

AEPI Report



FULLY BURDENED COST OF MANAGING WASTE IN CONTINGENCY OPERATIONS Final Technical Report



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PREFACE

This report was prepared by the National Defense Center for Energy and Environment (NDCEE)/ Concurrent Technologies Corporation (CTC) and the Energy and Security Group (ESG) under contract to the Army Environmental Policy Institute (AEPI). The views expressed do not necessarily reflect the official policy or position of the Department of Defense, Department of the Army, or the U. S. Government.

AEPI's mission is to assist the Army Secretariat in developing forward-looking policies and strategies to address environmental issues that may have significant future impacts on the Army. In the execution of this mission, AEPI is further tasked with identifying and assessing the potential impacts on the Army of emerging environmental issues and trends.

This report discusses the efforts conducted under Contract Number W91WAW-09-D-0022, Task Number 0609, Fully Burdened Cost of Managing Waste in Contingency Operations. The purpose of the task order was to develop and demonstrate a defensible method for calculating the fully burdened cost (FBC) of managing solid, hazardous, and medical waste in contingency operations. This task was completed in support of the *Army Strategy of the Environment* goal to minimize the effects and total ownership costs of Army systems, materiel, facilities and operations by integrating sustainability principles and practices.

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TABLE OF CONTENTS

	Page
Executive Summary.....	vii
1 INTRODUCTION.....	1
1.1 Background	2
1.2 Waste in Contingency Operations	3
2 APPROACH.....	6
2.1 Fully Burdened Cost Estimation Method	6
2.2 Nonhazardous Waste Generation and Disposal	7
2.3 Hazardous Waste and Medical Waste Generation and Disposal.....	8
2.4 Cost Components	10
2.4.1 Infrastructure Costs	10
2.4.2 Personnel Costs	11
2.4.3 Transport and Equipment Costs	12
2.4.4 Base Closure and Transfer Costs	12
2.5 Limitations.....	13
3 DEMONSTRATION RESULTS.....	15
3.1 Bagram Baseline Estimates	15
3.1.1 Nonhazardous Solid Waste (GW and WW)	16
3.1.2 Hazardous Waste	17
3.1.3 Medical Waste.....	20
3.2 Alternative Technology Demonstrations.....	21
3.2.1 Local Water Production/Distribution to Displace Bottled Water Demand	21
3.2.2 Oil CAT	233
4 CONCLUSIONS.....	25
5 RECOMMENDATIONS	29

LIST OF TABLES

Table 1. Waste Category Definitions.....	4
Table 2: Summary of Cost Components.....	10
Table 3. Variation in General Waste Generation Rates.....	17
Table 4. Fully Burdened Cost of Nonhazardous Solid Waste for Bagram.....	17
Table 5. Bagram Hazardous Waste Inventory Amounts.....	19
Table 6. Estimated Fully Burdened Cost of Waste per year Bagram AFB.....	21
Table 7. Fully Burdened Cost of Solid Waste Comparison.....	22
Table 8. FBC of Used Oil at Bagram with Base Case and Alternate Scenario (For a 1-Year Period).....	24
Table 9. Access Rates to Clean Water Technology in Iraq and Afghanistan.....	27
Table 10. Estimated Fully Burdened Cost of Waste per year Bagram AFB.....	29

LIST OF FIGURES

Figure 1. Base Camp Waste Management.....	5
Figure 2. Waste Process Flow Diagram.....	7
Figure 3. Bagram Process Flow Diagram.....	15

LIST OF APPENDICES

Appendix A. Process Flow Diagrams	
Appendix B. Bibliography	
Appendix C. Fully Burdened Cost of Waste Management Method	
Appendix D. Fully Burdened Cost of Waste Bagram Demonstration Results	
Appendix E. Characteristics of Hazardous Waste Streams in Iraq and Afghanistan	
Appendix F. Non-Monetary Risks and Liabilities	

LIST OF ACRONYMS

AEPI	Army Environmental Policy Institute
AFB	Air Force Base
AFM	Army Field Manual
ARCENT	Army Central
ASE	Army Strategy of the Environment
BC&T	Base Closure and Transfer
CERL	Construction Engineering Research Laboratory
CFH	Cost and Factor Handbook
CLIN	Contract Line Item Number
CTC	Concurrent Technologies Corporation
DFAC	Dining Facility
DoD	Department of Defense
DLADS	Defense Logistics Agency Disposition Services
ERDC	Engineering Research and Development Center
FBC	Fully Burdened Cost
FPG	Facilities Pricing Guide
FOB	Forward Operating Base
FORCES	Force and Organization Cost Estimating System
GAO	Government Accountability Office
GSA	General Services Administration
GW	General Waste
HAZMAT	Hazardous Materials
HNC	Host Nation Contractors
HW	Hazardous Waste
Lb	Pound
LOGCAP	Logistics Civil Augmentation Program
MW	Medical Waste
NDCEE	National Defense Center for Energy and Environment
Oil CAT	Oil Change Alternative Technology
POL	Petroleum, oil, and lubricants
RMW	Regulated Medical Waste
ROWPU	Reverse Osmosis Water Purifying Units
SME	Subject Matter Expert
SMP	Sustain the Mission Project
TCN	Third Country Nationals
U.S.	United States
UXO	Unexploded Ordinance
WW	Wastewater

EXECUTIVE SUMMARY

The Army Environmental Policy Institute contracted with the National Defense Center for Energy and Environment to develop and demonstrate a defensible method for calculating the fully burdened cost (FBC) of managing solid, hazardous, and medical waste in contingency operations. One of the *Army Strategy of the Environment* goals is to minimize the effects and total ownership costs of Army systems, materiel, facilities and operations by integrating sustainability principles and practices. This goal seeks to reveal life cycle costs that are not yet internalized and quantified in decision-making. Understanding that Army materiel costs more than the price charged at commodity procurement and that there are non-monetary costs in the form of risks is the basis of the “fully burdened” concept.

The cost estimating method developed and demonstrated here accounts for differences in waste management costs as military operations mature from initial deployment to stabilization and reconstruction. It begins with the waste *as already generated* and does not address materiel or operational decisions that influence the waste stream. The method builds on lessons learned from recent deployments to ensure cost calculations correspond with standard procedures and practices in theater. The method was created in a commercially available and transportable software tool to ensure easy transfer to potential users and stakeholders.

The FBC of waste method was used to estimate costs for a case study – Bagram Air Force Base in Afghanistan. The total annual costs for managing waste at Bagram are estimated at \$19,743,168, with nonhazardous waste (general waste and wastewater) representing 90% of the total costs. The project team then demonstrated the method’s capability to incorporate two waste reduction technology scenarios: Clarus Technologies’ Oil Change Alternative Technology, which recycles used oil, and Reverse Osmosis Water Purifying Units, which can reduce plastic water bottle waste by producing potable water onsite. Results of the demonstration proved that the method can be used for estimating cost impacts, but the estimated impacts of implementing these technologies was inconclusive. The cost impact results were inconclusive because of data limitations and because waste oil is typically re-used and not easily defined as a “waste.” The same applies to plastics, which Bagram recycles.

Lack of data is a major hindrance in estimating costs of managing waste in contingency operations. Base camps are heterogeneous in purpose, population, and maturity, and there are no standardized requirements for tracking solid waste related data. Without this documentation, estimating FBC of waste management at a specific base camp requires interaction with subject matter experts to obtain experiential information. Each location is unique and there are few standardized waste handling procedures. Lack of data is also an issue for assessing non-monetary risks and liabilities. The magnitude of these potential liabilities may be significant after Soldiers return from deployments and after base closure. These liabilities include air pollution fallout from burn pits, untreated wastewater discharge, and landfill leachate.

To help the Army reduce its FBC of waste, recommendations include implementation of cost-effective waste measurement tools to overcome data gaps and influence behavior. It is also recommended that waste management concerns be addressed during base camp planning along with other infrastructure needs. Cost data for the entire life cycle of materiel should include waste costs in order to provide the complete picture and focus efforts to reduce waste. Sustainability tells us that the best solutions incorporate all aspects of the materiel life cycle and the best waste management is the management that does not have to be implemented because the waste is never produced.

1 INTRODUCTION

The *Army Strategy of the Environment (ASE)*¹ establishes a long-range vision of sustainability that enables the Army to meet its mission requirements today and into the future. One of the ASE goals is to minimize the effects and total ownership costs of Army systems, materiel, facilities and operations by integrating sustainability principles and practices. This goal seeks to reveal life cycle costs that are not yet internalized and quantified in decision-making.

In support of the ASE, the Army Environmental Policy Institute (AEPI) contracted with the National Defense Center for Energy and Environment (NDCEE)² to develop and demonstrate a defensible method for calculating the fully burdened cost (FBC) of managing solid, hazardous, and medical waste in contingency operations.³ Understanding that Army materiel costs more than the price charged at commodity procurement is the basis of the “fully burdened” concept guiding the Sustain the Mission Project (SMP), initiated by AEPI in 2005. Understanding that there are costs and liabilities that are non-monetary is also part of a “fully burdened” perspective. Estimating the FBC of materiel use in contingency operations is one way to assess the overall life cycle impacts and improve overall sustainability, while also supporting mission accomplishment. The information presented here builds on previous FBC assessments⁴ and specifically addresses the FBC of waste.

The cost estimating method developed and demonstrated accounts for differences in waste management costs as Department of Defense (DoD) operations mature from initial deployment to stabilization and reconstruction. It also accounts for differences in the management activities of military waste streams: nonhazardous solid waste, wastewater, hazardous waste and medical waste. It begins with the waste *as already generated* and does not address materiel or operational decisions that influence the waste stream. The specific objectives of the project are.

- Build on lessons learned from recent deployments to ensure cost calculations correspond with standard procedures and practices in theater
- Develop an analytical method for calculating the fully burdened cost of managing non-hazardous solid waste, wastewater, hazardous waste, and medical waste in contingency operations
- Represent the waste management cost calculation method in a commercially available and transportable software tool to ensure easy transfer to potential users and stakeholders
- Demonstrate the method using available, unclassified data and reasonable scenarios approved by the Government.

¹ *The Army Strategy for the Environment: “Sustain the Mission – Secure the Future.”* (2004, October 1). Washington, DC: Office of the Assistant Secretary Of The Army for Installations and Environment. Retrieved October 19, 2010, from <http://www.sustainability.army.mil/>

² The NDCEE is operated by operated by Concurrent Technologies Corporation (CTC), a non-profit organization, on behalf of the DoD.

³ The U.S. military commonly uses the term “contingency operations” to refer to activities in combat zones. Contingency operations include, among other things, any military operation that the Secretary of Defense designates as an operation in which members of the armed forces may become involved in military actions against an opposing military force. See 10 U.S.C. § 101(13)(A). Washington, DC: *Office of the Law Revision Counsel, U.S. House of Representatives*. Retrieved November 30, 2010, from <http://uscode.house.gov/uscode-cgi/fastweb.exe?getdoc+uscview+109t12+41+1+++%28%29%20%20AND%20%28%2810%29%20ADJ%20USC%29%3ACITE%20AND%20%28USC%20w%2F10%20%28101%29%29%3ACITE>

⁴ Reports on the previous AEPI SMP work include: (1) *Sustain the Mission Project: Resource Costing and Cost-Benefit Analysis*; (2) *Sustain the Mission Project: Casualty Factors for Fuel and Water Resupply Convoys*, and (3) *Sustain the Mission Project: Energy and Water Costing Methodology and Decision Support Tool*. These documents are available at: <http://www.aepi.army.mil/>

The previous AEPI-sponsored SMP tasks studied the FBC of fuel and water resources delivered during contingency operations and used the military unit as the basis of the costing method. This is not possible with waste because the quantity of waste generated cannot be determined from the quantity of materiel procured. As there are no reliable methods to link waste with procurement data, the FBC of waste method required a bottom-up approach based on flow diagrams to identify each individual cost component. Waste generation rates – as the multipliers for the cost components – are based upon the professional judgment of subject matter experts (SMEs). The cost estimates that result from application of the method are therefore highly dependent on context and cannot be generalized to other bases or military units. Waste management costs vary greatly based on multiple factors, such as the base size, mission, remoteness, and existing infrastructure. The cost estimating method presented here allows for these variables to be accounted for.

The FBC of waste method was used to estimate costs for a case study – Bagram Air Force Base (AFB) in Afghanistan. This camp was selected because it has the most data available and provides an example of a complex cost analysis. After the costs for managing waste were estimated, the project team then demonstrated the flexibility of the method to incorporate alternative technology scenarios. Two readily available technologies were used for hypothetical application at Bagram AFB: Clarus Technologies Oil Change Alternative Technology (Oil CAT), which recycles used oil, and Reverse Osmosis Water Purifying Units (ROWPUs), which can reduce plastic water bottle waste by producing potable water onsite.

Many risks and liabilities are associated with waste generation, management, and disposal in contingency operations which are unique to each base and are not captured by monetary-based estimating methods. These include air pollution from burn pits, untreated wastewater discharge, and leachate from landfills. It is important to include these liabilities in decision-making processes along with the monetized costs from estimating tools such as the one developed here.

The purpose of this report is to present the results of the FBC of waste estimation method development and demonstration activities. It is organized as follows. The introduction includes a brief review of the issues associated with managing waste in contingency operations. Section 2 reviews the process by which the method was developed, cost components of the method were identified, and how data needs are addressed. In this section, various waste streams are presented individually, as generation and handling characteristics of each waste stream were found to be very different. Section 3 presents the results of the base case estimations and alternative technology demonstrations. Conclusions are presented in Section 4, and recommendations for next steps are presented in Section 5.

1.1 Background

Several studies have been conducted to qualify and quantify the issues associated with managing waste—solid, hazardous, and medical—in contingency operations. In a 2008 study sponsored by AEPI, the RAND Arroyo Group points to the multitude of risks to people and mission, and costs associated with managing waste in deployed situations.⁵ RAND also points to differences among host nations in terms of available infrastructure, environmental regulations, and participation in international treaties (e.g., the Basel Convention) as also having significant affect on waste management risks and costs. Other studies

⁵ Mosher, D.E., Lachman, B.E., Greenberg, M.D., Nichols, T., Rosen, B., and Willis, H.H. (2008). *Green Warriors: Army Environmental Considerations for Contingency Operations from Planning Through Post-Conflict*, Santa Monica, CA: RAND Arroyo Center. Retrieved October 19, 2010, from <http://www.rand.org/pubs/monographs/MG632/>

focus on characterizing and measuring solid waste generated at Army base camps, drawing upon experience in the Balkans as well as recent experiences in Afghanistan and Iraq.⁶

Public Works Technical Bulletin 200-1-511 (April 2008), *Solid Waste Generation Rates at Army Base Camps*, outlines differences in how waste is managed as operations evolve in a given theater and as base camps mature. The United States (U.S.) Army Engineering Research and Development Center (ERDC), Construction Engineering Research Laboratory (CERL) estimates solid waste generation rates at 15.8 pounds per person per day for a typical base camp. With a population consisting of a large Brigade Combat Team, ERDC-CERL estimates a “typical” base camp generates at least 58 tons per day of nonhazardous waste. Based on a number of assumptions, ERDC-CERL estimated the annual cost to landfill this waste is \$4.6 million.

There is no definitive method for calculating the FBC of managing all waste generated during contingency operations. As noted in a 2010 Government Accountability Office (GAO) report:⁷

...DOD has not evaluated the benefits and costs of the waste management alternatives and compared them with the benefits and costs of its existing practices or taken into account all the relevant cost variables, including the environmental and long-term health impacts that burn pits could have on service members, civilians, and host country nationals.

1.2 Waste in Contingency Operations

Many different types of waste are generated by contingency operations; the amount generated and types of waste vary greatly at each base camp because of differences in mission, size, and length of operation. The costs associated with each waste stream vary based on the characteristics of the waste – whether it liquid or solid; hazardous, nonhazardous, organic/non-organic, and recyclable/non-recyclable. It was therefore necessary to develop elements within the estimation method to address each specific waste stream. For the purposes of the cost estimation method, waste was divided into four main categories: (1) nonhazardous solid waste – referred to as general waste (GW); (2) wastewater (WW) of which there are two types – grey and black; (3) hazardous waste (HW) to include all regulated wastes; and (4) medical waste (MW) (Table 1). Definitions are based on Army Field Manual (AFM) 8-10-15, Appendix C, Field Waste, *Categories of Waste*, as well as input from SMEs.

Contingency operations waste management methods also vary depending on the size and sophistication of the base camp. Bases that are self-supported will bury, burn, or pack out waste. As the bases become larger and are provided with contract support, more waste management options are possible (Figure 1). Waste management options are also dictated by available resources, such as the contract support budget, proximity to urban markets for recyclables, availability of local waste handling contractors and equipment, and the availability of land for landfills.

⁶ Gerdes, G.L. and Jantzer, A.L. (2006). *Base Camp Solid Waste Characterization Study*, ERDC/CERL TR-06-24, Champagne, IL: United States Army Corps of Engineers, Engineer Research and Development Center, Construction Engineering Research Laboratory.

⁷ *Afghanistan and Iraq: DOD Should Improve Adherence to Its Guidance on Open Pit Burning and Solid Waste Management*. (October 15, 2010). GAO-11-63. Washington, DC: U. S. Government Accountability Office, pg 30. Retrieved November 30, 2010, from <http://www.gao.gov/products/GAO-11-63>

Table 1. Waste Category Definitions

General Waste – This category captures all waste not specifically classified as medical waste, hazardous waste, or wastewater. It includes such items as:	
1	Paper and plastic products (which are by far the most abundant solid waste generated in a field environment)
2	Garbage (generated by dining facilities)
3	Scrap material (wood, metal, and so forth)
Wastewater – This category includes such items as:	
1	Blackwater – This waste is comprised of human feces and urine. (This is referred to as “Human Waste” in AFM 8-10-15.)
2	Greywater – This includes liquid waste generated by laundry, shower, food service, and routine Military Treatment Facility (MTF) operations. (This is referred to as “Waste water” in AFM 8-10-15.)
Hazardous Waste – This category includes waste that is ignitable, corrosive, reactive, or toxic. Hazardous waste usually requires special handling and treatment to render it nonhazardous. Examples include:	
1	Petroleum, oil, and lubricants (POL), including waste fuel
2	Lead acid batteries
Medical Waste – This category is comprised of two types:	
1	Nonregulated – Solid material from medical treatments that can be disposed of as general waste. Examples include soiled bandages, gloves, and saliva-soaked or blood-tinged gauze.
2	Regulated Medical Waste (RMW) – Medical waste that could cause disease or pose a risk to people if not treated properly.

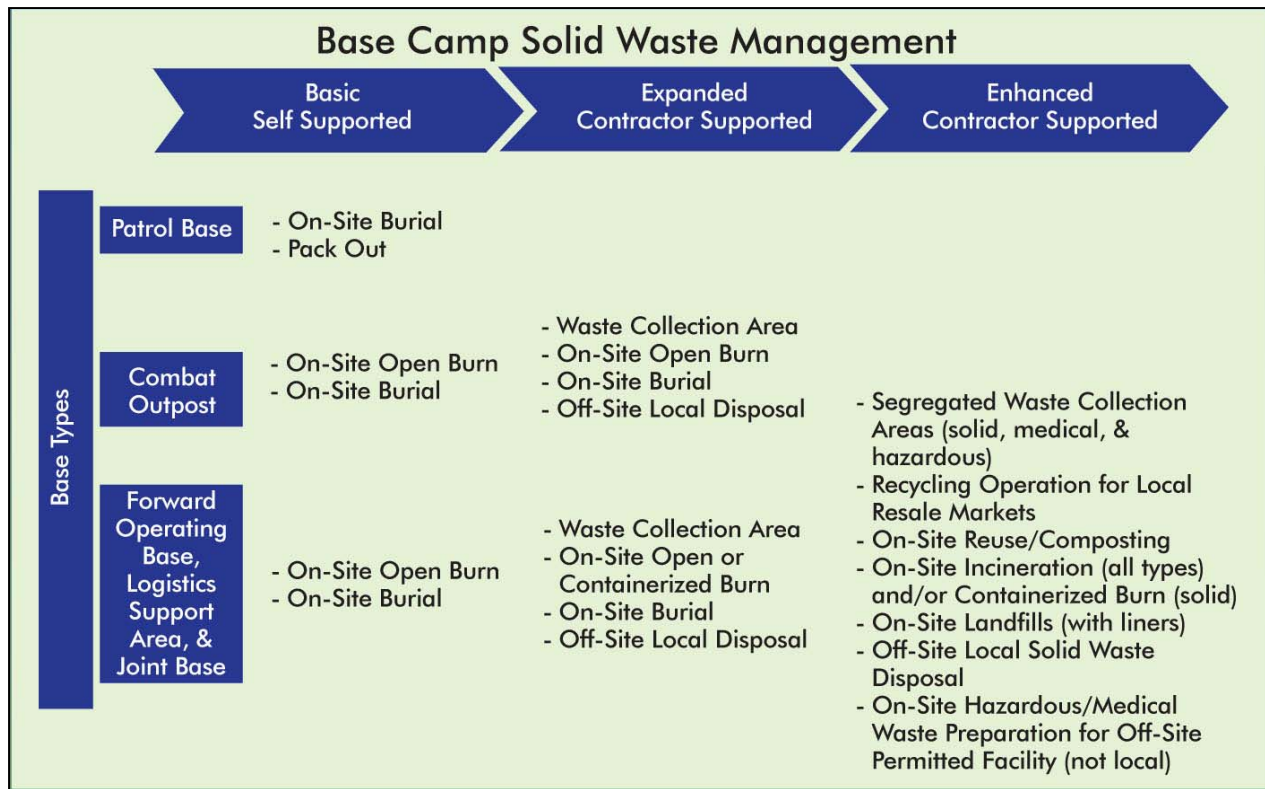


Figure 1. Base Camp Solid Waste Management

2 APPROACH

To build a method to calculate the FBC of managing waste in contingency operations, it was necessary to create a customizable tool that reflects the method and could be used to perform calculations. The tool consists of a basic framework of cost components that can draw on standardized cost data sources and also includes site-specific cost multipliers. This section outlines the approach taken to develop a cost estimating method for all waste streams generated at military contingency operations base camps: GW, WW, HW, and MW. The waste are addressed separately as nonhazardous (GW and WW) and hazardous (HW and MW) because of the significant differences in handling procedures and data availability.

2.1 Fully Burdened Cost Estimation Method

The project team created a method for estimating costs associated with managing waste using a bottom-up approach. The first step was to develop process flow diagrams for all types of base camps, from small Patrol Bases and Combat Outposts to large, enduring Joint Bases. These diagrams are included in Appendix A. The next step was to identify the infrastructure, transportation, equipment, and personnel resources needed for managing the various waste streams as they are transitioned from generation point to disposal point, as outlined in the Figure 2 schematic. Standardized rates for personnel and waste-related infrastructure could then be incorporated as cost components into tables of a readily transferable spreadsheet.

The method is a framework that includes non-cost categories, such as waste generation rates, and cost categories, such as infrastructure, transport and equipment, and personnel costs, in a Microsoft® Excel® workbook to estimate the total waste costs for a given scenario specified by the user. The method also recommends an assessment of potential risks and liabilities faced in managing solid waste and wastewater in contingency operations. While the drivers of base camp waste generation and disposal frequently change, this FBC method examines the base camp at a snapshot in time, holding the population fixed and capturing the costs associated with waste management over a 1-year period.

Building the process flow diagrams and obtaining site-specific data about the rates of generation (such as pounds generated per person) required consultation with various published reports, interviews with personnel in theater, and interviews with SMEs. Appendix B, Bibliography, presents all of the resources that were consulted throughout the course of this effort, including a list of SMEs and personal communication with SMEs. SME input was critical to development of the cost estimation method and the compilation of the base case information. Base camps are heterogeneous in purpose, population, and maturity, and there are no standardized requirements for tracking solid waste related data. Without this documentation, estimating FBC of waste management at a specific base camp requires interaction with SMEs to obtain experiential information. For instance, discrepancies within the multiple data sources were resolved based on consultation with SMEs. In cases where data did not exist, SMEs helped fill the gaps or describe scenarios that enabled better estimations by the project team.

Close examination of the waste pathway and means of disposal can provide insight into the costs associated with waste management which, broadly, would be included in one of the following categories: Infrastructure, Transport & Equipment, Personnel, or Base Closure and Transfer. Collectively these four cost categories are referred to as the Cost Components of the FBC of waste management method. Refer to Figure 2 for a graphical depiction.

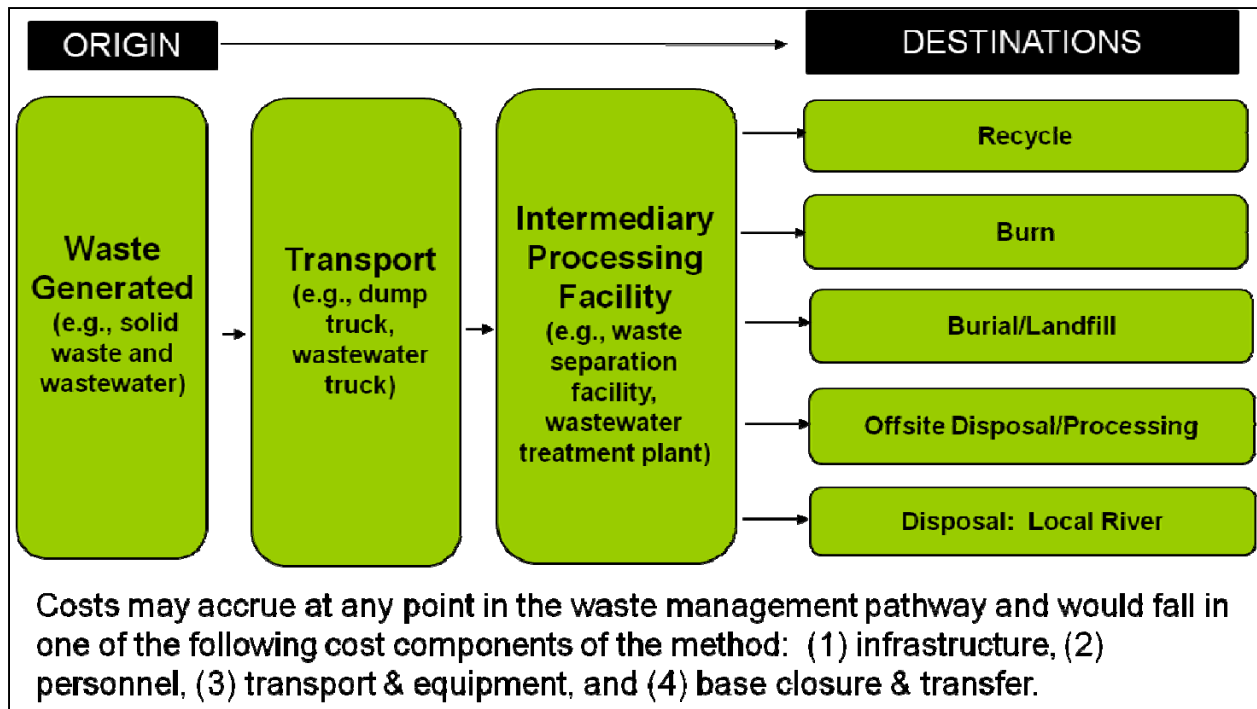


Figure 2. Waste Process Flow Diagram

2.2 Nonhazardous Waste Generation and Disposal

The initial step in the method is to determine waste generation rates. The quantity and quality of GW and WW generated in theater depends upon many factors, including base camp population, purpose, maturity, location in the supply chain, and the host nation environment. Data on GW and WW generation are inconsistently tracked – if tracked at all – in contingency operations. If GW and WW are measured, they are more commonly measured at large base camps (as opposed to smaller camps or outposts), and limited data availability often forces waste management planners to estimate generation rates. Based on discussions with SMEs, Kandahar, Afghanistan, is the only base camp that weighs waste.⁸

The generation rate can vary depending on the stage of the camp (i.e., camps still under construction may generate higher construction and demolition waste) and mission. In addition, it is generally accepted that the solid waste generation rates per person in theater are higher than those found in municipal solid waste in the United States, due in part to the disposable nature of dining facility waste in theater and also because everything is shipped to theater installations on wooden pallets.⁹

Planners frequently use planning factors that assess GW generation for a base camp population in terms of pounds of GW generated per person per day. For larger, mature base camps, the GW generation rate per person per day may be available based on historical data or may need to be estimated using planning factors. In the absence of historical data, GW generation under the FBC method was assessed using base

⁸ See Table B-1 in Appendix B for a listing of personal communication with SMEs and in-theater personnel.

