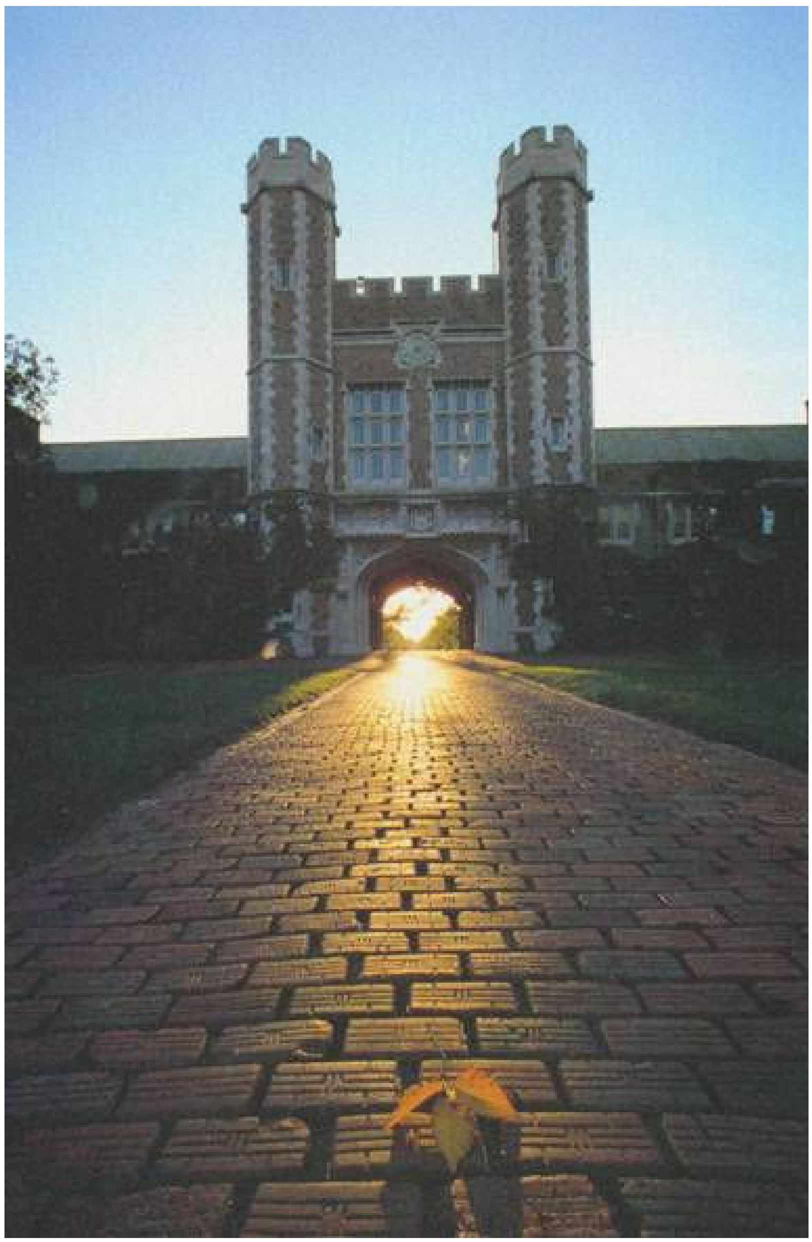
Sustainability at Washington University in St. Louis



Sustainability at Washington University in St. Louis

Prepared by Tara Fridhandler
Independent Study, Summer 2006
Advisor- Michael Repovich

A summary of an ecological footprint for Washington University Brookings Hall: a case study for campus-wide sustainability

All life is interrelated. All [of us] are caught in an inescapable network of mutuality, tied in a single garment of destiny. Whatever affects one directly affects all indirectly[1]

- Martin Luther King Jr.

methodology

This project proposes a methodology for evaluating and implementing building-scale sustainability at the Danforth Campus of Washington University in St Louis.

The study focuses on Brookings Hall which is both an icon for academic prestige and a microcosm of the university building typology. Evaluating various environmental issues determines the basic ecological footprint of the building's impact through:

-Energy Use
-Day-Lighting
-Waste Flows
-Water Consumption
-Landscape Strategy

The ecological footprint for Brookings is defined as the "land area necessary to sustain current levels of resource consumption and waste discharge[1]" both by the building and its occupants. Each of these categories is an excellent lens through which to focus a plan for short-term and long-term goals for the University.

By creating a methodology for evaluating Brookings, we generate a case-study that can be applied to any existing campus building. The Brookings case study is an example of how to investigate energy- and financial-saving benefits as well as propose new technologies and treatments for the built and natural landscape. The hope is that this study will be a useful tool in creating a healthier community and a more sustainable campus.

The Matrix
Evaluating campus infrastructure

	Energy	Sun/Lighting	Waste	Water	Landscape
Cost	Heating/cooling costs of the building per year	Relative cost of fixtures and electricity	Cost to landfill vs. cost of reuse vs. cost to recycle	Amount paid to use water as well as discharge it	Maintenance, watering cost relative to human use
Energy Use	Therms and kWh/ Emissions/ labor	kWh/emissions/ labor	Lifecycle losses and gains/ labor	Gallons/ labor	Gallons/ emissions/ labor/ etc
Human Comfort Surveying [a sample]	-Interior comfort levels -Thermostat locale -Window operation -Drafts	-Eye strain -Who controls? -Glare -Access to sunlight -Even light throughout day?	-Recycling visibility/ease -Policy? -Familiarity with policy -Reuse efforts? -Access to green products	-Education in water saving -Alternatives to using water -Watering amounts and when	-Which spaces effective/not? -What activities happen there? -Who is drawn there? -Enough variety?
Symbolism for the University	-Community leader in reducing emissions -Fostering renewable energy solutions	-More productive/ inspiring spaces -Campus wide comfort -Reduce energy use	-A solution in the process, not a contributor to waste -Visible recycling efforts	-Huge water savings -Community example -Decreased stress on city infrastructure	-Use of outdoor space -Thriving campus community -Managed sustainably
Information Gathering	-How is energy purchased? -How do systems work? -Heating and cooling loads -What is realistic?	-Energy source -Building orientation -Solar gains -Use of existing lighting	-Existing program's success and failures -Purchasing policy and product access	-Where and how much watering? -Types of planting -Sustainability of current methods	-Analyze human use -Existing biodiversity -Benefits and problems with space
Strategies and Solutions	-Wind/Solar Energy -Building Efficiency -Passive Systems	-Renewable energy Sources -Effective interior fixtures -Day lighting Strategies	-Recycling -Green Purchasing Program -Reuse Policy	-Storage Cisterns -Bioswales -Native Plants -Xeriscapes	-Size variety -Micro-habitats -Multi-use -Seasonal and Yearly

energy

The law of conservation of energy tells us we can't get something for nothing, but we refuse to believe it[1]
- Isaac Asimov

To many, the issue of energy-use is the most pertinent to the environmental movement. We no longer believe that our energy consumption has zero consequences. With projections of an energy crises occurring within a generation, acting now to decrease fossil fuel emissions as well as employing renewable energy sources is an important goal. Buildings currently consume 40% of the nation's energy[2] and as a result put a huge strain on the environment. For a university with large infrastructure it is essential to re-evaluate how the campus uses energy. Washington University runs on natural gas and electricity both of which contain and or use fossil fuels that contribute to the school's oversized environmental footprint as well as operating budget.

Decreasing the University's energy needs is a realistic and crucial goal. Shifting to more renewable sources of power and retrofitting existing buildings are realistic ways to become more sustainable. Besides huge financial benefits, the University plays a part in helping to promote green energy, save natural resources and create a healthier community at large. Reducing energy helps to secure a viable future for the University as well as set an important example for the city, other universities, and the country.

HVAC Systems & Human Comfort

The facts

In the 2004-2005 fiscal year, the University spent just under $100,000[3] [see appendix A] to heat and cool Brookings Hall. The heating, ventilation, and air conditioning systems (HVAC) have been added to and renovated over the years. This results in an amalgamation of different strategies that each require their own conditions for running [Fig. C]. This means interior air quality and temperature vary greatly within the building envelope and among offices. In addition, thermostats were not installed in each room leaving some occupants too cold and others too warm throughout the year [Fig. A]. One sensor cannot effectively react to the conditions across multiple spaces. As with any building, human density is not uniform either [Fig. D]. With differing numbers of people,[4] computers and other appliances in each department, the internal heat loads vary greatly adding to the complex micro-climates within Brookings.

What can be done?

The first important retrofit proposed for Brookings requires thermostats in each continuous space [Fig. B]. This creates more efficiently conditioned offices and more importantly; occupant comfort is established which allows staff to be more productive throughout the workday and places less strain on maintenance crews which do not have to come in and adjust systems.

When the time comes for additional renovations to Brookings, the HVAC systems can be remodeled in a more uniform way. Currently, steam heat, forced air, and radiant heat are just some of the systems built into Brookings.[5] [Fig. B] These vary by floor but also by department. A universal system makes it easier to use, fix and keep the building at desired temperatures. Instead of having some areas of the building constantly running energy and others shutting on and off, a comprehensive system is more efficient both environmentally as well as economically.

at a glance...

