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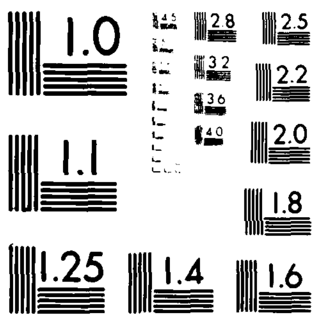


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# TECHNICAL REPORT

## CIVIL ENGINEERING LABORATORY

Naval Construction Battalion Center, Port Hueneme, California 93043

**SOLID WASTE MANAGEMENT IN MARINE AMPHIBIOUS FORCE (MAF) OPERATIONS: Analysis and Alternatives**



By E. P. Skillman

September 1980

Sponsored by

NAVAL FACILITIES ENGINEERING COMMAND

9 Final rept. Jul 77 - Jan 80,

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The management of Marine Amphibious Force (MAF) generated solid waste is extremely manpower intensive. The components of a MAF wastestream are unique (60% metal). To render immediate relief to these problems, state-of-the-art volume reduction equipment has been recommended provided modification requirements (weight, mobility, ruggedness, etc.) can be met. The scope of the modifications has been investigated, applications/limitations established, and conceptual drawings developed for the fabrication of experimental solid waste management equipment for use in MAF operations.

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CONTENTS

## INTRODUCTION

The Civil Engineering Laboratory (CEL) has been tasked by the Naval Facilities Engineering Command (NAVFAC) to develop solid waste management systems for use in Marine Amphibious Force (MAF) environments.

The management of solid wastes generated during MAF operations has been identified by the Marine Corps (MARCORPS) as an area needing improvement. Experience during the Southeast Asia conflict and elsewhere shows that MAF solid waste management requires a significant deployment of manpower and equipment, which could be better used to serve the primary mission.

The solid wastes generated during a MAF operation in a combat environment require effective and efficient means of collection and disposal. These operations should be performed without hampering a unit's primary mission and, therefore, should divert a minimum amount of manpower and equipment.

Present solid waste handling systems are manpower intensive and inefficient. Recent studies have shown that on the average about 1,100 tons of solid wastes are generated each day by a fully operational MAF. This reportedly requires the daily allocation of approximately 1,800 man-hours and about 72 vehicles originally intended for support of the primary mission. Of this man-hour allocation, approximately 75% is drawn from combat-ready troops who simply gather and stack these solid wastes. Traditional MAF solid waste management practices have, at most, included waste collection with available equipment, open pit burning, and modified landfill operations.

Open pit burning produces a characteristic target signature and requires regulatory firefighting personnel to supervise daily disposal activities. Landfilling adds to horizontal construction requirements by about one acre per day, complicates problems of scavenging, and increases manpower and equipment losses due to tactical vulnerability.

Noncombat-related casualties represent a threat to primary mission activities. In Vietnam, as in Korea and World War II, the effects of disease were the greatest drain on American combat and support resources. Disease accounted for more than two of every three hospital admissions in Vietnam during the 1965-69 period; battle injuries were responsible for approximately one of every six admissions during the same period. Furthermore, Army medical data show that the average case of viral hepatitis* resulted directly from operational shortcomings in the mess hall, field sanitation facilities, and nonpotable water supplies (Ref 1 and 2).

*The number of cases averaged 92,000/yr between 1967 and 1970.

The Bureau of Naval Medicine has reported that such vector populations as rats and flies proliferated as a result of poorly managed solid waste near hospitals and mess facilities, measurably amplifying the spread of disease during the Vietnam conflict. The mismanagement of solid wastes in foreign environments has been directly associated with the cause and enhanced spread of disease. In contrast, the spread of disease resulting from the mismanagement of solid waste in the United States is low.

This overall encroachment of primary mission activities as a result of inefficient management of solid waste must be reduced. The most effective way of solving this problem is to develop new solid waste disposal practices that are efficient and compatible with MAF contingency scenarios. Alternative systems must be:

- Cost-effective
- Adaptable to new combat support technology
- Flexible to operate in a variety of MAF scenarios
- Portable and self-contained
- Amenable to operation and maintenance with minimum field skills and manpower

Before a solid waste management system can be developed for MARCORPS advance base application, field operations must be evaluated for waste composition, generation rates, operational limitations, and resources. The scope of this evaluation includes:

- Characterization of the solid waste generated during the specific phases of a MAF operation
- Review of MAF scenarios and field operating conditions for design constraints of generic grouping of solid waste management equipment
- Identifying solid waste management problems and practices of a conceptual 50,000-man MAF operation
- Evaluating conceptual equipment design and performance specifications
- Projecting the expected savings in manpower and equipment brought about by deploying selected specialized waste management equipment

## THE STRUCTURE OF MAF OPERATIONS

The concept of amphibious warfare is to engage in an offensive assault against an enemy in his environment at a time and place of choice. The basic principles upon which this philosophy is based have remained unchanged since the first MARCORPS landing in the Bahamas in 1776 (Ref 3). Since that time, Marines have participated in more than 180 landings based upon the same fundamental assault doctrine.

The deployment of a MAF varies, by necessity, with the location or type of military action. Based in part on recent experience gained in the Southeast Asia conflict, a conceptual MAF was developed upon which waste generation estimates and waste management practices described in this study could be based. In this model, the three principal phases of an MAF operation are as follows:

| Phase | Approximate Time Period |
|---|---|
| Assault Echelon (AE) | D-Day through D+15 |
| Assault Follow-On Echelon (AFOE) | D+15 through D+30 |
| Flight Echelon (FE) | D+30 through end of operation (D+60) |

The AE phase is illustrated conceptually in Figure 1. This phase lasts approximately 15 days, during which time combat troops are deployed. Amphibious ships are used heavily, and high-priority cargo offloading is the major concern. The primary mission is to seize and hold while developing a Beach Support Area (BSA).

The AFOE (Figure 2) involves movement of troops inland, while supply and engineering personnel land to establish transportation, communication, and supply networks. The vast majority of equipment and supplies involved in the MAF operation are brought to the BSA during this phase.

The FE (Figure 3) consists of further development of facilities and the emplacement of landing and support facilities for large aircraft on shore. The FE begins upon the establishment of the BSA and, therefore, overlaps the AFOE.

During all phases of a MAF there exists both a moving and stationary zone (Figure 4). During the first two phases, the moving zone accounts for the majority of waste generation. It is assumed that beyond D+30, the MAF is fully operational and virtually all personnel, equipment, and supplies have been brought ashore (except for replacement purposes). Beyond D+30, the stationary zone accounts for most of the waste generation. Waste generation and solid waste management, therefore, take on a significantly different character in each of these two periods.

The above phases (echelons) of a MAF operation were outlined in Reference 4, "Analysis of Amphibious Task Force Embarkation and Landing Requirements Project," prepared by Potomac General Research Group in March 1977 under contract M00027-76-A-0060. They have been verified by the Chief Instructor of the Amphibious Warfare School at Quantico with the understanding that the time periods associated with each are highly dependent on the specific situation.

The unloading status (Figure 5) of materiel into an MAF operational area shows that a MAF would be completely landed and fully functional by D+19 with most landing operations completed on D+7. It is assumed that the MAF is fully developed by D+19 and operates at a strength of approximately 50,000. Actually, variations in locale, degree of resistance, and specific aspects of the mission will influence the types, quantities, and timing of material offloading.

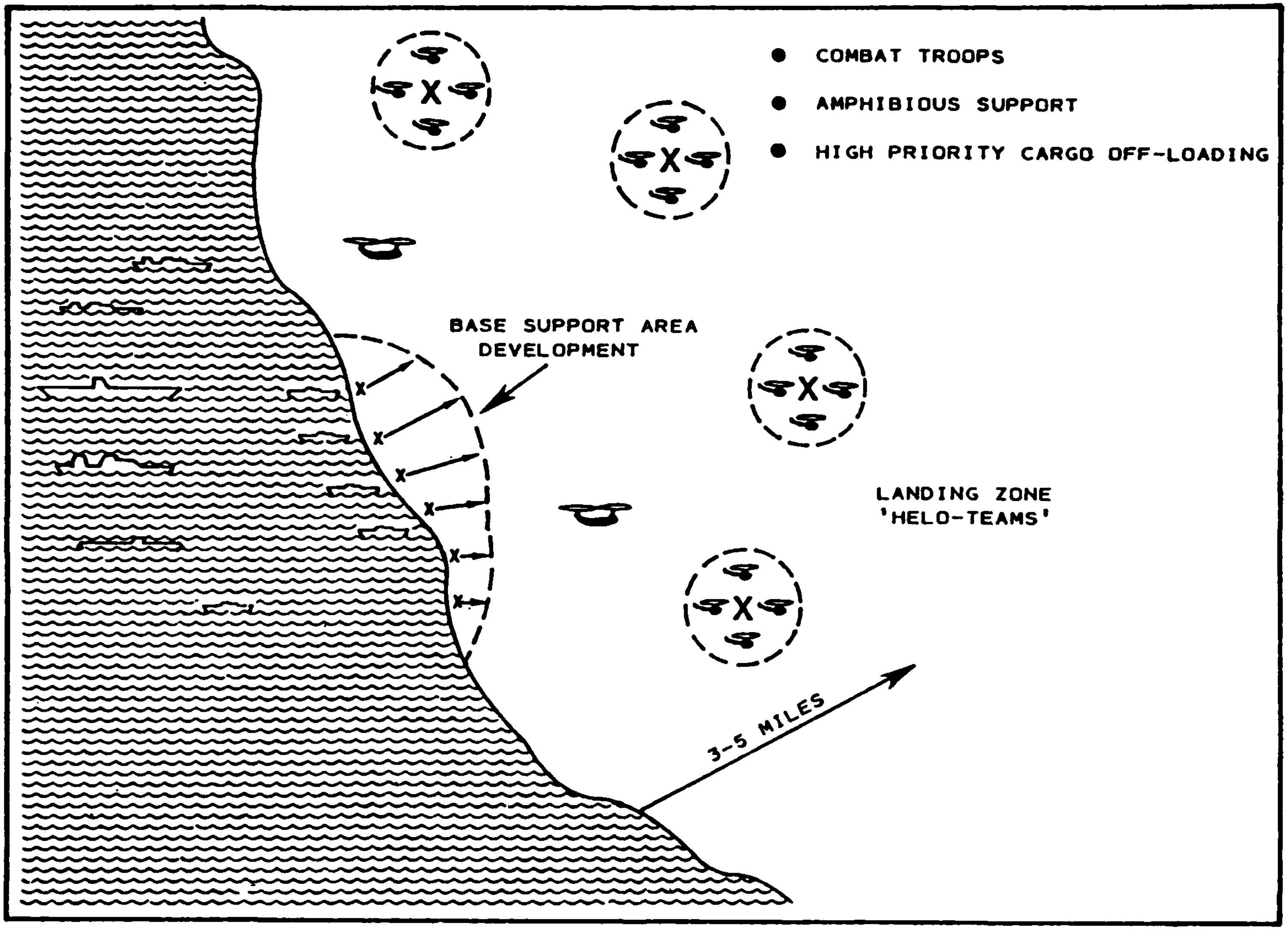


Figure 1. MAF first phase (assault phase, D + 15 days).

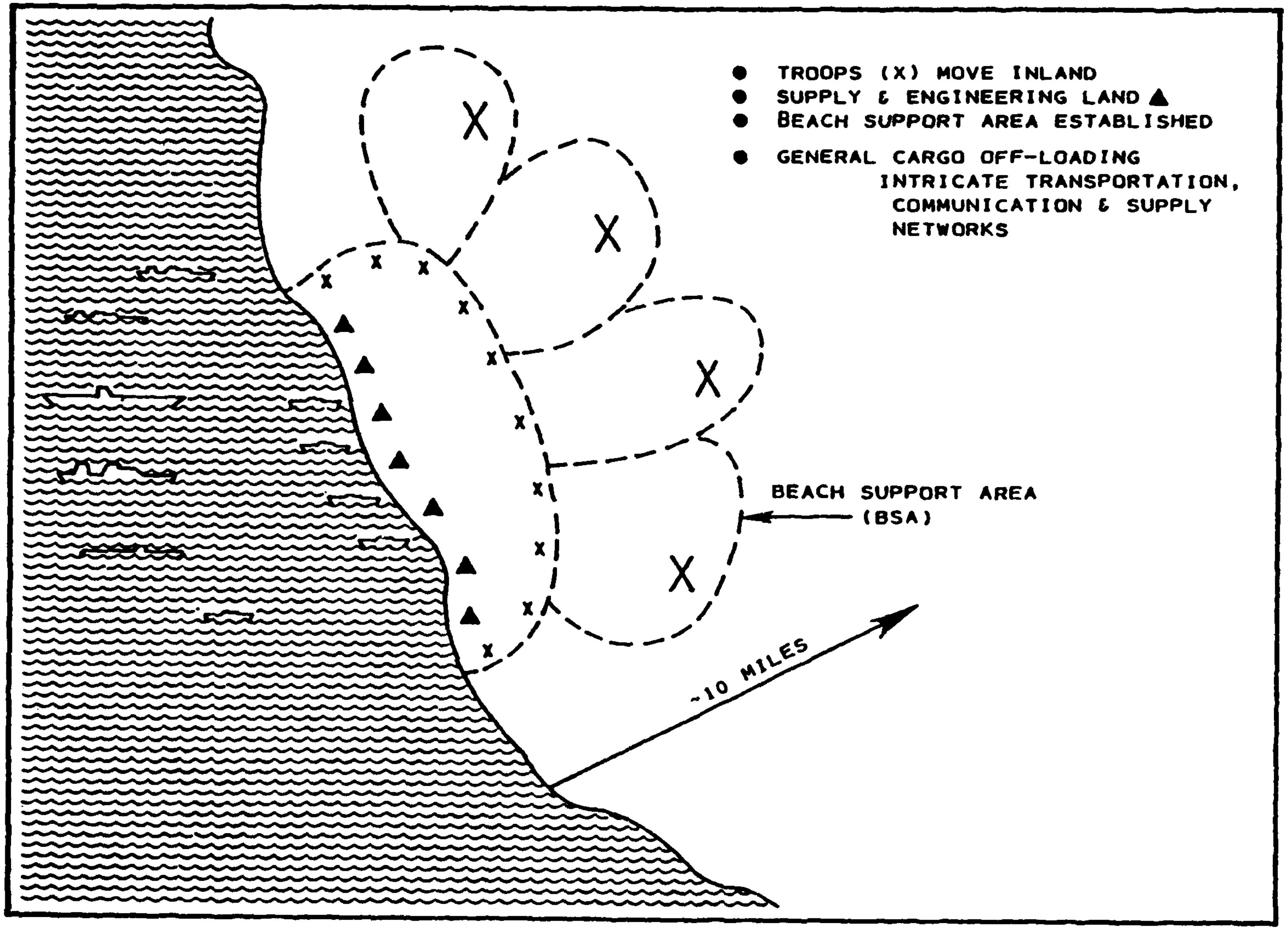


Figure 2. MAF second phase (assault follow-on phase, D + 30 days).