⁹ Gerdes, G. L., and A. L. Jantzer. 2006. *Base Camp Solid Waste Characterization Study*. ERDC/CERL TR-06-24, ADB323774. Champaign, IL: U. S. Army Corps of Engineers, Engineer Research and Development Center, Construction Engineering Research Laboratory.

camp population and a planning factor in terms of pounds of GW generated annually per person per day. This calculation provides an estimate of the total annual GW generation for a base camp.

Similarly, planners frequently use planning factors that assess WW generation for a base camp population in terms of gallons of WW generated per person per day. For larger, mature base camps, the WW generation rate per person per day may be available based on historical data or may need to be estimated using planning factors. In the absence of historical data, WW generation under the FBC method was assessed using base camp population and a planning factor in terms of gallons of WW generated per person per day over a 1-year period, along with estimates of the relative volumes of blackwater and greywater. These calculations provide estimates of the total annual WW generation for a base camp.

Disposal options are used to describe the pathway that waste follows to reach a final destination. These options are another critical piece of the cost estimation method. GW destinations include recycling, incineration, burial/landfill, or offsite processing, and most commonly involve some combination of those. WW destinations typically involve a local body of water. Blackwater must be treated, and typically passes through some form of treatment before being discharged into destinations such as: septic tank and drainage field; septic lagoon and settlement pond; or a body of water (e.g., the local river). Greywater may or may not be treated prior to discharge into destinations similar to those used for blackwater.

Under the FBC method, an assessment of GW and WW disposal pathways is required to determine the origins, intermediate destinations, and final destinations of various waste streams (e.g., recyclables and compostables). Costs associated with GW management - the transportation, infrastructure, personnel, and base closure and transfer costs are included in the method as cost components that vary based upon the estimated quantity and quality of GW and WW generated.

2.3 Hazardous Waste and Medical Waste Generation and Disposal

A critical piece of cost estimation is the incorporation of HW and MW generation, but the generation rates for HW and MW are even more difficult to estimate than for GW and WW. GW generation rates per person can be assumed to be similar from one base camp to another, making the calculations more straight-forward. In contrast, HW generation is not necessarily a function of the amount of people at a base camp. Specific mission functions, such as airfield operations or convoy support, often dictate the amount and nature of HW generated.¹⁰ Another challenge is the regulated nature of HW. Even though this information is often measured and tracked, the proprietary nature of the Logistics Civil Augmentation Program (LOGCAP) contract, however, makes this data not readily accessible. For the data that is available, the various reporting conventions make it difficult to assimilate the data with any confidence that everything is accounted for only once.

The management of HW is generally a LOGCAP responsibility until it is turned over to the Defense Logistics Agency Disposition Services (DLADS).¹¹ From there, the ultimate fate of hazardous waste depends upon the particular waste stream and the conventions followed in the host nation. For example, the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (commonly known as simply the Basel Convention) limits HW disposal options available to a

¹⁰ *AOR Environmental Component Plan*. (March 2009). Prepared for United States Army Central. Atlanta, GA: CH2MHill, Military Planning Group.

¹¹ Effective in mid-2010, both the Defense Reutilization and Marketing Service (DRMS) and the Defense Reutilization and Marketing Office (DRMO) were renamed as DLADS.

deployed force.¹² In Afghanistan, a Basel agreement is in place that dictates the transport of HW. As a result, most hazardous waste is driven overland through Pakistan, and then shipped overseas to Germany and other European countries for treatment and disposal.¹³ In Iraq, no Basel Agreement is in place to ship the HW to any other country for disposal. Therefore, all HW disposal and treatment must occur within Iraq.

Most of the SMEs and in-theater personnel consulted for this project concur that the majority of the HW, as much as 80 – 95% (the figures vary depending on the source) is made of a few waste streams. Depending on who is asked, these waste streams vary somewhat but usually include some or all of the following: used oil; waste or off-spec fuel; mixed petroleum, oil, and lubricants (POL); anti-freeze or coolant; lead acid batteries; and sometimes lithium batteries. According to some sources, anti-freeze is included as POL, but to others it is not. Used oil, sometimes erroneously referred to as waste oil, is technically not a HW, but it is often grouped with HW or regulated wastes because it is handled with greater care like a regulated waste. In some cases, used oil is included in the POL designation. To some personnel, POL includes waste fuel, used oil, and coolants. This lack of standardization, even among the nomenclature, makes it virtually impossible to accurately track the various HW streams. Due to the waste tracking conventions in theater, until the HW is turned over the DLADS, there is no visibility and accumulation estimates are imprecise.¹⁴

Like HW, MW management is a LOGCAP function and the waste is measured and tracked. Unlike HW, however, the generation quantities of MW are much smaller, the waste stream is more homogenous, and there is no storage and shipping component; in general, MW is incinerated within 24 hours of disposal pickup. The challenges with estimating the MW portion of the FBC method result from the accessibility of data and the units of measurement. Many bases report their MW generation in terms of volume instead of weight. There is at least one prior study in which MW generation rates were estimated in terms of pounds per person, but not much data were available for that study and it is now somewhat dated.¹⁵

As a result of the many challenges associated with estimating volumes of HW and MW, alternative approaches were used to incorporate this information into the FBC method. For both HW and MW, the project team relied upon actual measured waste volumes and weights provided by in-theater personnel. Even though this information is not exact and many assumptions were still necessary, this course of action proved to be the most reliable method for estimating the generation rates for HW and MW. The FBC method for HW and MW is described in detail for Bagram in the Demonstration section of this report.

In general, however, the process flow diagram in Figure 2 used to illustrate GW management at the more sophisticated base camps can also be applied to both HW and MW. Even at smaller bases, HW is segregated from other wastes, labeled, and stored separately. It is then transported to larger base camps within the same country that have the equipment, infrastructure, and contractor support to properly manage the requirements associated with hazardous waste. MW lacks the intermediary processing step present for the other waste streams. Instead, this waste is incinerated soon after transportation.

¹² The Basel Convention is an international treaty that was designed to address the uncontrolled transport and dumping of HW, specifically from developed to underdeveloped countries. For more information, see <http://www.basel.int/convention/basics.html>, accessed October 19, 2010.

¹³ See Table B-1 in Appendix B for a listing of personal communication with SMEs and in-theatre personnel.

¹⁴ See Table B-1 in Appendix B for a listing of personal communication with SMEs and in-theatre personnel.

¹⁵ *AOR Environmental Component Plan*. (2009, March). Prepared for United States Army Central. Atlanta, GA: CH2MHill, Military Planning Group.

2.4 Cost Components

Four main cost components were built into the FBC method (Table 2). Based on where the waste materials are coming from and going to, the following cost components can be calculated: (1) Infrastructure Costs, (2) Personnel Costs, (3) Transport and Equipment Costs, and (4) Base Closure and Transfer Costs.

Costs associated with waste in contingency operations can be examined at several stages in the life cycle of products moving through an international supply chain. The scope for this method, however, is limited to costs incurred from the point of waste generation on base (e.g., GW in the form of food containers after the food has been eaten) and ending with waste disposal (e.g., a landfill). In theory, the cost components for estimating the HW and MW portion of a cost estimation method should be similar to those of GW and WW. In real practice, however, developing Cost Components for HW and MW differed tremendously. At the heart of the issue is that HW and MW are regulated while GW and WW are not, and the storage and handling of these regulated waste streams almost always falls under the LOGCAP contract. Detailed information about the LOGCAP contract components is not easily obtained. The method for cost estimation of MW is more similar to that of nonhazardous waste, except the volumes are tracked, making the process more straightforward.

Table 2. Summary of Cost Components

Cost Component	Cost Drivers
Infrastructure	Facility type (e.g., waste separation facility, wastewater treatment facility) Facility purpose (e.g., utility building that houses both a waste separation facility and a recycling facility)
Personnel	Personnel type (e.g., military, U.S. contractor, third country national, host nation contractor)
Transport & Equipment	Vehicle/equipment type (e.g., dump truck, compactor) Vehicle/equipment quantity Vehicle purpose (e.g., transport of general waste or wastewater) Equipment purpose (e.g., baling, compacting)
Base Closure & Transfer	Exposure to risk of future liability

2.4.1 Infrastructure Costs

The Infrastructure Cost Component represents costs associated with fixed infrastructure dedicated to waste management. This component primarily applies to larger or more mature bases, where waste management requirements may be significant, as opposed to smaller and less permanent outposts. The method makes use of *DoD Facilities Pricing Guide* (FPG) for Fiscal Year 2009 as the primary data source; this source has a near comprehensive list of facilities commonly found at DoD sites worldwide.¹⁶ The FPG contains average facility cost information such as capital, sustainment, and operation unit costs, as well as information on how to identify and adjust cost data by geographic location.

¹⁶ *DoD Facilities Pricing Guide for Fiscal Year 2009*. (2010). UFC 3-701-01. Office of the Deputy Under Secretary of Defense, Installations and Environment (ODUSD[I&E]). Retrieved March-October 2010, from http://www.acq.osd.mil/ie/fim/programanalysis_budget/tool_metrics/FPG/fpg.shtml

In situations when detailed information is identified for fixed infrastructure, additional resources can be used to customize the analysis. Such was the case with incinerators. SMEs informed the project team of what incinerators were in place and operational. Annualized costs associated with this equipment were then calculated based on SME input, the U.S. General Services Administration (GSA), manufacturer's reported burn rates, and the DoD Facilities Pricing Guide (for operations and maintenance cost estimates only).

Depending on the base, the HW collection and storage area could be an entirely separate storage facility from the GW or it could be an adjacent area to the main waste storage complex. Either way, the HW storage areas at most base camps consists of a well-organized, covered storage building with secondary containment. In all cases, the HW appears to be properly labeled and sorted upon receipt into the HW storage area.¹⁷ In Iraq, where HW treatment and disposal occurs in-country, the infrastructure would also include HW incinerators, land farms, HW stabilization areas, and any other facility built to sort and treat the HW.

For MW, the infrastructure cost component is simple because there is not much storage associated with RMW. The infrastructure mainly consists of one to two RMW incinerators, located outside in a secure area. Most bases have onsite refrigeration units in the event of incineration equipment downtime or excess disposal time. Annualized costs associated with this equipment were obtained from the equipment manufacturers.

2.4.2 Personnel Costs

The Personnel Cost Component represents costs associated with personnel dedicated to waste management, inclusive of military and contractor personnel. This component applies to larger bases or smaller outposts. Military personnel are most often employed for waste management at smaller or more austere outposts. Contractor personnel are most often employed for waste management at larger, more mature camps, and there are primarily three categories of contractor: U.S. Contractor, Third Country Nationals (TCN), and Host Nation Contractors (HNC). Given the heterogeneity of base camps, a combination of military and contractor personnel frequently occurs in practice.

Multiple waste management functions are performed in contingency operations. At austere locations, military personnel may perform them all. For example, they may build latrines (e.g., dig holes), transport waste (e.g., individual garbage bags) and dispose of waste (e.g., pack out and haul waste back to a disposal site). In mature locations these functions are typically performed by a contractor, and depending on location and labor supply, some pattern of combined labor function and contractor category may emerge. In this FBC estimation, GW and WW management personnel are composed of waste management-dedicated contractors, according to SME input. GW management functions were identified and costs were calculated based on SME input and contractor salary estimates provided by contractor category.

In nearly all situations except the smallest of bases that are not contractor supported, the management of HW is a LOGCAP function. Therefore, the personnel costs are part of a rolled-up figure in a contract and cannot be broken out. In Afghanistan, personnel costs are embedded in the main HW disposal contract with Tadawulat. In Iraq, personnel costs are embedded in the main HW disposal contract with URS.

¹⁷ *AOR Environmental Component Plan*. (2009, March). Prepared for United States Army Central. Atlanta, GA: CH2MHill, Military Planning Group.

Force protection does not constitute a Cost Component in the analysis of potential costs at the base camp. However, there may be costs associated with security and escort services according to SME input.

2.4.3 Transport and Equipment Costs

The Transport and Equipment Cost Component represents costs associated with transporting the waste from generation point to disposal and the equipment dedicated to waste management. This component applies to larger bases or smaller outposts. At smaller bases, transport may be performed by soldiers physically carrying the waste to the designated site or hauling the waste in military vehicles. Equipment at smaller bases may include mostly hand tools (e.g., shovels, gloves, trash bags). At more mature bases, transport vehicles are commonly used to haul GW and WW from the waste generation site (e.g., a dining facility) to any intermediary destinations (e.g., refuse collection facility) and any final destinations (e.g., landfill). Equipment may include industrial items (e.g., trash compactors, balers, front-end loaders). Costs associated with the use and maintenance of transport vehicles and equipment are included in this cost component.

As with nonhazardous waste, the transport and equipment cost component for HW and MW consists of the capital and maintenance costs for the equipment used to transport the waste from its generation point to the waste storage complex. The capital costs for the trucks and heavy equipment are annualized, based on the expected useful service life of the equipment. The Operation and Maintenance (O&M) costs are calculated based on a rate per mile that includes service, repair, and fuel, as well as the approximate distance driven. For HW in Afghanistan, transportation costs are included on the HW disposal contract with Tadawulat.

Many larger bases usually have a contractor-run Hazardous Materials (HAZMAT) team. This team is responsible for spill response, among other duties. Depending on the structure of the LOGCAP contract and the operations at the base, the HAZMAT team may also pick up HW and transport it to the HW storage area periodically.

2.4.4 Base Closure and Transfer Costs

The Base Closure and Transfer Cost Component represents costs associated with base camp closure and transfer (BC&T) to another party (e.g., host nation). Potential liabilities and risks due to BC&T can be associated with base camps of any size or maturity. Costs would vary by base camp, and would generally represent any future liabilities associated with present-day waste management practice (for GW or WW). It is possible that waste management practice in contingency operations meets an operational need and causes long term affects to a host nation's environment. This possibility may lead to the accumulation of monetary and non-monetary (generally non-quantifiable and situation-specific) liabilities with the host nation or other party over time. If waste management practices are implemented to mitigate these risks, during the time period measured for calculation of FBC of waste, the cost of those practices would be assessed in the other Cost Component categories and would represent costs of ongoing operations. They would not be included in BC&T.

Base closure costs associated with solid waste management may include the cleanup cost required to deal with contamination due to waste management practices, as well as other affects because of the reduction in market activity surrounding base camp operations, more meaningful with large, mature bases. These economic costs compose an externality associated with base closure. Further, cleanup costs may vary for a number of reasons, including the degree of contamination, the type of environmental contaminants, the intended purpose of the transferred property, and the effectiveness of cleanup technology being used. The

degree of contamination varies depending on waste management methods, and compliance with waste management regulation; these factors are described in more detail in the “risks and liabilities” section. Last, the effectiveness of the cleanup technology being used will affect how quickly cleanup operations can be completed, causing variation because of personnel costs.

2.5 Limitations

Limitations are associated with creating a cost estimation method such as this. Most of the limitations are derived from the lack of readily available data regarding true-to-life waste management in-theater. As a result, assumptions must be made. These assumptions are listed in the cost estimation method spreadsheets where applicable. While necessary, they act as a simplification of reality.

The fundamental assumptions and limitations used in this cost estimation method include:

- **The solid waste generation rate per person is static:** The amount of waste per person and the type of waste generated can fluctuate based on a variety of factors including the maturity of a base camp, the amount of packaging brought in to a particular base, the amount of contractors present at a base camp, and the mission of a base. For this cost estimation method, the calculations assume that the amount of waste generated at a base is averaged over the population, regardless of the population demographics. In reality, it has been observed that contractors, in particular, expect more amenities in theater than military personnel.¹⁸ This expectation translates into a higher waste generation rate for contractors, but it has not been quantified.
- **The wastewater generation rate per person is static:** The amount of wastewater generated per person can vary tremendously depending on the amount of water that is available. For smaller, remote base camps, it may be more difficult to truck in water, both potable and non-potable. As a result, the amount of wastewater generated will be less.
- **Almost all of the waste amounts used in this cost estimation are volumetric estimates:** With the exception of Kandahar, waste is not measured at bases in theater. Whether this is intentional or simply an oversight, the result is an uncertainty of enormous scale regarding waste management planning. The measurements that have been performed for other studies involved estimating the approximate volumes of waste in cubic meters or equivalent.¹⁹ Then a certain weight per cubic volume must be assumed to convert the calculations to weight measurements. Estimates were verified by SMEs as much as possible for this cost estimation method.
- **No authoritative waste characterization study has been performed at Bagram.** Waste generation rates were provided by SMEs because solid waste (GW and WW) is not measured at Bagram.
- **The standardized data sources used to develop this analysis have limitations.** The DoD FPG²⁰ and the *Army Cost and Factor Handbook (CFH)*²¹ were used for much of the cost

¹⁸ See Table B-1 in Appendix B for a listing of personal communication with SMEs and in-theatre personnel.

¹⁹ *AOR Environmental Component Plan*. (March 2009). Prepared for United States Army Central. Atlanta, GA: CH2MHill, Military Planning Group.

²⁰ *DoD Facilities Pricing Guide for Fiscal Year 2009*. (2010). UFC 3-701-01. Office of the Deputy Under Secretary of Defense, Installations and Environment (ODUSD[I&E]). Retrieved March-October 2010, from http://www.acq.osd.mil/ie/fim/programanalysis_budget/tool_metrics/FPG/fpg.shtml

component data. The CFH is a component of the *Force and Organization Cost Estimating System (FORCES)*. Most infrastructure costs are based on the average facility descriptions taken from the DoD FPG. Every base is unique, and the facilities at Bagram may be larger or smaller than the average. Most transportation costs were estimated using the FORCES CFH, which reports costs for military vehicles. Waste transport at Bagram is largely provided by contractors and the costs associated with those vehicles are not publicly available.

- **Waste disposal practice may or may not comply with DoD policy.** For several situations, this analysis assumes compliance with DoD policy, and that may over- or underestimate the true costs of waste management.
- **Personnel costs do not include doctors, engineers, or other personnel whose activities may only be related to waste management in part.** Information was provided for personnel whose roles are solely dedicated to waste management.
- **Base Closure and Transfer costs are difficult to quantify.** Generally, the risk of liability increases when waste is improperly managed, but the extent to which this can lead to tangible costs is indeterminate. Costs of remediation may dwarf other costs if waste is improperly managed. It is important to mitigate this risk, and, according to SME input, certain actions are already under way. For example, Central Command has taken steps to measure and ensure compliance regarding DoD policy on burn pits.
- **Contractor data are not available through LOGCAP or other sources for this analysis.** As mentioned previously, LOGCAP or other contractor-specific information was not available for the FBC method. Instead, the method uses a bottom-up approach. If LOGCAP data should become available, this would serve as a valuable check against the cost estimates developed here.

²¹ *Army Cost and Factors Handbook (CFH), FY09.* (n.d). Army Financial Management, Assistant Secretary of the Army for Financial Management & Comptroller. Retrieved March-October 2010 from the FORCES website, <https://www.osmisweb.army.mil/>

3 DEMONSTRATION RESULTS

The FBC method is used to estimate costs for a case study at Bagram AFB in Afghanistan. Bagram AFB was selected as a base case for numerous reasons, including data availability. SMEs have more information tracked and recorded for a base of this size than for smaller, more remote bases. In addition, large, contractor-supported bases such as Bagram represent a more complex scenario to which the cost method can be applied. Command Outposts and smaller bases lack the complexity need as a proof-of-concept for the method. Finally, a complex base such as Bagram is more likely to use and support the alternative technologies that are presented later.

This section presents the results of the demonstration to include a description of the base case, the initial cost estimates, and the impact of implementation of alternative technologies.

3.1 Bagram Baseline Estimates

Bagram is one of the largest base camps in Afghanistan, and is one of the only base camps labeled as having an enduring presence by U.S. military leadership. The growing population has led to an increased demand for waste management services and a necessary investment in more sophisticated waste management facilities (Figure 3).

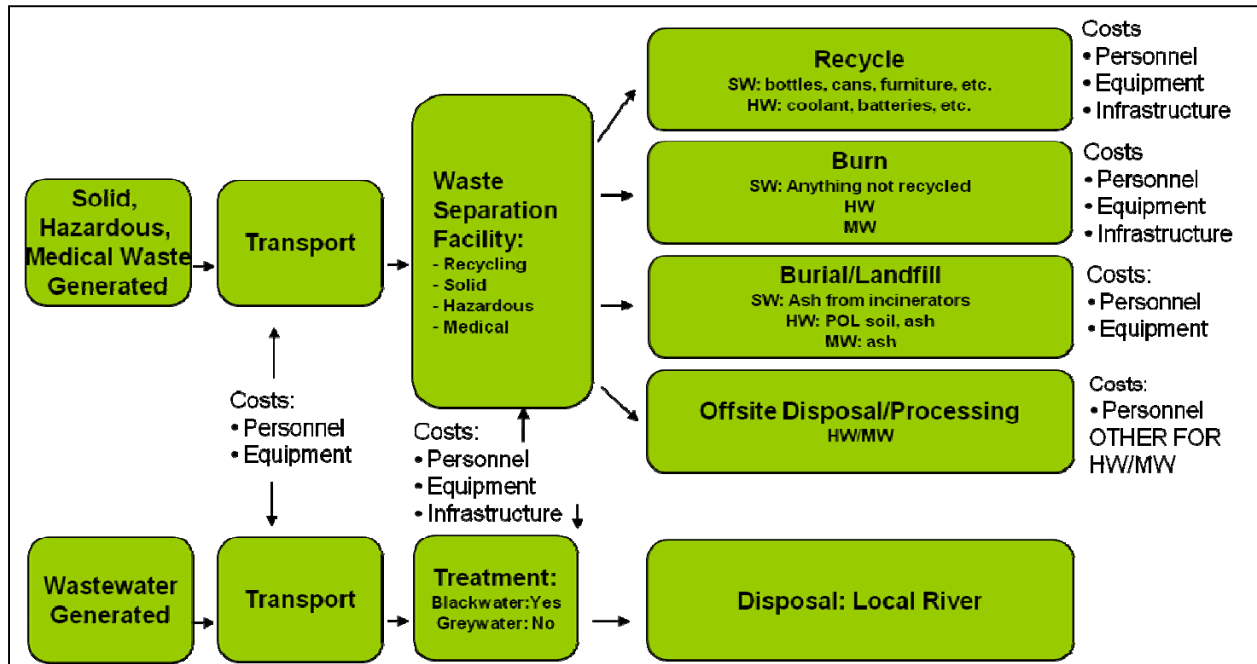


Figure 3. Bagram Air Force Base, Afghanistan, Waste Process Flow Diagram

Information from SMEs indicates that solid waste management is constantly changing at a dynamic base such as Bagram. For instance, the 40-acre landfill currently used for GW at Bagram is scheduled to close and a new disposal site is under consideration. The new site may be supplied with additional incineration capacity and a new ash pit. A 1-million gallon per day wastewater treatment plant is scheduled for completion. Furthermore, a wastewater management system with utility-scale infrastructure is being implemented, to include the use of ROWPUs at deepwater wellheads. It is clear that the FBC method

must be updated continually to reflect major changes such as these. This provides an opportunity to compare results before and after the new management infrastructure is operational and evaluate the changes in cost and risks.

3.1.1 Nonhazardous Solid Waste (GW and WW)

The cost calculations conducted for Bagram AFB involved calculating waste generation rates and then identifying waste management activities in order to identify personnel, infrastructure and transportation costs associated with these activities. The calculations were performed directly in the Excel cost estimation method spreadsheets, and portions of the spreadsheets are included in this section of the report (see appendix C for the full tool; also Appendix D). There are few standardized, centrally managed data sources for waste management data. Therefore, the method demonstration relies on input from SMEs to fill in data gaps (Appendix B). Although base closure costs are included in the method, Bagram's status as an "enduring base" precludes estimating these costs.

Solid Waste Generation

In 2010, Bagram AFB had a population of approximately 27,000 people.²² Per-person planning factors are used to estimate total daily GW and WW generation. This demonstration uses the Army Central (ARCENT) planning factor of 8 pounds (lbs) per person per day to calculate total GW generation, but research performed for this study identified a wide range of historical general waste generation rates. GW generation rates vary for multiple reasons (e.g., geographic location, included or excluded waste streams,) but primarily differ because of the quantity and quality of the underlying GW streams (Table 3).

The total quantity of WW generated at Bagram is a function of the population and an estimated WW generation rate of 65 gallons per person per day, yielding total annual WW generation of 641 million gallons.²³ According to planning factors used by in-theater personnel, blackwater accounts for 40% of the total wastewater generated at Bagram (26 gallons per person per day) and greywater accounts for 60% of the total wastewater generated at Bagram (39 gallons per person per day).

²² See Table B-1 in Appendix B for a listing of personal communication with SMEs and in-theatre personnel.

²³ See Table B-1 in Appendix B for a listing of personal communication with SMEs and in-theatre personnel.

Table 3. Variation in General Waste Generation Rates

Rate (lbs/person/day)*	Source
4	AF Pam 10-219 Volume 5, Bare Base Conceptual Planning Guide
8**	ARCENT
10	Government Accountability Office (2010)
10-14	U.S. Army Corps of Engineers Public Works Technical Bulletin 200-1-51
14***	U.S. Army Europe PAM 200-2 Contingency Operations Environmental Guide
16	Balkans Study Camp A- USACE Public Works Technical Bulletin 200-1-51
18	Balkans Study Camp A- USACE Public Works Technical Bulletin 200-1-51
* Rates may differ in terms of the included waste streams. Refer to the source document for further detail.	
** Based on SME input. This value represents an average of the AF Pam 10-219 and USACE PWTB rates.	
*** Calculated from SME email indicating an original value of 2.5 tons/person/year obtained from the source listed.	

Solid Waste Disposal

GW disposal methods at Bagram include (1) recycling, (2) combustion using an Air Curtain Incinerator (Burn Box), and (3) combustion using an Advanced Combustion Systems CA 3000 Incinerator. Discussions with SMEs identified the disposal pathways at Bagram and the portion of GW allocated to each pathway. Approximately 40% of Bagram’s GW is disposed of by recycling, and the remaining 60% is incinerated and disposed of in the nearby landfill, according to recent information.

