"GREEN" UNIVERSITY TOWN SUCCUMBS TO BLACKTOP: QUANTIFYING THE INCREASE IN IMPERMEABLE SURFACES AND RUNOFF THROUGH TIME

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High-resolution orthophotographs show a marked decrease over the past 20 years in greenspace in student neighborhoods surrounding the University of Vermont. Simple hydrologic modeling suggests that this paving of permeable areas increases run off volume and peak flow.

We determined land use changes in Burlington, VT neighborhoods using high-resolution, low-altitude orthophotographs taken in 1978 and 1999. Using these images, we identified and mapped 5 land-use categories: buildings, paved parking areas, unpaved parking areas, sidewalks, and greenspace. Questionnaire surveys, field assessment, and analysis of Historic Preservation Studies provided demographic profiles of the past and present residents of the study area.

The data generated from these maps and investigations showed an 8% loss of available greenspace over 21 years in the primary study area; 67% of this loss occurred on the 42% of parcels currently inhabited by students. Losses of greenspace in satellite study areas, as determined by teams of students in an undergraduate hydrology class, ranged upward toward 50% of available greenspace, particularly in neighborhoods with no owner occupants.

Loss of greenspace has occurred incrementally and in a predictable sequence. First, occasional lawn parking results in compaction, lowered infiltration rates, and muddy rutted areas. These areas are then "improved" with gravel, reducing detention storage. Finally, graveled areas are paved, reducing infiltration to zero.

Curve number and rational runoff method modeling of the 10-year, 6-hour storm event suggest increases from 1978 to 1999 of approximately 16% for both runoff volume and peak flow. Conversion of lawn parking to formalized paved parking often escapes zoning controls and usually occurs without thoughtful planning or approval by the land owner. Use of these methods illustrates a direct, quantifiable hydrologic impact that residents have on their immediate surroundings. Surveys of this kind can be done rapidly by students and provide data for urban environmental planning including urban catchment dynamics, increasing urban heat island effect, and possible remediation strategies.

Opportunities for Student Research Involvement

SEE OTHER SIDE OF BOOTH

Independent Senior Research

Jim Kurfis and Paul Melillo - air photo analysis, property surveys, occupant interviews, statistical analysis, infiltration measurements, hydrologic calculations (rational runoff, curve number), permit searches, sewer monitoring

Class Projects

Whole Class Involvement in GEOHYDROLOGY (junior and senior) – pairs of students mapped city blocks, prepared summary tables, interviewed occupants, presented posters, and considered means of intervention and remediation.

Single Student Projects in GEOMORPHOLOGY (sophomore and junior) - Lyman Persico-campus development history and change of impermeable surface area over time

Graduate Student Training

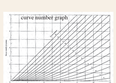
Supervision of students in classes as teaching assistants, involvement with project design and evaluation, field and modeling experience, write-up of approach for journal

Background

Burlington, Vermont is a city of 40,000 with 3 colleges and a housing shortage.
There is less than a 1% vacancy rate for rental units.
The campuses are surrounded by residential neighborhoods that house students and families.
Most of Burlington is built on glacial and deglacial sediment.
Soils are developed on till, glacial lake sand, and marine sand and silt.
In the 1960s, the University of Vermont expanded without building much additional housing.
Most of the junior and senior class now live off campus.
Many single family and multi-family apartments have been converted to student housing.
In most residential neighborhoods, zoning limits total lot coverage to 35%.
Parking on lawns and change in neighborhood character have led to repeated resident complaints.
Many University of Vermont students are environmentally active and aware.

Methods

Mapping done on low level orthophotos using tracing paper or "Canvas"; field checked for accuracy.
Infiltration rates measured by sprinkling ~1 m^2 plots - collecting runoff, monitoring rainfall; 2 trials per plot.
Door to door occupant surveys approved by Burlington code enforcement office; done by students.
Curve number and rational runoff methods for discharge done according to Dunne and Leopold (1977).
Data analysis and statistics in "Excel"; digital cameras and digital video used for images and movies.



Curve numbers used for hydrologic model

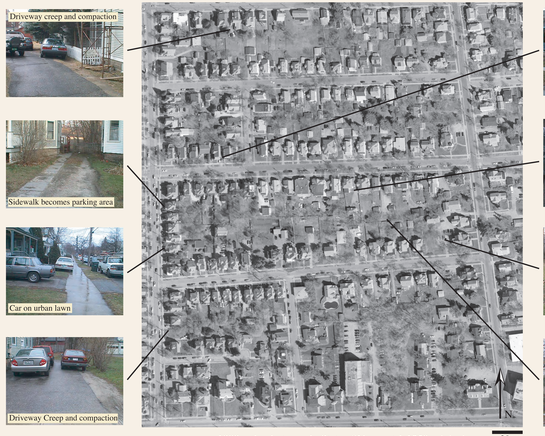
Land use	Curve#	Description
wooded (forest)	55	good condition
lawn	61	good condition
formal parking	98	paved area
sidewalk	98	paved area
greenspace	61	good condition
building	98	impermeable
informal parking	72	dirt, good condition

notes: Soil Group B, moderate infiltration
curves and numbers from Dunne and Leopold, 1978

PRECIPITATION INTENSITY (CM/HR)

Recurrence Interval (years)	Storm Duration (hours) 0.5	1	6	24
2	4.0	2.5	0.8	0.3
10	6.8	4.0	1.0	0.4
100	9.0	5.7	1.5	0.5

Parking of Automobiles Changes the Landuse and thus the Hydrology of Neighborhoods Surrounding the University of Vermont



1999 orthophotograph, State of Vermont 1:1250 original

Driveway creep and compaction

Sidewalk becomes parking area

Car on urban lawn

Driveway Creep and compaction

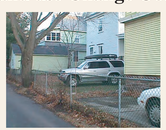
Informal curb cut and parking area

Parking area replaces lawn

Informal Gravel Parking area

Cars on lawn beyond gravel lot

Land use Change Occurs in a Predictable Sequence



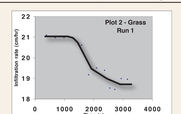
1. Parking begins on lawns, often at the end of or adjacent to existing driveways.

