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UT Water Sports Facility Design

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Honors Thesis Project

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Introduction

As a senior design and honors thesis project, I worked with a group of classmates to design a new water sports facility for the University of Tennessee (UT) campus. This facility could be used by the university's water sports clubs as well as other related groups. The overall goal of the project was to provide the university with a comprehensive site design that can be implemented in the future. Our final design consisted of specific calculations, computer generated drawings, estimated construction duration, and total cost for the project. This design package will provide an accurate description of the construction work and associated costs so that the university can proceed with fundraising efforts.

Background

UT currently has several water sports teams that compete and practice on the Tennessee River. In particular, the crew club, wakeboarding, and bass fishing teams have encountered problems with equipment damage and theft. Furthermore, each team rents riverside properties that are far from campus and do not provide the necessary storage space. This requires team members to commit a great deal of time and fuel just to get to practice. With an increasing number of students travelling to these locations, vehicular accidents are more likely to occur. The proposed facility will store any needed equipment while providing river access. Ideally, the location will provide students and faculty with easy access to the facility.

Overall Project Description

Several locations were initially considered for the proposed water sports facility. A preliminary location was considered across the street from Neyland Stadium. This is where the Women's Crew team practices and has its facilities. Though this is an ideal area for a facility,

there is very limited space and limited river access due to existing riverside facilities. A secondary site was considered on the Cherokee Farm campus located across the river from UT. Although there is an abundance of open area, limited pedestrian access would still require students to travel by vehicle to get to their respective practices. An empty plot of land located next to the UT Visitor's Center was finally chosen for the location of the site (Figure 1). This area was selected due to its easy river access, proximity to campus, and pedestrian accessibility.

Despite its convenient location, other factors had to be considered in determining the site's feasibility. A major concern with the proposed site location is its steep grade. A large amount of excavation and a retaining wall will ensure that the steep slope of the site does not cause any structural problems. Another cause for concern is that the site is located near the river and is susceptible to flooding. To avoid potential flooding problems, the building footprint will be located outside the 500 year floodplain. This means that there is less than a 1:500 chance that a flood will reach the building in a given year.

Other minor issues that must be addressed are site aesthetics and traffic. The site will be located between a historic house with an extensive garden and Neyland Drive. Our design will be aesthetically pleasing so that the nearby house's scenic view is not affected. Traffic will be another key issue as the site is located on a very crowded stretch of Neyland Drive. An individual access road will be created at the new sorority village intersection to alleviate any traffic problems.

