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1.85 Design Project  
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**MIT Kresge Parking Lot:  
Development of Rain Garden to Control Stormwater Runoff**

*Summary*

This proposal addresses the concern of stormwater runoff associated with the MIT Kresge Parking Lot. This problem has become a concern due to recent decisions by the Commonwealth of Massachusetts and the Department of Environmental Protection to apply the current state Stormwater Management Policy to pre-existing developments. The policy requires Best Management Practices (BMPs) which at minimum include extended detention time ponds, sand and organic filters, and/or pre-treatment devices in order to comply with water quality and quantity standards set forth by the state in compliance with the Clean Water Acts and the Wetlands Protection Act.

*Background*

Stormwater runoff, including rain and snowmelt, occurs in areas where impermeable surfaces such as cement and concrete have replaced what was once natural land, forcing precipitation that once slowly infiltrated the land to collect, often accumulating and transporting pollutants. Among the problems caused are flooding during heavy rain, increased erosion and stream velocities, movement of ground chemicals, pathogens, and metals into water streams, and nutrient transport and subsequent eutrophication of water bodies. All of these problems affect plants, animals, and humans through pollution of natural water bodies, groundwater, and human drinking water.

As such, the state requires BMPs that maintain at minimum the Stormwater Management Standards. These standards, as previously mentioned, require that stormwater be treated before discharge and maintain pre-development discharge rates. Likewise, groundwater recharge rates must not exceed pre-development rates. The standards also call for pre-treatment "to the extent practicable" and 80% removal of Total Suspended Solids (TSS). In order to do this, recommended BMPs include extended detention time ponds, sand and

organic filters, and/or pre-treatment devices. Further specifications are outlined in the Stormwater Management Policy (available through the DEP).

The Kresge Parking Lot site qualifies as a "high potential pollutant load" site due to pollution from cars parked in the lot and heavy pedestrian traffic. This designation makes it subject to the above regulations regarding stormwater runoff. Yet, currently, no such stormwater management strategy exists, even though the pavement prevents water from infiltrating into the water table below. Instead, the water often collects in the lot (although a small sewer exists on one end of the lot). This water becomes polluted and floods into nearby vegetation, roadways, and athletic fields

In order to evaluate potential solutions to this problem, some additional background information on the site should be considered. Located on the MIT campus, the lot is approximately flat and has a surface area of 24100 square feet. This area has a moderate climate, with less than 0.13 inches of precipitation daily throughout the year, although summer months may be even drier, expecting less than 0.10 inches of rain daily (NOAA, 2005). On average, only ten days per year receive precipitation of greater than one inch in one day, and in the past 50 years, precipitation has only exceeded five inches in one day once, in 1955 (NOAA, 2005). The flat surface area and moderate rain volumes suggest that a simple system may be sufficient in alleviating the stormwater problem. An MIT map and a detailed site map are included on pages 1 and 2 of the Appendix.

There are many potential solutions to the stormwater runoff at the Kresge site. Among those suggested in the Stormwater Management Policy are extended detention basins, wet ponds, constructed wetlands, sand/organic filters, and infiltration basins or trenches. While these are all viable solutions, many of these are expensive and require large areas of land that are not present at the Kresge location. In addition, the Kresge Lot is frequented by many visitors to MIT, and there is a strong desire for not only an economical solution, but also an aesthetically pleasing one. Likewise, MIT prides itself on seeking out new and creative engineering design solutions.

### *Proposed Solution*

The solution proposed here is for a rain garden, an innovative and inexpensive way of treating stormwater that requires little space and maintains that aesthetic quality of the area. A rain garden is a bio-retention area made up of plants and mulch that serve to collect and clean stormwater runoff and allow it to infiltrate into the water table below. At the same time, the area serves as a garden, providing "natural" beauty to the area. This approach to collecting and treating stormwater runoff was developed in 1990 in Maryland, and has only begun to gain popularity in the last ten years, as awareness of the method has increased and experimental data demonstrating its success has been published. Still, few rain gardens exist in New England, and thus such a solution would make MIT a "green" example to its neighbors (Pennell, 2003).

