The Watershed at Hillsdale
Community Partners for Affordable Housing

A 51-unit senior affordable housing project in Southwest Portland revitalized an existing brownfield site located in Hillsdale Town Center. The project employed a thermally sound envelope and high efficiency windows, eliminating the need for air conditioning. Despite the challenges posed by the brownfield conditions, the buildings' stormwater is managed on-site through a series of designed planters that flow between the two buildings and a 15,000-gallon rainwater harvesting system.

Project Highlights

- **Construction and demolition waste recycled**
- **Brownfield site redevelopment**
- **Energy and water efficient design**
- **Local and regional materials**
- **Resident and community education program**

Portfolio Contents

- **Final Report**
- **Monitoring & Verification**

- **Project Website (External Link)**

Green Investment Fund

Energy Trust of Oregon

Portland Water Bureau — From Forest to Faucet

Environmental Services

Bureau of Planning and Sustainability
Innovation. Collaboration. Practical Solutions.
City of Portland, Oregon
Sam Adams, Mayor • Susan Anderson, Director

City of Portland Green Investment Fund

Grantee Final Report

PROJECT INFORMATION

Name of Primary Contact:	Sheila Greenlaw-Fink				
Company or Organization:	Community Partners for Affordable Housing				
Address:	PO Box 23206				
City, State & Zip:	Tigard, OR 97281				
Phone:	503-968-2724	Fax:	503-598-8923	E-mail:	sgfink@cpahinc.org

PROJECT DETAILS

Project Name:	The Watershed at Hillsdale
Project Owner:	Bertha Senior Housing Limited Partnership Community Partners for Affordable Housing as General Partner
Project Address:	6380/6388 SW Capitol Highway
City, State, ZIP:	Portland, OR 97239
Date Project Started:	January 2007
Date of Completion:	December 2007
Building Certifications:	Anticipating LEED Silver Certification Enterprise Green Communities Initiative (Affordable Housing Certification)

Design and Construction Team

Architect or Designer:	William Wilson Architects
General Contractor:	Walsh Construction
Landscape Architect:	Vigil - Agrimis
Structural Engineer:	TM Rippey
Civil Engineer:	Vigil - Agrimis
Mechanical Engineer:	Interface Engineering performance spec. Hunter Davisson – Design Build
Electrical Engineer:	Interface Engineering performance spec. Peninsula Plumbing – Design Build
Interior Designer:	N/A
Green Building Consultant:	Green Building Services
Energy Modeler:	Green Building Services
LEED Consultant:	Green Building Services
Additional:	

Building Details

If building has mixed use, please include the sq. ft of each type of use
Gross Floor Area:

Building Type
☐ Single-family Residential
☒ Multi-family Residential
☐ Commercial
☐ Industrial
☐ Institutional
☒ Mixed-Use
☐ Other (describe)

Site Conditions (check all that apply)
☐ Previously Undeveloped Land
☐ Previously Developed Land
☒ Brownfield Site
☐ Preexisting Structure(s)

Project Type
☐ Renovation
☒ New Construction
☐ Addition

Project Costs

Land Acquisition:	$366,433
Site Clearing/Deconstruction:	N/A
Site Development:	$240,000 (brownfield cleanup)
Public Improvements:	$50,000
Design Fees:	$659,986
Permits:	$171,502
System Development Charges:	$306,400 (affordable housing SDC waiver received so net cost was 33,584)
Construction:	$7,604,095
Green Technologies:	$275,000
Other Costs:	$1,791,805
Total:	$11,465,221

Project Measure Matrix

In the following Matrix, as requested, please provide detailed information about all green products and materials identified in the Grant Agreement, Green Building Practices and Features. Additional rows may be added to the table in Word as needed.

Green Building Project Measure Matrix

Product/ brand or Measure by Category	Model #	Vendor	Cost				Efficiency/ Equipment Ratings or Capacity	Certifications	Incentives, Credits, rebates, grants, etc…
			Design	Material	Equipment	Labor			
Energy									
Energy Recovery Ventilation	ERV -1500 ERV-2500	Cook	40,000	52,250	22,500	114,750	980- 1400 CFM Sensible effectiveness – 88-93%		OHCS Low Income Weatherization $135,700
Boiler	PGC31001993NV	American/ Polaris	10,000	6,000	9,000	15,000	199 MBH, 100 gallon, 96% efficient		OHCS Low Income Weatherization $5,694
Heat pump	25HCA3	Carrier	5,000	1,000	16,500	22,500	13 SEER, 1.5 – 4 tons		
Furnaces	58MXA	Carrier	5,000	9,400	15,600	30,000	93% efficient, 40 – 80 MBH		OHCS Low Income Weatherization $2,791
Windows	Vinyl	Jeld Wen		70,000		17,600	U.34-U.35	Energy Star	
Lighting	2045, 5028	Brownlee	10,000	35,000		20,000		Energy Star	OHCS Low Income Weatherization $8,932
Refrigerators	GTH16BBS	GE		20,400		2,550	15.5 CF, 386 kWh/yr	Energy Star	
Dishwashers	GSM 1800N	GE		12,750		10,200	293kWh/yr	Energy Star	
Water Efficiency									
Toilets	Caravelle 270	Caroma		25,500		5,100	.8gpf/1.6gpf		
Lav Faucets	TS-20-2-BH-RF	Symmons		4,590		5,100	1.5 gpm		
Kitchen Faucets	TS-23-BH-RF	Symmons		4,080		5,100	1.5 gpm		
Shower	BP-56-2-LR-SS	Symmons		2,550		2,550	2.0 gpm		
Irrigation heads	Xerigation sprayhead & drip	Rainbird	2,000	7,750		7,750	Drip: .61-.92 gph Spray:0-31 gph		

Irrigation controls	Smartline Controls & weather station	Weather-matic			1,000	2,100			

Stormwater Management									
Rain Gardens & plantings	See attached memo from Vigil-Agrimis		15,000	45,000		45,000			
Materials and Resources									
Local materials	See spreadsheet from Walsh Const.	Various		878,265			41% regionally manufactured 23% regionally extracted		
Materials and Resources (cont)									
Recycled content materials	See spreadsheet from Walsh Const.	Various		337,670			8.6% post consumer 7.4% post industrial		
Indoor Environmental Quality									
Cabinets	Skyblend Particleboard	Roseburg Forest Products/ Lanz Cabinets		25,000		39,500		LEED compliant	
Paint	Horizon	Rodda		13,100		52,400	0 g/l VOC	Green Seal	
Adhesives	See attached list from Walsh Const			9500		18,825	0 – 490 g/l VOC	LEED compliant	
Carpet	DesignWeave	Shaw		62,000		16,750		CRI Green Label Plus	
Countertops	Skyblend Particleboard	Roseburg Forest Products/ Precision Countertops		9,000		16,500		LEED compliant	

Site									
Pedestrian and bike improvements	New sidewalks & future bike lane		7,500	29,800		36,450			
Flex car	Flex Car/Zip Car sited vehicle within 100’ of building					0			
Reduced heat island effect - Underground parking		Walsh Construction	85,000	567,450		693,550			Metro Transit Oriented Development Grant - $230,000
Reduced heat island effect - Roofing	UltraPly TPO	Firestone		44,400		66,600		Energy Star	
Brownfield redevelopment		Walsh Const	60,000	40,000		200,000			EPA Brownfield Cleanup Grant - $200,000
Durability									
4’ overhangs			7,000	45,000		55,000			
Rain screen siding system			17,500	112,500		137,500			
Construction and Demolition Waste Recycling									
97% C&D recycling	See spreadsheet from Walsh Const.	AGG/Walsh Construction				12,750			

PROJECT HIGHLIGHTS

Financial Savings & Benefits

Can any soft or hard cost savings be identified from installation of green measures? Please provide actual cost savings.	Savings of $1,200 for using crushed, recycled concrete as slab base instead of standard ¾" minus rock.
Can any operational cost savings from green measures be identified? Please provide actual or projected operational cost savings.	Annual energy savings of $20,768 per energy model (attached) Annual water/sewer savings of $6,000 based upon water savings calcs (attached) Maintenance and turnover expenses expected to be lower than typical but cannot be accurately estimated at this time.

Environmental Benefits

Please be as specific as possible. Compare against code or a similar conventional building as relevant.

