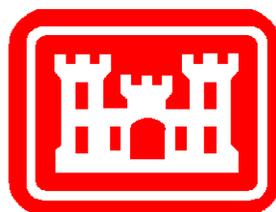


PUBLIC WORKS TECHNICAL BULLETIN 200-1-143  
30 AUGUST 2015

**UPDATE OF OPPORTUNITIES FOR  
REDUCING CONSTRUCTION AND  
DEMOLITION WASTE FROM RESIDENTIAL  
COMMUNITIES INITIATIVE (RCI) PROGRAMS**



Public Works Technical Bulletins are published by the U.S. Army Corps of Engineers, Washington, DC. They are intended to provide information on specific topics in areas of Facilities Engineering and Public Works. They are not intended to establish new Department of Army policy.

DEPARTMENT OF THE ARMY  
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Public Works Technical Bulletin

30 August 2015

No. 200-1-143

Facilities Engineering  
Environmental

UPDATE OF OPPORTUNITIES FOR  
REDUCING CONSTRUCTION AND DEMOLITION WASTE  
FROM RESIDENTIAL COMMUNITIES INITIATIVE  
(RCI) PROGRAMS

1. Purpose

a. This Public Works Technical Bulletin (PWTB) provides updated information for the recovery, reuse, and recycling of building materials that are typically disposed of as demolition waste.

b. This PWTB updates and replaces PWTB 200-1-48, which was also titled "Opportunities for Reducing Construction and Demolition Waste from Residential Communities Initiative (RCI) Programs." This older PWTB is now obsolete and should not be used for current guidance, but the information it contains will remain available for reference in the archives of the website below.

c. Information in this PWTB will enable installations, U.S. Army Corps of Engineer (USACE), or RCI partners to quickly estimate the types and amounts of building materials present and determine opportunities for debris reduction through salvage, reuse, and recycling.

30 August 2015

d. All PWTBs are available electronically at the National Institute of Building Sciences' Whole Building Design Guide webpage, which is accessible through this link:

[http://www.wbdg.org/ccb/browse\\_cat.php?o=31&c=215](http://www.wbdg.org/ccb/browse_cat.php?o=31&c=215)

## 2. Applicability

This PWTB applies to installation Directorates of Public Works (DPWs), Public Works Business Centers (PWBCs), Directorates of Engineering, and other U.S. Army facilities' engineering activities where RCI housing redevelopment is taking place. This PWTB is not mandatory for RCI programs; rather it is an information resource.

## 3. References

a. Army Regulation (AR) 200-1, "Environmental Protection and Enhancement."

b. Executive Order (EO) 13693, "Planning for Federal Sustainability in the Next Decade," 19 March 2015.

c. Memorandum, Principal Deputy Secretary of the Army Installations and Environment (PDSAI&E), "Deconstruction and Re-Use of Excess Army Buildings," 18 January 2001.

d. Assistant Secretary of the Army for Installations, Energy and the Environment (ASA[IE&E]), "Memorandum for Sustainable Design and Development Policy Update (Environmental and Energy Performance)" 26 May 2000, revised 27 October 2010 and 16 December 2013.

e. Memorandum, Office of the Assistant Chief of Staff for Installation Management (OACSIM), "Sustainable Management of Waste in Military Construction, Renovation, and Demolition Activities - Supplemental Guidance," February 2006, revised 11 July 2006.

f. United Federal Guide Specification (UFGS) 02 41 00, "Demolition and Deconstruction." June 2006, updated May 2010. Preparatory activity: USACE.

## 4. Discussion.

a. AR-200-1 contains policy for environmental protection and enhancement, implementation of pollution prevention, conservation of natural resources, sustainable practices, compliance with environmental laws, and restoration of previously damaged

30 August 2015

or contaminated sites. Chapter 10 includes requirements to integrate the management of waste into construction and demolition (C&D) activities to reuse materials in their original form through disassembly or deconstruction, more careful handling, segregating, and making them available to specialized markets.

b. EO 13693 instructs federal agencies to conduct their environmental, transportation, and energy-related activities in an environmentally, economically and fiscally sound, integrated, continuously improved, efficient, and sustainable manner. It also sets recycling goals.

c. EO 13693 lays out a 60% or higher diversion rate for non-hazardous solid waste and C&D materials, to be achieved by FY 2015.

d. The PDSAI&E memorandum requests ACSIM to issue policy and guidance for installations to work with nonprofits and other nontraditional contract entities to plan and carry out building deconstruction activities.

e. The ASAIE&E memorandum forwards Army policy that sustainable design and development (SDD) be incorporated into installation facility planning decisions and infrastructure projects.

f. The OACSIM memorandum and its enclosure outline the requirements for sustainable management of waste in military construction, renovation, and demolition activities. It requires installations to incorporate C&D waste management programs into their Integrated Solid Waste Management Plans (ISWPs).

g. UFGS 02 41 00 covers the requirements for demolition, deconstruction, dismantling, reconditioning, and disposal of existing building materials, equipment, and utilities as a part of new construction or renovation work.

h. C&D debris has accounted for up to 80% of some installations' solid waste streams, as reported by solid waste managers at several of the Army's largest troop installations (USACE 2006). This large waste stream is most critical where an installation is removing large numbers of World War II-era wood buildings and where new construction programs such as the RCI require the demolition of existing facilities. Even if the Facility Reduction Program (FRP) and new Military Construction (MILCON) programs are more modest, C&D debris constitutes a significant solid waste burden for Army installations.

