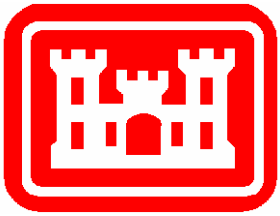
PUBLIC WORKS TECHNICAL BULLETIN 200-1-45
1 FEBRUARY 2007

DECONSTRUCTION OF WWII-ERA WOOD FRAMED BUILDINGS



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DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
441 G Street, NW
Washington, DC 20314-1000

CEMP

Public Works Technical Bulletin 1 Feb 07
No. 200-1-45

Facilities Engineering
Environmental

DECONSTRUCTION OF WWII-ERA WOOD FRAMED BUILDINGS

1. Purpose. This Public Works Technical Bulletin (PWTB) provides case studies and lessons learned on the deconstruction of excess or surplus buildings at seven Army installations. PWTB 200-1-23 provides detailed technical guidance for the recovery, reuse, and recycling of materials from building deconstruction.

2. Applicability.

a. This PWTB applies to installation Directorates of Public Works, Public Works Business Centers, Directorates of Engineering, and other U.S. Army facilities' engineering activities involving facility disposal.

b. All PWTBs are available electronically (in Adobe® Acrobat® portable document format [PDF]) through the World Wide Web (WWW) at the National Institute of Building Sciences' Whole Building Design Guide web page, which is accessible through URL: http://www.wbdg.org/ccb/browse_cat.php?o=31&c=215

3. References.

a. Memorandum for Assistant Chief of Staff for Installation Management (ACSIM), Subject: Deconstruction and Re-use of Excess Army Buildings, 18 January 2001.

b. Army Regulation (AR) 200-1, "Environmental Protection and Enhancement," 21 February 1997.

c. Unified Facilities Guide Specifications (UFGS) 01572, “Construction and Demolition Waste Management,” 03 February 2003.

d. Executive Order (EO) 13101, “Greening the Government through Waste Prevention, Recycling, and Federal Acquisition,” 14 September 1998.

4. Discussion.

a. Deconstruction is the disassembly of a building for the purposes of recovering components and materials for reuse.

b. Traditionally, the disposal of excess or surplus buildings from the Army’s real property inventory was accomplished by demolition and landfilling. The wood resources that exist in the Army’s excess wooden property inventory constitute the largest existing stand of old growth forests (Webster and Napier 2003). Webster and Napier state that over 50 million sq ft of these surplus buildings are being demolished at $7/sq ft and landfilled at approximately $30-$50 per ton. The authors further state that the demolition of such buildings is approximately 85 percent of the solid waste burden of participating installations.

c. Disposing of demolition debris in landfills is expensive. Additionally, Army installations often face diminishing landfill capacities. Landfilling of recyclable building materials wastes natural resources and valuable landfill space.

d. Salvaging building materials for reuse and recycling helps the installation meet the Department of Defense Pollution Prevention Measure of Merit for Nonhazardous Solid Waste. The goals of this Solid Waste metric are to consistently reduce the quantity of solid waste generated, to consistently increase quantity of solid waste diverted, and to better manage the total cost of solid waste management.

5. Points of Contact. HQUSACE is the proponent for this document. The POC at HQUSACE is Mr. Malcolm E. McLeod, CEMP-II, 202-761-0632, or e-mail: malcolm.e.mcleod@usace.army.mil.

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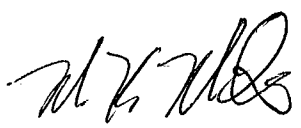

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APPENDIX A

1 Introduction to Deconstruction of WWII Buildings

In the past, the Army has commonly removed surplus buildings from its real property inventory through conventional demolition of the buildings and then landfilling the demolished debris. Conventional demolition generally does not produce salvageable material. Demolishing an average two-story World War II-era barracks (Figure A1) produces nearly 400 tons of debris.

Figure A1. Typical WWII-era, wood-frame buildings at Fort Hood.

Deconstruction is the disassembly and recovery of a building in order to maximize the recovery of salvageable material. Steel-framed buildings are often disassembled, although deconstruction is usually associated with wood-frame buildings. The salvage of deconstructed building materials can be a significant means to reduce solid waste volume and provide an installation with a revenue source from materials sale or reuse.

How an Army installation accomplishes the deconstruction activity can vary widely. One way is for the Army installation to contract out the deconstruction work but retain ownership of the salvaged materials. The salvaged materials may have a very high value. Another way is to have the contractor receive salvaged materials as in-kind payment so the cost of the deconstruction contract is reduced. A third option is for a deconstruction contractor to retain all salvaged material and charge a price based on the revenues to be received from resale of the materials. A fourth option is for a nonprofit contractor, such as Habitat for Humanity (HfH), to perform the deconstruction for a fee and the installation, in effect, donates the salvaged material to the nonprofit organization.

This PWTB examines the experiences, successes, and lessons learned of deconstruction projects at seven Army installations.

1.1 What Can Be Salvaged for Recycling or Reuse?

Lumber is typically the most sought after material from building deconstruction. Recently installed items such as sinks, toilets, tubs, wood flooring and carpeting, furnaces, and other products and equipment are also valuable on the salvaged material market. PWTB 200-1-23, “Guidance for the Reduction of Demolition Waste through Reuse and Recycling,” lists the resources that are frequently available in excess buildings. Table A1 provides a general categorization of materials that can be salvaged for recycling and/or marketed for reuse.

Table A1. Salvage and recovery patterns in demolition projects.

Typically recovered for Reuse:	• large, heavy timbers • dimensional lumber (e.g., 2x10, 2x8, 2x6) • metals, structural steel • concrete • brick/masonry • wood paneling, molding, and trim • hardwood flooring • siding • cabinets and casework • electric equipment and light fixtures • plumbing fixtures and brass • windows, doors, and frames • heating ducts • architectural antiques

Typically recovered for Recycling:	• dimensional lumber (2x4 or smaller) • gypsum drywall • carpet/carpet pad • structural concrete • rebar • brick/masonry • roofing material • insulation • ceiling tiles • glass • fluorescent tubes • scrap metal • electrical cable • copper and metal pipe

An example of all the items that can be recycled and reused when excess real property is made available for deconstruction versus traditional demolition is provided in a brochure for a sale of apartments at Fort Knox. The Fort Knox Recycle Program & Directorate of Community and Family Activities “sold” the recycled rights to the apartments at an auction and offered the following items:

Electronics: microwaves, vacuum cleaners and parts, washers, dryers, refrigerator, Frigidaire freezer, floor model television, Digital Video Disc player, Video Cassette Recorder, hot water heater, dishwashers, and three-door beer cooler.

Lighting: light fixtures and floor lamps.

Household: bedspreads, bed linen, towels, mini-blinds, scale, soap dispenser, and coat rack.

Furniture: recliners, night stands, head board, chairs, dining chairs, corner restraint chairs, table, and outdoor patio furniture.

Office: miscellaneous computer equipment, computer desks, wooden and metal desks, microfiche reader, and fax machines.

Building or Structure Supplies: bath boards, bathtub guards, upper and lower cabinets, countertops with sinks, wood, hardwood flooring, metal shelving, and metal cabinets.

Additionally, the brochure for this auction stated that the apartments for sale could contain kitchen cabinets, stainless steel sinks, plumbing fixtures, electrical fixtures, central air

and heat units, water heaters, double pane windows, doors, hard wood floors, and wood staircases. If one bidder did not purchase the entire building, then outside packages were to be auctioned off separately. Those packages included vinyl siding, aluminum gutters and attached sheds. Fort Knox stated that no structural components may be removed unless a successful bidder purchases the entire building.

1.2 What Is Meant By Salvage Value?

Salvage value is defined as the estimated value that an asset will realize on its sale at the end of its useful life. The salvage value depends on the material's quantity, quality, or condition, and on the type of salvageable building materials removed.

Salvage values fluctuate frequently and may vary significantly based on various economic factors. Whether a waste is cost-effectively recycled depends on local market conditions. Some areas may not have a market for certain materials, or an installation may not generate enough of a particular material to make recycling cost-effective. If no market exists, then an installation may have to pay for removal of some recyclable materials. This could still save money through avoidance of landfill disposal costs.

To calculate the potential salvage value of materials recovered during a deconstruction project refer to PWTB 200-1-26, "Market Valuation of Demolition Salvage Materials."

1.3 What Is the Deconstruction Process?

The deconstruction process roughly follows the reverse of the construction process. The materials that have been put on last will come off first. Deconstructing refers to the actual disassembly of a building and the processing and cleaning of the materials. The practice of focusing on each material type in reverse order of the construction process is more efficient for separating materials for reuse, recycling, and disposal at the time of removal.

Examples of building deconstruction activities are the removal of siding, sheetrock, windows, wall studs, flooring, trusses, and wood trim. Indoor and outdoor deconstruction activities are depicted in the following photographs (Figures A-2 through A-4).

Figure A2. Removing drywall at Fort McClellan.

Figure A3. Removing eaves at Fort McClellan.