Modeled Energy Savings: *(Annual kWh or therms per sq foot)*	416,653 kWh annual savings
Estimated Annual Water Savings: *(Annual savings in gallons per person)*	517,752 gallons/year for 78 occupants 6,637 gallons/person/year 18/gallons/person/day
Construction and Demolition Waste Recycling: *(% recycled by weight or volume of total waste)*	97.4% Recycling
Estimated Annual Reduced Stormwater Runoff: *(% total permeable surface area of total site area)*	Site has high impervious site coverage. Cascading rain gardens act to delay storm surge and filter stormwater prior to disposal into storm sewer system.
Enhanced Habitat: *(% area of restored or new habitat of total site area)*	25% of site is landscaped with native plantings
Other: Smart growth site	Brownfield infill site redeveloped reducing pressure on urban growth boundary and taking advantage on existing infrastructure. Density of 85 units/acre setting higher density standard for redevelopment in Hillsdale Town Center

Community Benefits

Can any specific community benefits be identified? Examples include educational opportunities, public access or community benefit programs.	Numerous presentations & tours have been given to neighborhood association, governmental agencies and other developers. Presentations at local and national conferences including EPA Brownfield conference and NeighborWorks Conferences. Neighborhood association holding meetings in building. Educational flyers available to tours Resident education on green building features

LESSONS LEARNED

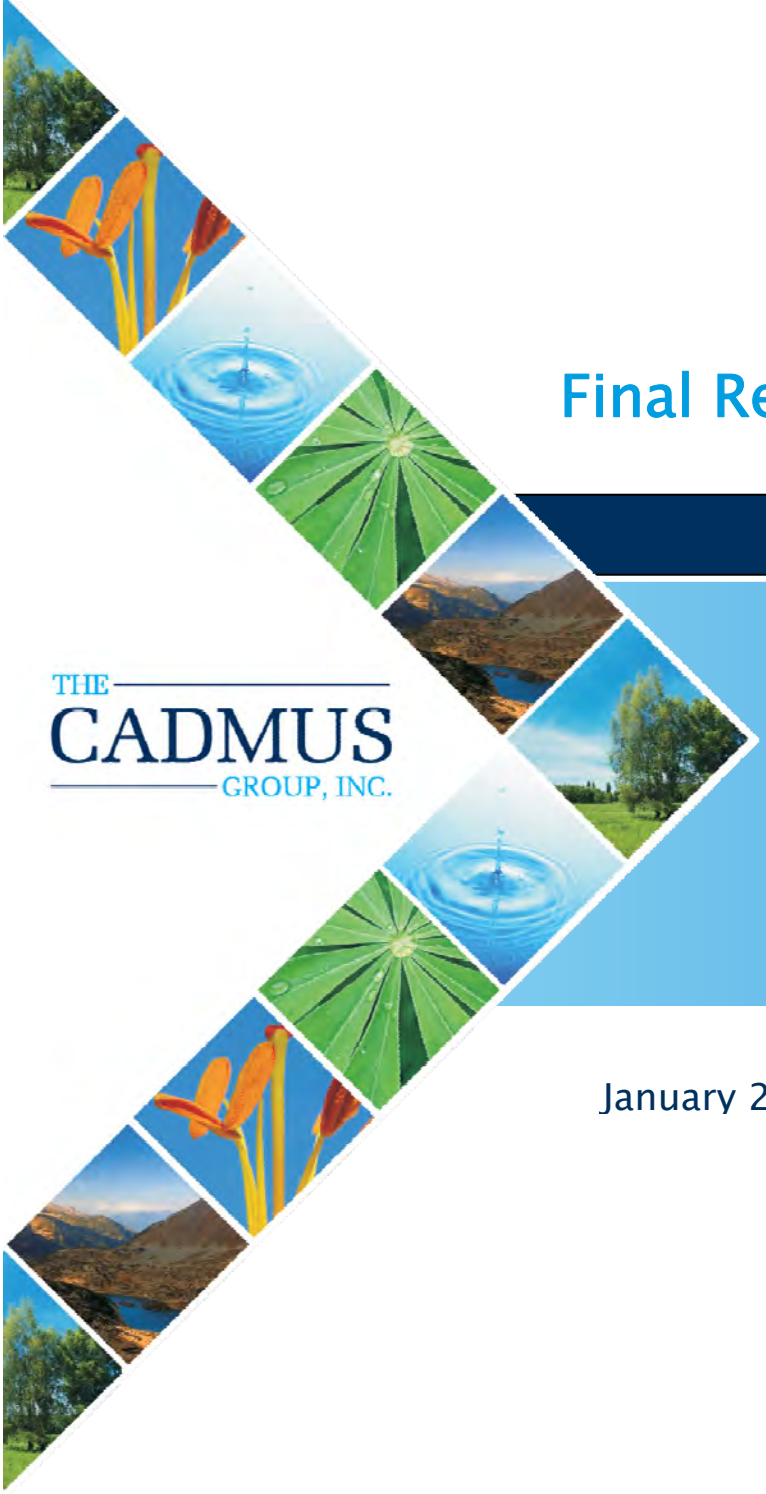
Describe key outcomes from this project. How has the project changed from its original scope and why? Would you recommend the green technology or practice to other projects? Were there any policy, zoning or building code related issues that affected the project?	**Key Outcomes** • Redevelopment of blighted site into gateway for Hillsdale Town Center taking advantage of access to transit and services • 30% energy savings • 30% water savings • 95% C&D recycling • Use of local and regional materials. • Excellent indoor environmental quality • Resident and community education **Changes to project** **Energy conservation:** The GIF grant performance criteria required energy conservation of 25-25% over conventional construction with Insulated Concrete Forms (ICFs) as the key strategy. The energy modeling performed by Green Building Services demonstrated that the ICF's were not providing the anticipated energy savings while adding cost due to the soils conditions. The team adopted a strategy of high efficiency central boiler for domestic hot water heating, high efficiency furnace for common spaces, and the heat recovery ventilation (HRV) system for the units. The HRV also improved the ventilation system for the building. The building ventilation is provided through a central supply and return system with the HRV units located in the attics. This system is a significant improvement over the standard ventilation system for this building type; which consists of a pressurized corridor, undercut units doors and negative pressure units with roof mounted fans and window vents. The conventional system has been shown in typical affordable housing units to have a high amount of tenant tampering because of drafts created at the doors and windows vents. The senior population in the Watershed is particularly susceptible to drafts and the proposed system will eliminate this issue. **Water conservation:** The performance criteria for the GIF for this area was 20-40% savings in water consumption, initially through the use of rainwater harvesting. Green Building Services provided modeling for water conservation using low flow fixtures, dual flush toilets, efficient appliances, drip irrigation systems and native plants. These combined measures resulted in a water savings of over 50% over standard construction without the use of rainwater harvesting. **Technology Recommendations** The HRV system significantly improves the energy performance of the building while also improving ventilation. The first cost for this system is significant but the team would highly recommend this strategy for future projects. **Policy issues** The project met green building criteria for Portland Development Commission, OSD, the Enterprise Foundation Green Communities Initiative and LEED. The criteria for these different programs were similar but not exactly aligned. The cost and time to track the different criteria and fill out separate reports was significant. Alignment of the goals and streamlining of funding (as is being discussed) would reduce the opportunity costs for all projects.

IMAGES AND GRAPHICS

Please attach drawings and photos that describe the project and the green technology or practice.

Photos and presentations have been emailed separately.

Questions? Please contact Kyle Diesner, 503-823-4166 at OSD. Thank you for taking the time to share what you've learned!



THE CADMUS GROUP, INC.

Final Report

GIF Project M&V Plan and Report: The Watershed at Hillsdale

January 21, 2011

Prepared by:

The Cadmus Group, Inc. / Energy Services
720 SW Washington Street, Suite 400
Portland, OR 97205
503.228.2992

Prepared for:

City of Portland Bureau of Planning and Sustainability

Prepared by:
Jeff Cropp
Bill Falkenhayn

Dr. Allen Lee
Principal
The Cadmus Group, Inc.

Executive Summary **2**

Project Description **5**

General Project Characteristics 5

Proposed Green Features 7

M&V Scope and Schedule 7

Verified Green Features **9**

Energy M&V **11**

Project and Counterfactual Characteristics 11

Analysis Approach 11

Preliminary Simulation Model Analysis 12

HVAC 12

Water Heating 14

ENERGY STAR Appliances 16

Windows 18

Lighting 19

Baseline and As-Built Consumption Data 19

Results 20

Water M&V **21**

Project and Counterfactual Characteristics 21

Analysis Approach 21

Results 24

Stormwater M&V **27**

Introduction and Purpose 27

Stormwater Features 27

Site Inspection 28

System Performance Assessment 30

Cost of Stormwater Component Maintenance/Replacement 31

Conclusions 31

References 32

Construction and Demolition Waste **33**

Executive Summary

The Watershed at Hillsdale ("The Watershed") is one of five apartment properties owned by the Community Partners for Affordable Housing (CPAH). These provide housing for families at 60% or less of the Portland metropolitan area median income. The City of Portland Green Investment Fund (GIF) provided incentives to achieve energy savings through the use of insulated concrete forms (ICFs) and water savings through rainwater harvesting. This monitoring and verification report (M&V) focuses on energy usage at the site, water usage, and the effectiveness of stormwater mitigation strategies.

The project is a mixed use development in the heart of the Hillsdale Town Center. Housing includes affordable rental housing for seniors (51 apartments), with 40 units available to those with incomes at or below 30% of median income, currently $15,270 per year. There are 47 single occupancy units and four double units, with a total occupancy of 55 tenants. The project also includes a 2,000 square foot community center and two commercial spaces on the ground floor, only one of which is occupied.

The building was completed in February 2008 with a vision to reduce tenant operating costs through energy efficiency. Key green measures installed in this project include energy saving windows; energy-efficient appliances; high performance heat pumps, furnaces, and water heater; an innovative heat recovery ventilation system; energy and water saving low flow shower heads, faucets, and drip irrigation; and stormwater retaining gardens filtering water from building runoff.

The Watershed project design originally included a stormwater system to capture all rain water and process it on site through vegetative swales. In 2006 a geotechnical report concluded that a high groundwater table made rainwater harvesting and the processing of all stormwater onsite impractical. Instead, rain gardens with underdrains were installed to meet the stormwater management goals of the GIF. However, it is unlikely that significant volume reductions or water quality benefits are being achieved by the rain gardens. Some peak flow and volume reductions are likely occurring, but this benefit cannot be quantified without conducting field tests outside the scope of this evaluation.

