53,798	$153,649	$353,357

However, keeping the labor and material costs of Alternatives 2 and 3 constant while increasing the disposal and procurement costs of Alternative 1 may not be reasonable. Consequently, a second sensitivity analysis was performed, making 25%, 50%, and 100% changes in labor and material costs of Alternatives 2 and 3 and applying them to the new total discounted costs (TDC) of the Alternative 1 sensitivity analysis changes. The results in Tables 30 and 31 indicate that, although changes in available HAZMAT input do make each alternative more economically attractive, only with a 100% increase in available HAZMAT input does Alternative 3 become

TABLE 30 - S/A (10% DSCNT) CHANGING ALT 2 LABOR/MAT'L COSTS

	25% CHANGE	50% CHANGE	100% CHANGE
LABOR/MAT'L	42,171	50,606	67,474
RECUR. COST	49,624	58,059	74,927
DSCNT RECUR	472,621	552,949	714,804
DSCNT NRECUR	109,552	109,552	109,522
TDC	$582,173	$662,501	$824,356
ALT 1 TDC	499,267	599,118	798,826
DIFFERENCE	$(82,906)	$(63,383)	$(25,530)

economically feasible. In all other combinations of inputs, Alternative 1 is still less expensive.

TABLE 31 - S/A (10% DSCNT) CHANGING ALT 3 LABOR/MAT'L COSTS

	25% CHANGE	50% CHANGE	100% CHANGE
LABOR/MAT'L	42,171	50,606	67,474
RECUR. COST	50,584	59,019	75,887
DSCNT RECUR	481,764	562,092	722,748
DSCNT NRECUR	44,032	44,032	44,032
TDC	$525,796	$606,124	$766,780
ALT 1 TDC	499,267	599,118	798,826
DIFFERENCE	$(26,529)	$(7,006)	$32,046

Sensitivity analyses were conducted in Tables 32 through 36 to determine whether or not changes in the discount factor would effect the outcome of the economic analysis. Although a 10% real discount rate is standard in Government economic

TABLE 32 - ALT 1 P.V. ANALYSIS (6% DISCOUNT)

Yr	TOTAL COST	6% DISCOUNT FACTOR	6% DISCOUNT COST
01	27,681	.972	26,906
02	29,065	.917	26,653
03	30,518	.865	26,398
04	32,044	.816	26,148
05	33,646	.770	25,907
06	35,328	.726	25,648
07	37,095	.685	25,410
08	38,950	.646	25,162
09	40,897	.610	24,947
10	42,942	.575	24,692
11	45,089	.543	24,483
12	47,343	.512	24,240
13	49,711	.483	24,010
14	52,196	.455	23,749
15	54,806	.430	23,567
16	57,546	.405	23,306
17	60,423	.382	23,082
18	63,445	.361	22,904
19	66,617	.340	22,650
20	69,948	.321	22,453
21	73,445	.303	22,254
22	77,117	.286	22,055
23	80,973	.270	21,863
24	85,022	.254	21,596
25	89,274	.240	21,426
		TOTAL DISCOUNTED COST	**$601,509**

TABLE 33 - ALTS 2 & 3 P.V. ANALYSES (6% DISCOUNT)

TYPE COST	TOTAL ANNUAL COST	# YEARS	DISCOUNT FACTOR	DISCOUNT COST
NONRECUR	$114,834	01	.972	$111,619
RECUR	$41,180	25	13.167	$542,217
	ALT 2 TOTAL DISCOUNTED COST			**$653,836**
NONRECUR	$46,155	01	.972	$44,863
RECUR	$42,150	25	13.167	$554,989
	ALT 3 TOTAL DISCOUNTED COST			**$599,852**

analyses, it may be too high. Changes in disposal and procurement costs and labor and material costs are once more made, but a 6% discount factor is now applied.