30 August 2015

i. Twelve family housing unit designs from four Army properties and one Air Force property were studied for this report. The buildings represented a large portion of the family housing buildings to be removed at Army installations, then and in the foreseeable future.

j. The procedures and supporting data outlined in this PWTB allow for assessing the material content of buildings and will enable a relatively quick quantity take-off to be established to determine opportunities for debris reduction. It is important to note that no single quantity for material content is applicable to all buildings, construction types, and locations. Therefore, several building categories are described to address a range of project-specific conditions.

k. Appendices to this document provide further details:

- o Appendix A provides background information and describes the general concept of applying C&D reuse to military residential facilities.
- o Appendix B provides quantity figures and material component descriptions pertaining to former Army Family Housing Units. Application of the modeled data to building types and special considerations are discussed.
- o Appendix C offers information to create a waste management plan.
- o Appendix D contains resources for finding outlets for C&D materials.
- o Appendix E provides the references cited.
- o Appendix F spells out abbreviations used in this PWTB.

## 5. Points of Contact

a. Headquarters, U.S. Army Corps of Engineers (HQUSACE) is the proponent for this document. The point of contact (POC) at HQUSACE is Mr. Malcolm E. McLeod, CEMP-CEP, 202-761-5696, or email: [Malcolm.E.Mcleod@usace.army.mil](mailto:Malcolm.E.Mcleod@usace.army.mil).

b. Questions and/or comments regarding this subject should be directed to the technical POC:

PWTB 200-1-143  
30 August 2015

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FOR THE COMMANDER:

A handwritten signature in black ink, appearing to read 'J. Dalton', with a long horizontal flourish extending to the right.

JAMES C. DALTON, P.E.  
Chief, Engineering and Construction  
U.S. Army Corps of Engineers

PWTB 200-1-143  
30 August 2015

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**APPENDIX A:  
CONSTRUCTION AND DEMOLITION DEBRIS DISPOSAL**

**General Background**

Disposal of construction and demolition (C&D) debris at Army installations has become problematic in both economic and environmental terms. Installations with Facility Reduction Program (FRP) requirements, active Military Construction (MILCON) programs, and Residential Communities Initiatives (RCI) projects are facing a significant C&D debris burden. Army-wide, C&D debris comprises just over half of total waste generation;<sup>1</sup> this figure can be much higher at installations with very active construction programs.

The major cost components of demolition are loading, hauling, and tipping the debris at landfills. Installations with on-post C&D landfills often allow tipping at no cost to the contractor. However, the landfill's operation, maintenance, long-term monitoring, and potential closure are still the installation's responsibility. While so-called "free" tipping reduces the initial cost of demolition, the life-cycle landfill cost is still borne by the installation. Army solid waste managers have reported costs of up to \$50 per ton of C&D debris over the life of their landfills.<sup>2</sup> When on-post C&D landfills close, off-post landfilling will be the only option.

Landfilling C&D debris also has environmental consequences. The U.S. Environmental Protection Agency (EPA) has identified C&D debris as a contributor to greenhouse gas emissions, and that is just one concern.<sup>3</sup> Other concerns include the life-cycle environmental effects of extracting materials from the earth, the depletion of natural resources, the burden to landfill space, and the manufacture, transport, and disposal of virgin materials in lieu of reusing or recycling existing materials. As an example of the positive environmental impact, on average 75 percent of the dimension lumber can be recovered from a woodframed building (Falk 2002).

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<sup>1</sup> Army C&D debris comprises 53% of total waste generation according to the FY2011 SWARWeb report.

<sup>2</sup> This is a prorated figure calculated based on the expected life span, maintenance cost, and closure cost of the C&D landfill at Fort Campbell.

<sup>3</sup> <http://www.epa.gov/climatechange/waste/SWMGHGreport.html>

Therefore, it is imperative that installations (and USACE Districts supporting those installations) adopt practices to reduce the quantity of demolition debris generated through building removal activities and to use those materials as resources instead of waste wherever possible. Numerous Executive Office, Department of Defense, Army, and USACE policy and guidance documents all reinforce this requirement (see listing and discussion in front pages of this PWTB).

The Principal Deputy Assistant Secretary of the Army (PDASA) has entered into discussions with Habitat for Humanity (HfH) and other federal agencies to include inexpensive and less wasteful avenues to dispose of surplus buildings. These alternatives include moving structures off installations or deconstructing them to salvage building materials for reuse. The PDASA has committed the Army to supporting initiatives whereby the Army and surrounding communities can benefit from the reuse of excess Army buildings.

### **Residential Communities Initiative Program**

To upgrade the quality of housing and neighborhoods for soldiers' families and address the shortage of on-post housing, many Army family housing units are being converted to private development under the RCI.<sup>4</sup> RCI partners coordinate with the garrison DPW offices to build new housing or remodel existing facilities. The RCI program focuses not just on new homes but also on the overall development of new neighborhoods and green spaces on military properties. RCI partners have assumed management and reconstruction of 98% of Army family housing in the United States.<sup>5</sup>

The Army's RCI partners are not required by regulation or policy to divert any construction and demolition waste from community development sites. Installations operating their own C&D landfills face the challenge of accepting debris generated by RCI programs, while attempting to reduce other C&D waste streams and prolong the lives of their landfills.

Several RCI partners have, however, implemented recycling measures on their own. In many cases, the partners have found that salvaging useable materials creates no added burden and

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<sup>4</sup> <http://www.rci.army.mil>

<sup>5</sup> <http://www.rci.army.mil/programinformation/rcisites.html>

30 August 2015

reduces hauling expenses. Installation managers can appropriately discuss waste reduction strategies with RCI partners when these efforts would be of mutual benefit. For example, some RCI partners (e.g., Fort Bragg, NC, Fort Leonard Wood, MO, and Schofield Barracks, HI) have initiated aggressive recycling practices (Boone and Smith 2007). By being proactive in this way, partners are not only being environmentally friendly but also are saving money. These companies are demonstrating that debris reduction and economic benefits can be achieved with no adverse impact to the RCI projects. Examples of successful waste reduction by RCI partners include:

- Picerne Military Housing<sup>6</sup> at Fort Bragg recycled concrete on site (Figure A-1) and sent metals to local recyclers.
- Picerne also partnered with the Fayetteville, NC, HfH ReStore<sup>7</sup> to salvage reusable items prior to demolition.
- Actus Lend-Lease at Fort Hood partnered with the Austin, TX, HfH ReStore to salvage reusable items prior to demolition (Figure A-2).