The same geotechnical study found the soils had low load bearing capacity. The subsequent redesign resulted in a substantial increase in the cost of the planned ICF walls, rendering that option infeasible. Alternatively a plan was developed to install a high-efficiency central boiler for domestic hot water heating, high-efficiency furnace for common spaces, and heat recovery ventilation (HRV) system for the air handling units. These combined strategies were intended to meet the GIF performance criteria while not adding to the weight of the building and the structural concerns.

The energy analysis began with site visits to verify the installed measures, and gain sufficient identifying information to determine their rated performance. Engineering calculations compared measure performance to code requirements or standard practice to estimate measure level savings. The third step involved the collection of electric and gas billing data over the period of a year to determine as-built energy use and estimate the baseline consumption if the project had only been built to code. Cadmus calculated that the various energy-efficiency measures offset 16% of the baseline energy savings.

The evaluation team reviewed the water-using fixtures and appliances in the apartments to verify they exceeded the efficiency requirements of applicable standards. All fixtures and appliances were more water-efficient than required by the standards, and included dual-flush toilets, faucet aerators, low flow showerheads, and an efficient landscape irrigation system. Cadmus calculated these measures should reduce water consumption by 24% over a comparable baseline building.

Overall, the project's original vision to reduce operating costs for low income tenants was achieved through efficiency. The design, construction, and operation of these living units and commercial space has produced significant reductions in gas, electric, and water usage, as well as decreasing detrimental impacts of runoff entering the City of Portland's stormwater system.

Project Description

General Project Characteristics

The Watershed at Hillsdale ("The Watershed") is a Community Partners for Affordable Housing (CPAH) project, located next to the Hillsdale Town Center in southwest Portland. The project is a mixed-use development including ground floor commercial space with three floors of housing above. The project began construction in January 2007 and was completed in December 2007.

The City of Portland Green Investment Fund (GIF) provided incentives to achieve energy savings through the use of insulated concrete forms (ICFs) and water savings through rainwater harvesting. This monitoring and verification report (M&V) focuses on energy usage at the site, water usage, and the effectiveness of stormwater mitigation strategies.

The Watershed offers 51 affordable rental apartments for seniors, with 40 serving households earning from 0% to 30% of the median income with rent subsidies provided through the Housing Authority of Portland. The project includes eight units for formerly homeless veterans in collaboration with the Veteran's Administration.

One of the main objectives of this project was to provide lower operating costs through use of highly efficient systems and environmentally friendly, durable materials. Innovations include a high-efficiency central boiler, durable building envelope materials, efficient windows, and an innovative heat-recovery ventilation system. Stormwater is channeled through two "cascading water gardens" that detain and filter the stormwater prior to disposal into the City of Portland's system. Water efficiency is achieved through low-flow fixtures, dual-flush toilets, efficient appliances, drip irrigation systems, and native plants in the surrounding landscape. The project has achieved an Enterprise Green Communities Initiative (Affordable Housing Certification) and achieved a LEED silver rating.

Figure 1 shows the south wing of The Watershed and Figure 2 demonstrates one of the cascading water gardens.

Figure 1. View with Sky Bridge from SW Bertha Ct

Figure 2. Cascading Water Garden

Proposed Green Features

The project included a variety of green features and practices. A set of measures was accepted by the Bureau of Planning and Sustainability (BPS) for funding under the Green Investment Fund (GIF).

The proposed green features included:

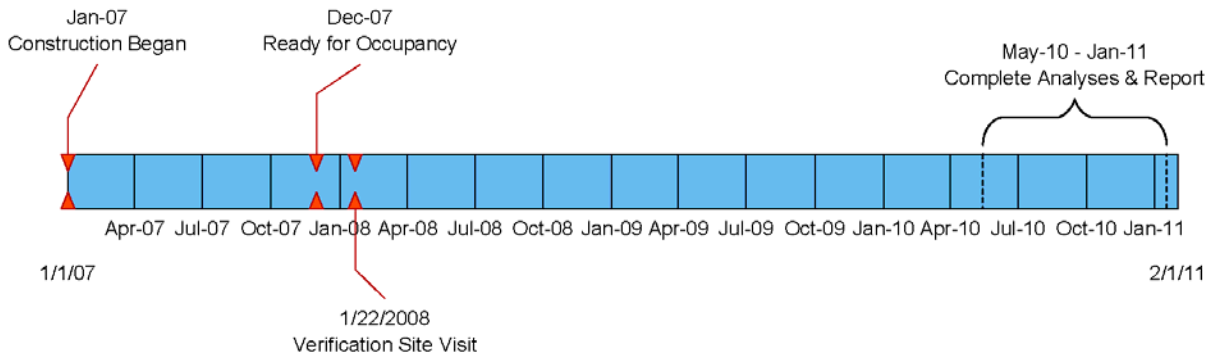
- Rainwater harvesting system
- Native plants to reduce water consumption
- Dual flush toilets
- Energy and water saving low flow shower headsand faucet aerators
- Insulated Concrete Forms (ICFs)
- ENERGY STAR appliances
- High performance windows with U-value of 0.35 or below

M&V Scope and Schedule

In accordance with the priorities identified by the BPS, the monitoring and verification (M&V) focus was on energy use and water use, although a limited stormwater analysis was also performed. The Cadmus Group (Cadmus) and Geosyntec performed the M&V for this project. Cadmus focused on the review of the green features installed and conducted the energy and domestic water analysis. Geosyntec led the stormwater analysis.

Our schedule for M&V activities is shown in Figure 3.

Figure 3. M&V Schedule



Verified Green Features

Cadmus and Geosyntec scheduled and performed a detailed site visit to verify that the green measures were incorporated into the building. As shown in the checklist, we reviewed the proposed measures to verify that they were present and properly installed in the tenant spaces and common areas. Measures for the relatively small commercial spaces were generally not verified or analyzed, with the exception of envelope measures such as efficient windows. Measures included in the GIF are noted in the second column of the table.

Table 1. Checklist for Site Visit

Proposed Measures	GIF Measure?	Installed	Comments
Exterior			
Two water gardens detaining and filtering stormwater	Yes	Yes	System installed and functioning
Use of native and adaptive plants	Yes	Yes	Native and adaptive plants around the property and in the water garden such as ferns and native reeds.
Water Efficiency			
Drip irrigation	Yes	Yes	All landscaped areas around the property, use low volume drip irrigation.
Low-flow showerheads/faucets	Yes	Yes	2.0 / 1.75 gpm respectively.
Low-flow toilets (Dual-flush)	Yes	Yes	Caroma dual-flush toilet (1.6/0.8 gpf).
Building Envelope			
Insulated concrete forms	Yes	No	Energy efficient structural material compared with standard wood framing
High performance windows with U-value of .35 or below	Yes	Yes	The window manufacturer is JELD-WEN with ENERGY STAR rating. Depending on window size, the U-factor is either 0.35 or 0.34 with a SHGC of 0.24.
Energy Efficiency			
ENERGY STAR appliances (see below)	Yes	Yes	See below.
High efficiency central boiler for hot water heating	Yes	Yes	High efficiency 95%-96% thermal efficiency central boiler for domestic water heating. Manufacturer: Polaris Commercial Gas Water Heater.
High efficiency furnaces for common spaces	Yes	Yes	High efficiency 93% AFUE central furnaces and heat pumps for the common areas.
Heat pumps	No	Yes	(1) Carrier 25HCA318A310 with 14.5 SEER and 7.9 HSPF (2) Carrier 25HCA348A500 with 13.8 SEER and 8.3 HSPF
HRV (heat recovery ventilation)	Yes	Yes	(3) RenewAire HRVs for building air handler units
Lighting power density	No	Yes	Below code lighting power density
Other			

Proposed Measures	GIF Measure?	Installed	Comments
Low VOC paint and finishes, non-toxic adhesives, and formaldehyde free wood products used throughout interior	No	Yes	Rodda Paint, Horizon with green seal used on all interior wall and ceiling surfaces. Low VOC adhesives were used, such as SF-565 Sub-Floor adhesive. All carpets are green label. No added urea formaldehyde composite wood for cabinets and countertops, used Medite II and Skyblend products.
Bike lock area	No	Yes	Located in the garage for tenants.
Construction waste and recycling program - 95%	No	Yes	Construction waste recycling - 98%.
Metering/Measurements			
Cadmus/PSU/Geosyntec: GIF verification			Site visit on January 18th, 2008
Cistern/harvested rainwater used for domestic and irrigation			Storage tank removed from project
Other: LEED			LEED Silver
Energy-Efficient Appliances			Model Number or Brand Name
Dishwasher			GE Model # GSM1800N EnergyGuide rating 293 kWh/yr
Refrigerator			GE 15.5 cu.ft. Model# GTH16BBS EnergyGuide rating 386 kWh/yr
Clothes washer			(2) Speed Queen SWTT21WN (1) Speed Queen SWRT71WN

Energy M&V

Project and Counterfactual Characteristics

Table 2 compares the energy efficiency measures of the units as built and verified through our site visit with the measures that would have been installed if the units were designed to just meet the Oregon energy code using conventional practice (the "counterfactual").

Table 2. Comparison of Energy Efficiency Measures

Measure	Code Requirement (Counterfactual)	Project As-Built
Space Heating	Gas Furnace, 80% AFUE	Gas Furnace, 93% AFUE
Space Heating	Heat pump, HSPF 7.7	Heat pumps, HSPF 7.9 and 8.3
Space Heating (HRV)	None	Heat recovery ventilator for AHUs
Space Cooling	Heat pump, SEER 13	Heat pumps, SEER 13.8 and 14.5
Windows	U-value 0.40 (OR Code)	U-value 0.35
Water Heating	Standard efficiency boiler, AFUE = 80%	High efficiency boiler, AFUE = 96%
Water Heating	Faucet aerator, 2.2 gpm	Faucet aerator, 1.75 gpm
Water Heating	Showerhead, 2.5 gpm	Showerhead, 2.0 gpm
Appliances	Standard	ENERGY STAR Appliances
Lighting	Code lighting power density by space	Reduced lighting power density by space[1]

The evaluation team's methodology for analyzing energy savings is discussed next.

