Permeability of the Berkeley Central Campus

Runoff Curve Numbers

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Abstract Urbanization changes a watershed's response to precipitation. Impervious surfaces such as buildings, streets, parking lots, driveways and sidewalks prevent stormwater from soaking into the ground, increase water flow into streams, and degrade aquatic habitats. In support of the Berkeley Long Range Development Plan, my research looked at the runoff curve number, a metric of impermeability based on soil type, land use and vegetation cover. This research provided a necessary first step in the process of moving towards the goal of "no net increase in runoff". An impervious surface ratio index and a GIS layer of runoff curve numbers were created to aid analysis of the impact of urban development on the UCB campus. Results show that the campus has a composite curve number of 69 and a 30 feet buffer from the creek of 62. Comparing natural land cover and current state of campus impermeability, results indicate that various land use type in developing the Berkeley central campus is significant enough to have an effect in influencing overall surface runoff volume.

Introduction

Because of urban sprawl, there's an increase in impervious surfaces with development and this causes urbanization to change a watershed's response to precipitation. Impervious surfaces are a primary cause of reduced infiltration, decreased travel time of water (amount of time it takes to pass over a surface) and increased volumes and rates of surface runoff (Guay 2002). The University of California, Berkeley's Long Range Development Plan has stated a goal to have "no net increase in runoff" and possibly even reduce the net runoff on the entire university campus (Karl Hans 2004, personal communication). This research had three objectives: (1) to look at the runoff curve number, a metric of imperviousness in helping to reach that goal (2) to develop a baseline map to monitor and track impervious surface area changes on the Berkeley central campus and (3) to make specific recommendations on impervious cover.

Runoff is determined primarily by the amount of precipitation and infiltration characteristics such as impervious surfaces and surface retention of water that flows from the land to streams or other surface waters (Urban Hydrology for Small Watersheds 1986). Impervious surfaces are surfaces that do not allow water or fluids to penetrate into the ground. As cities develop, natural land covers are replaced with landscaping and impervious surfaces such as buildings, streets, parking lots, driveways and sidewalks that block stormwater (rain) from soaking into the ground. These cause a reduction in the amount of rainwater that can infiltrate into the ground to recharge groundwater levels (Charbonneau 1987) as well as increase the amount of water running into streams, lakes and other marine waters (City of Olympia 1995). Increased water flow into creeks can cause pollution, stream bed degradation, bank erosion as well as destruction of aquatic habitat (Charbonneau 1987).

Each college campus in the University of California system is required by the Board of Regents to create a new Long Range Development Plan (LRDP) and environmental analysis every 15 to 20 years. The University of California, Berkeley (UCB) has developed and released a draft of the Long Range Development Plan and Environmental Impact Report that was adopted in 1990 (Janet Brewster 2004, personal communication). The plan provides detailed information on how the campus may change in the coming decades, including identification of planned land use changes and policies for development. The 2020 Long Range Development Plan Fact Sheet states that building space for academic and support programs could grow by up to 18 percent, with as much as 2.2 million new square feet of total impervious surface area over the campus.

The increase in impervious surfaces and reduction of natural land cover for infiltration could increase water runoff on campus and has the potential of greatly impacting Strawberry creek, which runs through the central campus. In addition, the LRDP has stated this goal: “Continuing Best Practice HYD-4-e: UC Berkeley shall continue to manage runoff into storm drain systems such that the aggregate effect of projects implementing the 2020 LRDP is no net increase in runoff over existing conditions.”

Although drafts of the Long Range Development Plan and Environmental Impact Report have been written, there is no good existing method or data to track the development changes in campus impervious surface space or the high flow rates of Strawberry Creek (Steve Maranzana 2004, personal communication). Pre-existing data only give information on seasonal conditions, but no per storm data exists to calculate runoff. Capital Projects is a unit within the UC Berkeley Department of Facilities Services which manages all campus buildings, including planning, design, construction, retrofitting, and restoration. Staff in the Capital Projects office uses an outline map of campus buildings and surrounding landscapes to help guide them in the spatial planning and decision making of development on campus, but the map contains no further information (Janet Brewster 2004, personal communication). An analysis on land use cover would result in information that would aid researchers and project managers in better campus improvement, planning and design.