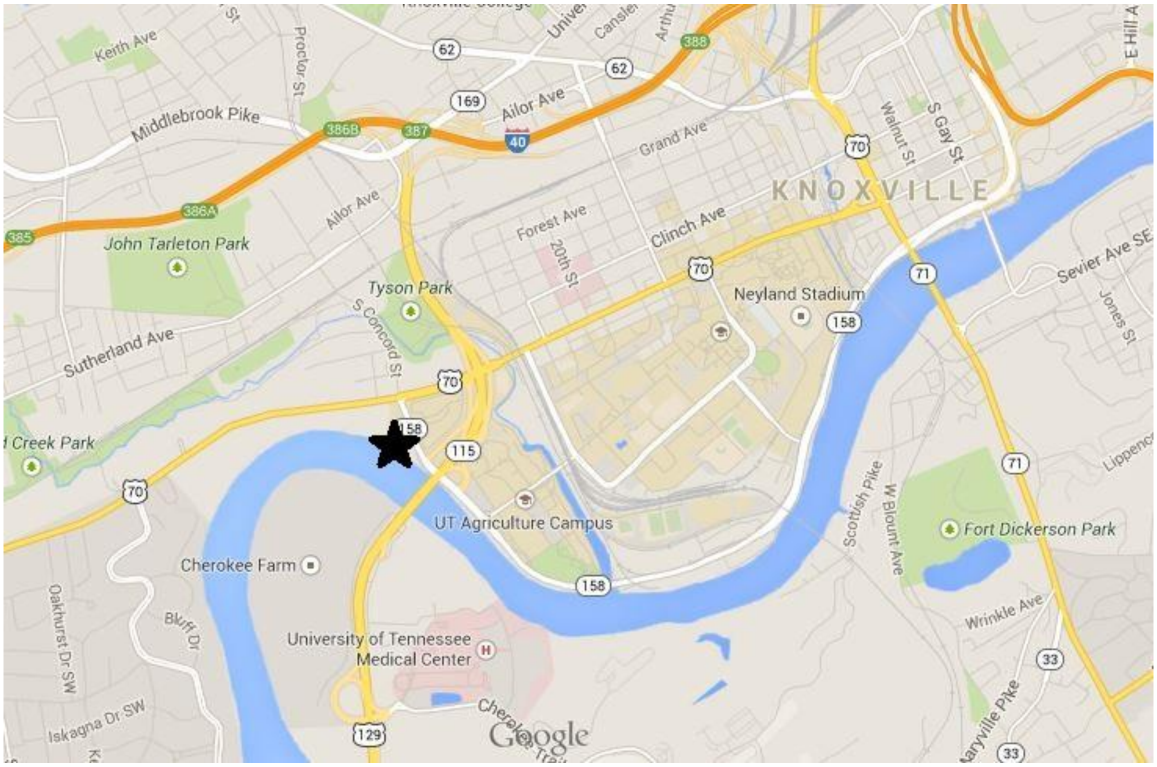

Figure 1: Site Location

Discipline Specific Description

Our project team was divided into separate work groups based on individual concentration sub-disciplines. Based on my areas of expertise within the Civil Engineering Department, I was part of the Environmental and Water Resources Engineering group. The overall goal of the Environmental and Water Resources group was to utilize sustainable practices to minimize the negative environmental effects associated with construction. A preliminary environmental assessment of the site was conducted to determine whether or not an Environmental Impact Statement (EIS) was necessary. Environmental permits were then filled out and presented to reregistered professional engineers. Based on the review of these professionals, it was concluded that an EIS would not be required.

As a part of the EPA Phase II regulations, any constructed site in Knoxville must develop site specific erosion control and stormwater pollution prevention plans (EPA, 2005). In order to do this, erosion control devices such as silt fences and sediment traps will be used to manage the site during construction (EPA, 2012). Additionally, several Best Management Practices (BMPs) need to be included in the site's construction as post development stormwater control measures. A BMP is defined as an engineered structure or system used to minimize stormwater runoff and improve runoff water quality (Knox County, 2008). This includes practices such as green roofs, bioretention cells, and retention ponds. BMPs have very unique individual functions and are used in specific areas. Because of this, it is imperative to understand a site's characteristics before choosing which BMPs to use.

The first step in this design process is evaluation of a site's pre-development and post development hydrology. This requires knowledge of the site's soil types, topographic characteristics, and construction area. Using hydrologic calculations, we determined how much rainfall volume needed to be treated and stored to prevent pollution and erosion. Next, we used a topographic map of the site to determine its steepness and the path that rainwater follows. Using this information, the appropriate site specific BMPs were determined.

Our group decided the best way to manage the site's runoff would be to implement two major BMPs with the option of including a third. The first major BMP was designed to handle the rainfall runoff from the roof. Ideally, this water would collect in a gutter around the perimeter of the roof and flow to the ground where the BMP is located. Due to the steep nature of the site, we decided that the best BMP for this specific situation would be a Step Pool Storm Conveyance System (SPSC). A SPSC system is a series of small water pools that are staggered along the slope of a hill. To ensure that these pools do not overfill, various sized rocks separate the pools

and an underlying sand filter allows water to infiltrate into the ground (Anne Arundel County, 2012). Based on a specific set of guidelines created by Anne Arundel County, Maryland, we designed a SPSC system that can manage the stormwater runoff from the building's roof. Our design was created to minimize the velocity or stormwater runoff and remove pollutants from the water.

A bioretention area was selected as the second BMP to treat the runoff created by the roads, parking lot, and other impervious areas on the site. Bioretention cells are areas that uses vegetation and special soil to remove pollutants found in stormwater. They are widely used due their versatility and are relatively inexpensive compared to other BMPs such as green roofs and retention ponds (EPA, 2012). We decided that this would be an excellent BMP for us to implement due to the limited amount of space between the parking lot and the river. Our design will capture the runoff created by the impervious sources and slowly release filtered runoff water into the river.