Analysis Approach

The energy M&V started with site visits to verify the installed measures, and gain sufficient identifying information to research their rated performance. This information was compared to similar code-required measure performance. Next, engineering calculations supported by secondary sources for building loads were incorporated to estimate measure level savings. The third step involved the collection of electric and gas billing data over the period of a year. The billing consumption data formed the basis for calculating actual consumption with all GIF measures installed. The counterfactual was then estimated to be the total of the billing consumption data plus the calculated measure savings.

Interactive effects on energy savings would be expected from the combination of the various energy-efficiency measures. As an example, energy savings from low flow water fixtures would be less when a more efficient water heater is in place than with a code-minimum water heater. Cadmus included interactive effects in calculations wherever possible. A full accounting of these effects would best be achieved through a building simulation model, however, which was beyond the scope of this study as described below.

[1] Not verified by Cadmus. Reported in "The Watershed @ Hillsdale: Green Building Strategies & Lessons Learned on a LEED Silver mixed use, affordable senior housing project," Housing Development Center, 12/2007

Preliminary Simulation Model Analysis

Green Building Services, Inc. (GBS) developed a simulation model to estimate energy savings for the proposed design of The Watershed compared with a baseline building. The GBS model relied on efficient envelope characteristics, such as insulated concrete forms (ICF), and examined energy efficiency measures such as lower than code lighting power density, high-efficiency package terminal air conditioning units, and solar thermal pre-heating for domestic water.

However, cost considerations eliminated many of the energy efficiency measures and envelope improvements (such as the ICF construction) in the final design. The subsequent mechanical and structural redesign represented a significant alteration to the as-built building compared with the proposed design developed for the simulation model. The extent of these differences required such significant changes to the model that they would have essentially resulted in a complete remodeling. This would have required an effort well beyond the scope planned for this study. Cadmus instead relied on standard engineering calculations and secondary sources to estimate energy savings.

HVAC

HVAC measures included high efficiency heat pumps, furnaces, and HRVs for common spaces. The three heat pumps included furnaces for supplemental heating, typically required when ambient temperatures drop below 40ºF. The building's three air handling units included furnaces and sensible heat recovery ventilators.

Cadmus calculated heating and cooling savings using standard engineering algorithms that calculate the difference in energy consumption between as-built and baseline efficiency parameters (SEER, HSPF, and AFUE). These algorithms rely on variables such as unit heating or cooling capacity and equivalent full load hours and are shown in Table 3 and Table 4.

Table 3. Furnace Energy Savings Algorithm

$$Therm\ Savings = \#_{Units} \times Cap \times \left(1 - \frac{AFUE_{Eff}}{AFUE_{Base}}\right) \times \frac{1}{100{,}000} \times EFLH$$

Input Variable	Input Definition	Value	Source
$\#_{Units}$	Number of Furnaces	(1) Carrier 58MXB040 (4) Carrier 58MXB060 (1) Carrier 58MXB080	Site Visit
Cap	Unit Heating Capacity (in BTU per hour)	58MXB040: 38,000 58MXB060: 56,000 58MXB080: 75,000	www.docs.hvacpartners.com/idc/groups/public/documents/techlit/58mxb-3pd.pdf
$AFUE_{Eff}$	Annual Fuel Utilization Efficiency for installed unit	58MXB040: 94.3% 58MXB060: 93% 58MXB080: 93%	www.docs.hvacpartners.com/idc/groups/public/documents/techlit/58mxb-3pd.pdf
$AFUE_{Base}$	Annual Fuel Utilization Efficiency for code baseline	78%	Oregon Code
100,000	Unit Conversion (1 Therm = 100,000 BTU)	100,000	Unit Definition
EFLH	Equivalent Full Load Hours	58MXB040: 459 (2) 58MXB060: 459 (2) 58MXB060: 1,418 58MXB080: 1,418	Engineering calculation

Table 4. Heat Pump Energy Savings Algorithm

$$Cooling\ kWh\ Savings = \#_{Units} \times \frac{Cap_C}{1{,}000} \times \left(\frac{1}{EER_{Base}} - \frac{1}{EER_{Eff}}\right) \times EFLH_C$$

$$Heating\ kWh\ Savings = \#_{Units} \times \frac{Cap_H}{1{,}000} \times \left(\frac{1}{HSPF_{Base}} - \frac{1}{HSPF_{Eff}}\right) \times EFLH_H$$

Input Variable	Input Definition	Value	Source
$\#_{Units}$	Number of Heat Pumps	(1) Carrier 25HCA318A310 (2) Carrier 25HCA348A500	Site Visit
Cap_C	Unit Cooling Capacity (in BTU per hour)	Carrier 25HCA318A310: 22,800 Carrier 25HCA348A500: 46,000	www.gogeisel.com/geiselonline/support/Carrier/25HCA3_PDD.pdf
Cap_H	Unit Heating Capacity (in BTU per hour)	Carrier 25HCA318A310: 22,800 Carrier 25HCA348A500: 46,000	www.gogeisel.com/geiselonline/support/Carrier/25HCA3_PDD.pdf
EER_{Eff}	Energy Efficiency Ratio for installed unit	Carrier 25HCA318A310: 10.5 Carrier 25HCA348A500: 10.8	www.gogeisel.com/geiselonline/support/Carrier/25HCA3_PDD.pdf
EER_{Base}	Energy Efficiency Ratio for code baseline	11.05	Oregon Code
$HSPF_{Eff}$	Heating Seasonal Performance Factor for installed unit	Carrier 25HCA318A310: 8.5 Carrier 25HCA348A500: 8.4	www.gogeisel.com/geiselonline/support/Carrier/25HCA3_PDD.pdf
$HSPF_{Base}$	Heating Seasonal Performance Factor for code baseline	7.7	Oregon Code
1,000	Unit Conversion (1 kWh = 1,000 Wh)	1,000	Unit Definition
$EFLH_C$	Equivalent Full Load Hours for cooling	900	Engineering calculation
$EFLH_H$	Equivalent Full Load Hours for heating	959	Engineering calculation

The efficiency parameters and capacities were determined based on nameplate specifications from the manufacturer. Cadmus applied EFLH estimates developed in a previous impact evaluation[2]. These estimates were calculated from simulation modeling data and modified to reflect to Portland-specific values. For tenant spaces, Cadmus applied values based on the hotel/motel building type, which represented the closest analogue to large multi-family structures. The resulting EFLH estimates were 1,418 for heating and 900 for cooling.

Cadmus further divided heating EFLH values between heat pumps and furnaces based on TMY3 data. We analyzed the portion of the year in which temperatures dipped below 40ºF, minimizing the effectiveness of the heat pumps, and estimated the proportion of time the heat pumps would operate at full load above 40ºF. The heat pumps were expected to represent 68% of EFLH, while the efficient furnaces provided 32% of EFLH.

Finally, Cadmus estimated savings for the HRV system in the three air handlers. That savings algorithm is shown in Table 5.

[2] "2008 New Buildings Program Impact Evaluation," The Cadmus Group, 11/2/2010 <energytrust.org/library/reports/101102_NB_Iimpact_2008.pdf>

Table 5. Energy Recovery Ventilation Energy Savings Algorithm

$$kiteating\ kWh\ Savings = \#_{Units} \times \frac{Cap_H}{1{,}000} \times AFUE_{Eff} \times EFLH_H \times ESF$$

Input Variable	Input Definition	Value	Source
$\#_{Units}$	Number of Furnaces with ERVs	(2) Carrier 58MXB060 (1) Carrier 58MXB080	Site Visit
Cap_H	Unit Heating Capacity (in BTU per hour)	58MXB060: 56,000 58MXB080: 75,000	www.docs.hvacpartners.com/idc/groups/public/documents/techlit/58mxb-3pd.pdf
$AFUE_{Eff}$	Annual Fuel Utilization Efficiency for installed unit	93%	www.docs.hvacpartners.com/idc/groups/public/documents/techlit/58mxb-3pd.pdf
1,000	Unit Conversion (1 kWh = 1,000 Wh)	1,000	Unit Definition
$EFLH_H$	Equivalent Full Load Hours for heating	1,418	Engineering calculation
ESF	Energy Savings Factor for Sensible Heat Recovery	22%	Technical Reference Manual TRM) for Ohio Senate Bill 221 Energy Efficiency and Conservation Program, 10/15/2009

Water Heating

Cadmus calculated water heating savings using standard engineering calculations for efficient central boilers, faucet aerators, and low flow showerheads. The boiler savings relied on the difference in efficiency between the installed and code baseline boilers, the temperature setpoint, number of tenants, days of use, density of water, and estimates for inlet water temperature and gallons of hot water use by tenant per day. The calculation algorithm and data sources for boiler savings are shown in Table 6.