Disposal of the waste shall be carried out in accordance with applicable regulations. As stated above, under existing RCI agreements waste diversion can be pursued on a voluntary basis unless there is a state, county, or local regulation that requires recycling or diversion. To develop a waste diversion plan, someone will have to assess the condition and contents of the housing units to be removed. It's impractical to survey all the units, but a representative sample should suffice.

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<sup>6</sup> Housing now known as Corvalis Military Living

<sup>7</sup> <http://www.habitat.org/env/restores.aspx>



Figure A-1. Concrete recycling at Fort Bragg.



Figure A-2. Partnering with Habitat for Humanity at Fort Hood.

### Availability of Construction & Demolition Data

Knowing the content of buildings and structures to be removed is fundamental to assessing the feasibility of recovering or recycling components and materials. However, the contents of Army buildings and structures, specifically as they pertain to

30 August 2015

resources and reuseable materials, are largely unknown by installation DPWs and USACE Districts. Thus, without a knowing value and opportunity, incentive for diversion is absent. By discovering sufficient value, some additional cost or schedule adjustment may be acceptable in order to recover or recycle materials, or some net cost savings may be achieved by virtue of the materials' value. Without sufficient value, any increase in cost or extension of schedule, compared with conventional demolition, will not be justifiable. Even advocates of debris diversion may be reluctant to initiate deconstruction or aggressive recycling if they feel uncertainty is high and risk may be greater than the reward.

The EPA has published two reports (1998, 2009) to determine the amount of building-related C&D materials generated and recovered in the United States and to summarize management practices for this waste stream. The 2009 report<sup>8</sup> provides data on national trends and magnitude of C&D materials as well as project specific studies that can yield "rules of thumb" for planning purposes. Table A-1 summarizes residential waste averages by type of activity.

**Table A-1. Average construction and demolition waste (EPA 2009).**

<b>Activity</b>	<b>Average waste factor (lb/ft<sup>2</sup>)</b>
New construction, job-site waste	4.4
Demolition, single family, not including foundations	50.0
Four-plex (one project)	127.0
Remodeling projects (average can vary widely)	25.0

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<sup>8</sup> <http://www.epa.gov/osw/conserves/imr/cdm/pubs/cd-meas.pdf>

**APPENDIX B:  
METHODOLOGY FOR DETERMINING QUANTITY OF  
CONSTRUCTION AND DEMOLITION WASTE**

**Background**

Appendix B provides data on residential-type construction. Two basic family housing building types are defined as: detached units (e.g., single family or duplex) and multifamily units (e.g., townhouse-style apartments). All building types within a category are of similar enough characteristics that they can be included within the same descriptions. For each category of building, components and materials are characterized by type and quantity.

The following material types are included in the characterization of wood-framed housing units.

- concrete
- reinforcing steel
- lumber
- exterior materials (roofing, siding materials, insulation, doors, and windows)
- interior construction materials (framing, doors)
- plumbing fixtures, equipment, and materials
- heat-generating equipment
- heating and ventilating equipment and materials
- electrical components and materials

To the extent possible, quantities are modeled on a per-square-foot basis per unit of building. Quantities represent a typical building in its standing condition – that is, the building as originally constructed and any items that most commonly have been added or removed during the building's life. Materials are represented in their common units of measure and weight. Unit measures are given for each material or component and for the total building,. The total weight of the standing building would represent the potential debris burden, assuming no other

30 August 2015

diversion takes place; this figure can be used as the basis of comparison for diversion.

The quantities are further annotated as to whether the material or component most commonly is (a) reusable, (b) either reusable or recyclable, or (c) recyclable. To provide the most accurate estimations, the potential diversion factors take into account deterioration and damage during removal of the materials.

The "typical" content of the basic individual housing unit, therefore, can be estimated by multiplying the unit quantity for each material by the square-foot floor area of the individual housing unit. A reasonable yield of these materials can be determined by applying the appropriate potential diversion factors. To estimate the total amount of material present in the entire building, the values found per individual housing unit should be multiplied by the total number of housing unit per building.

Assumptions have been made about the quantities of materials, components, and finishes for each of these variations. While not precisely accurate for an individual building, quantity differences will be minor with respect to the total building mass and will be appropriate for the purposes. The quantities of these additional materials must then be added to the basic building's reusable materials, recyclable materials, and debris quantities.

The condition of materials and components is critical to their potential for reuse or recycling. The effects of age (with regard to functionality or performance), physical condition (with regard to damage or deterioration), and the presence of contamination are described. These conditions will be unique to each building and therefore cannot be generalized. Where they apply to building materials or components, the effects on reuse, recycling, and debris generation are described in qualitative (usually "if ... then") terms. For example, if a component is damaged or may be functionally obsolete and is no longer reusable, its potential for recycling is described. Or, if a contaminate is present on otherwise recyclable material, the requirement for disposing as debris is described. Such conditions may effect all or part of a material's quantity in the standing building.

### **Summary of Methodology**

To summarize, content characterization of a wood-framed house can be performed as explained below.