Figure A4. Removing windows at Fort Campbell.

The processing of material includes activities like removing nails from wood items and cutting, sorting, and stacking of items. Cleaning may be required of items to be salvaged. Items may be processed from the building to a staging area. Trash and unusable materials that cannot be recycled may be removed and placed in dumpsters located on the job site.

In some cases, the deconstruction project is for abandoned buildings that may contain large quantities of trash and other debris. Considerable time may be spent “prepping” and cleaning the building before actual deconstruction begins.

Deconstruction methods can be manual, panelized, mechanical, or a combination thereof. An example of panel deconstruction is the removal of large sections of roof decking by cutting the decking into panels between rafters and removing the panels all at once. Figure A5 shows the panelization method of deconstruction.

Figure A5. Floor panelization at Fort McClellan.

Panelization allows roof, wall, and floor sections to be removed more quickly than manual methods but will reduce salvage yields. Manual deconstruction generally yields a higher percentage of salvaged materials than panel deconstruction. Manual deconstruction takes longer than panel deconstruction, however.

An example of mechanical deconstruction is the use of a bucket truck or an aerial manlift to provide an aerial work platform. A 45-ft manlift was used during a Fort Hood deconstruction project to safely remove windows, soffits, and siding.

Selection of the deconstruction method is usually determined by considerations such as the accessibility to the materials and the effort required to salvage the materials. The condition of the building components (e.g., presence of lead-based paint or rotted wood, etc.) also affects this decision. Typically, deconstruction is accomplished with a combination of methods.

2 Deconstruction Case Studies

2.1 Badger Army Ammunition Plant (BAAP), WI

BAAP is an excess installation, and the Army is working to remediate environmental and other hazards in preparation for new uses of the site. Under some circumstances, the Army is removing some of the buildings.

The Forest Products Laboratory (FPL) of the U.S. Department of Agriculture's Forest Service, led a study to evaluate the feasibility of using building deconstruction at BAAP. This evaluation included quantifying the quality and volume of salvageable lumber at the site and assessing the feasibility of using local community groups (for example, HfH) for some building removal.

Currently, BAAP plans to use its contractor, SpecPro, to administer the process. SpecPro is responsible for preparing sale documentation for buildings to be deconstructed. BAAP government staff will review the sale documents. SpecPro is responsible for sending out the bids and marketing the sales. Sealed bids are opened by BAAP, which accepts or rejects the bids.

Figure A6. BAAP excess building.

2.1.1 Building types and quantities deconstructed

One building has been deconstructed by FPL as a demonstration project using HfH for some building removal. BAAP has about 140 “magazine” buildings and some unknown number of warehouses. Of the 140 magazine buildings, a BAAP acquisition official reports that a “bunch” was recently put up for sale. Eight buildings are “down on the ground” with around six more to go.

All buildings at BAAP have been inspected for contaminants. BAAP estimates it has about 900 uncontaminated buildings that may be suitable for deconstruction.

2.1.2 Deconstruction process

BAAP’s installation contractor, SpecPro, removes asbestos and other contaminants before deconstruction. BAAP is developing plans for SpecPro to further deconstruct buildings and sell the salvaged materials, with the proceeds to go to the Government. Another option under consideration is to sell buildings to the public.

2.1.3 Salvaged materials

The lumber that was salvaged by FPL and HfH from the deconstruction of a 34 ft by 58 ft building at BAAP is described in Table A2. HfH reports that the lumber was sold as one lot for $2,500.

The proceeds from buildings sold for deconstruction return to BAAP. BAAP has put the proceeds back into deconstruction efforts as part of the Plant Clearance Program.

About 40 percent of the building material (by weight or volume) is reclaimed and the rest goes to the BAAP landfill. Typically, the studs, boards, and trusses are recovered. The trusses cannot be reused as is because they are “center-tied” and not up to code. The salvaged wood is generally of very good quality, with very few knots in the wood. Typical material that is landfilled: shingles (old and in bad shape), roof tar paper, T&G decking (rotted), lap siding, and asbestos-containing material.

Table A2. Lumber salvage at Badger AAP.

Lumber Dimensions (in. x in. x ft)	Quantity (No. of boards)
2 X 12 X 20	19
2 X 12 X 18	40
2 X 12 X 10	2
2 X 12 X 7	1
2 X 8 X 16	3
2 X 8 X 14	50
2 X 8 X 11	5
2 X 6 X 10	17
2 X 6 X 8	90
2 X 6 X 6	6
1 X 6 X 20	17
1 X 6 X 18	10
1 X 6 X 16	4
1 X 6 X 14	24
1 X 6 X 12	9
1 X 6 X 10	1
1 X 6 X 8	2
1 X 6 X6	12
1 X 6 X 4	4
2 X 4 X 12	10
2 X 4 X 10	10
2 X 4 X 9	10
2 X 4 X 8	20

2.1.4 Problems

The cost of asbestos removal is problematic when disposing of the buildings at BAAP. If the cost of asbestos removal plus the deconstruction costs exceed the sale proceeds of the buildings, then the acquisition official must spend additional Army money that is not appropriated for that facility. The acquisition official at BAAP reports that the Army will allow him considerable flexibility in his selection of disposal methods for removal of surplus property, as long as the bid covers the costs.

BAAP reports that a proposed concrete recycling program that would benefit the Wisconsin Department of Transportation is “not off the ground yet.” The concrete will come from foundations of buildings to be deconstructed.

2.1.5 Lessons learned

BAAP has proposed to have its contractor, SpecPro, conduct a study by doing the total deconstruction of one building to capture the actual costs of the deconstruction, marketing of recovered materials, etc. Questions were raised on the applicability of Davis-Bacon wage scales to deconstruction work. PWTB 200-1-23, “Guidance for the Reduction of Demolition Waste Through Reuse and Recycling” addresses this question: per U.S. Department of Labor, deconstruction (no new construction following the deconstruction) is not subject to the Davis Bacon Act. It is considered a "service"; therefore, the Service Contract Act and applicable wage determinations apply.”

2.2 Fort Campbell, KY

The deconstruction program is managed by the Public Works Business Center (PWBC), Environmental Division. The drivers for developing the deconstruction program: (1) no funding for demolition activities and the need to reduce disposal costs from building demolition activities, (2) limited landfill space, and (3) the need to make buildable land available for the Army’s Residential Communities Initiative.

The first deconstruction project involved a single building awarded to a sole bidder. Fort Campbell required the buyer to purchase the entire building and remove it down to the foundation. The buyer decided to move the entire building off-site for deconstruction.

The second deconstruction project (Figures A7 through A9) was a pilot study ERDC’s Construction Engineering Research Laboratory (ERDC-CERL), an HfH affiliate of Austin, Texas, the FPL, and the University of Florida’s Center for Construction and Environment.

Fort Campbell offers deconstruction “packages” through a sealed bid process managed by the Corps of Engineers Louisville District. The District selects the contractor based on the highest bid. The packages are marketed using a mailing list developed over many years and advertising in newspapers published within 100 miles of Fort Campbell.

Figure A7. Building deconstruction at Fort Campbell.

Figure A8. Building deconstructed down to the frame at Fort Campbell.

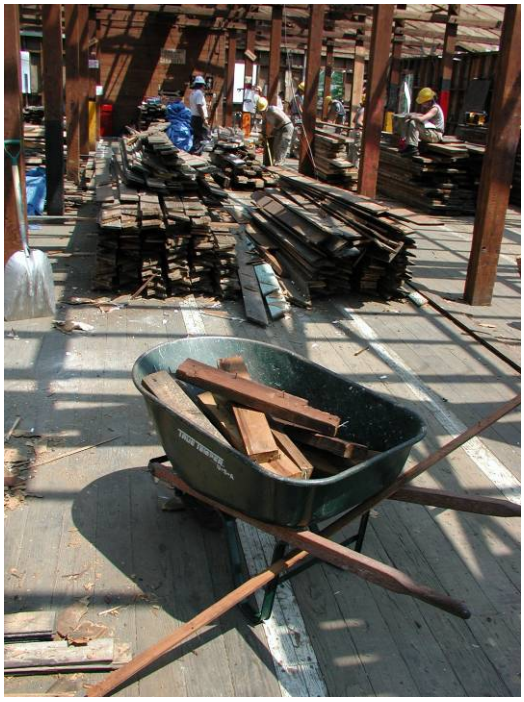

Figure A9. Stacking salvaged wood at Fort Campbell.

2.2.1 Building types and quantities deconstructed

Five buildings were deconstructed for the pilot study. All buildings were typical WWII-era, wood-frame construction. Dimensional lumber was the structural material, and wood sheathing and siding enclosed the buildings. All had been occupied up to the time of the project, and all had been upgraded to accommodate contemporary functions. The upgrades included replacement of the original heating systems, replacement of windows and exterior doors; addition of vinyl siding, re-roofing, and interior refinishing. While some rooms had been added, the buildings were not extensively partitioned. All of the buildings were in relatively good condition, and little deterioration was observed.