Table 6. Water Heater Energy Savings Algorithm

$$Therm\ Savings = \frac{\#_{tenants} \times 8.33 \times 1 \times Usage \times Days \times (T_{Set} - T_{In})}{100{,}000} \times \left[\left(\frac{1}{EF_{Base}}\right) - \left(\frac{1}{EF_{Eff}}\right)\right]$$

Input Variable	Input Definition	Value	Source
$\#_{tenants}$	Number of Multi-family Tenants	55	Site Visit
8.33	Conversion rate (1 gal of water = 8.33 lbs)	8.33	Unit Definition
1	Specific Heat Capacity of water (1 BTU/(°F x lbs)	1	Unit Definition
Usage	Average length of hot water use (in gallons per day per person)	20.4	Calculated from estimated total use for faucets, showerheads, and appliances for The Watershed
Days	Number of days hot water is used per year	365	Engineering Assumption
T_{set}	Water heater setpoint temperature (in °F)	135	Watershed Site Visit
T_{In}	Average water inlet temperature from water main (in °F)	51.6	For Portland, OR: Cold Water Inlet Temperatures: http://www1.eere.energy.gov/femp/pdfs/FTA_res_heat_pump.pdf
100,000	Conversion rate (1 therm = 100,000 BTU)	100,000	Unit Definition
EF_{Base}	Baseline Water Heater Efficiency	0.80	IECC 2006 Table 504.2, Minimum Performance of Water Heating Equipment
EF_{Eff}	Efficient Water Heater Efficiency	0.96	Site Visit

Faucet aerator and low flow showerhead savings calculations rely on differences in flow rate between installed and code fixtures, number of tenants, days of use, estimates of length of use, and difference between inlet and outlet temperatures. The calculation algorithms and data sources for these measure savings are shown in Table 7 and Table 8.

Table 7. Faucet Aerator Energy Savings Algorithm

$$Therm\ Savings = \frac{\#_{Units} \times 8.33 \times 1 \times Usage \times Days \times (GPM_{Base} - GPM_{Eff}) \times (T_{Out} - T_{In})}{100{,}000 \times EF}$$

Input Variable	Input Definition	Value	Source
$\#_{Units}$	Number of tenants	55	Site Visit
8.33	Conversion rate (1 gal of water = 8.33 lbs)	8.33	Unit Definition
1	Specific Heat Capacity of water (1 BTU/(°F x lbs)	1	Unit Definition
Usage	Average length of faucet use (in min per day per person)	5	http://www.focusonenergy.com/files/Document_Management_System/Evaluation/renewableenergystandardcalculationrecommendationsrevised_evaluationreport.pdf
Usage	Portion of hot water per faucet use	36%	Calculated from ratio of average temperature for faucet, inlet from main, and hot water outlet
Days	Number of days the faucet is used per year	365	Engineering Assumption
GPM_{Base}	Baseline Aerator Flow Rate (in GPM)	2.2	Federal Standard
GPM_{Eff}	Efficient Aerator Flow Rate (in GPM)	1.75	Site Visit
T_{Out}	Average water temperature from faucet (in °F)	80	Default temperature of faucets from the Vermont TRM 2009 p. 280
T_{In}	Average water inlet temperature from water main (in °F)	51.6	For Portland, OR: From Appendix D: Cold Water Inlet Temperatures: http://www1.eere.energy.gov/femp/pdfs/FTA_res_heat_pump.pdf
100,000	Conversion rate (1 therm = 100,000 BTU)	100,000	Unit Definition
EF	Water Heater Efficiency	0.96	Site Visit

Table 8. Low-Flow Showerhead Energy Savings Algorithm

$$Therm\ Savings = \frac{\#_{Units} \times 8.33 \times 1 \times Usage \times Days \times (GPM_{Base} - GPM_{Eff}) \times (T_{Out} - T_{In})}{100{,}000 \times EF}$$

Input Variable	Input Definition	Value	Source
$\#_{Units}$	Number of tenants	55	Site Visit
8.33	Conversion rate (1 gal of water = 8.33 lbs)	8.33	Unit Definition
1	Specific Heat Capacity of water (1 BTU/(°F x lbs)	1	Unit Definition
Usage	Average length of shower (in min per day per person)	8.2	Report claims average shower length is 8.2 minutes: Mayer, P. W., De Oreo, W. B., Nelson, J. O., Opitz, E., and Allen, R. (1997) North American Residential End Use Study Progress Report . American Water Works Association Research Foundation, Denver, CO.
Usage	Portion of hot water per shower	68%	Calculated from ratio of average temperature for shower, inlet from main, and hot water outlet
Days	Number of days the shower is used per year	365	Engineering Assumption
GPM_{Base}	Baseline Aerator Flow Rate (in GPM)	2.5	Federal Standard
GPM_{Eff}	Efficient Aerator Flow Rate (in GPM)	2.0	Site Visit
T_{Out}	Average water temperature from shower (in °F)	105	A BPA study measured average shower temperatures 104 - 106. http://www.focusonenergy.com/files/Document_Management_System/Evaluation/renewableenergystandardcalculationrecommendationsrevised_evaluationreport.pdf And 105 is the Default Temperature of Showers in the Vermont TRM 2009 p. 278
T_{In}	Average water inlet temperature from water main (in °F)	51.6	For Portland, OR: From Appendix D: Cold Water Inlet Temperatures: http://www1.eere.energy.gov/femp/pdfs/FTA_res_heat_pump.pdf
100,000	Conversion rate (1 therm = 100,000 BTU)	100,000	Unit Definition
EF	Water Heater Efficiency	0.96	Site Visit

ENERGY STAR Appliances

The analysis approach for the efficient appliances was relatively straightforward. Energy savings were estimated from ENERGY STAR calculators by comparing annual usage for the refrigerator, clothes washer, and dishwasher to baseline, non-ENERGY STAR appliances with the same specifications. The calculation algorithms and data sources for these measure savings are shown in Table 9 through Table 11.

Table 9. Refrigerator Energy Savings Algorithm

$$kWh\ Savings = \#_{tenants} \times [(9.80 - 7.84) \times AV + (276 - 220.8)]$$

Input Variable	Input Definition	Value	Source
$\#_{tenants}$	Number of Refrigerators	51	Site Visit (one refrigerator per apartment)
9.80	NAECA factor as of July 1, 2001	9.80	http://www.energystar.gov/ia/products/appliances/refrig/NAECA_calculation.xls
7.84	ENERGY STAR factor as of April 28,2008	7.84	http://www.energystar.gov/ia/products/appliances/refrig/NAECA_calculation.xls
AV	Adjusted Volume	15.54	Watershed Site Visit, Model # GTH16BBS
276	NAECA factor as of July 1, 2001	276.0	http://www.energystar.gov/ia/products/appliances/refrig/NAECA_calculation.xls
220.8	ENERGY STAR factor as of April 28,2008	220.8	http://www.energystar.gov/ia/products/appliances/refrig/NAECA_calculation.xls

Table 10. Dishwasher Energy Savings Algorithm

$$kWh\ Savings = \#_{Units} \times kWh_{Eff} \times \left(\frac{EF_{Eff}}{EF_{Base}} - 1\right) \times (1 - 56\%)$$

$$Therm\ Savings = \#_{Units} \times kWh_{Eff} \times \left(\frac{EF_{Eff}}{EF_{Base}} - 1\right) \times \frac{0.98}{0.96} \times \frac{3{,}412}{100{,}000} \times 56\%$$

Input Variable	Input Definition	Value	Source
$\#_{Units}$	Number of Dishwashers	51	Site Visit
kWh_{Eff}	Efficient dishwasher's annual consumption assuming electric water heating	281	Watershed Site Visit, Model #: GSM1800N
EF_{Eff}	Efficient energy factor	0.76	From ENERGY STAR database, based on model number
EF_{Base}	Baseline energy factor	0.46	Federal Standard Definition
0.98	Efficiency of electric water heater	0.98	Mid-Atlantic TRM assumption for clothes washers, assumed same electric water heater efficiency for dishwashers
0.96	Efficiency of gas water heater	0.96	Watershed Site Visit, Model # PGC3 100 199 3NV
56%	Percent of dishwasher energy used for water heating	0.56	ENERGY STAR calculator assumptions: Average, based on information from product manufacturers
3,412	Unit Conversion (1 kWh ≈ 3,412 BTU)	3,412	Approximate Unit Definition
100,000	Unit Conversion (1 Therm = 100,000 BTU)	100,000	Unit Definition

Table 11. Clothes Washer Energy Savings Algorithm

$$Clothes\ Washer\ Savings = 7\% \times \left[\left(\frac{1}{MEF_{Base}}\right) - \left(\frac{1}{MEF_{Eff}}\right)\right] \times Volume \times \frac{Cycles}{\#_{Unit}}$$

$$DHW\ Therm\ Savings = 26\% \times \left[\left(\frac{1}{MEF_{Base}}\right) - \left(\frac{1}{MEF_{Eff}}\right)\right] \times Volume \times \frac{Cycles}{\#_{Unit}} \times \frac{0.98}{0.96} \times \frac{3{,}412}{100{,}000}$$

Input Variable	Input Definition	Value	Source
67%	Percent of consumption for dryer	0.67	Mid-Atlantic TRM assumption: The Clothes Washer Technical Support Document, located at: http://www.eere.energy.gov/buildings/appliance_standards/residential/clwash_0900_r.html Energy and water savings estimates are located in Chapter 4, Engineering Analysis, Table 4.1,Page 4-5 http://www.eere.energy.gov/buildings/appliance_standards/residential/pdfs/chapter_4_engineering.pdf
7%	Percent of consumption for clothes washer	0.07	
26%	Percent of consumption for water heater	0.26	
MEF_{Base}	Baseline modified energy factor	1.26	Federal Standard
MEF_{Eff}	Efficient modified energy factor	#1 = 1.50 #2 = 2.16	Watershed Site Visit Two Model #1:SWTT21WN One Model #2:SWRT71WN
Volume	Volume of clothes washer (in cubic feet)	#1 = 2.69 #2 = 2.84	Watershed Site Visit Two Model #1:SWTT21WN One Model #2:SWRT71WN
Cycles	Number of cycles or loads per year per multifamily building	2,600	Watershed Site Visit, Site manager estimated 50 loads of laundry per week
$\#_{Unit}$	Number of clothes washers or dryers	3	Watershed Site Visit
0.98	Efficiency of electric water heater	0.98	Mid-Atlantic TRM assumption
0.96	Efficiency of gas water heater	0.96	Watershed Site Visit, Model # PGC3 100 199 3NV
3,412	Unit Conversion (1 kWh ≈ 3,412 BTU)	3,412	Approximate Unit Definition
100,000	Unit Conversion (1 Therm = 100,000 BTU)	100,000	Unit Definition

Windows

HVAC energy savings due to efficient windows rely on a variety of interactive factors such as building envelope, HVAC unit types, and operating characteristics, which are most effectively analyzed through a building simulation model. As noted, The Watershed simulation model required significant adjustment outside the scope of this evaluation. Therefore, Cadmus estimated efficient window savings by adapting results from prototypical simulation models developed for analysis in areas of the Pacific Northwest with approximately similar building codes and climate.