For the LRDP, a GIS analysis done by UCB showed the central campus is a little less than 60% covered by impervious surfaces based on the degree of impervious surfaces and vegetative ground cover (LRDP 2004). This information can be used with a runoff coefficient in assessing the impact of development on runoff over an area. The runoff coefficient is a ratio of the amount of water that is not absorbed by the surface to the total amount of water that falls during a rainstorm. The scale runs from 0 to 1.0, the closer to 1.0, the greater the amount of impervious surface over an area. A runoff coefficient is developed for the entire central campus to be 0.80 (LRDP 2004). However, there is no baseline map of specific landscape data (such as runoff coefficients) of the campus to assist the work of planners, designers and analysts (Janet Brewster 2004, personal communication). A runoff curve number (RCN) is similar to a runoff coefficient, but reflects the impermeability of a given land use. It is based on a scale of 0 (high permeability) to 100 (low permeability) and is commonly used in the Soil Conservation Service (SCS) curve number method for calculating surface runoff from precipitation. The parameters for determining the curve number are more defined than the ones given in the runoff coefficient and therefore is the preferred method over the runoff coefficient.[1] This study created polygon maps in GIS of impervious surfaces, runoff curve number data, and uncertainties for the various campus surface spaces to help campus planners and designers calculate surface runoff and evaluate the impact of development on the Berkeley central campus.

Methods

Study Site The study site for this project was UC Berkeley's central campus in northern California, located on the Strawberry Creek watershed. Data was collected in the months of March and April of 2005 in collaboration with the Office of Environment, Health and Safety Department and the Capital Projects Department of the University of California, Berkeley.

Materials Developed empirically by the Soil Conservation Service (SCS), the Runoff Curve Number Procedure is a simple and commonly used method to gather data for small, urban watersheds (Hans 2004 and Viesmann 1996). Data requirements for this project include soil data, land use, and drainage area (Roberts 2003). The classification charts, tables and graphs in the Technical Release 55 by the Natural Resources Conservation Service (NRCS) were used to help determine the RCN. Vector polygon layers for use in GIS were obtained from Janet Brewster in UCB Capital Projects in order to develop new map layer of runoff curve numbers. Input layers included *city blocks*, *campus hardscape* (outline of campus driveways, walkways, patios, buildings, etc.), *buildings* (campus buildings), *athletic fields* (campus sports fields), *green layer* (campus vegetation), *natural areas* (campus designated nature areas), and *streams* (Strawberry Creek). ArcGIS software is needed to record and compile the data into a map.

Step 1:	Step 2:	Step 3:	Step 4:	Step 5:
Obtain Vector layers	Divide map into quadrants	Go to field to determine curve numbers	Assemble map	Analyze map to determine relations with intense runoff and imperviousness.

Figure 1. Step-by-step summary of methods.

[1] The runoff coefficient is commonly used in urban environments where as the runoff curve number is more commonly used in suburban and agricultural areas. UC Berkeley is classified between urban and suburban environments with its classification closer to suburban.

Procedures Methods for use in this study are summarized in Figure 1. A campus map was compiled from the given vector polygon layers and the map was divided into 10 smaller quadrants for more accurate field data collection. Each land use space was represented by a polygon shape in the map. Figure 2 summarizes the procedure in determining the curve number. Because the SCS Runoff Curve Number Method was empirically developed, assumptions were made in all areas of data collection not clearly defined.