Wastewater at Bagram is disposed of in a river or *wadi*. Blackwater is held on-site until it can be picked up by truck and transported to a nearby lagoon treatment facility. It is then treated for a short period of time and released into a nearby body of water. Greywater is also held on-site until it can be picked up by truck, but it is directly released, untreated, into a nearby body of water. Wastewater is transported by sewage truck from the generation source to both the treatment and disposal site, where applicable.

The cost estimation method (Appendices C and D) was used to calculate the annual FBC of nonhazardous solid waste (GW and WW) managed at Bagram AFB (Table 4).

Table 4. Fully Burdened Cost of Nonhazardous Solid Waste for Bagram*

Cost Category	Base Case: Bagram
Solid Waste Infrastructure	\$ 7,144,811
Solid Waste Personnel	\$ 4,791,800
Solid Waste Transport & Equipment	\$ 5,801,552
Solid Waste Base Closure & Transfer	Indeterminate
Fully Burdened Cost of Solid Waste	\$ 17,738,163

* All values are for a 1-year period.

3.1.2 Hazardous Waste

The cost estimation method cannot be extended to HW Because of the proprietary nature of the large-scale HW management contracts. Fine-grained data are not available to build the cost estimation method using the same cost components as employed for GW and WW at Bagram.

According to DLADS, approximately 80% of the HW generated in theater consists of used oil, waste fuel, coolant, and lead acid batteries. The remaining 20% is a mixture of smaller HW streams. This 80/20 rule is often applied to HW estimation planning (Appendix E).

HW Generation

HW generation is not necessarily a function of the amount of people at a base camp. A review of the information regarding various base camps in theater, their populations, and their reported hazardous waste accumulation quantities demonstrates that a simple causal link does not exist between the two.²⁴ Therefore, a hazardous waste generation rate in terms of quantity per person was not used for the HW cost estimates. Instead, the Bagram HW baseline estimates are derived from the HW quantity generated by the entire facility at a given point in time. This estimation method could be applied to any other base with a known or estimated annual HW generation rate.

Monthly Environmental Activity Report Theater Summaries for Afghanistan were obtained for only two months, February and April 2009. These reports include monthly HW inventories for four bases that have HW storage facilities: Bagram, Kabul, Salerno, and Jalalabad. It is known that these four bases receive HW from nearby smaller bases, but there is no information about the waste received or generated at these four facilities. Based on conversations with in-theater personnel, the volume of HW received at Bagram from two nearby bases is not very large. Only the inventory amounts at the time of inspection are known. To further complicate the calculations, it is known that the accumulated HW is shipped out twice per year by DLADS, but only partial information is available. Therefore, it is not possible to calculate the generation rates per base without significant assumptions. For the purposes of this demonstration, it is assumed that the monthly generation rate at Bagram is equal to the monthly inventory rate provided in these reports (Table 5).

²⁴ *AOR Environmental Component Plan*. (March 2009). Prepared for United States Army Central. Atlanta, GA: CH2MHill, Military Planning Group.

Table 5. Bagram Hazardous Waste Inventory Amounts

Month	Used Oil	Waste Fuel	Anti-Freeze	Spill Cleanup Material	Lead Acid Batteries	NiCad Batteries	Lithium Batteries	Mercury Batteries	Total
Feb. 2009	35,323	30,832	4,945	2,340	23,756	150	3,753	111	101,210
April 2009	15,922	13,589	16,016	0	6,261	284	796	0	52,868
Totals (kg)	51,245	44,421	20,961	2,340	30,017	434	4,549	111	154,078
Totals (lbs)	112,944	97,904	46,198	5,157	66,157	957	10,026	245	339,588
Scaled up to 1 year	677,664	587,423	277,188	30,944	396,945	5,739	60,156	1,468	2,037,527

Note: Mixed POL quantities = zero for February and April, 2009.

Used oil, while not technically hazardous, is the largest HW stream generated by Afghanistan bases.²⁵ However, used oil is not included in the calculations for Bagram baseline HW generation. The reason is because used oil is not shipped to Europe for treatment with the other HW streams, but instead it is bartered, sold, or burned as fuel in incinerators. Therefore, the Bagram baseline estimate of HW generation is 2,037,527 lbs – 677,664 lbs = 1,359,863 lbs of HW generated per year.

HW Disposal

HW disposal in Afghanistan is coordinated by DLADS through a contract with Tadawulat. All costs for packaging, transportation, fuel, applicable equipment, labor, and final treatment and/or disposal are included in the contract price. There is a Contract Line Item Number (CLIN) for the disposal of each waste type, transportation (divided into units, includes security), and the purchase of new packaging containers for the waste. Because the CLINs are broken down into units, the contractor charges DLADS for each unit upon completion. The contract is the total price anticipated for the year, not to exceed the value of that year's particular contract. The only costs for HW not included in this contract are those costs incurred for handling and storing the waste prior to disposal pickup, mostly by contractors on base.

The total contract price for HW disposal in Afghanistan for the current year is €1,680,552, or \$2,344,875 (as of October 23, 2010), including a CLIN for transportation from Tajikistan. If the Tajikistan CLIN is removed, the adjusted total is \$2,243,930. Adding the CLINs for HW disposal, and excluding the CLINs for transportation and new packaging, brings the total to 772,005 kg or 1,703,681 lbs of HW.²⁶ A total for HW disposal costs for Bagram can be estimated by prorating the total contract amount by the amount of HW generation estimated for Bagram. Assuming the annual HW generation rate of Bagram, excluding used oil, is 1,359,863 lbs, this equals 79.8% of the HW generated in Afghanistan. This assumption seems valid because Bagram receives HW shipments from several nearby base camps and this is already included in Bagram totals. Applying 79.8% to the total contract cost (excluding the transport from Tajikistan), the total annual cost for HW disposal in Bagram is \$1,791,085. Once again, this amount does not include cost associated with handling and storing the HW on Bagram prior to pickup.

²⁵ See Appendix F for more information about used oil and the existing HW disposal contract.

²⁶ *DRMS Hazardous Waste Disposal/Cost*. (n.d.). Contract Number: SP442008D0011. Retrieved October 19, 2010, from <https://www.drms.dla.mil/hazmat/servlet/ShowContract?CONTRACT=SP442008D0011>

3.1.3 Medical Waste

According to the Army Field Manual, there are two types of medical waste: non-regulated and regulated. Non-regulated medical waste is solid material that requires no further treatment and can be disposed of as general waste. RMW is defined as medical or laboratory wastes that is potentially capable of causing disease in people and may pose a risk to people if not handled or treated properly.²⁷ As expected, the major sources of medical waste are generated in patient care areas, especially emergency rooms and operating rooms.

MW Generation

As discussed in Section 2.3, actual measured waste volume estimates were obtained for Bagram from in-theater personnel. The average daily volume of RMW generated at Bagram AFB is 5.63 cubic meters per day.

MW Disposal

Smaller combat outposts or patrol bases have two options for RMW disposal if transport to an incinerator is not available: burning or burying. Open burning is no longer a favored method of disposal, though some undated literature from the Army Public Health Command, formerly the U. S. Army Center for Health Promotion and Preventative Medicine (USACHPPM), directs open burning as the preferred method for RMW disposal over burying.²⁸ Various field manuals provide instruction on how to build an incline plane incinerator for controlled incineration in the field, if necessary.

Nearly all Forward Operating Bases (FOBs) now have Medi-Burn units or medical waste incinerators. According to the *Overseas Environmental Baseline Guidance Document* (OEBGD), incinerators used to treat medical waste must be designed and operated to maintain a minimum temperature and retention time sufficient to destroy all infectious agents and pathogens. They also must meet applicable [air emissions] criteria.²⁹

Cost components used for the FBC of MW at Bagram include infrastructure, transportation, and personnel costs. Contractors collect the RMW generated daily at Bagram and incinerate it within 24 hours. The infrastructure mainly consists of two RMW incinerators, located outside in a secure area. As previously mentioned, most bases have on-site refrigeration units in the event of incineration equipment downtime or excess disposal time, but these facilities were not included in the FBC of MW calculations because 1) it is unlikely that the refrigeration units are dedicated to RMW disposal and 2) these refrigeration units represent a contingency plan and are not generally used. It should be noted that fuel costs were not included in the FBC of MW calculations. The total annual cost of MW management at Bagram is approximately \$213,920 (Table 6).

²⁷ *Employment of the Field and General Hospitals: Tactics, Techniques, and Procedures*. (1997, March 26). Field Manual. FM 8-10-15. Washington, DC: Headquarters, Department of the Army.

²⁸ *Just the facts: Medical waste disposal during contingency operations*. (n.d.). Fact sheet 37-031-0205. Aberdeen Proving Ground, MD: Hazardous and Medical Waste Program (HMWP), U.S. Army Center for Health Promotion and Preventive Medicine. Retrieved October 19, 2010, from <http://phc.amedd.army.mil/PHC%20Resource%20Library/37-031-0205.pdf>

²⁹ *Overseas Environmental Baseline Guidance Document*. (May 1, 2007). DoD 4715.05-G. Washington, DC: Under Secretary of Defense for Acquisition, Technology, and Logistics.

Table 6. Estimated Fully Burdened Cost of Waste per year Bagram AFB

Waste Type	Cost
General Waste and Wastewater	\$17,738,163
Hazardous Waste	\$ 1,791,085
Medical Waste	\$ 213,920
Fully Burdened Cost of Waste (Annual)	\$19,743,168

3.2 Alternative Technology Demonstrations

Two technologies are used to test the capability of the FBC method to estimate the cost effects of using waste reduction technologies. This type of analysis should help decision makers as they select technologies for reducing waste at base camps. Two readily available technologies that can be used at Bagram AFB: Clarus Technologies Oil CAT, which recycles used oil, and ROWPUs, which would reduce plastic water bottle waste by producing potable water that is distributed onsite (Appendix D).³⁰

3.2.1 Local Water Production/Distribution to Displace Bottled Water Demand

A ROWPU is a trailer mounted piece of Army equipment that treats water from raw water sources such as wells, lakes, and rivers, to provide Soldiers with potable drinking water. Dissolved solids are removed from water via the ROWPU's filtering system, and purified water is treated with chlorine for storage. The ROWPU is equipped with its own power generation source (diesel generator).

The analysis demonstration measures the affect of substituting local prime water production and distribution for bottled water on the FBC of managing waste. Reducing this waste stream affects costs, lives exposed to risk in the supply chain, and the health risks from burning plastic. The cost estimates generated represent only one aspect of the potential beneficial effects of reducing the amount of water delivered to base camps – the waste portion. This analysis below builds on the base case calculations for Bagram AFB and identifies changes in the cost estimates because of the reduction in waste generation or, specifically, the reduction in costs and resources used in the management of plastic bottle waste. It also includes a qualitative discussion of the effects on potential risks and liabilities.

For illustrative purposes, this demonstration assumes that (1) the only plastic bottle waste at Bagram is composed of 0.5 liter drinking water bottles, and (2) the potable water yield from ROWPUs is sufficient to completely displace bottled water demand, thereby completely eliminating plastic bottle waste. Approximately 432,000 waste plastic bottles per day are generated (0.5 liter size) in Bagram, and the current disposal practice is to separate, bale, and recycle plastic bottles. This figure was calculated using the CENTCOM Planning Factor of 8 liters of water consumed per person per day in theater with an estimated population of 27,000 people.³¹

³⁰ The Army is moving to Tactical Water Purification Systems (TM-10-4610-309-24P Tactical Water Purification System Army) to eventually replace ROWPUs.

³¹ Meeting with G-4 on October 6, 2010. See Table B-1 in Appendix B for a listing of personal communication with SMEs and in-theatre personnel.

The magnitude of GW reduction is calculated by estimating the number of water bottles consumed annually and multiplying that number by the weight of one 0.5 liter plastic bottle (10 grams per bottle³²). As a result of the ROWPU installation, GW generation decreases by 3.5 million pounds, or 1,738 tons per year (WW generation remains constant). Less waste would reduce disposal requirements of the refuse collection and recycling facilities, resulting in an overall decrease for GW management. The reduction in plastic bottle waste reduces the demand on the following cost components: waste management facilities and infrastructure; personnel; and transport and equipment. Reduced demand for GW management reduces costs as follows:

- A reduction in annualized Infrastructure costs of \$35,417, or 0.50%
- A reduction in annualized Personnel costs of \$221,182, or 4.62%
- A reduction in annualized Transport & Equipment costs of \$17,119, or 0.30%
- An indeterminate change in Base Closure and Transfer costs

In sum, these changes result in an annualized decrease in FBC SW of \$273,718, or 1.54% of the total (Table 7).

Table 7. Comparison of the Fully Burdened Cost of Solid Waste

Cost Category	Base Case: Bagram	Bagram with Alternative Solid Waste Management Method	Change
Solid Waste Infrastructure	\$ 7,144,811	\$ 7,109,394	-0.50%
Solid Waste Personnel	\$ 4,791,800	\$ 4,570,618	-4.62%
Solid Waste Transport & Equipment	\$ 5,801,552	\$ 5,784,433	-0.30%
Solid Waste Base Closure & Transfer	Indeterminate	Indeterminate	0.00%
Fully Burdened Cost of Solid Waste	\$ 17,738,163	\$ 17,464,445	-1.54%

*All Values for a 1-Year Period

Other impacts are associated with utilizing ROWPUs for drinking water. According to SMEs, new wastewater (ROWPU Brine) would be generated and disposed of on-site as a result of ROWPU installation, which would not follow the same disposal pattern as other greywater. Therefore, no additional costs would be included in the Transport Cost Component. However, should the ROWPU brine prove to be hazardous, improper disposal could increase exposure to risk of future liability. Reducing plastic bottle waste would decrease the number of people exposed to risks in the resupply chain, reduce health risks from burning plastic, and may reduce health risks from spoilage in bottled water transport. The potential savings associated with these risks are indeterminate, but are an important part of the analysis.

³² Husky's Guide to PET Bottles. (n.d.). Retrieved October 19, 2010, from http://www.factsonpet.com/Articles/Facts%20on%20PET%20Flyer_June18%20PRINT.pdf

3.2.2 Oil CAT

The Oil CAT, manufactured by Clarus Technologies, is a portable oil filtering and blending device that can blend used oil with diesel or JP-8 fuel. The Oil CAT works by blending used motor oil collected from a vehicle during an oil change with fuel from the vehicle's fuel tank. The used oil can be blended at a concentration up to 7.5% with no negative effects on engine performance.³³ For every gallon of used oil blended and re-used, one gallon of fuel is saved. Because the blending occurs at the vehicle during an oil change, the costs of collecting, transporting, and storing used oil are also saved. Because the units are portable, they can be moved around to various vehicles. Despite the fact that several of these units are already in theater and that the Army is aware of the potential savings that could be provided with widespread implementation, the technology is not fully supported or used.³⁴

As part of the demonstration of this technology, the project team analyzed the potential savings at Bagram if this technology were fully implemented. The approximate used oil generation rate for Bagram is 677,664 lbs. Taking into account the density of used oil and the practical availability of this oil, the total annual used oil quantity available for re-use is estimated at 88,667 gallons.

Using an Oil CAT would completely eliminate some cost components in the model, which could result in a 100% change in costs for that particular component. Oil CAT use reduces costs as follows:

- A reduction in annualized Infrastructure costs of \$3,404 or 30%
- No reduction in labor costs, or 0%
- A reduction in annualized Transportation costs of \$1,422 or 100%
- A reduction in annual HW disposal costs of \$199,739 or 100%

Oil's lifecycle continues after it has been used or dirtied creating a revenue stream for used oil. Oil has various uses after its initial purpose to serve as an engine lubricant. At Bagram, used oil can be bartered for another commodity or burned in an incinerator as fuel. Each of these possibilities turns this waste product into revenue or costs savings, even though it is worth much less than the initial purchase price. The cost savings, or revenue, for used oil is.

- Annual revenue of \$38,182 for used oil in exchange for gravel
- Annual cost savings of \$207,480 for used oil displacing JP8 fuel use in incinerators

Several possibilities exist for what might happen to the used oil (Table 8).

³³ *Oil Cat: Oil - Change Alternative Technology*. (n.d.). Retrieved October 19, 2010, from http://www.clarustechnologies.com/pdf_files/brochures/Oil-CAT.pdf

³⁴ A recent Department of the Army Field Manual, *Environmental Considerations in Full Spectrum Operations*, provides an example of used motor oil generation and disposal in Afghanistan, along with a description of a technology for oil reutilization, similar to the Oil CAT. *Environmental Considerations in Full-Spectrum Operations*. (Date pending). Field Manual. FM 3-34.500/MCRP 4-11B (FM 3-100.4). Washington, DC: Headquarters, Department of the Army.

**Table 8. Fully Burdened Cost of Used Oil at Bagram with Base Case and Alternate Scenario
(For a 1-Year Period)**

Used Oil Cost Category	Bagram AFB		
	Base Case	Alternative Case: Using Oil CAT Technology****	Change
Infrastructure	\$ 11,347	\$ 7,943	-30%
Personnel	\$ 141,750	\$ 141,750	0%
Transport & equipment	\$ 1,422	-	-100%
Disposal through DLADS	\$ 199,739	-	-100%
Revenue Category			
Sold through DLADS*	Unknown	\$ 207,480	Unknown
Bartered for gravel**	\$ 38,182	\$ 207,480	443%
Burned in incinerators***	\$ 207,480	\$ 207,480	0%
Fully Burdened Cost			
Disposed	\$ 354,258	\$ (57,787)	-116%
Bartered	\$ 116,337	\$ (57,787)	-150%
Incinerator	\$ (52,961)	\$ (57,787)	9%

* Sold through DLADS – cost not available

** Bartered for gravel at \$0.55 per pound

*** Burned as fuel in incinerators (not recommended by incinerator manufacturer)

**** Recycled in Oil CAT and reused in fleet vehicles and power generation equipment

- **Fully Burdened Cost of Used Oil – Disposed:** For this base case, this scenario assumes the costs incurred for infrastructure, personnel, transport & equipment, and used oil disposal through DLADS. The total annual cost for this scenario is \$354,258. For the alternate case in which the Oil CAT is used instead of disposing of the used oil with the HW, this scenario assumes some savings for infrastructure costs. The personnel costs are the same as the base case. No costs are incurred for the transport and equipment because the Oil CAT is used in the same place that the used oil is generated. With all used oil recycled through the Oil CAT, the maximum volume of JP8 is replaced. This scenario results in a net savings of \$57,787 annually, or 116% savings for this base case.
- **Fully Burdened Cost of Used Oil – Bartered:** For this base case, this scenario combines the costs for infrastructure, personnel, transport and equipment, and used oil and then the used oil is bartered for gravel. The total annual cost for this scenario is \$116,337. For the alternate case in which the Oil CAT is used instead of bartering the used oil for gravel at a price of \$0.055/lb, this scenario assumes some savings for infrastructure costs, personnel costs are the same as the base case, and no costs are incurred for transport and equipment because the Oil CAT is used in the same place where the used oil is generated. With all used oil recycled through the Oil CAT, the maximum volume of JP8 is replaced. The scenario results in a net savings of \$57,787 annually, or 150% savings for this particular base case.
- **Fully Burdened Cost of Used Oil – Incinerator:** For this base case, this scenario assumes the costs incurred for infrastructure, personnel, transportation and equipment, and used oil burned as fuel in the SW incinerators. The total annual savings is \$52,961 because the used oil displaces fuel costs for the incinerators. For the alternate case in which the Oil CAT is used instead of

burning the used oil in the incinerators, despite the manufacturer's recommendation against burning oil in the incinerators. This scenario assumes cost savings for infrastructure and personnel costs are the same as the base case, and there are no transportation and equipment costs because the Oil CAT is used at the same place it is generated. With all the used oil recycled through the Oil CAT, the maximum volume of JP8 is replaced. The total savings is \$57,787 annually, or 9% savings for this particular base case. In this scenario, used oil is burned instead of JP8 for both the base case and the alternative so the maximum savings is made for both. For the Oil CAT alternative scenario, however, some cost savings are associated with requiring less storage for the used oil drums. There is no transportation and equipment costs.

In summary, the cost savings potential for implementing the Oil CAT is highly dependent on how the used oil is used after it is generated. Because used oil can be considered a revenue stream, it is difficult to assess the cost effects of the Oil CAT. Like ROWPU technology, other effects are associated with using the Oil CAT besides financial. If the used oil is bartered with a local contractor, there is no assurance that the contractor will handle the used oil in an environmentally responsible manner. Burning the used oil as fuel in an incinerator could potentially cause a reduced performance in the incinerator operation. As with the ROWPU, the potential savings associated with these risks are indeterminate, but are an important part of the analysis.

4 CONCLUSIONS

Base camps generate hazardous and nonhazardous waste that must be responsibly managed. Characterization and quantification of waste generated and disposed of in contingency operations is an important first step in effective and efficient waste management. The dynamic and transitional nature of base camps makes this difficult; generalizations cannot be made based on the number of units stationed there, the mission, or the quantity of goods purchased and shipped to the camps. At this time, the quantity of waste generated cannot be deduced from the quantity of materiel procured. Waste generation and disposal data have not been systematically collected for any single base camp, much less all of the Army base camps. Determining the fully burdened cost of managing waste in contingency operations represents one step the development of a cost estimating tool that can help decision-makers identify the costs associated with managing waste in order to assess and implement management actions. However, there are costs that cannot easily be monetized. These include health and safety risks to the Soldiers and civilians, risks to the environment, and long-term liabilities after base closure. These risks must also be incorporated into decision making.

4.1 Non-Monetary Costs and Liabilities

In addition to the monetary costs of waste management in contingency operations, waste management operations and disposal sites may expose Army personnel, contractor personnel, and the host nation population to risks including health, environmental, and security risks. These potential risks compose an additional aspect of the FBC. Informed decision-making must take these risks into account, but they often cannot be quantified in the same manner as other costs. This section presents a brief qualitative discussion of these risks which may become tangible liabilities if waste is improperly managed (Appendix F). The risks reviewed include health and environmental impacts due to landfills, incinerators, burn pits and wastewater disposal. There are other risks associated with security, transportation, and diplomatic relations.

Health risks can have both short- and long-run effects. In general, risks increase when waste is improperly managed. Short-term (acute) health risks are more likely to affect Army and contractor personnel living or working near the disposal sites, as well as host nation populations living near the disposal site. Long-term (chronic) health risks can affect Army and contractor personnel who lived or worked near the disposal sites, as well as host nation populations continuing to live near the disposal site. Environmental risks differ from health risks in that they can have a long-term effect on the ecosystem, or a short-term effect on the ecosystem that does not directly affect humans. Changes in the ecosystem can lead to changes in the livelihoods of local populations. Monetary costs associated with these risks at Army base camps are indeterminate at this time.³⁵

Insufficient quality control of landfill design and operation may lead to increased health and environmental risks. Landfills constructed without an impermeable liner will allow a greater quantity of leachate to enter the environment than one with an impermeable liner, as is directed in sanitary landfill construction documentation.³⁶ Improper general waste segregation may allow hazardous materials to be disposed of in a landfill, changing the leachate composition and causing hazardous chemicals to enter the environment untreated.³⁷ When solid waste is deposited in a landfill, water percolates through the waste, absorbing some of its material and creating leachate. If the landfill liner is permeable, leachate can leak into the environment causing ground and surface water pollution. In addition, waste decomposition produces air emissions that can be hazardous to human and environmental health. Short-term health risks associated with landfills include groundwater and air pollution. Long-run health risks, which may occur after landfill closure, are mostly related to groundwater pollution.³⁸

Incinerating solid waste produces heat, flue gas, and ash. Heat and flue gas are released into the air during the incineration process, whereas ash is disposed of in a landfill.³⁹ Health and environmental risks most directly related to managing solid waste with incineration result from exposure to flue gas, and the intensity of these risks depends on the chemical composition of the flue ash. Ash added to landfills contributes to leachate composition, which contributes to health and environmental risks associated with landfills described above. Insufficient quality control of incinerator operations may intensify these risks. Incinerator emissions are a health risk to nearby populations and may expose waste management personnel to additional occupational risks depending on the type of incinerator infrastructure. While emissions begin as air pollution, chemicals can enter other areas of the ecosystem, particularly water, soil, and food sources and affect human populations indirectly by different exposure routes.⁴⁰ Improper general waste segregation may result in the accidental combustion of materials which produce emissions

³⁵ Risks associated with human populations' exposure to pollutants have been quantified in dollars through various studies of health effects, legal settlements and, in cases of ecosystem damages, cleanup and restoration costs. This is an extensive body of literature and its application to waste management in contingency operations was beyond the scope of this project.

³⁶ *Sanitary Landfill*. (January 15, 1994). Technical Manual. TM 5-814-5. Washington, DC: Headquarters, Department of the Army.

³⁷ Barlaz, M.A., Baun, A., Christensen, T.H., Kjeldsen, P., Ledin, A., & Rooker, A. P. (October 2002). Present and long-term composition of MSW landfill leachate: A review. *Critical Reviews in Environmental Science and Technology*. London, UK: Taylor & Francis. Volume 32, no. 4 (2002): 297-336.

³⁸ In addition to leachate, solid waste decomposition in a landfill also produces gas. If the landfill is appropriately designed, the gas produced by the landfill can be harvested and used as natural gas or to produce electricity. Further, either end use may generate a stream of revenues and partially balance the risk of future liability.

³⁹ Knox, A. (February 2005). *An Overview of Incineration and EFW Technology as Applied to the Management of Municipal Solid Waste*. Ontario, Canada: University of West Ontario.

⁴⁰ Researchers have not been able to definitively conclude that incinerator emissions affect human health because they are unable to establish causality between incinerator emissions and air pollution in a given location. However, studies have been able to assess the chemical composition of incinerator emissions and identify potential health risks associated with those chemicals.

that are hazardous to human and environmental health. Inappropriate operation of the incinerator may result in inefficient or incomplete combustion, which may result in greater emission toxicity.⁴¹

Burn pits ignite solid waste in an open-air pit, producing ash and smoke.⁴² The fire receives a limited amount of oxygen and burns at a relatively low temperature, resulting in inefficient combustion and hazardous emissions. Health and environmental risks resulting from exposure to smoke can be both acute and/or chronic depending on the chemical and material composition of the smoke. Bottom ash is added to landfills and contributes to health and environmental risks associated with landfills described above. Insufficient quality control of burn pit operations may intensify these risks. Health and environmental risks occur from the toxins and pollutants produced by open air solid waste combustion. The exact chemical composition of burn pit emissions depends on the composition of the solid waste being combusted. Insufficient quality control of GW segregation may result in the accidental combustion of materials which produce hazardous emissions, such as plastics or tires. Inappropriate operation of the burn pit may result in inefficient or incomplete combustion, which may result in greater emission toxicity. Lawsuits regarding negligent management of burn pit operations have been filed by veterans returning from contingency operations. Both the contractors who operated the burn pits and the military personnel who constructed the burn pits have been identified as possibly responsible for intensified levels of human exposure.⁴³

Wastewater released into a water source, such as a river, without proper treatment may result in groundwater and surface water pollution. The type of health and environmental risks resulting from pollution depend on the contaminants present in the wastewater. Additionally, the extent of the human health effects depends on the extent to which surrounding populations use groundwater and surface water sources and the availability/use of water purification technologies. Insufficient quality control of wastewater management operations may intensify these risks. Host nation populations in Iraq and Afghanistan have different rates of access to clean water technology (Table 9).⁴⁴

Table 9. Access Rates to Clean Water Technology in Iraq and Afghanistan

Country	Urban Access to Clean Water	Rural Access to Clean Water
Iraq	98%	50%
Afghanistan	64%	32%

Vehicles used to transport solid waste generate environmental risks as a result of vehicle emissions, and security risks as a result of exposure to attack. Solid waste transportation equipment emits carbon monoxide, hydrocarbons, nitrogen oxides, and particulate matter as a product of fuel combustion. These pollutants reduce air quality and contribute to climate change.⁴⁵ Driving solid waste transportation equipment also exposes waste management personnel to a security risk, because the truck may be targeted

⁴¹ Board of Environmental Studies and Toxicology, Commission on Life Sciences, Committee on Health Effects of Waste Incineration, & National Research Council. (2000). *Waste Incineration and Public Health*. Washington, DC: National Academy Press.