TABLE 34 - S/A (6% DSCNT) CHANGING DISPOSAL/PROCURE COSTS

	0% CHANGE	25% CHANGE	50% CHANGE	100% CHANGE
ALT 1	**601,509**	**751,886**	**902,264**	**1,203,018**
ALT 2	653,836	653,836	653,836	653,836
DIFF.	**$(52,327)**	**$98,050**	**$248,428**	**$549,182**
ALT 3	599,852	599,852	599,852	599,852
DIFF.	**$1,657**	**$152,034**	**$302,412**	**$603,166**

The results of the discount factor sensitivity analysis (S/A) indicate that when a smaller discount rate is used, Alternatives 2 and 3 appear more economically feasible. In fact, Alternative 3 is economically feasible with no changes in labor/material and disposal/procurement costs inputs and

TABLE 35 - S/A (6% DSCNT) CHANGING ALT 2 LABOR/MAT'L COSTS

	25% CHANGE	50% CHANGE	100% CHANGE
LABOR/MAT'L	42,171	50,606	67,474
RECUR COST	49,624	58,059	74,927
DSCOUNT RECUR	653,399	764,463	986,564
DSCOUNT NRECUR	111,618	111,618	111,618
ALT 2 TDC	$765,017	$876,081	$1,098,182
ALT 1 TDC	751,886	902,264	1,203,018
DIFFERENCE	$(13,131)	$26,183	$104,836

Alternative 2 is economically infeasible only for a zero and 25% change in inputs.

TABLE 36 - S/A (6% DSCNT) CHANGING ALT 3 LABOR/MAT'L COSTS

	25% CHANGE	50% CHANGE	100% CHANGE
LABOR/MAT'L	42,171	50,606	67,474
RECUR COST	50,584	59,019	75,887
DSCOUNT RECUR	666,040	777,103	999,204
DSCOUNT NRECUR	44,863	44,863	44,863
ALT 3 TDC	$710,903	$821,966	$1,044,067
ALT 1 TDC	751,886	902,264	1,203,018
DIFFERENCE	$40,983	$80,298	$158,951

P. CONCLUSIONS AND RECOMMENDATIONS

The results of the economic analysis indicate that operating a HAZMAT reutilization facility on a U.S. Navy base is feasible, but that its economic worth depends greatly on how much business it generates and on how many people are assigned to operate it. Generally, if a reutilization facility is being contemplated, Base Supply should be considered first as potential operators. If they are unable to operate the facility, then using a private vendor should be considered. Only after these first two options have been exhausted should PWC be considered as potential operators. Of course, extenuating circumstances may make a commercial vendor or PWC the first choice of operator (e.g., Pan Am Service providing unusually inexpensive labor to operate the facility at SUBASE Bangor.)

The economic feasibility of operating a HAZMAT reutilization facility on a U.S. Naval base is very dependent on the amount of labor used. In most instances, only one or two people should operate the facility. The addition of further personnel can have a dramatic effect on the net discounted savings.

A 10% discount rate may be too high. Considering recent inflation rates, a 6% discount rate seems to be more in line with real interest rates. The lower discount rate provided a more positive indication that establishing a HAZMAT reutilization facility on a U.S. Navy base is a sound economic option.

VII. SUMMARY AND RECOMMENDATIONS

A. THESIS SUMMARY AND CONCLUSIONS

The intent of this thesis has been to provide a general model for establishing hazardous material reutilization facilities at U.S. Naval bases. The study focused on the hazardous waste minimization program within the U.S. Navy by analyzing the establishment and operation of HAZMAT reutilization facilities at SUBASE Bangor and NS San Diego. Using the SUBASE Bangor facility as the basis for HAZMAT supply and demand amounts and operating costs, both a forecast analysis and an economic cost-benefit analysis were performed to determine predicted HAZMAT levels and optimal cost alternatives.

In Chapter II, an eleven-step ranked sequential process for handling hazardous material and hazardous waste was applied to the military. Numerous examples of hazardous material substitution and waste minimization within the Navy were presented. The use of HAZMAT reutilization facilities was proposed as an effective way to minimize hazardous waste production.

Chapters III and IV presented the HAZMAT reutilization facilities at SUBASE Bangor and NS San Diego as examples of a mature operation and an infant operation, respectively. A comparison of the two facilities revealed that both sites had to deal with various local and state regulations which impacted the effectiveness of the operation. A common weak point at both facilities was the need for better advertising of facility services to tenant user commands. Finally, a list of lessons learned was presented to aid the Navy manager in establishing a new HAZMAT reutilization facility.