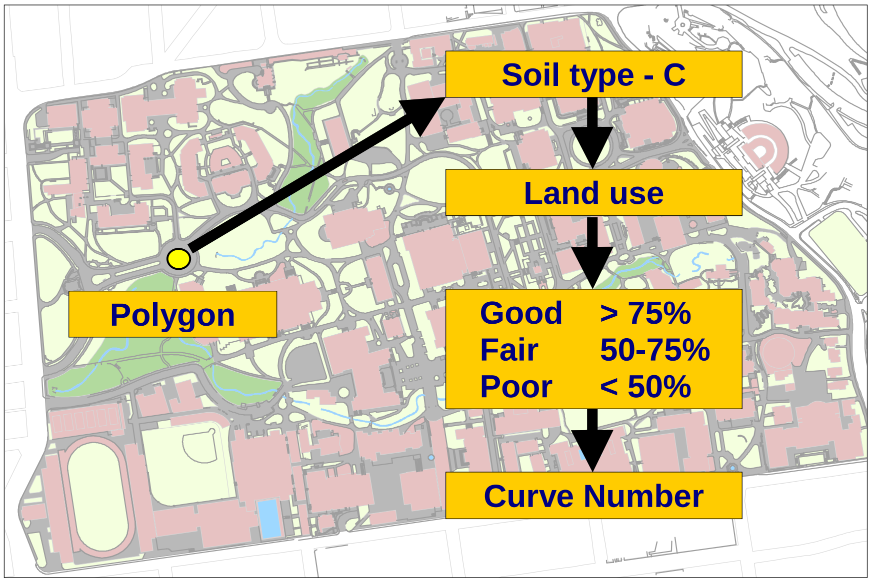

Figure 2. Procedure for determining runoff curve number.

Hydrologic soil groups defined by the SCS were used to estimate runoff potential of each soil type in the watershed based upon its infiltration capacity. Infiltration rates decrease and surface runoff potential increases as soil types are classified A through D (Urban Hydrology for Small Watersheds 1986). Soil type was determined through the Western Alameda Soil Survey (Welch, Lawrence 1981) with help from Ronald Amundson and Cristina Castanha. Soil type for the Berkeley central campus was assumed to be clay loams.

Field identification of land uses were either classified as *impervious* (buildings, roads, sidewalks, etc.) *pavers* (concrete bricks), *open space* (lawns, vegetation landscaping, parks, etc.), *bare soil* (no vegetation), *pools* or *fountains* in "urban areas". Open space land uses were further identified based on percentage of vegetation cover out in the field. Vegetation cover was either considered in good (>75% vegetation cover), fair (50-75% vegetation cover), or poor condition

(<50% vegetation cover). All plots of vegetation except for natural-areas were assumed to fall under '*open space*'. All vegetation cover was assumed to be the same as grass. Mulched areas were assumed to be bare soil or newly graded areas. Natural-areas were assumed to be the same as *Oak-aspen* in "arid and semi-arid rangelands". Synthetic athletic fields were assumed to be the same as grass. Tennis courts were assumed to be the same as impervious cover.

The appropriate hydrologic soil group (Appendix B) and land use were cross-referenced on a table developed by SCS to determine the RCN (Appendix A). Determination of drainage area was done by ArcGIS. All data collected were then inputted into ArcGIS software.

Technique of Analysis GIS technology enables data from the entire study site to be viewed clearly and easily through visual maps that allow for ease in interpretation and analysis. ArcGIS 8.3 software was used to assemble a polygonal layer of runoff curve numbers.

Results

The Western Alameda Soil Survey revealed the soil of the central campus to be urban (disturbed) soil. The hydrologic soil group classification for the Berkeley central campus is C with clay loams (Castanha 2005 and Amundson 2005, personal communication).

Cover Type		**RCN**
Impervious (Buildings, pavement, etc.)		98
Pavers		
	(Poor condition)	97
	(Good condition)	96
Athletic Fields		
	Tennis Courts	98
	Grass Fields/Synthetic Turf (Good condition)	74
Bare Soil		91
Open Space		
	(Poor condition)	86
	(Fair condition)	79
	(Good condition)	74
Natural Areas		
	(Poor condition)	75
	(Fair condition)	58
	(Good condition)	42
Pools and Fountains		1

Table 1. Runoff curve numbers used for UC Berkeley campus surfaces.

Table 1 shows the curve numbers for the different land uses in this study. All impervious surfaces such as buildings and roads on campus were found to have a RCN of 98. Pavers in good condition were found to have a RCN of 96; fair condition with 97. Bare soil or newly graded areas had a RCN of 91. Good condition open spaces have a RCN of 74, fair condition have a RCN of 79, and poor condition have a RCN of 86. Athletic fields were divided into two groups: pervious and impervious. Pervious fields were considered the same as grass with RCNs of 74 and impervious fields had a RCN of 98. Natural areas included Grinnell, Wickson, and Goodspeed, which had a runoff curve number of 49. Pools and fountains had a RCN of 1. Composite RCN for the central campus is 69. All numbers can be visually seen on the map created (Fig. 3). The composite RCN of the buffer around Strawberry Creek is 62 (Fig 4).