Generally, Fort Campbell does not require contractors to recover a minimum percentage of building material. Contractors are required, though, to remove an entire building down to the concrete foundation. Remaining concrete is removed during the demolition stage and stockpiled for future grinding and use. For more information on concrete recycling, see PWTB 200-1-27.

2.2.2 Deconstruction process

For the pilot study, manual volunteer labor (HfH and Americorps volunteers) was used. Workers segregated and labeled salvaged material, which was stored on base in a warehouse for later sale. HfH received the revenues generated from material sales. Remaining salvaged material was transported by HfH to an Austin HfH (AHfH) facility called ReStore.

2.2.3 Salvaged materials

Total material recovered included:

- 102,000 board-feet of lumber
- 23 gas heaters
- 11,000 square feet of vinyl siding
- 68 double-pane windows
- 71 roof trusses
- 23 doors.

Table A3 lists the materials AHfH salvaged from building 2748, which covered about 3,000 sq ft.

Table A3. Material salvaged from building 2748 at Fort Campbell.

Material (dimensions are given for lumber)	Quantity
Doors, metal, ea.	4
Small overhead gas heaters, ea.	2
Vinyl Siding, avg. 12 ft pieces, ea.	162
Windows, single pane, 3.5 ft x 5.5 ft, ea.	15
Windows, double pane, 3.5 ft x 5.5 ft, ea.	9
Manufactured trusses, 24 ft, ea.	31
Pine flooring, tongue-and-groove, 3-in.	1,550 ft^2
Plywood, 5/8 in.	64 full sheets
1 x 6, subflooring	2,362 linear feet (ft)
1 x 4	928 ft
2 x 4	213 ft
2 x 6	700 ft
2 x 8	24 ft
2 x 10	1,704 ft

Table A4 lists materials AHfH salvaged from a Fort Campbell warehouse, building 834, which covered about 9,000 sq ft.

Table A4. Salvaged material from building 834 at Fort Campbell.

Material (dimensions are given for lumber)	Quantity
Doors, metal, ea.	1
Doors, wood, ea.	3
Vinyl Siding, avg. 12 ft lengths, ea.	330
Red Metal Fire box, ea.	1
Mariner Lights w/cover, ea.	15
Oak Flooring, tongue-and-groove, 3 in.	225 ft^2
Oak Flooring, tongue-and-groove, 2.25 in.	2,800 ft^2
Pine Flooring, tongue-and-groove, 1 x 6 in.	3,000 ft^2
Manufactured trusses, 24 ft, ea.	31
Pine flooring, tongue-and-groove, 3 in.	1,550 ft^2
Plywood, 5/8 in.	64 full sheets
1x6, subflooring	2,362 linear feet (ft)
1 x 12	75 ft
2 x 4	1,724 ft
2 x 6	6,094 ft
2 x 6 flooring, tongue and groove	5,747 ft
2 x 8	9,500 ft
2 x 10	443 ft
2 x 12	15,915 ft

AHfH took aluminum and non-painted metals (heavy and light gauge steel) to the Defense Reutilization and Marketing Office (DRMO) on Fort Campbell to recycle. AHfH had to take the recycled items to DRMO; DRMO would not pick-up. Types of components that DRMO accepted from the building deconstruction were pieces of soffits, metal systems holding up the interior dropped ceiling, piping that was not painted or black piping material, ductwork that was not painted and with the surrounding insulation removed, gutter systems, and metal/aluminum siding pieces. AHfH estimated that using DRMO saved them several hundred dollars in disposal costs. It is estimated that 75 percent of all recyclable metals were salvaged to the DRMO. AHfH estimated that 160 cu yd, or four 40-yd dumpsters, would have been required to landfill the materials.

Components of each building that were deposited in the landfill included bricks, mechanical equipment that was not portable without heavy machinery, all drywall, and most exterior framing studs coated with lead-based paint (LBP).

In general, for the deconstruction packages that are bid out, Fort Campbell estimates that contractors recover between 95 and 98 percent of the building.

2.2.4 Problems

When deconstructing building 834 (warehouse), AHfH encountered some problems. The demolition of the concrete foundation stem walls was more difficult and expensive than anticipated. Also, installation security requirements caused the haul route for the removal to the landfill to be altered to a much longer route. Fort Campbell had to modify the contract to address this issue.

2.2.5 Lessons learned

During the pilot project with ERDC-CERL and the Austin HfH, AHfH sold a considerable amount of the salvaged materials directly from the job site. Availability of the material was made known by word of mouth, through people passing by the job-sites, by civilians and military personnel alike. AHfH found that they had to expend little effort through this means of selling the material. Buyers became frequent repeat buyers. AHfH did not have to move the salvaged material (a considerable logistic) to the buyer – the buyer came to them. As more buildings came down, more and more people came back. AHfH recommends that, for future projects, contractors work with the installation to set up a fence and establish a “lumber yard” to maximize on-site sale opportunities. The AHfH found that an estimated $4,000–$6,000 of salvaged material was sold through this method. A total of $13,500 worth of materials was sold by AHFH on-site throughout the duration of the pilot project.

The local DRMO accepted recycled aluminum and nonpainted metal from AHfH during the project. AHfH estimated that this method saved them several hundred dollars in disposal costs.

AHFH had assumed that a salvage market was already established when they took on the deconstruction project. This meant that a large volume of materials was “in the way” as the project continued. For example, building 834 was used as a processing area and warehouse for the materials salvaged from the other buildings. Yet, building 834 was to be deconstructed. An indeterminate amount of labor hours was spent moving wood out of the way that had been previously stacked. In some cases, the same pile of wood had to be handled several times before reaching its final destination on-site. Security of materials was an issue, too. Storage either on post or elsewhere needs to be factored into future projects.

Table A5 shows total debris diversion for the pilot deconstruction project.

Table A5. Total material diversion from Fort Campbell demonstration project.

Material Type	Pounds	Tons	Pounds/ft^2
Materials salvaged by AHfH	254,606	127.3	11.7
Metals delivered to DRMO	10,900	5.5	0.5
Concrete piers taken by troops	44,086	22.0	2.0
Air conditioning unit given away	400	0.2	0.0
Siding material reprocessed at FPL	2,140	1.1	0.1
Concrete rubble	855,068	427.5	39.4
TOTALS	*1,165,060*	*583.6*	*53.8*
Total potential debris	1,367,100	683.6	63.0
TOTAL BUILDING AREA:	21,700	-	-
TOTAL DIVERSION RATE	*85.4%*	-	-

2.3 Fort Carson, CO

Fort Carson initiated an installation sustainability program in 2002, with the goal of adopting practices that support long-term sustainability for the region. One of the program goals is to reduce the waste leaving Fort Carson to zero by the year 2027. Construction and demolition debris is about 60-70 percent of the solid waste stream leaving Fort Carson.

The Fort Carson Directorate of Environmental Compliance and Management (DECAM) supplemented Directorate of Public Works (DPW) Facility Reduction Program (FRP) funds in June 2004 to perform a pilot deconstruction study on two buildings already scheduled for removal. The DECAM provided additional funding to demonstrate the feasibility of deconstruction as a building removal technique on Fort Carson.

The purpose of the project was to collect and report data on the volume of materials diverted from the landfill, labor strategy, harvest rates, and potential market value of materials harvested. Fort Carson felt that this information could be used to determine and document the cost effectiveness of the project as well as help in evaluating the feasibility of deconstruction techniques on future projects.

Project results are reported in “Fort Carson Deconstruction Feasibility Assessment Report” (Innovar Environmental, Inc., 2005). The Innovar report is the information source for this section of the PWTB.

2.3.1 Building types and quantities

Buildings 6286 (Figure A10) and 227 were selected for deconstruction based on their distinct building types and planned removal dates. Buildings 6286 and 227 required different deconstruction approaches and techniques.

Building 6286 was a 13,128 sq ft, single story, World War II-era structure. It had a concrete masonry unit (CMU) exterior with 2 x 4 wood interior partition walls. It had wood rafters and "skipsheet" roofing. The roof sheeting was 1 x 10 and 1 x 12 butt-jointed boards with as many as five layers of asphalt roofing (generally three layers of shingles). The roof structure was supported by bolted trusses in some areas and a web truss style in the west wing. The interior surface of the roof was sheet rocked in some areas. The exterior of the building consisted of 2 x 2 x 10 nailers pinned to the CMU exterior wall. The building had been used in urban warfare training exercises. The building had some flooring comprised of a single layer of 2.25-in. tongue-and-groove (T&G) fir. Other areas had a plywood subfloor. The floor was supported on 2 x 12 floor joists, beams, and poured-concrete posts.

Figure A10. Building 6286 at Fort Carson, shortly before deconstruction.

(Source: Fort Carson Deconstruction Feasibility Assessment Report)

Building 227 (Figure A11) was one of six WWII-era warehouse buildings located near the Fort Carson rail yard. The building

dimensions were approximately 70 ft x 130 ft (10,000 sq ft). It was a single-story structure of wood construction, with few interior partition walls (approximately 1,500 sq ft of partitioned interior), wood rafters and skip-sheet roofing with four layers of asphalt shingle and rolled roof. The wood-frame building design of this warehouse was well suited for deconstruction.