⁴² Smoke contains fly ash. Ash that remains in the burn pit after combustion is bottom ash.

⁴³ *Afghanistan and Iraq: DOD Should Improve Adherence to Its Guidance on Open Pit Burning and Solid Waste Management*. (October 15, 2010). GAO-11-63, Washington, DC: U. S. Government Accountability Office. Retrieved November 30, 2010, from <http://www.gao.gov/products/GAO-11-63>

⁴⁴ Joint Monitoring Programme for Water Supply and Sanitation. (March 2010). “Estimates for the Use of Improved Sanitation Facilities: Iraq” and “Estimates for the Use of Improved Sanitation Facilities: Afghanistan.” WHO/UNICEF. Retrieved September 15, 2010, from www.wssinfo.org

⁴⁵ *Mobile Source Emissions – Past, Present and Future: Pollutants*. (July 2007). Washington, DC: U.S. Environmental Protection Agency, Office of Transportation and Air Quality. Retrieved October 19, 2010, from <http://www.epa.gov/otaq/inventory/overview/pollutants/index.htm>

for attack. In instances where host nation populations are hostile or unfriendly, waste disposal facilities have been located near Army living quarters and operating centers in order to avoid this security risk.⁴⁶

In addition to increasing environmental and health risks associated with solid waste management, insufficient monitoring of solid waste management operations exposes a base to security risks. Waste management facilities with multiple points of entry may allow unauthorized individuals to gain access to sensitive materials that have been improperly disposed of as waste, such as official documents or unexploded ordinances (UXO).⁴⁷ Externalities created by waste management methods may affect the host nation population's perception of a U.S. Army presence. Experience in contingency operations has taught planners that effective waste management practices help convince the host nation population of their good intentions, whereas ineffective waste management practices will increase tension and (potentially) aggression against U.S. forces.⁴⁸

4.2 Determining the Fully Burdened Cost of Managing Waste

One of the *Army Strategy for the Environment* goals is to minimize the effects and total ownership costs of Army systems, materiel, facilities, and operations by integrating the principles and practices of sustainability. To meet this goal it is necessary to incorporate life cycle costs that are not yet internalized and quantified into decision-making. As the previous AEPI-sponsored SMP projects and this project on waste management reveal, Army materiel costs more than the price charged at commodity procurement. This "fully burdened" perspective addresses all transportation, infrastructure and personnel costs associated with managing waste, and also considers non-monetary costs and liabilities. Estimating the FBC of materiel use in contingency operations is one way to assess the overall life cycle effects and improve overall sustainability, while also supporting the mission. This effort also found that waste management in theater is largely unplanned. SMEs indicated that planning is essential for proper waste management and that planning should start earlier on in the supply chain or during the design of the base. Furthermore, solid waste management is constantly changing at a dynamic base such as Bagram. It is clear that a FBC method for waste must be updated continually to reflect major changes at the base camp for which the estimates are being generated. This provides an opportunity to compare results before and after the new waste management infrastructure is operational and then evaluate changes to cost and risk.

The FBC waste method should be incorporated with more robust decision-support tools that include the entire life cycle of materiel use at base camps. The scope for the FBC of waste method is limited to costs incurred from the point of waste generation on base (e.g., GW in the form of food containers after the food has been eaten) and ending with waste disposal (e.g., a landfill). Costs associated with waste in contingency operations can be examined at several stages in a product's life cycle as it moves through an international supply chain. Full life cycle assessments are needed to understand the source of waste *before it becomes waste, preferably when the product is being designed.*

Lack of data is a major hindrance in estimating waste management costs in contingency operations. Base camps are heterogeneous in purpose, population, and maturity, and there are no standardized requirements for tracking solid waste related data. Without this documentation, estimating the FBC of waste

⁴⁶ Anderson, G., & Wolf, W. (October-December 2004). "One-stop" waste disposal – enhancing force protection in Afghanistan. *Engineer: The Professional Bulletin for Army Engineers*, 5-7.

⁴⁷ Anderson, G., & Wolf, W. (October-December 2004). "One-stop" waste disposal – enhancing force protection in Afghanistan. *Engineer: The Professional Bulletin for Army Engineers*, 5-7.

⁴⁸ Mosher, D. E., Lachman, B. E., Greenberg, M. D., Nichols, T., Rosen, B., & Willis, H. H. (2008). *Green Warriors: Army Environmental Considerations for Contingency Operations from Planning Through Post-Conflict*. AEPI-04001. Santa Monica, CA: RAND Arroyo Center. Retrieved October 19, 2010, from <http://www.rand.org/pubs/monographs/MG632/>

management at a specific base camp requires interaction with SMEs to obtain experiential/qualitative information. Each location is unique and there are few standardized waste handling procedures. Lack of data is also an issue for assessing non-monetary risks and liabilities. The magnitude of these potential liabilities after Soldiers return from deployments and after base closure may be significant.

The results of the Bagram AFB demonstration revealed that the costs associated with non-hazardous waste are relatively evenly split between annualized costs for infrastructure, personnel, transportation, and equipment (Table 10). Waste generation quantities are not currently measured at Bagram – this data element largely dictates the accuracy of any waste cost analysis and it will be necessary to determine the accuracy of these estimates to validate the results of this demonstration. The potentially significant risks and liabilities associated with Base Closure and Transfer costs were not addressed for this study, as Bagram is an “enduring base.” A fully burdened cost estimate must address these. The estimated cost impacts for the technology demonstration proved inconclusive because of data limitations. The results were inconclusive also because waste oil is typically re-used and not easily defined as a “waste.” The same applies to plastics that are recycled at Bagram.

Table 10. Estimated Fully Burdened Cost of Waste per year Bagram AFB

Cost Category	Cost
Nonhazardous Waste Infrastructure	\$ 7,144,811
Nonhazardous Waste Personnel	\$ 4,791,368
Nonhazardous Waste Transport & Equipment	\$ 5,801,552
Base Closure & Transfer	Indeterminate
Fully Burdened Cost of General Waste and Wastewater	\$ 17,738,163
Hazardous Waste	\$ 1,791,085
Medical Waste	\$ 213,920
Fully Burdened Cost of Waste (Annual)	\$ 19,743,168

5 RECOMMENDATIONS

The following recommendations are based on the results of the FBC waste method development and demonstration.

- **Conduct a pilot project** where specific items are tagged and tracked using radio-frequency identification (RFID)/cell phone technology to better understand how the waste moves in time and space at large bases.
- **Implement simple, cost-effective waste measurement tools to provide needed data.** SME input indicated that very basic waste measurement tools could be implemented at base camps, such as drive-on scales prior to dumping at landfills or at the waste sorting complex. This type of information could significantly in the planning and management of solid waste.
- **Implement simple, cost-effective waste measurement tools to influence behavior.** What gets measured, matters. SMEs indicated that simply by conducting the measurement of waste generation, behaviors could change for the better.
- **Combine cost data for the entire life cycle of materiel to provide the complete picture and focus efforts to reduce waste.** Waste management assumes the generation of waste. It is an

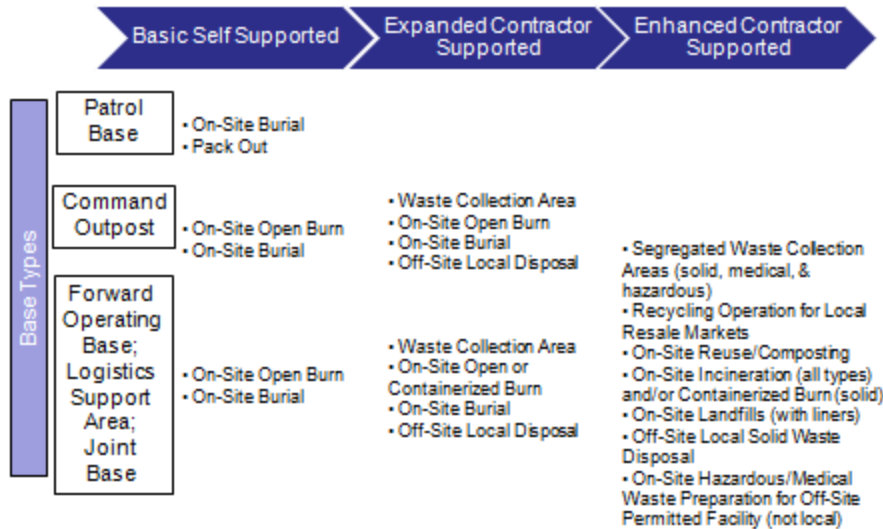
end-of-the-pipe approach. Sustainability tells us that the best solutions incorporate all aspects of the materiel life cycle and that the best waste management is the management that does not have to be implemented. This implies creative solutions for packaging and transport of materiel re-use of waste in theater and composting. Integrating the concepts of green engineering and green chemistry in the design of the products that the Army purchases that are eventually sent to contingency bases would significantly reduce the quantity and toxicity of the material requiring disposal.

- **Accurately document health and environmental liabilities for improved planning and decision making.** As documented in this report, multiple liabilities and risks are associated with waste management. Yet the magnitude and characteristics of these risks are poorly researched and poorly understood. This makes reducing risks a difficult endeavor. For example, the Department of Veterans Affairs did not anticipate the risks or costs associated with treating Vietnam War veterans who were exposed to Agent Orange during their service in Vietnam and have developed illnesses and diseases associated with that exposure.
- **Plan for waste management concurrently with other facility and infrastructure planning.** SMEs observed that foresight in establishing base camps could help avoid the issues that develop later as the camp grows and is active for extended periods of time. This finding is relevant to all infrastructure issues, such as water supply, energy supply security, and housing. Waste management concerns need to be incorporated as well.

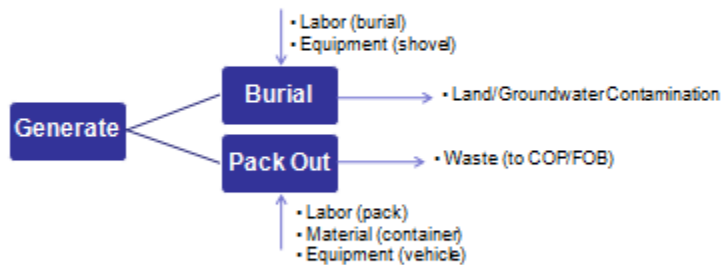
APPENDIX A

Process Flow Diagrams by Type of Base Camp

Base Camp Solid Waste Management

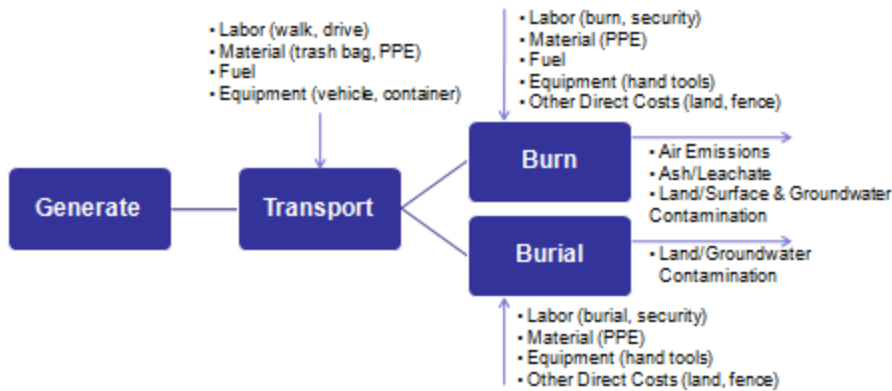


Basic: Self Supported Patrol Base (PB) Process Flow Diagram



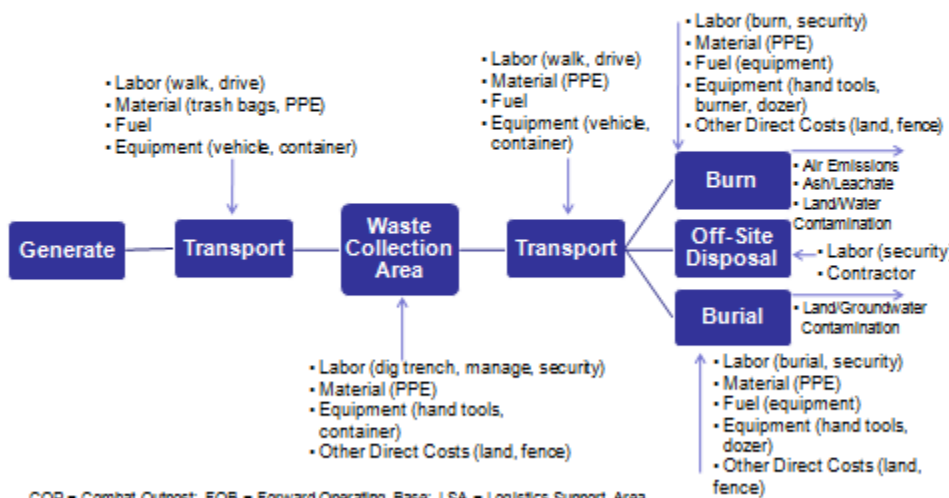
Basic - up to 60 days of initial camp establishment

Basic: Self Supported COP, FOB, LSA, & JB Process Flow Diagram

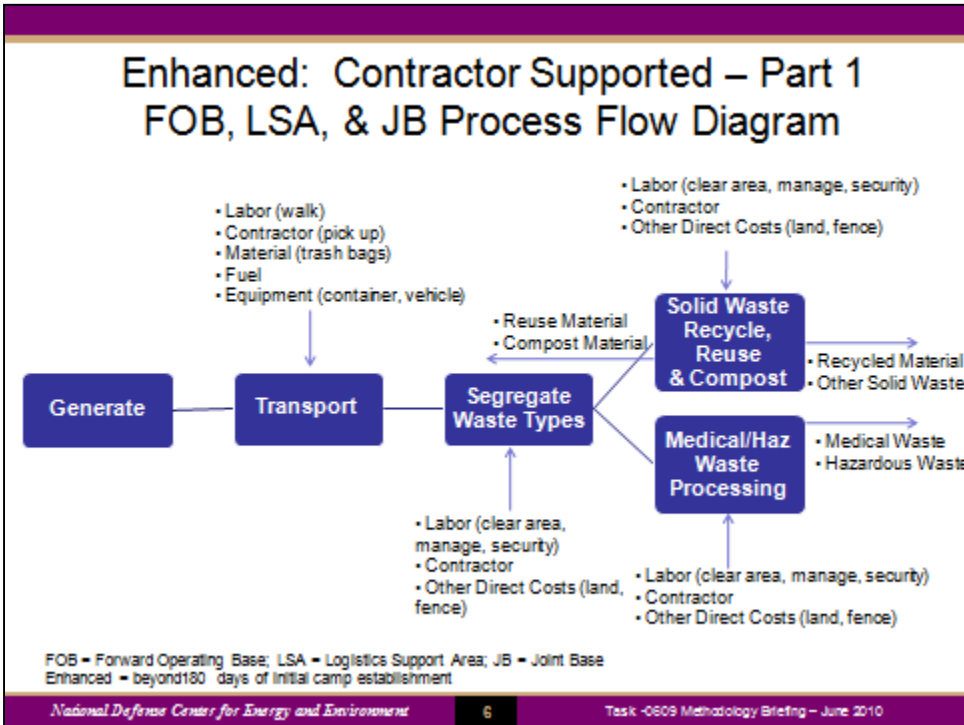
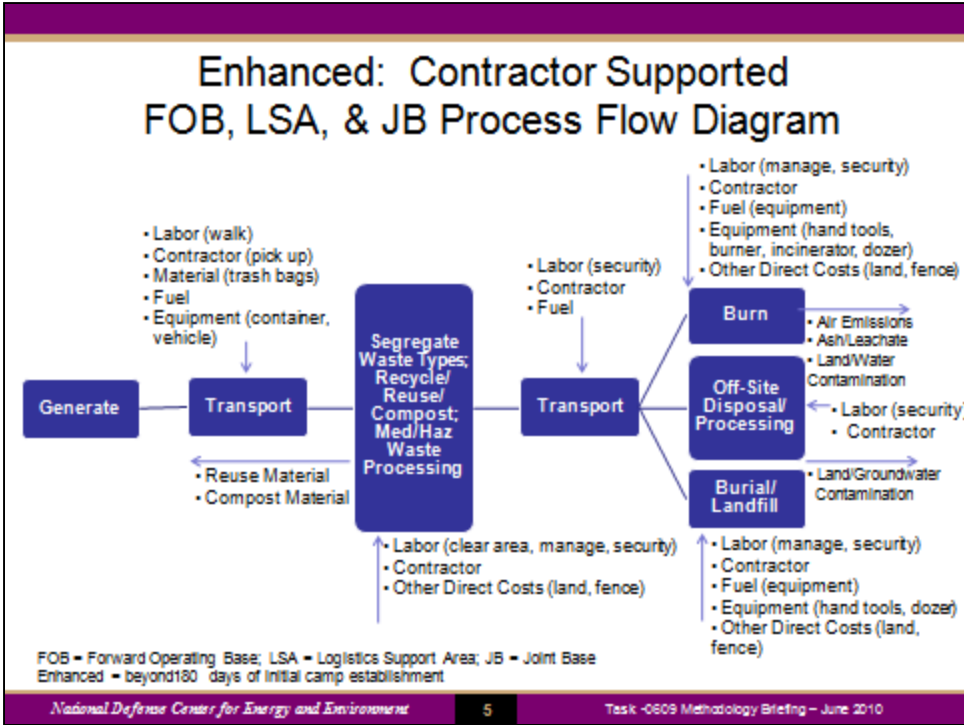


COP = Combat Outpost; FOB = Forward Operating Base; LSA = Logistics Support Area; JB = Joint Base
Basic = up to 60 days of initial camp establishment

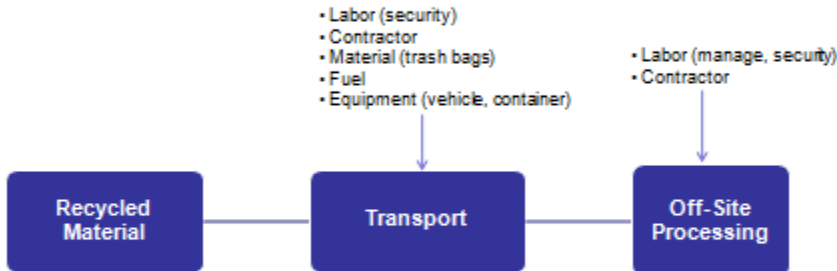
Expanded: Contractor Supported COP, FOB, LSA, & JB Process Flow Diagram



COP = Combat Outpost; FOB = Forward Operating Base; LSA = Logistics Support Area
Expanded = up to 180 days of initial camp establishment



Enhanced: Contractor Supported – Part 2 FOB, LSA, & JB Process Flow Diagram



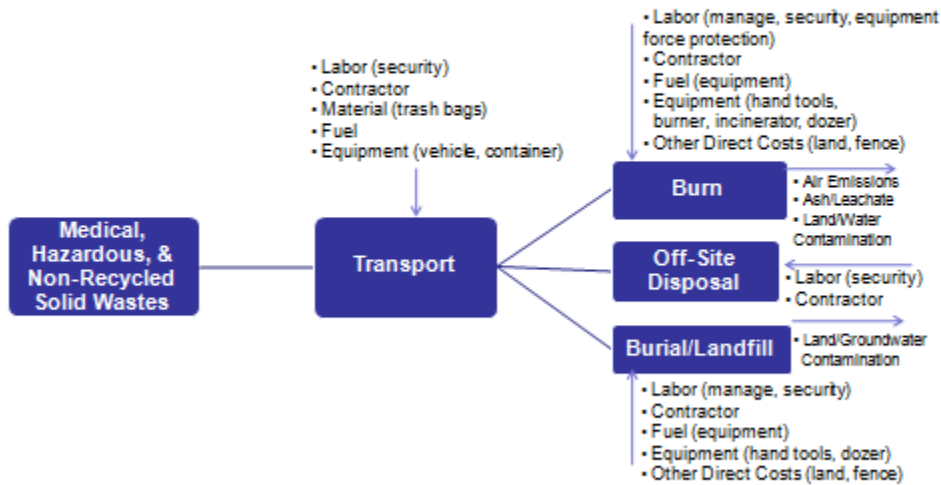
FOB = Forward Operating Base; LSA = Logistics Support Area; JB = Joint Base
Enhanced = beyond 180 days of initial camp establishment

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7

Task -0609 Methodology Briefing – June 2010

Enhanced: Contractor Supported – Part 3 FOB, LSA, & JB Process Flow Diagram



FOB = Forward Operating Base; LSA = Logistics Support Area; JB = Joint Base
Enhanced = beyond 180 days of initial camp establishment

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8

Task -0609 Methodology Briefing – June 2010

Fully Burdened Cost Method

- Cost estimating method

- Non-cost Categories = quantities that drive cost calculations

- Generation - i.e., lbs/person/day

- Disposal - i.e., lbs/year

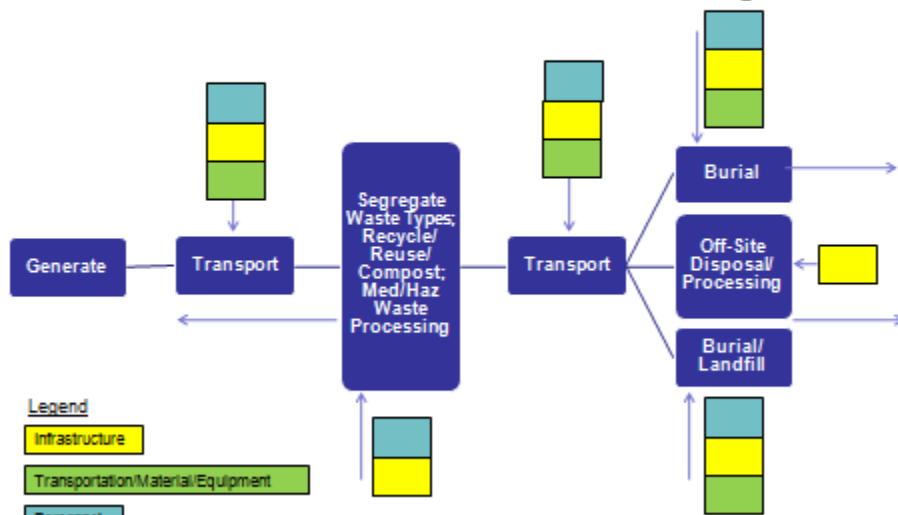
- Cost Categories

- Infrastructure

- Transportation/Material/Equipment

- Personnel

Enhanced: Contractor Supported FOB, LSA, & JB Process Flow Diagram



APPENDIX B
Bibliography

Table B-1 - Personal Communication with Subject Matter Experts and In-Theater Personnel

Person	Organization	Date	Type of Communication	Subject of Communication
Chapel Burgess	CTC, formerly a Portage Environmental contractor with AFCENT	3/16/10	Phone call	SW/HW/MW protocol in AFG bases
Bill Carico	Army G4	10/6/09	Meeting	Water Planning Factors
Brian Echtenaw	DLADS (formerly DRMS)	9/28/10, 10/21/10	Phone calls, email	HW in Iraq and AFG, HW contract for AFG, DRMS procedures
Brian Echtenaw	DLADS (formerly DRMS)	Numerous	Emails	HW totals in Iraq and AFG, DRMS HW contract info
John Horstmann	Dept. of Army civilian, working for ARCENT	4/8/10	Phone call	SW/WW/ HW/MW protocol in AFG bases; MILCON projects
John Horstmann	Dept. of Army civilian, working for ARCENT	4/26/10	Email	WW treatment options and marketing info
Kurt Kinnevan	USACE, CERL	5/3/10, 10/5/10	Phone calls	Waste mgmt planning, contractors in theater, measuring waste
Jennifer McCarthy	Environmental Chief, USF-I J7 Basing	9/16/10	Phone call	HW protocol in Iraq, URS contract, incinerators
Jennifer McCarthy	Environmental Chief, USF-I J7 Basing	Various	Emails	HW amounts in Iraq, used oil info
Ken Mioduski	USA MEDCOM	10/13/10	Phone call	MW contacts for Iraq/AFG, MW incinerators
Mickey Milnes	VP of ACS, Inc. (SW incinerator manufacturer)	9/28/10	Phone call, email	ACS SW incinerators in AFG, throughputs, fuels
Carter Mullen	CTC, in Kandahar, AFG for QA/QC audits	8/4/10	Phone call	Kandahar waste and WW procedures
Carter Mullen	CTC, in Kandahar, AFG for QA/QC audits	Numerous	Emails	Kandahar waste and WW reports
John Reddy	EnviroTech Corporation, AFG	6/11/10, 8/12/10	Phone calls	Waste mgmt practices in AFG, specifically

	Environmental Mgr			Bagram, water and WW at Bagram, other POCs for Bagram
John Reddy	EnviroTech Corporation, AFG Environmental Mgr	Numerous	Emails	Bagram specifics, used oil info
Jim Sheehy	Army Public Health Command (formerly CHPMM)	9/20/10	Phone call	MW contacts for Iraq/AFG, MW incinerators
Jon Sojka	Former KBR and TEAM Integrated Engr. employee stationed in various camps in Iraq	9/16/10, 10/15/10	Phone calls	HW procedures in Iraq; equipment, transportation, and personnel specifics
Jon Sojka	Former KBR and TEAM Integrated Engr. employee stationed in various camps in Iraq	Numerous	Emails	Iraq equipment, transportation, and personnel specifics
Chris Traywicke	APC Products, Inc. (MW incinerator manufacturer)	10/25/10	Phone call	MW incinerators in AFG, costs, protocol
LTC Robert Tucker, PhD	USFOR-A, Joint Program Integration Office	4/30/10	Phone call	Policies in Kabul, AFG; SW planning
LTC Robert Tucker, PhD	USFOR-A, Joint Program Integration Office	4/29/10	Email	Foam tents, DFAC waste costs
Christopher Waechter	Fluor (LOGCAP contractor in Bagram)	10/26/10	Emails	MW procedures in Bagram
Mike Wolford	Portage Environmental, contractor for AFCENT	4/6/10, 9/14/10, 9/23/10	Phone calls	SW/WW/ HW/MW protocol in AFG bases; MILCON projects, alternative technologies, Oil CATs, Bagram specific info
Mike Wolford	Portage Environmental, contractor for AFCENT	Numerous	Emails	Recycling info, HW amounts in AFG, used oil info, Oil CAT info, presentation materials

Bibliography

- 10 *United States code (USC) 101[a][13]*. (2010, February 1). Washington, DC: *Office of the Law Revision Counsel, U.S. House of Representatives*. Retrieved November 30, 2010, from <http://uscode.house.gov/uscode-cgi/fastweb.exe?getdoc+uscview+t09t12+41+1++%28%29%20%20AND%20%28%2810%29%20ADJ%20USC%29%3ACITE%20AND%20%28USC%20w%2F10%20%28101%29%29%3ACITE>
- 40 *CFR: Protection of the Environment*. (2010, July 1.) Washington, DC: United States Government Printing Office.
- Active Water Sciences (AWS) Self-Contained Wastewater Treatment System. (n.d.). Stockbridge, GA: EnvironTech.
- Active Water Sciences (AWS) Self-Contained Wastewater Treatment System: WATER IBIS™. (n.d.). Palestine, TX: AWS.
- Active Water Sciences (AWS) Self-Contained Wastewater Treatment System: Water Phoenix™. (n.d.). Stockbridge, GA: EnvironTech.
- Afghanistan and Iraq: DOD Should Improve Adherence to Its Guidance on Open Pit Burning and Solid Waste Management*. (2010, October 15). GAO-11-63, Washington, DC: U. S. Government Accountability Office. Retrieved November 30, 2010, from <http://www.gao.gov/products/GAO-11-63>
- Ailing vets sue over smoke from trash fires in Iraq, Afghanistan. (2010, August 6). Retrieved October 19, 2010, from http://www.msnbc.msn.com/id/38588943/ns/us_news-crime_and_courts/
- Anaparti, A.M. (2010, June). The effect of ammonia on aquatic plants. Retrieved September 1, 2010, from http://www.ehow.com/about_6666137_effect-ammonia-aquatic-plants.html
- Andel, J., Anderson, R., Gump, T., Matheson, S., & Riemer, N., Sverdrup Technology/TEAS Group. (2000, June). *Deployable Waste Management System Study*. AAC Technical Report 00-09. Eglin Air Force Base, FL: 46th Test Wing, Air Armament Center, Air Force Materiel Command, United States Air Force.
- Anderson, G., & Wolf, W. (2004, October-December). “One-stop” waste disposal – enhancing force protection in Afghanistan. *Engineer: The Professional Bulletin for Army Engineers*, 5-7.
- Anderson, J. (2007, March 27). Joint Facilities Utilization Board results for 27 Mar 2007. Memorandum for Multi-National Corps - Iraq, JFUB Validation Board. Baghdad, Iraq: Headquarters Multi-National Corps – Iraq.
- Anderson, J. (2007, April 28). Joint Facilities Utilization Board results for 28 Apr 2007. Memorandum for Multi-National Corps - Iraq, JFUB Validation Board. Baghdad, Iraq: Headquarters Multi-National Corps – Iraq.
- Anderson, J. (2007, June 15). Joint Facilities Utilization Board results for 15 June 2007. Memorandum for Multi-National Corps - Iraq, JFUB Validation Board. Baghdad, Iraq: Headquarters Multi-National Corps – Iraq.