Next, a forecast analysis of the SUBASE Bangor operation was presented. First, a regression analysis was performed to determine whether a possible relationship existed between incoming supply and incoming sales with their corresponding time periods. However, the residual analysis to determine whether the material-flow/time-period relationship followed a normal distribution was inconclusive. Further testing, with more data points, was recommended.

The study continued by presenting a forecasting model which could be used, should the relationship indeed turn out to be of a normal distribution. The results indicated that at current trends, HAZMAT levels within the facility would continue to grow uncontrollably. By simulating increased sales amounts, it was shown that HAZMAT awaiting usage within the facility could be reduced to more manageable levels. Active matching of HAZMAT with potential customers and reducing storage time limits were recommended as two sound procedures for increasing the outgoing sales rates. Recommendations included advertising through various media to potential users and limiting storage of any HAZMAT item to less than 60 days.

Finally, economic cost-benefit analyses were conducted to determine whether a HAZMAT reutilization facility should be established on a U.S. Naval base and, if so, which activity should be responsible for operating the facility. The cost effectiveness of operating the facility was found to be highly dependent upon labor cost and nonrecurring construction costs. Recommendations were made to operate a facility using Base Supply personnel, with no more than two full-time storekeepers employed. The renovation of an already existing building was considered to be more cost effective than building a brand new facility.

B. RECOMMENDATIONS FOR FUTURE WORK

This study has shown that great potential benefits can be obtained from the establishment and operation of a HAZMAT reutilization facility and that it is economically feasible. However, further work in the following related areas would be beneficial:

1. Determine what HAZMAT stock numbers (NSNs) are demanded from the facility within 60 days, between 60 and 120 days, and those exceeding 120 days. With this information, develop a list of fast and slow movers to aid managers in storage decisions.

2. Determine what is the maximum amount of HAZMAT potentially available from user commands and what amount is being disposed of as hazardous waste? This information would provide an estimate of how much more HAZMAT is available for reutilization.

3. Investigate other potential hazardous waste minimization and hazardous material substitution procedures and their application to the military. Develop a list of acceptable HAZMAT substitution materials from items currently available within the Navy Supply System.

4. Investigate current U.S. Navy regulations and procedures which are in conflict with sound HAZMIN objectives. Propose how these procedures can be changed and provide acceptable alternatives.

APPENDIX A: INTERVIEW QUESTIONNAIRE

A. **Delivery of Material to Facility**

1. Is material delivered to facility by the tenant command or does a facility worker retrieve material from commands?
2. Do tenant commands call the facility when there is HAZMAT to be delivered or is it picked up on an automatic, several-times-a-week pickup schedule?
3. How often is material delivered to the facility (if on an automatic schedule)?
4. Is a special staging area used at the tenant command for HAZMAT waiting for pickup?
5. How is the material transported from the command to the facility?
6. In what containers is material transported?
7. How many people does it take to transport material from command to facility?
8. Are special HAZMAT handling procedures involved in transporting material?
9. Explain the special logistics involved in offloading material from subs, ships, and boats after deployment.
10. Are there times of the year when you have a particular surge in HAZMAT supply business?

B. **Material Check-in**

1. Is a staging area used for check-in?
2. How is material identified and labeled?
3. How is "unidentifiable" material handled?
4. How is material catalogued (stock-coded)?
5. How many people are required for check-in?

C. **Storage and Warehousing**

1. Are special containers required for storage of material?
2. Is special handling equipment necessary to move material within facility?
3. What kind of inventory cataloguing system is used (manual or computer) to track your material?
4. Is material stored within special categories (alkalis away from bases, etc.)?
5. What are EPA/OSHA requirements for storage?
6. How many people are required for storage and warehousing?

D. **Delivery of Material to User Command**

1. Is a priority system used in issuing material (FIFO, etc.)?
2. Who picks up the material- command or facility?
3. Does Base Supply check with the facility for available material before issuing new material to commands?
4. How many people are required for delivery of material?
5. Are there times of the year when you have a particular surge in HAZMAT demand business?