2. Parking continues and muddy ruts develop as compaction reduces the ability of water to infiltrate.

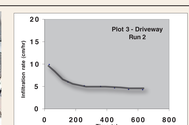
3. Responding to tenant complaints, landlords fill ruts with gravel and create informal curb cuts.

4. Single-width drive was widened by informal parking and formalized when city recurbed street.

Infiltration Tests and Hydrologic Calculations



GRASSY LAWN -- Required two sprinklers and rainfall rates > 20 cm/hr to generate even minimal runoff. Such rainfall rates exceed the intensity of the 100 yr, 30 min storm (<10 cm/hr) and indicate that lawns do not generate runoff unless seasonally saturated. Shallow subsurface flow during test was significant.



GRAVEL DRIVEWAY -- Required one sprinkler and rainfall rates < 10 cm/hr to generate significant runoff. Infiltration rates are much lower than grassed areas (4 vs 19 cm/hr). Rainfall intensity of this value is exceeded regularly. No shallow subsurface flow was observed during test.

Results of Mapping and Surveys

191 parcels in 4 blocks

Table 1. Orthophotograph Mapping Categories and Descriptions

Category	Description
Building Footprint	Identified as buildings, porches, garages, and other outbuildings. This unit is generally an unvegetated roof surface, but may be a vegetated carpet. This unit often appears to have a different color than the surrounding pavement, but in some circumstances, buildings may be an amalgamate due to shadowing and or distortion.
Sidewalk	Identified as paved walkways. Usually a rectilinear polygon that parallels streets or intersects streets or other sidewalks at or near right angles. This unit usually appears light in color, but may be dark if it is in shadow or if it is constructed of dark pavement.
Formal Parking	Identified as well defined parking areas and driveways. This unit has lower or curvilinear polygons with distinct well-defined edge. This unit ranges in tone from a very light gray to a very dark gray.
Informal Parking	Identified as a poorly defined parking areas, driveways, or automobile traffic on what was originally greenspace. This unit has irregular polygons with indistinct or poorly defined edge units. This unit has no distinct shape criteria, but is generally larger than 5 to 10 m.
Greenspace	Identified as vegetation including but not limited to grasses, trees, and shrubs. Areas that appear to be greenspace but are in shadow are classified as greenspace if they are dark. These areas appear to be dark around their edges, generally, and have no distinct footprint. This unit often has well rounded vertical developments transmitted as trees and shrubs.

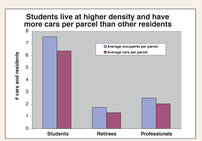
Base Map (1999)
Interpretive Map

Land use changes in the last 20 years are significant despite zoning controls

Percentage Land use for Study Area

	Greenspace	Formal Parking	Informal Parking	Building	Sidewalk
overall 1978	64.0	7.4	5.0	22.2	1.4
overall 1999	58.7	15.1	2.2	22.4	1.6
rental 1978	62.0	6.0	7.9	23.0	1.1
rental 1999	54.5	18.8	3.7	21.2	1.8
owner 1978	64.9	8.7	2.8	22.3	1.2
owner 1999	63.0	12.3	1.2	22.0	1.5

Greenspace loss is real and related mostly to non owner-occupied, rental properties.



UVM HYDROLOGY CLASS DATA 2001 -- LANDUSE CHANGE

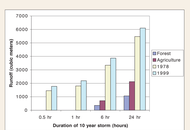
	LOCATION	PERCENT GREENSPACE LOSS SINCE 1978	PERCENT IMPERVIOUS COVER
Buell	South Side	43	76
Buell	North Side	46	78
Loomis	South Side (Willard to Union)	47	83
Loomis	North Side (Willard to Union)	48	81
Willard	Both sides (Prospect to Buell)	39	75

Students appear to catalyze greenspace loss because they live and own cars at high density.

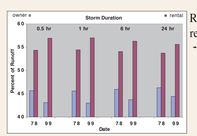
Greenspace Paving Since 1978 Increases Run Off 11% to 22% for 10-year Storm

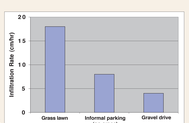
Percent of Rainfall that Runs Off -- 10 Year Storm

	30 minute	1 hour	6 hour	24 hour
Forest (<1790)	0%	0%	4%	9%
Agriculture (1820)	0%	0%	8%	17%
1978	32%	32%	38%	44%
1999	39%	39%	44%	49%
increase -- '78 to '99	22%	21%	16%	11%



RUN OFF HAS INCREASED SIGNIFICANTLY IN ONLY 20 YEARS.



Run off contribution from rentals is increasing

Parking on grass cuts infiltration by 50%