Fort Carson Deconstruction Feasibility Assessment Report






April 2005

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Prepared for:

The Directorate of Environmental Compliance and Management (DECAM) – Fort Carson, CO

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with technical assistance from Second Chance Deconstruction

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ACRONYMS

ACOE:	Army Corps of Engineers
BRL:	Below Reportable Levels
CMU:	Concrete Masonry Unit
DBA:	Davis-Bacon Act
DECAM:	Directorate of Environmental Compliance and Management
e^2M:	engineering-environmental Management, Inc.
HTHW:	High Temperature Hot Water
O&M:	Operations and Maintenance
RFP:	Request for Proposal
SCA:	Service Contract Act
T&G:	Tongue and Groove

EXECUTIVE SUMMARY

In 2002, Fort Carson initiated a sustainability program with the vision of reducing the environmental impact of its mission and adopting practices which support long term sustainability for the region. One of the program goals is to reduce waste leaving Fort Carson to zero by 2027. Construction and demolition debris comprises about 60-70% of the solid waste stream leaving Fort Carson and provides the best opportunity for achieving significant waste reduction measures through reuse and recycling. Several used building materials can be reused or recycled if building removal is planned, staffed and budgeted for appropriately. To demonstrate building material reuse and recycling opportunities, 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 DPW had already programmed and received funding for the removal of these buildings. 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 associated with the project, such as the volume of materials diverted from the landfill, labor strategy, harvest rates, and potential market value of materials harvested. In addition, 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. The DECAM and DPW chose Buildings 6286 and 227 for deconstruction based on their distinct building types and planned removal dates.

The DECAM contracted Innovar Environmental, Inc. to manage the deconstruction feasibility assessment and coordinate the demolition and deconstruction efforts. Innovar worked closely with the Installation demolition contractor, engineering-environmental Management, Inc. (e^2M), and Second Chance Deconstruction (Second Chance), a local deconstruction firm. e^2M volunteered some of their project budget, equipment and labor support to assist with the deconstruction effort. e^2M subcontracted Second Chance to provide the deconstruction expertise and labor needed to make this project a success. e^2M and Second Chance worked closely together on Building 6286 sharing significant tasks. Second Chance completed the majority of Building 227 as a subcontractor to e^2M.

Buildings 6286 and 227 were two separate and distinct building structures that required different deconstruction approaches and techniques. Building 6286 was a 13,128 ft^2 structure comprised of masonry unit (CMU) exterior construction with wood, built in place roofing, and wood flooring and subflooring. Building 227 was a 10,000 ft^2 structure comprised of almost entirely wood construction. Project budgets for each building were $ 81,158.49 for Building 6286 and

$ 52,646.00 for Building 227. The Building 6286 final project cost to deconstruct and demolish the building was $ 89,278.00, which exceeded the budget by $ 8,119.51. Estimated used material resale value is $ 9,500.00 and if sold, could yield a return of $ 2,599.49. However, material sales could take several weeks to months. Material handling and management costs are not included in these estimates. Only when these costs are identified can it be determined if deconstructing Building 6286 yielded a return at all. In contrast, Building 227 was deconstructed for $ 50,503.00, which is $ 2,143.00 below budget. In addition, used building material sales are expected to bring in approximately $ 10,718.25 when sold. Total revenues realized on deconstructing Building 227 could be as much as $ 12,681.65. Again, this does not include material management costs, but significantly exceeds expectations for Building 6286. In summary, Building 227 exceeded the revenue expectations for Building 6286, came in under budget and diverted more materials from the landfill. Building 227 diverted 67.3 tons of material whereas Building 6286 diverted approximately 57.7 tons. Each building had materials with reuse value, but 6286 should have been a skimming project whereas 227 is a prime example for full deconstruction.

This project demonstrated that deconstruction should be considered for each building removal or renovation project on Fort Carson as a technique to minimize waste and reuse or recycle materials. It is an obvious choice for wood building removal and can 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 the Installation combat roads and trails and could really impact the deconstruction outlook for these buildings in the future. Until then, CMU buildings are still well suited for skimming materials of value. As deconstruction becomes more popular, more local used building material markets will become available. In addition, contractors that perform deconstruction projects on Fort Carson type structures will become more efficient and cost effective.

1.0 INTRODUCTION

In 2002, Fort Carson initiated a sustainability program with the vision of reducing the environmental impact of its mission on the environment and adopting practices which support long term sustainability for the region. One of the program goals is to reduce waste leaving Fort Carson to zero by 2027. Construction and demolition debris comprises about 60-70% of the solid waste stream leaving Fort Carson and provides the best opportunity for achieving significant waste reduction measures through reuse and recycling. Several used building materials can be reused or recycled if building removal is planned, staffed and budgeted for appropriately.

To demonstrate building material reuse and recycling opportunities, the Fort Carson Directorate of Environmental Compliance and Management (DECAM) funded a pilot study to determine deconstruction feasibility on two Directorate of Public Works (DPW) funded demolition projects in 2004. The purpose of the project was to collect and report data associated with the project, such as the volume of materials diverted from the landfill, labor strategy, harvest rates, and potential market value of materials harvested as well as to document the cost effectiveness of the project. In addition, the project was to help in evaluating the feasibility of deconstruction techniques on future projects. The DECAM chose Buildings 6286 and 227 for deconstruction based on their distinct building types and planned removal dates.

The DECAM contracted Innovar Environmental, Inc. (Innovar) to manage and document the deconstruction feasibility assessment as well as coordinate the demolition and deconstruction efforts. Innovar worked closely with the Installation demolition contractor, engineering-environmental Management, Inc. (e^2M) and Second Chance Deconstruction, Inc. (Second Chance), a local deconstruction firm. e^2M was already under contract with the DPW to demolish Building 6286 and 227, but instead volunteered some of their project budget, equipment and labor to employ deconstruction as a technique. e^2M subcontracted Second Chance to provide the necessary deconstruction expertise and labor support to make the overall project a success. Innovar, e^2M and Second Chance, are hereinafter referred to as the “Team.” The following information describes each building and the Team’s approach to deconstruction, as well as an overall analysis of the project, and recommendations for future deconstruction projects on Fort Carson based on the Team’s findings.

2.0 DECONSTRUCTION OF BUILDING 6286

2.1 Building Description

Building 6286 was a 13,128 ft^2 World War II era building. Structurally, it was single-story building comprised of concrete masonry unit (CMU) exterior construction, with 2” x 4” wood interior partition walls, wood rafters and skip-sheet 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 attic contained batts of fiberglass insulation placed above the ceiling sheetrock. The exterior of the building consisted of 2” x 2” x 10’ nailers pinned to the CMU exterior wall. The interior surface of the exterior walls were covered with lathe and plaster attached to the nailers. There were interior partition walls (2” x 4” x 8’ covered in sheetrock), suspended ceiling, fluorescent lighting (2-lamp troughers), and various other items, many of which had been damaged in urban warfare training exercises. The building had some flooring comprised of a single layer of 2-1/4” 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 columns for posts. Figure 2.1 is a picture of Building 6286 before deconstruction and demolition efforts began.

Figure 2.1. Building 6286 Prior to Deconstruction and Demolition Efforts.

2.2 Approach to Deconstruction

Building 6286 was not contracted as a complete deconstruction project. Instead it was contracted for demonstrating concepts, gathering data and working through the deconstruction process. The abatement work had already been completed and much of the harvestable product (i.e. windows and interior doors, and lights) were damaged. Therefore, deconstruction efforts focused on the remaining higher yield items available. Budget and time constraints allowed for only 8,000 ft^2 to be deconstructed. The remaining 5,128 ft^2 were removed using traditional demolition practices. Initial deconstruction efforts focused on removing interior building materials of value that were reusable. Only a few vertical file cabinets were salvaged in addition to most of the fluorescent light fixtures. After interior materials were salvaged, attention was directed to the roof.

2.2.1 Roof, Attic and Ceiling

In this case the roof sheeting was sought as a harvestable product. Relief cuts were made from peak to soffit, every 16’ using a circular saw. The reach forklift was used to peel off sections of the roof (see Figures 2.2 thru 2.4). This allowed for preservation of the rafter boards by reducing the stress introduced during the process. The next level down included trusses that were lowered using the reach forklift so that they could be disassembled on the relative safety of the ground. The 2” x 6” x 20’ joists on the north wing were harvested by pulling out the exterior walls, allowing the ceiling to fall down to the decking. However, on the east wing, 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 (see Figure 2.5). At this point, steel tubing cross bracing for lateral support was encountered. Each 2” x 6” x 20’ was notched, which significantly reduced their market value for reuse (see Figure 2.6). After the roof removal, the Team focused their efforts on removing more of the interior building materials.