- Anderson, J. (2007, September 15). Joint Facilities Utilization Board results for 15 September 2007. Memorandum for Multi-National Corps - Iraq, JFUB Validation Board. Baghdad, Iraq: Headquarters Multi-National Corps – Iraq.
- Anderson, J. (2007, November 20). Joint Facilities Utilization Board results for 20 November 2007. Memorandum for Multi-National Corps - Iraq, JFUB Validation Board. Baghdad, Iraq: Headquarters Multi-National Corps – Iraq.
- AOR Environmental Component Plan*. (2009, March). Prepared for United States Army Central. Atlanta, GA: CH2MHill, Military Planning Group.
- Army Cost and Factors Handbook (CFH)*, FY09. (n.d). Army Financial Management, Assistant Secretary of the Army for Financial Management & Comptroller. Retrieved March-October 2010 from the *Force and Organization Cost Estimating System (FORCES)* website, <https://www.osmisweb.army.mil/>
- Army Equipping Enterprise System (AE2S). (2010). Retrieved October 19, 2010, from <https://afm.us.army.mil/ae2slogin/login.jsp?TYPE=33554433&REALMOID=06-03f88abb-871e-1020-914d-84a74d100cb3&GUID=&SMAUTHREASON=0&METHOD=GET&SMAGENTNAME=-SM-ejRmnYy3iZfHvD6XCHvgcDZ2wZR2APURU%2bnolsvKAXFn0AG1QxS5YvS1qMM5QuX8vkk3rFh8PGY8x4JOWe2mC7rw4A%2bUMak>
- The Army Strategy for the Environment: “Sustain the Mission – Secure the Future.”* (2004, October 1). Washington, DC: Office of the Assistant Secretary Of The Army for Installations and Environment. Retrieved October 19, 2010, from <http://www.sustainability.army.mil/>
- August, O. (2010, June 14). America leaves Iraq a toxic legacy of dumped hazardous materials. *The (London) Times*. Retrieved from October 19, 2010, <http://www.timesonline.co.uk/tol/news/world/iraq/article7149611.ece>
- Backyard Burning: Environmental Effects*. (2008, October). U.S. Environmental Protection Agency. Retrieved October 22, 2010, from <http://www.epa.gov/epawaste/nonhaz/municipal/backyard/env.htm>.
- Barlaz, M.A., Baun, A., Christensen, T.H., Kjeldsen, P., Ledin, A., & Rooker, A. P. (2002, October). Present and long-term composition of MSW landfill leachate: A review, critical reviews in environmental science and technology. London, UK: Taylor & Francis. Volume 32, no. 4 (2002): 297-336.
- Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal. (n.d). Geneva, Switzerland: Secretariat of the Basel Convention, International Environment House. Retrieved October 19, 2010, from <http://www.basel.int/convention/basics.html>
- Beehler, A.A. (2008, February 1). DoD Integrated (Non-Hazardous) Solid Waste Management Policy. Memorandum. Washington, DC: Under Secretary of Defense for Acquisition, Technology, and Logistics.
- Board of Environmental Studies and Toxicology, Commission on Life Sciences, Committee on Health Effects of Waste Incineration, & National Research Council. (2000). *Waste Incineration and Public Health*. Washington, DC: National Academy Press.

- Bush, T.A., Geiman, J.A., Harrison, M. A., Ruppert, W.H., & Verdonik, D.P. (2004, August). *Force Provider Solid Waste Characterization Study*. Baltimore, MD: Hughes Associates, Inc.
- Campbell, Jr., D. M. (2006, July 4). Joint Facilities Utilization Board results for 4 Jul 2006. Memorandum for Multi-National Corps - Iraq, JFUB Validation Board. Baghdad, Iraq: Headquarters Multi-National Corps – Iraq.
- Campbell, Jr., D. M. (2006, August 24). Joint Facilities Utilization Board results for 24 Aug 2006. Memorandum for Multi-National Corps - Iraq, JFUB Validation Board. Baghdad, Iraq: Headquarters Multi-National Corps – Iraq.
- Canes, M., Werle, C. P., Philipp, M. W., Logistics Management Institute; & Mosko, S. A., U.S. Army. (2004, February.) *An Analysis of the Energy Potential of Waste in the Field*. DRP30T1. McLean, VA: Logistics Management Institute.
- Canes, M. E., LMI Government Consulting. (2005, September 20). *Economics of Converting Military Waste to Fuel*. Briefing presented at the IAEE North American Meetings; Denver, CO.
- Carter, A. B. (2010, March 30). Use of open-air burn pits in Contingency Operations. Directive-type Memorandum (DTM) 09-032. Washington, DC: Under Secretary of Defense for Acquisition, Technology, and Logistics.
- Cawthorne. U.S. Army Central Command. (2009, February 25). Contingency Environmental: OIF/OEF. Presentation.
- Chen, I. (2010, July 5). In a world of throwaways, making a dent in medical waste. *The New York Times*. Retrieved October 19, 2010, from http://www.nytimes.com/2010/07/06/health/06waste.html?_r=2
- Cockerill-Kafka, K., Forrest, R., Funke, O., & Huppertz, C. (1992, July). *Analysis of U.S. Army Solid Waste Management Policy*. Champaign, IL: Army Environment Policy Institute.
- Concurrent Technologies Corporation (CTC). (2010). Retrieved October 19, 2010, from <http://www.ctc.com/>
- Cooper III, R. G., 76th Infantry Brigade Combat Team. (2008, July 14). Recycling contract turns trash into treasure. Retrieved October 19, 2010, from <http://www.balad.afcent.af.mil/news/story.asp?id=123106443>
- Cosper, S., Construction Engineering Research Laboratory, U.S. Army Engineer Research and Development Center. (2010, March 9). Forward Operating Bases Solid Waste Characterization. Presentation.
- Cosper, S., Construction Engineering Research Laboratory, U.S. Army Engineer Research and Development Center. (2008, May 28-29). Installation waste quantity & characterization. Briefing presented at the Installation Waste to Energy Workshop, Army Research Office, Research Triangle Park, NC.
- Curtis, D., Former Bioenvironmental Engineer, U.S. Air Force. Witness testimony during Democratic Policy Committee Hearing: Are burn pits in Iraq and Afghanistan making our soldiers sick?

- Curtis, D. L. (2006, December 20). *Burn Pit Health Hazard*. Balad Air Force Base, Iraq: Department of the Air Force.
- Defense Logistics Agency (DLA). (2004, April). Contingency operations update: DRMS. Presentation.
- Defense Logistics Agency (DLA), Disposition Services. (2010). Retrieved October 19, 2010, from <http://www.drms.dla.mil/drmo/drmo-locations.shtml>
- Department of the Army Cost Analysis Manual*. (2001 or 2002, May). U.S. Army Cost and Economic Analysis Center.
- DoD Facilities Pricing Guide for Fiscal Year 09*. (2010). UFC 3-701-01. Office of the Deputy Under Secretary of Defense, Installations and Environment (ODUSD[I&E]). Retrieved March-October 2010, from http://www.acq.osd.mil/ie/fim/programanalysis_budget/tool_metrics/FPG/fpg.shtml
- DRMS Hazardous Waste Disposal/Cost, Version 1.0.2. (n.d.). Retrieved October 19, 2010, from <https://www.drms.dla.mil/hazmat/servlet/Main>
- DRMS Hazardous Waste Disposal/Cost*. (n.d.). Contract Number: SP442008D0011. Retrieved October 19, 2010, from <https://www.drms.dla.mil/hazmat/servlet/ShowContract?CONTRACT=SP442008D0011>
- Dwyer, R.E. (2009, April). Who's the BOS-I? Base operating support integrator and senior airfield authority at deployed bases. Maxwell Air force Base, AL: Air Command and Staff College.
- Eady, D. S., Siegel, S. B., Bell, R. S., & Dicke, S. H., National Defense Center for Energy and Environment (NDCEE). (2009, September). *Sustain the Mission Project: Casualty Factors for Fuel and Water Resupply Convoys*. Final Technical Report. AEPI Report. Arlington, VA: Army Environmental Policy Institute.
- Eady, D. S., Siegel, S. B., Stroup, K. K., Tomlinson, T. M., Kaltenhauser, H. A., & Rivera-Ramirez, M. H., National Defense Center for Energy and Environment (NDCEE). (2006, July). *Sustain the Mission Project: Resource Costing and Cost-Benefit Analysis*. AEPI Report. Arlington, VA: Army Environmental Policy Institute.
- Efficient Solid Waste Collection*. (2009, December 31.) Public Works Technical Bulletin 200-1-68. Washington, DC: U.S. Army Corps of Engineers.
- Employment of the Combat Support Hospital Tactics, Techniques, and Procedures*. (1994, December 29). Field Manual. FM 8-10-14. Washington, DC: Headquarters, Department of the Army.
- Employment of the Field and General Hospitals: Tactics, Techniques, and Procedures*. (1997, March 26). Field Manual. FM 8-10-15. Washington, DC: Headquarters, Department of the Army.
- Engineer Operations*. (2009, April 3). Field Manual. FM No. 3-34. Washington, DC: Headquarters, Department of the Army.

- Environmental Aspects of Military Compounds, Phase II: NATO/SPS Short Term Project.* (2007, May – 2008, May). Final Report. Report No. 283.
- Environmental Considerations in Full-Spectrum Operations.* (Date pending). Field Manual. FM 3-34.500/MCRP 4-11B (FM 3-100.4). Washington, DC: Headquarters, Department of the Army.
- Environmental Considerations in Military Operations.* (2000, June 15). Field Manual. FM 3-100.4/MCRP 4-11B. Washington, DC: Headquarters, Department of the Army.
- Environmental Guidebook for Military Operations.* (2008, March). Retrieved October 19, 2010, under the reference in the “international section” of US in <https://www.denix.osd.mil>
- Environmental Quality: Environmental Protection and Enhancement.* (2007, December 13). Army Regulation 200-1. Washington, DC: Headquarters, Department of the Army.
- Environmental Regulations and Technology: Control of Pathogens and Vector Attraction in Sewage Sludge.* (2003, July). EPA/625/R-92/013. Washington, DC: U.S. Environmental Protection Agency, Office of Research and Development.
- Facilities Engineering: Army Facilities Management.* (2008, February 12). Army Regulations 420-1. Washington, DC: Headquarters, Department of the Army.
- Field Hygiene and Sanitation.* (2000, June 21). Field Manual. FM 21.10 and MCRP 4-11.1D. Washington, DC: Headquarters, Department of the Army and Commandant, Marine Corps.
- Fiscal Year 2007 Defense Environmental Programs Annual Report to Congress.* (2008). Washington, DC: Office of the Deputy Under Secretary of Defense (Installations and Environment). Retrieved October 19, 2010, in <https://www.denix.osd.mil/portal/page/portal/ARC>
- Fully Burdened Cost of Delivered Fuel—Methodological Guidance for Analyses of Alternatives and Acquisition Tradespace Analysis.* (2009). Defense Acquisition University.
- Gerdes, G. L., Curtin, D., & Gutkowski, C. (2008, September). *Hydrothermal Processing of Base Camp Solid Wastes To Allow Onsite Recycling: Final Report.* ERDC/CERL TR-08-13. Champaign, IL: Construction Engineering Research Laboratory, U.S. Army Engineer Research and Development Center.
- Gerdes, G. L. & Jantzer, A. L. (2006, September). *Base Camp Solid Waste Characterization Study.* ERDC/CERL TR-06-24. Champaign, IL: Construction Engineering Research Laboratory, U.S. Army Engineer Research and Development Center.
- Glor, J. (2010, June 26). Cloud of smoke could put soldiers’ lives at risk. *CBS Evening News.* Retrieved October 19, 2010, from <http://www.cbsnews.com/stories/2010/06/26/eveningnews/main6622262.shtml?tag=contentBody;featuredPost-PE>
- Green, B., & Horstmann, J., U.S. Army Central Command. (n.d.). USARCENT – Base Camp Requirements. Briefing presented at the September 24-25, 2009, Expeditionary Basing Collaborative Program Planning Workshop, Natick, MA.

Greenberg, M. D., Lachman, B.E., Mosher, D.E., Nichols, T., Rosen, B., & Willis, H. H. (2008). *Green Warriors: Army Environmental Considerations for Contingency Operations from Planning Through Post- Conflict*. Santa Monica, CA: RAND Corporation.

Guidance for the Sampling and Analysis of Municipal Waste Combustion Ash and for the Toxicity Characteristic. (1995, June). EPA Publication No. EPA530-R-95-036. Washington, DC: U.S. Environmental Protection Agency, Office of Solid Waste.

Guide for Developing Integrated Solid Waste Management Plans at Army Installations. (2007, September). Technical Guide 197. Aberdeen Proving Ground, MD: USACHPPM Ground Water and Solid Waste Program.

Guide to Army Real Property Category Codes. (2006, April 11). Pamphlet 415-28. Washington, DC: Headquarters, Department of the Army.

Guidelines for Field Waste Management. (2006, September, 15.) Technical Bulletin. TB MED 593. Washington, DC: Headquarters, Department of the Army.

Haddad, R. & Hampton, A., United States Army Natick Soldier Research, Development & Engineering (RD&E) Center; United States Army Research, Development, and Engineering Command (RDECOM). (2009, September 24). Combat Outposts & Patrol Bases: Recent Experiences & Lessons Learned. Briefing presented at the September 24-25, 2009, Expeditionary Basing Collaborative Program Planning Workshop, Natick, MA.

Hall, K. D., Guo, J., Dore, M., & Chow, C. C., Laboratory of Biological Modeling, National Institute of Diabetes and Digestive and Kidney Diseases. (2009, November). The progressive increase of food waste in america and its environmental impact. PLoS ONE 4(11): e7940. doi:10.1371/journal.pone.0007940

Harrison, E.Z., & McBride, M. (2008, September). *Case for Caution Revisited: Health and Environmental Impacts of Application of Sewage Sludge To Agricultural Land*. Ithaca, NY: Cornell Waste Management Institute.

Hazardous Material/Hazardous Waste Management Guidance for Maneuver Units During Field and Deployment Operations. (2000, October). Technical Guide. TG 217. Aberdeen Proving Ground, MD: U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM).

Headquarters and Headquarters Units, Petroleum and Water Distribution Organization. (1996, September 12). Field Manual. FM 10-602. Washington, DC: Headquarters, Department of the Army.

Holcomb, F. H., U.S. Army Engineer Research and Development Center (ERDC)/Construction Engineering Research Laboratory (CERL); Parker, R. S, Select Engineering Services (SES); Hartranft, T. J., ERDC/CERL; Preston, K., U.S. Army Research Office (ARO); Sanborn, H. R., U.S. Army Tank Automotive Research Development and Engineering Center (TARDEC), National Automotive Center (NAC); & Darcy, P. J., Benét Laboratories. (2008, August). *Proceedings of the 1st Army Installation Waste to Energy Workshop*. Final Report. ERDC/CERL TR-08-11. Washington, DC: U.S. Army Corps of Engineers.

Hubbard, B. E., Litke, D. W., Michel, R. L., Plummer, L. N., Rezai, M. T., Senay, G. B., Hull, C., Eriksson, M., MacDermott, J., Ruden, F., & Waleij, A. (2009, December). *Managing Unintended Consequences of Peace Support Operations*. FOI-R-2916-SE. Stockholm, Sweden: FOI, Swedish Defence Research Agency.

Husky's Guide to PET Bottles. (n.d.). Retrieved October 19, 2010, from http://www.factsonpet.com/Articles/Facts%20on%20PET%20Flyer_June18%20PRINT.pdf

In re: KBR burn pit litigation. (n.d.). Case 8:09-md-0283RWT, Document 49. United States District Court for District of Maryland.

Jeziarski, K. (1991). *Reliable, Secure and Efficient Energy Demonstrations (RSEED) at Military Installations*. Washington, DC: Department of Defense.

Joint Engineer Operations. (2007, February 12). Joint Publication 3-34. Joint Chiefs of Staff.

Joint Monitoring Programme for Water Supply and Sanitation. (2010, March). Estimates for the use of improved sanitation facilities: Iraq. WHO/UNICEF. Retrieved September 15, 2010, from www.wssinfo.org.

Joint Monitoring Programme for Water Supply and Sanitation. (2010, March). Estimates for the use of improved sanitation facilities: Afghanistan. WHO/UNICEF. Retrieved September 15, 2010, from www.wssinfo.org.

Just the facts: Balad Burn Pit. (n.d.). Aberdeen Proving Ground, MD: USACHPPM Deployment Environmental Surveillance Program.

Just the facts: Medical waste disposal during contingency operations. (n.d.). Fact sheet 37-031-0205. Aberdeen Proving Ground, MD: Hazardous and Medical Waste Program (HMWP), U.S. Army Center for Health Promotion and Preventive Medicine. Retrieved October 19, 2010, from <http://phc.amedd.army.mil/PHC%20Resource%20Library/37-031-0205.pdf>

Just the facts: Particulate matter (PM) air pollution exposures during military deployments. (n.d.). Fact sheet 64-009-0708. Aberdeen Proving Ground, MD: U.S. Army Center for Health Promotion and Preventive Medicine, Directorate of Occupational and Environmental Medicine. Retrieved October 19, 2010, from http://phc.amedd.army.mil/PHC%20Resource%20Library/Particulate%20Matter_Factsheet_2008_30%20July_08_final.pdf

Just the Facts...Solid waste burning (trash and feces fires) - individual. (n.d.). Fact sheet 65-036-0503. Aberdeen Proving Ground, MD: USACHPPM Deployment Environmental Surveillance Program.

Just the facts: Solid waste burning (trash and feces fire) - medical. (n.d.). Aberdeen Proving Ground, MD: USACHPPM Occupational and Environmental Medicine.

Keith, L.R., Former KBR Medic. (2009, November 6). Witness testimony during Democratic Policy Committee Hearing: Are burn pits in Iraq and Afghanistan making our soldiers sick?

- Kidd, S. R. (2006, August 1). Blending of waste oil with fuel on tactical wheeled vehicle systems. Memorandum. Warren, MI: Department of the Army, Program Executive Office, Combat Support and Combat Service Support.
- Kinnevan, K. J., United States Army Engineer School, Directorate of Environmental Integration; & Preston, K., United States Army Research Office, Environmental Sciences Division. (2006, July). Environmental aspects of military compounds, base camps: "the environment, sustainability link." Briefing presented at the July 25-27, 2006, Overseas Environmental Workshop (location unknown).
- Knox, A. (2005, February). *An Overview of Incineration and EFW Technology as Applied to the Management of Municipal Solid Waste*. Ontario, Canada: University of West Ontario.
- Kramer, S. (2009, June 11). Statement at a press conference on proposed burn pit legislation. Washington, DC: Epidemiology International.
- Lemieux, P. M. (1997, November). *Evaluation of Emissions from the Open Burning of Household Waste in Barrels*. Volume 1. Technical Report. EPA-600/R-97-134a. Research Triangle Park, NC: U.S. Environmental Protection Agency, National Risk Management Research Laboratory, Air Pollution Prevention and Control Division.
- Logistic: Integrated Logistics Support*. (2008, July). Washington, DC: Headquarters, Department of the Army.
- LSA Anaconda – Virtual tour & dump. (2008, April 8). Retrieved October 19, 2010, from <http://missingman.blogspot.com/2008/04/lsa-anaconda-virtual-tour.html>
- Mack, T. J., Akbari, M. A., Ashoor, M. H., Chornack, M. P., Coplen, T. B., Emerson, D. G., Miller, G. T., & Spoolman, S. (2004). *Living in the Environment: Principles, Connections, and Solutions*. 13th edition. Belmont, CA: Brooks/Cole.
- Maron, D. F. (2009, December 22). Air pollution: Pentagon shifts stance on burn pits, acknowledges health effects. Retrieved October 19, 2010, from <http://www.eenews.net/public/Greenwire/2009/12/22/2>
- Martinsson, E., Waleij, A., Lewis, J., & Liljedahl, B. (2010, April). *Base Camp Solid Waste Management: Challenges and Way Forward, Towards Sustainable Management Practices*. FOI-R-2849-SE. Stockholm, Sweden: FOI, Swedish Defence Research Agency.
- Mayes, B. G. (2010, April 26). Environmental hazards in Iraq, Afghanistan, and other military installations. Training Letter 10-03. Washington, DC: Department of Veterans Affairs, Veterans Benefits Administration.
- MEWEPS: Military Encampment Waste to Electrical Power System*. (n.d.). Detroit, MI: Next Energy.
- Mobile Source Emissions – Past, Present and Future: Pollutants*. (2007, July). Washington, DC: U.S. Environmental Protection Agency, Office of Transportation and Air Quality. Retrieved October 19, 2010, from <http://www.epa.gov/otaq/invntory/overview/pollutants/index.htm>
- Mosher, D. E., Lachman, B. E., Greenberg, M. D., Nichols, T., Rosen, B., & Willis, H. H. (2008). *Green Warriors: Army Environmental Considerations for Contingency Operations from Planning Through*

- Post-Conflict*. AEPI-04001. Santa Monica, CA: RAND Arroyo Center. Retrieved October 19, 2010, from <http://www.rand.org/pubs/monographs/MG632/>
- Mukhtar, S., Nash, C., Harman, W., & Padia, R. (2008, July). How much does that incinerator cost? B-6209. AgriLIFE EXTENSION, Texas A&M System.
- Nasuti, M. (2010, May 2). Exclusive report: American military burn pits pollute Afghan countryside (part 2 of 3). *Kabul Press*. Retrieved October 19, 2010, from <http://kabulpress.org/my/spip.php?article9030>
- National Defense Authorization Act for Fiscal Year 2010*. (2009, October 28). 123 STAT. 2190, Public Law 111–84. Washington, DC: United States Government Printing Office.
- National Defense Center for Energy and Environment (NDCEE). (2010). Retrieved October 19, 2010, from <http://www.ndcee.ctc.com/>
- O&S Cost Web. (2010). Retrieved October 19, 2010, from <https://www.osmisweb.army.mil/>
- Oil Cat: Oil - Change Alternative Technology*. (n.d.). Retrieved October 19, 2010, from http://www.clarustechnologies.com/pdf_files/brochures/Oil-CAT.pdf
- Overseas Environmental Baseline Guidance Document (OEBGD)*. (2007, May 1). DoD 4715.05-G. Washington, DC: Under Secretary of Defense for Acquisition, Technology, and Logistics.
- Peterson, S. (2010, July 22). As Iraq war winds down, US military cleans up hazardous waste. *The Christian Science Monitor*. Retrieved October 19, 2010, from <http://www.csmonitor.com/World/Europe/2010/0722/As-Iraq-war-winds-down-US-military-cleans-up-hazardous-waste>
- Plumbing, Pipe Fitting, and Sewerage*. (2001, August 31). Field Manual. FM 3-34.471. Washington, DC: Headquarters, Department of the Army.
- Responsible Drawdown: Brigade Combat Team Redeployment*. (2010, March). Handbook No. 10-32. Fort Leavenworth, KS: Center for Army Lessons Learned (CALL).
- Revised Risk Assessment for the Air Characteristic Study*. (1999, November). Volume I. EPA 530-R-99-091a. Washington, DC: U.S. Environmental Protection Agency, Office of Solid Waste.
- Rosenthal, E. (2010, October 4). U.S. military orders less dependence on fossil fuels. *The New York Times*. Retrieved October 19, 2010, from http://www.nytimes.com/2010/10/05/science/earth/05fossil.html?_r=4&th&emc=th
- Ruppert, W. H., Bush, T. A., Verdonik, D. P., Geiman, J. A., & Harrison, M. A. (2004, August). *Force Provider Solid Waste Characterization Study*. Technical Report. Natick/TR-04/017. Baltimore, MD: Hughes Associates, Inc.
- Sanitary Control and Surveillance of Field Water Supplies*. (2010, May 1). Army Technical Bulletin Medical , Navy Bureau of Medicine and Surgery, Air Force Manual 48-138_IP. Technical Bulletin. TB MED 577/ NAVMED P-5010-10/AFMAN 48-138_IP. Washington, DC: Departments of the Army, Navy and Air Force.