Personal Contribution

As a team leader, I was responsible for promoting cross-disciplinary communication within our team as well as dealing with other administrative issues. Additionally, I was the leader of the Environmental and Water Resources Engineering group. As the leader of this group, I assisted with the completion of all necessary tasks. This included calculations, design work, computer drawings, computer modeling, regulation identification, and project report writing.

For the technical component of the project, I focused on the basic hydrologic analysis of the site. The initial step I took to understand the site's hydrology was defining the site area and identifying the topographic contours of the site via Kgis.org. This was necessary in

understanding the drainage path that stormwater would take when coming in contact with the site. Using these parameters and design storms as specified in the National Oceanic and Atmospheric Administration (NOAA) data server, hydrologic calculations were performed following the TR-55 guidelines outlined in the North Carolina stormwater BMP manual. The final and most crucial step in understanding the site's hydrology was developing a unit hydrograph of pre development and post development conditions. The comparison of these two functions was necessary in determining the degree to which the site must be able to handle stormwater. Once hydrologic analysis was completed, I helped design the SPSC system and the bioretention area. Based on the design specifications, I created several computer generated drawings of our designed BMPs and the overall site plan (see appendix).

References

Anne Arundel County Government. Step Pool Storm Conveyance (SPSC) Guidelines – Revision 5: December 2012

Environmental Protection Agency (EPA). *Stormwater Menu of BMPs*. Bioretention (Rain Gardens); 2012.

Environmental Protection Agency (EPA). *Stormwater Menu of BMPs*. Construction Site Stormwater Runoff Control; 2012.

Environmental Protection Agency (EPA). *Stormwater Phase II Final Rule: An Overview*; 2005.

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Knox County, TN Stormwater Management Manual, Vol. 2; 2008.

North Carolina Division of Water Quality. Stormwater Best Management Practices Manual; 2007.

National Oceanic and Atmospheric Administration (NOAA). Point Precipitation Frequency Estimates; 2014

Wagner and Keys Engineering, LLC Project Binder. *Water Sports Boathouse*; 2014

Appendix

Runoff Calculations

Table 1: Site Land Use Characteristics

Land Type	Area (acres)	% Total Area	Curve Number
Urban, Good Condition (grass cover > 75%)	0.3	11.54%	61
Road/Parking Lot	0.5	19.23%	98
Permeable Pavement Lot	0.3	11.54%	98
Rooftop	1.5	57.69%	98

Total Area = 0.3 + 0.5 + 0.3 + 1.5
= 2.6 acres

Discrete SCS Method

$CN_{composite} = \Sigma\, CN_i * \%\ total\_area$

$CN_{composite} = 61*.1154 + 98*.1923 + 98*.1154 + 98*.5769$

$CN_{composite} = 93.73$

$S = 1000/CN – 10 = 0.67$

$I_a = 0.2S = 0.13$

$Q^* = (P - I_a)^2/(P-I_a+S) = 4.3$ in.

CN = Curve Number
I_a = Initial Abstraction Before Ponding (in.)
S = Potential Maximum Retention (in.)
P = Depth of Precipitation (in.)
Q* = Excess Precipitation of Direct Runoff (in.)
Volume = ft^3

Time of Concentration

Velocity Method

$T_c = T_1 + T_2 + T_3$

Flow
Type: Sheet Flow Grass
Use: ASCE Kinematic Wave Equation

$$T_1 = \frac{0.007\,(nL)^{0.8}}{P_2^{0.4} S^{0.5}}$$

L = 90'
S = 0.168067
P_2 = 3.04"
n = 0.15

T_1 = 0.065726 hrs

Flow
Type: Shallow Concentrated Flow- Parking Lot
Use: Flow Equations from Viessman Table 15-3

$$T_2 = \frac{L}{20.328(s)^{0.5}}$$

L = 185'
S = 0.041667

T_2 = 0.006694 hrs

Flow
Type: Shallow Concentrated Flow- Swales
Use: Flow Equations from Viessman Table 15-3

$$T_3 = \frac{L}{16.135(s)^{0.5}}$$

L = 230'
S = 0.114754

T_3 = 0.011689 hrs

T_c = 0.084109 hrs
5.046533 minutes

Hydrograph Calculations

Tc =	0.424208	hrs
A =	0.004063	mi^2
CN =	61	

L = 0.6*Tc	=	0.254525	hrs
ΔD = .133Tc	=	0.05642	hrs
Tp = ΔD/2 + L	=	0.282735	hrs
Qp = 484AQ*/Tp		6.954393	ft3/s