Thermostat Placement

one thermostat for a series of offices

poor distribution of air

gradient of hot and cold rooms

= uncomfortable climate & decreased productivity

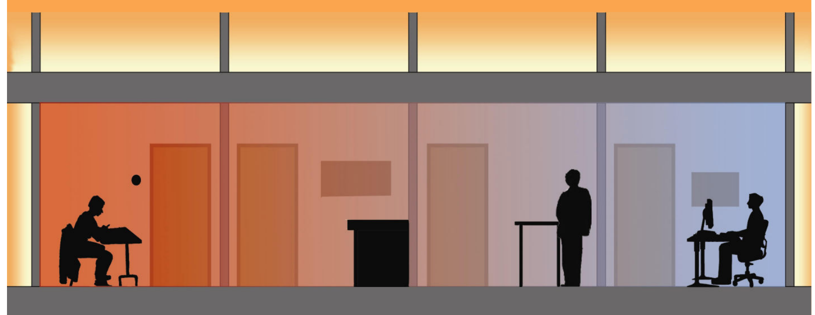


Figure A

Heating Systems in Brookings

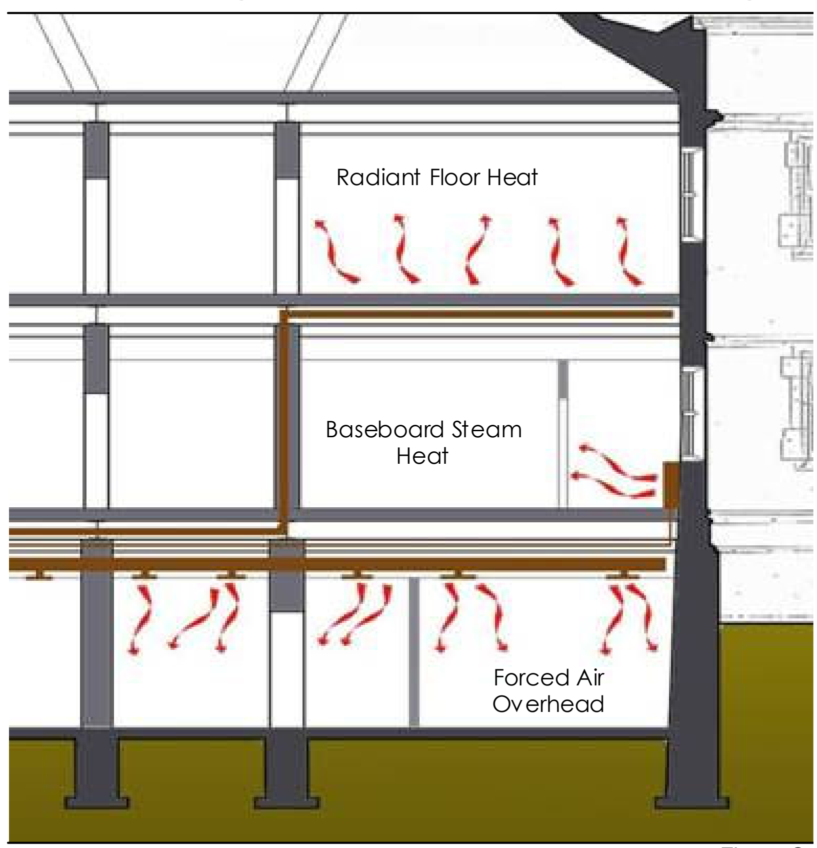


Figure C

one thermostat for a each office

desired distribution of air

each room sets its own temperature

= comfortable climate & increased productivity

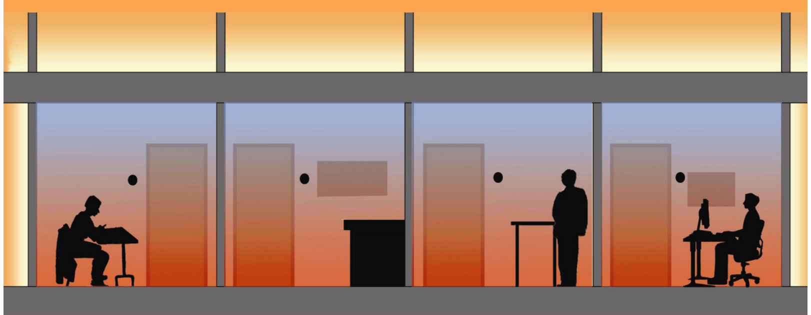
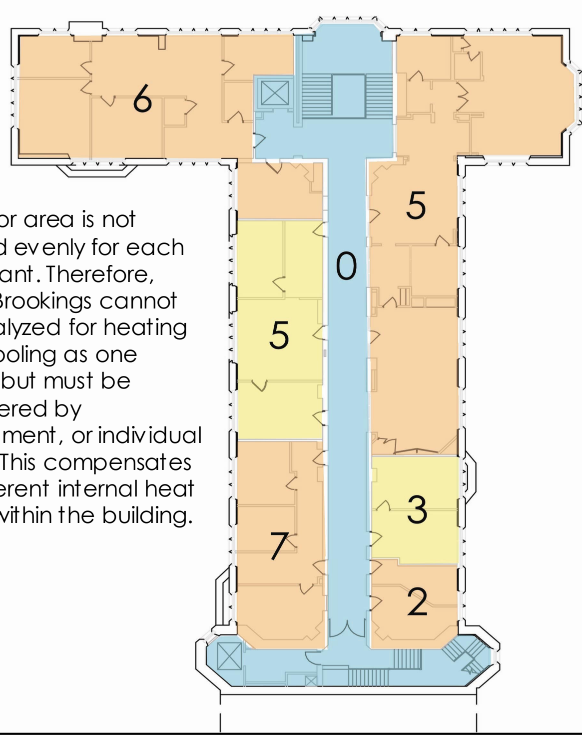


Figure B

Occupancy of 2nd floor North Brookings by department



The floor area is not divided evenly for each occupant. Therefore, North Brookings cannot be analyzed for heating and cooling as one space but must be considered by department, or individual office. This compensates for different internal heat loads within the building.

Figure D

It is important to consider that Brookings is among the oldest buildings on campus and therefore has undergone many renovations in its lifetime. As a result, evaluating its interior heating and cooling systems is much more complicated than a more recent structure. Either way, it would be important during any renovation to look at the possibilities for making HVAC systems more efficient and more sustainable.

The result

At this point, it is impossible to estimate the exact benefits of revising indoor air systems. Both internal and external heat loads affect the temperature inside Brookings as well as impact each unique heating/cooling system creating many micro-climates within the building that are hard to evaluate. Despite these measurement challenges, it is clear that occupant satisfaction and building efficiency can be greatly enhanced. Timing the changes with other projects reduces costs and makes them more viable.

Human comfort is as much a part of sustainability as energy efficiency.

Currently, maintenance crews get called in unnecessarily for HVAC issues inherent in their designs. With properly working systems these issues are resolved and staff have the advantage of working in an environment in which heating and cooling are both out of sight as well as out of mind.

Energy Production

The facts

Brookings Hall is heated and cooled in a variety of ways. Different systems are supported by two basic power sources. During the winter, steam is channeled to the building from a plant at the north end of campus which runs on natural gas. In the summer, electricity is purchased to chill water that is piped directly to the building. Due to rising energy costs and a hodgepodge of existing HVAC techniques, Brookings Hall's ecological footprint can be reduced by a variety of sustainable heating and cooling techniques.

What can be done?

There are many ways to reduce the heating and cooling needs of Brookings Hall. Each method can be tailored specifically to the building and requires much more research, energy audits, and so forth to determine the best strategies. A basic overview of some potential strategies are meant to provide a vision of a possible future Brookings Hall.

Interventions can be made at various points in the heating/cooling process. A basic approach is to modify the fresh air intake for the building. A system of earth-air cooling tubes can be installed in shallow trenches, (a few feet underground) [Fig. F]. This takes advantage of the relatively constant temperature of the earth which ranges from 50 to 60 degrees Fahrenheit. Fresh air is passed through the maze of tubing and during that time is tempered to the ground temperature. Once the air reaches the building, interior temperatures need less adjustments to reach human comfort levels. By having the intake area further away from the building and closer to green spaces the air quality is increased as well.

at a glance...

Yearly heating needs for Brookings[6]