E. **Facility**

1. How large is the facility?
2. How is it laid out?
3. Are there special ventilation, lighting, shelving requirements?
4. What are the hours of operation? Does Base Supply and tenant commands know them?
5. Do you run a night and mid shift, and, if not, how are users served during off-hours?

F. **Costs of Running the Facility**

1. Trucks and transportation?
2. Facility building cost and/or rent?
3. Lighting, heating, A/C, and other utilities?
4. Depreciation?
5. Storage containers?
6. Special handling equipment?
7. Advertising and administrative?
8. Labor (including fringe benefits):
   a. Supervisor?
   b. Clerical?
   c. Drivers/Movers?
   d. Warehousemen?
9. If contractor, how much was bid for one-year job contract?
10. Disposal costs?

G. **Disposal of Material**

1. What happens to material once it reaches the end of its shelf-life?
2. Is there a procedure for extending the shelf-life on material?
3. What criteria are used to determine that material should be disposed?
4. Where is material sent when disposed?
5. Does a commercial outfit purchase the material?
6. If so, how much do they pay for it?
7. Does it cost the Government any money to dispose your material? If so, how much?
8. How is material transported to disposal?

H. Material Movement

1. Are certain items particularly faster movers than others? If so, which ones?
2. Are certain items particularly slower movers than others? If so, which ones?
3. Do certain items take up particularly more space than others? If so, which ones?
4. Do certain items take up particularly less space than others? If so, which ones?
5. Are certain items more labor-intensive in movement than others? If so, which ones?
6. What type of tracking system is used to record incoming and outgoing material?
7. How far back do your records go?
8. Do you track trends in your material movement?
9. If one particular material begins to stockpile do you allow it to continue growing or do you take some sort of action to dispose some of the material?
10. According to historical records, what is the average arrival rate of HAZMAT coming into the facility.
11. What is the average output rate of HAZMAT leaving the facility?
12. What is the average customer rate arriving to the facility?

I. Types of Material

1. Does the facility discriminate against what materials it handles?
2. If so, how does it screen and separate items?
3. How does the facility classify material as being a hazardous material?
4. What are some of the methods used for separating mixed materials, cleaning contaminated materials, and/or refurbishing used material to make it ready for issue?
5. Can non-refurbished material be issued?
6. Are materials certified as being what you say they are when they are issued? Is a certification/identification test performed on material you carry?
7. Are mixed products sold as one material (ie., paints)? If so, explain?
8. Do you carry any materials which seem obsolete, never seem to move, and no command ever orders? If yes, what is done with the material?

J. Tenant Commands (Users) and Customer Service

1. How many commands make up your customers? List who they are?
2. Are there certain commands who use the facility more often than others? Less?
3. How is the facility advertised to tenant commands?

4. Is use of the facility limited to only those commands assigned to Subase Bangor? Does Bremerton Shipyard use the facility also?
5. What are the workers attitudes about customer service? Do you have a written customer service policy?

K. **Administration**
1. Is there a requirement (base instruction) for commands and/or Base Supply to check with the reutilization facility for available material before any new material is issued by Supply?
2. What form is used by user commands to order material from facility?
3. What reports (daily, weekly, monthly) are required by Subase Bangor, EPA/OSHA, Navy, etc.?
4. What instructions, format, or rules guide the way you operate the store?
5. How often is the HAZMAT facility inspected? Who inspects?
6. How often and how in depth do supervisors/workers receive performance evaluations?
7. What is the organization of the facility?
8. Who is ultimately responsible for the performance of the facility?
9. Are there job descriptions for all workers? Are workers familiar with what is expected from them?
10. What type of training takes place in HAZMAT handling and storage procedures, safety regulations and first aid, inventory and clerical procedures, customer service and TQM?

L. **User's Needs and Views of Customer Service**
1. Name of tenant user.
2. User's occupation and position in command.
3. User's command, type (sub, ship, etc.), and purpose of command.
4. Are you aware of what the Bangor Subase HAZMAT Reutilization Facility is, what it handles, and the potential advantages for your command by using the facility?
5. What are the operating hours of the HAZMAT facility?
6. What is the difference between hazardous material and hazardous waste?
7. What materials, and in what quantities, do you normally requisition from the facility? Are they usually in stock?
8. Are you familiar with what is available at the HAZMAT facility and the quantities available?
9. Are you satisfied with the quality of the material?
10. Are you satisfied with the quality of service you receive from the HAZMAT store?

a. If yes, what particular areas are especially good?
b. If no, what particular areas are especially poor?