30 August 2015

- Multiply the *unit weight* for the individual housing unit by the building unit's square-foot floor area. The total weight represents the potential building debris burden per unit. Multiply the total weight found for the unit by the number of units per building to find the total weight represented for the entire building unit.
- Multiply the *unit quantity* for each component and material by the square-foot floor area of the building unit to estimate material quantities. Identify what materials are reusable, recyclable, or debris. Apply the appropriate potential diversion factors and estimate a total weight of each reusable material and recyclable material; include lost materials in the debris total. Multiply the total weight found for each component and material for the individual unit by the number of units per building to find the total weight for each component and material represented for the entire housing unit building.
- *Identify conditions* that apply to the building or materials. Where the conditions would suggest that all or some portion of the materials would not be reusable or recyclable, subtract that amount from the reusable and recyclable totals and add it to the debris total.
- *Compare the total diversion potential* (reusable and recyclable quantities) with the total potential debris burden. This ratio defines the potential debris diversion rate.

### **Building Categories**

The majority of wood-framed houses can be categorized in one of two ways: (1) detached housing (e.g., single-family or duplex) or (2) multifamily (e.g., townhouse-type apartments). Each of these types may have one of the following foundations: slab-on-grade, crawl space, or a full basement. Proper categorization is the most significant feature in modeling quantities on a unit basis (i.e., quantity per square foot of building). It should be noted that all quantity estimates are based on gross square feet, which includes the basement.

#### *Light-frame, one- and two-story housing*

These buildings are constructed with common dimensional lumber members (2x4 through 2x12 joists, studs, and rafters). One unit

is typically 35-44 ft wide in nominal dimension, averaging about 30 ft in depth, and ranging from 1,050-1,320 sq ft. Most buildings consist of a single housing unit or two units per building with mirrored plans. Examples of typical Army wood-framed housing are shown in Figure B-1 through Figure B-6.



**Figure B-1. Exterior façade of an eight-unit family housing building.**



**Figure B-2. Exterior entry façade of an eight-unit family housing building.**



Figure B-3. Exterior rear façade of an eight-unit family housing building.



Figure B-4. Typical aluminum window of an eight-unit family housing building.



Figure B-5. One-story slab-on-grade housing unit.



Figure B-6. Front door of one-story slab-on-grade housing unit.

30 August 2015

Building contents for these types of houses are summarized below.

- *Foundation:* One-story houses are built either with a slab-on-grade or continuous concrete wall footings. Two-story units are built either with a basement or as slab-on-grade. Carports are typical; if a garage is present, its foundation is slab-on-grade.
- *Floor framing:* Slab-on-grade foundations act as the floor system for some housing units with either  $\frac{3}{4}$ -in. plywood sheets (or 1-in. boards in immediately post-war buildings) as subflooring. Where a basement or crawl space is present, the floors are either 2x8 or 2x10 floor joists, with  $\frac{3}{4}$ -in. plywood sheets as subflooring.
- *Exterior walls:* 2x4 studs are spaced at 16 in. on center (OC). Exterior sheathing is either  $\frac{3}{4}$ -in. plywood sheets or 1x8 boards (in immediate post-war buildings). Siding is 8- or 12-in. wood lap siding. Vinyl, aluminum, or steel siding is typically applied over the original wood siding, and insulation board frequently accompanies the added siding. Other areas may have a brick veneer. Aluminum soffits and gutters are typically present.
- *Doors and windows:* Insulated hollow metal doors have often replaced the original exterior doors. The original wood frames typically remain. Windows are typically vinyl or aluminum-framed double-hung replacement type, which may be single- or double-glazed.
- *Roof:* Gable and hip roofs are framed from 2x6 rafters, 16 in. O.C. Plywood sheathing  $\frac{1}{2}$ -in. thick is placed on the rafters. Roofing is three-tab asphalt shingles on roofing felt. One layer of shingle is common, although up to three layers may be present.
- *Interior construction:* Partitions are framed with 2x4 studs and finished with painted  $\frac{1}{2}$ -in. gypsum wallboard (GWB). Ceilings are painted  $\frac{1}{2}$ -in. GWB. The original flooring at framed floors is 3-in. tongue-and-groove (T&G) hardwood strip flooring; carpeting or vinyl tile or sheets with particleboard or plywood underlayment may have been added over the original wood strip flooring. Flooring on slabs is most often vinyl sheet or carpet, although hardwood flooring does appear on occasion. Interior doors are typically hollow-core wood veneer.

30 August 2015

- *Mechanical / Electrical / Plumbing:* A forced-air furnace typically supplies heat and is located in a utility closet at an outside wall. In regions where air conditioning is provided, heat pumps or compressor/condenser units are often mounted near the patio area at the back side of the unit. Ductwork is most commonly strung in the crawlspace or attic of one-story units, depending on whether the floor is built on a crawlspace or slab. Standard light fixtures are present in the ceilings of each room; duplex receptacles are present within any enclosed spaces. Load centers and distribution are typically upgraded over original materials. Bathrooms typically include one toilet, one tub/shower, and one porcelain sink. Some units have powder rooms that include one toilet and one porcelain sink. Kitchens contain one stainless steel sink, range/oven, refrigerator, and dishwasher.

### **Potential Contaminants**

The presence or absence of contaminants will have a significant effect on the feasibility of reusing or recycling building materials. Intentions to minimize waste must be tempered with human health and safety considerations.

#### *Asbestos-Containing Materials*

In most states, and therefore at most Army installations, all asbestos-containing materials (ACM) must be removed prior to building removal regardless of whether the building is mechanically demolished or manually deconstructed. This task is the responsibility of the RCI partner. The demolition (or deconstruction) contractor will be allowed to proceed only after abatement work is completed and the building is certified to be safe. Therefore, no ACM should be present if and when personnel salvage or recycle materials. The only time ACM becomes a problem with demolition or deconstruction is when undetected ACM is found, at which point all demolition, salvage, or deconstruction activities must stop until the ACM is removed. While the presence of ACM is of concern, it is not problematic to the issue of salvage and recycling if it is abated as a standard practice.