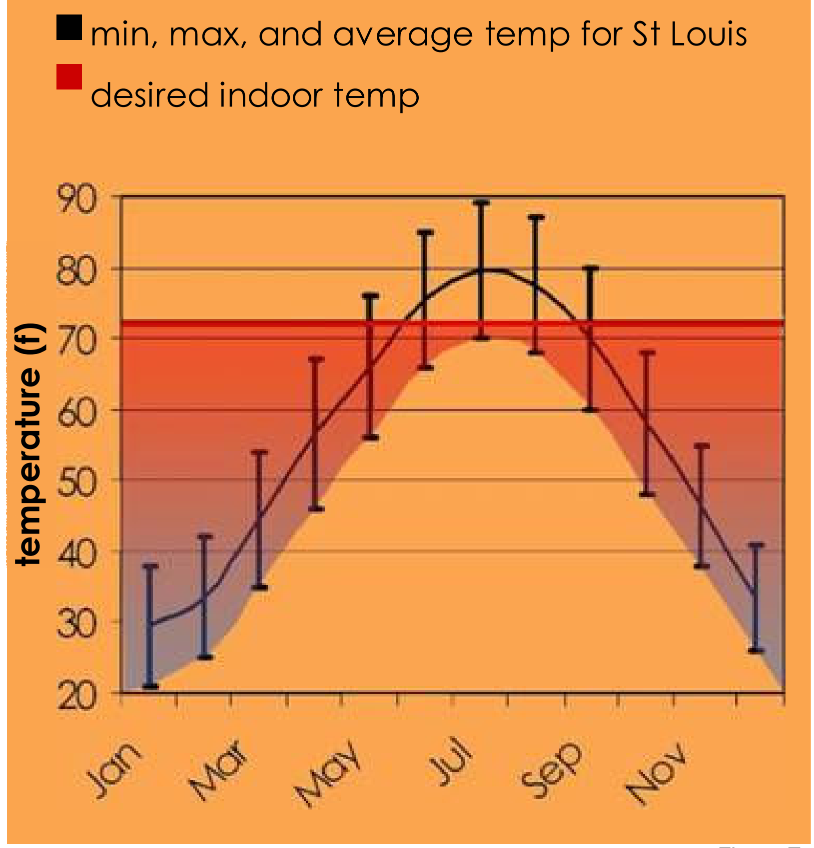


Figure E

Winter diagram of earth-air heat exchange system

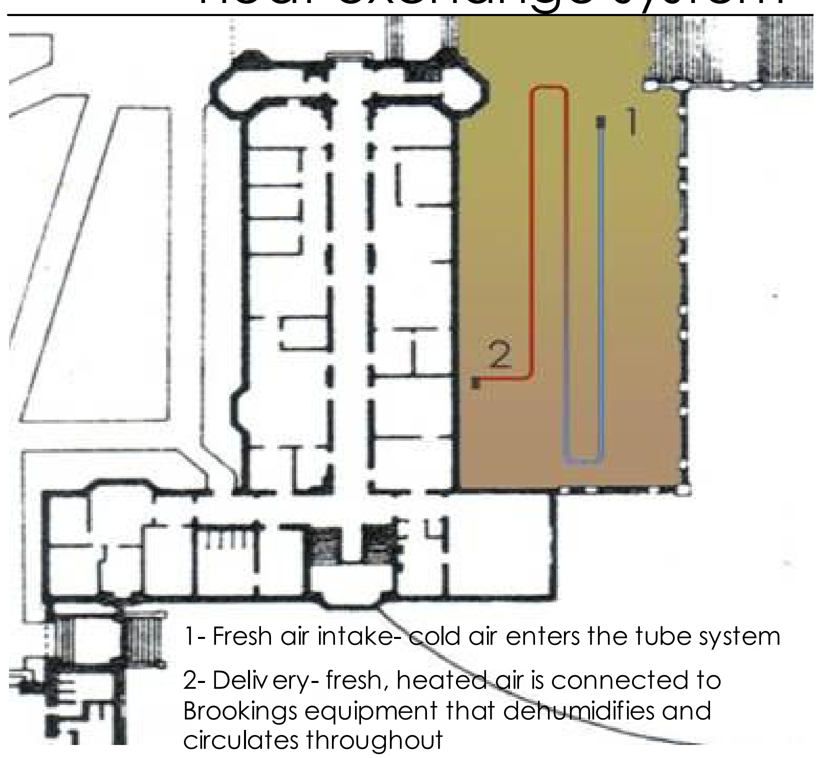


Figure G

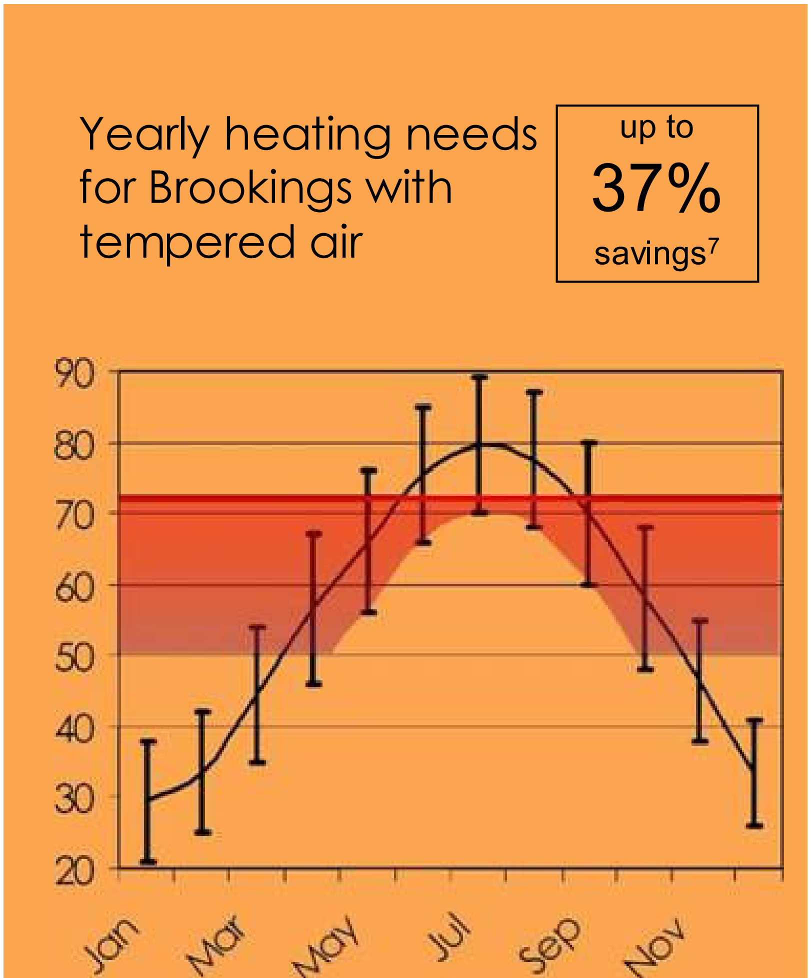


Figure F

Winter diagram of closed – loop geothermal heating

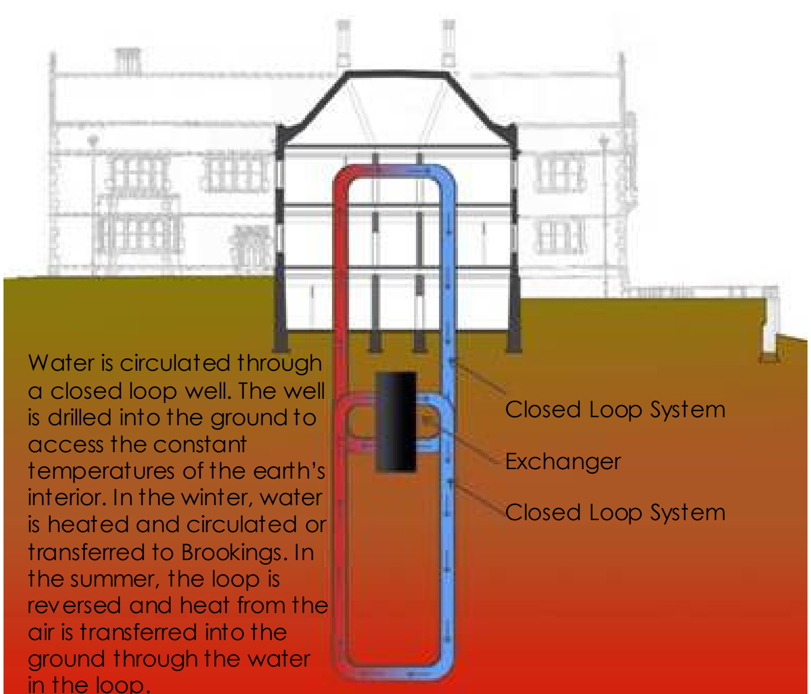


Figure H

Another way to decrease energy use is revise the way steam reaches Brookings Hall. Instead of burning fossil fuels, the natural heat of the earth can again be tapped. Geothermal wells can be drilled into the ground near the building [Fig. H]. These small pipes circulate water or another fluid down into the ground which is heated passively and then circulated up to the building. This loop runs through the structure and serves directly as the radiant heating system or the loop simply generates heat that is transferred to a forced air system or supplements a heat exchanger.

Both earth-air heat exchangers and geothermal wells can be reversed in the summer to release hot air back into the cooler temperatures of the earth.

The result

Figures E and F show the amount of energy saved simply by tempering air before it is used to heat or cool. Creating a system that does not have to deal with outside air temperature but instead air that is a constant temperature, creates huge savings. Of course, this is only the beginning of the possible savings.

There is also the potential for the University to save money and energy by investigating these strategies further. Systems vary in cost and viability, but creating a responsive and realistic plan of action surely creates a healthier and more sustainable campus.

lighting

The tantalizing thing is not always to who the source of light, but the effect of light[1]
- Edgar Degas

Cynthia Weese, the former dean of the University's school of architecture, once said in a lecture that a "shaft of sunlight can make your day better.[2]" It is amazing to think that something as basic as light can be so essential to our physical and mental well-being. This idea does not stop when one ventures indoors, instead, it becomes more important. We spend most of our time inside buildings and the interior environment can either help productivity and attitude or hurt it. By harnessing daylight in a useful way and supplementing it with artificial light, the workplace becomes a comfortable, uplifting place. In addition, electricity will be in less demand, reducing strain on our natural resources and the environment at large.

Washington University is well situated to reduce its electricity use. Purchasing green energy credits, choosing efficient fixtures and urging the design of buildings sensitive to a day-lighting plan, will make the University a symbol for change. The well-being of students, faculty and staff increases and educational efforts reduce energy use in other ways. If the University commits to change, it can lead the way for the rest of the St. Louis region.

Day Lighting & Electricity

The facts

Brookings Hall uses over $20,000 worth of electricity for power and lighting per year. 500,000 kilowatt hours are purchased from Ameren, the local power company.[3] [see Appendix A] The University recently began investigating the possibility of purchasing renewable energy to either offset emissions or to provide electricity directly.