We analyzed savings based on the three space types represented at The Watershed - office, tenant, and multi-family common area. Cadmus first determined the total size allocated to each

space type, as shown in Table 12. The multi-family tenant space most closely approximated results for the Hotel/Motel space type used in the prototypical models.

Table 12. HVAC Energy Savings Parameters For Efficient Windows

Space Type	HVAC Type	Floor Area (sf)	End Use Savings (U=0.4 to U=0.35)	End Use EUI (kBtu/SF)	Base Energy Savings (MBtu)	Adjusted Energy Savings (MBtu)
Office	Heat Pump	1,300	1.6%	4.8	0.1	0.1
Common	Heat Pump	8,970	2.9%	7.3	1.9	1.8
Common	Gas Furnace	7,955	2.9%	7.3	1.7	1.6
Tenant	Electric Baseboard	32,975	5.5%	8.8	16.1	15.2

Cadmus interpolated the prototypical model saving results per space type based on differences between modeled and actual baseline and installed window U-values to determine the HVAC end use energy savings. The prototypical models provided values for energy use intensity (EUI) for the relevant HVAC type. Electric baseboard heating is significantly less efficient than other heating sources, which resulted in both higher EUI and higher resulting end use savings due to more efficient windows. We calculated the base energy savings by multiplying the space area by the end use savings and end use EUI.

Finally, Cadmus adjusted base energy savings to Portland-specific values based on the ratio of heating degree days from the location where the prototypical design was modeled. We neglected the cooling degree day conversion because it was determined to have a minimal impact on heat pump savings due to relatively cool climate conditions and small area served by heat pumps.

Lighting

New construction projects can achieve significant savings by installing lighting at a power density below that required by code. The reduced lighting power density was not originally considered as a GIF measure, and was not analyzed during Cadmus' site visit. Cadmus determined the savings value of 14,994 kWh per year reported in a presentation by Housing Development Center[3] appeared reasonable based on site visit observations of lighting fixture types and quantities.

Baseline and As-Built Consumption Data

After the renters occupied their apartments for one at least one year, a year's worth of utility billing data was requested. Electric, gas, and water billing data for 2009 and 2010 were collected from over 90% of the units, and the two commercial spaces. The energy billing data were

[3] "The Watershed @ Hillsdale: Green Building Strategies & Lessons Learned on a LEED Silver mixed use, affordable senior housing project," Housing Development Center, December 2007

extrapolated to the full building and represented as-built consumption of 381,644 kWh and 5,787 therms, equivalent to a total of 1,881 MMBtu.

There was no baseline consumption measurement since the project involved new construction. Cadmus assumed the baseline consumption data could be represented as the sum of as-built consumption data and the overall energy savings.

Results

Based on verification of the measures installed and the engineering calculations we conducted, the estimated savings from the various energy-efficiency measures are shown in Table 13. Water heating measures represented the largest amount of savings, followed by HVAC measures. Reduced lighting power density, ENERGY STAR appliances, low flow water fixtures, and efficient windows produced smaller, but still significant savings.

Table 13. Energy Savings by Measure

Measure	Electric Savings (kWh)	Gas Savings (therms)	Energy Savings (MMBtu)
Water Heater	0	659	66
Furnace/HP	1,320	541	59
Heat Recovery Ventilation	0	543	54
ENERGY STAR Appliances	9,779	198	53
Lighting	14,994	0	51
Low Flow Showerhead	0	328	33
Windows	5,009	16	19
Faucet Aerator	0	116	12
Total	31,103	2,400	346

The combined savings of all installed appliances and measures is 31,103 kWh and 2,400 therms, equal to 346 MMBtu combined end-use energy savings. The standard code baseline building (using the sum of actual energy use and energy savings) would be expected to use 412,747 kWh and 8,187 therms annually, equal to 2,227 MMBtu. Therefore, the energy savings in the efficient as-built building result in a 16% reduction in annual energy usage.

Water M&V

Project and Counterfactual Characteristics

The evaluation team reviewed all the water-using fixtures and appliances in the apartments to determine which ones exceeded the efficiency requirements of applicable standards or standard practice. All the fixtures and two appliances were more water-efficient than required by the standards. Table 14 shows the water-efficient fixtures and appliances, along with the efficiency requirement of the standards and the actual rated efficiency of the fixture or appliance.

Table 14. Efficiency of Water-Using Equipment

Equipment	Water Efficiency Standard	Actual Water Efficiency
Faucet aerators	2.2 gpm	1.75 gpm
Low-flow showerheads	2.5 gpm	2.0 gpm
Caroma dual-flush toilets	1.6 gpm	0.8 / 1.6 gpm
GE ENERGY STAR dishwashers	13 gallons per cycle	5.8 gallons per cycle
Speed Queen ENERGY STAR clothes washers (3)	25.6 gallons per cycle	14.8 and 23.7 gallons per cycle (two different models)
Efficient landscape irrigation with control system	522 gallons per week	87 gallons per week

Analysis Approach

For most measures, the analysis approach was relatively straightforward and relied primarily on usage data combined with code versus as-built efficiency comparisons. The team contacted the facility manager to obtain an estimate of the average number of clothes washer and dishwasher loads per week. Faucet aerator and low flow showerhead usage relied on the same sources noted in the Energy M&V chapter. Dual-flush toilet savings relied on self-reported data obtained in previous multi-family projects analyzed for the GIF evaluation. Irrigation savings relied on calculations submitted by the landscape contractor.

The team obtained the standard requirements for each water saving measure. Water savings for the dual-flush toilet were estimated by multiplying the number of low-volume flushes per year times the difference in water usage of the low-volume and standard-volume flushes. Faucet aerator and low flow showerhead savings calculations relied on differences in flow rates between installed and code fixtures, number of tenants, days of use, and estimates of length of use. Water savings for appliances were estimated by multiplying the number of cycles per year times the difference in the water usage of the installed unit and a unit just meeting the standard. The algorithms and data sources are noted in Table 15 through Table 19.

Table 15. Dual Flush Toilet Water Savings Algorithm

$$Water\ Savings\ (in\ Gallons) = \#_{Units} \times Usage \times Days \times (GPF_{Base} - GPF_{Eff})$$

Input Variable	Input Definition	Value	Source
$\#_{Units}$	Number of tenants	55	Site Visit
Usage	Average number of low-volume flushes per week	30	Average of self-reported data from multi-family M&V analysis performed on other GIF projects
Days	Number of weeks the toilet is used per year	52	Engineering Assumption
GPF_{Base}	Baseline Flush (in gallons per flush (GPF))	1.6	Federal Standard
GPF_{Eff}	Efficient Flush (in GPF)	0.8	Site Visit

Table 16. Faucet Aerator Water Savings Algorithm

$$Water\ Savings\ (in\ Gallons) = \#_{Units} \times Usage \times Days \times (GPM_{Base} - GPM_{Eff})$$

Input Variable	Input Definition	Value	Source
$\#_{Units}$	Number of tenants	55	Site Visit
Usage	Average length of faucet use (in min per day per person)	5	http://www.focusonenergy.com/files/Document_Management_System/Evaluation/renewableenergystandardcalculationrecommendationsrevised_evaluationreport.pdf
Days	Number of days the faucet is used per year	365	Engineering Assumption
GPM_{Base}	Baseline Aerator Flow Rate (in GPM)	2.2	Federal Standard
GPM_{Eff}	Efficient Aerator Flow Rate (in GPM)	1.75	Site Visit

Table 17. Low-Flow Showerhead Water Savings Algorithm

$$Water\ Savings\ (in\ Gallons) = \#_{Units} \times Usage \times Days \times (GPM_{Base} - GPM_{Eff})$$

Input Variable	Input Definition	Value	Source
$\#_{Units}$	Number of tenants	55	Site Visit
Usage	Average length of shower (in min per day per person)	8.2	Report claims average shower length is 8.2 minutes: Mayer, P. W., De Oreo, W. B., Nelson, J. O., Opitz, E., and Allen, R. (1997) North American Residential End Use Study Progress Report . American Water Works Association Research Foundation, Denver, CO.
Days	Number of days the shower is used per year	365	Engineering Assumption
GPM_{Base}	Baseline Aerator Flow Rate (in GPM)	2.5	Federal Standard
GPM_{Eff}	Efficient Aerator Flow Rate (in GPM)	2.0	Site Visit