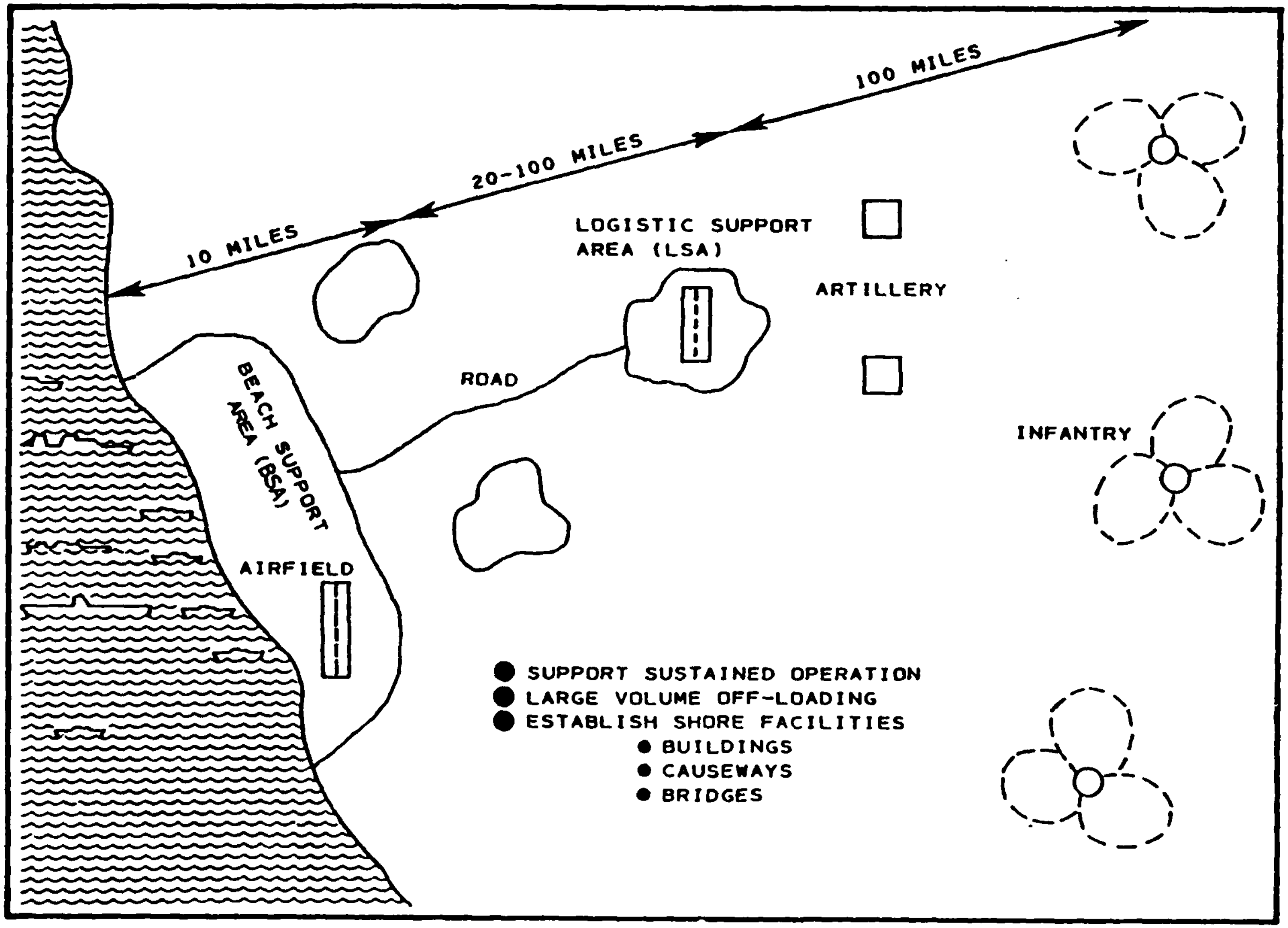


Figure 3. MAF third phase (final phase, D + 30 days).

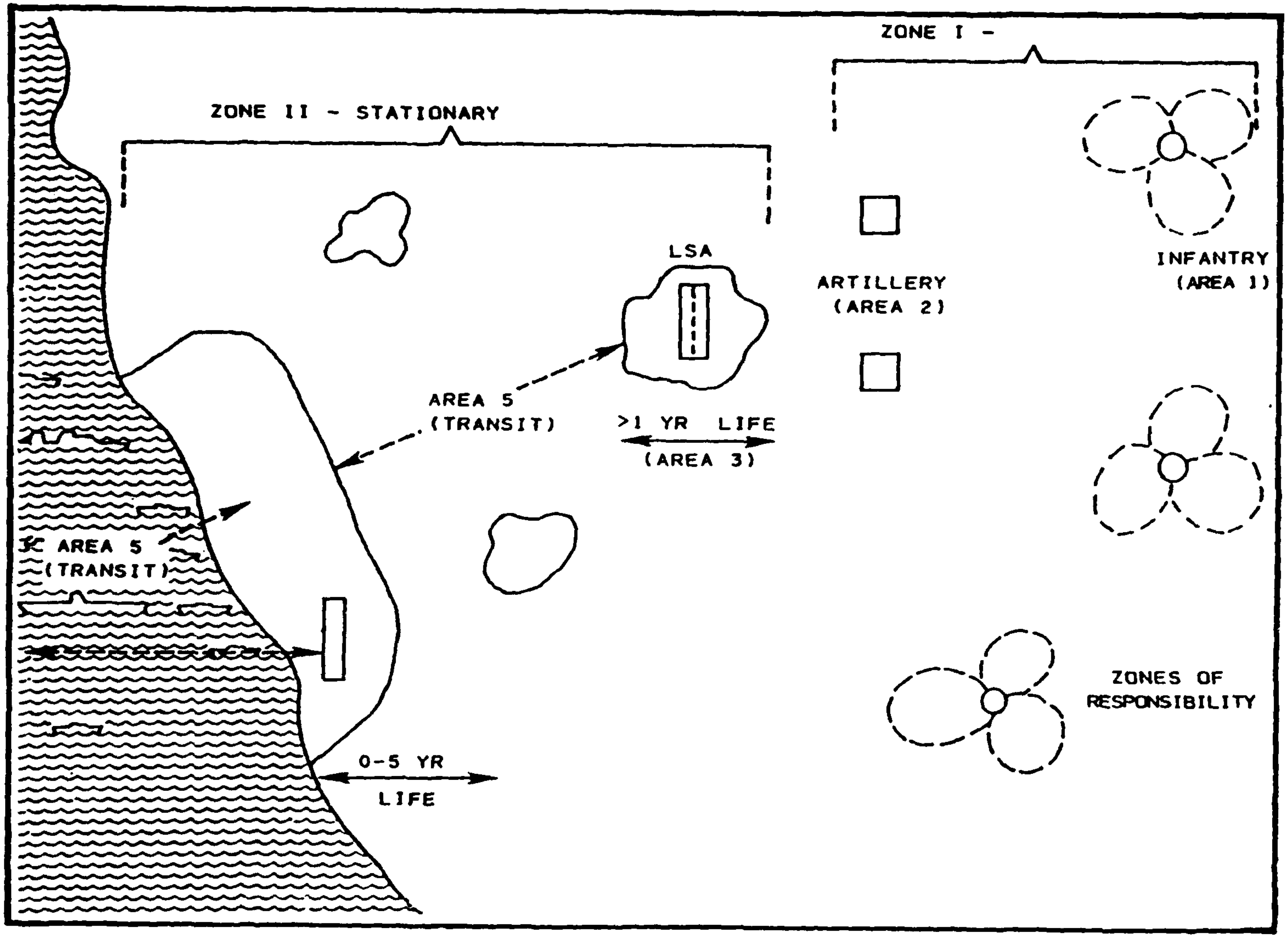


Figure 4. Established operational MAF (51,000 troops at D + 30 days).

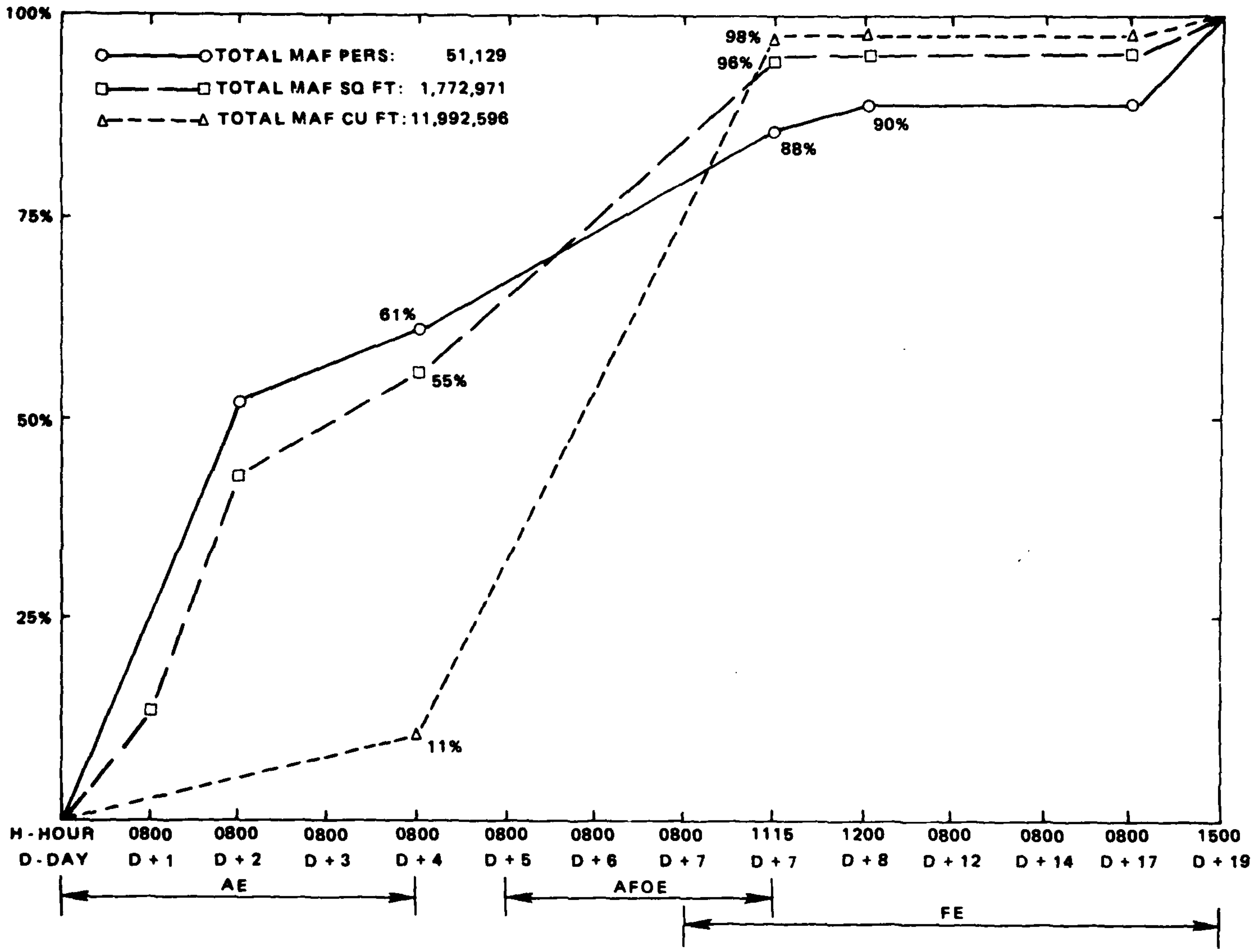


Figure 5. MAF unloading status.

For purposes of discussion of solid waste management, it is assumed that operations will be completed by D+60. This is supported by MARCORPS logistics estimates covering 30-day intervals and recent changes in logistics doctrine requiring supplies and replacement equipment for 60 days of operations to be physically stored at host bases. FMFLANT and FMFPAC (essentially Camp Lejeune/Cherry Point and Camp Pendleton/El Toro, respectively) must have this materiel on hand or on requisition.

## Functional Groups

The functional groups of a MAF each exhibit different waste characteristics, generation and waste management requirements. Major MAF functional groups include:

- Administration
- Combat (infantry, artillery, and air)
- Construction
- Medical and dental
- Supply
- Residential
- Maintenance

Administration. Management and direction of personnel and equipment including command, communication, and other office-related functions.

Combat.

1. Infantry: The infantry locates and engages the enemy in close combat.
2. Artillery: The artillery provides fire support to the infantry.
3. Air: Air activities include fire support for the infantry, resupply, and evacuation; these activities involve fixed and rotary wing aircraft.

Construction. Design, erection, maintenance, and repair of all structures and other types of construction.

Medical and Dental. Collection, emergency treatment, temporary hospitalization, and evacuation of the sick and wounded, and the supervision of sanitary and preventive medicine measures in the combat area.

Supply. All aspects of receiving, marking, warehousing, repacking, control and distribution of equipment, supplies, and repair parts.

Residential. All aspects of sheltering combat and support personnel, not including the erection or maintenance of structures (these activities are considered a part of construction). It does include personnel support activities such as housing, messing, latrines, and recreation. As an example, solid waste from the erection of a mess tent is considered construction waste while garbage and broken utensils generated during its operation are residential waste.

Maintenance. Activities associated with the repair or servicing of equipment; the generally centralized maintenance of mechanical and electrical equipment including vehicles, weapons, and communication units.

Essentially all personnel in a MAF are assigned to one of three groups; Marine Division, Air Wing, or Force Services Support Group (FSSG). The division and wing are the combat elements; the other six functional groups are the parts of the FSSG, which supplies the logistics, command, and other support for the entire MAF.

### Variability of Operations

There is a great degree of variation in Marine amphibious operational scenarios. Two basic variables are the timing of the operation (which may partially reflect the amount of enemy resistance being encountered) and the location of the operation. Extremes of location would call for unusual types or quantities of equipment and supplies (e.g., skis in a northern area or additional canteens or water supplies in a hot, dry climate).

Locale, degree of resistance, and interaction with the native population are variables which influence the types and amounts of equipment and supplies used; thus, they influence waste generated, and the potentials for recovery and reuse of wastes. A "typical" operation, however, will be considered with qualifying discussion of the impact of some variables.

## COMPONENTS OF WASTE - QUANTITY AND TYPES

### Solid Waste Defined

MAF solid waste is materiel that has no further direct value to MAF operations, i.e., discards. General types of materiel classified as solid waste include:

- Equipment, structures, weapons, furniture, etc., worn out or damaged beyond field repair or of such low value that recovery and removal for reuse or depot-level repair is not worthwhile
- Refuse generated through daily activities (e.g., wastepaper, empty containers, garbage)

General types of materiels not classified as solid waste include:

- Sewage and other liquids treated by sewage treatment systems in peacetime
- Contaminated POL

### Solid Waste Disposition in MAF Operations

All equipment and supplies brought into a MAF operation fall generally into one of the following categories of disposition:

- Expended. Ammunition, explosives, missiles, fuel, food
- Wasted. Anything accidentally, purposely, or of necessity discarded
- Reused. Empty boxes, pallets, or packing cases used for bookcases or retaining walls
- Recovered. Equipment collected for later repair/reuse - a damaged tank engine to be shipped to a repair depot outside MAF area, recovered brass, etc.
- Removed. Equipment no longer needed but still functional or repairable - a major factor only when an MAF leaves an area

Items in one of the categories shown may change into another category as a MAF operation progresses. For example, reused boxes or pallets may become waste if damaged or when the MAF leaves an area. Likewise in withdrawal, virtually all materiel is either removed or wasted.

It was reported (see personnel contacted or interviewed in the Appendix) that there was a high degree of reuse of potential waste items (i.e., packaging materials) during virtually every portion of a MAF operation. This reuse of potential waste items does not remove them from the waste category. Much of this material will become waste at the end of an amphibious operation. It will either be systematically dismantled and disposed of, or will be left in place. An example of the latter situation is the use of packing boxes for the construction of retaining walls. These boxes are filled with soil or sand and left in place when a fortification is abandoned.

## Units of Solid Waste Generation

Weight. The unit of solid waste generation recommended in the study of MAF solid waste is the number of pounds generated per person per day (lb/pers/day). This unit relates the mass of waste to the number of personnel involved and to the length of the operation. It allows for ready computation of wastes generated during operations of various sizes and lengths and can easily be converted to metric units as that system becomes more widely used in Marine Corps logistics.

Another recommended unit is tons generated per activity per day (tons/activity/day). The estimate of waste generation per activity is useful in developing individual solid waste management systems for specific types of MAF functions.

Other units considered involved volume rather that weight, groups of personnel rather than individuals, and periods of time other than a day.

Volume. Both weight in pounds and volume ("cube") in $ft^3$ are available for most supplies and equipment used in MAF operations. Weight was considered superior because weight data are somewhat more readily available. Also, weight is better understood by personnel at all levels (i.e., there is a better "feel" for weight than for volume). Weight does not change during the majority of MAF activities, whereas volume does vary as containers are dismantled, etc. Finally, even where volume is known for supplies and equipment, it can be deceiving. Some vehicles, for example, are prepackaged with equipment while other similar vehicles are not. The volume occupied in a ship's hold is the same for both vehicles, but the weights (and potential waste) are different.