Figure 2.2. Reach Forklift Peeling Off Sections of North Wing Roof.

Figure 2.3. Exposed Section of Roof After Reach Forklift Use.

Figure 2.4. Exposed Roof Truss of North Wing.

Figure 2.5. East Wing Sheetrocked Attic.

Figure 2.6. East Wing Notched Ceiling Joists.

2.2.2 Interior Walls

The interior walls were 2” x 4” x 10’ stud partitions with sheetrock on both sides, of which was 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. Structural load-bearing supports were left in place to support the roof and ceiling where necessary. Figure 2.7 shows the interior of Building 6286 after most of the walls and studs were removed. Several hours of labor and effort were expended to remove the interior lathe and plaster from the inside of the exterior walls to facilitate handling of the cinder block, which was sought for recycling. After some trial and error, the Team decided to use the reach forklift 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.

Figure 2.7. Interior of Building 6286 After Harvesting Studs.

2.2.3 Exterior Walls

Exterior cinder block walls and glass block were sought as recyclable product. The cinder block was intended to be recovered for use as aggregate on Fort Carson's combat roads and trails. The glass block was intended for resale. Initial efforts focused on removing the glass block by using the reach forklift. The forks were covered with an 8' x 4' length of used carpet and were used to penetrate the cinder block beneath the each window. After penetrating the wall, the window was tilted back against the forklift arm and salvaged (see Figures 2.8 and 2.9). Following the window removal, efforts focused on preparing the inside of the exterior walls by removing the plaster and 1" x 2" furring strips. Once the interior was prepared, the Team focused on pulling down the exterior walls from the inside out using the excavator (see Figure 2.10). By using this technique, the interior floors were not damaged and block was easily picked up by the wheel loader and stockpiled (see Figure 2.11). Unfortunately, the accumulated cinder block had to be disposed of as rubble. The Team had coordinated with Range Control to crush the block in an Army Reserve engineer unit's rock crusher. However, the rock crusher's arrival had been postponed indefinitely and the material could not be accumulated on site. If the Team could have executed the recycling of this block as planned, it would have made a significant impact on the future removal techniques employed for these types of buildings.

Figure 2.8. Reach Forklift Removing Glass Block Windows.

Figure 2.9. Salvaged Glass Block.

Figure 2.10. Excavator Pulling Down Exterior Walls.

Figure 2.11. Cinder Block Intended For Recycling.

2.2.4 Flooring and Foundation

The wood flooring, concrete pillars and footers were sought after for reuse and recycling, respectively. Plywood subflooring was pulled up, exposing the 2" x 12" floor joists (see Figure 2.12). The floor joists were then removed by hand and either denailed or recycled. Most of the floor joists in the north and south wing were exposed to extreme temperatures from the steam pipes beneath the building and suffered from dry rot. Once this characteristic was identified, the Team used the reach forklift to lift off the subflooring and accumulate it for recycling rather than for reuse or resale. The excavator was then used to pluck the floor joists from the foundation and place them in a stockpile. After the flooring was removed, the excavator was used to remove the concrete pillars and foundation for recycling.

Figure 2.12. Floor Joists and Concrete Piers Exposed.

2.3 Project Challenges and Successes

The deconstruction of Building 6286 posed many challenges. Timetables for demolition inhibited deconstruction project pre-planning. Building materials and construction style proved another challenge in regard to removal and recycling. Existing damage to internal fixtures and building structure decreased salvaging potential of some materials. Despite obstacles encountered, deconstruction of Building 6286 experienced some successes as well. The site proved ideal for the logistical requirements of deconstruction and significant volumes of materials were diverted from the landfill.

The most challenging obstacle in the deconstruction of Building 6286 was the demolition schedule already in place prior to the deconstruction project commencing. Originally slated for machine demolition, Building 6286 was being prepared to be demolished when the Team decided to attempt deconstruction. This quick shift in approach impeded effective project pre-planning that was needed well in advance. Because of the lack of opportunity for this phase, obstacles occurred that could have otherwise 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 shutoff 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 two-day work request had to be executed for the Installation Operations and Maintenance (O&M) contractor to perform the work. In addition, Building 6287 which was adjacent to Building 6286 serves as the Fort Carson Courthouse and the Team was required to stop work for approximately four days due to a Courts Martial hearing being conducted.

Building materials and construction style of Building 6286 posed another challenge. One wing of the building contained an attic comprised of sheetrock. This feature resulted in additional labor costs and debris generation. As the Colorado Springs area offered no asphalt roofing or gypsum recycling opportunities, the sheetrock and roofing materials necessitated disposal as waste. Additional structural challenges surfaced when this wing's ceiling joists proved to have steel tube cross bracing as lateral supports. Each 2" x 6" x 20' beam was notched, significantly reducing their reuse value. The aforementioned HTHW pipe steam leaks generated excessive heat and caused the floor joists to bake. This preempted a good harvest of usable boards. However, the boards were separated and accumulated for use as mulch, averting the need for more waste disposal. The final challenge offered in regard to reusing construction materials was with reusing the CMU block exterior. The Team had coordinated for the reuse of this material with Range Control. It was going to be crushed using an Army Reserve engineer unit's rock crusher and reused on Fort Carson's combat roads and trails as aggregate. However, the placement of the rock crusher was indefinitely postponed and was unavailable for use. The material could not be stockpiled and had too much wood debris in it to be recycled at local concrete recyclers. It had to be disposed of as rubble as a result of this situation. Reuse of the CMU exterior block could prove to be a major opportunity for solid waste diversion in the future if the rock crusher becomes available.

The previous function of Building 6286 also created a setback. The building had previously been used as an urban warfare training building. The nature of this type of training rendered many of the interior fixtures and other materials of value, specifically doors, unsuitable for resale. This resulted in additional debris and landfill disposal.

Despite the obstacles and challenges Building 6286 posed during the pilot deconstruction project, there were successes as well. The building site was well suited for the execution of deconstruction. It had ample space for staging areas as well as enough space for several de-nailing stations. This flexibility contributed to improved work conditions and efficiencies. Additionally, easy accessibility for equipment facilitated efficient removal of roofing and interior building materials. The exterior walls of Building 6286 were CMU construction. The interior of the exterior walls were lined with nailer board, lathe and plaster. The reach forklift was used to push in the window frames and casing. This loosened the lathe and plaster with minimal labor effort or contamination of recyclables (e.g., mixing of cinder block, wood, plaster). The most significant success for Building 6286 was the substantial quantity of materials diverted from the landfill. As previously mentioned, the building was taken down in two distinct phases. The deconstructed phase was 8,000 ft^2 and the demolished section was 5,128 ft^2. The demolished section of the building generated approximately 756 yd^3 of debris. By correlating this area to the 8,000 ft^2 area that was deconstructed it can be estimated that the deconstructed area could have generated approximately 1,180 yd^3 of debris had it been demolished. Therefore, the deconstructed area reduced the overall volume entering the waste stream by 58%.

While the deconstruction phase of this project presented its challenges, most were overcome. By performing deconstruction on this building several ideas, techniques and lessons learned were used on Building 227 and will be used on more deconstruction projects in the future. The deconstruction efforts on Building 6286 achieved the Team's intent which was to design and implement deconstruction techniques on similar buildings while diverting materials from the landfill at the same time.

2.4 Labor and Equipment Used

The deconstruction study for Building 6286 was initially contracted using e^2M laborers. In the interest of limiting the additional management challenges this presented, the labor strategy was modified after the first week using only Second Chance employees. Therefore, the Second Chance crew was ramped up in the following two weeks. This impacted data collection significantly in the first week which represented 25-35% of the total project timeline. e^2M provided the heavy equipment and operators on this project.

Second Chance Deconstruction used 755 man hours of their employees during this project, plus 142 man hours of e²M laborers totaling 897 man hours for the 8,000 ft^2 of structure deconstructed. There were an additional 322 equipment operator man hours and an excavator and wheel loader required after during and after they vacated the project to complete the demolition of the remaining structure and backfill the site. This deconstruction effort resulted in just under 9 ft^2 of building per man hour being completely deconstructed, materials cleaned and processed for removal from site, mobilization, demobilization, safety training, administrative, etc. Second Chance estimated that complete deconstruction for this building type could have been accomplished within 6 – 9 ft^2 per man hour, had this project been initiated and executed as a full-on deconstruction project from the beginning.