Rain gardens consist of several mechanisms to alleviate stormwater runoff concerns. As Hunt and White (2001) describe, rain gardens first act to congregate and store the water in one place, removing the issue of potential flooding. Next, the top-level mulch and soil act on the principle of absorption to remove some metals and phosphorus from the water. Absorption occurs as the charged dissolved metal and phosphorus are attracted to and effectively removed by the charged soil and mulch particles. The shallow root area below the surface then stimulates microbes which breakdown organics and remove pathogens. In addition, because rain gardens are *not* wetlands, they are rather dry and further facilitate the breakdown of pathogens, which cannot exist in drier areas. Nutrient levels are also slightly depleted through plant uptake by garden vegetation. Note that dead plants must be removed from the rain garden so that nutrients do not enter the water stream. In addition, because water is being held in the garden and slowly infiltrated into the water table instead of flowing directly into lakes and streams, there is additional time for nutrient removal.

As Horne (2005) describes, rain gardens maintain recharge and discharge rates no faster than pre-development rates. Discharge rates through the soil are controlled because water may only infiltrate as quickly as the soil below and around the garden basin allow it. Likewise, an overflow box located in the center of the garden will collect excess water and pipe it into the existing MIT stormwater system, where it may discharge into the Charles

River. Yet, due to the presence of the rain garden, significantly less water will be going into this system to begin with, controlling discharge rates.

Finally, the most critical problem with wastewater flows is TSS levels. Rain gardens use sedimentation and flocculation to remove dissolved particles. Sedimentation occurs naturally because flows are slowed down and held for longer periods of time in the garden, whereas otherwise they may flow quickly into other areas. Filtration also occurs to a lesser degree due to the presence of vegetation, such as grass, which filter out larger pieces of debris (Hunt and White, 2001).

### *Specifications*

The rain garden at the Kresge Lot will be located along the central median of the parking lot. Because the area already has limited parking, the goal is to not remove any parking spaces. Luckily, with spacing as it is right now there is room to move the car spaces out and still have sufficient room for cars to move through the lot and park. As the calculations on page 4 of the Appendix demonstrate, a surface area of 1730 square feet is desired in order to maintain a rain garden surface area to total surface area ratio of between three and eight percent (as suggested by Hunt and White, 2001). Because there are already two islands of grass located on each end of the parking lot's central median, it is natural that the rain garden will extend between these two, especially considering the lot sewer is directly connected to one of the islands. Thus, the rain garden will consist of a 216-ft by 8-ft rectangle located along the median of the parking lot. See attached map of proposed rain garden site on page 2 of the Appendix.

Because the lot is approximately flat and already contains a slight slope toward the center for drainage into the sewer, the garden should require relatively little excavation or amendments to the lot itself. Instead, the garden will be simply surrounded by curbs to protect it from cars. The water will flow in through the spaces between the curbs and enter into the garden, which will be recessed approximately three inches below the edge of the pavement. This will prevent blockage of water coming in, as the plants within the garden will grow up slightly. Next, as suggested by Hunt and White (2001), the garden will be trough-shaped, dipping to approximately 11 inches in depth along a wide center line and

encouraging water to flow fully into the garden. The land will be shaped to slope downwards radially outwards from all inputs to help enhance even spread of flow. The 11-inch depth was calculated such that the entire water garden may hold one-inch of precipitation coming from the parking lot. This one-inch value is the standard design specification recommended in the SMP. Detailed site drawings and full calculations are shown on pages 3 and 4 of the Appendix

Of course, to control for the possibility that more than one inch of precipitation occurs, a storm grate and catch basin will be built in the center of the rain garden and rise 11 inches out of the garden. This event occurs on average 10 times per year (NOAA, 2005). The metal box will be approximately 2-ft by 1-ft and likely painted green to blend in with surroundings. On the top of the box will be a grate so that water, but not large objects, may flow into the box and drain through an exit pipe on the bottom into the MIT storm sewer, which then flows into the Charles River. See map on page 2 of the Appendix.