Personnel. A MAF is made up of various groups of personnel: platoons, companies, groups, etc. The MARCORPS is mission oriented; therefore, the number and size of these groups vary from one situation to the next (as does the total number of personnel in the entire MAF). Likewise, there are differences between group sizes in air and ground activities (e.g., a squadron is not equivalent to a company). Thus, the individual troop was selected as the unit of solid waste generation. The generation rate per person will be calculated using the "typical" number of personnel present during each phase of an MAF operation as shown below:

| Phase | Number Personnel Added | Cumulative Personnel |
|---|---|---|
| Assault Echelon (AE) | 31,400 | 31,400 |
| Assault Follow-On Echelon (AFOE) | 13,500 | 44,900 |
| Flight Echelon (FE) | 6,100 | 51,000 |

Per-person generation rates may be easily differentiated between phases of a MAF, as the quantity and type of supplies distributed in each phase of a MAF are different for each phase.

Time. Essentially all planning for MAF operations is based on days and hours from D-Day, as shown in Figure 5. The day was selected as the time unit for solid waste generation due to the fairly rapid chain of events in amphibious operations and the 60-day time frame previously discussed. Any shorter time period would yield an extremely small generation rate, and activities cannot realistically be predicted down to the hour. Longer time periods (weeks) would mask changes from one phase of operation to another.

Areas. The concentrated waste generation areas in a MAF operational scenario (based on discussions with FSSG personnel) are:

Beach Support Area (BSA)
Logistic Support Area (LSA)
Marine Amphibious Wing (airfield)
Artillery Area

The most effective use of specialized solid waste management equipment would be in these areas.

## MAF Solid Waste Generation Data

Solid waste generation estimates were derived in part from gross supply quantity data for a MAF, obtained from the Type Unit Mobility Statistics System (TUMSS), provided by the Division Information Systems Management Office of the Second Marine Division at Camp Lejeune, N.C. In order to convert the supply data into solid waste generation data, detailed supply descriptions, direct observation of supply packaging, and interviews with knowledgeable MARCORPS personnel were conducted. Engineering judgment was then used to estimate the percent by weight of each component which would ultimately appear in the solid waste stream.

Tables of equipment and operation were used to identify the specific types of equipment employed during each phase and by each functional group of an MAF. Information on the composition of each piece of equipment and its expected functional life in the MAF permitted the formulation of detailed composition estimates for each phase and time period.

## MAF Solid Waste Content

Overall, solid wastes from MAF operations are seen as containing much higher quantities of metal and wood than found in civilian municipal wastes. Metal composition in solid waste varies from 70% during the assault echelon phase (AE), to approximately 61% during the flight echelon phase (FE). While the solid waste generation rate increases from the AE to the FE by an approximate factor of 6, the relative percentage of metal is diminished by statistical impact of the increase in construction and residential wastes. Waste aluminum, which accounts for a very small fraction of the metal, is associated with battle-damaged aircraft and aircraft repair parts. The major sources of metal are: (1) expended shell casings from artillery and other combat missions, and (2) waste iron and steel from damaged vehicles and construction supplies.

Packaging and preservation materials are a major type of waste item. Supplies and equipment are well protected for shipboard transportation and rough handling in the amphibious landing. Most items in a MAF's operational deployment stocks and mount out (OPDEP/Mount Out) are stored in heavy, wooden mount-out boxes containing various arrangements of smaller wooden or fiberboard boxes that contain the actual supplies or replacement parts, themselves often sealed in paper or plastic envelopes. Medical supplies, an exception, are stored in metal chests. Mount-out boxes and the metal chests are designed for use as stock shelves or for the removal of items out of the combat area at the conclusion of a MAF operation. However, larger items (e.g., jeep fenders and ammunition) are packaged in wooden boxes not designated for reuse.

The following six tables present the quantitative aspects of solid waste generated during MAF operations.

Table 1 summarizes waste generation. It shows functional group waste generation activity during each of the three phases of the first 30 days, the total for this period, and a total for a second 30-day period. Particularly notable is the high daily per capita rate of 90 pounds during the AFOE. This is attributable to a rapid buildup of the FSSG and the growth of supply, maintenance, and administrative functions during this period.

Table 1. Waste Generation Summary

| Functional Group | Solid Waste (tons) | | | | |
|---|---|---|---|---|---|
| | Assault Echelon | Assault Follow-On Echelon | Flight Echelon | Total | |
| | | | | First 30 Days | Second 30 Days |
| Supply | -- | 36 | 176 | 212 | 130 |
| Construction | 467 | 470 | 1,630 | 2,567 | 1,560 |
| Administration | 43 | 213 | 623 | 879 | 536 |
| Medical/Dental | 26 | 67 | 402 | 495 | 217 |
| Residential | 71 | 258 | 1,459 | 1,788 | 1,339 |
| Maintenance | -- | 215 | 912 | 1,127 | 544 |
| Combat | | | | | |
| Infantry | 899 | 761 | 1,901 | 3,561 | 2,509 |
| Artillery | 1,976 | 3,579 | 12,204 | 17,759 | 11,369 |
| Air | -- | 599 | 3,189 | 3,747 | 5,969 |
| Total | 3,482 | 6,158 | 22,496 | 32,135 | 24,173 |
| Personnel Serviced | 31,400 | 44,900 | 51,000 | 51,000 | 51,000 |
| Days in Period | 5 | 3 | 22 | 30 | 30 |
| Waste Generation Rate (lb/person/day) | 44 | 91 | 40 | 42 | 32 |

Tables 2, 3, and 4 show the approximate tonnage of waste generated by each functional group during each MAF operational phase. Note that the combat group accounts for the vast majority of waste, with artillery being the single biggest generator. Reasons for this include the combat losses of equipment and the large amount of waste from ammunition (shell casings, boxes, and pallets).

Table 2. Waste Generation by Material and Source (Tons): Assault Echelon

| Component | Supply | Construction | Administration | Medical | Residential | Maintenance | Combat | | | | Grand Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Infantry | Artillery | Air | Total | |
| **Metal** | | | | | | | | | | | |
| **Aluminum** | | | 1 | 1 | 2 | | 12 | 18 | | 30 | 34 |
| **Other** | | 328 | 34 | 14 | 18 | | 666.8 | 1,376.6 | | 2,043.4 | 2,437.4 |
| **Paper** | | | | | | | | | | | |
| **Corrugated** | | 4 | -- | 0.6 | 2 | | 4.7 | 94.7 | | 99.4 | 106 |
| **Misc. Paper** | | 2 | -- | 0.9 | 5 | | 86.8 | 61.7 | | 148.5 | 156.4 |
| **Plastics** | | 1 | 0.5 | 3.3 | 3 | | 19.7 | 37.5 | | 57.2 | 65 |
| **Wood** | | 89 | 7 | 2 | 20 | | 55 | 349 | | 404 | 522 |
| **Textiles** | | -- | -- | 1.5 | 20 | | 27.2 | 15 | | 42.2 | 63.7 |
| **Garbage** | | -- | -- | -- | 0 | | 3 | 2 | | 5 | 5 |
| **Glass/Ceramics** | | -- | -- | 1.2 | 0 | | 0.1 | 0 | | 0.1 | 1.3 |
| **Rubber** | | 13 | 0.5 | 0.1 | 0 | | 8 | 15 | | 23 | 36.6 |
| **Other** | | 30 | -- | 1.1 | 1 | | 16.1 | 6 | | 22.1 | 54.2 |
| **Total**[a] | | 467 | 43 | 26 | 71 | | 899 | 1,976 | | 2,875 | 3,482 |

[a]Nearest ton.

Table 3. Waste Generation by Material and Source (Tons): Assault Follow-On Echelon

| Component | Supply | Construction | Administration | Medical | Residential | Maintenance | Combat | | | | Grand Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Infantry | Artillery | Air | Total | |
| Metal | | | | | | | | | | | |
| Aluminum | 1 | | 6 | 3 | 9 | 10.5 | 12 | 18 | 68.5 | 98.5 | 128 |
| Other | 15 | 331 | 92.6 | 27.3 | 73 | 155.5 | 534.2 | 2,480 | 255.8 | 3,270 | 3,964.4 |
| Paper | | | | | | | | | | | |
| Corrugated | 5 | 4 | 16.2 | 3.7 | 35 | 5.1 | 5.5 | 226 | 27.1 | 258.6 | 327.6 |
| Misc. Paper | 4 | 2 | 24.2 | 3.9 | 32 | 4.1 | 77.6 | 88 | 12.1 | 177.7 | 247.7 |
| Plastics | 1 | 1 | 13 | 9.9 | 17 | 1 | 20.1 | 68.4 | 15 | 103.5 | 146.4 |
| Wood | 9 | 89 | 44 | 6 | 49 | 0.24 | 57 | 661 | 135 | 853 | 1,074 |
| Textiles | -- | | -- | 4.4 | 24 | 1 | 26.5 | 15 | 22 | 63.5 | 92.9 |
| Garbage | - | | -- | 0 | 13 | 0 | 3 | 1 | | 4 | 17 |
| Glass/Ceramics | -- | | -- | 4.7 | 4 | 0 | 0.1 | 0 | | 0.1 | 8.8 |
| Rubber | -- | 13 | 13 | 1.3 | | 10.5 | 9 | 16 | 14 | 39 | 76.8 |
| Other | 1 | 30 | 4 | 3.3 | 2 | 3.5 | 16.1 | 6 | 9 | 31.1 | 74.9 |
| Total[a] | 36 | 470 | 213 | 67 | 258 | 215 | 761 | 3,579 | 559 | 4,899 | 6,158 |

[a]Nearest ton.

Table 4. Waste Generation by Material and Source (Tons): Flight Echelon

| Component | Supply | Construction | Administration | Medical | Residential | Maintenance | Combat | | | | Grand Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Infantry | Artillery | Air | Total | |
| Metal | | | | | | | | | | | |
| Aluminum | 6 | | 28 | 18 | 41 | 45 | 33 | 52 | 276 | 361 | 499 |
| Other | 54 | 1,052 | 299.4 | 239.6 | 527 | 637.1 | 1,341.8 | 8,528.8 | 1,213.3 | 11,083.9 | 13,895 |
| Paper | | | | | | | | | | | |
| Corrugated | 30 | 11 | 63.8 | 10.1 | 136 | 30.2 | 20.1 | 678.6 | 203.4 | 910.1 | 1,191.2 |
| Misc. Paper | 26 | 6 | 110.8 | 9.1 | 157 | 21.2 | 162.4 | 266.6 | 67.4 | 496.4 | 826.5 |
| Plastics | 9 | 5 | 31 | 34.2 | 114 | 4 | 50 | 246.4 | 121 | 417.4 | 614.6 |
| Wood | 45 | 364 | 59 | 36 | 287 | 101 | 146 | 2,318 | 1,045 | 3,509 | 4,401 |
| Textiles | -- | -- | -- | 10.1 | 96 | 9 | 68.6 | 45 | 138 | 251.6 | 366.7 |
| Garbage | -- | -- | -- | 0 | 50 | 0 | 4 | 1 | | 5 | 55 |
| Glass/Ceramics | -- | -- | -- | 21.8 | 18 | 0 | 0.1 | | | 0.1 | 39.9 |
| Rubber | -- | 47 | 15 | 3.8 | 0 | 45 | 29 | 50 | 56 | 135 | 245.8 |
| Other | 6 | 145 | 16 | 18.8 | 33 | 17 | 38.1 | 18 | 69 | 125.1 | 360.9 |
| Total[a] | 176 | 1,630 | 623 | 402 | 1,459 | 912 | 1,901 | 12,204 | 3,189 | 17,294 | 22,496 |

[a]Nearest ton.

Tables 5 and 6 summarize tonnage wastes for the first and second 30-day period of the operation. The predominance of metal should not be too surprising to those familiar with military operations. Most of the wasted aluminum is associated with battle-damaged aircraft and aircraft repair parts. Thus the airfields should be potential sources of recoverable aluminum. Brass is exclusively shell casings. Casings were considered waste items in these calculations but are normally recovered for recycling. The other metal wasted is almost exclusively steel. It comes from various sources, but is predominantly battle-damaged combat equipment and related repair parts. The other major waste material is wood. It comes mostly from packaging and construction materials.

## CURRENT SOLID WASTE MANAGEMENT PRACTICES

### Solid Waste Management Organization

Solid waste management during MAF operations is the responsibility of the FSSG. The FSSG provides personnel and equipment for solid waste management, and also draws from other functions during periods when such personnel and equipment are available.

During the Assault phase, virtually no organized solid waste management is conducted. Assuming that troop movement inland is fairly rapid, waste items such as food containers and ammunition casings are discarded directly on the ground, with densities being directly related to the amount of time spent in a particular location.

During the Assault Follow-On phase, the FSSG becomes operational. Large quantities of supplies and equipment are brought ashore. The FSSG supply, maintenance, and medical functions provide semipermanent centers of logistic and support activity. These semipermanent centers lead to the generation of solid waste at specific locations on the beach and inland. Relatively innoxious wastes, such as broken parts or cardboard boxes, are generally collected in various locations or containers at each functional group. Waste becomes concentrated as a result.

Waste management usually begins once waste begins to interfere with regular operations. Personnel from each functional group are assigned to remove the waste materials and either bury, or burn and bury the waste. This results in numerous waste disposal areas operated by the individual functional groups.

Pathogenic wastes from hospital areas and garbage from messing facilities are given more regular and thorough disposal treatment. Again, it is often a combination of burning and burying, done primarily to decrease the possibilities of disease. Most personnel interviewed confirmed the popularity of burning wastes even though the smoke generated could be a location identifier to the enemy. It was the contention of those interviewed that the enemy already knew the location of the MAF, and thus additional smoke from waste disposal was of no combat significance.

Table 5. Waste Generation by Material and Source (Tons): to 30 Days

| Component | Supply | Construction | Administration | Medical | Residential | Maintenance | Combat | | | | Grand Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Infantry | Artillery | Air | Total | |
| Metal | | | | | | | | | | | |
| Aluminum | 7 | | 35 | 22 | 52 | 55.5 | 57 | 88 | 345 | 490 | 661.5 |
| Other | 69 | 1,711 | 426 | 280.9 | 618 | 794.6 | 2,542.8 | 12,385.4 | 1,469 | 16,397.2 | 20,296.7 |
| Paper | | | | | | | | | | | |
| Corrugated | 35 | 19 | 80 | 14.4 | 173 | 35.3 | 38.3 | 999.3 | 230 | 1,267.6 | 1,624.3 |
| Misc. Paper | 30 | 10 | 135 | 13.7 | 194 | 25.3 | 326.8 | 416.3 | 79 | 822.1 | 1,230.1 |
| Plastics | 10 | 7 | 44.5 | 47.4 | 134 | 5 | 89.8 | 352.3 | 136 | 578.1 | 826 |
| Wood | 54 | 542 | 110 | 44 | 356 | 125 | 258 | 3,328 | 1,180 | 4,766 | 5,997 |
| Textiles | -- | -- | -- | 16 | 140 | 10 | 122.3 | 75 | 160 | 357.3 | 523.3 |
| Garbage | -- | -- | -- | 0 | 63 | 0 | 10 | 4 | | 14 | 77 |
| Glass/Ceramics | -- | -- | -- | 27.7 | 22 | 0 | 0.3 | | | 0.3 | 50 |
| Rubber | -- | 73 | 28.5 | 5.2 | 0 | 55.5 | 46 | 81 | 70 | 197 | 359.2 |
| Other | 7 | 205 | 20 | 23.2 | 36 | 20.5 | 70.3 | 30 | 78 | 178.3 | 490 |
| Total[a] | 212 | 2,567 | 879 | 495 | 1,788 | 1,127 | 3,561 | 17,759 | 3,747 | 25,067 | 32,135 |

[a]Nearest ton.