Figure A11. Building 227 at Fort Carson.

2.3.2 Cost information/contracting arrangements

Fort Carson contracted with Innovar Environmental, Inc. to manage the deconstruction feasibility assessment. Innovar was responsible for the coordination of the demolition and deconstruction efforts. For demolition, Fort Carson contracted with engineering-environmental Management, Inc. (e2M), who volunteered some of their project budget, equipment, and labor support to assist with the deconstruction effort. e2M subcontracted Second Chance Deconstruction, a local deconstructtion firm, to provide the deconstruction expertise and labor needed to make this project a success. e2M and Second Chance worked closely together on building 6286, sharing significant tasks. Second Chance completed the majority of building 227 as a subcontractor to e2M.

Fort Carson reports that project budgets were $81,158.49 for building 6286 and $52,646.00 for building 227. The building 6286 final project cost for deconstruction and follow-up demolition of the building was $89,278.00, which exceeded the budget by $8,119.51.

2.3.3 Deconstruction process at building 6286

For building 6286, much of the harvestable product (i.e., windows, interior doors, and lights) was damaged so

deconstruction efforts focused on the remaining higher-yield items available. Budget and time constraints allowed for only 8,000 sq ft to be deconstructed. The remaining 5,128 sq ft were removed using traditional demolition practices.

The roof sheeting was sought as a harvestable product. Relief cuts using a circular saw were made from peak to soffit every 16 ft. The reach forklift was used to peel off sections of the roof (Figure 12).

Figure 12. Reach forklift removing a roof section.

Fort Carson used this method to enable preservation of the rafter boards. Trusses were lowered using the reach forklift so that they could be disassembled on the relatively safer ground. The 2 x 6 x 20 joists on the north wing of the building were harvested by pulling out the exterior walls, allowing the ceiling to fall to the decking. On the east wing, however, rafter boards were pulled, and interior ceiling drywall was loosened and dropped to the floor exposing the ceiling joists. This wing also had the attic space finished with drywall, which added to the debris and labor required to harvest the joists. At this point, steel tubing cross bracing for lateral support was encountered. Fort Carson discovered that each 2 x 6 x 20

was notched, which significantly reduced their market value for reuse.

The interior walls were 2 x 4 x 10 stud partitions with sheetrock on both sides. The partitions were removed with hand tools. The sheetrock could not be salvaged and was disposed of as general demolition debris. The exposed studs were cut at the top and bottom with a “Saws-All” and collected for reuse or resale.

Fort Carson reports that several hours of labor and effort were expended to remove the interior lathe and plaster from the inside of the exterior walls. They wanted to facilitate handling of the cinder block, which was sought for recycling. After some trial and error, the reach forklift was used to push the lathe and plaster away from the interior walls by punching through the outside of the building and pushing through to the inside. This technique pushed in a good bit of interior finish from the cinder block and allowed for cleaner handling of cinder block debris.

Wood flooring, concrete pillars, and footers (Figure A13) were sought for reuse and recycling. Plywood subflooring was pulled up, exposing 2 x 12 floor joists. The floor joists were then removed by hand and either denailed or recycled. Most of the floor joists in the north and south wing had been exposed to extreme temperatures from the steam pipes beneath the building. These floor joists had dry rot, so a reach forklift was used to lift off the subflooring and accumulate it for recycling rather than for reuse or resale. An excavator was then used to pluck the floor joists from the foundation and place them in a stockpile. Once the flooring was removed, the excavator was used to retrieve the concrete pillars and foundation for recycling.

Figure A13. Floor joists and concrete piers exposed during deconstruction of building 6286.

2.3.4 Deconstruction process at building 277

Lumber and plate steel offered the most potential for reuse and resale from deconstructing building 277. The building was easily accessible from both the inside and outside. The deconstruction approach was from the top down. Shingles, roof decking, rafters, blown-in insulation, siding, framing, and flooring were removed in sequence.

In 5-1/2 weeks, 10,000 sq ft of structure was deconstructed. Only wood pilings, concrete stairways and a small portion of wood structure (approx. 450 sq ft) were left for removal and disposal by a demolition crew. The remainder of the site was graded and compacted within one week after deconstruction.

The roof sheeting was 1 x 10 and 1 x 12 butt-jointed boards. The roof had up to five layers of asphalt shingles, which were removed by hand labor using mostly claw hammers and flat bars. The roof structure was supported by 8 x 8 built-up columns extending from the floor joists through the flooring and up to the rafters, spaced 12 ft on center (see Figure A14). Columns

were bolted/bracketed to the bottom of the rafters. The interior surface of the roof was sheeted with 3/8-in. fiber board. Blown-in, cellulose insulation sandwiched between the fiber board and roof sheeting was removed using a vacuum truck.

Figure A14. Interior view of columns and roof structure in building 227.

Building 227 had approximately 1,500 sq ft of finished interior partition walls (2 x 4 x 10 studs with vinyl-covered sheet rock), a suspended ceiling grid, and fluorescent troughers on the south end. The remainder of the building was open and had four loading dock areas with roll-up doors, one of which had a concrete ramp and docking area.

The fluorescent lights and most of the ceiling tiles were removed and salvaged. The interior studs were not salvaged because the potential salvage value was not worth the effort. The interior studs were instead knocked down by a skid-steer and recycled as mulch. The 8 x 8 wood columns were salvaged and were removed by using a skid-steer removal technique. Each

column was attached to the skid steer using metal chains and pulled free.

Building 227's exterior was covered with vinyl siding. The building exterior was characterized by 2 x 6 x 10 studs with 1 x 8 lap siding with lead painted exterior. The interior surface of the exterior walls was 1 x 6 T&G and painted with LBP. The exterior walls were removed using the reach forklift (see Figure A15) and dropped inside the building.

Figure A15. Reach forklift removing exterior walls

Vinyl and lap siding were removed from the inside using claw hammers and flat bars. Fort Carson reports that the presence of LBP on the siding did not negatively impact the siding removal process. Three members of the workforce were outfitted with lead air monitoring cassettes and monitored for lead exposure. None of the individuals exceeded Occupational Safety and Health Administration (OSHA) action levels. Precautionary measures were taken to adequately wet the walls prior to removal in other areas. Fort Carson felt this technique aided in reducing the amount of dust exposure for workers.

The flooring in building 227 was double-layer, 2 x 6 T&G wood. The aisles were covered in 1/4-in. diamond plate sheet steel. Each steel sheet measured 4 ft x 8 ft and weighed 365 pounds. They were bolted through both layers of the T&G floor. The plate steel was removed by grinding the bolt heads. A total of 45 sheets were recovered for resale.

The second layer of T&G was toe-nailed into the first layer on-diagonal. Steel wedges were fabricated to facilitate the removal of this layer. Laborers initially used sledgehammers to pound the wedges into the T&G flooring in order to facilitate removal. Using the skid steer equipment to push several wedges into the T&G flooring proved to be a faster and more effective method of flooring removal (see Figure A16).

Figure A16. Removing flooring with skid-steer.

The first layer of T&G flooring was surface-nailed down into the floor joists on square with the joists. The flooring was supported by 2 x 12 floor joists, built-up beams, and utility poles for posts. A chain saw cut through the first layer of this flooring. The loosened flooring was removed and stockpiled for resale. Floor joists were removed by hand labor using the chain saw and claw hammers.

2.3.5 Salvaged Materials from Deconstruction of building 6286

Most of the reusable material salvaged for resale was lumber, which equated to approximately 18,000 linear feet. Figure A17 shows harvested wood bundled for reuse and sale at Fort Carson.

Figure A17. Harvested wood bundled for sale.

Table A6 summarizes the deconstruction and demolition data for building 6286. The data source is the Innovar report on Carson Deconstruction Feasibility, page 14.

Table A6. Deconstruction data for building 6286, Fort Carson

Parameter	Deconstruction Section	Demolished Section
Area	8,000 ft^2	5,128 ft^2
Time required	4 weeks	3 weeks
Labor-hours	897	55
Debris sent to landfill	684 yd^3	756 yd^3
Lumber harvested	18,000 ft	0
Materials salvaged for reuse (lumber, ceiling tiles, windows, fixtures, etc.)	37 tons	0
Clean wood diverted from landfill, including mulch	11.9 tons	0
Roofing material salvaged for study purposed, not marketed	9.8 tons	0
Ferrous metals diverted	7.9 tons	0
Copper diverted	550 lbs	0
Aluminum diverted	1,280 lbs	0

The estimated resale value for the used material from building 6286 was $9,500. Material handling and management costs were not included in the estimate. The used building material sales

from building 227 were expected to bring in approximately $10,718 when sold. Because building 227 was deconstructed for $2,143 below budget, Innovar projected that total revenues realized on deconstructing building 227 could be as much as $12,681. Again, this does not include material management costs.

Fort Carson reports that building 227 diverted 67.3 tons of material; building 6286, approximately 57.7 tons.