In those locations where non-friable ACM is allowed to remain commingled with demolition debris, salvage and recycling become more problematic.

- Items may be removed prior to abatement (i.e., "soft stripping" or "cherry picking") if removal does not disturb any ACM. However, if removing items will disturb ACM and

30 August 2015

release fibers into the air, then removal must be accomplished under controlled conditions. The most common scenario is that these items will be removed as part of the abatement process. But because the abatement crew's task is removing ACM, not salvage, the items attached to ACM are most frequently destroyed during the abatement process. For example, kitchen cabinets, countertops, fixtures, and appliances are desirable for salvage, but may be anchored to walls with asbestos-containing wallboard or joint compound. The abatement crew typically rips out the cabinetry to remove wallboard, damaging the otherwise salvageable items to the extent they are no longer useful. Abatement crews would have to be instructed, encouraged, or given incentives to recover these items intact, but possibly at the expense of a lengthier abatement schedule.

- If otherwise salvageable materials were inaccessible because of non-friable ACM, the ACM would either have to be abated, or the materials would be abandoned as demolition debris. For example, if vinyl asbestos tile (VAT) flooring were present, the underlying hardwood strip flooring and floor framing could not be salvaged unless the floor tile were removed, which would be an additional task not required by prevailing regulations. Another example would be where VAT was applied to a concrete slab-on-grade. Unless the VAT was removed, the concrete could not be recycled.

#### *Lead-Based Paint*

Concern is frequently expressed about salvaging materials that have been coated by lead-based paint (LBP). Any building removal activities – whether demolition, salvage, or deconstruction – must observe the Code of Federal Regulations (CFR) 29 CFR 1926, the "Occupational Safety and Health Administration (OSHA) Construction Safety Standards," specifically Section 62, "Lead in Construction." All occupational protection requirements are described in these standards. However, previous Army deconstruction projects suggest personal exposure to lead is not problematic. Exposure assessments typically result in no more than nondetectable levels of lead being found through personal and ambient air monitoring, even when removing LBP siding by hand.

Consideration must be given to what materials have and have not been painted throughout the buildings' life. Typically, roof, wall, and floor framing has never been painted, and these materials constitute the vast majority of lumber in residential buildings.

30 August 2015

Environmental regulations do not prohibit LBP materials. Prudent practice dictates, however, that the installation and RCI partner show due diligence when allowing LBP materials to be removed for possible resale. This practice would include disclosing the likely presence of LBP and requiring the contractor to disclose the likely presence of LBP to whomever they sell or donate these materials. Housing and Urban Development (HUD) 24 CFR Part 35 and EPA 40 CFR Part 745 "Lead; Requirements For Disclosure Of Known Lead-Based Paint And/Or Lead-Based Paint Hazards In Housing; Final Rule" may provide an appropriate model for this disclosure (HUD 1996). This document also requires a reference to the EPA pamphlet "Protect Your Family From Lead In Your Home" as part of this disclosure. Adopting similar information and disclosure practices would be advisable.

### **Family Housing Quantity Models**

This section presents an example of detailed calculations for estimates of different construction materials in a housing unit (Table B-1), and what portion of each is likely salvagable, recyclable, or to be wasted (Figure B-7). Only one building type is presented here for brevity; however, other models are available from the technical POC for this document.

A few notes on Table B-1:

- As a multiplex structure, quantities are based on per-square-foot per one individual housing unit
- The abbreviation "gsf" is gross square feet, which means the entire floor area of one housing unit
- The abbreviation "bf" is board-foot, a unit of measure in the lumber industry; one bf is a piece of wood that is nominally 1-ft x 1-ft x 1-in.