The fixtures inside Brookings are fairly standard. Blinds are installed in all windows and can be adjusted as needed. Most spaces are lit by overhead ceiling lights recessed into a drop ceiling. All of the rooms are equipped with manual light switches that may or may not be turned off at the end of the work day [Fig. A]. During recent renovations, Low-E windows[4] were installed in the entire building. Day-lighting strategies do not extend beyond what the original architects (Cope and Stewardson) designed.

What can be done?

There are many strategies for reducing electricity use, harnessing sunlight and increasing human comfort. Unfortunately, the orientation of Brookings is not ideal for the best day lighting. The long sides of the building face east and west bringing too much sun to one side in the morning and harsh glare to the other in the afternoon [Fig. B]. Despite this issue, solutions exist. Solar shades [Fig. C] can be installed in all windows on the east and west sides of the building. These roll-down shades diffuse light and prevent glare without obstructing views. This creates a softer-lit interior environment that reduces eye strain and increases occupant comfort. In addition, properly managed day light reduces the need for electricity and lowers energy consumption.

at a glance...

Current Lighting Strategies

Standard blinds on all windows

Limited functionality

Overhead lighting in most of the office spaces

Direct and focused

Light switches in all rooms

Dependent on human control

Figure A

Brookings' solar orientation

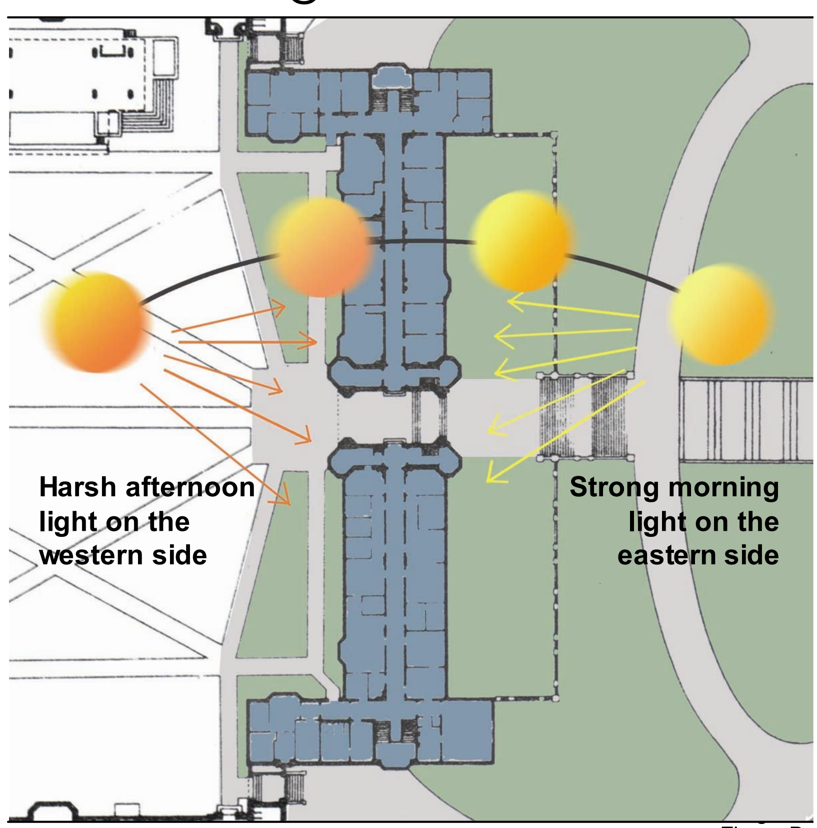


Figure B

Potential Lighting Strategies

Permeable solar shades

Variable lighting with preserved view and elimination of glare

Lighting provides both direct & diffuse light

Even lighting is easier on occupants' eyes and more comfortable

Motion Sensors

Save energy without any responsibility

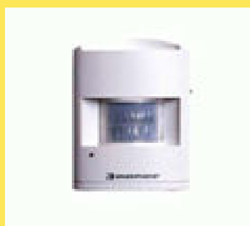


Figure C

Another way to reduce electricity demand is by installing more efficient and effective lighting fixtures. Instead of direct overhead light which creates a highly contrasted environment, hanging fixtures can be installed that direct focused down light as well splash diffuse light onto the ceiling [Fig. C]. This provides brighter areas where people are working but also fills in the shadows so that eye strain is reduced.

Daylight and artificial light should be finely tuned to appropriate occupant work conditions during the day. Once people leave the building, however; energy use *can be* virtually non-existent. For instance, motion sensors should be installed in the building [Fig. C] so that when people do leave, electricity is not running unnecessarily.

The result

Harnessing sunlight reduces energy costs, but more importantly, creates a better working environment for occupants. Instead of frustrating glare and stark interior light levels, natural light brings happier, more focused and healthier University staff. Nothing is more sustainable than creating a place where people feel comfortable at work.

A better lit Brookings

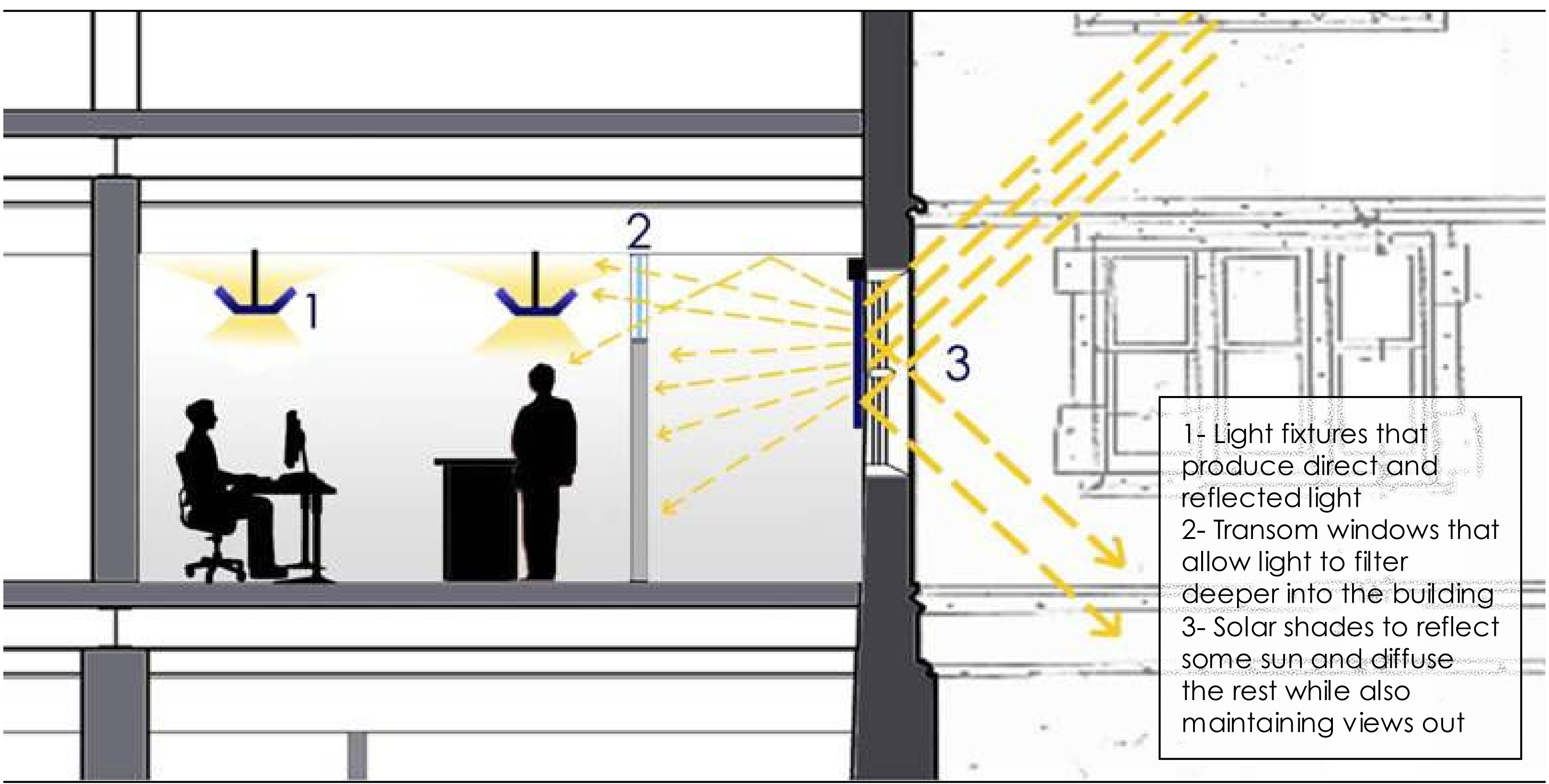


Figure D

waste

I only feel angry when I see waste. When I see people throwing away things we could use[1]
- Mother Teresa

Material cycling currently begins at production, goes through the useful life of an item and ends in a landfill. This type of linear thinking has a negative impact on issues ranging from land conservation and pollution to resource depletion and cost. In the title of their book, *Cradle to Cradle*, William McDonough & Michael Braungart challenge this thinking. Instead of products going "cradle-to-grave," now the standard model, they propose materials that are perpetually recycled and reintroduced into productive supply streams. The benefits of this approach are immense. Less energy goes into creating initial materials, dangerous and polluting substances are avoided and physical waste diminishes.

While the University does not create the materials and products it needs, it certainly chooses where to purchase them and where to send them once they have been used. A policy of green product purchasing as well as supplementing the existing recycling program helps diminish waste. By re-evaluating the way materials flow in-to and out-of campus, the University plays a part in decreasing that flow all together. It's easy to imagine a healthy, responsible and waste-free community. More importantly: it is not an impossible goal to reach.