2.3.6 Salvaged materials from deconstruction of building 277

Building 277 was almost completely deconstructed. Over 28,618 linear feet of lumber was harvested. The materials harvested from building 277 equate to over 58 tons diverted from the landfill. The entire waste stream from this large warehouse was contained in six 40-yard dumpsters.

Approximately 80 percent of all roofing nails were removed during tear-off. That meant a minimal amount of additional denailing took place on the ground. The boards were fairly brittle but applying appropriate care when prying nails out meant that about 75 percent of the roofing boards were harvested for resale. The remaining portion was separated for recycling. Fort Carson reports that several 2 x 8 rafters were also harvested.

Table A7 summarizes the deconstruction data for building 277. The source of the data is the Innovar report on the Carson Deconstruction Feasibility, page 31.

Table A7. Deconstruction data from building 277, Fort Carson.

Parameter	Quantity
Area	10,000 ft^2
Time required	5.5 weeks
Labor-hours	1,012
Debris sent to landfill	240 yd^3
Lumber harvested	28,618 ft
Materials salvaged for reuse (lumber, ceiling tiles, windows, fixtures, etc.)	58 tons
Clean wood diverted from landfill, including mulch	6.6 tons
Roofing material salvaged for study purposed, not marketed	12.6 tons
Ferrous metals diverted	2.6 tons
Copper diverted	125 lbs
Aluminum diverted	0 lbs

2.3.7 Problems at building 6286

Exterior cinder block walls and glass block were sought as recyclable products (see Figure A18). Fort Carson had hoped to recover the cinder block for use as aggregate on Fort Carson's combat roads and trails. The glass block was intended for resale. But the accumulated cinder block had to be disposed of as rubble due to the unavailability of an Army Reserve Engineer Unit's rock crusher. The material could not be accumulated on site. Fort Carson felt that if they could have executed the recycling of this block as planned, it would have made a significant impact on the future removal techniques employed for buildings similar to building 6286.

Figure A18. Cinder block intended for recycling.

Building 6286 was originally slated for machine demolition. It was being prepared for demolition when Fort Carson decided to attempt deconstruction. The demolition schedule was already in place prior to the deconstruction project starting. The quick shift in approach impeded effective project pre-planning.

The lack of pre-planning meant that obstacles occurred that could otherwise have been avoided. Building 6286 had numerous leaking higher temperature hot water (HTHW) pipes under the building (below grade) that had remained in use during the deconstruction project. They could not be shut off because these pipes distributed heat to several adjacent buildings that were still standing. The pipes were still attached to the floor

joist hangers, which impeded flooring removal because a 2-day work request had to be executed for the Installation Operations and Maintenance (O&M) contractor to perform the work.

The HTHW pipe steam leaks generated excessive heat and caused the floor joists to bake. This precluded a good harvest of usable boards.

Building 6287, adjacent to building 6286, served as the Fort Carson Courthouse. Fort Carson had to cease deconstruction operations on building 6286 for approximately 4 days due to a Court Martial held in the Courthouse.

Building materials and construction style of building 6286 posed another challenge. One wing of the building contained an attic comprised of sheetrock. The Colorado Springs area offered no asphalt roofing or gypsum recycling opportunities. The sheetrock and roofing materials were disposed of as waste. This resulted in additional labor costs and debris generation.

Structural challenges at building 6286 surfaced when ceiling joists proved to have steel tube cross-bracing as lateral supports. Each 2 x 6 x 20 beam was notched, which significantly reduced its reuse value.

2.3.8 Problems at building 277

Roofing and flooring removal required much more effort than anticipated. Unanticipated equipment trouble caused minor delays and added costs to the project.

Manually removing five layers of roofing was a significant hurdle to overcome. This roofing was excessively nailed, which complicated the shingle and sheeting removal and the denailing process. The roof sheeting was of sufficient quality and quantity, however, to warrant the work.

The flooring in the warehouse was a challenge. Bolts holding down the quarter inch, diamond-shaped steel plates had to be ground down with a hand grinder. The floor itself was a double layer of 2 x 6 T&G decking. The removal required significant effort while workers were also trying not to damage the product. The top layer of flooring proved easier to remove than the bottom layer because the top layer was toe-nailed. The bottom layer was face-nailed to the floor joists.

The tires of the skid steer were not foam-filled. Several flats on the skid steer occurred during the first week and a half of

deconstruction. Solid-core tires were purchased for the equipment.

2.3.9 Lessons learned

The results of the Fort Carson pilot demonstration project show that certain building types are better suited for deconstruction than others. For example, building 227 proved to yield a significant amount of reusable building materials and was cost effective. Building 6286 was better suited for limited deconstruction, such as skimming fixtures and some roofing and flooring materials. It was not suited for full deconstruction due to the unavailability of local rock crushing opportunities and the amount of intense labor required to remove the wood furring strips and other building material contaminants.

The deconstruction plan for building 277 was well designed. Project execution was smooth. Electricity, water, and telephone services were available for most of the project. Appropriate equipment selection and availability were crucial to the success of this project. Nearly every phase of the deconstruction work used some mechanical equipment that replaced labor costs and improved efficiencies.

The deconstruction techniques used at building 277 resulted in approximately 80 percent of all roofing nails being removed during tear-off. A minimal amount of additional denailing took place on the ground. The boards were fairly brittle but applying appropriate care when prying nails out meant that about 75 percent of the roofing boards were harvested for resale.

Fort Carson reports that the results of the demonstration project overall show that deconstruction should be considered for each building removal or renovation project on Fort Carson as a means to minimize waste and reuse or recycle materials. Deconstruction is an obvious choice for wood building removal. Deconstruction can also be used in a more limited capacity on masonry type buildings until a rock crusher becomes available on Fort Carson. Much of the CMU block building exteriors can be used as aggregate on installation combat training roads and trails. As deconstruction becomes more popular, additional used building material markets will become available locally. In addition, Fort Carson expects contractors that perform deconstruction projects on installation structures will become more efficient and cost effective.

2.4 Fort Hood, TX

Fort Hood wanted to remove building 919 (see Figure A19) as quickly as possible using deconstruction rather than conventional demolition practices. In doing so, however, Fort Hood also wanted to evaluate deconstruction methods that would yield the maximum amount of salvaged/recycled material from a particular building. So the project was established as a research project to compare manual deconstruction methods with panel deconstruction methods. Fort Hood hoped to determine an optimal combination of manual and panel deconstruction methods for further deconstruction projects at Fort Hood.

Figure A19. Building 919 at Fort Hood.

2.4.1 Building types and quantities deconstructed

Building 919 was two stories and 11,800 square feet. The floor plan was similar to that of a standard barracks. The building's wings were similar to a single story dining hall building. The type of building and floor plan, for the purpose of evaluating deconstruction methods, lent itself to extrapolation as a template for most types of standard wood-framed buildings.

The building was in a U shape, with each side a mirror image of the opposite side. It was originally the first school built on Fort Hood in 1948. Over the years it has served as a Brigade Headquarters building, unit administrative facility, and then as a training facility for installation police and Special Weapons

and Tactics units. The building interior was in very poor condition, which led to a longer building preparation time (932 hours) than what would be considered normal.

2.4.2 Deconstruction process

HfH was involved in the deconstruction of building 919 at Fort Hood. HfH has developed a capability to deconstruct wood-frame buildings and resell the salvaged materials through the service's ReStore network. Sources of labor on this project were the Fort Hood HfH local affiliate, the AHfH, and outside contractors. HfH arrived at Fort Hood on 30 August 2004. Their last day on site was 11 February 2005. Total project time was 113 working days. Table A8 shows the tasks and time required by workers to complete the steps for deconstructing building 919.

Table A8. Time required for deconstruction of building 919.

Task	Hours
Building preparation/clean-up	932
Abatement/preparation (universal waste)	132
Shingle removal	72
Panel/manual deconstruction	913
Volunteer hours	1,084
Total hours	3,133
Total hours (per square foot)	0.2655

The project had a break for 28 working days to allow the abatement of asbestos floor tiles, which was not detected in previous asbestos-containing material (ACM) surveys. During most weeks of the project, HfH worked four 10-hour days to maximize the actual time on the site. HfH used volunteers from other organizations, and their labor is counted toward labor hours actually worked.

Fort Hood allowed the following to remain in place after deconstruction: walks, driveways, hardstands, culverts and drainage structures, other paving nominally at grade, piers, slabs and foundations to grade, and underground utilities.

2.4.3 Cost information/contracting arrangements

The Environmental Division of DPW tried to secure funding for this deconstruction project through various Army environmental funding programs. Not until 2004, when the project was funded with Army Facility Reduction Program funds, was Fort Hood able to begin the project.

Fort Hood contracted with AHfH to perform the deconstruction. The AHfH contract totaled $67,417. The USACE Huntsville Engineering and Support Center (HNC) sent the funds for this project via Military Intergovernmental Purchase Agreement (MIPR) to Tulsa District, which then awarded the contract to HfH. The contract was “sole sourced” to HfH because of their expertise with deconstruction and salvaging work. The contract was awarded on 2 July 2004. HfH mobilized to Fort Hood on 30 August 2004.