A total of 886 polygons were used in this study. *Buildings* had a total of 128 polygons and *campus pavement* had a total of 95 polygons. *Pavers* had a total of 10 polygons, a*thletic fields* had a total of 20 polygons and g*reen layer* had a total of 621 polygons. *Natural areas* had 4 polygons and *pools and fountains* had 8 polygons.

Vector Layer	Area (sq ft)
Buildings	2,589,496
Campus pavement	2,435,937
Pavers	75,881
Athletic fields	736,966
Green layer	2,598,005
Natural Areas	383,727
Pools and Fountains	24,478
Total	8,844,490

Table 2. Area distribution of land use on UC Berkeley central campus.

Imperviousness of the Berkeley central campus is calculated to be about 61% (Fig. 5).

The UC Berkeley central campus is comprised of 8,844,490 square feet, distributed as follows: 29.3% occupied by buildings, 27.5% by campus pavement, 0.9% by pavers, 8.3% by athletic fields, 29.4% by green layer (vegetation), 4.3% by natural areas, and 0.3% by pools and fountains (Table 2). Relative amount of space and number of polygons for each curve number were plotted (Fig. 6).

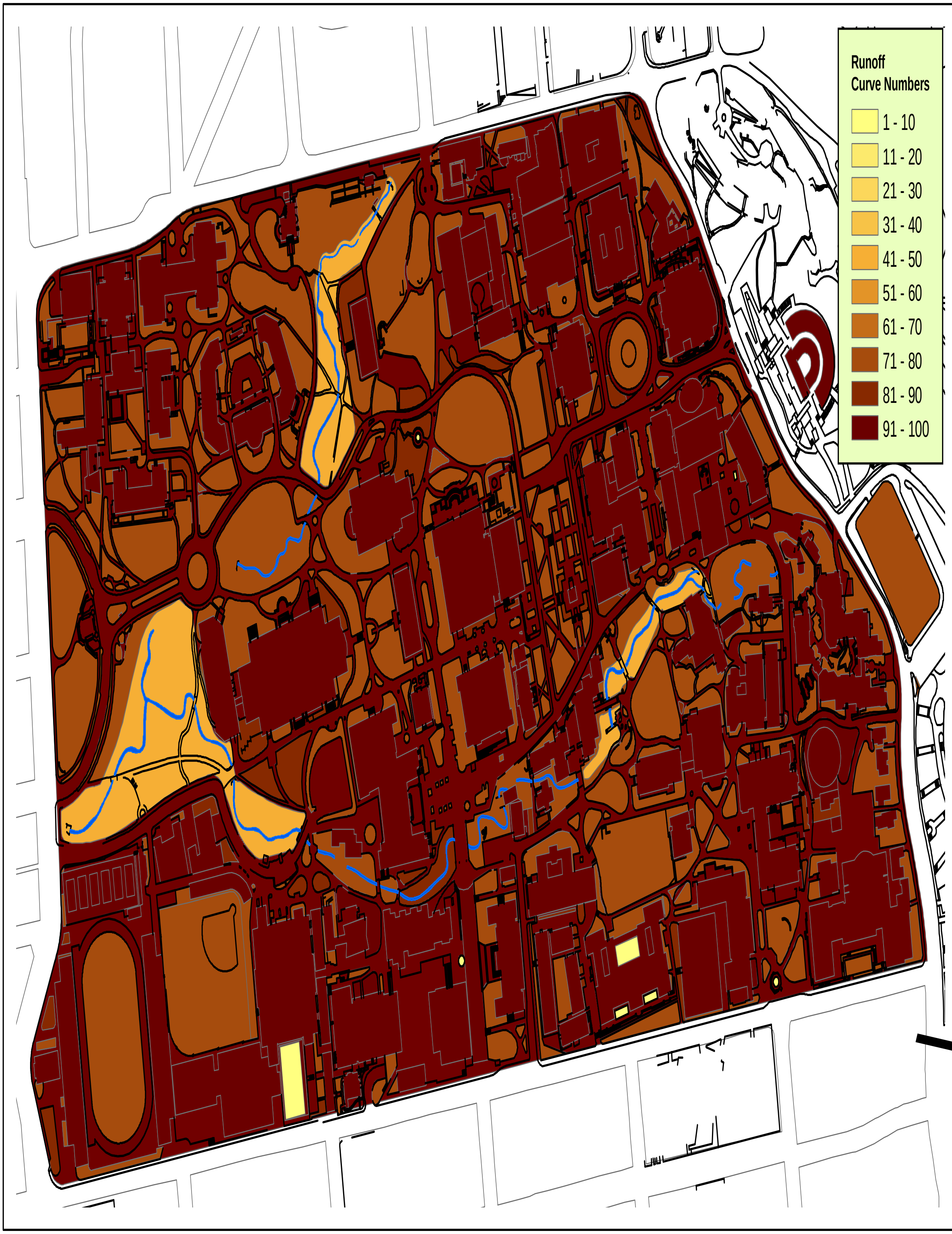

Figure 3. Curve number of the Berkeley central campus. Map created by Christina Yeung 5.9.05