Waste Flows

The facts

Washington University produces many types of garbage ranging from medical products to solid waste. For example in 2003, the Danforth campus produced over 268,000 ft^2 of garbage.[2] [Fig. B] Brookings Hall does not have any food services, and the majority of its waste is produced from paper, office supplies, and during renovations, furniture and building materials.

Currently, there are no policies dictating the environmental impact of products purchased. There is, however, a recycling plan in place for the University. The program has not reached its full potential, but committees and task forces are working to increase recycling on campus.

What can be done?

When considering waste flows for Brookings Hall it makes sense to evaluate the campus as a whole and examine ways that implementation of University-wide policy impacts the amount of waste the building produces. To effectively evaluate waste streams at Washington University, the entire life-cycle of a product must be considered. This begins with the purchasing of an item, goes through its productive life and then follows it either to the dump or to effective reuse.

Purchases are made on a departmental scale; each one is responsible for determining its needs and working within its budget. Most departments purchase from the companies shown in Figure A.[3] This is beneficial because these well-known companies already have green product lines that meet their own environmental standards. Corporate Express, the major office supply company for the University has a sixteen page index listing green products defined by their own standards as well as two nationally-recognized standards: the Environmentally Preferable Purchasing guidelines, and the Comprehensive Procurement Guideline program.

at a glance...

Some of the companies the University purchases from now

Allsteel — Designed to work. Built to last.

-Orders placed by department through purchasing division at Washington University

Steelcase — Do what you do better.

-Budgets, choices and times of purchases vary

Knoll

-No environmental guidelines currently in place

Corporate Express — A Buhrmann Company

-Purchases based on department members' needs and comfort

Figure A

Danforth campus annual waste

268,800 ft^3 garbage/year[2]

49 boxcars-worth of garbage stretching ½ mile![4]

Figure B

All of these companies ALREADY sell green products

What does this mean?
- -they contain recycled materials
- -are made with minimal materials
- -are made with reusable parts
- -are produced with limited/renewable energy
- -contain healthy coatings and dyes
- -contain no VOCs
- -use limited/reusable packaging
- -versatile use and long life

University-wide green purchasing policy
= smaller ecological footprint
= healthier staff/visitors
= sustainability fostered in office culture

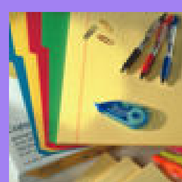


Figure C

Dealing with campus trash

The University, as the consumer, can intervene to save materials from the trash.

Figure D

These listings mean the research is already done. Without purchasing from new companies or investigating current business' products the University can implement a campus-wide green purchasing policy. Encouraging departments to buy green products or compensating them when they do so creates a healthier indoor environment for all. Competitions can be established between departments to create the most environmentally-friendly work spaces. This drastically reduces the University's waste even before products appear on campus.

The result

With green products entering campus and more recycled materials leaving campus, Washington University is able to drastically reduce its contributions to land fills. Materials are greener, last longer, remain safer throughout their entire life and are reused instead of discarded. This saves money and energy at the same time it fosters a healthier, safer and more responsible campus community.

water

The frog does not
Drink up
The pond in which
He lives[1]
- American Indian Proverb

While the St Louis region is not currently threatened by decreasing water tables and a lack of potable water sources, this resource remains one of the most important to conserve in the long term. Now in the St Louis region water is plentiful and extremely cheap. This makes it difficult to convince people to lower their consumption based on economic concerns. For the University, however, this is a perfect opportunity to be a leader in education and an example to the city. With over 150 buildings throughout its campuses, Washington University has the potential to decrease its water consumption and as a result, have a huge impact on the city's water resources as well as sewer systems.[2]

The costs of these improvements initially outweigh the savings benefits, but over time, purchasing less water and therefore paying less to discharge it, results in huge savings. More importantly, Washington University plays a role as a leader in St Louis' efforts towards sustainable growth. It can become a model for the city and its inhabitants in water conservation projects. The large physical demands a university has on a community can be reduced as well. Millions of gallons of water prevented from being discharged into sewer systems results in a lower impact on regional infrastructure and a decreased role in contributing to sewer overflow and flash flooding.

Indoor Water Consumption

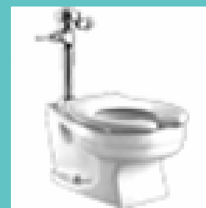
The facts

As is the standard practice, the bathrooms in Brookings Hall run on clean drinking water purchased by the university. Between North and South Brookings, approximately 488,000[3] gallons are consumed in a typical year. With standard fixtures in the restroom, a typical visit uses anywhere from 2.5 -3.1 gallons of water. All of the water, both from the sinks and the toilets or urinals, discharges into the local sewer systems at a cost to the university.

What can be done?

There are multiple ways to decrease the amount and type of water these bathrooms consume. By simply replacing the current fixtures with more efficient ones, less water is used as well as purchased. A variety of commercial models of low-flow toilets and urinals exist that can drastically reduce water use per flush. Another option is a dual-flush toilet that has two flush settings based on the amount of water needed. For sinks, simply adding an aerator nozzle to the faucet can decrease flows by up to half a gallon per minute [Fig. B]. This is the easiest and most cost effective way to begin conserving water.

at a glance...



Toilet
8 units
1.6 gallons per use[4]

Urinal
3 units
1 gallon per use

Sink
7 units
1.5 gallons per use

Overall consumption w/out reuse
488,800 gallons per year
Overall cost
$2,175

Figure A

Cost and use analysis

Data For One Year*	Consumption in gallons	Cost	Gallons Saved	Money Saved	% Saved
Current Water Use	488,800	$2175	-	-	-
Efficient Water Use	231,920	$103	256,880	$1,144.00	52.50%
Recycling Water and Current Use	262,600	$1169	226,200	$1,006.00	46.20%
Recycling Water and Efficient Use	135,720	$603	353,080	$1,572.00	72.20%

*see appendices B & C

Dual Flush/Low Flow Toilet

8 units

0.5 gallons per use[5]

Low Flow Urinal

3 units

0.5 gallons per use

Faucet Aerator

7 units

0.9 gallons per use

Overall consumption w/ reuse

135,720 gallons per year

Overall cost

$603

72.2%

Savings

Figure B

Another way to begin evaluating water consumption is by looking at what type of water is being used in a specific system. Why should a toilet be filled with fresh drinking water? Instead, certain waste water can be easily and safely reused. Grey water, the end result of using a sink, shower, or laundry, can be reused in toilets (whose waste water is known as black water). The grey water from the sinks in Brookings Hall easily provide all the water needed to operate the toilets and urinals in the building. The grey water is processed mildly and stored. This can easily be done in small underground tanks, and then returned to the building for flush water [Fig. C]. With this system in place, water consumption is reduced by half.

The result

Incorporating both new plumbing fixtures and grey water recycling, water consumption in Brookings Hall can be reduced by a dramatic 72% [see table at left]. Extrapolating these savings to the other campus buildings, Washington University has the potential to save up to **53 million** gallons of water per year.