Several pieces of equipment were used during the project as many deconstruction techniques were attempted. A boom lift was used to lift up roofing materials after the sections were cut into 16' strips using a circular saw. Sledge hammers and pry bars were the predominant tools used in removing the interior structure. A listing of equipment and tools used for each major task of project are described below in Tables 2.4.1 and 2.4.2, respectively.

Table 2.4.1. Equipment Usage Crosswalk for Building 6286.

Equipment Used	**Job/Action Performed**
30' Boom Lift	Helped with removing roof sheeting, disassembling trusses, and lowering heavy timbers
Excavator	Used to knockdown vertical walls and remove debris from the project site
Front Loader	Used to load debris and clean materials into respective containers or areas

Table 2.4.2. Tools Used for Deconstructing Building 6286.

Major Tools Used	**Job/Action Performed**
Pneumatic Wrench	Assisted in the removal of large bolts and nuts in the trusses
Heavy Duty Sawhorses	Used to stockpile large amounts of nailed lumber while wood was being denailed
Nail Kicker	Used to denail most materials. Nearly constant in use throughout the project
Gorilla Bars, Wonder Bars (Flat Bars)	Used for prying and pulling apart materials
Steel Banding Equipment	Used to package harvested lumber for ease of movement

As a demonstration project an asphalt shingle tear-off labor study was conducted by the crew simply to record the time and labor required. A 580 ft^2 area resulted in the following data (the remainder of the roofing was removed as described above):

580 ft^2/8 man hours = 72.5 ft^2/hr   Note: Estimating a 75% tear-off efficiency against an 80% daily efficiency equates to a 60% total daily process efficiency. Therefore, a reasonable tear-off production rate would translate to approximately 362 ft^2/day/man for this type of roofing scenario.

Typical tear-off removal by roofing companies does not include the removal of any nails. Nails are typically driven down and covered with the felt paper prep for the replacement roof. Therefore, this study used specially designed notched shovels to pull up as many nails as possible along with the shingles. Tear-off costs by local roofing contractors range from \$25 - \$30 per square (100 ft^2) first layer and \$8/square each additional layer (including disposal). Cost per ft^2 varies depending on the wage.

2.5 Harvest and Diversion

Variables including timeline, labor strategy, budget, and the resale value of materials had significant impacts on harvesting strategies. Although this building was not as well suited for deconstruction, 102 yds^3 were still salvaged from the first 8,000 ft^2 of the structure (see Appendix A for a breakdown of the items salvaged). Appendix B provides a listing of common materials and weights the Team used to determine volumes. Most of the reusable materials salvaged for resale were lumber, which equated to approximately 18,000 linear feet. See Table 2.5 below for a summary of the key aspects of diversion and harvesting, as well as the demolished portions of Building 6286.

Table 2.5. Deconstruction and Demolition Data for Building 6286.

Parameter	Deconstructed Section	Demolished Section
Area	8,000 ft^2	5,128 ft^2
Time required	4 weeks	3 weeks
Man hours	897 hours	55 hours
Debris sent to landfill	684 cubic yards	756 cubic yards
Lumber harvested	18,000 linear feet	0 linear feet
Materials salvaged for reuse (lumber, ceiling tiles, windows, fixtures, etc.)	74,000 lbs (37.0 tons)	0 lbs
Clean wood diverted (mulch included)	23,724 lbs (11.9 tons)	0 lbs
Roofing debris (no market)	19,530 lbs (9.8 tons)	0 lbs
Ferrous diverted	15,780 lbs (7.9 tons)	0 lbs
Copper diverted	550 lbs (0.3 tons)	0 lbs
Aluminum diverted	1,280 lbs (0.6 tons)	0 lbs

Figure 2.13. Salvaged Wood From Building 6286.

Figure 2.14. Harvested Wood Bundled For Reuse and Sale.

2.6 Cost Summary

Building 6286 was not planned for complete deconstruction and was only partially deconstructed. However, based on the Team's initial findings, it is easy to determine cost effectiveness in regard to deconstruction efforts on this building. Building 6286 was completely removed using deconstruction and demolition techniques. The final project cost for removing it was $ 89,278.00, which exceeded the $ 81,158.48 budget by $ 8,119.51. Estimated used material resale value is $ 9,500.00 and if sold, could yield a return of $ 2,599.49 or an overall project cost of $ 78,558.99 (see Appendix A for estimated resale values). However, material sales could take several weeks to months. Material handling and management costs are not included in these estimates and it is easy to see how deconstructing Building 6286 could yield very little or nothing at all. Table 2.6.1, below, outlines the cost factors considered and compares both the deconstruction and demolition cumulative efforts. Building 6286 and similar buildings, if for nothing else, could be deconstruction efforts with more focus on recycling materials than reuse and through repetition may be able to be performed under current budget constraints.

Table 2.6.1 - Deconstruction Cost Summary For Building 6286.

Parameter	**Building 6286** (Deconstruction and Demolition)	**Building 6286** (Estimate if only Demolished)
Total man hours used	1219	480
Total cost of manpower used	$ 52,874.00	$ 17,858.00
Demo equip. use cost (fuel, rental, maint., etc.)	$ 7,200.00	$ 15,212.00
Landfill tipping fees paid	$ 6,900.00	$ 12,471.00
Hauling cost (fuel, truck, etc.)	$ 6,725.00	$ 12,373.00
Fill dirt, reseeding, and other miscellaneous project costs	$ 10,400.00	$ 10,400.00
Bonding	$ 2,050.00	$ 2,050.00
Revenue from wood/lumber sold (estimate)	+ $6,300	+ $0.00
Revenue from ferrous	+ $ 300.00	+ $ 300.00
Revenue from copper	+ $ 600.00	+ $ 600.00
Revenue from glass block (estimate)	+ $1,800.00	+ $0.00
Revenue from other miscellaneous items (estimate)	+ $500.00	+ $0.00
Total Project Cost	$ 76,649.00	$ 69,464.00

3.0 DECONSTRUCTION OF BUILDING 227

3.1 Building Description

Building 227 was one of six WWII era warehouse buildings located near the Fort Carson rail yard (see Figure 3.1). The building dimensions were approximately 70’ x 130’ (10,000 ft^2). It was a single-story structure comprised of wood construction, with few interior partition walls (approximately 1,500 ft^2 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 3.1. Building 220 Series Warehouses at Fort Carson.

3.2 Approach to Deconstruction

Several items were sought after in this building, but lumber and plate steel offered the most potential in regard to significant reuse and resale opportunities. Since the building was easily accessible from both the inside and outside our approach was very simple, from the top down. We removed the shingles, roof decking, rafters, blown-in insulation, siding, framing and flooring in sequence. The Huntsville Army Corps of Engineers (ACOE) hired a contractor to videotape our removal sequencing on the north end, which initially caused some inefficiencies, but all were overcome. The deconstruction efforts on this building commenced July 12, 2004 and ended August 20, 2004. In 5-1/2 weeks, 10,000 ft^2 of structure was deconstructed leaving only wood pilings, some concrete stair-ways and a small portion of wood structure (approx. 450 ft^2) for removal and disposal by the demolition crew. The remainder of the site was graded and compacted within one week after deconstruction. The following sections describe each part of the building, and our methods and approach to deconstructing specific parts of it.

3.2.1 Roofing

The roof sheeting was 1" x 10" and 1" x 12" butt-jointed boards with as many as five layers of asphalt roofing (see Figures 3.2 and 3.3). Two layers of rolled roofing, and two or three layers of shingles were present depending on the area. Shingle removal was done by hand labor using mostly claw hammers and flat bars. Most of the work was performed in the early mornings and late afternoons to avoid the heat. 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' on centers (see Figure 3.4). Columns were bolted/bracketed to the bottom of the rafters. The interior surface of the roof was sheeted with 3/8" fiber board, with blown-in cellulose insulation sandwiched between the fiber board and roof sheeting. The insulation was removed using a vacuum truck (see Figure 3.5).

Figure 3.2. West Side of Building After Shingles Removed.

Figure 3.3. Project Personnel Removing Roof Decking and Rafters.

Figure 3.4. Interior View of Columns and Roof Support Network.

Figure 3.5. Vaccuum Truck Removing Blown-in Insulation.

3.2.2 Interior Walls

There were approximately 1,500 ft^2 of finished interior partition walls (2” x 4” x 10’ studs with vinyl covered sheet rock), a suspended ceiling grid, and T-12 fluorescent (2-lamp) 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. Most of the ceiling tiles were removed and salvaged as well as the fluorescent troughers. The interior studs were not salvaged due to the amount of effort required to remove them and their potential salvage value. Instead, they were knocked down by a skid-steer and recycled as mulch. The 8” x 8” wood columns were salvaged and were removed by employing a skid-steer removal technique. The Team attached each column to the skid steer using metal chains and pulled them free (See Figure 3.6). After removing the columns, our efforts focused on removing the exterior of the building.