- Sanitary Landfill*. (1994, January 15). Technical Manual. TM 5-814-5. Washington, DC: Headquarters, Department of the Army.
- Sharpe, S. (n.d.). Ammonia poisoning. Retrieved October 1, 2010, from <http://freshaquarium.about.com/cs/disease/p/ammoniapoison.htm>.
- Solid Waste Disposal Civil Engineering Design Manual 5.10*. (1997, September 1). SN0525-LP-300-5077. Alexandria, VA: Naval Facilities Engineering Command.
- Solid Waste Generation Rates at Army Base Camps*. (2008, April 1). Public Works Technical Bulletin 200-1-51. Washington, DC: U.S. Army Corps of Engineers.
- Solid Waste Management*. (1990, May). Navy Manual, Air Force Regulation, and Army Technical Manual. NAVFAC MO-213, Air Force AFR 91-8, and Army TM 5-634. Washington, DC: Departments of the Army, the Navy, and the Air Force.
- Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks*. (2006, September). Edition 3. Washington, DC: U.S. Environmental Protection Agency.
- Sterling, Jr., J. E. (2006, September 8). Authorization for blending of waste oil with fuel on tactical wheeled vehicle systems. Memorandum. Fort Leonard Wood, MO: Department of the Army, Assistant Commandant, United States Army Engineer School.
- Stockholm International Water Institute. (2005). *Securing Sanitation—The Compelling Case To Address the Crisis*. Stockholm, Sweden: World Health Organization, Water Sanitation and Health.
- Storage and Handling of Hazardous Materials Manual*. (1999, January 13). Technical Manual. TM 38-410. Department of Defense.
- Strategic Environmental Research and Development Program (SERDP): Sustainable Forward Operating Bases*. (2010, August 3). Falls Church, VA: Noblis.
- Szema, A., Chief of Allergy Section in Veterans Affairs Medical Center. (2009, November 6). Witness testimony during Democratic Policy Committee Hearing: Are burn pits in Iraq and Afghanistan making our soldiers sick?
- Targeted National Sewage Sludge Survey Sampling and Analysis Technical Report*. (2009, January). Washington, DC: U.S. Environmental Protection Agency, Office of Water.
- Tchobanoglous, G., Davis University. (2003). Solid waste management. In J. A. Salvato, N. L. Nemerow, & F. J. Agardy (Eds.), *Environmental Engineering*, Fifth edition. Hoboken, NJ: John Wiley & Sons, Inc.
- Unified Facilities Criteria (UFC): Design: Hazardous Waste Storage*. (2004, January 16). UFC 4-451-10N. Department of Defense.
- Unified Facilities Criteria: DoD Facilities Pricing Guide*. (2009, September 15). UFC 3-701-09. Department of Defense.

- Unified Facilities Criteria: Sanitary Landfill*. (2004, January 16). UFC 3-204-10A. Department of Defense.
- Unit Field Sanitation Team*. (2002, January 25). Field Manual 4-25.12. Washington, DC: Headquarters, Department of the Army.
- United States Army Environmental Command (USAEC), Environmental Reporting Office. (2010). Retrieved October 19, 2010, from <http://aec.army.mil/usaec/aecorg-ero.html>
- United States Air Force (USAF). (2010). The Official Web Site of Bagram Air Field. Retrieved October 19, 2010, from <http://www.bagram.afcent.af.mil/>
- United States Air Force (USAF). (2010). The Official Web Site for Joint Base Balad, Iraq. Retrieved October 19, 2010, from <http://www.balad.afcent.af.mil/>
- United States Army Engineer Research and Development Center/U.S. Army Cold Regions Research and Engineering Laboratory (ERDC/CRREL) Remote Snow Assessment Team. (2010, May 27). Assessment of the state of the snowpacks in the major Afghanistan snow-impacted watersheds. Presentation.
- United States Army Training and Doctrine Command (TACOM). (2010). Retrieved October 19, 2010, from <http://www.tradoc.army.mil/tpubs/pamndx.htm>
- United States Department of the Interior, U.S. Geological Survey (USGS). (2010). USGS Projects in Afghanistan: Evaluation of groundwater in the Kabul Area. Retrieved October 19, 2010, from http://afghanistan.cr.usgs.gov/eval_groundwater.php
- Vargesco, A.M., Army Engineer School, Fort Leonard Wood. (2006, May-June). Fuel-oil blenders save time, money, and lives. *Army Logistician*. PB 700-06-03. Volume 38, issue 3. Retrieved October 19, 2010, from http://www.almc.army.mil/alog/issues/may-june06/oil_cat.html
- Verdin, J. P., & Verstraeten, I. M. (2010). *Conceptual Model of Water Resources in the Kabul Basin, Afghanistan: U.S. Geological Survey Scientific Investigations Report 2009-5262*. Retrieved October 19, 2010, from <http://pubs.usgs.gov/sir/2009/5262/>
- Vietas, J. A., Air Force Institute for Operational Health; Taylor, G., Rush, V., & Deck, A., U.S. Army Center for Health Promotion and Preventive Medicine. (2008, May). *Screening Health Risk Assessment Burn Pit Exposures, Balad Air Base, Iraq and Addendum Report*. IOH-RS-BR-TR-2008-0001; USACHPPM 47-MA-08PV-08. Brooks City-Base, TX: Air Force Institute for Operational Health, Risk Analysis Directorate, Health and Safety Division.
- Wang, Y., Naval Sea Systems Command, Environmental and Fluid Systems Group, Environmental Protection Systems Division (NAVSEA 03L1). (1997). Navy's Shipboard Solid Waste Management Program: Update 1997. Paper published in the Proceedings of The American Society of Naval Engineers, Tidewater Section, Environmental Symposium '97.
- Wolford, M., United States Army Engineer School Directorate of Environmental Integration. (n.d.). Fuel/oil blending. Briefing presented at the May 21-24, 2007, Joint Services Environmental Management (JSEM) Conference, Columbus, OH.

APPENDIX C

Fully Burdened Cost of Waste Management Method



App C_FBC of Waste
Method - Generation.

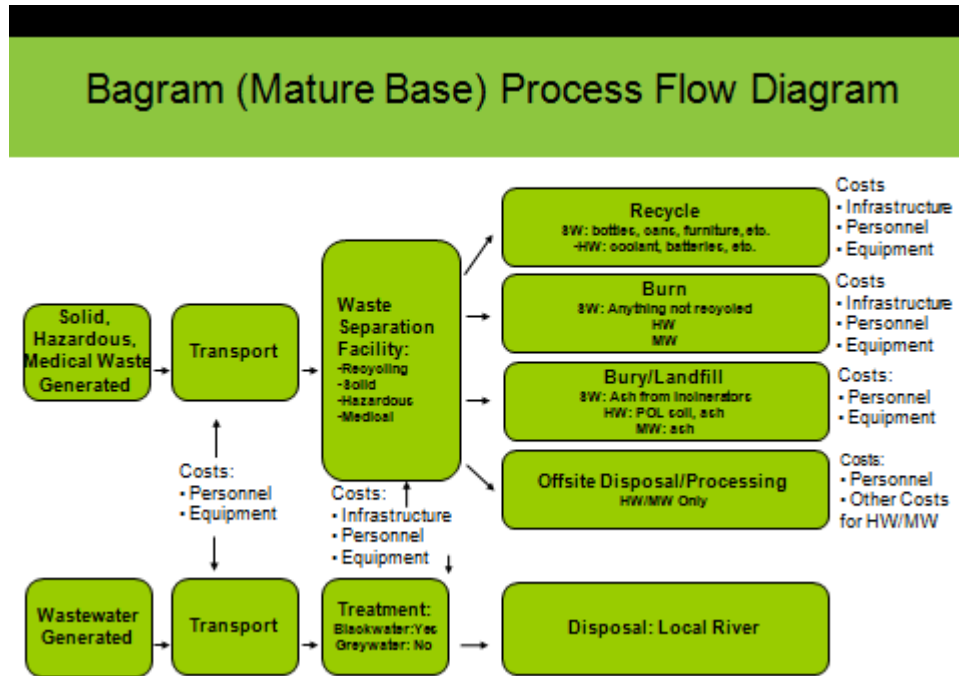
APPENDIX D

Fully Burdened Cost of Waste Bagram Demonstration Results

Demonstration Results

This Appendix includes details of the individual cost calculations conducted for the selected demonstration location, Bagram Air Force Base (AFB), Afghanistan. Steps included calculating waste generation rates, and then identifying waste management activities to quantify personnel, infrastructure, and transportation costs associated with these activities. Figure D-1 is the waste management process flow diagram for Bagram AFB.

Figure D-4: Bagram Process Flow Diagram



D.1 Bagram Baseline Estimates

Solid Waste Generation

Table D-1 shows a sample of the waste generation inputs from the cost estimation method spreadsheets created through the fully burdened cost (FBC) method. As shown in this table, both general waste (GW) and wastewater (WW) were calculated together in the spreadsheets based on the generation rates discussed in this section of the report. The estimated GW amount is 8 pounds (lbs) per person. According to planning factors used by in-theater personnel, blackwater accounts for 40% of the total wastewater generated at Bagram (26 gallons per person per day) and greywater accounts for 60% of the total wastewater generated at Bagram (39 gallons per person per day).

Table D-1. Data Inputs to Solid Waste Generation Calculations

Field	Value	Unit
# of people on base	27,000	people
General waste	8	lbs/year
Wastewater: total	65	gallons/year
Wastewater: blackwater	26	gallons/year
Wastewater: greywater	39	gallons/year

The total quantity of waste generated at Bagram is calculated as a function of the population (27,000 people) and the estimated GW generation rate of 8 lbs per person per day, yielding total annual waste generation of 78.8 million lbs or 39,420 tons. The total quantity of wastewater generated at Bagram is a function of the population and an estimated wastewater generation rate of 65 gallons per person per day¹, yielding total annual wastewater generation of 641 million gallons. Using the breakdown of blackwater/greywater shown in Table D-1, Bagram’s total annual blackwater generation is 256 million gallons and its total annual greywater generation is 384 million gallons (Table D-2).

Table D-2. Total Solid Waste Generation for Bagram (1-Year Period)

Waste Type	Value	Unit
General waste	78,840,000	lbs/year
Wastewater: total	640,575,000	gallons/year
Wastewater: blackwater	256,230,000	gallons/year
Wastewater: greywater	384,345,000	gallons/year

Solid Waste Disposal

General Waste

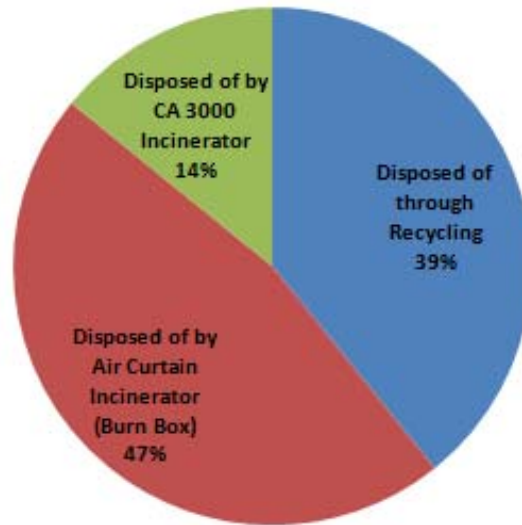
Bagram AFB uses several methods to dispose of solid waste. Each method is identified in the method section of the cost estimation method. To calculate costs based upon the demand for equipment use, the disposal pathway followed by each waste stream and the means by which it is disposed must be identified. In the cost estimation method, a percentage of the total waste generated is allocated to each of these disposal methods.

Methods of GW disposal available at Bagram include (1) recycling, (2) combustion using an Air Curtain Incinerator (Burn Box), and (3) combustion using an Advanced Combustion Systems CA 3000 Incinerator.

Discussions with subject matter experts (SMEs) identified the disposal pathways at Bagram and the portion of GW allocated to each pathway. Approximately 40% of Bagram’s GW is disposed of by recycling. The remaining 60% was incinerated and disposed of in the nearby landfill at the end of 2009 and beginning of 2010 (Figure D-2).

¹ See Table B-1 in Appendix B for a listing of personal communication with SMEs and in-theatre personnel.

Figure D-2. General Waste Disposal by Destination for Bagram (1-Year Period)



Wastewater

At Bagram, wastewater is released into a river or *wadi*. Greywater is directly disposed of without treatment. Blackwater is trucked to a nearby lagoon near a sewage treatment facility and later disposed of in a river. The non-monetary risks and liabilities that are associated with these waste treatment and disposal methods are discussed in the following.

Solid Waste Management Infrastructure Costs

Waste management facilities and infrastructure include all buildings associated with waste collection, treatment, and disposal. Fencing used for building security is also included in this category. From an accounting standpoint, facilities and infrastructure costs include: (1) annualized capital cost, (2) cost of equipment operations and maintenance (O&M) incurred during use, and (3) fuel costs.

Bagram AFB is equipped with facilities used for general waste collection, recycling, and incineration, in addition to a fenced 40-acre landfill.² Annual waste management facility and infrastructure costs are the sum of annual capital and O&M costs for all facilities (Tables D-3 and D-4).

² See Table B-1 in Appendix B for a listing of personal communication with SMEs and in-theatre personnel.

Table D-3. Solid Waste (GW and WW) Management Infrastructure Cost Calculations for Bagram (1-Year Period)

Refuse and Garbage Facilities	Value	Unit	Annualized Capital Cost	Annualized O&M Cost *	Annualized Capital & O&M Cost
Refuse Collection Facility	1	Each	\$ 5,845	\$ 5,655	\$ 11,500
Recycling Facility	1	Each	\$ 5,845	\$ 5,655	\$ 11,500
Utility Building (Refuse and Garbage Building)	40,000	Square Feet	\$ 121,732	\$ 165,119	\$ 286,851
Sanitary Landfill	40	Acres	\$ 771,033	\$ 272,244	\$ 1,043,277
Incinerator (CA 3000)	1	Tons per Hour (for 1 CA 3000)	\$ 6,387	\$ 1,018,787	\$ 1,025,174
Air Curtain Incinerator (Burn Box)	1	Tons per Hour (for 2 Burnboxes)	\$ 7,205	\$ 1,997,621	\$ 2,004,827
Boundary Fence and Wall	5,280	Linear Feet	\$ 8,622	\$ 8,993	\$ 17,615
Septic Lagoon and Settlement Pond	702,000	Gallons per Day	\$ 21,079	\$ 10,596	\$ 31,675
Sewage Treatment Plant	702	Kilograms	\$ 81,608	\$ 92,830	\$ 174,438
Utility Building (Sewage/Waste Treatment Building)	40,000	Square Feet	\$ 121,732	\$ 165,119	\$ 286,851

Table D-4. Total Solid Waste Infrastructure Costs for Bagram (1-Year Period)

Sum of Infrastructure Annualized Capital & O&M Costs for Base Case: Bagram	\$ 4,893,706
DoD Area Cost Factor	1.46
Total Infrastructure Costs for Base Case: Bagram (Adjusted by Area Cost Factor)	\$ 7,144,811

Bagram AFB has a sewage lagoon and sewage treatment facility which treats blackwater. Blackwater is transported to the lagoon then taken into the nearby sewage treatment facility for a short period of time. It is then disposed of in a nearby river.

Solid Waste Management Personnel Costs

Waste management personnel costs include all labor costs associated with solid waste collection, transportation, treatment, disposal, and security during these operations. Bagram AFB uses host nation contractors (HNCs), third-country national (TCN) contractors, and U.S. contractors for these tasks. Labor requirements by contractor category were identified by SMEs as:

1. HNCs separate waste at the refuse collection facility in three shifts of 10 people each, where they separate out recyclables (furniture, plastics, explosives, and cans).
2. HNCs drive the solid waste and wastewater collection trucks.
3. U.S. contractors (2 total: 1 Manager and 1 Deputy Manager) are in charge of waste management facilities.

4. TCNs likely operate the incinerators and front-end loaders with three full-time equivalents (FTEs) (defined as one person for three shifts each day) and balers (three FTEs also one person for three 8-hour shifts each day).
5. One TCN provides security at the landfill.

Wastewater treatment plant personnel were calculated as requiring 50% of the labor required for the refuse collection facility, or three shifts of five HNCs each (Table D-5).

Table D-5. Solid Waste Contractor Personnel Costs for Bagram (1-Year Period)

	U.S. Contractor Costs	Third Country National Contractor	Host Nation Contractor Costs
Annual Total Pay & Allowances	\$183,500	\$67,600	\$35,600
Full Time Equivalent (FTE)	2	7	107
Annual Hours	2,080	2,080	2,080
Hourly Rate	\$ 88.22	\$ 32.50	\$ 17.12
Number of Hours Spent on Solid Waste Management per year	4,160	14,560	223,142
Contractor Personnel Waste Management Costs, by Type	\$ 367,000	\$ 473,200	\$ 3,819,168
Total Contractor Personnel Waste Management Costs	\$4,659,368		

Solid Waste Management Transport and Equipment Costs

Bagram AFB uses several vehicle types for transporting solid waste from the generation source to the disposal site. The waste transport and equipment costs account for annual vehicle use and include (1) annualized capital cost of the equipment, and (2) annualized operation and maintenance (O&M) costs for equipment incurred during use. For the purposes of this analysis, repairs and spares costs included in the annualized O&M are assumed sufficient to keep transport and equipment items operational over the useful life (no significant replacement or upgrade costs are assumed).

Vehicles used to transport general waste on Bagram AFB include a 2.5-ton truck, a 5-ton truck, and a 20-ton truck. A front-end loader (backhoe) is used at the incinerators and landfill, and a baler is used to bale recyclable goods. The total cost associated with general waste transport and equipment is displayed in Tables D-6, D-7, and D-8.

Table D-6. Solid Waste Transport Costs for Bagram (1-Year Period)

Transport Costs by Category	Rate/ Mile Total Parts & Fuel (\$)	Vehicle Capacity	Round Trips/ Truck/ Day	# of Trucks Required	Distance (miles)	Annualized Capital Cost	Annualized O&M Cost	Annualized Capital and O&M Costs
GW*	2.80	2.5 tons	3.60	4.0	8.2	\$36,428	\$121,764	\$158,192
GW*	2.69	5 tons	3.60	2.0	8.2	\$62,290	\$58,490	\$120,780
GW*	5.46	20 tons	1.80	1.0	8.2	\$24,097	\$29,680	\$53,777
WW (total)	5.46	10000 gallons	11.7	15.0	14.42	\$ 361,458	\$5,088,843	\$5,450,301
Total Transportation Costs								\$5,783,050

* Assume 1/3 total volume

Table D-7. General Waste Equipment Costs for Bagram (1-Year Period)

Equipment	Annualized O&M Cost per hour	Daily Operation (hours)	Annual Operation (hours)	Annualized Capital Cost	Annualized O&M cost	Annualized Capital and O&M Costs
Front-End Loader	\$1.29	22	8,030	\$ 5,631	\$ 10,348	\$ 15,978
DC-72 Extra Heavy Deep Chamber 72" Baler	\$0.20	22	8,030	\$ 889	\$ 1,634	\$ 2,524
Total Equipment Costs						\$ 18,502

Table D-8. Fully Burdened Cost of Solid Waste for Base Case Bagram (All Values for a 1-Year Period)

Cost Category	Base Case: Bagram
Solid Waste Infrastructure	\$ 7,144,811
Solid Waste Personnel	\$ 4,791,800
Solid Waste Transport & Equipment	\$5,801,552
Solid Waste Base Closure & Transfer	Indeterminate
Fully Burdened Cost of Solid Waste	\$17,738,163

* All values are for a 1-year period.

D.2 Water Bottle Reduction Demonstration

The purpose for this analysis is to measure the affect of substituting local prime water production and distribution for bottled water on the FBC of managing waste. Reducing this waste stream may affect costs, lives exposed to risk in the resupply chain, and health risks from burning plastic. As such, the cost estimates generated represent only one aspect of the potential beneficial effects of reducing the amount of water delivered to base camps – the waste portion. This analysis builds on the base case calculations for Bagram AFB and identifies changes in the cost estimates because of the reduction in SW generation or,

specifically, the reduction in costs and resources used in the management of plastic bottle waste. It also includes a qualitative discussion of the affects on potential risks and liabilities.

This demonstration assumes that the (1) the only plastic bottle waste at Bagram is composed of 0.5 liter drinking water bottles, and (2) the potable water yield from Reverse Osmosis Water Purification Units (ROWPUs) is sufficient to completely displace bottled water demand, thereby completely eliminating plastic bottle waste.

A ROWPU is a trailer-mounted piece of Army equipment that treats water from raw water sources (wells, lakes, rivers) to provide Soldiers with potable drinking water. Dissolved solids are removed from the water via the ROWPU's filtering system, and purified water is treated with disinfectant for storage. The ROWPU is equipped with its own power generation source.

Approximately 432,000 waste plastic bottles per day are generated (0.5 liter size) in Bagram, and the current disposal practice is to separate, bale, and recycle plastic bottles. This figure was calculated using the Central Command's planning factor of eight liters water consumed per person per day in theater and the population estimate of 27,000 people.³

The magnitude of GW reduction was calculated by estimating the number of bottles of water consumed per year and multiplying that number by the weight of one 0.5 liter plastic bottle (10 grams per bottle).⁴ As a result of the ROWPU installation, GW generation decreases by 3.5 million pounds, or 1,738 tons per year (WW generation remains constant). Less waste would require fewer disposals through the refuse collection and recycling facilities, meaning fewer resources would be required for GW management.

³ See Table B.1 in Appendix B for a listing of personal communication with SMEs and in-theatre personnel.

⁴ *Husky's Guide to PET Bottles*. (n.d.). Retrieved October 19, 2010, from http://www.factsonpet.com/Articles/Facts%20on%20PET%20Flyer_June18%20PRINT.pdf

Table D-11. General Waste Generation Impacts of Eliminating Plastic Water Bottles

	General Waste Generation (lbs/year)
Base Case: Bagram	78,840,000
Bagram with Alternative Waste Management Method	75,363,751
Change (reduction in plastic bottle waste)	(3,476,249)

Affects on Resources and Costs Associated with Existing Waste Streams

The reduction in plastic bottle waste reduces the demand on the following cost components: waste management facilities and infrastructure; personnel; transportation, and equipment. In sum, these changes result in an annualized decrease in FBCSW of \$242,781, or 1.37% of the total (Table D-10). This analysis is described in detail below in the following calculations.

Table D-10. Bagram Base Case with ROWPU Technology Summary

Cost Category	Bagram with Alternative Solid Waste Management Method		Change
	Base Case: Bagram		
Solid Waste Infrastructure	\$ 7,144,811	\$ 7,109,394	-0.50%
Solid Waste Personnel	\$ 4,659,368	\$ 4,465,401	-4.16%
Solid Waste Transport & Equipment	\$ 5,881,931	\$ 5,868,534	-0.23%
Solid Waste Base Closure & Transfer	Indeterminate	Indeterminate	0.00%
Fully Burdened Cost of Solid Waste	\$ 17,686,110	\$ 17,443,330	-1.37%

*All Values for a 1-Year Period

The reduction in plastic bottle waste reduces the demand on waste management facilities and infrastructure. Given the assumption that all plastic bottle waste is displaced, the percent share of GW represented by plastic bottles was used to estimate the cost reduction associated with waste management at the facilities along the bottle waste disposal path (refuse collection facility, recycling facility, and utility building) (Table D-11).

Table D-11. Plastic Bottle Waste Percentages for Bagram with Alternative Solid Waste Management Method

Plastic Bottle Waste Share of Total Waste, by Facility	Percent Share
Plastic Bottle Waste as % of Total Waste Disposed of Through the Refuse Collection Facility	4.41%
Plastic Bottle Waste as % of Total Waste Disposed of at Recycling Facility	11.25%
Plastic Bottle Waste as % of Total Waste Disposed of through Utility Building* (Houses both the Refuse Collection and Recycling Facilities)	7.83%
*Average of the two numbers above	

These reductions were then applied to the annual capital and O&M cost of the facilities to calculate the infrastructure cost effects in dollars (Table D-12).

Table D-12. General Waste Infrastructure Cost Impacts for Bagram with Alternative Solid Waste Management Method

Total Infrastructure Costs for Base Case: Bagram	\$ 7,144,811
Facility	Change in Annual Capital & O&M Cost
Refuse Collection Facility	\$ (740)
Recycling Facility	\$ (1,889)
Utility Building (Refuse and Garbage Building)	\$ (32,788)
Total Change in Cost	\$ (35,417)
Total Infrastructure Costs for Bagram with Alternative Solid Waste Management Method	\$ 7,109,394

The reduction in plastic bottle waste also reduces the demand on transportation and equipment resources. The study assumed that the only truck to transport plastic bottle waste was a 5-ton truck. Therefore, the reduction in transport resources and costs was due to the reduction in use of the 5-ton truck (Table D-13 for detailed calculations).

Table D-13. General Waste Transport Cost Changes for Bagram with Alternative Solid Waste Management Method (1-Year Period)

Transport Costs by Category	Rate/ Mile Total Parts & Fuel (\$)	Vehicle Capacity	Round Trips/ Truck/ Day	# of Trucks Required	Distance (miles)	Annualized Capital Cost	Annualized O&M Cost	Annualized Capital and O&M Costs
GW* (via 5 ton truck)	2.69	5 tons	2.648	2.0	8.2	\$ 62,290	\$ 42,633	\$ 104,923

* Assume 1/3 total volume

Baler equipment costs would be reduced significantly if plastic water bottles were eliminated at Bagram. It is assumed that baler equipment costs are reduced by the percentage of the waste stream eliminated with the reduction in plastic bottle waste, assumed to be 50% for illustrative purposes (Table D-14).

Table D-14. General Waste Baler Equipment Cost Changes for Bagram with Alternative Solid Waste Management Method (1-Year Period)

Equipment	% of Baled Goods = Plastic Bottle Waste	Annualized Capital and O&M Costs	Source/Notes
DC-72 Extra Heavy Deep Chamber 72" Baler	50%	\$ 1,262	Calculated

No change was made in the front-end loader use because 100% of plastic bottles were assumed to have been removed from the solid waste stream and recycled prior to installation of the ROWPUs.

Lastly, the reduction in plastic bottle waste reduces the demand upon waste management personnel resources (Tables D-15 and D-16).

Table D-15. Descriptions of Impact on Contractor Personnel Resources

Contractor Category	Impacts of Alternative Waste Management Method
U.S. Contractor	Calculations of personnel cost decrease by % of plastic bottle waste of total GW displaced by new technology
TCN	Calculations of personnel cost decrease by % of FTE allocated to baling plastic bottles
HNC	Calculations of personnel cost decrease by % of FTE dedicated to waste separation and % of FTE driving trucks (now no longer required to drive trucks)

These effects are reflected in the Personnel Cost Component calculations (Table D-16). Note that the Solid Waste Contractor Personnel Costs for Base Case Bagram are \$4, 791,800. Cost reductions are \$221,182.

Table D-16. Solid Waste Contractor Personnel Costs for Bagram with Alternative Solid Waste Management Method (1-Year Period)

	U.S. Contractor Costs	Third Country National Contractor	Host Nation Contractor Costs
Annual Total Pay & Allowances	\$183,500	\$67,600	\$35,600
Full Time Equivalent (FTE)	1.9118	5.5000	108.0899
Annual Hours	2,080	2,080	2,080
Hourly Rate	\$ 88.22	\$ 32.50	\$ 17.12
Number of Hours Spent on Solid Waste Management per year	3,977	11,440	224,827
Contractor Personnel Waste Management Costs, by Type	\$ 350,818	\$ 371,800	\$ 3,848,000
Total Contractor Personnel Waste Management Costs	\$4,570,618		

The projected cost effects of eliminating plastic water bottles are summarized in Table D-17.