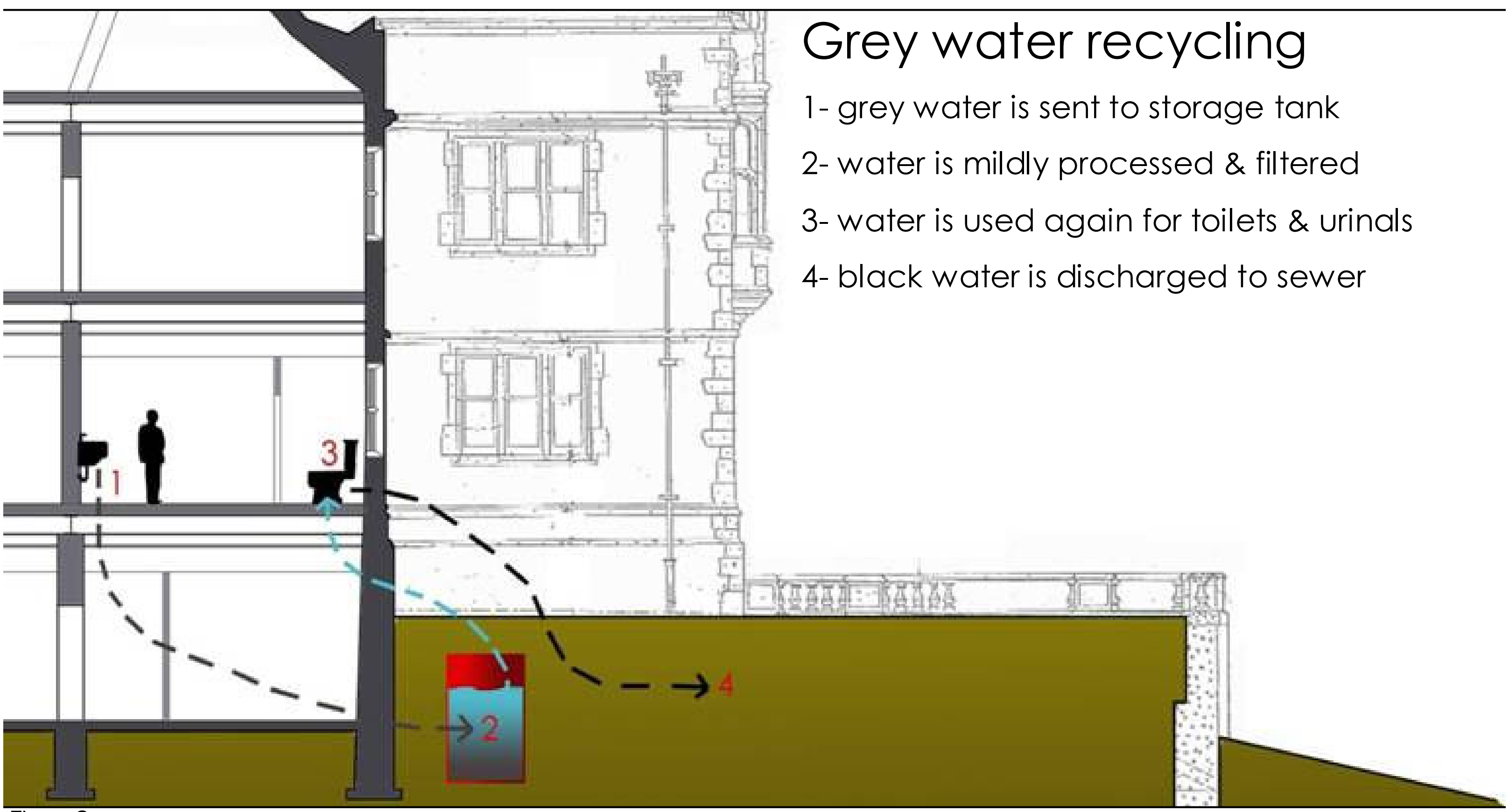


Figure C

Outdoor Water Consumption

The facts
Washington University has extensive and well planned grounds. Most planted areas are not irrigated except during drought periods. Those that are, only need to be watered for approximately three months of the year.[6] When plants are watered, they are usually cared for three times a week and provided with an equivalent of one inch of rainfall by sprinklers or groundskeepers [Fig. D]. The Brookings site is well proportioned in that is has the same amount of green space as the built and paved areas together [Fig. F]. This helps reduce runoff and flooding during storm events. In addition, the green space is almost exclusively grass.

What can be done?
The University has already established an abundance of successful campus green spaces. Plantings were chosen (in most cases) for low maintenance and watering needs. This does not mean, however, that watering does not occur. Currently, this is done with municipal water supplies. As seen in the chart below, Brookings receives tens of thousands of gallons on average of rainfall per month. This more than compensates for the watering needs of the plants located on the site.

at a glance…

Oak walk from Skinker

wet season vs. dry season

duration	
9 months per year	3 months per year
care	
just rainfall	watering 3x per week
gallons paid for	
0	**3,273**

Figure D

Brookings site data*

St Louis	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Rainfall (inches)	2	2.1	3.3	3.8	3.9	4.1	3.6	3	2.9	2.8	3.1	2.5
Rainwater Collected on Impermeable Surfaces @ 90% Efficiency	6,641	6,973	10,958	12,619	12,951	13,651	11,954	9,962	9,630	9,298	10,294	8,302
Rainwater Collected on Permeable Surfaces @ 50% Efficiency	3,514	3,690	5,798	6,677	6,852	7,204	6,325	5,271	5,095	4,920	5,447	4,393
TOTAL Rainwater Collected on Site (Gallons)	10,155	10,663	16,756	19,296	19,803	20,855	18,279	15,233	14,725	14,218	15,741	12,695

TOTAL Rainwater Collected Per Year	188,419 Gallons

*see appendix D

duration	
9 months per year	3 months per year
care	
just rainfall	watering 3x per week from catch basin
gallons paid for	
0	**0**

Figure E

Brookings site boundaries*

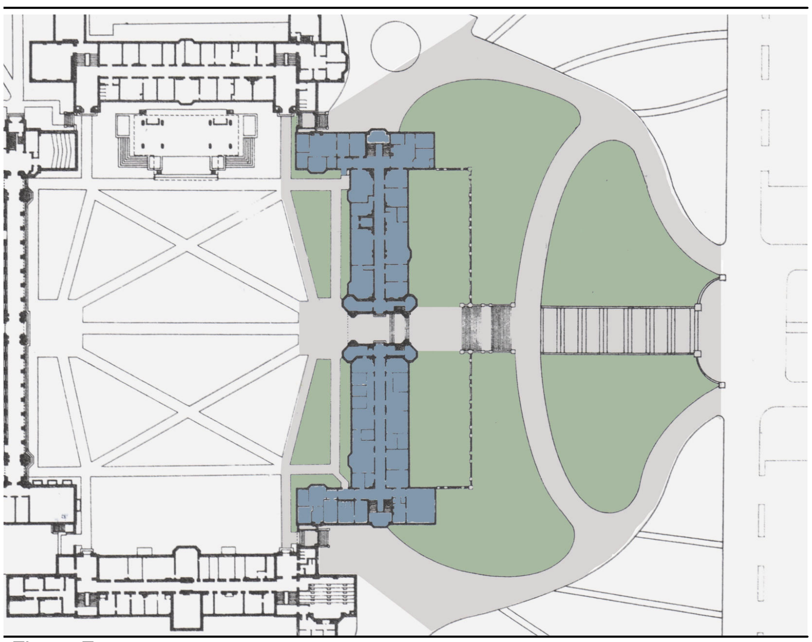


Figure F *as considered in this study- see appendix D

To put it in perspective, the oak walk which extends approximately 700 feet from Skinker to the steps of Brookings requires only a little over 3,000 gallons of watering per year.[7] This compared to the thousands of gallons of rain the area receives on average per month. Burying a small cistern under the walk, it can easily absorb the water needed for irrigation later in the year [Fig. E]. This eliminates the need for purchasing water for maintenance. If a few cisterns are placed strategically around campus (they can even be buried when new buildings are built to decrease costs), all of the irrigation needs of the campus are met without purchasing even a drop of water.

The result

If the University installs catch basins for holding water, grounds maintenance occurs completely independent of the city's water system. This prevents a large portion of clean, drinking water from being pulled out of municipal water supplies and used unnecessarily for gardening. In addition, because the water is stored during rain events, it mitigates loads on sewers and instead, releases the stored water during dry, sunny, days. This saves the University money in the long term and helps thousands of gallons of water per month remain clean and available.

landscape

It is in man's heart that the life of nature's spectacle exists; to see it, one must feel it[1]

- Jean-Jacques Rousseau

The benefits of natural landscapes in urban settings cannot be stressed enough. Access to light and air, a haven for wildlife and plants, and a gathering space for community, parks and gardens provide a an exciting and diverse experience. People use them to exercise, play, stroll, and rest. These spaces are for leisure just as much as they are essential areas for healthy cities. They aid in water management, habitat preservation and a score of other important environmental issues. It is imperative to preserve them, not just for human use, but for a sustainable ecosystem as well.

Washington University is an oasis of green space within the city of St Louis. Planned carefully, the campus has an abundance of outdoor places ranging from sports fields to tiny court yard gardens. All of these spaces serve different functions and vary in use. While there is no lack of green space much of the current landscape is laid out with grass, notorious for its high energy consumption and maintenance needs. By re-evaluating the landscape of the University, diverse green spaces can continue to exist, but will be designed to contribute to a sustainable community, not detract from it.

Site Strategies

The facts
The site surrounding Brookings is well planned and plant life well established. Laid out decades ago, the quadrangle remains one of the most successful campus outdoor spaces. On the east side of Brookings the oak walk stretches out to Skinker Blvd, providing a grand processional up to the steps of the hall. Trees line the paths and ivy grows in the shade near buildings. Many of theses spaces require minimal maintenance and watering.
Between the oak walk and Brookings, however, vast expanses of grass exist that are under-utilized and over-managed based on what they provide the University [Fig. A]. People do not gather there and the sloping site makes the area unfavorable for pick-up games in nice weather. While it is good that these areas are not watered, the grass is dry in the summer and becomes a monolithic, uninteresting front to Brookings.

What can be done?
These grass lawns can easily be reconsidered. Without drawing attention away from the University's architecture, a series of interesting, terraced spaces can replace the grass [Fig. D]. Retaining walls can be planted with vines that are reminiscent of the school's colors (Virginia Creeper, American Bittersweet or Honeysuckles to name a few). From the street, strong swaths of color flank the grounds below Brookings, making a strong visual statement. This creates variety without compromising the clarity of the University's most symbolic space.
The new terraces accomplish much more than the grass lawns do. They will draw people down from the archway to walk through the gardens that run in strips across the site. Meandering through slowly, or sitting to enjoy the sun, these people will be greeted by butterflies and birds attracted to the new micro-habitats.

at a glance...