**Table B-1. Quantity calculations for light-framed housing unit (two-story, slab-on-grade).**

Building Component Categories	Description	Average Quantity per Gross SF of Building	Units	Potential Diversion								
				Salvage for Reuse			Recycle			Debris		
				Percent	Quantity	Units	Percent	Quantity	Units	Percent	Quantity	Units
Dim. Lumber	Framing lumber greater than 6 ft in length	7.40	bf/gsf	75	5.55	bf/gsf	20	1.48	bf/gsf	5	0.40	bf/gsf
		17.80	lb/gsf		13.32	lb/gsf		3.55	lb/gsf		0.89	lb/gsf
Scrap Lumber	Less than 6 ft in length	0.80	bf/gsf	0	0.00	bf/gsf	90	0.72	bf/gsf	10	0.10	bf/gsf
		1.90	lb/gsf		0.00	lb/gsf		1.73	lb/gsf		0.19	lb/gsf
Siding	Metal siding	0.80	lb/gsf	75	0.62	lb/gsf	20	0.17	lb/gsf	5	0.00	lb/gsf
Sheathing	Plywood	0.60	bf/gsf	75	0.47	bf/gsf	20	0.13	bf/gsf	5	0.00	bf/gsf
		1.50	lb/gsf		1.13	lb/gsf		0.00	lb/gsf		0.08	lb/gsf
Plywood	1/4 in. plywood sheathing	2.70	lb/gsf	90	2.39	lb/gsf	5	0.13	lb/gsf		0.00	lb/gsf
T&G Flooring	1x T&G flooring	0.10	bf/gsf	90	0.13	bf/gsf	5	0.01	bf/gsf	5	0.00	bf/gsf
		0.30	lb/gsf		0.30	lb/gsf		0.00	lb/gsf		0.02	lb/gsf
		0.90	sf/gsf	0	0.00	sf/gsf	0	0.00	sf/gsf	100	0.90	sf/gsf
Drywall	1/2 in. GWB	1.80	lb/gsf		0.00	lb/gsf		0.00	lb/gsf		1.83	lb/gsf
Asphalt Shingles & Felt Paper*	235 lb Shingles	0.70	sf/gsf	0	0.00	sf/gsf	99	0.68	sf/gsf	1	0.01	sf/gsf
		1.70	lb/gsf		0.00	lb/gsf		0.00	lb/gsf		0.02	lb/gsf
Concrete	RC foundation slabs & piers	54.90	lb/gsf	0	0.00	lb/gsf	99	54.39	lb/gsf	1	0.55	lb/gsf
Reinforcing Steel	Typical steel reinforcement	0.50	lb/gsf	0	0.00	lb/gsf	99	0.52	lb/gsf	1	0.01	lb/gsf
Masonry	Brick chimney	0.80	lb/gsf	50	0.40	lb/gsf	50	0.40	lb/gsf	0	0.00	lb/gsf
Plumbing	Fixtures, piping, misc.	1.00	lb/gsf	50	0.49	lb/gsf	50	0.49	lb/gsf	0	0.00	lb/gsf
HVAC**	Equipment, ductwork, misc.	0.40	lb/gsf	0	0.00	lb/gsf	90	0.32	lb/gsf	10	0.04	lb/gsf
Doors	Sizes vary	0.50	lb/gsf	85	0.38	lb/gsf	10	0.05	lb/gsf	5	0.02	lb/gsf
Windows	Sizes vary	0.90	lb/gsf	85	0.73	lb/gsf	10	0.09	lb/gsf	5	0.04	lb/gsf
Equipment	Typical kitchen equipment	0.40	lb/gsf	85	0.34	lb/gsf	10	0.04	lb/gsf	5	.02	lb/gsf
Electrical	Light fixtures, conductors, misc.	0.90	lb/gsf	50	0.45	lb/gsf	25	0.23	lb/gsf	25	0.23	lb/gsf
		<b>87.40</b>	lb/gsf		<b>19.80</b>	lb/gsf		<b>61.80</b>	lb/gsf		<b>3.70</b>	lb/gsf

**Potential Debris**  
**87.40 lb/gsf**

**Potential Diversion**  
**81.59 lb/gsf**

\* Asphalt Shingles may not have outlet for recycling; in this case they become debris.

\*\* Newer components of HVAC systems may be reused. GWB = gypsum wall board

bf/gsf = board foot per gross square foot; lb/gsf = pound per gross square foot; sf/gsf = square foot per gross square foot

lb/sf	General Summary
24.19	Wood
55.73	Concrete
0.53	Metals
1.31	Enclosures
2.63	MEP*

\*Mechanical, Electrical, Plumbing

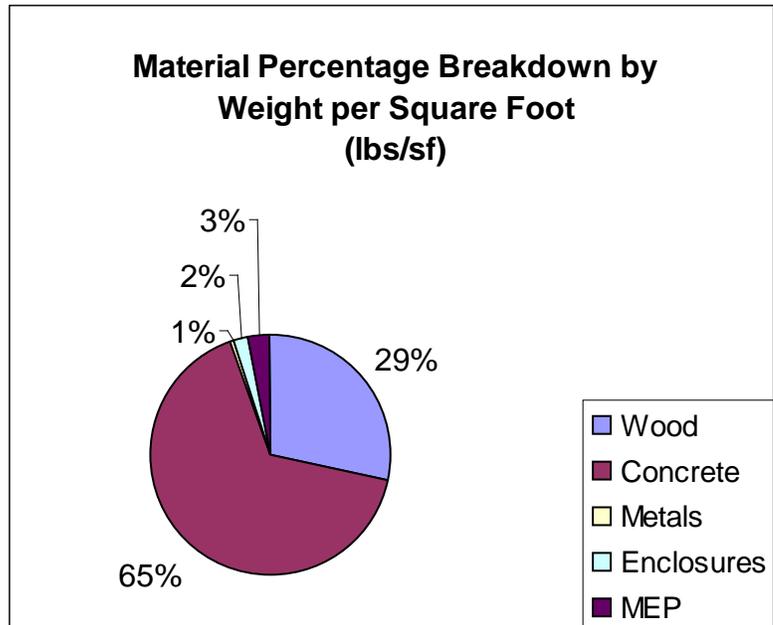


Figure B-7. Summary weight and percentage of recyclable or salvageable material categories from a typical light-framed housing unit, as calculated in Table B-1.

**APPENDIX C:  
DEVELOPING A WASTE MANAGEMENT STRATEGY**

**Planning with Partners**

RCI partners are ultimately responsible for their own C&D waste management and disposal. Beyond encouraging them to reduce and divert C&D waste, the installation also can support the RCI partner in a number of ways. As a minimum, the installation should assemble and provide information on installation and local waste reduction programs, local waste management agencies and their resources, or salvaged and recycled materials services and outlets. Installation personnel can collaborate with the RCI partner in identifying salvage and recycling resources, assessing market values for recyclable materials, and identifying opportunities for waste diversion. Note that the installation ought not to develop a waste management plan or make arrangements on behalf of the RCI partner. However, developing options and promoting feasible alternatives with the appropriate supporting information is entirely appropriate. If the installation can illustrate that both parties benefit, the likelihood is greater that the RCI partner will participate in waste diversion.

One option to consider is reusing the diverted materials on post. Inform the RCI partner of installation requirements for aggregate products, wood mulch or compost, or other common C&D materials. This is a potential "win-win" situation, whereby less material goes to the landfill and the DPW can avoid the purchase cost of virgin materials.

**Reuse/Recycle Options**

Many materials have a variety of reuse or recycle options, and it is important to understand the potential value in these materials. Some possible material diversion potentials are outlined below.