Figure 4. Curve numbers of buffered creek Map created by Christina Yeung 5.9.05

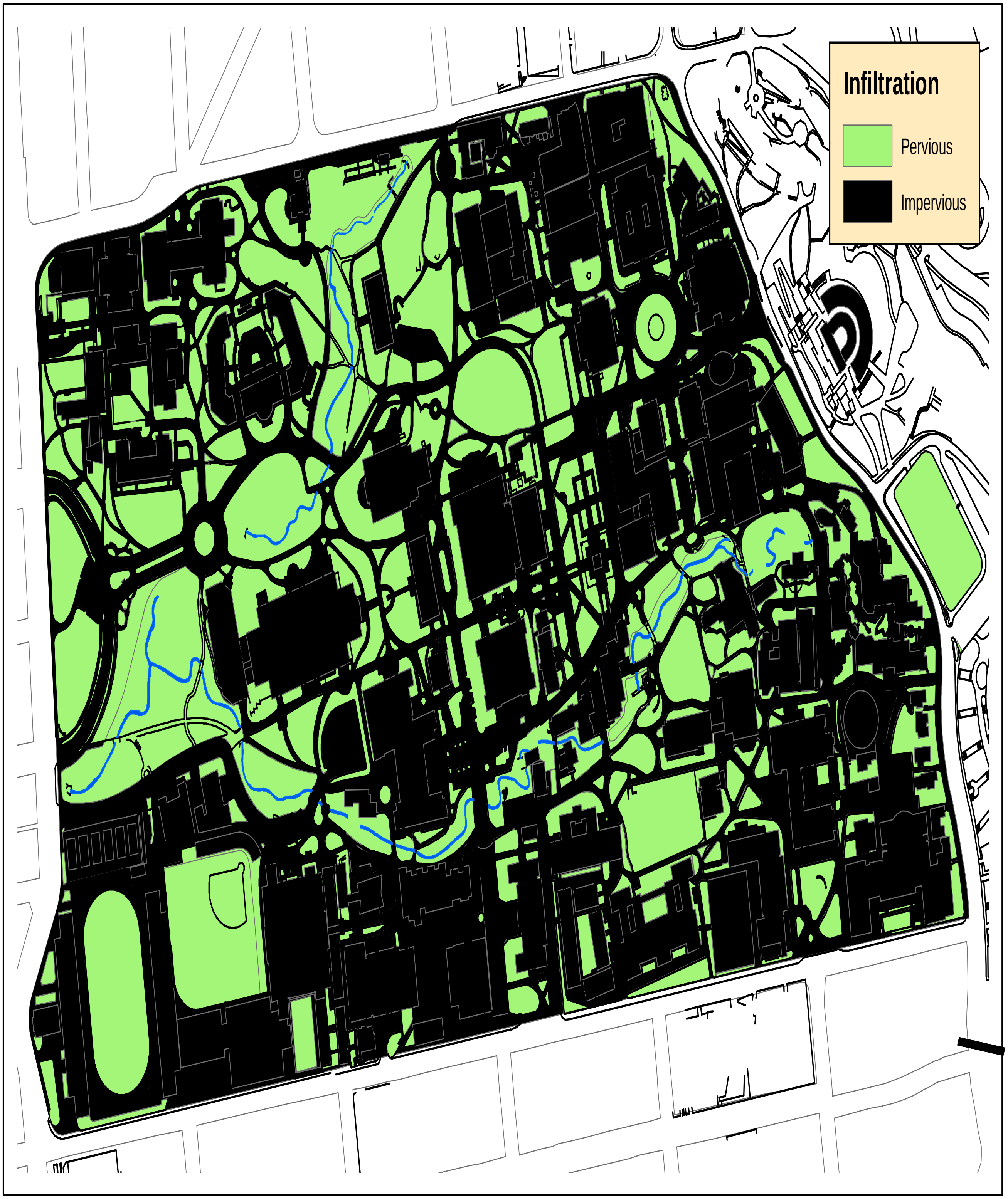

Figure 5. Permeability of the Berkeley central campus

Map created by Christina Yeung 5.9.05

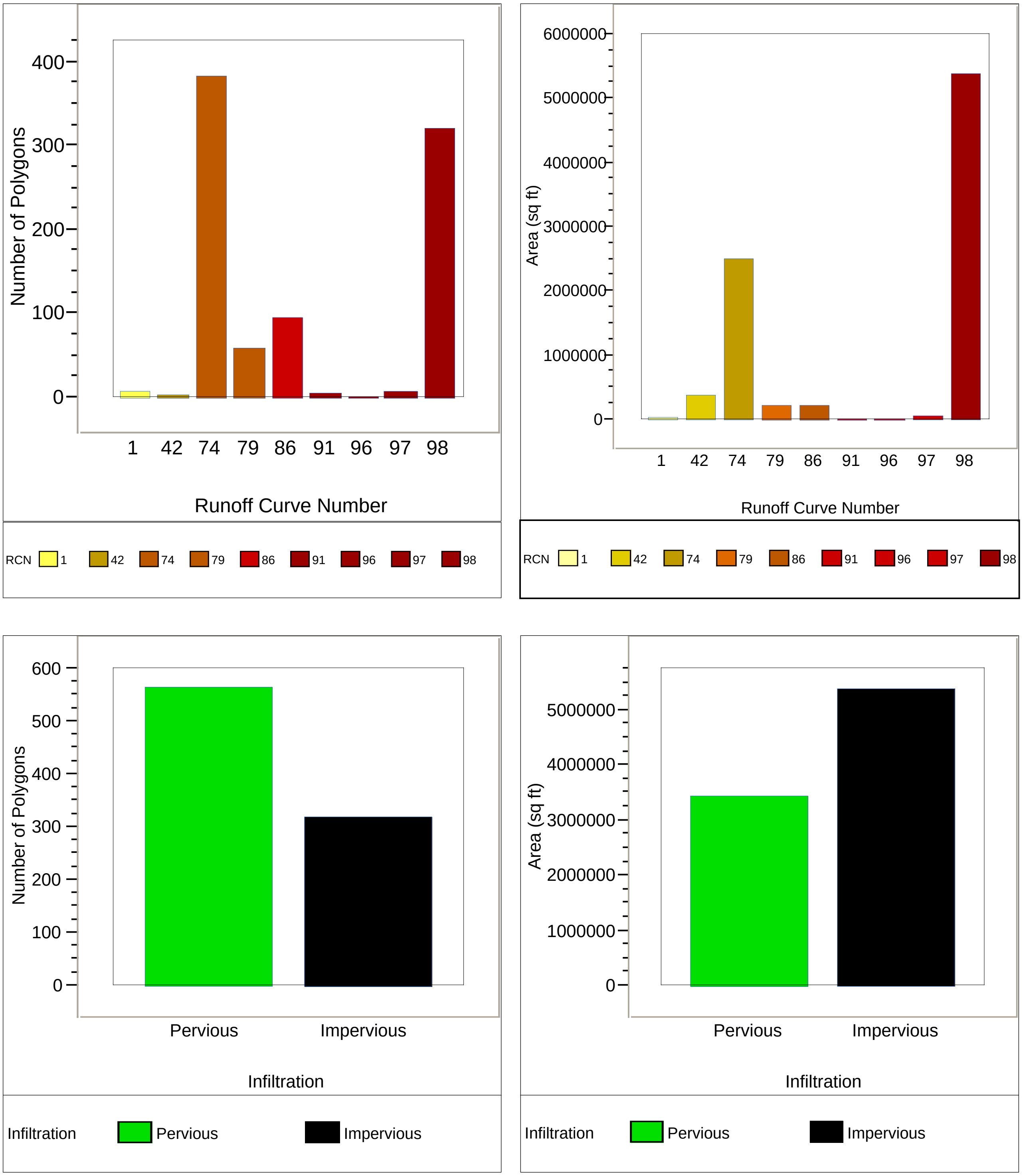

Figure 6. Frequency distribution showing number of polygons by curve number (left) and area by curve number (right).

Discussion

The map layer of runoff curve numbers generated by this study will be used by University researchers, planners and designers to determine how patterns of intense runoff distribution correlate with the streams, city blocks, buildings, and vegetation layers of the Berkeley campus. The map will track the development of impervious surface cover and be used as a gauge to assess runoff patterns and areas of most influence and impact based on concentration of high and low curve numbers. These patterns will guide policy, regulations and plans in the development projects on campus. Runoff curve numbers will also indicate percent of impervious surface cover and the new map will be useful for research and planning analyses of the Berkeley central campus.

Native soil characteristics do not accurately represent the soil profile under Berkeley's central campus because the soils have been greatly disturbed due to development. The classification of "urban land" under the central campus from soil surveys gives little to no information as to what the soil properties are. This makes it difficult to assess the hydrologic group appropriate for this study. Based on estimation of