Figure 3.6. Skid Steer Technique for Removing Vertical Supports.

3.2.3 Exterior Walls

The exterior of the building was 2” x 6” x 10’ studs with 1” x 8” lap siding with lead painted exterior and covered with vinyl siding (See Figure 3.7). The interior surface of the exterior walls was 1” x 6” T&G and also lead painted. The Team removed the exterior walls using the reach forklift (See Figure 3.8) and dropped them inside the building. From the inside, the Team removed the vinyl and lap siding with claw hammers and flat bars. The lead based paint did not negatively impact the siding removal process. Three team members were outfitted with lead air monitoring cassettes and were monitored for lead exposure. None of the team members exceeded the OSHA action level of 30 ug/m^3 throughout the duration of our exposure testing. The maximum exposure level was 7.46 ug/m^3 and was the result of removing the interior 1” x 6” T&G by hand. Lead exposure levels for lap siding removal are annotated in Table 3.2.1 below. Precautionary measures were taken by adequately wetting the walls prior to removal in other areas. This technique aided in reducing the amount of dust workers were exposed to as well.

Figure 3.7. Exterior of Building 226 With Siding and 227 With Siding Removed.

Figure 3.8. Reach Forklift Technique for Removing Exterior Walls.

Table 3.2.1. Lead Exposure Results for Building 227 Lap Siding Removal.

Sample Date	Sample ID	ug Lead/$m^{3(1)}$	Task
July 21, 2004	LD227-1	7.46	Removed Interior Lap Siding
July 21, 2004	LD227-3	2.40	Removed Interior Lap Siding
July 27, 2004	LD227-6	BRL[2]	Removed Exterior Vinyl Siding
July 27, 2004	LD227-7	2.81	Removed Exterior Vinyl Siding
July 27, 2004	LD227-8	BRL[2]	Removed Exterior Vinyl Siding
July 28, 2004	LD227-14	2.39	Removed Exterior Lap Siding
July 28, 2004	LD227-15	BRL[2]	Removed Exterior Lap Siding
July 28, 2004	LD227-16	BRL[2]	Removed Exterior Lap Siding
July 29, 2004	LD227-19	BRL[2]	Removed Exterior Lap Siding
July 29, 2004	LD227-20	2.36	Removed Exterior Lap Siding

[1] Lead samples were performed using NIOSH Method #7082
[2] BRL – Below Reportable Level

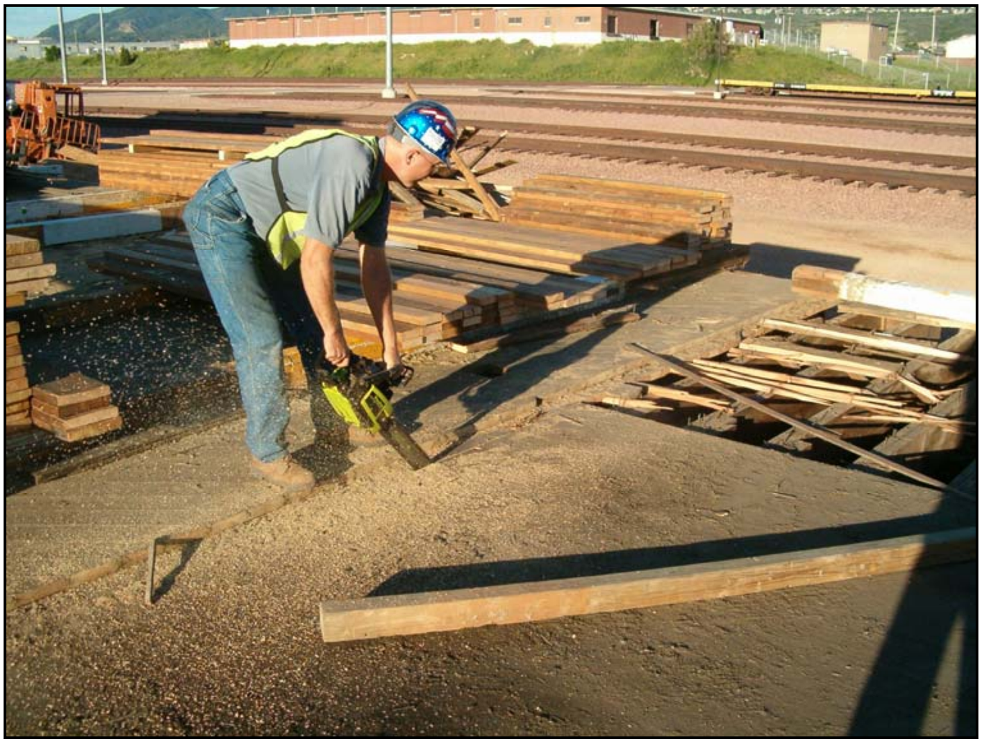
3.2.4 Flooring and Foundation

The flooring was comprised of double layer 2” x 6” tongue and groove (T&G), with aisles covered in ¼” diamond plate sheet steel (4’ x 8’ sheets each weighing 365 pounds) bolted through both layers of T&G. The plate steel was removed by by grinding the bolt heads off (See Figure 3.9). A total of 45 sheets were recovered for resale. The second layer of T&G was toe-nailed into the first layer on-diagonal. The Team fabricated several steel wedges to facilitate the removal of this layer. Initially, laborers used sledgehammers to pound the wedges into the T&G flooring to remove it. A faster more effective method of removal was discovered by using the skid steer to push several wedges into the T&G (See Figure 3.10). The first layer of T&G was surface nailed down into the floor joists on square with the joists. The flooring was supported on 2” x 12” floor joists, built-up beams, and utility poles for posts. A chain saw was used to cut through the first layer of T&G (See Figure 3.11). Loosened T&G flooring was removed and stockpiled for resale. Floor joists were removed by hand labor using the chain saw and claw hammers as necessary.

Figure 3.9. Project Member Removing Metal Plate Flooring.

Figure 3.10. Skid Steer Technique for Removing Flooring.

Figure 3.11. Chain Saw Being Used to Score and Remove Subfloor.



3.3 Challenges and Successes

The deconstruction of Building 227 went relatively smoothly. However, there were some challenges to overcome. The COE deconstruction filming effort compromised the schedule some, and the roofing and flooring removal required more intense efforts than originally anticipated. Some equipment proved troublesome, but most challenges were overcome.

The COE filming required an adjustment to the deconstruction plan. In order to minimize the duration of the filming, one section was taken down and filmed through the various stages from roof to floor joists. This was not a particularly efficient process since the Team had to break the over all routine and try to accommodate the film crew. However, the Team was able to effectively demonstrate techniques from start to finish.

The roofing itself posed a significant hurdle to overcome. There were five layers of roofing that had to be removed by hand. This roofing was excessively nailed which complicated the shingle removal as well as the sheeting removal and denailing process. The roof sheeting was of sufficient quality and quantity to warrant the work. The subcontracted the tear-off but this proved to be cost-prohibitive ($28/ 1st layer and $8/each additional layer). So the Team completed the tear off in multiple early morning sessions to avoid the mid-day heat.

The flooring on the warehouse proved a challenge. Bolts holding down the 1/4" diamond plate had to be ground down with a hand grinder. The floor itself was a double layer of 2" x 6" T&G decking, requiring a significant effort for removal without damaging the product. The top layer proved much easier than the bottom since it was toe-nailed versus the bottom layer which was face-nailed to the floor joists.

Unanticipated equipment trouble caused some minor delays and added costs to the project. The skid steer tires did not have foam filled tires which resulted in several flats during the first week and a half. The Team ended up getting solid-core tires for the equipment.

Deconstruction on Building 227 got off to a good start. The deconstruction plan was well designed and project execution was smooth. Electricity, water and phone service was available for most of the project. Appropriate equipment selection and availability was crucial to the success of this project. Almost every phase of work involved some piece of equipment, replacing labor costs and improving efficiencies.

3.4 Labor and Equipment Used

It took 1,197 man hours for the deconstruction of the 10,000 ft^2 of Building 227. This equates to 7.5 ft^2 per man hour. The film crew required some accommodations which slowed down efficiency. An estimated 185 hours were used to support the film crew and when subtracted from the total, 1,012 man hours or 8.9 ft^2 per man hour were used to deconstruct the facility.