- Concrete and concrete masonry can be crushed (Figure C-1) and used for base, fill, erosion control, or other applications of aggregate. Brick can be crushed with concrete rubble, or it can be crushed separately for landscaping material. Note that it is usually more efficient to bring a crusher on site and avoid shipping the materials to be crushed.



**Figure C-1. Concrete recycling with on-site crusher.**

- Asphalt has a variety of potential as a recycled material: hot mix asphalt, cold patch, dust control on rural roads, temporary roads or driveways, aggregate road base, new shingles, or even fuel.
- Scrap metals (Figure C-2) currently have a high recycling value. Metals tend to have a large market covering a large range of materials, and a local company should be easy to find. A company should be found that will pay for the metal by weight. Some companies may charge for pickup or may charge to have a container left on site to be picked up when full. Over the past 50 years, approximately 50% of the steel produced in America has been recycled and used in every application from food cans to new cars to structural steel.<sup>9</sup>
- Lumber can be salvaged for reuse in other buildings. With careful deconstruction techniques, 75% or more (Falk 2002) of the lumber in a residential building can be salvaged for reuse (Figure C-3). If deconstruction is not an option, the wood should be separated from the demolition rubble. Even scrap wood can be recycled by simply being chipped to make mulch, or it can be processed as fuel by waste-to-energy plants.

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<sup>9</sup> <http://www.recycle-steel.org>



Figure C-2. Scrap metal rebar separated for recycling.



Figure C-3. A worker loads salvaged lumber for recycling.

30 August 2015

- In some areas, GWB can be returned to the factory and recycled into new GWB products.<sup>10</sup> Recycled gypsum can also be applied as an agricultural soil amendment.
- Doors, windows, kitchen cabinets and appliances, hardwood flooring, plumbing fixtures and equipment, electrical fixtures, and other detachable items can be removed intact and taken by a local salvage group such as HfH. HfH ReStores may be able to provide "soft-stripping" or "cherry-picking" services themselves.

### **Management Plan Checklist**

A C&D waste management plan typically includes the information listed below.

- List of building materials and components in place. These items can be described simply as wood, metals, plastics, concrete and rubble, shingles, and other major material categories. Further definition can be useful, especially if various services and outlets may be involved with salvage or recycling efforts.
- Estimated total quantity of each material in place for the project.
- The quantity of each material that can be salvaged for reuse, recycled, or disposed.
- Methods for reducing waste or salvaging/ recycling options associated with each material.
- Destinations for each material to be recycled, salvaged, or disposed; include any on-post agencies that can use recycled materials.
- How each material will be handled, processed, and transported to be recycled, salvaged, or disposed.
- Method for calculating the estimated diversion.

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<sup>10</sup> <http://www.drywallrecycling.org>

## **Costs**

The cost of landfilling all materials is compared with the cost (and potential revenue) of salvage and recycling. Costs can vary greatly depending on the tipping fees at area landfills, the availability of diversion outlets, and the values for recyclable materials. Once all costs, cost-avoidance savings, and potential revenue are known, the net cost can be determined. A waste management analysis or plan should, therefore, include the following information.

- Estimated total cost for hauling and landfilling all materials.
- Cost and/or revenue associated with salvaging and recycling each identified material.
- Cost for hauling and landfilling remaining debris materials.
- Cost avoidance by using recycled materials in lieu of purchasing new materials.

Once overall net cost can be estimated, the RCI partner can identify the most economical and efficient waste diversion options available to them and conclude their arrangements with the appropriate salvage, recycling, and waste hauling services.

## **Waste Diversion Methods**

Below is a summary of waste diversion methods commonly used on construction sites.

- *Reduce packaging and packing.* The RCI partner can instruct (or require) their contractors and suppliers to reduce packaging and packing materials in several ways. Purchase materials in bulk where possible. Avoid individual packaging for volume purchases. Utilize returnable containers and packing materials. Reuse nonreturnable containers on the jobsite. Collect and distribute these resources to subcontractors and tradespersons. Give away nonreturnable containers where possible. Contact local and community organizations (schools, youth groups, community service groups, HfH, other similar).
- *Maximize the use of materials.* Use scrap in lieu of cutting full new materials. The RCI partner can encourage (or require) their contractors and tradespersons to set up cutting and fabricating locations and to sort scrap by size for easy

30 August 2015

access. Alternatively, tradespersons can collect scrap and deposit it in dedicated scrap centers. Collect paints and similar liquid materials from almost-empty containers.

- *Purchase in limited quantity when necessary.* For materials that are heated, mixed, exposed to environmental conditions, or have a limited time for use, purchase only those quantities that can reasonably be used within that sensitive timeline. Ensure volatile materials and those that degrade when exposed to heat, cold, or moisture are protected from spoilage.
- *Recycle damaged or unsuitable materials.* When components, products, or materials are damaged and unsuitable for the work, recycle them or disassemble them into their constituent materials for recycling.
- *Return, sell, or donate unused materials.* The contractor and/or subcontractors should establish a return or buy-back arrangement with suppliers. Alternatively, the used but serviceable and the unused materials and products can be sold or donated to building materials reuse or architectural salvage retail outlets. A donation to a nonprofit outlet, such as a HfH ReStore, is usually tax-deductible. Proceeds from ReStore sales support HfH homebuilding programs. Proceeds from other similar nonprofit organizations also support other community programs.
- *Recycle commingled waste off site.* The RCI partner, or their subcontractor, may contract with a C&D recycling firm who accepts commingled debris. The debris is collected at the jobsite in common receptacles and hauled to the off-site recycling facility. At the recycling site, concrete and masonry rubble are separated for crushing into aggregate products. The remaining debris is typically crushed or shredded, then conveyed along a pick line for sorting and separating (Figure C-4). Recycling commingled debris and waste off site requires virtually no adjustment in practice on the contractor's part. This method typically achieves a very high diversion rate. However, clean wood is frequently sold for boiler fuel, and some agencies (including EPA) do not classify waste-to-energy use as debris diversion.