Tc = Time of Concentration (hrs)
A = Area (mi^2)
CN = Curve Number
L = Lag Time (hrs)
ΔD = Incremental Time
Tp = Time to Peak (hrs)
Qp = Peak Runoff (ft^3/s)

Tc =	0.084109	hrs
A =	0.004063	mi^2
CN =	93.73077	

L = 0.6*Tc	=	0.050465	hrs
ΔD = .133Tc	=	0.011186	hrs
Tp = ΔD/2 + L	=	0.056059	hrs
Qp = 484AQ*/Tp		35.07492	ft3/s

Tc = Time of Concentration (hrs)
A = Area (mi^2)
CN = Curve Number
L = Lag Time (hrs)
ΔD = Incremental Time
Tp = Time to Peak (hrs)
Qp = Peak Runoff (ft^3/s)

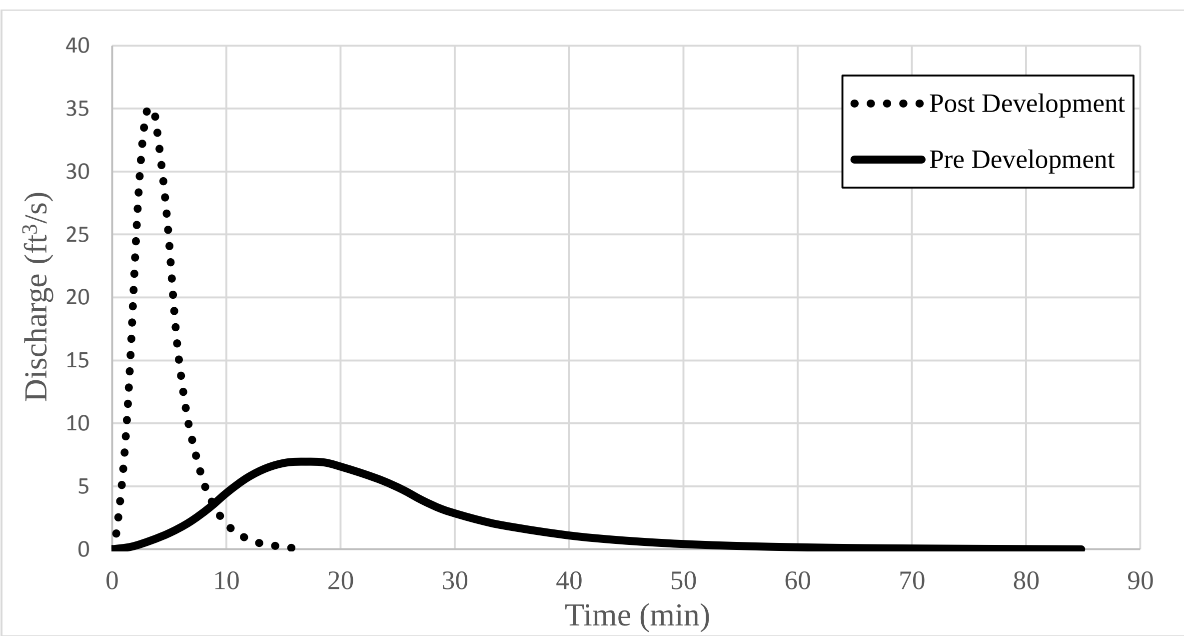

Figure 2: Pre Development and Post Development Hydrographs

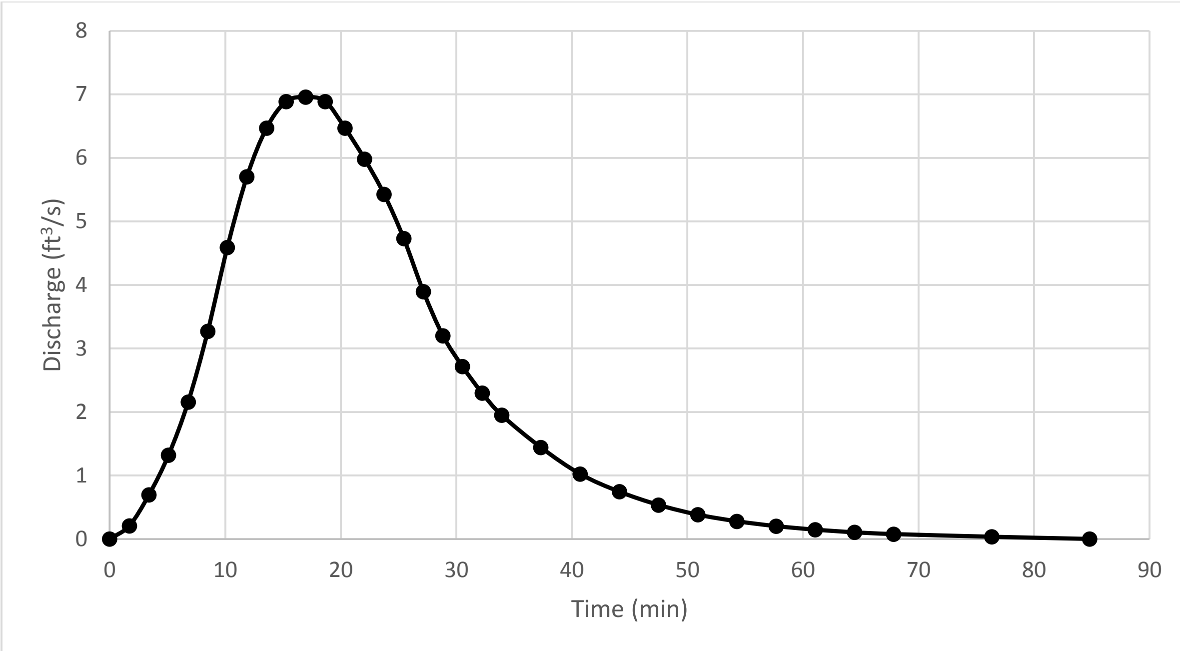

Figure 3: Pre Development Unit Hydrograph

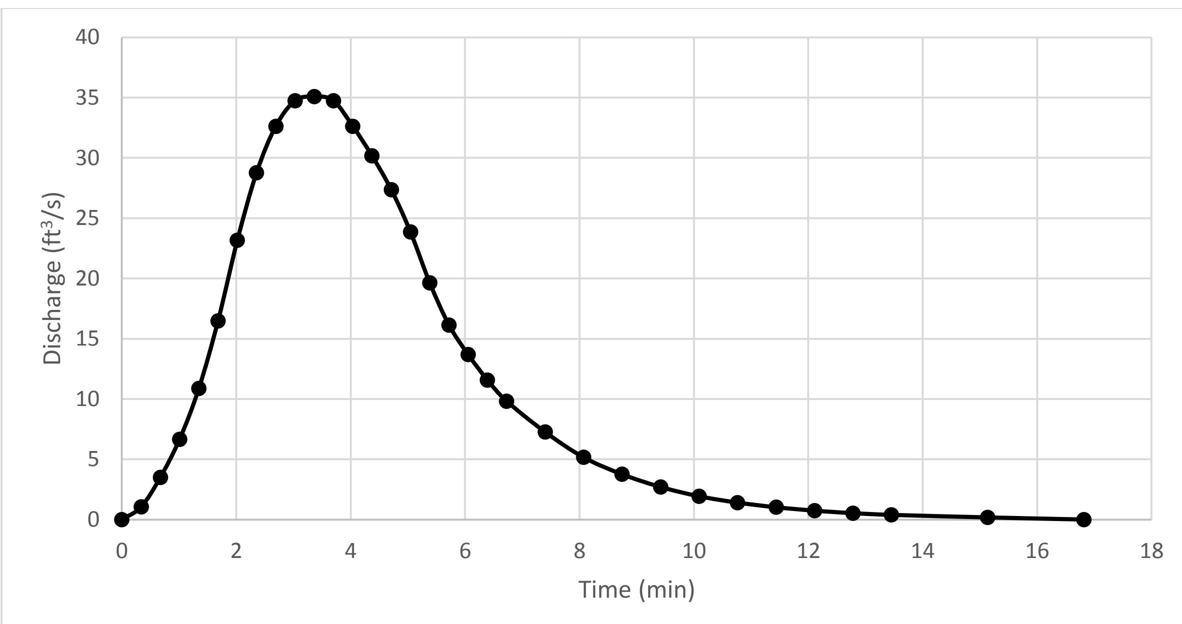

Figure 4: Post Development Unit Hydrograph

Table 2: Unit Hydrograph Ordinates

Pre Development					Post Development				
t/tp	Time (hr)	Time (min)	q/qp	Flow (cfs)	t/tp	Time (hr)	Time (min)	q/qp	Flow (cfs)
0	0	0	0	0	0	0	0	0	0