The entire area of the garden will have to be excavated approximately four and a half feet. As recommended by Hunt and White (2001), there will be a three-inch mulch layer everywhere except along a one-foot grass radius of the rain garden. This grass ring will greatly reduce TSS levels as water enters into the garden. Additionally, between the grass and mulch coverings will be a thin perimeter of gravel to further facilitate even distribution of water into the rain garden. The mulch within this will be double shredded hardwood mulch, which has shown to work best because it doesn't float (Hunt and White, 2001). See detailed site drawing on page 3 of the Appendix.

Below all of the surface covering will be a four-foot layer of loamy sand fill soil, as multiple sources recommend. Approximately the top six inches of this will contain roots and vegetation, thus the soil will be mixed with organics. The loamy sand soil has shown to work well because of its balance between clays and sand. As Pennell (2003) recommends, the soil should be 50-60 % sand in order for water to infiltrate through it, yet must contain enough clay to absorb pollutants. Such a soil will have permeability of one to six inches per hour. Below this soil, the water will continue to infiltrate into the water table below. A garden profile is shown on page 3 of the Appendix.

Within the mulch layer, plants will be grown to provide a natural look to the area. keep humans off the land, and aid in absorption and nutrient removal. The rain garden is not a wetland, but it must be able to handle inundation with stormwater periodically. Note that the plants will be planted into the soil, and then covered with the mulch. Hunt and White (2001) suggest that facultative plants work best. There is some flexibility in plant choice, although one should choose greenery that will compliment each other aesthetically, provide growth during all seasons, and not develop extensive root systems that may clog up the rain garden. Native plants are also preferred and generally work best. Some plants suggested by Taylor Creek Nurseries are the New England aster, sneezeweed, elderberry, and bottlebrush sedge (2004). In addition, some larger shrubs will be added.

### ***Timeline, Maintenance, and Costs***

The garden building process will require small rented machinery to break up and transport the parking lot pavement. From there, excavation of the soil may occur either manually or using a small excavator. Either way, this entire process may likely be done over the course of one to two days. Curbs must then be placed surrounding the outside of the garden, and parking space lines will need to be extended. This may take one day also. Next, the overflow grate and pipes must then be imported and connected to the main system, which given the location should be a simple process requiring only a few hours of manpower. The rest of the garden should then be filled with soil as specified above, and plants, grass, and gravel placed on top. Depending on growth times of the grass and plants (some of which may be imported pre-grown), the garden may be fully functional within a few weeks.

Once in place, the garden requires very little maintenance. The plants must be groomed, the grass cut, and the dead plants removed, however beyond that there is little required in maintaining a rain garden. Additionally, studies have shown that such gardens seem to work well at treating waste water for approximately ten years, after which time it may be necessary to replace soil and mulch (Hunt and White, 2005).

The costs associated with such a project are difficult to predict and will require on site evaluations. However, in general, multiple other projects (Hunt and White, 2001; Horne, 2005) suggest that costs should run less than \$10 per square foot and may be as low as \$1.50 per square foot. This data suggests a total cost of \$17,300, plus the costs of maintenance. This is significantly less than other projects, which may run as high as \$100,000

**References:**

Horne, John, 2005. King of Glory Lutheran Church: Rain Garden Demonstration Project. Website. Protecting Resources in Delicate Environments: Water Quality Education Program, James City County, Virginia. ([http://www.protectedwithpride.org/news\\_101803\\_pr.html](http://www.protectedwithpride.org/news_101803_pr.html))

Hunt, W. F., and N. White, 2001. Urban Waterways: Designing Rain Gardens (Bio-Retention Areas). Fact Sheet AG-588-3. North Carolina Cooperative Extension Service, Raleigh, North Carolina. June 2001. ([http://www.bae.ncsu.edu/content/bioretention/lecture/design\\_rain.pdf](http://www.bae.ncsu.edu/content/bioretention/lecture/design_rain.pdf))

National Oceanic and Atmospheric Administration, 2005. Website. U.S. Department of Commerce. April 22, 2005. (<http://www.erh.noaa.gov/box/climate/pcpnbos.html>)

Pennell, Patricia, 2003. Rain Gardens of West Michigan. Website. West Michigan Environmental Action Council, Grand Rapids, Michigan. (<http://www.raingardens.org/Index.php>)