Table D-17. Increased Resource Availability and Associated Cost Reduction

Infrastructure Freed Up*	Value	Unit	Monetized Cost Reduction
% Reduction in Refuse Collection Facility Use	4.41%	percent	\$ 740
% Reduction in Recycling Facility Use	11.25%	percent	\$ 1,889
% Reduction in Utility Building Use (Houses both the Refuse Collection & Recycling Facilities)	7.83%	percent	\$ 32,788
Personnel Freed Up			
	Value	Unit	Monetized Cost Reduction
US Contractor Hours Freed Up	183	hours	\$ 16,182
Third Country National Hours Freed Up	3,120	hours	\$ 101,400
Host Nation Contractor Hours Freed Up	6,053	hours	\$ 103,600
Transport & Equipment Freed Up			
	Value	Unit	Monetized Cost Reduction
Baler Hours Freed Up	4,015	per year	\$ 1,262
Roundtrips (5T Truck) Freed Up	348	per year	\$ 15,858
<i>*Infrastructure costs are reduced by the fraction of costs represented by plastic bottle waste disposed of at or through the facility.</i>			

Table D-18 again shows the FBC of SW summary of the Base Case: Bagram as well as Bagram with Alternative Solid Waste Management Method. All values are for a 1-year period.

Table D-18. Bagram Base Case with ROWPU Technology

Cost Category	Base Case: Bagram	Bagram with Alternative Solid Waste Management Method	Change
Solid Waste Infrastructure	\$ 7,144,811	\$ 7,109,394	-0.50%
Solid Waste Personnel	\$ 4,791,800	\$ 4,570,618	-4.62%
Solid Waste Transport & Equipment	\$ 5,801,552	\$ 5,784,433	-0.30%
Solid Waste Base Closure & Transfer	Indeterminate	Indeterminate	0.00%
Fully Burdened Cost of Solid Waste	\$ 17,738,163	\$ 17,464,445	-1.54%

*All Values for a 1-Year Period

D.3 Oil CAT Demonstration

The Oil CAT technology has been in limited use with the Department of Defense (DoD) since at least 1997.⁵ In 2006, the U.S. Army Tank-automotive and Armaments Command (TACOM) issued guidance authorizing fuel/oil blending in non-turbine engines at a concentration less than or equal to 7.5%. The Oil CAT can also be used for oil changes with power generation equipment to offset fuel use by a generator at a concentration of 5%.

As part of the demonstration of this technology, the project team analyzed the potential savings at Bagram if this technology were fully implemented. The costs to implement this technology, usually performed as part of a cost benefit analysis (CBA), are out of the scope of this project. However, some costs for Oil CAT purchase and maintenance are provided at the end of this section. To perform the analysis, the various cost components for used oil management and disposal are analyzed, even though they were not explicitly defined in earlier sections of this report.

Baseline Used Oil Generation

As demonstrated in the Section 3.1.2, Table 5, the approximate used oil generation rate for Bagram is 677,664 lbs. For ease of calculations and taking into account the lack of precision of the estimates, 700,000 lbs per year is assumed. Assuming that used oil has a density of 7.5 lbs per gallon, this equals 93,333 gallons.⁶ Assuming further that some of this oil is too dirty to be re-used, a 95% use rate is assumed. Therefore, the total annual used oil quantity available for re-use is 88,667 gallons per year.

Used Oil Cost Components

Infrastructure

At Bagram, used oil is stored in the hazardous waste (HW) storage area with other HW. Because the facility has already been built and is used to store many different types of wastes, one could make the

⁵ Wofford, M., United States Army Engineer School Directorate of Environmental Integration. (n.d.). Fuel/oil blending. Briefing presented at the May 21-24, 2007, Joint Services Environmental Management (JSEM) Conference, Columbus, OH.

⁶ In-theatre personnel assume a 55-gallon drum of used oil weighs 163 kg or 359 lbs. Assuming the drum is full, the density of oil using these values is 6.52 lbs/gallon. In reality, however, the drum is not full to allow for expansion.

argument that the storage area is a sunk cost and should not be included in the analysis. However, because used oil is the largest HW stream at Bagram and so much of the HW storage area is often occupied by used oil, this component should be included as a cost. If more waste oil could be re-used at the source, then the HW storage area possibly could become smaller. For calculation purposes, it was assumed that 30% of the HW storage area is dedicated to used oil storage.

Cost estimates were obtained from the DoD Facilities Pricing Guide. In this guide, a HW Storage facility is the same capital cost as a Refuse Collection Facility, which has a total \$259,384 replacement cost. Annualizing the capital cost over the standard 45 years, this amounts to \$5,764 per year. O&M costs from this guide total \$5,583 per year. Therefore, the annualized capital and O&M infrastructure costs per year total \$11,347. Assuming 30% of this facility is dedicated to used oil, the infrastructure costs total \$3,404 per year for used oil.

Personnel

The LOGCAP contract and the URS HW treatment contract both include costs for personnel at various rates and skill levels. This information is proprietary and the project team was unable to ascertain the personnel costs required for managing HW or specifically, used oil. Therefore, it was assumed that 25% of the contract was attributed to labor. This figure is supported by the personnel costs estimated for the FBC of solid waste (SW) in the Bagram base case scenario. Using the \$0.81/lb treatment cost for HW disposal multiplied by 700,000 lb per year of used oil multiplied by 25% for personnel cost, totals \$141,750 per year for used oil treatment labor costs.

Transport and Equipment

According to in-theater personnel, to get the used oil from the generation points to the HW storage area, a request is put in for flatbed truck transportation every 2 weeks. Assuming it takes approximately 4 hours from start to finish to collect and transport the used oil, and assuming the truck is busy 12 hours each day in that two week period, then truck time for used oil pickup is 4/168 hours, or 2.38% of the time.⁷ According to the *Army Cost and Factors Handbook*⁸, the capital cost for a flat bed truck = \$133,697. Assuming the standard 9-year life, this amounts to an annualized cost of \$14,855/year. A cost for fuel and repair of \$3.00/mile was assumed. The annual O&M costs can be estimated by assuming \$3/mile multiplied by 8.2-mile round trip loop in Bagram, with five roundtrips per every day = \$44,895/year for O&M. The total annual cost is the sum of the annualized capitals costs (\$14,855) plus the annual O&M costs (\$44,895) for a total of \$59,750. Assuming 2.38% of this total is for hazardous material (hazmat) use, then \$1,422/year is for transport to the HW storage area.

Disposal through DLADS

The existing HW disposal contract with Tadawulat has a contract line item number (CLIN) for waste used oil, which includes engine oil, transmission oil, transformer oil, and many other types of oils. The disposal rate for this waste stream is €0.45 per kg or \$0.285 per pound as of October 23, 2010. If all 700,000 lbs were disposed of with the other HW on this contract, this would cost Bagram approximately \$199,739 annually.

⁷ See Table B.1 in Appendix B for a listing of personal communication with SMEs and in-theatre personnel.

⁸ *Army Cost and Factors Handbook* (CFH), FY09. (n.d). Army Financial Management, Assistant Secretary of the Army for Financial Management & Comptroller. Retrieved March-October 2010 from the FORCES website, <https://www.osmisweb.army.mil/>

Revenue From Used Oil

Bartered for Gravel

An oil-for-gravel agreement has been made with a local contractor to sell or barter the used oil from Bagram in exchange for gravel.⁹ The used oil is “sold” at a market rate of \$0.12 per kg. They also sell used lead acid batteries at \$0.18 per kg. Bagram is then paid in gravel at the rate of \$9.20 per cubic meter. The credits and debits are tracked to record the exchange. According to in-theater personnel, as of October 2010, Bagram had sold approximately \$50,000 worth of used oil and about \$40,000 worth of batteries. They had not received any stone in return, however, because they were not ready to handle that commodity yet.

Using the \$0.12/kg price, which equals \$0.055/lb, the annual revenue received for 700,000 lbs of used oil totals \$38,182.

Burned in Incinerator

The newer SW incinerators were ordered with used oil injectors so that used oil can be burned as a supplement to JP8 fuel. Assuming 95% of the 700,000 lbs/year or 93,333 gallons/year of used oil is burned in the incinerators (which = 88,667 gallons per year), displacing new JP8 at a current cost of \$2.34/gallon, the cost savings totals \$207,480 annually.

It should be mentioned that the practice of burning used oil as fuel in incinerators is not without environmental issues. According to the *Overseas Environmental Baseline Guidance Document*¹⁰, used oil may be burned only in industrial furnaces, boilers, and some space heaters; incinerators are not specified. Furthermore, based on a conversation with the incinerator manufacturer, ACS, used oil is not an approved fuel source and therefore, not recommended for this purpose.

Oil CAT Cost Savings for Fuel

Assuming 95% of the 700,000 lbs/year or 93,333 gallons/year of used oil can be used in the Oil CAT, this would replace 88,667 gallons of JP8 annually. Using the current cost of \$2.34/gallon of JP8, the cost savings is \$207,480 annually.

Comparison

The used oil costs and revenues were combined into a comparison chart (Table D-19). The costs incurred are shown in the top half of the table, and the savings, or revenues, are shown in the bottom half. The base case for Bagram is shown in the left column, and the base case with the Oil CAT technology implemented is shown in the column to the right. At the bottom of the table, the scenarios are combined into the following three options.

⁹ See Table B.1 in Appendix B for a listing of personal communication with SMEs and in-theatre personnel.

¹⁰ *Overseas Environmental Baseline Guidance Document* (OEBGD). (2007, May 1). DoD 4715.05-G. Washington, DC: Under Secretary of Defense for Acquisition, Technology, and Logistics.

**Table D-19. Fully Burdened Cost of Used Oil at Bagram with Base Case and Alternate Scenario
(For a 1-Year Period)**

Used Oil Cost Category	Bagram AFB		
	Base Case	Alternative Case: Using Oil CAT Technology****	Change
Infrastructure	\$ 11,347	\$ 7,943	-30%
Personnel	\$ 141,750	\$ 141,750	0%
Transport & equipment	\$ 1,422	-	-100%
Disposal through DLADS	\$ 199,739	-	-100%
Revenue Category			
Sold through DLADS*	Unknown	\$ 207,480	Unknown
Bartered for gravel**	\$ 38,182	\$ 207,480	443%
Burned in incinerators***	\$ 07,480	\$ 207,480	0%
Fully Burdened Cost			
Disposed	\$ 354,258	\$ (57,787)	-116%
Bartered	\$ 116,337	\$ (57,787)	-150%
Incinerator	\$ 52,961)	\$ (57,787)	9%

* Sold through DLADS – cost not available

** Bartered for gravel at \$0.55 per pound

*** Burned as fuel in incinerators (not recommended by incinerator manufacturer)

**** Recycled in Oil CAT and reused in fleet vehicles and power generation equipment

- Fully Burdened Cost of Used Oil – Disposed: For this base case, this scenario assumes the costs incurred for infrastructure, personnel, transport & equipment, and used oil disposal through Defense Logistics Agency Disposition Services (DLADS). The total annual cost for this scenario is \$354,258. For the alternate case in which the Oil CAT is used instead of disposing of the used oil with the HW, this scenario assumes some savings for infrastructure costs. The personnel costs are the same as the base case. No costs are incurred for the transport and equipment because the Oil CAT is used in the same place that the used oil is generated. With all used oil recycled through the Oil CAT, the maximum volume of JP8 is replaced. This scenario results in a net savings of \$57,787 annually, or 116% savings for this base case.
- Fully Burdened Cost of Used Oil – Bartered: For this base case, this scenario combines the costs for infrastructure, personnel, transport and equipment, and used oil and then the used oil is bartered for gravel. The total annual cost for this scenario is \$116,337. For the alternate case in which the Oil CAT is used instead of bartering the used oil for gravel at a price of \$0.055/lb, this scenario assumes some savings for infrastructure costs, personnel costs are the same as the base case, and no costs are incurred for transport and equipment because the Oil CAT is used in the same place where the used oil is generated. With all used oil recycled through the Oil CAT, the maximum volume of JP8 is replaced. The scenario results in a net savings of \$57,787 annually, or 150% savings for this particular base case.
- Fully Burdened Cost of Used Oil – Incinerator: For this base case, this scenario assumes the costs incurred for infrastructure, personnel, transportation and equipment, and used oil burned as fuel in the SW incinerators. The total annual savings is \$52,961 because the used oil displaces fuel costs for the incinerators. For the alternate case in which the Oil CAT is used instead of burning the used oil in the incinerators, despite the manufacturer’s recommendation against

burning oil in the incinerators. This scenario assumes cost savings for infrastructure and personnel costs are the same as the base case, and there are no transportation and equipment costs because the Oil CAT is used at the same place it is generated. With all the used oil recycled through the Oil CAT, the maximum volume of JP8 is replaced. The total savings is \$57,787 annually, or 9% savings for this particular base case. In this scenario, used oil is burned instead of JP8 for both the base case and the alternative so the maximum savings is made for both. For the Oil CAT alternative scenario, however, there is some cost savings associated with requiring less storage for the used oil drums. There is no transportation and equipment costs.

Oil CAT Costs

The Oil CAT is available on the General Services Administration website for \$3,848 per unit. These units require minor maintenance, including filter changes once or twice per year, depending on use. The filters cost approximately \$56 each. Assuming that an Oil CAT unit would last for five years and two filter changes are required per year, the annual costs to purchase and operate an Oil CAT unit are \$882 (Table D-20).

Table D-20. Oil CAT Annual Costs

Oil CAT Filtration Unit	Unit Price	Annual Price
Capital Cost	\$3,848	\$770
Filter Costs	\$56	\$112
TOTAL		\$882

APPENDIX E

Characteristics of Hazardous Waste Streams in Iraq and Afghanistan

Characteristics of Hazardous Waste Streams in Iraq and Afghanistan

There are many different hazardous waste (HW) streams, and each could be handled in a different way. The waste streams are often handled differently depending on whether they are generated in Iraq or Afghanistan. Following is a brief summary of the various HW streams in Iraq and Afghanistan. In Iraq, the term hazardous waste has been replaced with regulated waste.

Iraq Hazardous Waste Streams

HW in Iraq accumulated in country from the war's beginning in 2003 until 2009 when a contract was awarded to the URS Corporation through the Air Force Contingency Augmentation Program to treat and dispose of the HW backlog. Over 162 million pounds of used oil, waste fuel, coolant, and lead acid batteries—representing 80% of the HW—was generated and turned over to Defense Logistics Agency Disposition Services (DLADS) since 2003. URS's contract addressed the treatment and disposal of the remaining 20% or 32 million pounds of various HW types.

HW was transferred from over 500 base camps around Iraq to two main HW Treatment, Storage, and Disposal Facilities (TSDFs) built in Iraq: Camp Speicher and Camp Al Asad. Due to this situation, there was ample time to collect and record information about the HW accumulated in the backlog (Figure E-1).¹¹ It should be noted that some of the HW backlog, such as waste fuel, used oil, and batteries, were likely separated out and sold through DLADS rather than being treated as part of the URS contract. A description of each of these waste types follows.

Petroleum-Contaminated Soil

Also called POL-contaminated soil, petroleum-contaminated soil was the largest HW stream in the backlog. This waste stream is currently treated by land farming with microbial remediation.

Other Chemicals

This category includes chemicals other than fuel and oil, such as various acids and bases, solvents, and paints, that are treated by neutralizing, stabilizing, and possibly incineration.

Used Oil

Used oil is one of the largest regulated streams, even though it is not considered hazardous. Used oil was previously sold through DLADS by a single contractor. These sales have ceased, following accusations that the lead acid batteries sold by the same contractor were not being handled in an environmentally responsible manner. As a result of these accusations, agreements are in place with the Government of Iraq's (GoI) Ministry of the Environment (MoE) for used oil, coolant, and other waste streams. The used oil is donated to the GoI and transported to an MoE-approved refining and recycling facility.

¹¹ Information regarding HW accumulation in Iraq and the URS contract to treat this HW is available from a variety of published sources, including <http://www.csmonitor.com/World/Europe/2010/0722/As-Iraq-war-winds-down-US-military-cleans-up-hazardous-waste> (retrieved October 19, 2010). The information obtained for this report came from in-theatre personnel in Iraq. See Table B-1 in Appendix B for a listing of personal communication with SMEs and in-theatre personnel.

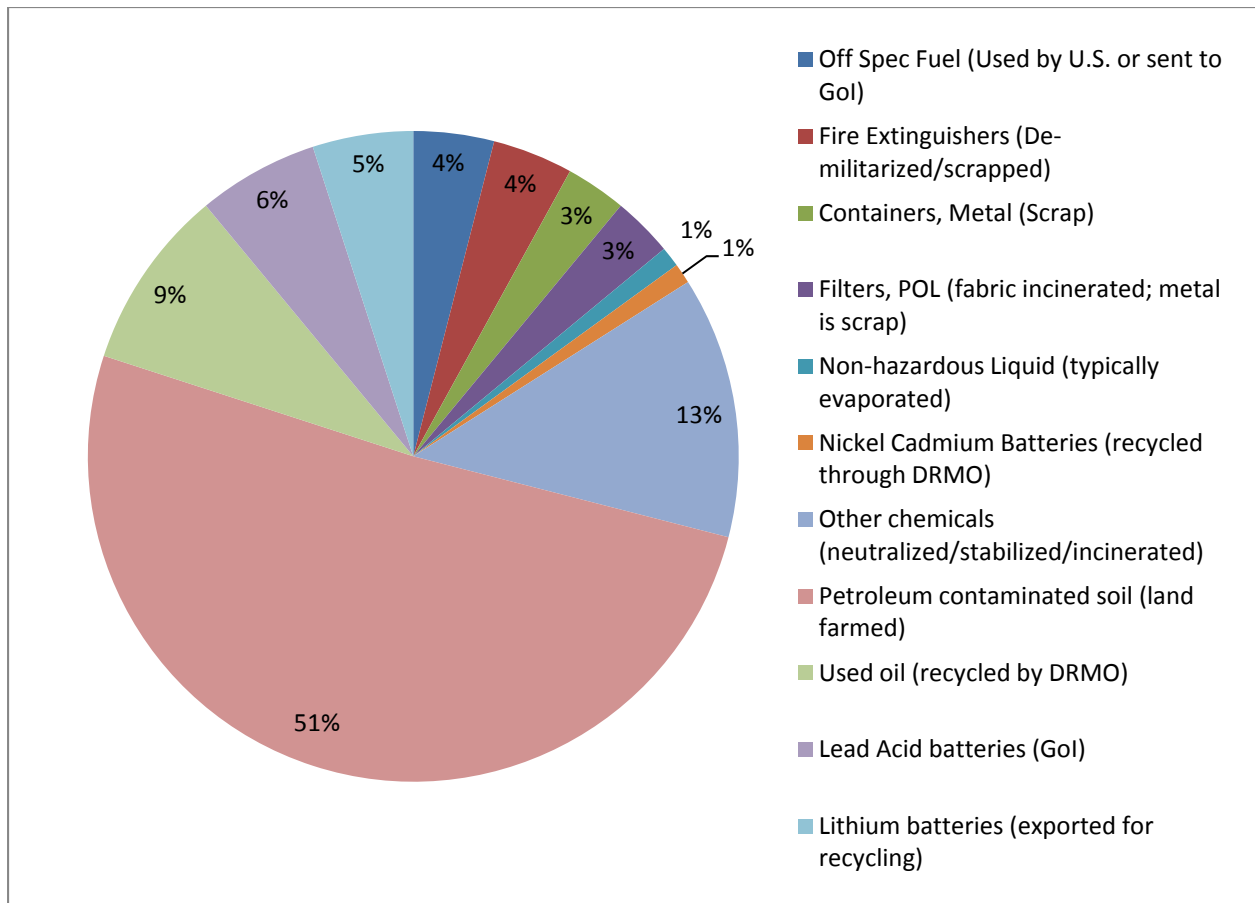


Figure E-1. Estimation of Backlog Hazardous Waste Types in Iraq

Lead Acid Batteries

Like used oil and coolant, lead acid batteries were sold in Iraq through a sales contractor, but these sales were discontinued in April 2010. Lead acid batteries are now donated to the GoI and transported to a MoE-approved recycling facility.

Lithium Batteries

Lithium batteries are mostly notebook-sized batteries used for backpacks; more than a million lithium batteries were accumulated at Al Asad. The project team uncovered little information about this waste stream. According to the U.S. Forces-Iraq pie chart, this waste stream is exported for recycling, presumably to the GoI approved facilities.

Off-Spec or Waste Fuel

Waste fuel is often considered one of the larger regulated waste streams in theater, and sometimes it is grouped under the POL category. Waste fuel may be able to be used as an alternate fuel in on-site incinerators. Currently, waste fuel is part of the agreement for donation to the GoI.

Fire Extinguishers

Based on conversations with in-theater personnel in Iraq, fire extinguishers are most likely emptied, shredded, and sold as scrap within Iraq. Since 2009, 70 million pounds of scrap metal have been sold through DLADS.¹²

Containers

Based on conversations with in-theater personnel in Iraq, the “container” waste stream likely includes compressed gas cylinders. The waste disposal method is probably similar to that for fire extinguishers.

POL Filters

Also known as fuel filters, the fabric portion of POL filters is burned in on-site incinerators for fuel. The metal parts are sold for scrap.

Non-Hazardous Liquids, Nickel-Cadmium Batteries

The project team was unable to get any information about these waste streams. It is assumed that the nickel-cadmium batteries are donated to the GoI and recycled, along with the other batteries.

Coolant

Coolant was not included in the pie chart, but is one of the larger regulated waste streams. According to in-theater personnel, coolant used to be filtered and recycled in Iraq. The coolant now is to be donated to the GoI and transported to a MoE-approved recycling facility.

HW Disposal costs for Iraq

The storage, treatment and disposal of 32 million pounds of HW in Iraq presented a unique opportunity to document the cost of this process. URS Corporation won the \$55 million contract to build two TSDFs and treat the backlog of HW that accumulated for six years. The contract covered the capital costs, transporting the wastes, and treating the wastes. Fuel cost was not included in the contract; the government supplied the necessary fuel (Appendix B). Of the \$55 million, \$29.1 million was for the treatment centers, leaving \$25.9 million to treat the 32 million pounds (lbs) of HW. Splitting the total cost of \$55 million into capital costs and treatment costs yields the following information summarized in Table E-1.

Table E-1. HW Capital and Treatment Costs

Capitalized Cost (annualized over 10 yrs)	Treatment Cost	Total Cost
\$0.55/lb	\$0.81/lb	\$1.36/lb

The capitalized cost is derived from dividing the \$29.1 million for building the two treatment centers, assuming that these facilities will be operational for 10 years. Then, the backlog of 32 million lbs was divided by six to estimate the amount of HW that was generated per year.¹³

$$\$2.91 \text{ million/year divided by } 5.33 \text{ lbs/year} = \$0.55/\text{lb for capital costs}$$

The treatment cost is derived from dividing \$25.9 million for treatment by the backlog of 32 million lbs to get \$0.81/lb for treatment.

¹² See Table B-1 in Appendix B for a listing of personal communication with SMEs and in-theatre personnel.

¹³ The \$55 million URS contract was designated to treat the HW backlog from 2003 to 2009. A follow-on contract for \$4.3 million took effect in April 2010 for the HW generated in 2010.

This estimate is crude and includes many assumptions and generalizations, but provides the only existing per pound estimate of HW treatment costs in Iraq. The HW treatment provided by URS was for waste streams other than those sold/donated/recycled through DLADS, including waste fuel, used oil, coolant, lead acid batteries, and scrap metal.

Afghanistan Hazardous Waste Streams

No HW treatment or disposal occurs in Afghanistan. Most HW is collected and turned over to DLADS, where it is then shipped to Europe for treatment and disposal. DLADS has had a contract in place with Tadawulat since 2008. Tadawulat goes to bases, packages the waste, and delivers it to Europe for its ultimate disposal. There is a contract line item number (CLIN) for the disposal of each waste type, transportation (divided into units, includes security), and the purchase of new packaging containers for the waste. Because the CLINs are broken down into units, the contractor charges DLADS for each unit upon completion. The contract is the total price anticipated for the year, not to exceed the value of that year's particular contract. Tadawulat has the right to make a Request for Equitable Adjustment (REA), essentially a change order, if it feels that the costs incurred for disposing of waste from a particular base is more than the amount allowed in the contract, i.e., if extra security is necessary to ensure safe transport. Each REA is reviewed individually. The contract also includes waste disposal from Tajikstan, but there have been no deliveries from that country since the contract has been in place. The total contract price for Option Year 2 (which includes most of 2010) is €1,680,552, or \$2,344,875 as of October 23, 2010.

A pie chart illustrating the estimated breakdown of regulated waste in Afghanistan is provided in Figure E-2. This pie chart is from a 2009 report and may not represent accurate HW inventories for present day volumes.¹⁴

Used Oil

Used oil is the largest HW stream in Afghanistan and is considered hazardous property (HP) by DLADS, even though it is not hazardous. All HP sales were discontinued in 2009, because it could not be confirmed that HP sales were being handled in an environmentally responsible manner. Even though the existing HW disposal contract with Tadawulat has a CLIN for used oils, used oil is not usually disposed of with the other hazardous wastes. The reason is because the volume is too great and transportation of this much used oil poses a security risk.¹⁵ Instead, an agreement was made with a local contractor to sell or barter the used oil in exchange for gravel, i.e., "Oil-for-Gravel". Another disposal pathway for used oil in Afghanistan is incineration. The newest SW incinerators procured for Afghanistan were ordered with waste oil injectors with the intent of burning used oil as a supplemental fuel.¹⁶

¹⁴ *AOR Environmental Component Plan*. (March 2009). Prepared for United States Army Central. Atlanta, GA: CH2MHill, Military Planning Group.

¹⁵ Convoys are well-known targets of enemy attacks. As a result, commanders have stopped convoys of used oil. Source: Vargesco, A.M., Army Engineer School, Fort Leonard Wood. (May-June 2006). Fuel-oil blenders save time, money, and lives. *Army Logistician*. PB 700-06-03. Volume 38, issue 3. Retrieved October 19, 2010, from http://www.almc.army.mil/alog/issues/may-june06/oil_cat.html

¹⁶ See Table B-1 in Appendix B for a listing of personal communication with SMEs and in-theatre personnel.