0.1	0.0283	1.6964	0.03	0.2086	0.1	0.0056	0.3364	0.03	1.0522
0.2	0.0565	3.3928	0.1	0.6954	0.2	0.0112	0.6727	0.1	3.5075
0.3	0.0848	5.0892	0.19	1.3213	0.3	0.0168	1.0091	0.19	6.6642
0.4	0.1131	6.7856	0.31	2.1559	0.4	0.0224	1.3454	0.31	10.8732
0.5	0.1414	8.4820	0.47	3.2686	0.5	0.0280	1.6818	0.47	16.4852
0.6	0.1696	10.1785	0.66	4.5899	0.6	0.0336	2.0181	0.66	23.1494
0.7	0.1979	11.8749	0.82	5.7026	0.7	0.0392	2.3545	0.82	28.7614
0.8	0.2262	13.5713	0.93	6.4676	0.8	0.0448	2.6908	0.93	32.6197
0.9	0.2545	15.2677	0.99	6.8848	0.9	0.0505	3.0272	0.99	34.7242
1	0.2827	16.9641	1	6.9544	1	0.0561	3.3635	1	35.0749
1.1	0.3110	18.6605	0.99	6.8848	1.1	0.0617	3.6999	0.99	34.7242
1.2	0.3393	20.3569	0.93	6.4676	1.2	0.0673	4.0362	0.93	32.6197
1.3	0.3676	22.0533	0.86	5.9808	1.3	0.0729	4.3726	0.86	30.1644
1.4	0.3958	23.7497	0.78	5.4244	1.4	0.0785	4.7089	0.78	27.3584
1.5	0.4241	25.4461	0.68	4.7290	1.5	0.0841	5.0453	0.68	23.8509
1.6	0.4524	27.1426	0.56	3.8945	1.6	0.0897	5.3816	0.56	19.6420