Asbestos was found in building 919. Asbestos abatement cost was $50,000. HNC paid this cost to Fort Worth District, which contracted out the asbestos abatement. The total cost for the project then became $117,706.

2.4.4 Salvaged materials

The material weight of the recycled items from the deconstruction of building 919 was 46.2 tons. Table A9 shows a breakdown of those items.

Table A9. Materials recovered from building 919

Materials Recovered	Quantities
Flooring:	
3-in. tongue-and-groove, pine	6,750 ft^2
Windows:	
3 ft by 5 ft, single pane, aluminum, ea.	43
Electrical circuit breaker box, ea.	1
Lumber:	
2 x 4	3,337 linear feet (ft)
2 x 6	3,919 ft
2 x 8	2,476 ft
2 x 10	99 ft
2 x 12	9,154 ft
6 x 6	543 ft
6 x 9	7 ft
Scrap metal	8.96 tons
Wood, to compost	45.5 tons
Asphalt shingles	7.81 tons

Besides lumber, flooring, and windows, this project produced 8.96 tons of scrap metal. The amount of compostable material (wood) produced was 45.4 tons. Nearly 8 tons (7.81) of shingles were removed to be used for an asphalt project.

The total amount of all materials/waste generated during this project was 207.29 tons. The total amount of recycled/re-used materials was 108.37 tons. This project generated 74.42 tons of refuse. The amount of special waste generated (lead-based paint) was 24.5 tons. Asphalt and concrete that the HfH workers encountered were left in place for Fort Hood to remove later. Fort Hood reported that this material would be sent to the Inert Material Management Facility for processing for re-use.

Between materials salvaged for resale and recycling, an estimated 75-85 percent of building 919 was kept out of the Fort Hood landfill.

2.4.5 Problems

Building 919 turned out to have three levels of flooring and multiple layers of siding. The outside layer of siding was metal, which was recycled. Fort Hood determined that the initial layer of wood lap siding contained LBP. Fort Hood was hopeful the initial layer of lap siding would be in useable condition (minimal pealing and chipping). Unfortunately, the condition of this lap siding was too poor for HfH to use. Fort Hood was unsuccessful in securing a device to plane the siding to remove the LBP.

An extra floor layer was found in September 2004. Discovered under two layers of flooring were 9 in. x 9 in. tiles that contained mastic with asbestos. A contractor for Fort Hood had surveyed the building for ACM before the deconstruction project began. Based on those results, Fort Hood estimated that only a small fraction of one bathroom floor contained asbestos material: an approximate area of 100 sq ft. Actually, approximately 12,000 sq ft of flooring was required to be abated. Fort Hood secured funding from HNC for the abatement of this tile. The cost of abatement was $50,000. The abatement work delayed the project by almost 2 months in addition to the cost it added to the project.

2.4.6 Lessons learned

As a research project, experimental hand tools were used to determine whether they made the process of removing flooring and wall sheathing easier and/or quicker. Unfortunately, the wall removal tools were made available to the workers late in the process, so they were used for only a short time. The use of this hand tool did show promise though. The tool designed to aid in the removal of flooring, however, was not of the scale needed for the work. Workers felt the shaft length of the tool

needed to be much longer (36-42 in. in length versus 12 in.) in order to be effective. The floor removal hand tool was not used after initial assessment.

HfH considered the initial layer of T&G flooring valuable. Because of its value, manual deconstruction was the preferred deconstruction method because it salvaged the most flooring.

Fort Hood used several dumpsters on the job site for specific recyclables and for debris to be removed. The workers felt that the disposal company slowed down the overall project by about 3 days because the workers had to wait for the full dumpster to be switched out with empty ones. This delay happened when panel deconstruction of the exterior walls occurred. The panel cuts of the exterior walls filled a waste dumpster in a matter of 2 hours, but the full dumpster was not replaced with an empty one for at least 24 hours. The panelization often continued although this meant that the panels to be removed were then handled twice (when the empty dumpster finally arrived). The workers felt that had dumpster availability been more frequent, the removal of all exterior walls could have taken less than 2 days, instead of being spread over 2 weeks.

Fort Hood was successful in securing the appropriate approval to remove wood that possibly contained LBP. Fort Hood modified the HfH contract to include a mandate for customer notification of the presence of LBP in the wood. Since the AHfH had handled wood with LBP for many years, they had established their own notification program that met state regulatory requirements for notification.

The results of this project revealed that manual deconstruction yielded a higher percentage of salvaged materials than panel deconstruction. However, manual deconstruction takes longer than panel deconstruction. Panel deconstruction is most efficient in those areas where the materials are not useable. When lap siding was identified as not usable, for example, cutting the exterior into panels (panel deconstruction) for placement into the container was the most efficient method of deconstruction.

2.5 Fort Knox, KY

Fort Knox sells recycle rights to the parties performing deconstruction as opposed to selling the building. The Fort Knox deconstruction program is operated through the installation’s Qualified Recycling Program (QRP), within the Directorate for Community and Family Activities. Bid

solicitations are offered through open auctions that are conducted on the weekends. The catalyst for their deconstruction program was the lack of funding in the Real Property budget to maintain the buildings. Revenues from the recycle rights return to the Fort Knox Recycle Program instead of going to the U.S. Treasury. So far, the deconstruction program has generated $256,000 in revenue.

2.5.1 Building types and quantities deconstructed

The Fort Knox Recycle Program reports that, in roughly 3 years of operation, 258 primarily wooden WWII-era buildings and 451 brick Family Housing apartments have been disposed of by deconstruction.

2.5.2 Deconstruction process

Before the work begins, Fort Knox removes the ACM, polychlorinated biphenyl (PCB)-containing ballasts and mercury-containing thermostats. Paint is also tested for lead content and, if found to be above threshold level, the buyer is notified.

When abatement activities and other screening requirements are completed, Fort Knox transfers the property to the QRP. When salvage is completed, the QRP transfers the property back to the DPW, which then contracts for demolition services to remove the remainder of the debris. The demolition contractor then separates concrete and masonry rubble and any leftover metal materials for recycling.

2.5.3 Cost information/contracting arrangements

The contract includes criteria to extract a minimum volume of salvaged materials, safety requirements, period of performance, disclosure statements for LBP materials, identification, site security, and times of the day at which salvage activities may take place. The purchaser must report to the installation the types and quantities of materials they are recovering (1) so the installation can take credit in its required Solid Waste Analysis Report, and (2) to verify salvage of the minimum amount of materials.

2.5.4 Salvaged materials

Generally, Fort Knox requires deconstruction contractors to recover a minimum of 50 percent of the building material (by weight), excluding foundations or, for apartment sales, 3,500 pounds from each apartment.

Some contractors will remove salvageable items such as kitchen cabinets and auction them off during a Fort Knox auction. Fort Knox receives a percentage of those sales as a handling fee.

2.5.5 Problems

The deconstruction program underwent several modifications during the early stages. The number of buildings selected for deconstruction was reduced. Initially, Fort Knox found that when too many buildings were assigned to one contractor for deconstruction, the amount of salvaged material was less than satisfactory (only easily recovered items were removed). Fort Knox also tried advertising contracts and requesting sealed bids, but this generated little interest.

2.5.6 Lessons learned

Fort Knox reports that 153,468 tons of debris were diverted from the Fort Knox construction and demolition (C&D) landfill. This action extended the C&D landfill's life by 20 years. This has resulted in $1.5 M in landfill savings and $1.2 M in potential demolition savings.

It takes about 3 weeks for the Recycling Center to prepare everything once a parcel of property has been identified. The open auction method chosen by Fort Knox allows interested parties to bid on the recycling rights to buildings. The bid solicitation paperwork and negotiations are handled by Fort Knox personnel. The auction is promoted through a mailing list developed over the years and advertised on local television. The QRP receives a percentage of sales. Recycle Program personnel are responsible for maintaining the program checklist, mailing the flyers that advertise the auction, and inspecting the site(s) of the building(s) to be deconstructed.

2.6 Fort McClellan, AL

Base Realignment and Closure marked Fort McClellan for closure in 1995; it is now a 26,000-acre former military base. The base officially closed in 1999, although the Army National Guard maintains a permanent presence there. A Joint Powers Authority (JPA) was established from members of the local county, the local city governments, and state officials. This JPA facilitates the transfer of remaining buildings for commercial and private use.

In 2003 the University of Florida's Center for Construction and Environment (CCE) completed a deconstruction research project at

Fort McClellan. The purpose of the project was to investigate different methods by which deconstruction can be an economically viable option to demolition. The results of the research are reported in “Pollution Prevention Through Optimization of Building Deconstruction for DoD Facilities: Fort McClellan Deconstruction Project” (Guy and Williams 2004).