infiltration rate and a general description of the soil to be a clay loam, an assumption was made for the central campus soil to be classified as hydrologic soil group C. A limitation to this assumption is that the actual behavior of the soil may be closer to hydrologic soil group D because the level of disturbance and compaction of soil from development may cause the infiltration rate of the central campus to be lower than expected. An unexpected result of this study was that landscaping is a huge factor in changing the soil properties of the campus. Landscaped areas have a general compaction of 85% (Kate Bolton, personal communication) perhaps to keep the land leveled enough for heavy lawnmowers to maintain the grass without modifying the natural hills and bumps on the campus landscape.

The rate of infiltration of all vegetation was assumed to be similar to grass. In actuality, different types of vegetation take up different amounts of water at different times and this variability will therefore add some degree of uncertainty to the map. Another limitation to this study is the range of uncertainty due to seasonal change. All data collected represent only a snapshot in time, not an accurate representation of the average RCN over the year. Years with more rain may produce better vegetation cover than years with less rain. This study quantified the range of uncertainties (Fig. 7). Further research should however be done to reduce these uncertainties.

Since campus runoff flows into Strawberry Creek, its health is especially sensitive to the surrounding area. The composite curve number of central campus was compared to that of the buffered area of 30 feet taken around Strawberry Creek, which was assumed to represent an area with naturally high infiltration. The composite RCN around the creek was 62, however, which is high compared to the overall campus curve number (69). This suggests that the areas around the creek are fairly impacted by impervious cover and any increases in impervious surfaces in these areas can have major effects on the curve number. Further research needs to be made around the creek buffer to see if tree vegetation will mitigate the problem of bare ground cover and help to reduce the uncertainty level of each land cover. However, because of the small amount of impervious surface area present 30 feet around the creek, there are few recommendations that can be made to reduce the RCN.

Recommendations Because the level of imperviousness for the Berkeley central campus is high, best management practices such as using pavers should be implemented during all construction projects on campus. These permeable surfaces can influence the level of runoff into the stream during small storms. Implementation of these practices would be a small step towards maintaining the level of runoff from increasing. More research in mapping vegetation data onto the map would help in decreasing some of the uncertainties in the runoff curve number and account for more accurate assessment of runoff. Continuous monitoring of land use cover would eventually decrease the uncertainty of seasonal changes.