The Team was able to complete an average of 1,400 ft^2 of roof tear off in 3.5 hours each morning before it got too hot to work, which averages out to 400 ft^2 per hour. Second Chance had five men working which equates to 80 ft^2 per man hour (contrasted with 72 ft^2 per man hour on Building 6286). Unfortunately, the building generated 60 yds^3 of shingle waste (not recycled).

An articulated boom helped workers remove the vinyl siding and a skid-steer (a Case 1845) with forks and bucket was used for removal and material handling of steel plates, flooring, and placement of debris into the dumpsters. This equipment was rented. The final piece of equipment was an electric scissor lift (30' lift) for the majority of interior harvest (including rows of lights, removal of the fiber board and insulation, bumping the roof sheeting boards loose from the bottom with rams, unbolting the trusses and lowering timbers. Steel wedges were designed for removing the 2" x 6" T&G (wood wedges did not hold up for this type of heavy flooring removal). A summary of the equipment and tools used to remove the building and process its pieces are show below in Tables 3.4.1 and 3.4.2, respectively.

Table 3.4.1. Equipment Used and Job/Action Performed for Deconstructing Building 227.

Equipment Used		**Job/Action Performed**
Articulated boom lift		Vinyl siding removal and flooring removal
Skid-steer		Multiple removal jobs, material handling (steel plates at 365 lbs./each)
Skid-steer		Flooring removal (2x6 car decking), debris handling
Electric scissor lift		Helped with the majority of the interior harvest including lights, interior sheeting, etc.
Electric scissor lift		Helped with removing roof sheeting, disassembling trusses, lowering heavy timbers
Rolling scaffolding		Used for lower overhead work while the scissor lift was occupied elsewhere
Vacuum truck		Vacuumed out the blown in insulation and hauled it away for reuse/recycling

Table 3.4.2 - Tools Used and Job/Action Performed for deconstructing Building 227.

Major Tools Used		**Job/Action Performed**
Steel wedges		Assisted in the removal of 2x6 decking
Pneumatic wrench		Assisted in the removal of large bolts and nuts in the trusses
Heavy duty sawhorses		Used to stockpile large amounts of nailed lumber until/while it was being denailed
Nail kicker		Used to denail most materials - nearly constantly in use throughout the project
Gorilla bars, wonder bars (flat bars)		Prying and pulling apart materials
Circular saw/chain saw		Cutting
Generator		Used to power tools during the last two weeks of the project
Steel banding equipment		Used to package harvested lumber for ease of movement

3.5 Harvest and Diversion

In summary, over 28,618 linear feet of lumber was harvested from this structure and reintroduced into the consumer stream, thereby reducing new materials consumption. All the materials harvested from this facility equates to over 58 tons diverted from the landfill. The entire waste stream from the 10,000 ft^2 building was contained in six 40-yard dumpsters.

The techniques used allowed for approximately 80% of all roofing nails to be removed during tear-off, leaving minimal additional denailing required on the ground. The boards were fairly brittle but with appropriate care for prying, about 75% of the roofing boards were harvested for resale. The remaining portion was separated for recycling. A good number of 2” x 8” rafters were also harvested (See Figure 3.12).

Figure 3.12. Harvested Roofing Lumber for Reuse and Sale.

Some of the boards which were painted have limited resale application due to the lead based paint on them. Workers were fitted with personal pumps to monitor for lead exposure. The cartridge samples were sent to a laboratory and analyzed and did not reach action levels for any of the activities including removal, handling, cutting and denailing. The only engineering method used was to ensure good cross-flow circulation and adequately wetting surfaces periodically. These boards were surface nailed with 16P nails. They were very brittle. Second Chance salvaged about 65% to be used on a different siding project where the painted side could be nailed to the studs thus encapsulating the paint (See Figure 3.13).

Figure 3.13. Interior Lap Siding Salvaged for Reuse.

Once the vinyl siding and foam insulation were removed, as well as the interior 1" x 6" T&G siding, Second Chance was able to lay the exterior walls down on to the deck, quickly remove the exterior lap siding and separate the studs and plates with +95% harvest. There was a layer of sheet rock nailed to the studs on the outside, underneath the lap-siding. The cross brace 1" x 6" was cut flush with the stud to leave a "plug" rather than a notch. A large number of 2" x 6"s were harvested using this technique.

The interior portion of the deconstruction was similar to any residential or commercial partition wall activity. Walls were skimmed by removing usable doors, lights, ceiling tiles, electrical fixtures, etc. All of the wiring was pulled out, separating reusable product from materials slated for recycle. The ability to utilize the skid steer greatly reduced Second Chance's labor by kicking the bottom plate with the bucket blade and pushing the studs loose. This dropped the majority of drywall to ground to be removed and the studs could then be carried to the denailing station with very minimal effort expended towards their extraction.

Second Chance was able to reuse all of the rolled batt insulation on another project and/or sell it. However, there was not an identified market for the old cellulose insulation. For demonstration purposes Second Chance did show that it could be easily vacuumed into sacks directly from the ceiling for reuse/resale.

A chain saw was used on the columns where necessary, cutting them near their base. After the rafters were removed, the crew pulled the columns up out of the floor with a chain and the skid steer . These columns proved to be very useful for "stickers" during the project and later used for structural columns on an out-building project.

The top-side of the 2" x 6" T&G flooring was heavily worn and discolored, but the under-side of the top layer was like new. The 50 years of dust and dirt however made the harvest impossible without getting the underside dirty. The top layer harvest rate was about 85%. The bottom layer harvest rate was only about 40% due to the fact that it was so heavily nailed to the floor joists. Several techniques were employed to lift it. Prying manually was impossible. Second Chance workers built a fulcrum point under the telehandler forks to pry up the bottom layer but many were too brittle to pry without breaking. The floor joists were constructed of double 2" x 12"s face-nailed together. These were harvested, split and denailed. The joists rested on some built-up under-girders, which rested and were strapped to the tops of the utility posts. Water/rot damage at each of the loading dock bays ruined much of the floor joist material within 100 ft^2 of the roll-up door. This also prevented a clean harvest of the bottom layer of T&G since the joists simply pulled apart (split) when exposed to the lift pressure of the forks. The flooring was cut every 16' for harvesting the T&G. This assisted with the floor harvest by providing a natural relief for the boards to be pulled up.

The top layer of T&G was lifted much like a typical hardwood T&G floor. However, steel wedges designed by Second Chance were used. The wedges were started by hand driving them, but then transitioned to driving the wedges with the bucket of the skid steer. Obviously, this technique isn't an option for most structures, since running heavy equipment on the floor joists would be impossible. But this available option increased the productivity on flooring removal by about 65% (See Figure 3.14).

Variables including timeline, labor strategy, budget, and the resale value of materials had significant impacts on harvesting strategies. This building was well suited for deconstruction and all 10,000 ft^2 of structure was deconstructed (see Appendix A for a breakdown of the items salvaged). See Table 3.5 below which summarizes the key aspects of diversion and harvesting from Building 227.

Figure 3.14. Bundles of Floor Joists for Reuse and Sale.

Table 3.5. Deconstruction Data for Building 227.

Parameter	Quantity
Square Footage	10,000
Time required	5.5 weeks
Man hours	1,012 hours
Debris sent to landfill	240 cubic yards
Lumber harvested	28,618 linear feet
Materials salvaged for reuse (lumber, ceiling tiles, windows, fixtures, etc.)	116,000 lbs (58.0 tons)
Clean wood diverted (mulch)	13,180 lbs (6.6 tons)
Roofing debris (no market)	25,110 lbs (12.6 tons)
Ferrous diverted	5,246 lbs (2.6 tons)
Copper diverted	125 lbs (0.1 tons)
Aluminum diverted	0 lbs (0.0 tons)

3.6 Cost Summary

Building 227 was almost completely deconstructed. Several key aspects, which have a cost factor, were considered to determine the cost effectiveness for deconstructing this facility. Most of the revenues generated from the deconstruction of Building 227 have yet to be realized. However, deconstructing this building has already proven to be more cost effective than traditional demolition in regard to cost savings and landfill diversion. Total costs for deconstructing Building 227 and preparing the groundwork for future construction were $ 50,503.00. Had the building been demolished it would have cost approximately $ 52,646.00. With some additional assumptions based on industry experience, the harvested building materials should yield a significant amount of revenue, thus driving down costs as well. The most significant returns should come from lumber and the plate steel. Lumber sales assumptions are a return of approximately $ .25/linear foot, which equates to $ 7,154.00. The diamond plate steel sheets should yield approximately $ 50.00 each for a total of $ 2,250.00. Costs to manage and broker the sale of these materials are not included in the overall projections for this project and are difficult to determine as some materials may not sell for several months. Based on the above assumptions, the total cost to deconstruct Building 227 could be as low as $ 39,784.75. Table 3.6 outlines the cost factors considered when comparing the efforts on Building 227 alongside the estimated costs had the facility just been demolished.