Taylor Creek Nurseries, 2004. Build your own Rain Garden. Design Sheet # 1. Native Landscapes by AES, Brodhead, Wisconsin. (<http://www.appliedeco.com/Projects/Rain%20Garden.pdf>)

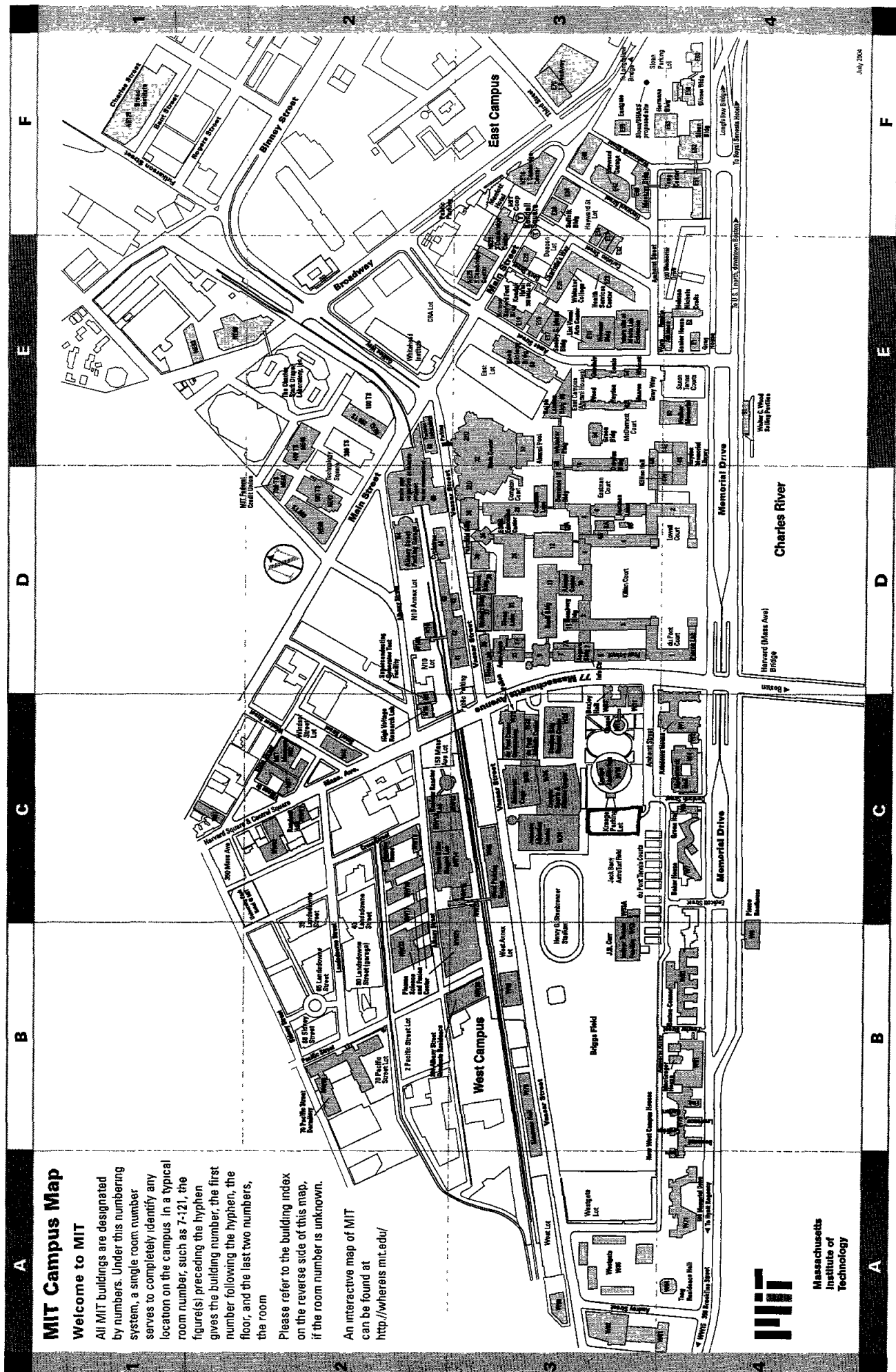
**APPENDIX:**  
**Maps, Figures, and Calculations**



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# MAP 1: Campus Map (site highlighted and outlined in red)



## MIT Campus Map

### Welcome to MIT

All MIT buildings are designated by numbers. Under this numbering system, a single room number serves to completely identify any location on the campus. In a typical room number, such as 7-121, the figure(s) preceding the hyphen gives the building number, the first number following the hyphen, the floor, and the last two numbers, the room.