**Figure C-4. C&D recycling pick line.**

- *Segregate waste materials on site.* The RCI partner, or their contractor, may contract with individual recycling firms who deal in specific materials and a general waste hauler. The construction process lends itself to on-site segregation. When the recyclable materials are segregated, the recycling firms will generally offer a higher price for the material (if the contractor hauls it), or a lower hauling rate if the recycler performs this task. Alternatively, the contractor can subcontract with a waste hauler who provides separate receptacles for recyclable materials and debris but hauls all materials as a single service. Hauling costs for segregated materials are frequently much less than for commingled debris.

The waste diversion potential with demolition is considerable. Develop the project schedule with consideration of tasks involved in material salvage, reuse, or recycling. Prior to demolition, salvage as much useable components and materials as the schedule will allow. If none of the alternative salvage, reuse, or recycling options are possible, mixed demolition debris can be hauled to a C&D debris recycling facility, as described above.

### **Design for Waste Reduction**

The RCI partner's design team can also contribute to waste reduction in several ways, as listed below

- Balance cut and fill to reduce borrow and spoil requirements.
- Utilize natural topography for stormwater management to reduce artificial drainage construction requirements.
- Incorporate existing vegetation into the landscape design to reduce the need for land clearing.
- Design buildings to optimize systems' and components' use. Avoid extraneous materials that do not contribute to function. Various publications on optimum value engineering (OVE) and efficient framing techniques provide details.
- Be efficient in area and volume. The more materials required by the design, the more waste is generated on the jobsite.
- Observe standard material and product dimensions. Locate features "on module" to reduce cutting and special fitting, which creates scrap.
- Select construction systems that do not require construction aids, or other materials that are not part of the finished product and will not be disposed of as debris during the project. Reuse construction aids to the maximum extent possible. Use scrap material in lieu of purchasing or using new materials.
- Select materials that do not rely on adhesives, which require containers and create residue and packaging waste.
- Select materials with integral finishes to reduce the need for on-site finishing work and the associated scrap, packaging, and waste.
- Prevent damage and spoilage by avoiding materials sensitive to damage, contamination, environmental exposure, or spoilage on site, to decrease the potential for jobsite waste.

Army deconstruction experience has revealed a need for construction materials by troop units. The most common request has been for lumber, doors, windows, and concrete components such as piers. These materials have been used for training

PWTB 200-1-143

30 August 2015

exercises on ranges and at Military Operations on Urbanized Terrain (MOUT) facilities. Ordinarily, the units would have to purchase new construction materials, only to demolish them in training. There are also other uses for C&D materials in lieu of purchasing new materials. One request for salvaged materials at Fort Lewis, WA, involved construction of decks and landscape features by soldiers suffering combat wounds and undergoing rehabilitation. Each DPW should exploit these types of opportunities to the greatest extent possible, to reduce the C&D waste stream and provide resources to other activities on post.

**APPENDIX D:  
CONSTRUCTION AND DEMOLITION WASTE REDUCTION  
AND DIVERSION RESOURCES**

One of the greatest challenges to diverting C&D debris in some regions is identifying construction-related services to perform salvage or deconstruction activities and outlets for the salvaged and recycled materials. The installation's environmental personnel may be well-versed in municipal solid waste recycling resources, but may not be familiar with resources for salvaging and recycling building materials. Furthermore, the RCI partner's primary business is likely in development and construction. Thus, the salvage and recycling industry and infrastructure in the region may not be well known to either partner.

Following are webpages of some suggested resources for salvaging and recycling building materials.

<http://www.habitat.org/restores?place=us>

<http://bmra.org>

<http://www.thebluebook.com/cl/all3455.htm>

<http://www.shinglerecycling.org/>

[http://www.astswmo.org/Pages/Resources/State\\_Agency\\_Links.htm](http://www.astswmo.org/Pages/Resources/State_Agency_Links.htm)

<http://www.cdrecycling.org/>

<http://www.cdrecycling.org/drywall-recycling>

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## APPENDIX F: ABBREVIATIONS

Abbreviation	Spell Out
ACM	asbestos-containing material
AR	Army Regulation
ASAIE&E	Assistant Secretary of the Army for Installations, Energy and the Environment
bf	board foot
C&D	construction and demolition
CECW	Directorate of Civil Works, U. S. Army Corps of Engineers
CFR	Code of Federal Regulations
CERL	Construction Engineering Research Laboratory
DPW	Directorate of Public Works
EO	Executive Order
EPA	U.S. Environmental Protection Agency
ERDC	Engineer Research and Development Center
FRP	Facility Reduction Program
gsf	gross square feet
GWB	gypsum wallboard
HfH	Habitat for Humanity
HQUSACE	Headquarters, U.S. Army Corps of Engineers
HUD	Housing and Urban Development
ISWP	Integrated Solid Waste Management Plan
LBP	lead-based paint
MILCON	Military Construction
MOUT	Military Operations on Urban Terrain
OACSIM	Office of the Assistant Chief of Staff for Installation Management
OC	on center
OSHA	Occupational Safety and Health Administration
OVE	optimum value engineering
PE	professional engineer
PDASA	Principal Deputy Assistant Secretary of the Army
PDASAI&E	Principal Deputy Assistant Secretary of the Army Installations and Environment
POC	point of contact
PWBC	Public Works Business Center
PWTB	Public Works Technical Bulletin
RCI	Residential Communities Initiative
SES	Senior Executive Service
SDD	Sustainable Design and Development
sf	square feet
T&G	tongue-and-groove
UFGS	United Federal Guide Specification
USACE	U.S. Army Corps of Engineers
VAT	vinyl asbestos tile

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