Table 3.6. Deconstruction Cost Summary for Building 227.

Parameter	**Bldg 227 (Deconstruction)**	**Bldg 227 (Demolition Estimate)**
Total man hours used	1,012	440
Total cost of manpower used	$ 35,905.00	$ 18,396.00
Demo equipment use cost	$ 6,658.00	$ 12,733.00
Landfill tipping fees paid	$ 1,890.00	$ 8,534.00
Hauling cost (e.g., fuel, truck)	$ 1,950.00	$ 8,883.00
Fill dirt, reseeding, and other miscellaneous project costs	$ 2,600.00	$ 2,600.00
Bonding	$ 1,500.00	$ 1,500.00
Revenue from wood/lumber sold (estimate)	+$7,154.00	+$0
Revenue from ferrous	+$143.00	+$0
Revenue from copper	+$106.25	+$0
Revenue from other miscellaneous items (estimate)	+$3,315.00	+$0
Total Project Cost	$39,784.75	$52,646.00

4.0 ANALYSIS

Deconstruction is a cost effective and environmentally responsible building removal technique on Fort Carson. It can be used as the sole technique, or in conjunction with traditional demolition projects. Several considerations must be taken into account prior to employing deconstruction in whole or in part. The most significant considerations are:

- Time available;
- Building type;
- Cost;
- Used building materials market demand;
- Service Contract Act versus Davis-Bacon Act contracting and wages; and
- Use of free or volunteer labor.

Time constraints can significantly impact the amount of deconstruction that can be performed on any given project. Deconstruction generally takes significantly longer than traditional demolition. Building 6286 was used as more of a learning tool than a deconstruction project, but was taken down in seven weeks using deconstruction and demolition versus three to four weeks using traditional demolition practices alone. Building 227 was completed in seven weeks using mostly deconstruction techniques. Using traditional demolition practices, the building could have been completed in two to three weeks using a two person crew.

Some 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 at this time for limited deconstruction, such as skimming fixtures and some roofing and flooring materials. It was not suited for full deconstruction due to the availability of local rock crushing opportunities and the amount of intense labor required to remove the wood furring strips and other building material contaminant. Moving forward, CMU block removal techniques should improve and render this material reusable as road aggregate on Fort Carson.

Cost considerations are significant in regard to choosing deconstruction, demolition, or a blend of the two. Building 6286 was completely removed for $ 89,278.00 using both deconstruction and demolition techniques. This cost exceeded the budget by $ 8,119.51. This building was only two thirds deconstructed and the rest was demolished. Labor costs would have significantly increased should the Team have deconstructed the entire building. Materials from this building may yield $ 7,211.95 in return. In contrast, Building 227 was completed for $ 50,503.00, which was $ 2,143.00 below the demolition estimate and could yield a return of $ 10,718.25 in the future. Material revenues could drive the cost down for government agencies as contractors will begin to take revenues into consideration when bidding.

Used building material resale and recycling opportunities are variables to be considered when bidding on building removal projects. Both buildings had significant amounts of roofing shingles that could have been recycled elsewhere, but recycling opportunities were not available in the Colorado Springs area. Sending the shingles elsewhere was cost prohibitive. So the labor invested in removing them was wasted since the roof decking in both buildings was of little value. In addition, resale value of wood fluctuates throughout the year. So there are times when companies are not interested or will want to charge full rates for deconstruction efforts not banking on material returns in revenue.

Federally mandated wage requirements inherently drive up the cost of all deconstruction and demolition projects. There are two Federal Acts that require specific wages to be paid depending on how the building removal project is contracted. The two Acts are the Service Contract Act (SCA) and Davis-Bacon Act (DBA). The SCA and DBA are used for service contracts and construction contracts, respectively. Building removal has been contracted under both acts on Fort Carson. Generally, if building removal is considered part of a building removal program, it will be contracted via SCA. If building removal is required to build new construction and is part of a new overall construction project then it is generally contracted via DBA. The SCA wages are generally lower than DBA wages. For example, a laborer under the SCA Wage Determination Number 1994-2079 (Revision 28) for El Paso County, Colorado has a minimum wage rate of $ 10.01/hr. plus $ 2.59/hour for health and welfare. This equates to a total of $ 12.60 per hour. In comparison, the DBA General Decision Number CO030006 laborer wage rate for building construction is $ 14.20/hr. plus $ 4.55/hr. fringe. This equates to $ 18.75/hr. and is approximately 49% higher than the similar labor classification under the SCA. Both Buildings 6286 and 227 were contracted as Service Contracts. It is clear that if they were contracted under the DBA that the labor wages and cost of the overall project would have been significantly higher and cost prohibitive.

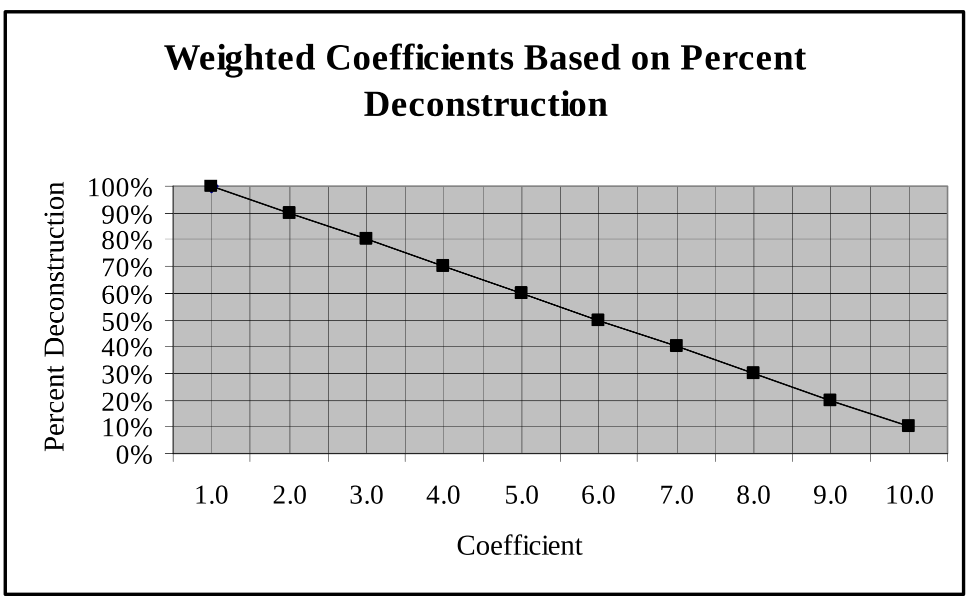
Use of free and/or volunteer labor was not explored on this deconstruction project. However, free labor has been used on buildings similar to Building 227 at Fort Carson. Previous organizations and/or personnel have deconstructed significant areas on these types of buildings for the demolition contractor. As long as the deconstructing organizations or personnel are given the materials in lieu of a subcontract and/or payment, local authorities have deemed their efforts fall outside the SCA or DBA application of scope. Use of free labor is obviously the least expensive means to remove buildings and should always be considered as a means to reduce costs.

5.0 RECOMMENDATIONS

As Fort Carson continues to remove structures for future development, the installation should consider and promote deconstruction practices in all construction programs, to include both the cantonment and Military Family Housing (MFH) areas. Fort Carson can promote deconstruction by making it a mandatory practice in future building removal contracts. Contracts should be issued as Request for Proposals (RFPs) and awarded to the contractors with the most technically acceptable and cost effective proposal that meets or exceeds the intent of the solicitation.

Currently, the benefits of deconstruction are not factored in the contract selection criteria. Contract language that assigns bid selection criteria a weighted value for waste diversion, reuse and recycling will result in more deconstruction versus traditional demolition, not by subsidizing deconstruction but simply by bringing deconstruction into the performance requirements. Using a percent deconstruction and cost model to determine a weighted coefficient could be created for competitive bidding purposes. The lowest value as determined by multiplying the deconstruction coefficient and a cost index should be the determining factor for contract award. Figure 5.1, below is an example model based on percent deconstruction. The higher percent deconstructed, the lower the coefficient becomes. For example, if Contractor A proposes to deconstruct 50% of a building, he will be given a coefficient of 6.0. If Contractor B proposes to deconstruct 60% of the same building, he will be given a coefficient of 5.0. If this were the only criterion, Contractor B has the lowest coefficient and will be awarded the contract. However, cost should be a consideration as well.