Based on the high RCN of the buffer around the creek, few changes would have a high impact in increasing infiltration and decreasing the RCN. Suggestion of similar research on mapping of sewer intakes that drain into the creek would be a step in seeing if major reduction of runoff is possible.

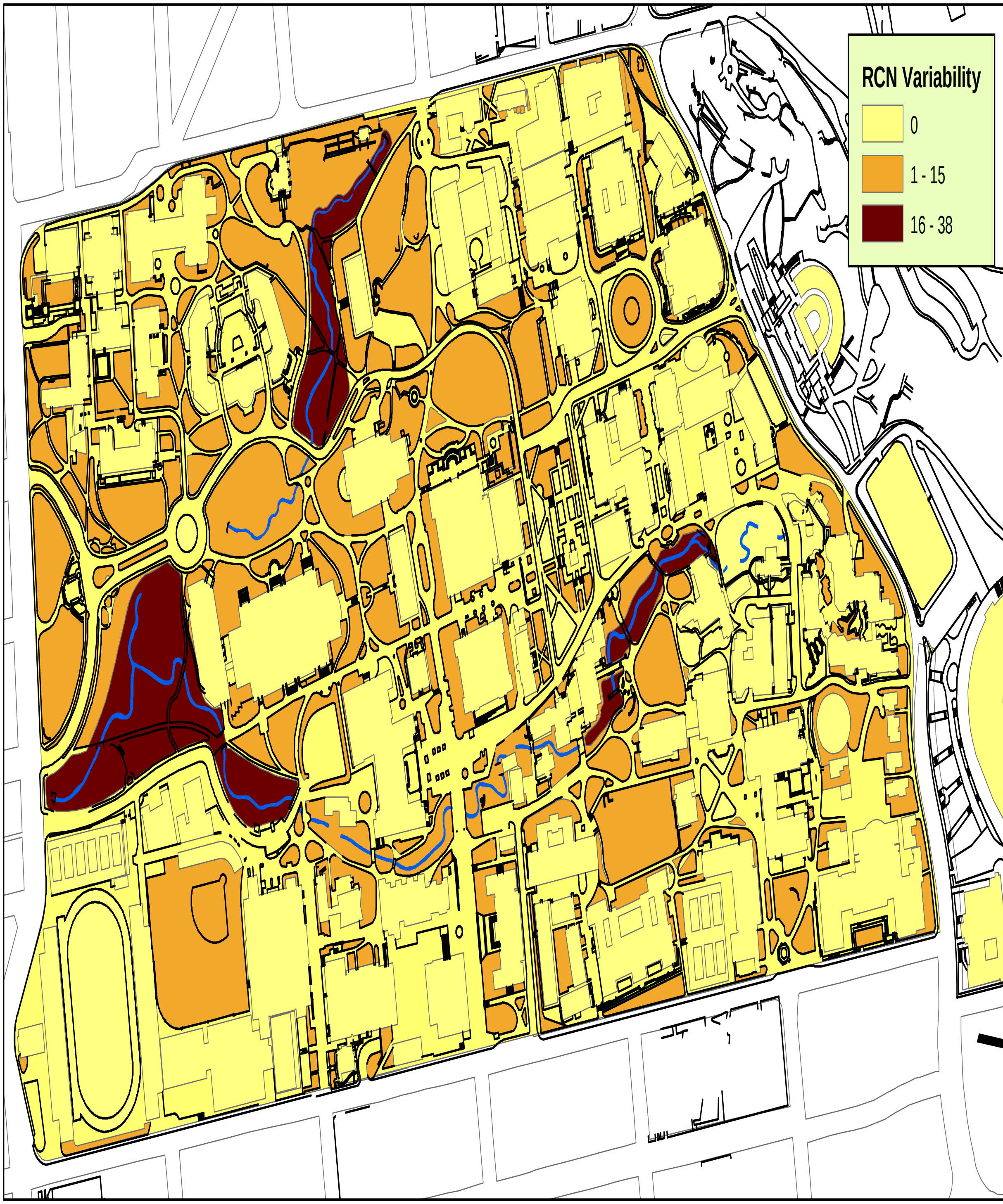

Figure 7. Uncertainty of runoff curve numbers

Map created by Christina Yeung 5.09.05

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