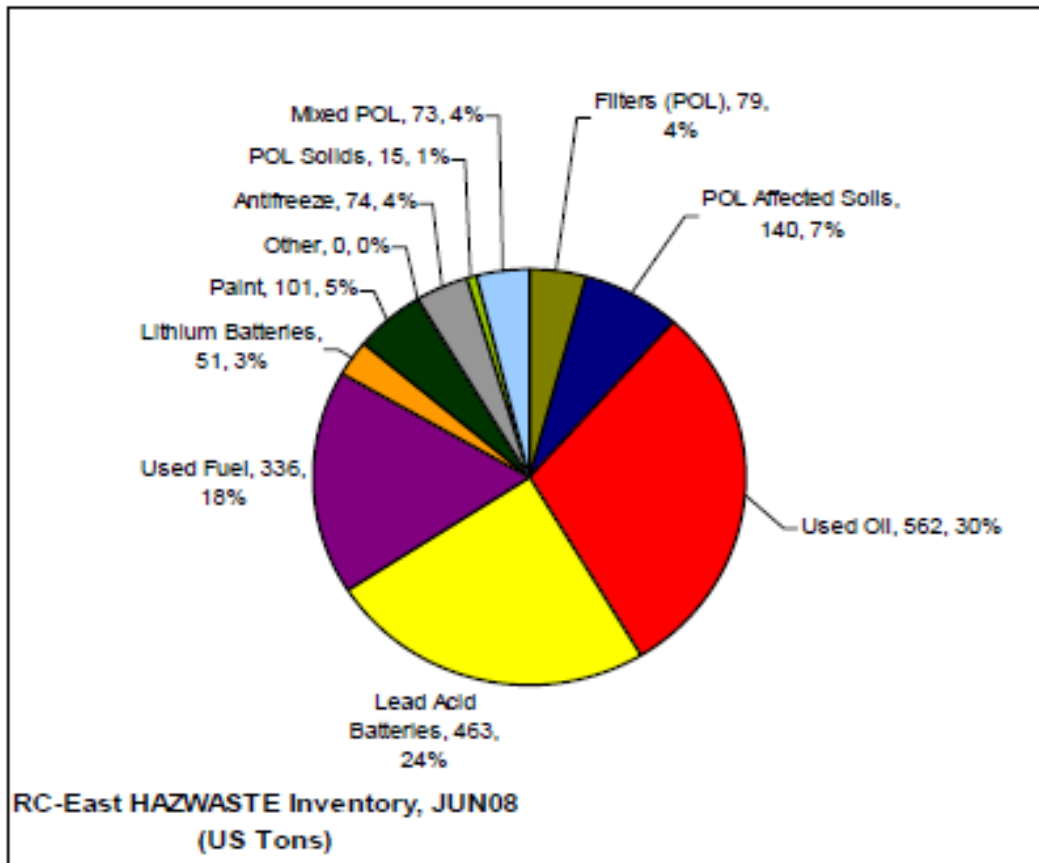


Figure E-2. U.S. Forces-Afghanistan Estimate of Hazardous Waste in Afghanistan

Lead Acid Batteries

Lead acid batteries, thought to be the second largest HW stream in Afghanistan, were recently added to the oil-for-stone barter. The batteries will be recycled in Afghanistan by a local contractor. Prior to the summer of 2010, lead acid batteries were shipped to Europe on the HW disposal contract.¹⁷

Waste Fuel

It has been reported that waste fuel is also sold locally to contractors, but the project team was unable to confirm this information.

¹⁷ See Table B-1 in Appendix B for a listing of personal communication with SMEs and in-theatre personnel.

APPENDIX F
Non-Monetary Risks and Liabilities

Non-Monetary Costs and Liabilities

In addition to the monetary costs of waste management in contingency operations, waste management operations and disposal sites may expose Army personnel, contractor personnel, and the host nation population to risks including health, environmental, and security risks. These potential risks compose an additional aspect of the Fully Burdened Cost (FBC). Informed decision-making must take these risks into account, but they often are not as readily quantified as other costs. This section presents a qualitative discussion of these risks that may become tangible liabilities if waste is improperly managed.

Health risks can have both short- and long-run effects. In general, risks increase when waste is improperly managed. Short-run (acute) health risks are more likely to affect U.S. Army and contractor personnel living or working near the disposal sites, as well as host nation populations living near the disposal site. Long-run (chronic) health risks can affect U.S. Army and contractor personnel who lived or worked near the disposal sites, as well as host nation populations continuing to live near the disposal site. Environmental risks differ from health risks in that they can have a long-term effect on the ecosystem, or a short-term effect on the ecosystem that does not directly affect humans. Changes in the ecosystem can lead to changes in the livelihoods of local populations. Monetary costs associated with these risks are indeterminate.¹⁸

F.1 Landfill Risks

Insufficient quality control of landfill design and operation may lead to increased health and environmental risks. Landfills constructed without an impermeable liner will allow a greater quantity of leachate to enter the environment than one with an impermeable liner, as is directed in sanitary landfill construction documentation.¹⁹ Improper general waste segregation may allow hazardous materials to be disposed of in a landfill, changing the leachate composition and causing hazardous chemicals to enter the environment untreated.²⁰ When solid waste is deposited in a landfill, water percolates through the waste, absorbing some of its material and creating leachate. If the landfill liner is permeable, leachate can leak into the environment causing ground and surface water pollution. In addition, waste decomposition produces air emissions that can be hazardous to human and environmental health. However, waste decomposition also produces natural gas that can be extracted to produce electricity.

Short-term health risks associated with landfills include groundwater and air pollution. The groundwater pollutants most likely to leach into the environment in the short term are ammonia and xenobiotic organic compounds (XOCs). The most prevalent XOC carcinogens, which are also harmful to the liver, are nitrosodiethylamine, 2-nitropropane, and 1,3-butadiene.²¹ Air pollution from landfills contains known carcinogens and pulmonary irritants. Long-term health risks, which may occur after landfill closure, are mostly related to groundwater pollution. Ammonia may continue to leach into the water table as waste continues to decompose, creating a persistent source of groundwater toxicity. Surface water may be subject to oxygen depletion and diminishing quality. Additionally, leachate can result in long-term, mutagenic activity, which could lead to health problems that transcend generations.

¹⁸ Risks associated with human populations' exposure to pollutants have been quantified in dollars through various studies of health impacts, legal settlements and, in cases of ecosystem damages, cleanup and restoration costs. This is an extensive body of literature and its application to waste management in contingency operations was beyond the scope of this Task.

¹⁹ *Sanitary Landfill*. (January 15, 1994). Technical Manual. TM 5-814-5. Washington, DC: Headquarters, Department of the Army.

²⁰ Barlaz, M.A., Baun, A., Christensen, T.H., Kjeldsen, P., Ledin, A., & Rooker, A. P. (October 2002). Present and long-term composition of MSW landfill leachate: A review, critical reviews in environmental science and technology. London, UK: Taylor & Francis. Volume 32, no. 4 (2002): 297-336.

²¹ *Revised Risk Assessment for the Air Characteristic Study*. (November 1999). Volume I. EPA 530-R-99-091a. Washington, DC: U.S. Environmental Protection Agency, Office of Solid Waste, Sections 4-1 – 6-1.

In addition to being a health risk, water pollution may also be an environmental risk associated with landfills. Landfills produce leachate with a high concentration of ammonia both before and after closure, causing ammonia pollution of ground and surface water systems. Increased ammonia toxicity causes respiratory distress, tissue damage, and internal organ damage in aquatic animals. If exposed to ammonia for extended periods, aquatic animals will ultimately die.²² Increased ammonia levels result in increased growth in aquatic plants, leading to increased vegetation decay, oxygen depletion in the water, and lowered overall water quality. Because the majority of ammonia-fuelled growth occurs on the surface of a body of water, vegetation blooms will block the sun from submerged vegetation and reduce the underwater habitat.²³

Heavy metals do not pose a substantial health or environmental risk as a result of landfill solid waste disposal methods. Longitudinal studies of leachate composition have shown that heavy metal concentrations in leachate are equal to or below maximum levels required to meet U.S. drinking water standards. Furthermore, heavy metal leaching is unlikely to present a long-term environmental risk, as less than 0.02% of all heavy metals originally disposed of in a landfill are expected to leach into the environment within 30 years after closure. Greenhouse gas emissions are another environmental risk associated with landfills. Decomposition in landfills produces both methane (CH₄) and carbon dioxide (CO₂). Materials with the greatest CH₄ emissions are mixed paper (to include office paper) and cardboard.²⁴

F.2 Risks from Incinerator Use

Incinerating solid waste produces heat, flue gas, and ash. Heat and flue gas are released into the air during the incineration process, whereas ash is disposed of in a landfill.²⁵ Health and environmental risks most directly related to managing incinerated solid waste result from exposure to flue gas and the intensity of these risks depends on the chemical composition of the flue ash. Ash added to landfills contributes to leachate, which contributes to health and environmental risks associated with landfills as described above. Insufficient quality control of incinerator operations may intensify these risks.

Incinerator emissions are a health risk to nearby populations and may expose waste management personnel to additional occupational risks depending on the type of incinerator infrastructure. While emissions begin as air pollution, chemicals can enter other areas of the ecosystem (particularly water, soil, and food sources) and affect human populations indirectly by different exposure routes.²⁶ Populations immediately surrounding the incinerator are at a high risk of deleterious health effects from particulate matter and lead emissions, and at moderate risk from mercury, other metals, and acidic aerosols. Broader populations exposed to emissions from multiple incinerator facilities are at substantial risk of dioxin exposure, with moderate risk of exposure to lead, mercury, other metals, and acidic aerosols. Workers in incinerator facilities are exposed to substantial health risks as a result of particulate matter, dioxin, and heavy metal emissions. These workers also face moderate health risks as a result of acidic gas and aerosol emissions (Table F-1).

²² Sharpe, S. (n.d.). Ammonia poisoning. Retrieved October 1, 2010, from <http://freshaquarium.about.com/cs/disease/p/ammoniapoison.htm>.

²³ Anaparti, A.M. (June 2010). The effect of ammonia on aquatic plants. Retrieved September 1, 2010, from http://www.ehow.com/about_6666137_effect-ammonia-aquatic-plants.html

²⁴ *Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks*. (September 2006). Edition 3. Washington, DC: U.S. Environmental Protection Agency, pgs 79-95.

²⁵ Knox, A. (February 2005). *An Overview of Incineration and EFW Technology as Applied to the Management of Municipal Solid Waste*. Ontario, Canada: University of West Ontario.

²⁶ Researchers have not been able to definitively conclude that incinerator emissions affect health since they are unable to establish causality between incinerator emissions and air pollution in a given location. However, studies have been able to assess the chemical composition of incinerator emissions and identify potential health risks associated with those chemicals.

Table F-1. Health Effects of Incineration Emissions Pollutants

Pollutant	Health Effects/Additional Characteristics
Heavy Metals	Heavy metals are vaporized at extremely high temperatures, and may enter the environment in the form of air pollution. Includes: cadmium, lead, mercury, chromium, arsenic
Acid Gases	Acid gases become fully formed as a result of oxygen availability and heat during combustion. Includes: nitrous oxides, sulfur oxides, hydrochloric acid, acidic aerosols
Products of Incomplete Combustion (PIC)	High-combustion temperatures destroy PICs. Low temperatures cause PICs to be released into the environment in the form of air pollution. Includes: dioxins, furans, aldehydes, polycyclic aromatic hydrocarbons)
Particulate Matter (PM)	Released in the form of fly ash
Carbon Monoxide (CO)	Cardiovascular and respiratory disease; can interfere with pregnancy (major damage to brain and lung). Fetuses, newborns, and pregnant women are especially susceptible to CO. Other high-risk groups include those with pre-existing heart disease and those over 65 years old.

In addition to the emissions that result in health risks, incinerating solid waste also produces greenhouse gases that create an environmental risk. Solid waste combustion produces both carbon dioxide and nitrous oxide. Insufficient quality control of incinerator design may lead to inefficient solid waste combustion, resulting in greater emission toxicity. Inefficient combustion may result both from low-combustion temperatures, which can produce dioxins, furans, aldehydes and polycyclic aromatic hydrocarbons, and from high-combustion temperatures, which vaporize heavy metals and allow them to enter the ecosystem. Improper general waste segregation may result in the accidental combustion of materials, which produce emissions that are hazardous to human and environmental health. Inappropriate operation of the incinerator may result in inefficient or incomplete combustion, which may result in greater emission toxicity.²⁷

F.3 Risks from Operation of Burn Pits

Burn pits ignite solid waste in an open-air pit, producing ash and smoke.²⁸ The fire receives a limited amount of oxygen and burns at a relatively low temperature, resulting in inefficient combustion and hazardous emissions. Health and environmental risks resulting from exposure to smoke can be both acute and/or chronic depending on the chemical and material composition of the smoke. Bottom ash is added to landfills and contributes to health and environmental risks associated with landfills described above. Insufficient quality control of burn pit operations may intensify these risks.

Health and environmental risks occur from the toxins and pollutants produced by open air solid waste combustion. The exact chemical composition of burn pit emissions depends on the composition of the solid waste being combusted. These chemicals may include dioxins, particulate matter (PM), polycyclic aromatic hydrocarbons, volatile organic compounds (VOC), carbon monoxide (CO), hexachlorobenzene, nitrogen oxides, and ash (Table F-2).²⁹

²⁷ Board of Environmental Studies and Toxicology, Commission on Life Sciences, Committee on Health Effects of Waste Incineration, & National Research Council. (2000). *Waste Incineration and Public Health*. Washington, DC: National Academy Press.

²⁸ Smoke contains fly ash. Ash that remains in the burn pit after combustion is bottom ash.

²⁹ Szema, A., Chief of Allergy Section in Veterans Affairs Medical Center. (November 6, 2009). Witness testimony during Democratic Policy Committee Hearing: Are burn pits in Iraq and Afghanistan making our soldiers sick?

Table F-2. Emissions Associated with General Waste Materials Placed in Burn Pit

Material	Emission
Plastic	Dioxin, hydrochloric acid
Polystyrene	Carcinogens, including dioxin, benzene, styrene, furans
Treated wood	Pro-carcinogenic arsenic
Bleached paper	Halogenated hydrocarbons, furans
Colored paper	Heavy metals, including lead and cadmium
Plywood	Formaldehyde
Cardboard for packaging foodstuffs	Fungicides

Short-term (acute) health risks include immune system suppression, aggravated pre-existing respiratory problems (such as asthma or bronchitis), headache, loss of coordination, congestion, nausea, vomiting, diarrhea, fatigue, and irritation of the skin, eyes, upper respiratory tract, lungs, and sinuses. Contractor paramedics and military medical personnel stationed on bases using burn pits observed an increase in patient traffic because of these symptoms on days when burn pit smoke was especially thick.³⁰ Long-term (chronic) health risks include adult and pediatric cancers, respiratory diseases, birth defects, fetal mortality, and damage to the liver, kidneys, immune system, cardiovascular system, endocrine system and central nervous system (Table F-3).³¹

Health professionals have observed an increased number of young veterans returning from Iraq and Afghanistan who are being diagnosed with respiratory illnesses, such as asthma or chronic bronchitis, rendering them unfit for military duty. In particular, one survey of 15,000 soldiers deployed to Iraq and Afghanistan observed that 60% of returning soldiers suffered from respiratory illness, 17% of which required medical care. Additionally, several deployed contractor personnel have attributed the recent onset of their respiratory and neurological medical conditions on prolonged proximity to burn pits.³²

³⁰ Curtis, Lt. Col. D., Former Bioenvironmental Engineer, U.S. Air Force; and Keith, L.R. Former KBR Medic. (November 6, 2009). Witness testimony during Democratic Policy Committee Hearing: Are burn pits in Iraq and Afghanistan making our soldiers sick?

³¹ Kramer, S. (2009, June 11). Statement at a press conference on proposed burn pit legislation. Washington, DC: Epidemiology International.

³² Szema, A., Chief of Allergy Section in Veterans Affairs Medical Center; and Keith, L.R., Former KBR Medic. (November 6, 2009). Witness testimony during Democratic Policy Committee Hearing: Are burn pits in Iraq and Afghanistan making our soldiers sick?

Table F-3. Toxins and Associated Health Risks Resulting from Burn Pit Combustion

Toxin/Pollutant	Health Risks
Particulate Matter (PM)	Aggravated respiratory problems (preexisting asthma, bronchitis) Increased risk of cardiac arrhythmia and heart attack Can absorb polycyclic aromatic hydrocarbons, dioxins and metals, facilitating deep inhalation of those substances
Ash	Vary depending on metal content Can absorb polycyclic aromatic hydrocarbons, dioxins and metals, facilitating deep inhalation of those substances
Dioxin	Stored in fat cells and are accumulative Hepatotoxicity Endocrine disease Neurological damage Cardiovascular disease Reproductive and growth problems (includes birth defects) Chloracne Impaired immune functioning Increased risk of cancers (lymphoma, soft tissue sarcoma, leukemia, respiratory & digestive cancer)
Polycyclic aromatic hydrocarbons	Enhances toxicity of other toxins Mutations in DNA Birth defects Liver damage Immune system damage Increased risk of cancers
Volatile Organic Compounds (VOCs)	Includes: benzene, toluene, xylenes, vinyl chloride, methylene chloride, butadiene Aggravated pre-existing medical conditions (especially respiratory and heart problems) Eye, nose, and throat irritation Headache Nausea Neurological and sensory impairment Damage to liver, kidney, central nervous, hematopoietic and immune system Birth defects Increased risk of cancers (leukemia, lymphoma, myeloma, brain and central nervous system malignancies, liver, respiratory)
Carbon Monoxide (CO)	Headache Fatigue Nausea Vomiting
Hexachlorobenzene	Damage to fetal development Increased risk of cancer, kidney, and liver damage Fatigue Skin irritation

Environmental risks associated with burn pit smoke affect the ecosystem and may also affect humans who have not had direct contact with burn pit smoke. Several toxins produced by burn pit smoke, particularly dioxins and hexachlorobenzene, are persistent, bioaccumulative, toxic (PBT) pollutants, meaning they

persist in the environment and bioaccumulate in food chains. Carbon monoxide and nitrogen oxides create harmful ozone, deplete the ozone, and cause acid rain. Carbon monoxide is also a greenhouse gas which reacts with sunlight. Larger size particulate matter, such as VOCs, PM, and ash, reduce visibility, and can create haze and smog. In extreme cases, burn pit smoke can reduce visibility to the point of interfering with Army missions (Table F-4).^{33, 34}

Table F-4. Toxins and Environmental Risks Resulting from Burn Pit Combustion

Toxin/Pollutant	Environmental Risks
Dioxin	Persistent, bioaccumulative, toxic pollutant (PBT)
Particulate Matter (PM)	Smoke reduces visibility Creates haze Transports other dangerous chemicals
Volatile Organic Compounds (VOC)	Ground-level ozone pollution (smog)
Carbon Monoxide (CO)	Reacts with sunlight to create harmful ozone Greenhouse gas
Hexachlorobenzene	Long-range atmospheric transport, bioaccumulation in fish
Ash	Can contain toxic metals, which can be absorbed by plants and ingested by humans, or which can leak into groundwater
Nitrogen oxides (NO _x)	Acid rain, ozone depletion, smog

Insufficient quality control of GW segregation may result in the accidental combustion of materials that produce hazardous emissions, such as plastics or tires. Inappropriate operation of the burn pit may result in inefficient or incomplete combustion, which may result in greater emission toxicity. Lawsuits regarding negligent management of burn pit operations have been filed by veterans returning from contingency operations. Both the contractors who operated the burn pits and the military personnel who constructed the burn pits have been identified as possibly responsible for intensified levels of human exposure.³⁵

F.4 Risks due to Improper Wastewater Management

Wastewater released into a water source, such as a river, without proper treatment may result in groundwater and surface water pollution. The type of health and environmental risks resulting from pollution depend on the contaminants present in the wastewater. Additionally, the extent of the human health effects depends on which local populations use groundwater and surface water sources and whether water purification technologies are used. Insufficient wastewater management quality control may intensify these risks.

Pathogens affecting human health found in wastewater include bacteria, enteric viruses, protozoa and Helminth worms. Common diseases and symptoms caused by these pathogens include food poisoning,

³³ *Backyard Burning: Environmental Effects*. (October 2008). U.S. Environmental Protection Agency. Retrieved October 22, 2010, from <http://www.epa.gov/epawaste/nonhaz/municipal/backyard/env.htm>.

³⁴ In re: KBR burn pit litigation. (n.d.). Case 8:09-md-0283RWT, Document 49. United States District Court for District of Maryland.

³⁵ *Afghanistan and Iraq: DOD Should Improve Adherence to Its Guidance on Open Pit Burning and Solid Waste Management*. (October 15, 2010). GAO-11-63. Washington, DC: U. S. Government Accountability Office, pg 30. Retrieved November 30, 2010, from <http://www.gao.gov/products/GAO-11-63>

dysentery, gastroenteritis, moderate-to-severe diarrhea, digestive disturbances, abdominal pain, vomiting, coughing, chest pain, fever, anemia, weight loss, hookworm disease, and infectious hepatitis (Table F-5).³⁶

Table F-5. Pathogens Common in Wastewater and Associated Health Risks

Organism	Health Risks
Bacteria	
<i>Salmonella sp.</i> *	Salmonellosis (food poisoning), typhoid fever
<i>Shigella sp.</i> *	Bacillary dysentery**
<i>Yersinia sp.</i>	Acute gastroenteritis (including diarrhea, abdominal pain)**
<i>Vibrio cholera</i> *	Cholera
<i>Campylobacter jejuni</i> *	Gastroenteritis**
<i>Escherichia coli</i> (pathogenic strains)*	Gastroenteritis**
Enteric Viruses	
<i>Hepatitis A virus</i> *	Infectious hepatitis
<i>Norwalk and Norwalk-like viruses</i> *	Epidemic gastroenteritis with severe diarrhea**
<i>Rotaviruses</i>	Acute gastroenteritis with severe diarrhea**
<i>Enteroviruses</i>	
- <i>Polioviruses</i>	Poliomyelitis
- <i>Coxsackieviruses</i>	Meningitis, pneumonia, hepatitis, fever, cold-like symptoms, etc.**
- <i>Echoviruses</i>	Meningitis, paralysis, encephalitis, fever, cold-like symptoms, diarrhea, etc.**
<i>Reovirus</i>	Respiratory infections, gastroenteritis**
<i>Astroviruses</i>	Epidemic gastroenteritis**
<i>Caliciviruses</i>	Epidemic gastroenteritis**
Protozoa	
<i>Cryptosporidium</i> *	Gastroenteritis
<i>Entamoeba histolytica</i> *	Acute enteritis
<i>Giardia lamblia</i> *	Giardiasis (including diarrhea, abdominal cramps, weight loss)**
<i>Balantidium coli</i>	Diarrhea and dysentery**
<i>Toxoplasma gondii</i>	Toxoplasmosis
Helminth Worms	
<i>Ascaris lumbricoides</i> **	Digestive and nutritional disturbances, abdominal pain, vomiting, restlessness
<i>Ascaris suum</i> **	May produce symptoms such as coughing, chest pain, and fever
<i>Trichuris trichiura</i>	Abdominal pain, diarrhea, anemia, weight loss
<i>Toxocara canis</i>	Fever, abdominal discomfort, muscle aches, neurological

³⁶ *Environmental Regulations and Technology: Control of Pathogens and Vector Attraction in Sewage Sludge.* (2003, July). EPA/625/R-92/013. Washington, DC: U.S. Environmental Protection Agency, Office of Research and Development.

	symptoms
<i>Taenia saginata</i>	Nervousness, insomnia, anorexia, abdominal pain, digestive disturbances
<i>Taenia solium</i>	Nervousness, insomnia, anorexia, abdominal pain, digestive disturbances
<i>Necator americanus</i> **	Hookworm disease
<i>Hymenolepis nana</i>	Taeniasis

*Pathogens identified by U.S. Army regulation as health hazards from drinking unpurified water.

**Pathogens and symptoms identified by the WHO as health hazards from drinking unpurified water.³⁷

Human exposure to these pathogens occurs with contact with contaminated surface water contact. Exposure to contaminated groundwater is less common. Humans will only come into contact with pathogens present in water sources because of ineffective wastewater management if they are consuming or using untreated water. U.S. Army personnel will therefore only come into contact with these pathogens if they fail to comply with water purification standards.³⁸ Portions of the host nation population may come into contact with wastewater-related pathogens if they lack access to water purification technology. Host nation populations in Iraq and Afghanistan have the following rate of access to clean water technology (Table F-6).³⁹

Table F-6. Access to Clean Water in Iraq and Afghanistan

Country	Urban Access to Clean Water	Rural Access to Clean Water
Iraq	98%	50%
Afghanistan	64%	32%

Sewage sludge may also contain metals, carbon monoxide, nitrogen oxides, sulfur dioxide, hydrocarbons, and anthropogenic substances, such as pharmaceuticals or steroids. These chemicals will be released into the environment if untreated sewage is improperly disposed. In instances where sewage sludge is applied to land, either arbitrarily or as a fertilizer, these chemicals may alter the productive capacity of the land.⁴⁰ Insufficient wastewater treatment quality control increases the risk that wastewater containing hazardous water pollutants will be released into the environment.

F.5 Transportation Related Risks

Vehicles used to transport solid waste generate environmental risks as a result of vehicle emissions and create security risks as a result of exposure to attack. Solid waste transportation equipment emits carbon monoxide, hydrocarbons, nitrogen oxides, and particulate matter as a product of fuel combustion. These pollutants reduce air quality and contribute to climate change.⁴¹ Driving solid waste transportation equipment also exposes waste management personnel to attack. When host nation populations are hostile

³⁷ Stockholm International Water Institute. (2005). *Securing Sanitation—The Compelling Case To Address the Crisis*. Stockholm, Sweden: World Health Organization, Water Sanitation and Health, pgs. 5-15.

³⁸ “Chapter 8: Water Contaminant Health Effects” in *Technical Bulletin: Sanitary Control and Surveillance of Field Water Supplies*. (December 2005). TB MED 577. Headquarters, Department of the Army, pgs 65-87.

³⁹ Joint Monitoring Programme for Water Supply and Sanitation. (March 2010). Estimates for the use of improved sanitation facilities: Iraq. WHO/UNICEF. Retrieved September 15, 2010, from www.wssinfo.org.

⁴⁰ *Targeted National Sewage Sludge Survey Sampling and Analysis Technical Report*. (January 2009). Washington, DC: U.S. Environmental Protection Agency, Office of Water, pgs. 39-57.

⁴¹ *Mobile Source Emissions – Past, Present and Future: Pollutants*. (2007, July). Washington, DC: U.S. Environmental Protection Agency, Office of Transportation and Air Quality. Retrieved October 19, 2010, from <http://www.epa.gov/otaq/inventory/overview/pollutants/index.htm>

or unfriendly, waste disposal facilities have been located near Army living quarters and operating centers in order to avoid this security risk.⁴²

F.6 Security and Diplomatic Risks

In addition to increasing environmental and health risks associated with solid waste management, insufficient monitoring of solid waste management operations exposes the base to security risks. Waste management facilities with multiple points of entry may allow unauthorized individuals to gain access to sensitive materials that have been disposed of as waste, such as official documents or unexploded ordnances (UXO).⁴³

Externalities created by waste management methods may affect the host nation population's perception of the U.S. Army. Experience in contingency operations has taught planners that effective waste management practices help convince the host nation population of their good intentions, whereas ineffective waste management practices will increase tension and (potentially) aggression against U.S. forces.⁴⁴

⁴² Anderson, G., & Wolf, W. (October-December 2004). "One-stop" waste disposal – enhancing force protection in Afghanistan. *Engineer: The Professional Bulletin for Army Engineers*, 5-7.

⁴³ Anderson, G., & Wolf, W. (October-December 2004). "One-stop" waste disposal – enhancing force protection in Afghanistan. *Engineer: The Professional Bulletin for Army Engineers*, 5-7.

⁴⁴ Mosher, D.E, Lachman, B.E., Greenberg, M.D., Nichols, T., Rosen, B., and Willis, H.H. (2008). *Green Warriors: Army Environmental Considerations for Contingency Operations from Planning Through Post-Conflict*, Santa Monica, CA: RAND Arroyo Center. Retrieved October 19, 2010, from <http://www.rand.org/pubs/monographs/MG632/>