1.7	0.4806	28.8390	0.46	3.1990	1.7	0.0953	5.7180	0.46	16.1345
1.8	0.5089	30.5354	0.39	2.7122	1.8	0.1009	6.0543	0.39	13.6792
1.9	0.5372	32.2318	0.33	2.2949	1.9	0.1065	6.3907	0.33	11.5747
2	0.5655	33.9282	0.28	1.9472	2	0.1121	6.7270	0.28	9.8210
2.2	0.6220	37.3210	0.207	1.4396	2.2	0.1233	7.3997	0.207	7.2605
2.4	0.6786	40.7138	0.147	1.0223	2.4	0.1345	8.0724	0.147	5.1560
2.6	0.7351	44.1067	0.107	0.7441	2.6	0.1458	8.7451	0.107	3.7530
2.8	0.7917	47.4995	0.077	0.5355	2.8	0.1570	9.4178	0.077	2.7008
3	0.8482	50.8923	0.055	0.3825	3	0.1682	10.0905	0.055	1.9291
3.2	0.9048	54.2851	0.04	0.2782	3.2	0.1794	10.7632	0.04	1.4030
3.4	0.9613	57.6779	0.029	0.2017	3.4	0.1906	11.4359	0.029	1.0172
3.6	1.0178	61.0708	0.021	0.1460	3.6	0.2018	12.1087	0.021	0.7366
3.8	1.0744	64.4636	0.015	0.1043	3.8	0.2130	12.7814	0.015	0.5261
4	1.1309	67.8564	0.011	0.0765	4	0.2242	13.4541	0.011	0.3858
4.5	1.2723	76.3384	0.005	0.0348	4.5	0.2523	15.1358	0.005	0.1754
5	1.4137	84.8205	0	0	5	0.2803	16.8176	0	0