The deconstruction project was part of a larger Department of Defense (DoD)/Environmental Protection Agency (EPA) Region 4 Pollution Prevention grant program. Coinciding with the deconstruction at Fort McClellan, the University of Louisville conducted a 2-day workshop for DoD personnel from across the country. Participants learned about deconstruction techniques first-hand and heard presentations from others who had fostered successful programs at their own installations.

2.6.1 Building types and quantities deconstructed

Three WWII-era barracks were dismantled: buildings 830, 844, and 829 (Figure A20). Each building was approximately 4,500 sq ft. Each of the buildings had a brick chimney, which Fort McClellan had hoped could be partly salvageable. The brick chimneys, originally about 8-ft tall, were added to the buildings probably circa 1970s. The bricks in the upper part of the chimneys appeared to be concreted together. Initial attempts at knocking down the top bricks were unsuccessful. The buildings were of balloon construction (i.e., the studs went up two floors). These buildings were 70 ft in length (including the 10 ft on the end that was a bathroom/boiler room), 30 ft in width, and about 8 ft in height. The buildings were divided into bays, each 10 ft in length.

Figure A20. Building 829 at Fort McClellan.

2.6.2 Cost information/contracting arrangements

A private company with relevant experience, Costello Dismantling, was contracted to perform the physical deconstructions as directed by the CCE. The contractor was responsible for most of the deconstruction labor, equipment rental, licensing and bonds, and disposal of waste materials.

2.6.3 Deconstruction process

One goal of the project was to identify the optimal combination of manual and mechanical deconstruction methods. Buildings 830, 844, and 829 were dismantled. The salvaged material was donated to the local community for reuse. The study identified that the barracks deconstructed by a combination of manual and mechanical methods showed a 22 percent reduction in overall deconstruction time but nearly a third less (31 percent) in material salvage when compared with the baseline manual deconstruction method. The barracks dismantled with mechanical labor was completed in 90 percent less time but also with 83 percent less salvage than the baseline manual method.

Building 829 had much water damage and a severe mold problem, so not much was salvageable. Building 829 was dismantled using mechanical means. The panelization method at Building 844 involved roof assemblies, walls, and floors that were all cut into 10 ft by 10 ft (or larger) panels and then carried by a

Bobcat skid steer to a staging and salvage area. Building 830 was deconstructed using predominantly manual methods. The following is a report of the types of manual deconstruction activities used to dismantle Building 830.

- The east end of building 830 contained a boiler room and bathrooms that were demolished using an excavator and a Bobcat.

- Beams were cut into about 12-ft lengths for removal. Four men were required to remove the beams: one held the end of beam; one cut using a chain saw; one dropped the beam to ground; and the fourth operated the Bobcat to carry the beam to the dumpster (LBP present).

- Columns (12 ft x 6 in. x 6 in., two pieces nailed together) were cut through about 2 in. from the floor with a chain saw (average time to cut was 15 seconds). One man held the column while another used the chain saw and a third person dropped the column to the ground. Sometimes two men were needed to support a column. The cut columns were removed by a Bobcat to the dumpster, again because of the presence of LBP.

- The floor covering was stripped off manually and put in the dumpster. T&G flooring was removed manually. Hand tools of adze and crowbar were used to lift the T&G boards (three boards at a time) in about 20-ft lengths. Most of these boards were salvaged.

- Siding (2 ft x 6 in.) was removed on the first floor with crowbars. This destructive method was used because no salvage value existed due to the presence of LBP. The siding did not come off cleanly. A person in a lift removed the siding and tar paper on the second floor. A Bobcat carried the siding to a dumpster.

2.6.4 Salvaged materials

Salvaged from the building sections containing the boiler room and bathrooms were metal from boilers and piping, concrete from the floors, and bathroom fittings previously not removed. A total of 32.75 tons of building materials were salvaged from the three barracks deconstructed for the study.

2.6.5 Problems

The barracks selected for the study were found to have extensive LBP and severe water damage. Bldg 829 had much water damage and mold, so there was not much to salvage, except for bathroom and plumbing fixtures, boiler room items for scrap metal, and concrete supports and bathroom and boiler room floors. Thus, material recovery rates were significantly lower than what would be expected for typical barracks deconstruction.

CCE reported that the original scope of work changed considerably and frequently throughout the life of the project.

2.6.6 Lessons learned

CCE estimated that the maximum practical salvage from the study buildings at Fort McClellan using hand deconstruction techniques was about 39 percent. This low percentage was because of the poor conditions of the buildings, presence of extensive interior partitions and drywall not suitable for reclamation, and the prevalence of smaller dimension lumber used in very light-framing applications. Another impediment was the presence of LBP on all exterior siding and on the inside surfaces of exteriors walls, including all 2 x 4 wall framing.

Manual labor was lower cost per labor-hour than mechanical labor, and the salvaging potential was higher. This is an important consideration if time is not an overarching constraint. The study showed that, if attempting to maximize salvage on a net dollars per square foot basis (net dollars = gross costs - salvage value), a specific combination of mechanical and hand labor for deconstruction was most effective. The mechanical and hand labor scenario was almost equal to hand deconstruction in extracting salvage value per unit of cost to remove the building, while taking almost half the total labor-hours, making it the most cost-effective deconstruction method.

2.7 Fort McCoy, WI

As part of a Facilities Reduction Program to eliminate surplus buildings and save money, Fort McCoy had a goal of removing 601,737 sq ft of World War II-era temporary buildings, plus a one-for-one removal for any new Military Construction, Army (MCA) construction (i.e., for every square foot of new construction, a square foot of demolition must occur).

The Fort McCoy Directorate of Public Works (DPW), Engineering Division developed a process for dismantling surplus buildings

in cooperation with their host community. A private citizen or community group purchases a building on post, disassembles it by hand, and takes the salvaged lumber off post to build homes, garages, barns, etc. Responsibilities of the government and of the individual are clearly spelled out in a simple contract.

Fort McCoy sells the buildings through a competitive bidding process and relies on the Corps of Engineers Omaha District to administer the real property transactions. The successful bidder signs a contract and makes payment to the U.S. Treasury.

Public Works Technical Bulletin (PWTB) 420-49-30, “Alternatives to Demolition for Facility Reduction”, reports on Fort McCoy’s deconstruction program. The PWTB also describes the 1987 McKinney Homeless Assistance Act and the process by which excess Federal property is made available to the homeless.

2.7.1 Building types and quantities deconstructed

Fort McCoy removes surplus World War II-era buildings (Figure A21) with their deconstruction program. The Fort McCoy DPW reports that, since 1992, more than 140 buildings have been deconstructed for an estimated savings of $3.5 million.

Figure A21. WWII building at Fort McCoy.

2.7.2 Deconstruction process

Installation personnel inspect each building for hazardous materials before turning it over to the contractor. Fort McCoy removes all friable and nonfriable asbestos before deconstruction begins.

Fort McCoy provides the dumpsters for collection of debris during deconstruction. The DPW then disposes of the debris in the on-post landfill. The contractor has a period of 60 days to complete salvage and remove materials and debris. The bidder must provide all labor, materials, and equipment needed to complete removal work.

The buyer is required to dismantle the building down to the foundation and remove the salvaged materials from the site. After the contractors take possession of the building, the contract stipulates the order in which to perform the deconstruction. This stipulation is required by Fort McCoy in order to avoid having contractors "cherry picking" the most desirable building elements and then disappearing. The goal is to remove the entire building. Therefore, the roofing and siding must come off first, because those elements are labor intensive and not desirable as salvage. With this order, if a contractor should leave in the middle of the process, the remaining structure (with the least desirable building components removed) would be more valuable to the next bidder.

Figure A22 shows a mess hall under deconstruction. This process allows access to the desirable structural members such as roof trusses and floor joists. The actual process used by the individual contractors varies widely. The methods depend greatly on the tools available, number of people involved, and personal experience and preferences. Most of the people bidding on deconstruction have some professional construction experience.

The typical design of a World War II-era wood building has a foundation of concrete piers (instead of the more modern continuous poured foundation or blocks). Individual contractors typically have no means to remove these piers, so their removal is not required.

Figure A22. Fort McCoy mess hall under deconstruction.

2.7.3 Cost information/contracting arrangements

The Fort McCoy Invitation for Bid/Sale Contract package contains about six pages of general conditions that spell out the bid procedure, terms of payment, liability issues, bidder eligibility, and a warning about friable asbestos. The contract includes a list of points of contact, scheduling, safety information, grounds for extensions, and other specific concerns. The actual bid form and a safety checklist that the contractor must follow are included.

2.7.4 Salvaged material

Lumber used in the World War II-era structures at Fort McCoy is often of very high quality. Figure A23 shows roof trusses of the World War II-era theatre.) Original grade stamps on the lumber are often visible. Lumber of this quality generally cannot be purchased new today but is acquired only through deconstruction.

Fort McCoy uses troop equipment and labor to remove concrete foundation piers as part of a training exercise for Engineering units. Fort McCoy grinds the bricks from the large chimneys attached to the buildings (Figure A24) into landscaping material.