The hill in front of Brookings

Current Conditions
all grass on a sloping hill-
some water absorption-
runoff to sewer during storm event-
no wildlife-
unused by people-
monolithic street front-

Figure A

Indian Paintbrush
a sustainable alternative

Figure C

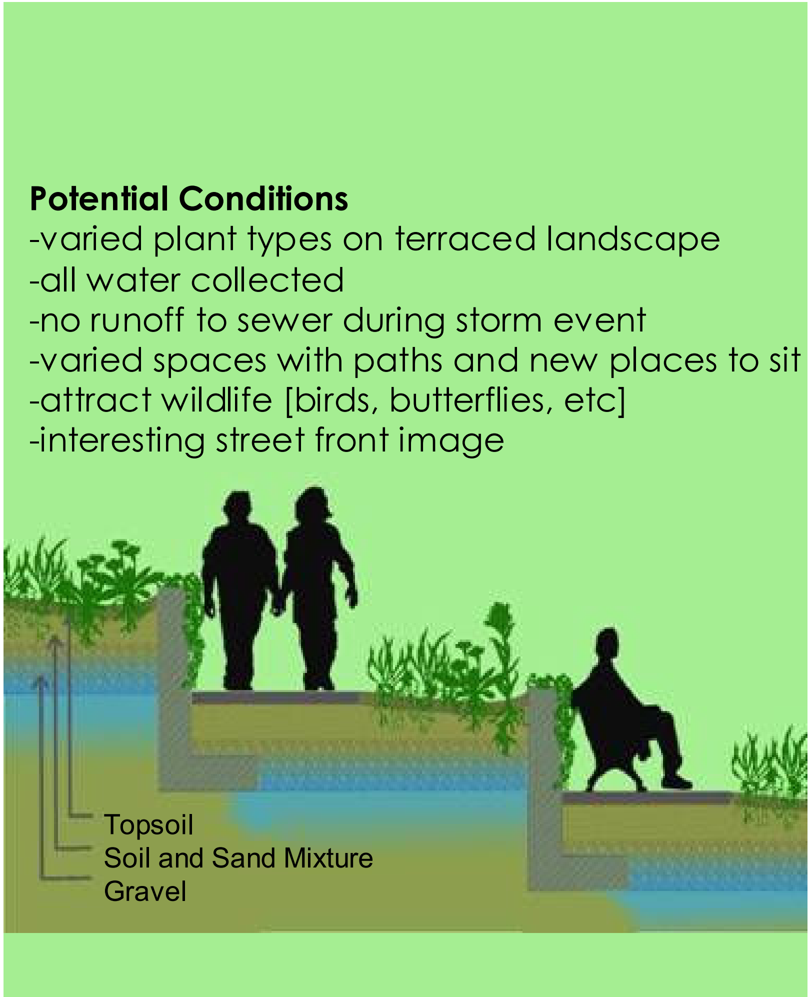


Figure B

Terracing the Brookings hill

Figure D

In addition, terraces would hide a complex and effective system of water management. As seen in the previous section there is too much rainfall in St Louis for all of it to be collected for later use. It is also important to replenish groundwater. Therefore, the terraces would have bioswale systems [Fig. B] built into them. A bioswale consists of different layers of filtration: soil, sand, and gravel that capture rainwater and slowly release it into groundwater while removing contaminants in the process. It is a completely passive system, that once built, requires no cost or energy to run. During a storm event, they do not allow runoff into storm sewers and mitigate flooding as well.

Another area grass could be removed is behind the balustrades in front of Brookings [Fig. C]. These spaces can be planted with Indian Paintbrush, a native flower that requires limited maintenance and blooms a deep red through the spring and summer. This solution draws attention to Brookings while lowering cost, eliminating mowing, and decreasing water use.

The result

The potential for this area of campus is immense. Now only a space for traffic, it can become a beautiful outdoor place for people to enjoy a walk or rest. These terraces, and plantings become new habitat for wildlife/plants and include effective solutions for water management. Such a project integrates environmental technology and human comfort, while creating a stunning visual statement of the University's commitment to sustainability.

executive summary

Come, O friends, in great delight,
And join us in a song of glee,
We're soon to leave our crowded site,
And be once more most gladly free.
The thund'ring noise of passing cars,
The soot that sprinkles us all o'er,
The smoke that all our pleasure mars,
Shall vanish then forever more.[1]

- William E. Shahan,
A.B. 1901, Washington University in St Louis

This poem was written in anticipation of the new hilltop campus being built west of downtown during the early years of the 1900s. Shahan reminds us that environmental concerns were just as potent a century ago as they are today. He validates the University's current efforts to provide a healthy and sustainable campus by showing us that these values cross generations and list among our most basic desires.

Evaluating the ecological footprint of Brookings Hall shows that energy use and operating costs can be reduced significantly, that human comfort and health is improvable and that the University can become a sustainable environment for students and staff alike.

Within the building, energy use is decreased through implementation of renewable strategies and techniques to lower demand. Water consumption is cut in half. Day-lighting strategies reduce electricity use and increase occupant comfort. Under-utilized campus outdoor space is invigorated and contributes to increased biodiversity. All of these strategies are realistic goals to set for a revitalized Brookings environment.

More importantly, this study shows that the methodology used to evaluate Brookings Hall can be applied to all the existing buildings at Washington University. The solutions exist and the campus is poised for change. These efforts are a process through which the school can create a healthier place to be, a dynamic natural and built environment, and a role as a world leader in campus sustainability.

Acknowledgements

A list of those who helped make this research possible

Washington University

Ray Barber	Project Manager – Facilities
Ed Barry	Manager of Utility Operations
Bruce Backus	Assistant Vice Chancellor for Environmental Health and Safety
John Davidson	Maintenance Crew, Yellow Zone
Richard Ellis	Zone Manager
Jonathan Lane	Chair of Committee on Environmental Quality
Paul Norman	Horticulturalist/Grounds Manager
Andrea Pruitt	Cad Operator – Capital Projects and Records
Miranda Rectenwald	Archives Librarian
Bob Weinstein	Senior Contract Management Liaison – Resource Management

Administrative and Executive Assistants/Service Representatives at Brookings Hall

Barbara Hanson	College of Arts & Sciences
Cynthia Jorgenson	Executive Vice Chancellor & General Counsel
Barb Knipshild	Graduate School of Arts & Sciences
Joyce Knolhoff	Executive Vice Chancellor & Alumni and Development
Delise LePool	Undergraduate Admissions
Jacquelin Metcalfe	Student Financial Services
Jane Miller	Governmental and Community Relations
Mary Most	Human Resources
Gloria Richman	Office of the Chancellor
Noreen Satterlee	Operations Support Processor - Admissions
Jane Stone	Board of Trustees
Dawn Wanish	Office of the Executive Vice Chancellor for Administration

Contacts Outside the University

Maren Engelmohr	Mackey Mitchell Associates
Tom Schultz	Laclede Gas

My Mentors and Guides

Michael Repovich	Field Office Architecture, Interiors, Planning, Research
Elysse Newman	Field Office Architecture, Interiors, Planning, Research

A Note-

I am deeply indebted to Michael Repovich, my advisor for the summer, for all the work he did helping me through my research and taking time out of his busy days to envision, discuss and edit. He helped me remain focused, always making sure I was inspired and passionate. It was a wonderful way to learn from his extensive experience. Thank you.

Appendix A

Energy Use Analysis

	Campus Use	Brookings ft²	Brookings Use	Cost	Total Cost
Natural Gas-Heating	4,062,863 therms	63,655	≈55,921 therms per year	≈$1.00 per therm	$55,921.00 per year
Electricity-Cooling	74,257,029 kWh	63,655	≈1,022,723 kWh per year	≈$0.04 per kWh	$40,908.92 per year
					Total Heat/Cool Cost
					$96,829.92
					$1.52 per ft²

	Campus Use	Brookings ft²	Brookings Use	Cost	Total Cost
Electricity-Power/Lighting	37,128,514 kWh	63,655	≈511,362 kWh per year	≈$0.04 per kWh	$20,454.48 per year

Overall Energy Costs
$117,284.40 per year

Appendix B

Plumbing Fixtures Analysis

Water Consumption	Total #	Water Used per Use	Uses per Day	# of People	Total Consumption	Cost (2.034 per 1000 Gallons)	Total Cost
Toilets	8	1.6 Gallons	4-fem. 1-male 1-visitor	80, 80, 50	720 Gallons per day	$1.46 per day	$379.60 per year
Urinals	3	1 Gallon	3-male 1-visitor	80,50	290 Gallons per day	$0.59 per day	$153.40 per year
Sinks	7	1.5 Gallons	3-male/fem. 1-visitor	160, 100	870 Gallons per day	$1.77 per day	$460.20 per year
					Overall Consumption		**Overall Cost**
					488,800 Gallons per year		$993.20 per year
Efficient Water Use	**Total #**	**Water Used per Use**	**Uses per Day**	**# of People**	**Total Consumption**	**Cost (2.034 per 1000 Gallons)**	**Total Cost**
Dual/Low Flush Toilets	8	0.5 Gallons	4-fem. 1-male 1-visitor	80, 80, 50	225 Gallons per day	$0.46 per day	$119.6 per year
Low Flush Urinals	3	0.5 Gallons	3-male 1-visitor	80,50	145 Gallons per day	$0.29 per day	$75.40 per year
Aerator Faucets	7	0.9 Gallons	3-male/fem. 1-visitor	160, 100	522 Gallons per day	$1.06	$275.60 per year
					Overall Consumption		**Overall Cost**
					231,920 Gallons per year		$470.60 per year