Figure 5.1. Example Weighted Coefficient Model for Percent Deconstruction.



The lowest technically acceptable bids should be given a cost index coefficient as well to assist with contractor selection. Using the percent deconstruction examples above, Contractor A's cost proposal of $ 50,000.00 and Contractor B's cost proposal of $ 60,000.00 it is easier to select a contractor based this model. Contractor A's cost proposal divided by Contractor B's is equal to a coefficient of .83. Contractor B's cost proposal divided by Contractor A's proposal is equal to a coefficient of 1.2. By multiplying the deconstruction and cost index coefficients a final product is determined. The contractor with the lowest product in this model would be given the contract award. In this scenario, Contractor A would be awarded the deconstruction contract. See Table 5.1.1, below for a summary of this information. Table 5.1.2 is provided to further illustrate the weighted matrix concept by demonstrating that a higher percent deconstructed in concert with a higher proposed cost can be the best technically, cost effective acceptable offer. This model is only an example of this concept and can be modified to fit Fort Carson's deconstruction goals as necessary.

Table 5.1.1. Weighted Percent Deconstruction versus Cost Scenario No. 1.

Contractor	Proposed Deconstruction	Proposed Cost	Deconstruction Coefficient	Cost Index Coefficient	D x CI
	(% by weight)	($)	(D)	(CI)	
A	50	50,000.00	6.0	.83	4.98
B	60	60,000.00	5.0	1.2	6.0

Table 5.1.2. Weighted Percent Deconstruction versus Cost Scenario No. 2.

Contractor	Proposed Deconstruction	Proposed Cost	Deconstruction Coefficient	Cost Index Coefficient	D x CI
	(% by weight)	($)	(D)	(CI)	
A	50	50,000.00	6.0	.96	5.76
C	60	52,000.00	5.0	1.04	5.2

As described in this report, not all buildings are suited for deconstruction, but certain areas of each building have potential for limited deconstruction. At a minimum, deconstruction contractors should be consulted prior to commencing any demolition practice. Some of these contractors will mobilize and perform deconstruction efforts for no cost, thus reducing demolition costs up front. In addition, performance based contracting should be considered for this type of work. If contractors meet their proposed diversion rates, their award fee should be fixed. However, if contractors exceed their proposed contracted diversion rates, additional compensation should be considered and budgeted. This technique will provide incentives to both the government and the contractor, which will facilitate a "win-win" situation.

6.0 CONCLUSION

Deconstruction is a viable building removal technique to be used in part or in whole on Fort Carson. This is largely based on the type of materials used to construct each building. Wood warehouse buildings provide more cost effective, higher yields than the World War II era masonry unit buildings. Most materials recovered from wood constructed buildings have a greater reuse value than those recovered from masonry constructed buildings. Most materials in masonry constructed buildings can be recycled, but require a more intensive handling effort and the return on investment is marginal. If recycling or reuse opportunities present themselves on Fort Carson, such as placement of a rock crusher, then it may prove worthwhile to fully deconstruct WWII era masonry buildings. Until then, deconstruction efforts should be considered and implemented on both types of buildings, but masonry buildings are better suited for skimming materials of value. In contrast, wood constructed buildings can be targeted for full deconstruction. Building removal contracts should be issued as Request for Proposals (RFPs) and should be weighted according to proposed percent deconstruction and cost. Contracts should be issued as Service Contracts versus Construction Contracts to keep the overall labor costs down. By targeting specific buildings for deconstruction and contracting them via the least expensive means available, significant progress can be made towards achieving Fort Carson's Sustainability Program goals.

Buildings 6286 and 227 were two separate and distinct building structures that required different deconstruction approaches and techniques. Building 6286 was a 13,128 ft^2 structure comprised of masonry unit exterior construction with wood, built in place roofing, and wood flooring and subflooring. Building 227 was a 10,000 ft^2 structure comprised of almost entirely wood construction. Project budgets for each building were $ 81,158.49 for Building 6286 and $ 52,646.00 for Building 227. The Building 6286 final project cost to deconstruct and demolish the building was $ 89,278.00, which exceeded the budget by $ 8,119.51. Estimated used material resale value is $ 9,500.00 and if sold, could yield a return of $ 2,599.49. However, material sales could take several weeks to months. Material handling and management costs are not included in these estimates and it is easy to see how deconstructing Building 6286 could yield very little or nothing at all unless rock crushing becomes available. Building 6286 could have diverted up to 105 yds^3 of CMU block from the landfill if a local opportunity was available. In contrast, Building 227 was deconstructed for $ 50,503.00, which is $ 2,143.00 below budget. In addition, used building material sales are expected to bring in approximately $ 10,718.25 when sold. Total revenues realized on deconstructing Building 227 could be as much as $ 12,681.65. Again, this does not include material management costs, but significantly exceeds expectations for Building 6286. In summary, Building 227 exceeded the revenue expectations for Building 6286, came in under budget and diverted more materials from the landfill. Building 227 diverted 67.3 tons of material whereas Building 6286 diverted approximately 57.7 tons. Each building had materials with reuse value, but 6286 should have been a skimming project whereas 227 is a prime example for full deconstruction. If Fort Carson establishes rock crushing capabilities on the Installation, then Building 6286 could be attempted as a full deconstruction project. The CMU block exterior has reuse value as road aggregate. Each remaining WWII era masonry building is two stories tall and can yield as much as 225 yd^3 of road aggregate material per building. This is a significant amount of material that can be reused and diverted from the landfill per building.

Contracting methods have a significant impact on the overall costs of any deconstruction contract and could prove to be the deciding factor in determining whether a project is suitable for deconstruction. Free and volunteer labor are the most desirable means for building removal efforts from a cost perspective. However, due to contracting complexities, a contract generally must be issued in order to execute work and costs must be incurred. Therefore, there are two contracting mechanisms in regard to facility reduction that are presently employed. The mechanisms are through either a Service Contract or Construction Contract. Both require a different wage determination. A Service Contract requires that a local Service Contract Act wage determination be used. Whereas a Construction Contract requires a local Davis-Bacon Act wage determination to be used. Generally, Service Act wages are less than Davis-Bacon and prove to be more cost effective in regard to deconstruction efforts because labor is the most significant cost in these type of projects. The local Davis-Bacon wage determination for a general laborer is approximately 49% higher than the local Service Act wage determination. With labor values being as high as 70% of project costs it is easy to see that Construction Contracts could negatively impact deconstruction efforts on certain projects.

Deconstruction should be considered for each building removal or renovation project on Fort Carson as a technique to minimize waste and reuse or recycle materials. It is an obvious choice for wood building removal and can be used in a limited capacity on masonry type buildings. As deconstruction becomes more popular, more local used building material markets will become available. In addition, contractors that perform deconstruction projects on Fort Carson structures will become more efficient and cost effective.

APPENDIX A

BUILDINGS 6286 AND 227 HARVEST DATA TABLES

Building 6286 Material Harvest			
Material	Project Total	Unit	Market Value Estimate
Ferrous	15,780	Pounds	$433.95
Aluminum	1,280	Pounds	$432.00
Copper	550	Pounds	$467.00
Stainless	0	Pounds	$0.00
Clean Wood for Mulch	7,000	Pounds	$0.00
4 ft. Fluorescent fixtures	9	Each	$45.00
8 ft. Fluorescent fixtures	4	Each	$40.00
2’ x 4’ ceiling tiles	210	Each	$105.00
3’ x 5’ windows	22	Each	$440.00
Emergency light fixtures	6	Each	$0.00
Bathroom doors w/casing and hardware	2	Each	$30.00
Urinals w/flushometer	2	Each	$20.00
2’ x 2’ difuser	6	Each	$30.00
Fire alarm misc	8	Each	$0.00
8"x8" Glass block	550	Each	$549.00
Metal Shelf Units	6	Each	$120.00
Lumber	18,000	Linear Ft.	$4,500.00
Gross Harvest Value (cost of logistics & sales excluded)			**$7,211.95**

Building 6286 Lumber Breakdown			
Type	Quantity	Type	Quantity
2” x 4” x 8”	360	2” x 10” x 8”	4
2” x 4” x 10”	4	2” x 10” x 12”	1
2” x 6” x 8”	67	2” x 12” x 8”	8
2” x 6” x 10”	50	2” x 12” x 10”	19
2” x 6” x 12”	1	2” x 12” x 12”	41
2” x 6” x 14”	4	2” x 12” x 14”	41
2” x 6” x 16”	3	3” x 6” x 8”	4
2” x 8” x 8”	1	3” x 8” x 8”	6
2” x 8” x 10”	25	3” x 8” x 10”	2
2” x 8” x 12”	82	4” x 6” x 10”	6
2” x 8” x 14”	27		

Building 227 Material Harvest			
Material	Project Total	Unit	Market Value Estimate
Ferrous	5,246	Pounds	$143.00
Aluminum	0	Pounds	$0.00
Copper	125	Pounds	$106.25
Stainless	0	Pounds	$0.00
Clean Wood for Mulch	13,180	Pounds	$0.00
8 ft. Fluorescent fixtures	48	Each	$480.00
Electrical outlets/ boxes/misc. connectors	16	Each	$16.00
2x4 ceiling tiles	48	Each	$24.00
Roll-up Bay doors	8	Each	$400.00
Gas Water Heater	1	Each	$45.00
Gas Furnace	1	Each	$100.00
Vinyl Siding	1,100	Each	$0.00
Plate Steel	45	Each	$2,250.00
Lumber*	28,618	Each	$7,154.00
Gross Harvest Value (cost of logistics & sales excluded)			**$10,718.25**

*Note – Specific lumber breakdown unavailable.