Please refer to the building index on the reverse side of this map, if the room number is unknown.

An interactive map of MIT can be found at <http://whereis.mit.edu/>



Massachusetts  
Institute of  
Technology

# MAP 2: Details of Kresge Lot and Basic Design Proposal

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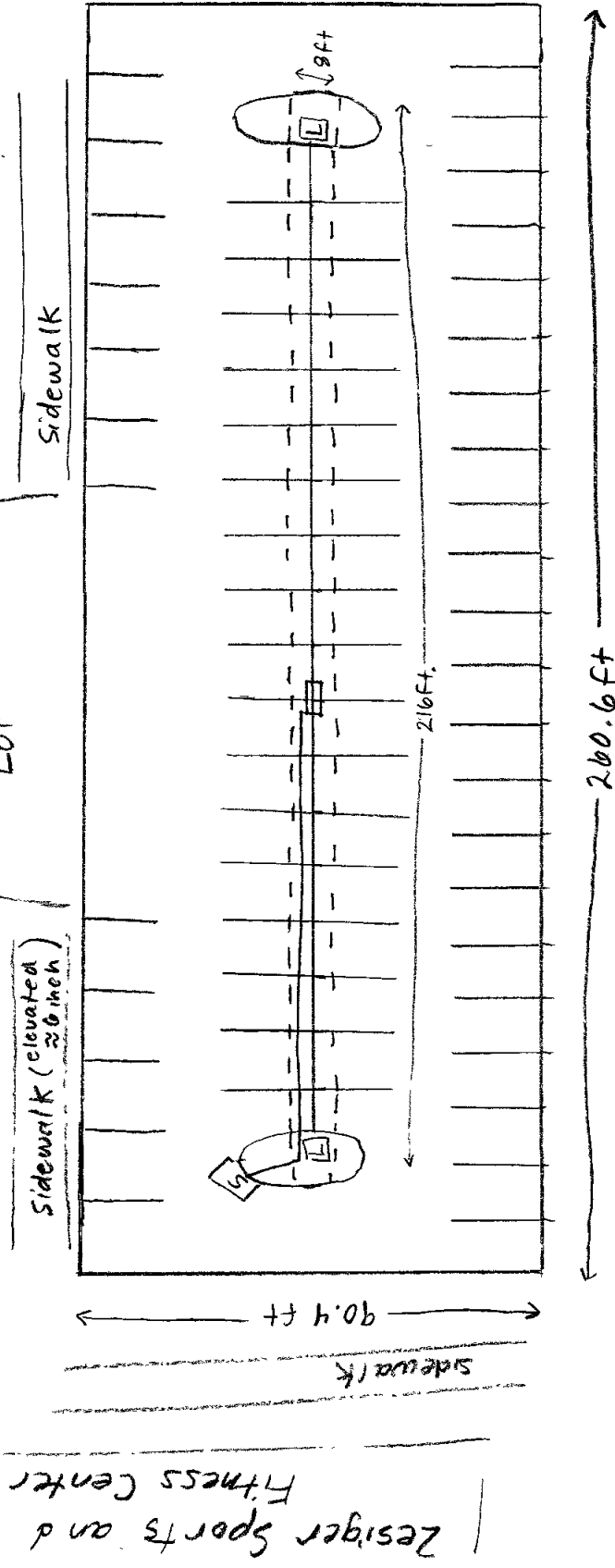
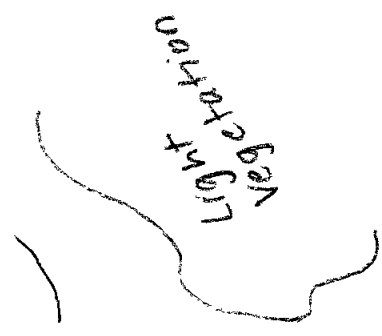
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scale: 1 inch = 35 ft