Table 6. Waste Generation by Material and Source (Tons): D+30 to D+60 Days

| Component | Supply | Construction | Administration | Medical | Residential | Maintenance | Combat | | | | Grand Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Infantry | Artillery | Air | Total | |
| Metal | | | | | | | | | | | |
| Aluminum | 4 | | 24 | 8 | 55 | 27 | 25 | 30 | 130 | 185 | 303 |
| Other | 33 | 870 | 212 | 1,033 | 339 | 329.7 | 1,854.6 | 7,956.4 | 1,464 | 11,275 | 13,162 |
| Paper | | | | | | | | | | | |
| Corrugated | 27 | 11 | 76 | 9.8 | 178 | 38.2 | 15.4 | 643.3 | 553.5 | 1,212.2 | 1,552.2 |
| Misc. Paper | 22 | 7 | 132 | 10.5 | 207 | 23.3 | 251.8 | 264.3 | 127.5 | 643.6 | 1,045.4 |
| Plastics | 7 | 4 | 26 | 31.1 | 91 | 3 | 70 | 225 | 325 | 620 | 782.1 |
| Wood | 33 | 446 | 40 | 16 | 234 | 66 | 148 | 2,192 | 2,721 | 5,061 | 5,896 |
| Textiles | -- | -- | -- | 14.5 | 99 | 15 | 74.2 | 18 | 416 | 508.2 | 636.7 |
| Garbage | -- | -- | -- | 0 | 50 | 0 | 7 | 2 | | 9 | 59 |
| Glass/Ceramics | -- | -- | -- | 11.2 | 44 | 0 | 0.2 | | | 0.2 | 55.4 |
| Rubber | -- | 28 | 8 | 3.2 | 0 | 27 | 18 | 30 | 24 | 72 | 138.2 |
| Other | 4 | 194 | 18 | 9.2 | 42 | 15 | 45.2 | 8 | 208 | 261.2 | 543.4 |
| Total[a] | 130 | 1,560 | 536 | 217 | 1,339 | 544 | 2,509 | 11,369 | 5,969 | 19,847 | 24,173 |

[a]*Nearest ton.*

At D+20 to D+30, when the FSSG is fully operational, more organized waste management develops. This consists of designating collection vehicles and establishing disposal sites. Functional groups are directed to bring solid wastes to the designated site, unless prevented by combat commitments. In such instances, FSSG personnel would instead be dispatched for collection. The disposal site would also be under the control of the FSSG, operated with equipment from the engineering battalion.

As a MAF operation advances into the Flight Echelon phase, no significant changes occur in solid waste management. The centralized disposal sites continue to operate. As troops move further inland, supply lines are extended and additional disposal sites are established. It was noted that as the troops advance farther from the beach area, trucks hauling supplies to the front lines are used to back-haul waste materials. This is particularly true of recoverable items such as shell casings.

Solid waste management has traditionally been given a low priority during the first 30 to 60 days of a MAF operation. Organized solid waste management is secondary to the MAF mission and is typically undertaken only after the Logistics Support Area has been established and/or accumulated solid waste begins to become a nuisance. Detailed descriptions of specific waste management practices are summarized in Table 7. In general, solid waste collection does not begin until after engineering support has established a landfill, and men and equipment can be deployed for the waste management function. Engineering or motor transport personnel are most often tasked with operating the collection system, using stake-bed or dump trucks as they become available. Refuse is generally stacked in place at the point of generation due to the lack of appropriate containers.

Table 7. Current Solid Waste Disposal Practices[a]

| | Disposal Practice[b] | | | | | |
|---|---|---|---|---|---|---|
| | Burn | Bury | Salvage | Destroy | Reuse/ Retrograde | None |
| <u>Electronics Equipment</u> | | | | | | |
| • Communications equipment | 5 | 5 | | 5 | 95[c] | |
| • Data processing equipment | 10 | 10 | | 10 | 95[c] | |
| • Carrying cases | | 10 | | | 90 | |
| • Tapes | | 10 | | | 90 | |
| • Reels | | 10 | | | 90 | |
| • Electronic equipment and components | | | | | | |
| • Cables | | 100 | | | 50 | |
| • Wire | | | | | | 100 |
| • Antennae | | 100 | 80 | 100 | | |
| • Antennae poles | 100 | 100 | 25 | | | |

continued

Table 7. Continued

| | Disposal Practice[b] | | | | | |
|---|---|---|---|---|---|---|
| | Burn | Bury | Salvage | Destroy | Reuse/ Retrograde | None |
| <u>Chemicals</u> | | | | | | |
| • Drugs | | 10 | 90[c] | | | |
| • Desiccants | | 100 | | | | |
| • Chemical additives | | 100 | | | | |
| • Cement | | 100 | | | | |
| <u>Paper Products</u> | | | | | | |
| • High grade paper[d] | 20 | 20 | 80 | 10 | | |
| • Computer print-out[d] | 20 | 20 | 80 | 10 | | |
| • Tab cards[d] | 20 | 20 | 80 | 10 | | |
| • Tape[d] | 20 | 20 | 80 | 10 | | |
| <u>Furnishings</u> | | | | | | |
| • Metal furniture | 50 | 50 | | | 50[c] | |
| • Wooden furniture | 50 | 50 | | | 50[c] | |
| • Plastic office supplies | 50 | 50 | | | 50[c] | |
| <u>Medical and Laboratory Supplies</u> | | | | | | |
| • Chemical bottles | 100 | 100 | | | | |
| • Stoppers | 100 | 100 | | | | |
| • I.V. bottles | 100 | 100 | | | | |
| • Gauzes | 100 | 100 | | | | |
| • Bandages | 100 | 100 | | | | |
| • Wrappings | 100 | 100 | | | | |
| • Syringes | | 100 | | 90 | | |
| • Drugs | | | | | 100[c] | |
| • Chemicals | | 100 | | | | |
| • Glassware | | 100 | | 100 | | |
| <u>Textiles</u> | | | | | | |
| • Netting | 100 | 100 | | | 50 | |
| • Rope | 100 | 100 | | | 50 | |
| • Tentage[e] | 100 | 100 | | | 75 | |
| • Canvas[e] | 100 | 100 | | | 75 | |
| • Insulation | 100 | 100 | | | 50 | |
| • Ground cover | 100 | 100 | | | 50 | |
| • Tarps[e] | 100 | 100 | | | 75 | |
| • Uniforms | | | | 100 | | |
| • Other clothing | 50 | 50 | | | 50[c] | |
| • Sheets | 100 | | | | | |
| • Toweling | 100 | | | | | |
| • Other linen | 100 | | | | | |
| • Gauzes | 100 | 100 | | 90 | | |
| • Bandages | 100 | 100 | | 90 | | |

continued

Table 7. Continued

| | Disposal Practice[b] | | | | | |
|---|---|---|---|---|---|---|
| | Burn | Bury | Salvage | Destroy | Reuse/ Retrograde | None |
| <u>Heavy Boxes and Storage Containers</u> | | | | | | |
| • Oil cans | | 100 | | | | |
| • Plastic containers | | 100 | | | | |
| • Mount-out boxes | | 25 | | | 90 | |
| • Light wooden construction boxes | | 100 | | | 50 | |
| • Barrels[f] | 50 | 50 | | | 90 | |
| • Ammunition boxes | 50 | 100 | | | 75 | |
| • Metal containers[g] | 50 | 50 | 50 | | | |
| • Food containers | | 100 | | | | |
| <u>Corrugated and Packing Materials</u> | | | | | | |
| • Paperboard boxes[h] | | | | | 75[c] | |
| • Shelving | 100 | 100 | | | | |
| • Folding box board[h] | 25 | 25 | | | 75[c] | |
| • Partitioning[h] | 25 | 25 | | | 75[c] | |
| • Wooden pallets | 25 | 25 | | | 90 | |
| • Metal pallets | | 25 | | | 90 | |
| • Dunnage | | | | | 100 | |
| • Rubber wrapping | 100 | 100 | | | | |
| • Rubber cushioning | 100 | 100 | | | | |
| • Rubber pading | 100 | 100 | | | | |
| • Plastic wrapping | 100 | 100 | | | | |
| • Plastic sheeting | 100 | 100 | | | | |
| • Plastic insulation | 100 | 100 | | | | |
| • Plastic bladders | 100 | 100 | | | | |
| • Nails | | 100 | | | | |
| • Fasteners | | 100 | | | | |
| • Latches | | 100 | | | | |
| • Strapping | | 100 | | | | |
| <u>Machine Parts</u> | | | | | | |
| • Engine and machine parts | | 50 | 50 | | | |
| • Aircraft parts | 100 | 100 | | 100 | | |
| • Tires | 100 | 100 | | | 30 | |
| • Light tubing | | 100 | | | | |
| • Hosing | | 100 | | | | |
| <u>Weaponry</u> | | | | | | |
| • Shell casings | | 10 | 90 | | | |
| • Guns (handguns-rifles-mortars)[i] | 75 | 75 | 25[c] | 75 | | |

continued

Table 7. Continued

| | Disposal Practice[b] | | | | | |
|---|---|---|---|---|---|---|
| | Burn | Bury | Salvage | Destroy | Reuse/ Retrograde | None |
| Miscellaneous | | | | | | |
| • Optical equipment | | 70 | | | 30 | |
| • Hand tools | 100 | 100 | | | | |
| • Tent poles | 100 | 100 | | | | |
| • Glassware | | 100 | | 50 | | |

[a]AFOE or FE only.

[b]Figures represent % estimate of waste disposed of by each method.

[c]Donated to nationals, contracted for salvage, or scavenged by nationals.

[d]Classified materials are burned in barrels.

[e]Canvas reused for progressively lighter applications; estimated 4-month useful life.

[f]Used to burn sludge.

[g]Parts containers are used to backhaul salvageable parts to U.S.

[h]Corrugated is scavenged heavily in Far East operations.

[i]Salvage may be contracted to certified subcontractor.

Most MAF solid wastes are disposed of by open burning or burial in a landfill. Open burning of waste in a combat zone is uncommon, although certain materials such as sewage sludge, classified documents, and high-technology equipment require disposal in this manner.

Depending on the specific circumstances, there will be some reuse of waste materials. The greatest reuse application is in nonengineered construction where container materials are often used. Reconditioning of certain more valuable wastes is also common although this accounts for only a small percentage of the total waste. Damaged vehicles, machine parts, tires, optical equipment, and electronic equipment are examples of items which are often reconditioned in the field. Recycling (reprocessing of waste to extract its raw material value) is rarely practiced due to the excessive handling and transportation requirements. Only artillery shell casings have ever presented any real possibility for recycling, and recent changes in shell casing material may preclude this possibility.

The two greatest MAF waste management manpower sinks are: (1) equipment and material destruction and (2) waste collection and transport. Equipment and material destruction is currently accomplished through burning or manual dismantling. MARCORPS solid waste management has historically relied upon "fox-hole strength" manpower to collect and transport solid waste in its naturally discarded, least dense form. Table 8 summarizes MAF solid waste collection requirements in terms of manpower and equipment for each echelon. These data show that a daily allocation of approximately 1,800 man-hours is required to collect about 1,100 tons of solid waste. This practice requires 72 trucks and 216 men that were intended for primary mission activities.

Table 8. MAF Solid Waste Collection Requirements[a]

| Function | Assault Echelon (5 days) | Follow-On Echelon (3 days) | Flight Echelon (22 days) | Average (30 days) |
|---|---|---|---|---|
| Collected Waste (tons) | 3,482 | 6,158 | 22,496 | 32,136 |
| Required Truck Loads (B) | 2,321 | 4,105 | 14,997 | 21,424 |
| Daily Collected Loads | 464 | 1,368 | 681 | 714 |
| Required Truck/ Day (D) | 47 | 137 | 69 | 72 |
| Manpower Consumed (men/day) (A, C, D) | 141 | 414 | 207 | 216 |
| Total Man-Hours (A) | 5,816 | 10,246 | 37,493 | 53,560 |
| Man-Hours/Day (total/duration) | 1,163 | 3,415 | 1,704 | 1,785 |

[a]Daily collection to intermediate storage with no treatment/disposal. Assuming a density of 500 $lb/yd^3$ for the 32,136 tons of solid waste generated over the 30-day period translates into a conventional landfill requirement of about 0.88 acre per day, 1 yard deep, for disposal.

NOTES: Analysis based upon the following assumptions:

(A) 8-1/4 hours productive work/cap./day at 0.6 ton collected/ man-hour

(B) 2-1/4 ton multipurpose 6x6 truck at 1.5 tons/load/truck

(C) 3 men/truck

(D) Utilizing 50 min collection cycle, 10 loads/truck/day

The general lack of mechanized solid waste management practices utilized in Vietnam demonstrates the need for such a capability. Because there was insufficient time to manually destroy the large quantities of sophisticated weapons and support equipment during "pull-out" operations, they were left behind. As a result, these supplies and equipment were either captured or retained by the Communist Vietnamese.*

## Specific Solid Waste Management Practices

Areas. Formal solid waste management is practiced in three principal areas of an MAF:

- Logistics Support Area
  - Supply dump
  - Residence, mess
  - Hospital
  - Construction
- Beach Support Area (BSA)
  - Supply dump
  - Airfield
- Artillery

Formal solid waste management programs do not exist in most other areas of a MAF.

Equipment. Equipment support for solid waste collection is drawn from other functions within the MAF. Typical collection vehicles include *jeeps, stake-bed trucks*, and dump trucks. In certain supply and operation areas, semi-trailer trucks are employed for refuse transport. In these instances, the trucks used to transport supplies backhaul the solid wastes to either a formal disposal site or storage area for later repair and reuse. Equipment used for waste collection in peacetime exercises include helicopters and commercial compactor vehicles; however, neither is used for solid waste collection during combat operations. Helicopters are not considered a realistic alternative in combat due to their prescribed combat and maintenance functions.

Methods. Solid waste disposal is conducted by one or more of five methods, as follows:

| Operation | Description | Typical Applications |
|---|---|---|
| Burning | Incineration in drums or at a specific burn site (such as a landfill) | • Sewage sludge<br>• Paper products, classified documents<br>• Medical/dental wastes<br>• Packing materials<br>• Aircraft parts |

continued

*Vietnam now has the 4th largest air force in the world, more bullets per capita than the Russian Army, and a Navy with world ranking.

| Operation | Description | Typical Applications |
|---|---|---|
| Burial | Excavated pit with bulldozer periodically covering deposited waste | • Burn residue<br>• Drugs and chemicals<br>• Heavily damaged machine parts<br>• Demolition waste<br>• Other wastes not suitable for burning in drums |
| Reuse/ Retrograde | Waste items may be reused in damaged condition or scavenged by nationals | • Electronics supplies (antennas, wire, etc.)<br>• Machine parts<br>• Wood or corrugated cardboard for temporary construction |
| Recondition | Field repair of damaged article, or shipment to repair facility | • Tires<br>• Optical equipment<br>• Most electronics equipment<br>• Heavy-duty containers<br>• Vehicles |
| Salvage | Use of component value only | • Metal, shell casings |

The prevalence of each method within a MAF is dependent upon several factors including the phase of operation, the nature of the waste, and the specific location of waste generation. The waste disposal practice is best described in terms of waste type or component, as opposed to area of waste generation.

Observations of MAF exercises and interviews with FSSG personnel demonstrated the prevalence of these various disposal methods. Table 7 displays the estimated prevalence of each method by component type. Components for which waste management practice predominance adds up to more than 100% are those which are reused until the end of their useful life. The following discussion presents a general overview of waste management practices according to waste type.

Electronics Equipment. Equipment falling in this category is typically limited to communications and data processing equipment and support material. Communications equipment is typically repaired in the field or returned stateside for repair if it is not completely destroyed. Data processing equipment is repaired by contractors who are often in the field during combat. Associated materials such as tapes, cables and wires, and antennas are reused until they become damaged beyond repair. Electronic equipment disposal is usually limited to simple burial, unless equipment requires destruction for security reasons.

Chemicals. Most waste chemicals generated within a MAF are simply stored, collected, and buried at the disposal site. Waste fuels are used to assist in the combustion of liquid waste or classified material.

Paper Products. Most paper products generated in combat are similar to those generated in an office environment. High-grade paper, computer printout, tab cards, and tape are virtually recycled. Recyclable paper is boxed at the point of generation and transported to larger boxes for storage and subsequent transportation to the nearest recycling facility. Classified documents are destroyed, usually by burning, at their point of generation.

Furnishings. There is no formal retrograde procedure for damaged furniture. All waste furniture is either buried directly or first burned and then buried. Some scavenging of this material by nationals does take place.

Medical and Laboratory Supplies. Most medical and laboratory supplies are burned and/or buried at the landfill, as appropriate. Waste syringes are destroyed. Infectious wastes are disposed of in open pits near the point of generation and often present nuisance and health problems.

Textiles. Most waste textiles are destroyed by burning prior to burial. However, waste uniforms are destroyed at the point of generation. Canvas items are typically reused over a period of several months until they finally disintegrate.