Table 18. Clothes Washer Water Savings Algorithm

$$Water\ Savings\ (in\ Gallons) = (WF_{Base} - WF_{Eff}) \times Volume \times \frac{Cycles}{\#_{Unit}}$$

Input Variable	Input Definition	Value	Source
WF_{Base}	Baseline water factor	9.5	Federal Standard
WF_{Eff}	Efficient water factor	#1 = 8.8 #2 = 5.2	Watershed Site Visit Two Model #1:SWTT21WN One Model #2:SWRT71WN
Volume	Volume of clothes washer (in cubic feet)	#1 = 2.69 #2 = 2.84	Watershed Site Visit Two Model #1:SWTT21WN One Model #2:SWRT71WN
Cycles	Number of cycles or loads per year per multifamily building	2,600	Watershed Site Visit, Site manager estimated 50 loads of laundry per week
$\#_{Unit}$	Number of clothes washers	3	Watershed Site Visit

Table 19. Dishwasher Water Savings Algorithm

$$Water\ Savings\ (in\ Gallons) = \#_{Units} \times (WF_{Base} - WF_{Eff}) \times Cycles$$

Input Variable	Input Definition	Value	Source
$\#_{Units}$	Number of Dishwashers	51	Site Visit
WF_{Eff}	Efficient water factor	5.8	From ENERGY STAR database, based on model number
WF_{Base}	Baseline water factor	13	Based on average from FEMP Domestic Water Conservation Technologies: http://www1.eere.energy.gov/femp/pdfs/22799.pdf
Cycles	Average number of cycles per year	215	ENERGY STAR calculator assumptions

The water efficient irrigation system combines spray, rotor, micro, and drip irrigation heads, managed through a water efficient controller, to achieve an 83% reduction in water usage over a conventional spray head design. There is no applicable irrigation standard or code, so Cadmus relied on standard practice as identified by the landscape contractor. The landscape contractor provided calculations to estimate water savings. He first determined areas for distinct landscape segments targeted for irrigation, as well as the irrigation run time at a standard spray level of 18 gallons per minute, as shown in Table 20. He then provided data that noted the specific as-built irrigation strategy for each landscape segment and the associated gallons per week required, as shown in Table 21. The irrigation savings were expected to occur over a 21-week period from May to September.

Table 20. Standard Landscape Irrigation Parameters

	Spray Area (sf)	Run time (minutes per day)	Gallons per week
Rain Garden	1,145	7	126
Bed Area	7,571	7	126
Rough Seed	5,602	15	270
Total	14,318	29	522

Table 21. As-Built Landscape Irrigation Parameters

	Total Area (sf)	Rotor Head Area (sf)	Micro Spray Area (sf)	Drip Area (sf)	Run time (minutes per day)	Gallons per week
Rain Garden	1,145		1,145		5	7.6
Bed area	7,571			7,571	10	0.6
Rough seed	5,602	5,602			7	78.4
Total	14,318	5,602	1,145	7,571		86.6

Results

The billing history for The Watershed shows an annual usage of 968,660 gallons per year. As with the energy savings, there was no baseline consumption measurement since the project involved new construction. Cadmus assumed the baseline consumption data could be represented as the sum of as-built consumption data and the overall water savings.

The estimated water savings from use of the efficient fixtures, systems, and appliances are shown in Table 22. Water savings ranged from 9,143 to 82,308 gallons per year by measure. Overall savings were estimated at 214,156 gallons per year, or 587 gal/day. Based on the billing consumption data, the baseline consumption was estimated at 1,182,816 gallons per year. The overall water savings were therefore determined to be 24% of the baseline.

For comparison, the average Portland single-family resident uses 64 gallons per day per occupant[4], including outdoor applications such as irrigation. There were 55 tenants at The Watershed, indicating an estimated use of 1,284,800 gallons per year by applying the average Portland data. However, the outdoor water use for a multi-family tenant should be slightly less than that for a single family resident due lower irrigated square footage per person, as reflected in the calculated baseline The Watershed usage of 1,266,715 gallons per year (63 gallons per day per tenant). This value is within 2% of the estimated consumption based on average Portland residential usage, and indicates the calculated results are reasonable.

[4] Email from Jeff Sandberg, City of Portland Water Bureau, 4/29/09

Table 22. Water Savings Results

Fixture / Appliance	Weekly Usage per tenant	Annual Water Savings (gal/year)	Total Water Savings (gal/year)	Baseline Building Water Use (gal/year)	Savings, % of Baseline Water Use
Low Flow Showerhead	57 minutes	82,308	298,055	1,266,715	24%
GE dishwasher	~4 load	78,948			
Dual Flush Toilet	30 flushes	68,640			
Faucet Aerator	70 minutes	45,169			
Speed Queen clothes washer	~1 load	13,848			
Efficient Irrigation	Varies by season	9,143			

Stormwater M&V

Introduction and Purpose

The designers of The Watershed initially planned to integrate several innovative stormwater features into the project, including onsite infiltration and stormwater harvesting. However, site constraints limited the options available. For example, the site was a previous brownfield site (ODEQ Site ID 3158) with soils and groundwater containing petroleum products, perchloroethylene (PCE) and its degradation products, heavy metals, and pesticides. Over 2,300 tons of contaminated soil were excavated from the site and the groundwater plume was found to be stable (ECSI Database, 2010). However, because of the danger of potential contaminant migration, and because of the high groundwater table, infiltration was not a feasible option for stormwater disposal. In addition, a geotechnical investigation in January 2006 revealed that the soils were susceptible to liquefaction during seismic events due to poor load-bearing characteristics and the high water table (HDC, 2006). These conditions were a significant structural concern to the design team with regard to the rainwater harvesting tank. Consequently, the team abandoned this stormwater feature in favor of more aggressive water-saving measures elsewhere in the project.

With limited ability to reduce runoff volumes through infiltration or rainwater harvesting, the team resorted to the use of stormwater management features that primarily function to reduce peak flows and improve the quality of stormwater runoff. Incidental volume reductions associated with soil moisture storage and evapotranspiration are often seen from these stormwater features. The following sections describe these features, summarize their design and implementation, and summarize conclusions regarding the overall stormwater system performance.

Stormwater Features

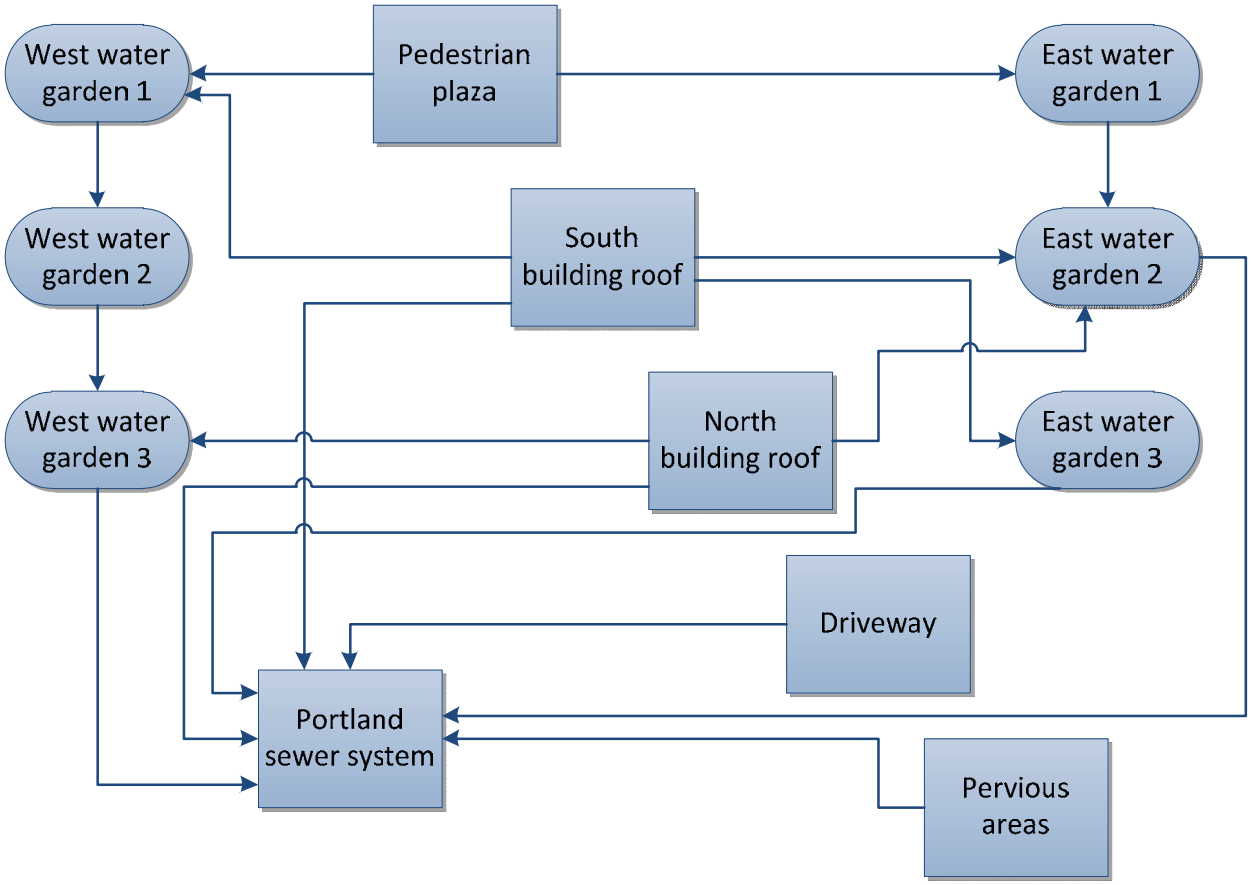
The Watershed is located on the divide of Fanno Creek and Stephens Creek watersheds. To maintain the existing drainage areas of these watersheds, runoff from the site is split and separately routed to the different storm drain systems that feed each creek.