Legend:

- [L] = light
- [S] = sewer
- - - = proposed rain garden
- [ ] = overflow grate
- - - = underground piping to sewer

Exit driveway



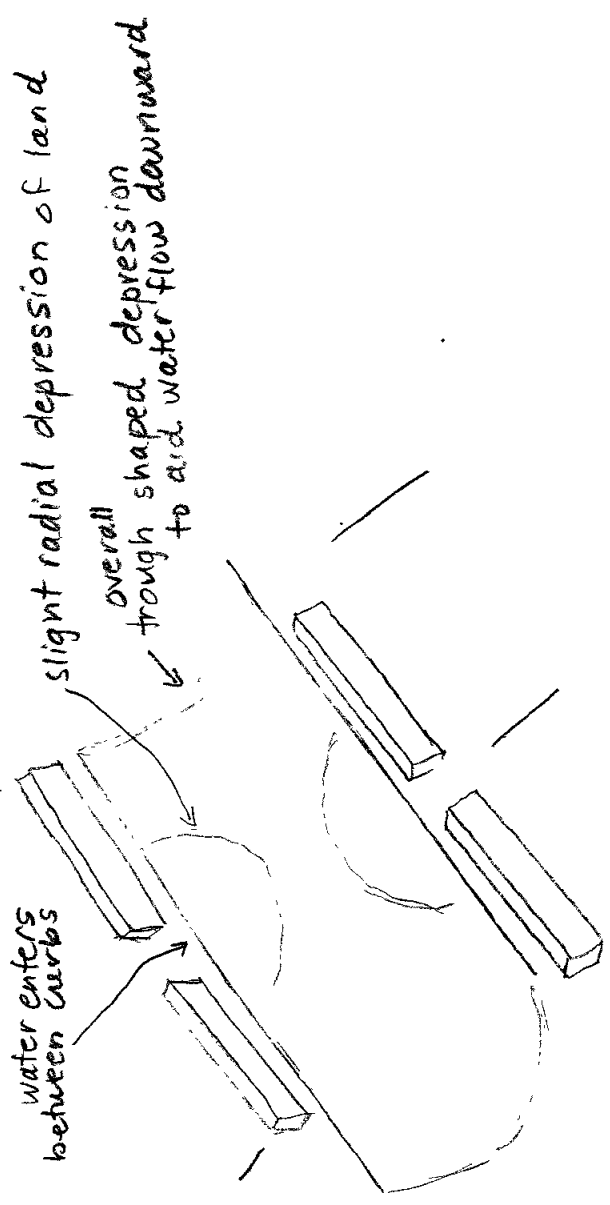
## NOTES:

- The side lot was ignored in this analysis for purposes of simplicity. The lot is actually separated from the Kresge main lot by a curb and sidewalk that rises above approximately six inches and then slants downward toward Kresge and has its own sewage drainage (thus justifying neglect).
- Proposed design will also require placing curbs along central parking spaces.