Heavy Boxes and Storage Containers. Most containers generated during a MAF operation are reused for some secondary function. Oil cans, for example, are used as makeshift sludge incinerators. Wooden containers, such as mount-out boxes and light wooden construction boxes, are broken down and used for construction material. Certain types of containers which are used to store new parts are reused for shipping damaged parts of the same size to the rear for retrograde.

Corrugated and Packing Materials. Corrugated cardboard has a high salvage value in many depressed areas of the world. Disposal of waste corrugated cardboard is typically accomplished through scavenging by nationals. Wood and metal pallets are reused for their remaining useful life and then broken down for use as construction material. Waste packing materials and fasteners have little reuse potential and are most often disposed of upon generation.

Machine Parts. Machine parts, in general, show the greatest level of reuse and recycling in the field. Engine and machine parts from vehicles are serviced at motor pool areas or repacked and trucked to the rear for repair. Most reusable aircraft parts are destroyed for security reasons. Tires have, in some instances, been recapped in the field where such facilities are available, although this is more the exception than the rule in combat operations.

Weaponry. Concentrated shell casing generation occurs in the artillery areas, where they are stockpiled and reboxed for transport (backhaul) and reprocessing. Shell casings generated by hand-held weapons are typically not recycled. Hand-held weapons and other small arms are typically demilled or torched in the field. In some locations, certified salvage contractors may be awarded this responsibility. Items falling into the latter category typically do not possess any reuse potential.

## SOLID WASTE MANAGEMENT ALTERNATIVES

The scope of CEL research extended beyond current operational scenarios and current Tables of Equipment and Operation; it was also considered essential to analyze changing trends in materiel, containerization, and MAF doctrine. This has resulted in the formulation of short-range, mid-range, and long-range solid waste management goals.

- Short-range goals address current solid waste management problems and immediate solutions.
- Mid-range goals anticipate solid waste management problems approximately 10 years in the future.
- Long-range goals represent planning for solid waste management approximately 20 years in the future.

### Short-Range Goals

1. Recommend commercially available solid waste management equipment.

2. Perform the minimum required modifications.

3. Operate the units in MARCORPS training exercises, shore facilities, and limited remote base environments.

Commercial solid waste handling/disposal technology is not directly applicable to MAF environments. This is due primarily to the limited mobility, the absence of fail-safe provisions, and the low reliability encountered in extended operations.

The large components and high metal content of the MAF waste stream also limit direct transfer between commercial and MARCORPS applications.

### Mid-Range Goals

1. Provide a single system capable of handling all MARCORPS solid waste while conforming to the rigors of a MARCORPS combat field environment. This is the primary objective of the MAF solid waste research and development.

2. Provide equipment specifically designed for management of the MAF solid waste stream approximately 10 years into the future. The current containerization research and development program, the development of modern, more mechanized weapon systems, the higher quality of the individual Marine, and the streamlining of current packaging procedures all influence reaching the mid-range goal.

3. Provide a system for future MAF scenarios; this includes highly mobile, modular facilities, "over-the-beach" objectives with air-cushioned vehicles, and, in general, a change in assault warfare philosophy. The solid waste stream generated from these scenarios will be different from the waste stream generated today.

Long-Range Goals

1. During a 20-year time frame, recommend solid waste management systems, conceived in terms of sophisticated packaging reduction techniques, to alleviate solid waste problems before they develop*

2. Energy conversion systems to provide power from solid waste constituents

3. Recycling/reuse operations for use during the next 20-year time frame

Any improvement in waste management practice should have, as its first priority, the reduction in manpower and/or equipment requirements for waste transport, handling, and disposal. Once a proposed system meets this criterion, it must also provide improvement in one or more of these areas:

- A simpler method of destroying secure information or equipment, such as electronic equipment, aircraft parts, classified papers, etc.
- A reduction in nonreusable packaging, thereby increasing reuse and recycle potential while decreasing disposal and handling requirements
- An improved method of infectious waste disposal
- A more efficient means of waste storage and handling

Improvements in waste management for mobile forces, such as the infantry, was not considered because formal waste management practices during combat would jeopardize their primary mission. It is apparent that the only feasible method of improving waste management at the combat troop level would be through a reduction in waste or an increase in reusable materials.

The two greatest MAF waste management manpower sinks are: (1) equipment and material destruction; and (2) waste collection and transport. A "typical" MAF would require a daily allocation of approximately 1,800 man-hours and about 72 vehicles originally intended for support of the primary mission.

Equipment and material destruction is currently accomplished through burning or manual dismantling. Mechanical means of destruction could instead be incorporated, thereby reducing manpower requirements. The excessive manpower and vehicle requirements for refuse handling and collection could be reduced through the use of specialized volume reduction equipment.

The following discussion of waste management equipment will address these key points:

---

*The use of MILVAN type 8 x 8 x 20-foot containers can measurably reduce the production of potential solid waste. This approach to packaging eliminates the need for about 30 1/2-inch-thick plywood boxes per container and represents a manpower savings of approximately 120 man-hours.

- locations in an MAF where specialized equipment can be best utilized
- the value of waste densification in manpower savings
- the problems associated with key waste components, especially the high proportion of metal in the MAF waste stream
- the adaptability of commercial equipment to MAF requirements

Discussions with FSSG personnel indicated that the most effective use of stationary waste management equipment would be in the four areas providing the greatest concentration of waste generation and, therefore, the greatest potential for improvement:

- Beach Support Area
- Logistic Support Area
- Marine Amphibious Wing (airfield)
- Artillery

Current waste collection and transport activities alone can account for more than four man-hours and two vehicle-hours per ton of solid waste collected due to the low density of the material. MAF solid waste density, particularly in supply areas generating waste paper and cardboard, can be as low as 150 lb/yd$^3$. Volume reduction is therefore the key to immediate waste management improvement.

At present, the key to improving MAF solid waste management is in maximizing waste "capture" while minimizing manpower and equipment deployment per unit of waste.

Aside from the possible savings in manpower and equipment, additional evaluation criteria of importance to military application include the following:

- Mobility - Any piece of equipment should be either self-motive or compatible with the capacity and availability of equipment to handle it.
- Maintenance - Equipment should be as simple in design as possible and based on mechanical components which are similar in concept to existing MAF equipment. Standard commercial designs are desirable because spare parts will be much easier to obtain over the service life of the equipment.
- Operation and Repair - Equipment should require a minimum of dedicated personnel and maintenance equipment. In addition, operator and repair training requirements should be minimal.

Balers, stationary compactors, shredders, compacting vehicles, and incinerators are proven means of volume reduction in municipal applications. Development of one or more of these items for MAF operation has the potential of providing substantial manpower and equipment savings. Through proper design, these devices also have the capability of destroying much of the equipment and material which is currently destroyed by hand. Many of these devices have a built-in shear that "shapes" (and therefore destroys) solid waste before compacting or baling. Table 9 shows specific equipment available.

Table 9. Solid Waste Management Alternatives

| Component | Purpose | Location | Design Specifications |
|---|---|---|---|
| Baler | Compact and package solid waste for easier storage, transport, disposal, and destruction | 1-BSA[a]<br>2-FSSG<br>1-MAW<br>1-Artillery[b] | • Semi-Automatic<br>• Compact with destructive force (reciprocating)<br>• Maximum bale dimensions 48 in. for 4,000-lb fork lift |
| Compactor | Compact solid waste for easier storage, transport, and destruction | 1-BSA[a]<br>2-FSSG<br>1-MAW<br>1-Artillery | • Compact with destructive force<br>• Volume compatible with available vehicles, or<br>• Mobile compaction unit |
| Shredder | Volume reduction, destruction | With baler or compactor | • Compatible with baler or compactor<br>• Lowest power for specified function |
| Compacting Vehicle | Collect solid waste from small concentrations of personnel | BSA<br>Artillery<br>Infantry | • MIL spec for off-road application<br>• Minimum 6-ton capacity<br>• Diesel engine<br>• Alternative applications |
| Compacting Vehicle | Collect solid waste from large concentrations of personnel | BSA<br>LSA<br>MAW | • MIL spec for off-road application<br>• Minimum 10-ton capacity<br>• Diesel engine<br>• Alternative applications |
| Incinerator | Destruction of classified material, equipment | LSA | • Portable<br>• Minimum 500-lb/hr capacity<br>• Solid waste only |

[a]Per beach activity.

[b]Optional.

Such equipment could be designed with sufficient compacting force to destroy selected equipment items. Because stationary compactors require a specialized vehicle to transport the waste, these vehicles would need to be designed with multiple-use potential. Bales must be compatible with existing materials handling equipment such as forklifts and collection vehicles. In addition, shredders could be applied to both stationary compactors and balers for use in volume reduction and equipment destruction.

Commercial compacting vehicles, as they now exist, are often too large and fragile to meet combat military specifications. However, compactor designs are currently well developed and could be matched with a more durable chassis and drive train. This would imply a compaction body designed for field installation on an available MARCORPS vehicle, particularly a military stake-bed truck.

Incinerator designs are showing greater levels of sophistication on the municipal scale and could provide a variety of capacities for combat application and, if necessary, in a portable mode.

Each one of these alternative equipment applications shows potential for improved efficiency in MAF waste management. Defining in quantitative terms how much of an improvement can be effected requires: (1) that a model MAF be assumed; and (2) that transportation and handling times be estimated.

## Development of a Model Waste Management System

The configuration of a MAF solid waste management system evolves only after the support functions have been located and established. Estimating "typical" distances to landfill or burning sites is meaningless unless a specific action is referred to. Based on discussions with FSSG personnel, it was elected to develop a model solid waste management system for the size of MAF used in this study.

Figures 6 and 7 display the second and third phase, respectively, of the model MAF with the associated locations of BSA, LSA, airfield, and support landfill operations. The figures alsc display possible baler and compactor locations should they be used in support of the landfill operations. In this MAF model, a baler or compactor is brought ashore at approximately D+15 to support the BSA. After D+30, when the LSA and airfield have been established, additional compactors or balers would be brought ashore to support these functions. Small shredders could be incorporated as part of the baler or compactor systems to provide additional volume reduction and destruction capability. Either a small or large compacting vehicle could be deployed for waste collection at various support activities. Incinerators could be employed in a variety of sizes, depending on the scale of application. Small-scale incinerators might be employed to support medical activities, or at the salvage yard for the destruction of classified equipment.

Table 10 presents the model waste management system logistics and equipment deployment. Part I describes the model collection systems for the LSA, BSA, and artillery areas. For example, the LSA supply dump generates an estimated 6 tons/day of solid waste which is collected by a two-man crew using a stake-bed truck and transported to the LSA central landfill.

Modifications to these systems are shown in Part II.

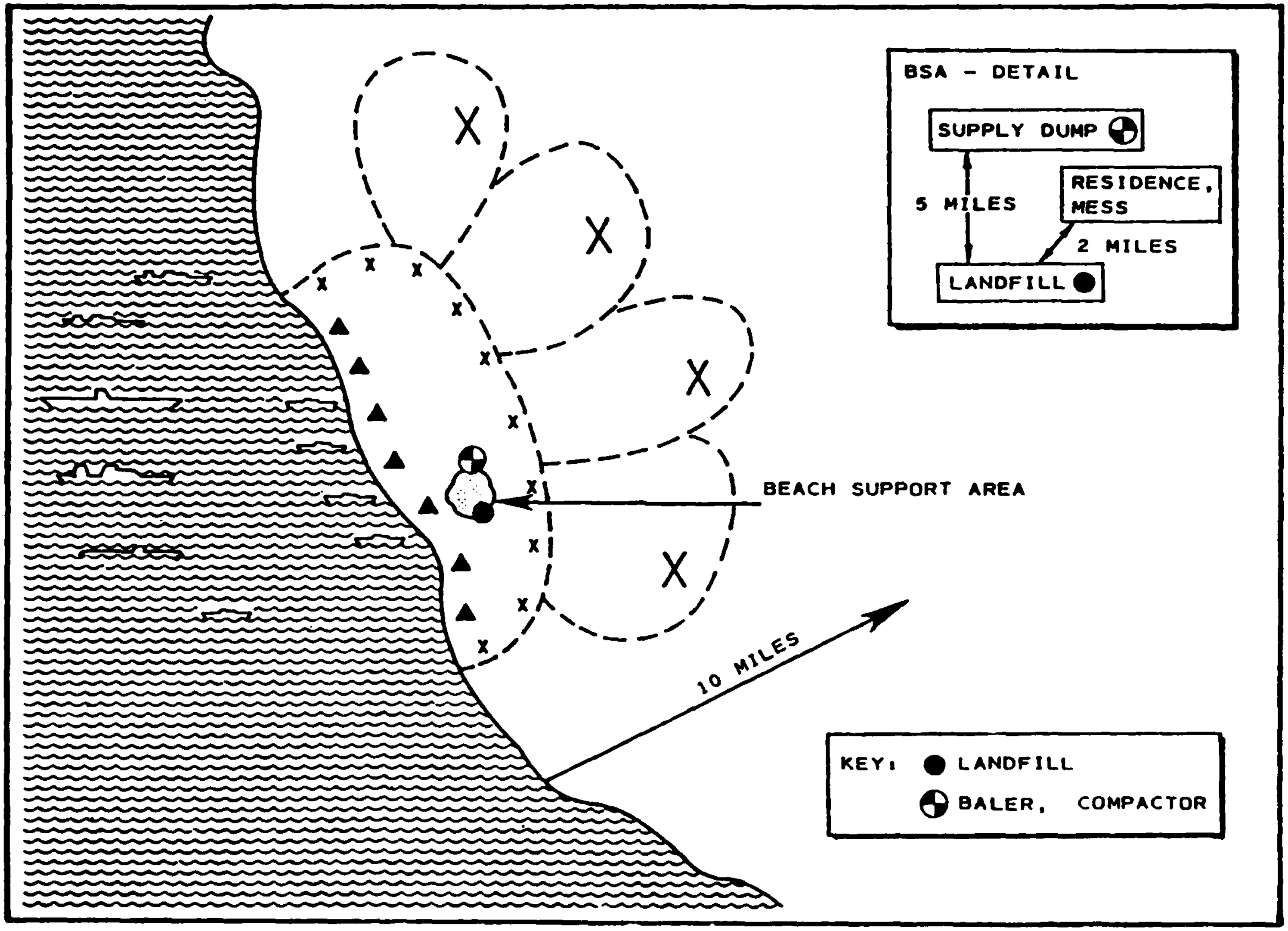


Figure 6. Model MAF (assault follow-on phase, D + 15 to D + 30 days).