Appendix C

Recycled Water Analysis

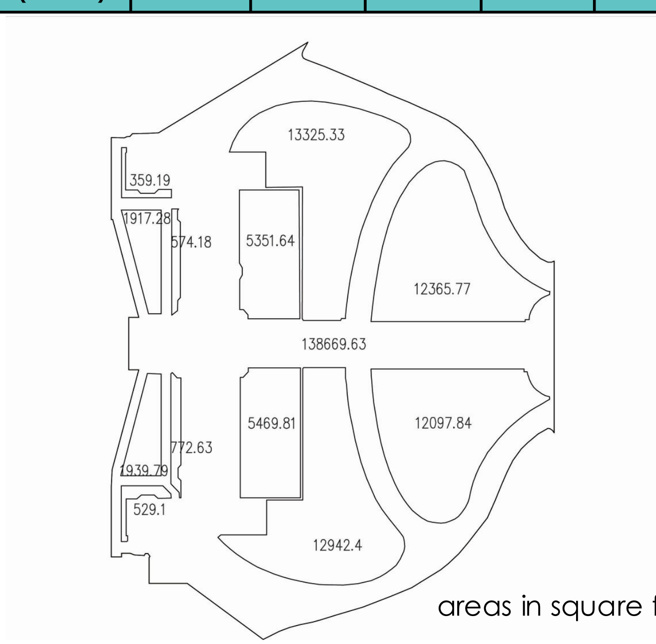
Water to Sewer Cost	Use per Year	Cost to Discharge	Use per Year	Total Cost
[toilets and sinks]	488,800 Gallons	$1.81 per 100 ft³	65,343 ft³	$1,182.70
				Overall Cost
				$2,175.90
Water to Sewer Cost	**Use per Year**	**Cost to Discharge**	**Use per Year**	**Total Cost**
[efficient toilets and sinks]	231,920 Gallons	$1.81 per 100 ft³	31,003 ft³	$561.15
				Overall Cost
				$1,031.75

		Per Day	Per Year
Grey Water used for Black Water	**Gallons Used by Sinks**	870	226200
[reg. toilets and sinks plus recycling for]	**Gallons Used by Toilets/Urinals**	1010	262600
	Total Gallons Used With Offset	1010	262600
	Cost to Buy (2.034 per 1000 Gallons)	$2.05	$534.13
	Cost to Discharge ($1.81 per 100 ft³)	$2.44	$635.40
	Total Cost	$4.49	$1169.5
Grey Water used for Black Water	**Gallons Used by Sinks**	522	135720
[effic. toilets and sinks plus recycling]	**Gallons Used by Toilets/Urinals**	370	96200
	Total Gallons Used With Offset	522	135720
	Cost to Buy (2.034 per 1000 Gallons)	$1.06	$275.60
	Cost to Discharge ($1.81 per 100 ft³)	$1.26	$327.60
	Total Cost	$2.32	$603.20

Appendix D

Site Rainfall Analysis

St Louis	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Rainfall (inches)	2	2.1	3.3	3.8	3.9	4.1	3.6	3	2.9	2.8	3.1	2.5
Rainfall on Impermeable Surfaces (in³)	1704600	1789830	2812590	3238740	3323970	3494430	3068280	2556900	2471670	2386440	2642130	2130750
Rain Collected on Imperm. Surf. @ 90% Efficiency (in³)	1534140	1610847	2531331	2914866	2991573	3144987	2761452	2301210	2224503	2147796	2377917	1917675
Rain Collected on Imperm. Surf. @ 90% Efficiency (gallons)	6641	6973	10958	12618	12950	13614	11954	9961	9629	9297	10294	8301
Rainfall on Permeable Surfaces (in³)	1623480	1704654	2678742	3084612	3165786	3328134	2922264	2435220	2354046	2272872	2516394	2029350
Rain Collected on Perm. Surf. @ 50% Efficiency (in³)	811740	852327	1339371	1542306	1582893	1664067	1461132	1217610	1177023	1136436	1258197	1014675
Rain Collected on Perm. Surf. @ 50% Efficiency (gallons)	3514	3689	5798	6676	6852	7203	6325	5271	5095	4919	5446	4392
TOTAL Rainwater on Site (in³)	4868861	5112304	8033621	9250836	9494280	9981165	8763950	7303291	7059849	6816406	7546735	6086076
TOTAL Rainwater Collected on Site (in³)	2345880	2463174	3870702	4457172	4574466	4809054	4222584	3518820	3401526	3284232	3636114	2932350
TOTAL Rainwater Collected on Site (Gallons)	10155	10663	16756	19295	19802	20818	18279	15232	14725	14217	15740	12694



areas in square feet

	ft²	in²
Impermeable Area [Brookings Roof /Paths]	71,025	852,300
Permeable Area [Grass /Plantings]	67,645	811,740
Total Area	138670	1,664,040

Citations

Cover Image- Strode, William. *Washington- A University Portrait* (Rhode Island: Fort Church Publishers, 1985)

Title Page

1- Herbert, Adam W. "Martin Luther King Jr. Celebration: "Courage, Wisdom & Praise," http://www.indiana.edu/~pres/comments011606.shtml

[All figures unless otherwise noted were created by Tara Fridhandler]

Methodology

1- Wackernagel, William & Willaim Rees. *Our Ecological Footprint: Reducing Human Impact on the Earth*. As quoted by Sustain Dane- Madison Area Green Pages, www.sustaindane.org/main/ef1.htm

Energy Section

1- Rodes, Barbara K., and Rice Odell, comp. *A Dictionary of Environmental Quotations* (Baltimore: The Johns Hopkins University Press, 1992) p. 78.
2- As determined by the Energy Information Administration - http://www.eia.doe.gov/
3- Based on data from Ed Barry, Manager of Utility Operations, Washington University. [see appendix A]
4- Department sizes determined through discussion with admin. assistants and service reps in Brookings
5- Information regarding internal HVAC systems gathered during an interview with John Davidson, a yellow zone maintenance staff member, Washington University.
6- Min, max and average temperatures for St Louis from *Sun Wind and Light* climatic design resources online. Managed by Mark DeKay and the College of Architecture at the University of Tennessee. http://sunwindlight.net/
7- Savings calculated by determining the area under the curve of the minimum average temperatures in St Louis as cited above. Simply meant as a rough estimate of possible savings with tempered air.

Light Section

1- As quoted by R. Lee Kennedy, Associate Professor of Lighting Design, University of Virginia. http://wsrv.clas.virginia.edu/~rlk3p/desource/quotes.html
2- Lecture given in A46 ARCH 111A, Introduction to Architecture I, Fall 2003.
3- Based on data from Ed Barry, Manager of Utility Operations, Washington University. [see appendix A]
4- Low-E glass- according to the EPA- "glass that lowers the amount of energy loss through windows by inhibiting the transmission of radiant heat while still allowing sufficient light to pass through." http://www.p2pays.org/ref/01/text/0040221.htm

Fig. A- http://www.procol.ltd.uk/image_large/habitatblind1.jpg
http://www1.istockphoto.com/file_thumbview_approve/48307/2/istockphoto_48307_office_lights.jpg
http://www.joburg.org.za/images/light-switch.jpg
Fig. C- http://www.solar-screen.com/
http://www.light-my-house.co.uk/images/products/154332.jpg
http://www.electronicsoutfitter.com/images/items/139890-ame-am-sx.jpg

Waste Section

1- From *A Gift for God*, 1975. As quoted by the EPA at http://www.epa.gov/Region2/library/quotes.htm
2- Waste statistic from student research, 2003. A46 ARCH 336A Sustainability, Professor Michael Repovich.
3- General purchasing information from Bob Weinstein, Senior Contract Management Liason, Washington U.
4- Standard boxcar dimensions from CSX - http://www.csx.com/?fuseaction=customers.search_car&n=Typical%20Boxcar%20Dimensions

Citations [cont'd]

Waste Section [cont'd]

Fig. A- http://www.allsteeloffice.com
http://www.steelcase.com
http://www.knoll.com
http://www.corporateexpress.com

Fig. B- Train Engine Image- http://members.shaw.ca/mikeswebsite/photos3/pc1a9.jpg
Boxcar Image-
www.swedenfreezer.com/avr/images/AVR%20SCRR%2004%201INCH%20OUTSIDE%20BRACED%20BOXCAR.jpg

Fig. C- http://www.allsteeloffice.com/allsteeloffice/products/storage/?application=File+Pedestal
http://www.steelcase.com/na/products.aspx?f=11811
http://www.knoll.com/environment/env_pro_seating.jsp
http://www.corporateexpress.com/office_products.html

Water Section

1- Rodes, Barbara K., and Rice Odell, comp. *A Dictionary of Environmental Quotations* (Baltimore: The Johns Hopkins University Press, 1992) p. 286.

2- Facts about Washington University, 2006. http://facts.wustl.edu/about.htm

3- All water consumption calculations based on current price of water and Danforth campus water use for fiscal year 2004-2005 as recorded by Ed Barry, Manager of Utility Operations, Washington University. [See Appendices B & C]

4- Plumbing fixture ratings from current fixtures installed in Brookings Hall

5- Efficient plumbing fixture ratings based on an average of multiple models currently on the market.

6- Information on grounds and upkeep estimated by Paul Norman, Horticulturalist and Grounds Manager, Washington University.

7- Average rainfall data for St Louis from *Sun Wind and Light* climatic design resources online. Managed by Mark DeKay and the College of Architecture at the University of Tennessee. http://sunwindlight.net/

Fig. A- http://www.americanstandard-us.com/images/shared/images/products/imgLarge183.jpg
http://www.zurn.com/operations/aquaflushsense/images/catalog/Z5798.jpg
http://www.homecenter.com/pics/info220-170/American%20Standard/9061.250.gif

Fig. B- http://www.ecofriend.org/images/dual_flush_toilet.gif
http://www.americanstandard-us.com/images/shared/images/products/imgLarge187.jpg
http://www.wattbusters.com/store/files/thumbs/ES-NAG-3210T.jpg

Landscape Section

1-Rodes, Barbara K., and Rice Odell, comp. *A Dictionary of Environmental Quotations* (Baltimore: The Johns Hopkins University Press, 1992) p. 143.

Executive Summary

1- O'Connor, Candace. Beginning a Great Work: Washington University in St Louis, 1853-2003 (St Paul, Minnesota: Litho, Inc., 2003) p. 89.