APPENDIX B

CONVERSION FACTORS: CONSTRUCTION AND DEMOLITION

(Source: www.ciwmb.ca.gov/LGLibrary/DSG/ICandD.htm)

Material/Item	**Size/Amount**	**Study***	**LB**
Ashes, dry	1 cubic foot	FEECO	35–40
Ashes, wet	1 cubic foot	FEECO	45–50
Asphalt, crushed	1 cubic foot	FEECO	45
Asphalt/paving, crushed	1 cubic yard	Tellus	1,380
Asphalt/shingles comp, loose	1 cubic yard	Tellus	418.5
Asphalt/tar roofing	1 cubic yard	Tellus	2,919
Bone meal, raw	1 cubic foot	FEECO	54.9
Brick, common hard	1 cubic foot	FEECO	112–125
Brick, whole	1 cubic yard	Tellus	3,024
Cement, bulk	1 cubic foot	FEECO	100
Cement, mortar	1 cubic foot	FEECO	145
Ceramic tile, loose 6"x 6"	1 cubic yard	Tellus	1,214
Chalk, lumpy	1 cubic foot	FEECO	75–85
Charcoal	1 cubic foot	FEECO	15–30
Clay, kaolin	1 cubic foot	FEECO	22–33
Clay, potter's dry	1 cubic foot	FEECO	119
Concrete, cinder	1 cubic foot	FEECO	90–110
Concrete, scrap, loose	1 cubic yard	Tellus	1,855
Cork, dry	1 cubic foot	FEECO	15
Earth, common, dry	1 cubic foot	FEECO	70–80
Earth, loose	1 cubic foot	FEECO	76
Earth, moist, loose	1 cubic foot	FEECO	78
Earth, mud	1 cubic foot	FEECO	104–112
Earth, wet, containing clay	1 cubic foot	FEECO	100–110
Fiberglass insulation, loose	1 cubic yard	Tellus	17
Fines, loose	1 cubic yard	Tellus	2,700
Glass, broken	1 cubic foot	FEECO	80–100
Glass, plate	1 cubic foot	FEECO	172
Glass, window	1 cubic foot	FEECO	157
Granite, broken or crushed	1 cubic foot	FEECO	95–100
Granite, solid	1 cubic foot	FEECO	130–166
Gravel, dry	1 cubic foot	FEECO	100
Gravel, loose	1 cubic yard	Tellus	2,565
Gravel, wet	1 cubic foot	FEECO	100–120
Gypsum, pulverized	1 cubic foot	FEECO	60–80
Gypsum, solid	1 cubic foot	FEECO	142
Lime, hydrated	1 cubic foot	FEECO	30
Limestone, crushed	1 cubic foot	FEECO	85–90
Limestone, finely ground	1 cubic foot	FEECO	99.8
Limestone, solid	1 cubic foot	FEECO	165
Mortar, hardened	1 cubic foot	FEECO	100

Material/Item	**Size/Amount**	**Study***	**LB**
Mortar, wet	1 cubic foot	FEECO	150
Mud, dry close	1 cubic foot	FEECO	110
Mud, wet fluid	1 cubic foot	FEECO	120
Pebbles	1 cubic foot	FEECO	90–100
Pumice, ground	1 cubic foot	FEECO	40–45
Pumice, stone	1 cubic foot	FEECO	39
Quartz, sand	1 cubic foot	FEECO	70–80
Quartz, solid	1 cubic foot	FEECO	165
Rock, loose	1 cubic yard	Tellus	2,570
Rock, soft	1 cubic foot	FEECO	100–110
Sand, dry	1 cubic foot	FEECO	90–110
Sand, loose	1 cubic yard	Tellus	2,441
Sand, moist	1 cubic foot	FEECO	100–110
Sand, wet	1 cubic foot	FEECO	110–130
Sewage, sludge (see Appendix H)	1 cubic foot	FEECO	40–50
Sewage, dried sludge (see Appendix H)	1 cubic foot	FEECO	35
Sheetrock scrap, loose	1 cubic yard	Tellus	393.5
Slag, crushed	1 cubic yard	Tellus	1,998
Slag, loose	1 cubic yard	Tellus	2,970
Slag, solid	1 cubic foot	FEECO	160–180
Slate, fine ground	1 cubic foot	FEECO	80–90
Slate, granulated	1 cubic foot	FEECO	95
Slate, solid	1 cubic foot	FEECO	165–175
Sludge, raw sewage (see Appendix H)	1 cubic foot	FEECO	64
Soap, chips	1 cubic foot	FEECO	15–25
Soap, powder	1 cubic foot	FEECO	20–25
Soap, solid	1 cubic foot	FEECO	50
Soil/sandy loam, loose	1 cubic yard	Tellus	2,392
Stone or gravel	1 cubic foot	FEECO	95–100
Stone, crushed	1 cubic foot	FEECO	100
Stone, crushed, size reduced	1 cubic yard	Tellus	2,700
Stone, large	1 cubic foot	FEECO	100
Wax	1 cubic foot	FEECO	60.5
Wood ashes	1 cubic foot	FEECO	48

*Source acronyms and data used

- **CIWMB: C**alifornia **I**ntegrated **W**aste **M**anagement **B**oard (Source Data - http://www.ciwmb.ca.gov/LGLibrary/DSG/ICandD.htm)
- **FEECO: FEECO** Incorporated
- **Tellus: Tellus** Institute, Boston Massachusetts
- **U.S. EPA: U**nited **S**tates **E**nvironmental **P**rotection **A**gency (Business Users Guide)

APPENDIX C

ACKNOWLEDGEMENTS

Acknowledgements

"The Fort Carson Deconstruction Pilot Project is the culmination of many talents and combined efforts. This project not only demonstrates the inherent advantages of deconstruction but also represents a working model for collaborative efforts within the local community."

Key Project Participants:

engineering-environmental Management, Inc. sponsored the deconstruction project by volunteering funding, equipment, labor and environmental compliance and oversight.

Mr. K.C. Kuykendall of **Second Chance Deconstruction** led the deconstruction planning and on-site work efforts and coordinated with the local community to find outlets for harvested materials.

Mr. Jim Primdahl provided critical insights into the deconstruction process for both buildings in this pilot project. Jim was brought in to the team as a recognized expert in the field and his consultation improved the safety, efficiency and productivity of the entire process.

Mr. Tom Napier of **The U.S. Army Corps of Engineers Construction Engineering Research Laboratory** provided key insights and technical expertise in regard to deconstructing Building 227.

Mr. Carlos de Aguilar and Mr. Scott Clark of the **Fort Carson Directorate of Environmental Compliance and Management (DECAM)** both encouraged and championed the deconstruction project by providing the concept, support and funding.

Vendor Participants:

Colorado Industrial Recycling provided the metal salvage services for this project. The owner, Mr. Dave Koscove, provided roll-off containers and purchased the salvage metal from the project. Dave assisted the project by offering many helpful hints to improve the metal recycling harvest and value.

Mr. Mark Pforr of **Rental Service Center** provided equipment support for this project. RSC was responsive and cost-competitive which aided in the favorable cost/benefit ratio for the project.

Colorado Roll-Off provided general waste disposal containers for this project.

Recycled Aggregate provided concrete crushing services, an option not available in all communities.

Rocky Top Resources provided wood shredding services for the clean wood debris.