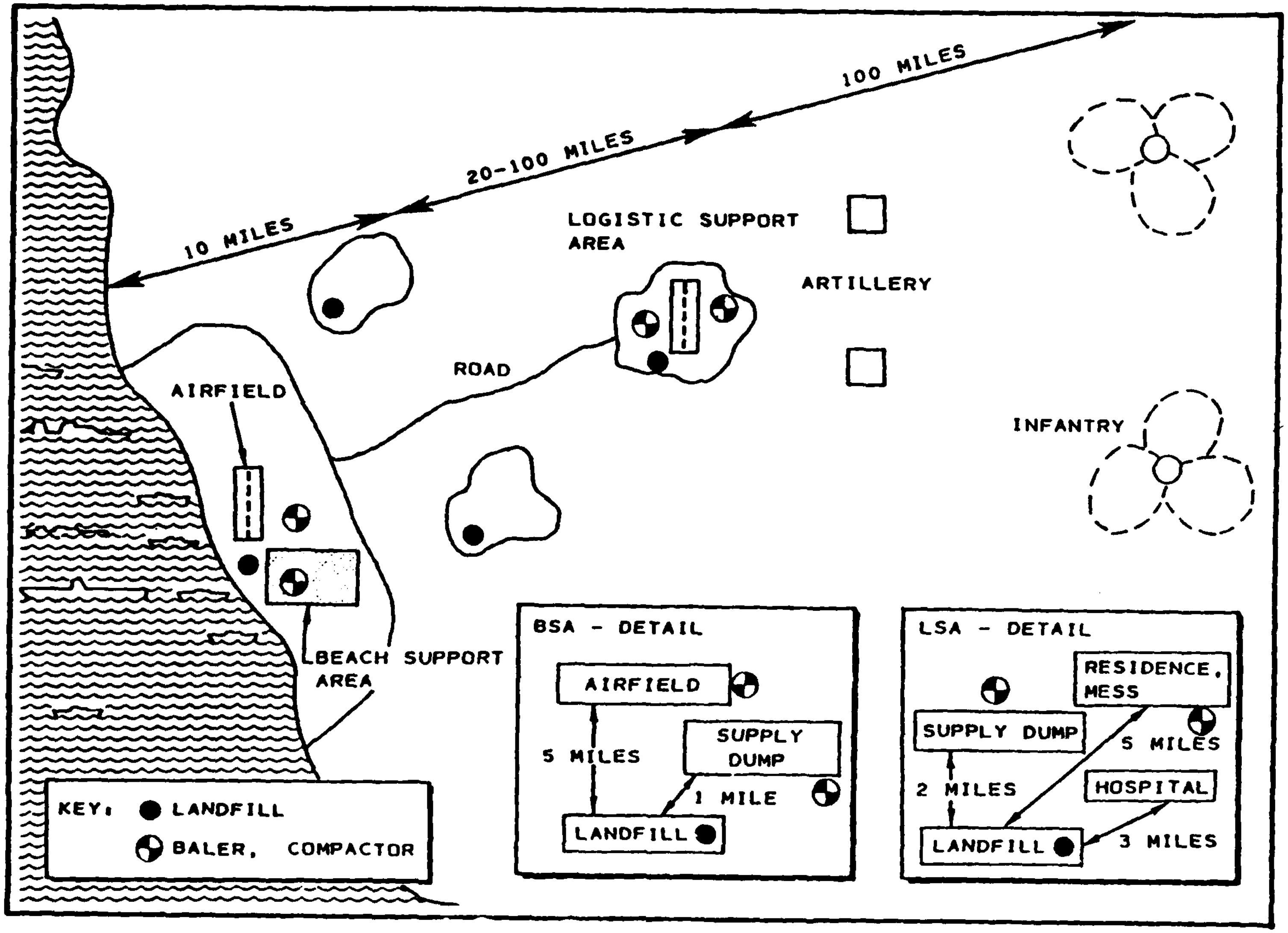


Figure 7. Model MAF (established operation).

Table 10. System Design Premises for Comparative Analysis

I. Basic Collection Systems

1. Logistic Support Area (D+30)

- Supply dump
  - 6 tons/day solid waste
  - 2 miles to landfill
  - 2-man collection crew with stake-bed truck
- Residence, mess
  - 20 tons/day solid waste
  - 5 miles to landfill
  - 2-man crew, stake bed
- Hospital
  - 1-2 tons/day solid waste
  - 3 miles to landfill
  - 2-man crew, stake bed
- Construction (MBC)
  - 10 tons/day solid waste
  - Varying distance to landfill
  - 2-man crew, dump truck

2. Beach Support Area (D+30)

- Supply dump
  - 3 tons/day solid waste
  - 1 mile to landfill
  - 2-man crew, stake bed
- Airfield
  - 100 tons/day solid waste
  - 5 miles to landfill
  - 2-man crew, stake bed

3. Artillery

- 350 tons/day solid waste
- 10-20 miles to landfill
- 2-man crew, semi-trailer truck

4. Infantry

- 80 tons/day solid waste
- No field landfill
- No collection

continued

Table 10. Continued

II. Modifications to Basic Collection Systems

1. Baler

   - 1 man loads baler as waste is delivered
   - Bales are stored (700 lb each)
   - Stake bed with 2-man crew is loaded with 2 to 4 bales by on-site forklift
   - Bales are driven to disposal site

2. Shred and Bale

   - Same as 1, only waste is shredded into baler hopper

3. Stationary Compactor

   - Solid waste is loaded into compactor on site
   - Special vehicle removes compactor to disposal site
   - Compactor is returned to site
   - Total of 4 to 5 compactors spaced throughout MAF

4. Compactor Vehicle

   - 6 to 10 $yd^3$ compactor has specified route through remote infantry or LSA areas
   - 20 to 30 $yd^3$ compactor collects solid waste from (1) artillery and (2) LSA concentrations

5. Incinerator

   - Truck-mounted unit services supply, medical, and maintenance areas to dispose of classified and other specified materials
   - Stationary (smaller) units located as above

## Comparative Analysis of Alternatives

The system design premise presented in Table 10 provides a quantitative means of comparing a model existing waste management system for each area with an alternative waste management system. This comparison would be based on comparable system logistics such as collection, waste generation, and distance to landfill sites. Because each of the alternatives concentrates on either volume reduction or waste destruction, the principal savings would be realized during waste handling and transport, not disposal. With the exception of incineration, manpower and equipment requirements for disposal to landfill were therefore assumed to be the same in all cases.

The actual comparison of alternatives was based on manpower and equipment required to load, transport, and unload a load of solid waste between the point of generation and the disposal site. The following specific motion study elements were used in the analysis:

- Handling and processing of solid waste at the collection point (collection and accumulation of solid waste within an activity was assumed constant for all alternatives)
- Loading solid waste onto a collection vehicle
- Transporting the solid waste to the landfill
- Offloading the solid waste at the landfill
- Returning: (1) to the next collection point, or (2) to the original collection point (to return mobile compaction equipment)

Using the distances specified in Table 10, times of performance were estimated for each of the above elements. This simulated time study permitted the computation of total time per load.

Assuming the time required to transport a load of solid waste is the same, regardless of waste condition, the only variation between alternatives would be realized in the handling, loading, and unloading elements. However, because a load of compacted or baled waste is much denser and, therefore, heavier than a load of uncompacted waste, expressing the manpower and equipment requirements on a per-ton basis would amplify any difference. Per-ton requirements can then be applied to the generation rate estimates for each activity to estimate absolute man-hour and vehicle-hour differences between alternatives.

Table 11 is a typical example of the above calculation comparing manpower and equipment requirements at the LSA residence and mess: loose solid waste storage and transport versus baled waste storage and transport. The table shows the following time study information:

1. Collection and transport of one 1,500-pound load of solid waste from this area consumes 4.5 man-hours and 2.3 vehicle-hours, which equates to 6.0 man-hours and 3.1 vehicle-hours per ton.

2. Collection, baling, and transport of one 2,800-pound load (four 700-pound bales), while requiring more manpower for processing, consumes a comparable number of man-hours and vehicle-hours overall (4.2 and 1.4, respectively). However, the estimates of 3.0 man-hours and 0.9 vehicle-hours per ton show a substantial improvement over those for unbaled waste collection.

The comparison of per-ton manpower and vehicle requirements provides a measure of the potential savings. Application of these unit expenditures to the actual daily tonnage at each location provides an absolute measure of savings. For example, the LSA residence/mess generates an estimated 20 tons/day of solid waste. The current method of collection consumes an estimated 120 man-hours per day (6.0 man-hours/ton, 20 tons/day). Adding a baler to the system would reduce the manpower requirement to approximately 60 man-hours (3.0 man-hours/ton), a 60 man-hour per day saving.

Table 12 is a summary of similar computations of manpower savings for all areas. The numbers in general demonstrate the great potential for decreasing current manpower allocations for solid waste management.

Table 11. Comparison of Solid Waste Management Alternatives for MAF Operations: LSA Residence/Mess Area

| Waste Management Activity[a] | Man-Hour | | Vehicle-Hour | | Waste Management Activity[b] | Man-Hour | | Vehicle-Hour | |
|---|---|---|---|---|---|---|---|---|---|
| | Per Load | Per Ton | Per Load | Per Ton | | Per Load | Per Ton | Per Load | Per Ton |
| 1. Load solid waste at generation point(s) supply dump area | 1.00 | 1.3 | 0.50 | 0.6 | 1. Operator loads baler unit at residence | 1.30 | 0.9 | 0 | 0 |
| 2. Transport solid waste to landfill (5 miles) | 1.25 | 1.8 | 0.65 | 0.9 | 2. Vehicle hauls baled waste to landfill | 1.25 | 0.9 | 0.6 | 0.4 |
| 3. Off-load solid waste at landfill | 1.00 | 1.3 | 0.50 | 0.6 | 3. Vehicle dumps waste | 0.40 | 0.3 | 0.2 | 0.1 |
| 4. Return to supply dump to return bins, collect next load | 1.25 | 1.7 | 0.65 | 0.9 | 4. Vehicle returns to baler unit | 1.25 | 0.9 | 0.6 | 0.4 |
| Total | 4.50 | 6.0 | 2.30 | 3.0 | Total | 4.20 | 3.0 | 1.4 | 0.9 |

[a]System premises:

- Stake-bed truck, 2-man crew, 1,500 lb full load
- 5 miles to landfill
- Solid waste stored in 55-gal drum equivalents

[b]System premises:

- Stake-bed truck, 2-man crew, 4-bale capacity
- Compacting horizontal baler
- 700-lb bales loaded by forklift

Table 12. Estimated Manpower Reductions Available Through Selected MAF Solid Waste Management Alternatives[a]

| Location | Current Practice | Baler | | Stationary Compactor | | Shredder/Baler | | Compactor Vehicle | |
|---|---|---|---|---|---|---|---|---|---|
| | Estimated Man-Hours | Estimated Man-Hours | Projected Saving | Estimated Man-Hours | Projected Saving | Estimated Man-Hours | Projected Saving | Estimated Man-Hours | Projected Saving |
| 1. LSA | | | | | | | | | |
| • Supply Dump 15 | 60 | 30 | 30 | 11.3 | 49 | 30 | 30 | 16.5 | 43.5 |
| • Residence/Mess 20 | 120 | 60 | 60 | 39 | 81 | 60 | 60 | 28 | 92 |
| 2. BSA | | | | | | | | | |
| • Supply Dump 10 | 32 | 16 | 16 | 13 | 19 | 16 | 16 | 13.5 | 18.5 |
| • Airfield 100 | 600 | 300 | 300 | 197 | 403 | 300 | 300 | 130 | 470 |
| 3. Artillery 120 | 1,152 | 240 | 912 | -- | -- | 240 | 912 | -- | -- |
| Total Reduction | | | | | | | | | |
| • Man-Hours | 1,964 | | 1,318 | | 552 | | 1,318 | | 624 |
| • Man-Days | 245 | | 165 | | 69 | | 165 | | 78 |

[a]All estimates expressed in man-hours/day. Projected saving refers to daily difference between current practice and modified practice.

The greatest manpower saving is realized through baling. Whether or not shredding is incorporated as an initial step, proper deployment of five balers could reduce manpower requirements by an estimated 165 man-days per day. To put this figure in perspective, the model MAF (51,000 men) requires that approximately 245 men handle and transport solid waste each day beyond D+30. This 67% reduction in manpower is due primarily to: (1) a reduction in the number of trips to the landfill per ton of waste; and (2) a substantial reduction in handling and loading requirements. The estimates are in fact conservative as they do not account for either the savings in equipment distribution time or disposal time (landfilling bales versus loose waste).

Similarly, Table 13 shows that baling could produce a 90% reduction in vehicle requirements, or 124 vehicle-days, for the entire MAF operation. This statistic is even more impressive when one realizes that MAF collection vehicles are drawn from a variety of functions, each with an immediate need for these vehicles.

Incineration was not quantitatively evaluated as a general waste management alternative. The physical size of an incinerator capable of burning all waste generated in a given area is too large to be practical in mobile combat operations. However, a smaller mobile unit might be considered for special small-volume applications (medical waste, classified equipment, etc.).

## WASTE MANAGEMENT EQUIPMENT EVALUATIONS

It was stated earlier that the greatest manpower and equipment savings would be brought about by applying waste volume reduction equipment in areas of concentrated waste generation. Several such areas were identified, including the administrative and support function concentrated in the BSA and LSA; the artillery section; and the major airfields. This section discusses two key pieces of equipment (compacting collection vehicles and stationary balers) in detail. It considers MAF needs and currently available equipment.

### Evaluation of Compacting Collection Vehicles

These factors were considered in evaluating a compacting collection vehicle:

- Mobility
- Capacity
- Operating power
- Feed mechanics
- Operation under varying climatic conditions
- Maintenance
- Product characteristics

Mobility. The current trend in Table of Equipment development is to minimize equipment volume and provide equipment with maximum versatility. Therefore, a compaction body must be designed for field installation on an available MARCORPS vehicle, particularly a military stake-bed truck. The body should be readily detachable when the vehicle is required for other purposes.

Table 13. Estimated Vehicle Use Reduction Available Through Selected MAF Solid Waste Management Alternatives[a]

| Location | Baler | | Stationary Compactor | | Shredder/Baler | | Compactor Vehicle | | Current Practice |
|---|---|---|---|---|---|---|---|---|---|
| | Estimated Vehicle Hours | Projected Savings | Estimated Vehicle Hours | Projected Savings | Estimated Vehicle Hours | Projected Savings | Estimated Vehicle Hours | Projected Savings | Estimated Vehicle Hours |
| 1. LSA | | | | | | | | | |
| • Supply Dump | 7.5 | 25.5 | 3.2 | 30.8 | 7.5 | 25.5 | 0.6 | 32.4 | 33 |
| • Residence/Mess | 6 | 62 | 10.8 | 57.2 | 6 | 62 | 12 | 56 | 68 |
| 2. BSA | | | | | | | | | |
| • Supply Dump | 3 | 15 | 3 | 15 | 3 | 15 | 3 | 15 | 18 |
| • Airfield | 38 | 302 | 54 | 286 | 38 | 302 | 60 | 280 | 340 |
| 3. Artillery | 60 | 588 | NA | NA | 60 | 588 | NA | NA | 648 |
| Total Reduction | | | | | | | | | |
| • Vehicle-Hours | 992.5 | 992.5 | | 389 | | 992.5 | | 383.4 | 1,107 |
| • Vehicle-Days | | 124 | | 49 | | 124 | | 48 | 138 |

[a]All estimates expressed in vehicle-hours/day. Projected saving refers to daily differences between current practice and modified practice.

Capacity and Weight. The capacity of the compaction body is limited to the chassis capacity and dimensions of the mating vehicle. The load limit for a military stake-bed truck is 5 tons for operation on unimproved roads, and 10 tons for improved road operation.

The dimensions of the chassis further limit capacity. Assuming a body height limit of 6 feet above the chassis, the maximum capacity of the compaction body would be approximately 10 $yd^3$. A body incline of 5 to 8 degrees from front to rear would be necessary for rear wheel clearance on rough terrain.

Operating Power. A self-powered compaction body would be required; an engine power takeoff might otherwise need to be installed in the field without the aid of a skilled mechanic. The use of an integrated power plant is quite common in civilian collection vehicles.

Feed Mechanics. Much of the refuse generated in a MAF operation is not collected from containers. Because of this, it is better to use a side- or rear-loading vehicle rather than requiring that the collectors pitch the waste from over their heads into a dump truck. A compaction body should therefore be designed for minimum lift height, recognizing that the bottom of the compaction body will rest on or near the top of the chassis.

Operation Under Varying Climatic Conditions. The compactor is not anticipated to require modification in any way to account for varying weather conditions. Most of these variations are of greater significance to the operation of the vehicle than to the operation of the body.

Maintenance. The use of standard commercial equipment is preferable where possible because of easy availability of parts. The compaction body should be of a state-of-the-art design or a modified version of a commercially available model.

Product Characteristics. The compaction body should achieve a waste density of 400 to 500 $lb/yd^3$. This is the range of density achieved by commercial compaction bodies in civilian application.

Operating Concept. An artist's conception of a military vehicle equipped with the detachable compaction body is shown in Figure 8. The compaction body is shipped without the cab, engine, or chassis. When its use is required, the body is mounted on a slight incline on a stripped vehicle chassis using special temporary fasteners. The power supply is attached to the chassis in front of the compaction body, although it could also be designed into the body structure.

In use, waste is loaded through special access doors on either side located approximately 60 inches above the ground. At selected intervals, the waste is compacted within the body by a blade moving from front to rear. When the body is filled, the waste is transported to the landfill and ejected, using the packing blade for ejection.