PWTB 420-49-30 reports that one couple purchased a two-story barracks from Fort McCoy and over a period of 10 weeks extracted about 30,000 board-feet of high quality lumber (one “board-foot” is an industry measure of wood volume, equivalent to 1 ft by 1 ft by 1 in., nominal thick). The couple used the lumber to construct a house. Their cost under the contract amounted to only about 3 percent of the retail cost for new lumber.

Figure A23. Roof trusses of WWII-era theater.

Figure A24. Salvage bricks from chimneys.

2.7.5 Lessons learned

Initially, response to bid solicitations was considered modest by Fort McCoy staff. Participation improved over time, however, as the program became better known. A lengthy bidders list has been compiled, largely on the strength of word-of-mouth advertising for the program. Fort McCoy (and Fort Knox) emphasizes the necessity of widely publicizing bidding or auctions within their communities, fostering good community relations, and refining the process so that they can better respond to their constituencies.

Fort McCoy staff administers the individual demolition contract on-site. They have hands-on experience and can better stay focused on removing buildings at least cost. Fort McCoy recommends removing administrative barriers, such as requiring concrete removal or a bid bond, that limit the participation of potential smaller customers.

Fort McCoy requires that labor intensive deconstruction activities (e.g., roofing removal) be completed before any salvaged material leaves the site. If a contractor should leave in the middle of the deconstruction, the remaining structure (with the least desirable building components removed) would be more valuable to the next bidder.

3 Overall Summary of Lessons Learned

3.1 Key Points for a Successful Deconstruction Program

1. Commander's Support — For deconstruction projects to be successful, they need support and sign-off from the highest level at a base, i.e., Garrison Commander.

2. The planning process must include the various organizational elements of the Army base. "Process" means from the initial development of a deconstruction program through execution of marketing and sales of salvaged material. Various concerns in the areas of the DRMO, master planning, legal, safety, and real property as well as environmental and public works arise in deconstruction programs, so all elements need to be involved.

3. The need to identify environmental hazards exists whether the building disposal method is deconstruction or conventional demolition. Building preparation activities must take place to identify and remove contaminants from LBP, ACM, and/or PCB-containing material. Although Fort Campbell does not sample the buildings selected for deconstruction, the installation does inform all deconstruction bidders of the potential for finding LBP in the buildings. Fort Campbell provides the winning bidder EPA material on protecting a family from LBP. In contrast, Fort Knox analyzes painted surfaces for LBP. If LBP is found in quantities above regulatory limits, Knox informs the contractor via the contract specifications. Knox stipulates in the project contract for building deconstruction that the contractor is responsible for proper disposal of LBP.

4. The Army needs guidance that explicitly addresses the removal of materials from a building with the purpose of reusing or recycling, handling of materials containing LBP, any reprocessing or remanufacturing that may be performed, and re-use of the product. The issue of LBP is frequently problematic in deconstruction work. LBP appears on much of the building materials recovered through deconstruction; therefore, available for resale and reuse. Salvaged building material is not Resource Conservation and Recover Act (RCRA) hazardous waste, however, if it is not introduced into the waste stream. Army installations are usually unwilling to allow LBP-containing materials off of the installation, or unwilling to consider deconstruction or recycling of any materials containing LBP. The reason cited is "liability."

This reluctance seems to be based on a perceived risk. Demolishing a typical WWII-era barracks will generate more than 100 tons of debris (not counting concrete). Yet, the hundred or so pounds of lead contained in the painted siding can "contaminate" the entire debris stream. This seems contrary to environmental principles of resource conservation.

5. Project duration – It must be understood by all participants in a deconstruction project that building deconstruction requires more time than conventional demolition. It is important that the contract include a specific schedule to complete the deconstruction project. It must be communicated to the upper level of base command that the deconstruction process can be lengthy. Fort Knox provides a window of 5 weeks for a contractor to complete a deconstruction project, with a maximum of 10 buildings made available in each bid package. Fort Campbell allows a contractor 60 days to completely deconstruct one building.

6. Use a nontraditional workforce such as Habitat for Humanity for building removal. The Austin, TX, HfH affiliate has been designated by Habitat International as HfH's center of expertise for deconstruction. During the Fort Campbell project, no resources were available to AHfH from any other affiliate. However, the Austin affiliate has stated that HfH would further develop its national capabilities as a nonprofit deconstruction contractor if the Army or DoD were to initiate a large-scale program of building deconstruction. HfH acts essentially as a general contractor by assembling a work force for deconstructing Army buildings. HfH obtains construction management consultants, a site superintendent, and subcontractors for tasks the workforce cannot perform (such as concrete removal). Volunteers receive deconstruction and safety training before beginning deconstruction activities. HfH is conversant with the requirements of OSHA's 29 CFR Part 1926, Section 62 (Lead) and Subpart T (Demolition). HfH is also insured and can obtain bonding. The installation, however, must ensure these capabilities will be in place for any specific deconstruction project.

7. Installation utility information (such as maps and locations of underground electrical, water, and gas lines) needs to be complete and on-hand before deconstruction begins. To accurately locate utilities, a dig permit usually has to be requested ahead of time. In one case, a nonprofit deconstruction contractor (and its subcontractors) broke a water pipe during final demolition because they did not have

the necessary utility information. The contractor spent valuable man-hours trying to track down the information but found that no single installation office could provide them with the information they needed.

8. To eliminate material going to the landfill during deconstruction, the installation needs to identify those recycled items and their quantities that area recycling services and the local recycling market can bear, especially during large deconstruction projects (several buildings). Additionally, the installation should know beforehand how the local recycling market defines certain categories of recyclables, e.g., clean wood scrap. At one installation, for example, it was found that no system was in place to receive very large quantities of unpainted wood (e.g., salvaged roof decking). Over 15 tons of clean wood ended up in the landfill at that installation.

9. Until deconstruction becomes a common business practice at installations, uncertainty will likely be part of every new deconstruction project. Uncertainty about what to do with unexpected materials (e.g., ceiling insulation) can lead to extra handling, which can lead to materials not being salvaged. During one installation’s deconstruction project, not being prepared to protect ceiling insulation resulted in its being lost to water damage. Identifying all materials present and planning for their salvage or disposal and protecting them to preserve value should prevent this type of unproductive labor.

10. An on-site market emerged unexpectedly at one installation simply by word of mouth from soldiers, retirees, and civilians walking by a deconstruction project. Installations should consider advertising to get full benefit of sales proceeds as well as keeping even more material out of the landfill. Before a project starts, internal advertising across the base using the assets of the installation Public Affairs Office (PAO), Morale, Welfare and Recreation (MWR), and base newspaper should be an established practice. Information advertised should include types and quantities of material that potentially could be available. Additionally, military personnel looking for materials for training exercises can be made aware of available material. Examples include using scrap lumber to make targets and doors in Military Operations in Urban Terrain (MOUT) training exercises and foundation piers for demolition exercises. In many cases, the units

would otherwise have to purchase new building materials from local retail “box stores,” only to destroy them in training.

3.2 Technical Issues Relevant to Ensuring a Successful Deconstruction Project

Based on its experience of deconstructing 6 wood-frame houses in Gainesville, FL, the Center for Construction and Environment of the University of Florida has put together a list of technical issues relevant to the success of the deconstruction process.

1. The working platform or area and how well that assisted or impeded the deconstruction of an element adjoining, overhead, or below.

2. Clearing a work site around a building, particularly so that roll-offs (dumpsters) and the movement and stacking of materials was not impeded, was found to be critical.

3. Timely removal of full and drop-off of empty roll-offs was necessary in order to support the removal of components directly into the roll-off, while having them as close as possible to where the major deconstruction effort might be occurring. For example, a roll-off is placed next to the structure to capture asphalt roofing shingles, but removed when full and the next roll-off placed to not impede the removal of exterior siding.

4. Removing reusable, recyclable, and disposable materials in a timely manner is critical to the safety of the job-site and the efficiency of both the deconstruction and the processing activities.

5. Many nails are placed so they are not readily accessible to a prying device. Wood is sometimes damaged in the extraction process. In all cases, a material will be removable by levering, unscrewing, or unbolting, and should not require a sledgehammer or other smashing tool.

6. Arranging on-site removal of materials as they are processed is important in order to minimize the effort invested in loading, transporting, and storing materials in another location, while at the same time ensuring that materials left at the site are not stolen.

7. Good deconstruction sites require sufficient room to work around the building, including denailing and stacking areas located away from the structure, space for roll-off delivery

and pick-ups, but that is also highly visible to attract potential customers for the salvaged materials.

8. Coordinating workers and increasing their awareness of how materials must be removed and the importance of balancing efficiency with minimal damage to the materials is critical.

9. Maintaining awareness of the difference between salvage and disposal requires a high degree of supervision.

10. Place denailing stations either inside or under trees for shade and catch nails on the interior floor surface, wheelbarrows, or tarps/carpet scraps.

11. Nails often were more easily removed when the material was still in place in the building such as along the length of a vertical stud wall member. Damage to or multiple nails in the ends of lumber were more readily removed by using a battery-powered saw to simultaneously trim the end and cut off the nails.

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