11. Is service particularly timely?
12. Do you use the facility to dispose of half-used hazardous materials?
13. If yes, what materials, and in what quantities, do you normally deposit at the facility?
14. Do you have any difficulty transporting HAZMAT to or from the reutilization store?
15. How complicated is the paperwork process for obtaining or getting rid of hazardous material?

LIST OF REFERENCES

1. Telephone conversation between Mr. Robert Woods, Naval Energy and Environmental Support Activity (NEESA), Port Hueneme, CA, and the author, 27 September 1990.

2. Department of Transportation, Code of Federal Regulations, Title 49, Section 173.1.

3. Chief of Naval Operations, OPNAVINST 4110.2, Hazardous Material Control and Management (HMC&M), 20 June 1989.

4. Zaccor, J.V., Hau, H.L., and Wilton, C., An Approach To The Management Of Hazardous Materials, Federal Emergency Management Agency, Washington, DC, pp.C2-C4, September 1981.

5. Turner, Wayne C., and others, "IEs Will Play Bigger Role In Companies' Management Of Hazardous Material/Waste," Industrial Engineering, pp. 46-52, April 1989.

6. Kosowatz, John J., "Cleaning Up After the Military," ENR, Washington, DC, pp. 82-84, 25 May 1989.

7. Turner, Wayne C., and others, "Industrial Engineers and Hazardous Material/Waste Management," from lecture notes given at IEE Proceedings conference, Washington, DC, 1987.

8. Public Law 93-633, 93rd Congress, H.R. 15223, 3 January 1975.

9. Department of Transportation, Code of Federal Regulations, Title 29, Section 1910.1200.

10. Lee, H.J., Substitution and Minimization of Solvent Cleaners Used at the Naval Air Rework Facilities, Naval Air Development Center, Warminster, PA, pp. 12-15, 5 March 1980.

11. "DoD Sees New Role: Save Environment," Navy Times, pp.42-43, 10 September 1990.

12. Messenger, M., and others, Interactive Hazardous Materials Information System (HMIS): Description and Assessment, U.S. Army Construction Engineering Research Laboratory (USA-CERL), Champaign, IL, pp. 7-11, December 1983.

13. Messenger, M., and others, Description and Implementation of the Hazardous Material Tracking System (TRACKER), U.S. Army Construction Engineering Research Laboratory (USA-CERL), Champaign, IL, pp. 5-9, June 1984.

14. Messenger, M., and others, The Trade Name Translator (TNT) Subsystem of the Hazardous Materials Management System: Description and User Instructions, U.S. Army Construction Engineering Research Laboratory (USA-CERL), Champaign IL, pp. 5-7, April 1985.

15. Telephone conversation with Mr. Hayden Street, (Code 8316), Environmental Branch, Public Works Department, SUBASE Bangor, WA, and the author, 26 September 1990.

16. United States Government Federal Standard FED-STD-793, Depot Storage Standards, pp. 1-2, 30 October 1985.

17. Pfaffenberger, Roger C., and James H. Patterson, Statistical Methods for Business and Economics, Irwin, Inc., Homewood, IL, pp. 648-713 and 1156, 1987.

18. Naval Facilities Engineering Command, Economic Analysis Handbook (NAVFAC-P488), Alexandria, VA, June 1986.

19. Interview between Mrs. Jackie Rhodes, Civilian Personnel Director, Naval Postgraduate School, Monterey, CA, and the author, 29 November 1990.

20. Naval Comptroller, NAVCOMPT Manual, Volume III, Section X, Subsection 035750, "Statistical Costing of Military Personnel Services," Alexandria, VA, pp. 5-91 through 5-105, January 1990.

21. Interview between Mr. George Nelson, Facilities Planner, Public Works Department, Naval Postgraduate School, Monterey, CA, and the author, 25 October 1990.