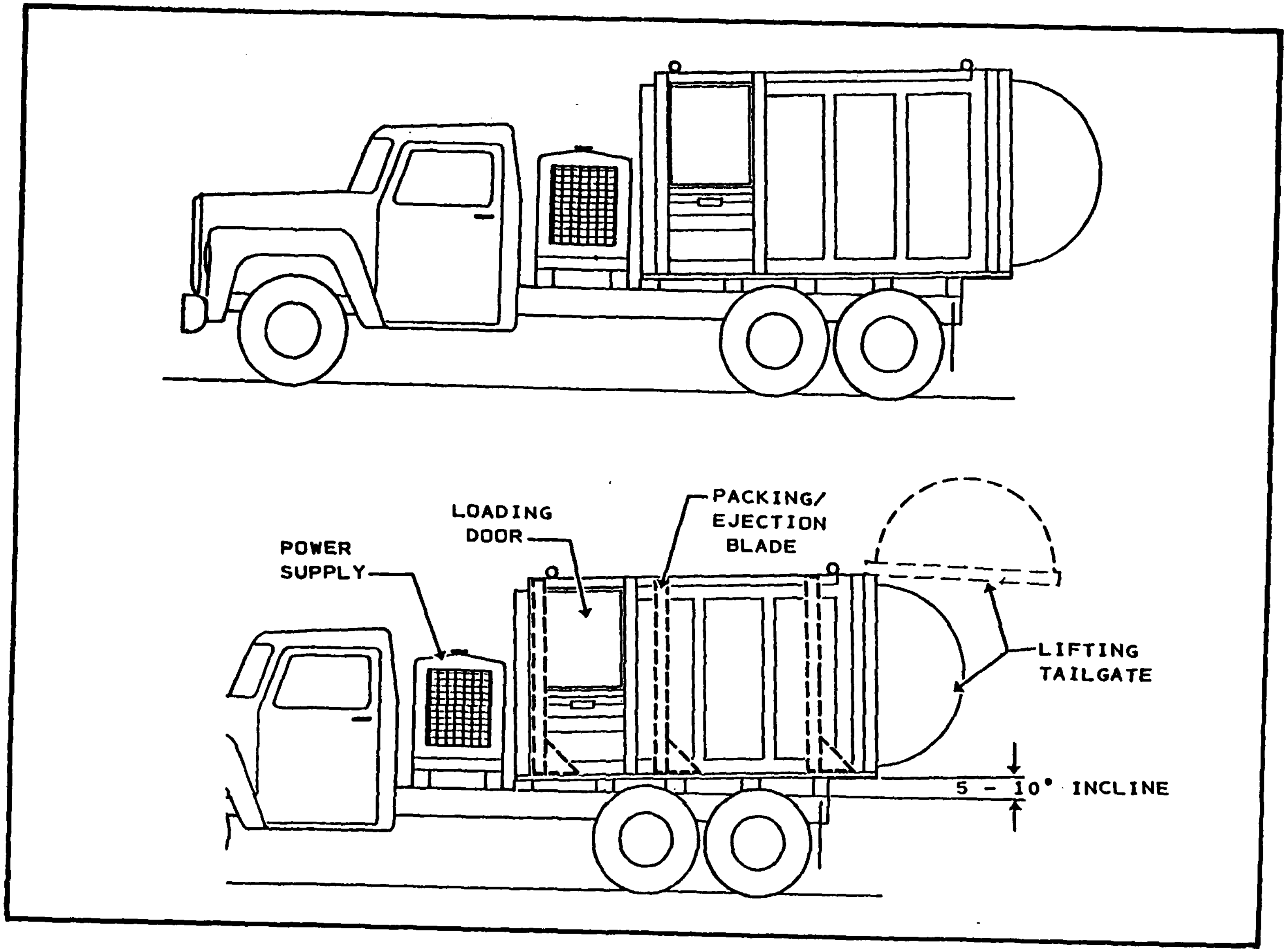


Figure 8. Vehicle-mounted compaction body.

The principal drawback to the side-loading configuration is the inability to load the vehicle when compacting or when nearly full. An alternative concept, shown in Figure 9, employs a waste-loading compartment which is separate from the storage compartment. The small packing blade forces the refuse into the storage compartment during loading. When emptied, the waste is ejected from the storage compartment by a full-width ejection blade.

Both concepts are state-of-the-art designs, and could be readily adapted to MAF applications.

Comparison With Commercial Equipment. One body selected for use as an example is the NORCAL Econo-Pak, whose specifications are shown in Table 14. Note that these specifications meet or approach those described in the design criteria. There are also several other side loader designs incorporating the concepts described above, including the Maxon Shu-Pak, currently one of the most widely used collection vehicles in the Western United States.

Modifications required for MAF application are only minor and could be performed on a production model.

Application. Any area with a concentration of waste-generating activities provides a possible location for vehicle deployment. Within a Supply Battalion, for example, such a vehicle could be used nearly full-time for removing waste from container breakdown and packaging removal. In the vicinity of the supply dump, removal of miscellaneous packaging, food waste from the mess, waste from maintenance and certain repair activities would occupy another one or more of these vehicles. Depending on the level of MAF activity and the governing logistics, as many as five to ten compaction vehicles could be deployed at one time to serve the MAF.

The proper time for deployment of compaction vehicles would be sometime between D+15 and D+30, with the establishment of the FSSG and the beginning of formal waste management activities. The use of compaction vehicles could be expanded once the FSSG is in place and formal channels of supply have been developed.

Equipment Cost. The approximate cost of the NORCAL Econo-Pak and power supply is about $25,000. Design and construction of a similar, but original, concept might increase the cost by as much as 50%.

## Evaluation of High Density Balers

Design Criteria. The general design criteria for evaluating the baler system are essentially the same as those for collection vehicles.

Mobility. The baler envisioned for MAF application is small, compared to commercial balers. The unit could be mounted either on a truck or on skids for stationary operation. A skid-mounted stationary baler is most appropriate because (as with the compacting collection vehicle) it does not require a vehicle be "dedicated." Most balers are quite long (up to 30 feet), and in many cases will require ground transport by lowboy trailer.

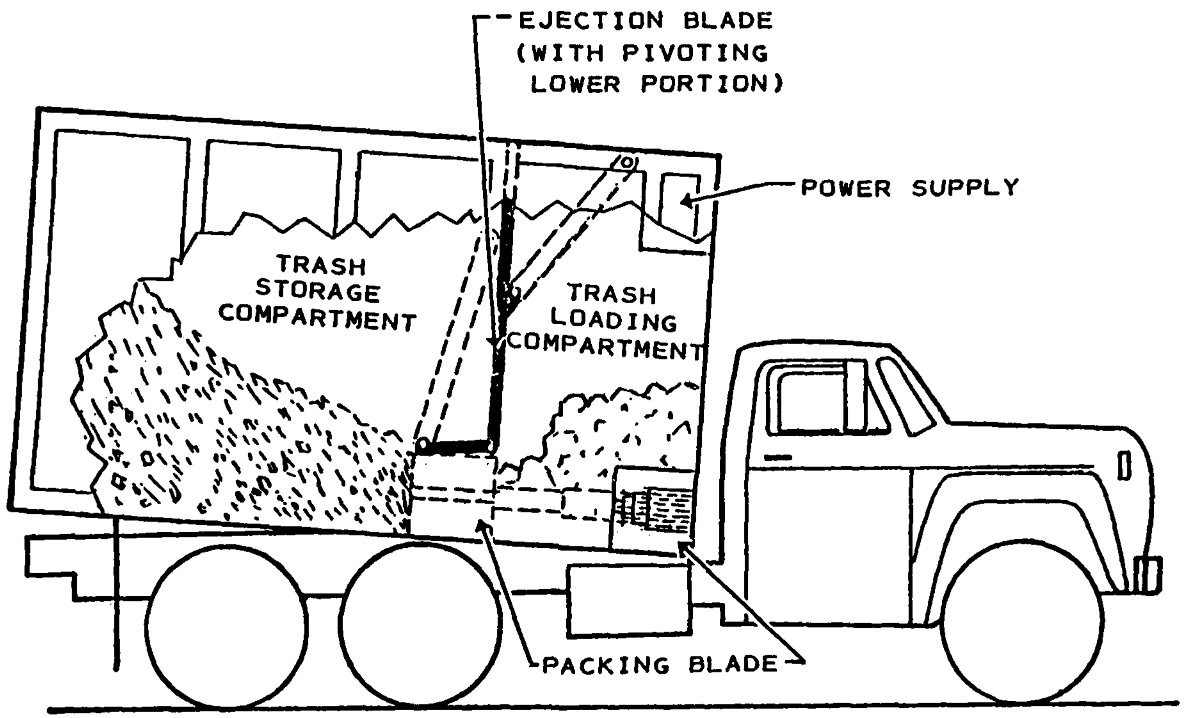


Figure 9. An alternative side-loading compaction body mounted on vehicle.

Table 14. Specifications for Norcal Econo-Pak[a] Compaction Body

| Item | 10 Cubic Yards | 13 Cubic Yards |
|---|---|---|
| Overall Length, Dim. "A" (in.) | 133 | 157 |
| Body Length, Dim. "B" (in.) | 96 | 120 |
| Overall Width (in.) | 90 | 90 |
| Height Above Chassis Frame (in.) | 66 | 66 |
| Packing Plate Cylinder | Telescopic | Telescopic |
| Packing Blade Force (lb) | 50,000 | 50,000 |
| Working Pressure (psi) | 1,800 | 1,800 |
| Oil Tank Capacity (gal) | 10 | 10 |
| Guide Block Wear Shoes | 4 (cast) | 4 (cast) |
| Loading Door Width, Dim. "C" (in.) | 36 | 36 |
| Top Door (in line w/side doors) (in.) | 36 x 20 | 36 x 20 |
| Weight of Body (lb) | 3,740 | 4,380 |
| Cab to Axle, Dim. "D" (in.) | 60/84[b] | 72/84[b] |
| GVW Rating (lb) | 10,000/14,000 | 14,000 |

| | |
|---|---|
| Body Construction: | High tensile steel sheet, reinforced with structural steel |
| Hydraulics: | High quality heavy duty commercial shearing telescopic packing cylinder |
| Pump: | Borg Warner |
| Valve: | Gresen or equal |
| Controls: | Manual, Dead Man |
| Paint: | Top grade automotive, white standard |
| Optional Equipment: | Hopper loader, barrel lift |

[a]Includes specifications for use of special cab/chassis.

[b]Add 24 inches between body and cab for power unit.

Capacity and Weight. A baler capacity of 2 to 5 tons/hr was specified, based on the waste generation rate of several major MAF functions. The weight of a 5-ton/hr baler is approximately equal to the maximum lift capacity of MAF equipment. Also, larger balers would generate bales which exceed the capacity of the largest MAF forklifts.

Operating Power. Solid waste balers do not generally include their own source of power. An external source is therefore needed. A separate 30- to 50-horsepower generator must be specified as part of a 5-ton/hr baler system. Integration of the power supply with the baler is not possible, as the dimensions of the baler are already restricted in regard to MAF handling and transport capabilities.

Feed Mechanics. Most high-volume solid waste balers are of horizontal design. Solid waste is loaded into a hopper from the top, with a reciprocating ram compacting the waste against one end of the baler. The hopper height, on even the smallest baler, can be as much as 5 to 6 feet. Some type of mechanical loading device may be necessary for MAF application due to the high percentage of loose waste. An inclined, cleated conveyor, a special forklift attachment, or an end loader would serve this purpose.

Operation Under Varying Climatic Conditions. It is not anticipated that the baler unit will require modification in any way to account for varying climatic conditions. Most solid waste balers are designed for sheltered operation in civilian application. If the manufacturer feels that protection of the baler electrical and hydraulic systems is important, the baler could instead be designed for outdoor use. Weather protection is not a major concern in baler design.

Maintenance. Simplicity of design and availability of replacement parts are both critical to the continued maintenance and operation of a solid waste baler. For these reasons, a standard commercial baler is preferable.

Product Characteristics. The baler should achieve the greatest degree of compaction possible. The maximum allowable bale weight is 4,000 pounds, based on the capacity of MAF forklifts used to handle the bale. Commercially available balers with a capacity of 3 to 5 tons/hr generally produce a bale which is well within weight limitations for MAF handling.

Operating Concept. An artist's conception of an MAF baler system in operation is shown in Figure 10. The waste is delivered by compactor truck to the baler location where it is loaded either mechanically or manually into a feed conveyor supported by a soil berm. The conveyor then meters the feed to the baler until a bale is completed. The completed bale is then strapped, ejected, and stacked for later transport to the landfill. A plan view of the baler and conveyor layout is shown in Figure 11.

Handling and transportation of the baler and conveyor are keys to successful MAF application. The hydraulic ram and strapping unit can be removed and stored separately for ease of transport, significantly reducing the length and width of the baler for shipment.

The conveyor should not be permanently fixed to the baler itself. It should instead disconnect from the baler at the pivot point for more convenient transportation. The baler and conveyor each require a separate generator, which could be drawn from existing supplies or deployed at the same time as the baler for this specific function.

Both the conveyor and the baler concepts are based on state-of-the-art designs and could be readily adapted for MAF application.

Comparison With Commercial Equipment. Table 15 is a summary of commercially available refuse balers in the 1- to 10-ton/hr capacity range. Most of the balers listed do not meet the specifications due to foundation requirements or vertical designs.

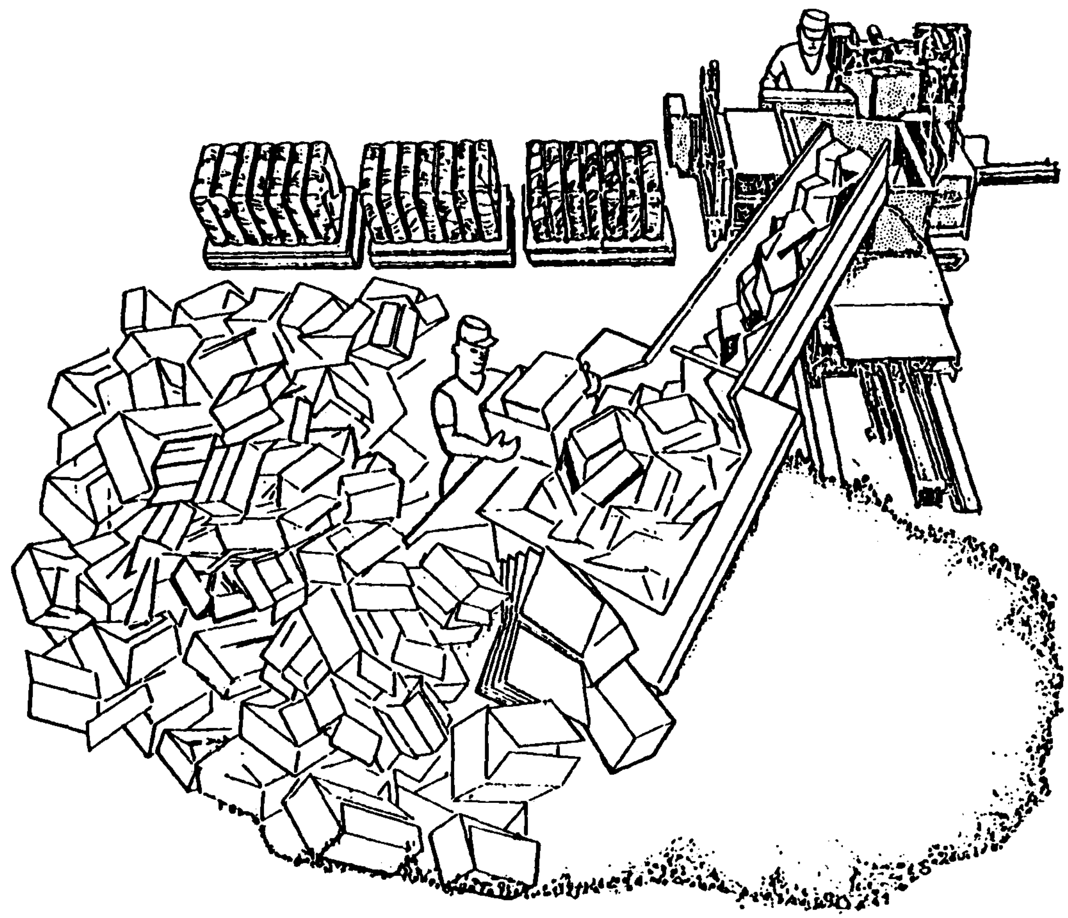

Figure 10. Conceptual view of an operating MAF baler and feed conveyor.