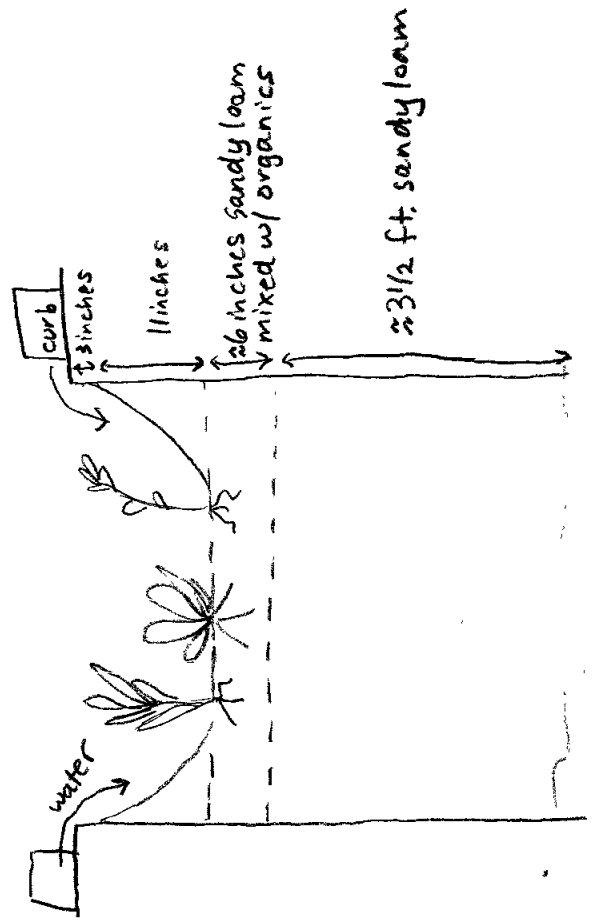
- The lot is almost entirely surrounded by a 6-inch curb that separates the precipitation into the lot with precipitation onto outside areas, which themselves add very little runoff to the lot.
- The red dotted line represents the proposed rain garden. This will require moving spots out 4 ft. on each side but current excess driving space should make this unproblematic. The overflow grate collects water in extreme situations and discharges to existing sewer.

# DETAILED FIGURES OF DESIGN

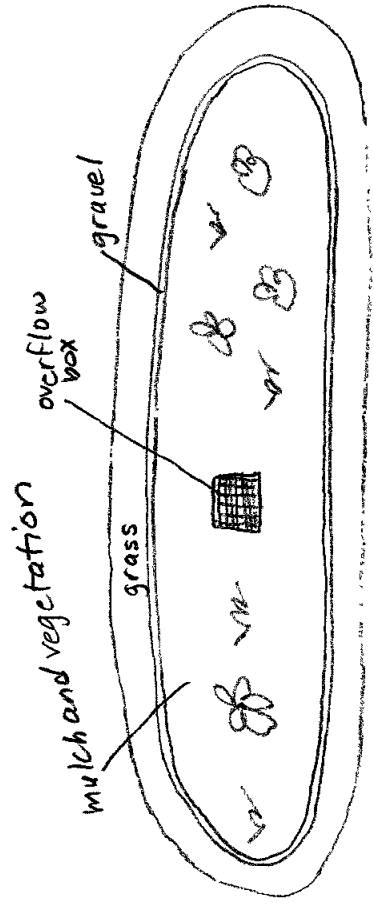
## ANGLED AERIAL VIEW OF SELECTION



## CROSS SECTION VIEW



## AERIAL VIEW OF GARDEN PLANT SETUP



CALCULATIONS: (NRCS method used, as sited in Hunt and White, 2001) 4/28/05 EW p. 4

① Design rain garden to treat first inch of rainfall (as mandated by MA stormwater Management Policy and recommended by Hunt + White, 2001)

a. Runoff depth (in inches) =  $\frac{(P - 0.2S)^2}{P + 0.8S} = R$  (E. 1)

P = precipitation = 1 inch

S =  $1000/CN - 10$

CN = curve number = how much water will infiltrate during a storm

CV = 98 for impervious surface  
(in this case parking lot)

$R = \frac{(1 \text{ inch} - 0.2(1000/98 - 10))^2}{(1 \text{ inch} + 0.8(\frac{1000}{98} - 10))} = 0.79 \text{ inches runoff}$

b. Runoff volume = Area · Runoff depth (E. 2)

$= (24100 \text{ ft}^2)(0.79 \text{ inch}) \left( \frac{1 \text{ ft}}{12 \text{ inch}} \right) = 1590 \text{ ft}^3$

c. Rain garden surface area =  $\frac{\text{Rain garden volume}}{\text{Average depth of water}}$  (E. 3)

Average depth of water = 11 inch (empirical value often chosen b/w 6-12)  
→ want rain garden to be b/w 3-8% of total area, so may need to change depth accordingly

$SA = \frac{1590 \text{ ft}^3}{(11 \text{ inch}) \left( \frac{1 \text{ ft}}{12 \text{ in}} \right)} = 1730 \text{ ft}^2 \rightarrow \frac{1730 \text{ ft}^2}{24100 \text{ ft}^2} = 7.2\% \text{ of total}$   
so works!