A diagram of the stormwater flow routing at the site is shown below in Figure 4. The Watershed includes two systems of water gardens that receive runoff from the roofs of the two buildings and the pedestrian plaza. The eastern water gardens are located along the east side of the building and run approximately north to south along Bertha Court. The western water gardens are located on the west side of the buildings and include a series of three cascading landscaped planter boxes that drain approximately east to west. In addition to the water gardens, there is perimeter landscaping around the north, west, and south edges of the property. Both of the water gardens and the other landscaped features were designed to reduce peak flows and improve water quality of stormwater runoff leaving the site.

Stormwater runoff from the pedestrian plaza is divided between east water garden 1 and west water garden 1. The north building has 3 roof drains that lead to east water garden 2, west water garden 3 and directly to the storm sewer system. The south building has four roof drains, which

lead to west water garden 1, east water garden 2, east water garden 3, and directly to the storm sewer system.

Figure 4. Diagram of Stormwater Flow



Site Inspection

The initial site inspection occurred in January 2008. At that time, the vegetation in the water gardens had not yet been established and standing water was present even though no rain had occurred in the past couple of days (see Figure 5 below). The cause of the standing water was not known, but no standing water was observed during another site visit that occurred in December 2010 (see Figure 6 and Figure 7), despite a significant amount of rainfall over the previous 24 hours. Personal communications with the architectural firm Vigil Agrimis and retrofit drawings provided by them revealed that, due to severe drainage problems in the gardens (standing water for over a week), gravel-filled vertical perforated pipes (3”-4” diameter) were installed at various locations to provide a direct flow path from the surface to the gravel drainage layer below. While these inexpensive retrofits appear effective at eliminating standing water and, therefore, reducing the potential to breed mosquitoes, the media bed is now largely being bypassed, which greatly reduces its treatment effectiveness both in terms of pollutants captured and stormwater retained.

Figure 5.Photos of Western Water Gardens (left) and Eastern Water Garden Two (right) in January 2008

Figure 6. Photos of the West Water Gardens in December 2010.

During the December 2010 site visit the vegetation was well established in both water gardens as well as in the much of the perimeter landscaping. On the eastern side of the building, vegetation was well established and effectively minimizing erosion, but on the north side of the building (see Figure 8), large plants were doing well, but groundcover was non-existent. Noticeable channeling from erosion was present.

Figure 7. Photos of Eastern Water Gardens 2 (left) and 3 (right) in December 2010

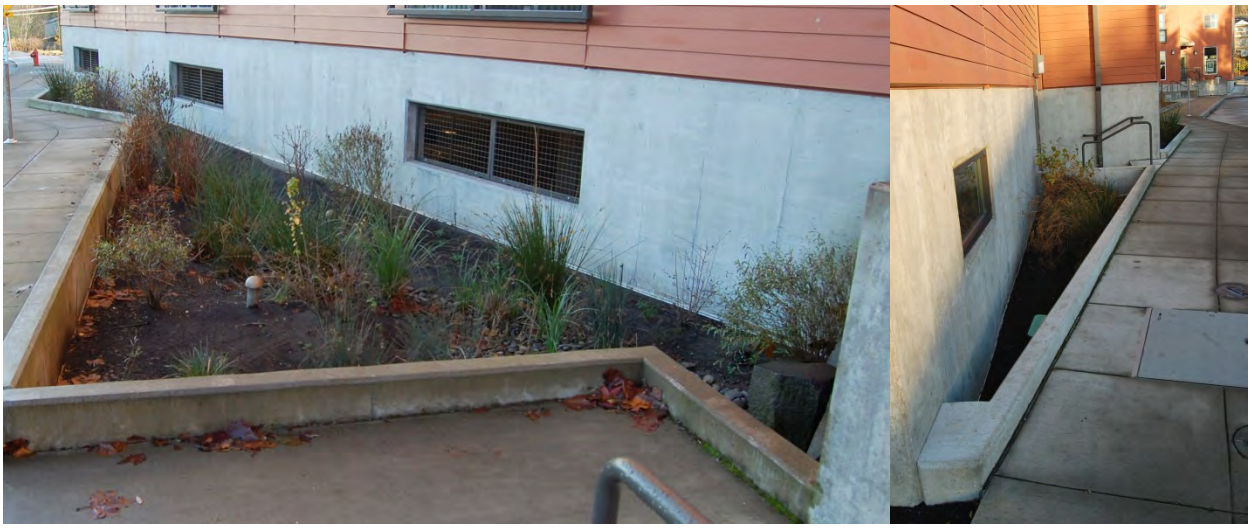


Figure 8. Photos of Vegetation on the Eastern (left) and Northern (right) Sides of the Site

System Performance Assessment

Due to the problems implementing infiltration BMPs and a rainwater harvesting tank at the site as discussed above, The Watershed's stormwater components consists of two systems of rain gardens that process much, although not all, of the site's runoff (see Figure 4) prior to discharging to the City of Portland's separate storm sewer system. Unfortunately, based on the required retrofit it is highly doubtful that the rain gardens are functioning as originally intended. The most likely cause of previous drainage problems is that soils of very low permeability (i.e., silts/clays) were used in the media beds. Although underdrain blockage could also cause these problems, a vertically placed perforated pipe filled with gravel would not be expected to fix blockage problems. If poor soil in the rain gardens was indeed the cause of the previous

drainage problems, then the perforated pipe would primarily serve as a preferential pathway, allowing little, if any, of the water to pass through the media bed.

Infiltration of water through the media bed is the primary mechanism by which rain gardens with underdrains provide volume, peak flow, and pollutant concentration reduction benefits. Volume reductions are achieved by water retention within the media bed and peak flow reductions are achieved by delaying and reducing the rate of discharge. In addition, the soil acts as a filter and adsorptive medium to reduce the concentration of pollutants such as sediment, metals, and organic compounds. The preferential flow path provided by the vertical drain pipes reduces the contact between the stormwater and the media bed thereby reducing their effectiveness. However, these facilities are still likely providing some benefits. Temporary ponding on the surface of the rain gardens is expected to provide some peak flow reduction and incidental volume losses would be expected as surface soils absorb the temporarily ponded water. Also, as the vegetation becomes more established the stems and roots will open up the soils and allow for a larger quantity of water to infiltrate through the media beds.

Unfortunately, there is no way to reasonably quantify the effectiveness of the retrofitted rain gardens. The number and locations of vertical perforated pipes installed as part of the retrofit is unknown and there is no way to estimate the drawdown rate of each rain garden. Also, the underdrain pipe has a diameter of 6-inches, so it is unlikely this pipe will restrict flow enough to behave like an orifice and cause any significant detention in the system. In addition, the drainage areas of each roof drain are highly uncertain. Finally, given the impervious surfaces that contribute runoff to the rain gardens (building roofs and the plaza) the concentrations of typical urban pollutants (i.e., sediment, metals, nutrients, bacteria, and organic compounds) are likely very low. Any pollutants that are detectable in runoff are probably in a highly dissolved state rather than particulate-bound. Dissolved constituents are not as readily removed, particularly if contact with the media bed is minimal. Therefore, it is unlikely that significant pollutant reductions occur, but they also may not be needed. If these facilities received runoff from the street, then much higher pollutant concentrations and concentration reductions would be expected.

Cost of Stormwater Component Maintenance/Replacement

The primary recurring cost associated with the stormwater system at The Watershed is landscape maintenance. While the actual costs are currently unknown, the 2010 Oregon prevailing wage rate, including fringe benefits, for a landscape laborer in Multnomah County is approximately $19 per hour (Oregon BOLI, 2010). Assuming two hours are needed, on average, per week to maintain the site landscaping, the annual maintenance costs for this site would be approximately $2000 per year. No other major maintenance costs are expected for the stormwater components at this site.

Conclusions

Due to challenging site conditions, all of the stormwater components originally planned for the project, including a large cistern and infiltrating planter boxes, could not be implemented. Instead, rain gardens with underdrains (a.k.a. flow-through planter boxes), were installed to meet the stormwater management goals of the GIF. However, based on the above discussion and

given the perforated pipe retrofit of the gardens, it is unlikely that significant volume reductions or water quality benefits are being achieved by the rain gardens. Some peak flow and volume reductions are likely occurring, but this benefit cannot be quantified without conducting field tests to determine how quickly the rain gardens drain and how much water they retain. As the vegetation in these systems becomes more established, the performance is likely to improve over time as plant stems and roots penetrate, aerate, and break up the soil to allow for greater stormwater contact with the planting media. Until then, most of the stormwater that enters these rain gardens is expected to short-circuit the media bed by preferentially flowing to the vertical perforated pipes. One potential retrofit option to improve the performance of these systems without complete media replacement would be to install an outlet control that would restrict the outflow rate.

References

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Construction and Demolition Waste

Starting with GIF projects funded in 2006, awardees were required to submit to Cadmus the material description, weight, and disposal or recycling receipts for all C&D waste. This project was funded in 2005, and therefore, this requirement did not apply. However, the project reported recycling 98% of construction waste.