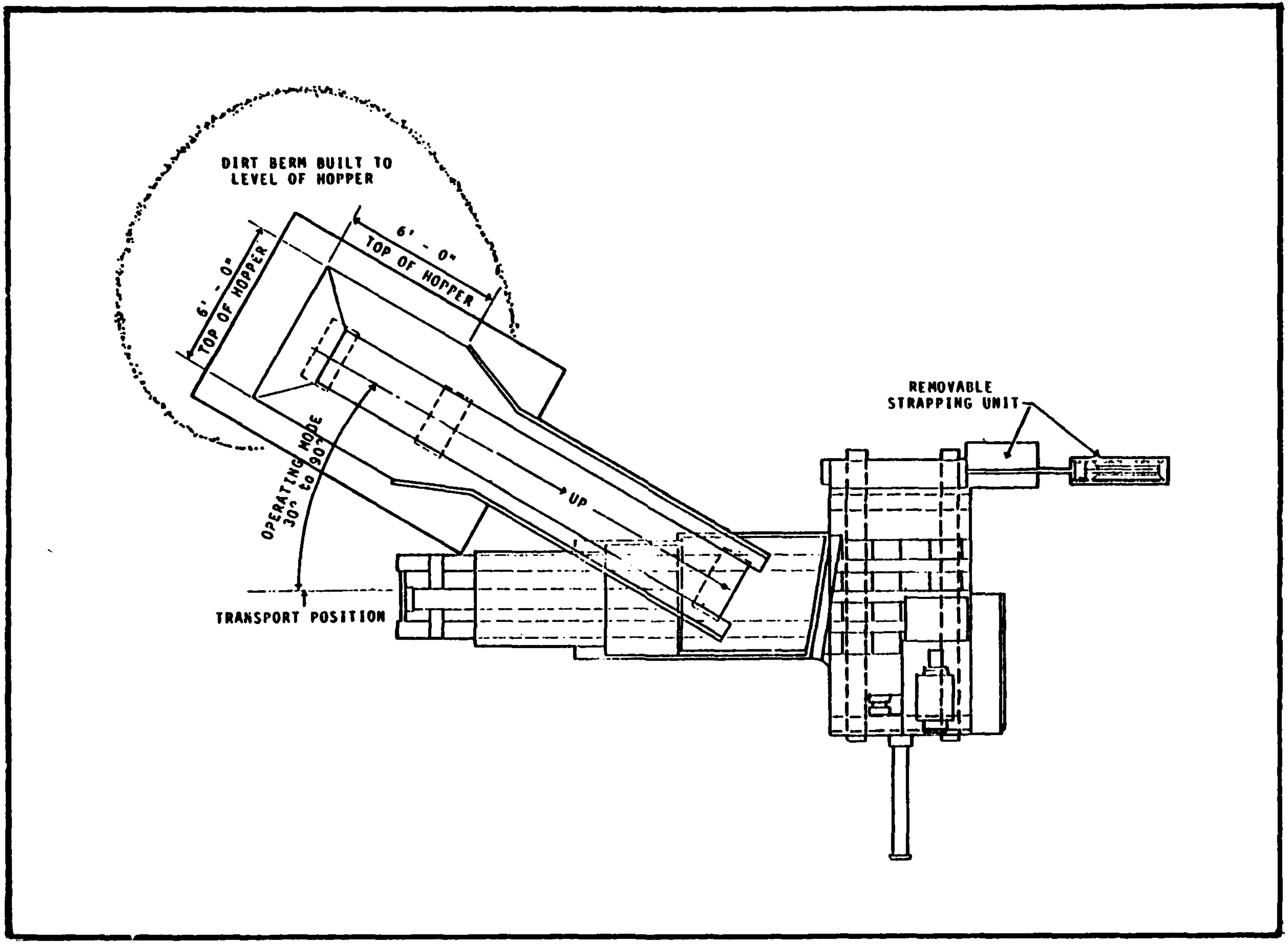


Figure 11. Baler and attached feed conveyor (plan view).

Table 15. Summary of Commercially Available Solid Waste Balers

| Vendor | Model and Type | Capacity (tons/hr) | Materials Baled | Dimensions (in.) | | | Weight (lb) | Power (hp) | Mounting |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Length | Width | Height | | | |
| American Baler Company<br>Hickory Street<br>Bellevue, OH | 10,000 vertical | 2-6 | all grades of paper and other compressible materials | 252 | NA | NA | 6,400 | 15-30 | floor bolted |
| | 127 vertical | 1-6 | all grades of paper and other compressible materials | 135 | 96.5 | 236.5 | 11,575 | 10 | portable |
| | 127RE vertical | 1-6 | all grades of paper and other compressible materials | 135 | 98.75 | 244.38 | 12,975 | 10 | portab.e |
| | 54-SA-36 vertical | 2.8-4.9 | all grades of paper and other compressible materials | 164 | 88.38 | NA | 5,100 | 10 | floor bolted |
| Logeman Brothers Co.<br>3150 W. Burleigh<br>Milwaukee, WI | 245-1 vertical | 20 | fibre, light gauge ferrous metal, or mixed municipal solid waste | 373 | 246 | 81 | 45,000 | 40 | per table |
| International Baler Corp.<br>5400 Rio Grande<br>Jacksonville, FL | NA-1295 vertical | 2.5-3.7 | corrugated material | 222 | 61 | 73.38 | NA | 30 | floor bolted |

continued

Table 15. Continued

| Vendor | Model and Type | Capacity (tons/hr) | Materials Baled | Dimensions (in.) | | | Weight (lb) | Power (hp) | Mounting |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Length | Width | Height | | | |
| Weathershield Corporation 1689 Main St. Buffalo, NY | LP20C3 horizontal | 2-5 | paper, corrugated board, printing waste | NA | NA | NA | NA | 25 | floor bolted |
| | LP20C4 horizontal | 2-6 | paper, corrugated board, printing waste | NA | NA | NA | NA | 30 | floor bolted |
| | LP40CH1 horizontal | 2-7 | paper, corrugated board, printing waste | NA | NA | NA | NA | 25 | floor bolted |
| | LP40CH2 horizontal | 3-10 | paper, corrugated board, printing waste | NA | NA | NA | NA | 40 | floor bolted |
| | LP50CH3 horizontal | 7-14 | paper, corrugated board, printing waste | NA | NA | NA | NA | 60 | floor bolted |
| | LP40VH1 horizontal | 3-9 | paper, corrugated board, printing waste | NA | NA | NA | NA | 25 | floor bolted |
| | LP40VH2 horizontal | 4-11 | paper, corrugated board, printing waste | NA | NA | NA | NA | 30 | floor bolted |
| American Solid Waste Systems 63 S. Robert St. Paul, MN | HRB-SWC1 horizontal | 13 | MSW | 444 | 190 | 102 | 51,000 | 100 | floor bolted |

continued

Table 15. Continued

| Vendor | Model and Type | Capacity (tons/hr) | Materials Baled | Dimensions (in.) | | | Weight (lb) | Power (hp) | Mounting |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Length | Width | Height | | | |
| Union Environmental Division<br>401 Bridge St.<br>Old Forge, PA | 7230 vertical | cycle time not stated; bale weight 900-1,200 lb | corrugated waste | 91 | 48 | 151 | 4,700 | 10 | portable; should be located on vibration pad though |
| Philadelphia Tramrail Co.<br>2207 E. Ontario<br>Philadelphia, PA | 1800 vertical | cycle time not stated; bale weight 400-600 lb | corrugated waste | 42.5 | 62.63 | 121.25 | 4,200 | 5 | portable |
| | 3400 vertical | cycle time not stated; bale weight 600-1,000 lb | corrugated waste | 42.5 | 62.63 | 147.5 | 5,200 | 10 | portable |
| National Baling Press Co., Inc.<br>841 E. 43rd St.<br>Brooklyn, NY | HY-72A horizontal | cycle time not stated; bale weight up to 1,700 lb | cardboard, paper, rags, nonferrous metals, plastics, and mixed trash | 90 | 48 | 144 | 8,000 | | portable |
| Muncher<br>P. O. Box 772<br>St. Cloud, MN | 48 horizontal | 3.5 | corrugated waste | 67 | 36 | 92 | 2,690 | 3 | portable |
| | 60 horizontal | 6.75 | corrugated waste | 82 | 44 | 118 | 5,725 | 7-1/2 | portable |

continued

Table 15. Continued

| Vendor | Model and Type | Capacity (tons/hr) | Materials Baled | Dimensions (in.) | | | Weight (lb) | Power (hp) | Mounting |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Length | Width | Height | | | |
| Freeman and Son 5201 S.W. Westgate Portland, OR | standard hydraulic horizontal | 2.5 | paper, rags, cans, cotton and fibre products | NA | NA | NA | 2,780 | 10 | portable |
| | standard mechanical horizontal | up to 20 | paper, rags, cans, cotton and fibre products | NA | NA | NA | 6,000 | 20 | portable |
| Economy-Lake American Hoist and Derrick Co. Ann Arbor, MI | HRB-1 horizontal | up to 20 | corrugated waste | 413.5 | 80.5 | 92.5 | 75,000 | 100 | floor bolted |
| | 72-36 vertical | 3 | corrugated waste | 193 | 42 | 44 | 6,700 | 15 | floor bolted |
| Compaction Devices Mfg. Co., Inc. 1208 62nd Ave. N.E. Fairmont Hts., MD | LU501 horizontal | cycle time not stated; bale weight 175-250 lb | paper, cardboard, corrugated boxes | 61 | 42 | 92 | 1,500 | 5 | portable |
| Balemaster 4801 Railroad Ave. E. Chicago, IN | 400 series vertical | 1.5 | corrugated waste, paper, newsprint | NA | NA | NA | 8,500 | 20 | floor bolted |
| | 300 series vertical | 1.5 | corrugated waste, paper, newsprint | NA | NA | NA | 7,900 | 20 | floor bolted |

One example, however, of a suitable baler is the Model HRB-2S, manufactured by Harris Press and Shear (American Hoist and Derrick Company). Specifications for this unit are presented in Table 16. The HRB-2S would meet the design criteria set forth earlier with only minimal modification. The hydraulic rams and strapping device are all detachable, and the unit can be readily mounted on skids. The principal design modification required would be the installation of a sleeve in the ram compartment, as this model is designed to bale paper rather than solid waste. Given that the HRB-2S and several other baler models also meet the weight and power constraints, modification of these commercially available systems for MAF application appears feasible.

Application. Balers in MAF operations would be used in areas of deployment similar to those specified for the refuse collection vehicle, including any area with a concentration of waste-generating activities.

Equipment Cost. The cost of a 5-ton/hr baler, modified to meet the proposed MAF performance specifications, would be approximately $125,000. Including the portable generator and feed conveyor, the total system cost is approximately $160,000, excluding shipment and design.

## CONCLUSIONS AND RECOMMENDATIONS

An analysis of MAF solid waste generation and composition has shown waste generation to exceed an average of 1,100 tons/day during the 60 days of an MAF operation. Because waste management activities are manpower-intensive and limited to the use of available general-purpose military vehicles, there is room for improvement in both manpower and equipment efficiency. Mechanization of MAF solid waste would provide substantial manpower and equipment savings and thus provide more resources for support of the primary mission. The manpower-intensive approach of handling undensified fractions of the solid waste indicates that volume reduction equipment is the most appropriate alternative for MAF solid waste management.

A review of solid waste management concepts has shown volume reduction devices to be effective in reducing manpower and equipment requirements. Specifically, compacting collection vehicles and high-density solid waste balers present the greatest potential for improvement in MAF solid waste management activities.

Incorporating conceptual MAF scenarios for the development of solid waste management alternatives resulted in the identification of compacting collection vehicles to demonstrate the potential of reducing manpower and equipment requirements for solid waste management by more than 60%. Proper deployment of five to ten such vehicles could potentially reduce manpower requirements by several thousand man-hours during the first 60 days of an MAF operation.

The use of a detachable compaction body on a conventional military stake-bed truck best meets MAF requirements for compaction collection vehicles. The body would permit the truck to return as necessary to general use, would be designed for simple installation in the field, and would be based on a state-of-the-art design.

Table 16. Specifications for Harris HRB-2S Baler

| Specification | Details |
|---|---|
| Approximate Bale Size (expanded) | |
| • Length (in.) | 62 |
| • Width (in.) | 45 |
| • Height (in.) | 30 |
| • Volume (cu ft) | 48.5 |
| Approximate Bale Weight (lb) | 900-1,000 |
| Power (hp) | 30 (standard) |
| • Motor | 230-460-volt, 3-phase, across-the-line starting standard |
| Approximate Hourly Production (corrugated cardboard waste) (tons/hr) | 3-4 |
| Approximate Bale Density (corrugated cardboard waste) (lb/cu ft) | 18.5-20.5 |
| Hydraulics | |
| • Cylinders | |
| • Bale Compression | |
| • Bore (in.) | 8 |
| • Force (tons) | 75 |
| • Ram Unit Force (psi) | 122 |
| • Bale Ejector | |
| • Bore (in.) | 7 |
| • Force (tons) | 57 |
| • Hydraulic System Capacity (gal) | 125 |
| Cooling | Oil-to-air heat exchanger is standard |
| Automatic Bale Tier | 0.5 x 0.015-inch flat strap type |
| Approximate Machine Weight (lb) | 28,000 |

In situations where the landfill is remote from the principal sources of waste generation, a solid waste baler could find application as a transfer point and volume reduction step. A review of commercially available balers shows that several models with capacities of 3 to 5 tons/hr would best suit MAF operations. The baler would be designed for stationary operation, powered by a portable generator, and fed from either an elevated tipping area or an inclined conveyor system. Only minor modifications would be required to meet MAF requirements. Use of the stationary baler in a remote landfill scenario shows manpower and vehicle savings in excess of 50% over the use of a compaction vehicle alone.

## General Recommendations

If immediate relief in MARCORPS training exercises, shore facilities, and limited remote base environments is desired, the adaptation of commercially available equipment should be investigated.

Improvements in MAF solid waste management in the future should be directed toward three principal areas:

- Reducing the quantity of material which has no reuse potential
- Reducing the physical volume of waste to be collected and disposed of
- Mechanizing the destruction of classified or otherwise secure equipment

Any level of improvement in these areas will result in significant reductions in manpower and equipment diverted from other functions for solid waste management. The "cost" of solid waste management in MAF operations is best thought of in these terms.

A reduction in solid waste generation can be accomplished in several ways:

1. Equipment and supplies should employ a minimum of packaging material.

2. Packaging material used should be specified for reuse in other functional areas. Recycling, in most instances, is not practical but reuse of discarded equipment, supplies, and packaging material is common and should be made easier by employing materials with several functional uses.

3. Nonreusable materials contained in the MAF Tables of Equipment and Supplies should be identified and an effort made to redesign the items for multiple use.

4. Updating and confirmation of the MAF waste generation data base should be continued so as to account for any changes in the Tables of Equipment and Supplies and differences between levels of MAF activity.

5. The Marine Corps should pursue the design, manufacture, and testing of a detachable compaction body for MAF refuse collection. The potential for manpower and equipment savings appears to far overshadow the relatively low cost of the prototype.

6. The Marine Corps should also consider the design, manufacture, and testing of a stationary baler for selective use in MAF operations. Because of the relatively high cost of the prototype, the decision to proceed with a baler test should be predicated on the success of the compaction vehicle in a similar test situation. Tests for both the compaction body and the baler should be performed as part of full-scale MAF exercises.

Volume reduction is the most commonly used processing step in municipal solid waste collection and disposal. The only reduction in waste volume which takes place during an MAF operation is open burning at the dump site. The real advantage to volume reduction is realized through reduced handling and transport requirements, which are shown to be excessive during MAF operations.

## LIST OF ABBREVIATIONS

| | |
|---|---|
| AE | Assault Echelon (D-Day through D+15) |
| AFOE | Assault Follow-On Echelon (D+15 through D+30) |
| BSA | Beach Support Area |
| FE | Flight Echelon (D+30 through end of operation, D+60) |
| FSSG | Force Services Support Group |
| LSA | Logistics Support Area |
| MAF | Marine Amphibious Force |
| MAW | Marine Air Wing |
| OPDEP | Operational Deployment |
| TUMSS | Type Unit Mobility Statistics System |

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## Appendix

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