Birch Mill Pond

Spillway

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Date: Dec 10, 2009

From:

Senior Projects, Inc
University of Connecticut
261 Glenbrook Rd
Storrs, CT 06269

To:

Donald Himsel
38 South Winds Drive
Essex, CT 06426

Dear Mr. Himsel:

This letter is to inform you that enclosed is our Birch Mill Pond Spillway final senior design report. The spillway proved to be inadequate to handle a 100 year storm. This report gives details backing this statement and provides multiple solutions to correct this problem. This project was overseen by our supervising engineer, Charles Elias, P.E. and our project supervisor Howard I. Epstein, Ph.D.

Sincerely,

Daniel Hoffman

Tsambikos Marasiotis

Colin Mucci

Anthony Santiago

DCAT Associates

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Relevant Engineering Standards:

- American Concrete Institute 318-08 Code

Problem Statement

The Birch Mill Pond spillway is located behind 8 South Winds Drive in Essex, CT. The pond covers an area of approximately 12 acres with three inlet streams and a single outlet over the spillway. The site is mostly wooded with some residential lots around the eastern perimeter of the pond. The problem we are faced with is determining if the spillway will safely handle the amount of water produced from a 100-yr storm. If the spillway is not adequate it will overtop causing erosion of the earthen dam and damage to the surrounding areas. This is especially important due to the close proximity of a nearby house which is located approximately 10 feet from the outlet stream. Overtopping of the dam could cause flooding and possible structural damage to this house. If the spillway is found to be inadequate, alternative design solutions will be investigated that will safely handle the flow of water and direct it downstream.

Watershed Area

Two values are needed to determine if the spillway has sufficient capacity to handle the runoff from a 100-yr storm. The first is the maximum amount of water that the spillway can handle given its dimensions. The second is the amount of water that would be entering the pond during a 100-yr storm. If the amount of water entering the pond is more than the spillway can handle, the spillway will be deemed inadequate.

Several things must be known to find the amount of water entering the pond during a 100-yr storm. The first is the size of the watershed area. A watershed is an extent of land where water from rain or snow melt will drain downhill into a pond, lake or river. The extent of the watershed area is determined by looking at contour map of the area. Since water will always run down hill and perpendicular to the contour lines, a perimeter can be formed which shows the edges of the drainage basin. If rain falls anywhere inside of this line, it will drain into the pond. The contour map for this area was created using computer aided design software called Microstation with Inroads Site. To create the contours, a digital elevation model (DEM) of the Essex, CT area, was downloaded from the U.S Geologic Survey website. A DEM gives elevation data for a specific area in a digital format which can be easily imported into CAD programs. Once the DEM was imported into Microstation with the correct units, a contour map was drawn using the Inroads Site commands. This program uses triangulation between points to draw the contours at the specified interval. This produced a contour map of the Essex area which could then be used to find the extent of the watershed area. Following the logic stated earlier, the perimeter of the watershed area was drawn and using Microstation commands it was determined to enclose an area of 231 acres as seen in Appendix D.

General Overview

The total area of the watershed including the pond is 231 acres. It was designed for a 100 year 24 hour storm with a rainfall precipitation of 7.1 inches. A value of 7.1 inches was obtained from the Connecticut Department of Transportation drainage manual because this is the corresponding value for

Middlesex County. A shape factor of 484 was used which is a standard value for these types of watersheds. A Type III storm was chosen because this is the category of storm that occurs throughout this region of our country. Type III storms are events with fairly low rainfall intensity towards the beginning and end of the 24 hour event. The intensity is the greatest around the twelfth hour of the storm with the majority of the total precipitation falling during this period. A 2 minute time interval was chosen to accurately represent the design storm.

Curve Number

There are several factors that affect the amount of runoff that will enter the pond during a storm. The first is the type of land cover that is present in the watershed area. If the area is densely wooded, much of the rain will soak into the ground instead of entering the pond. Developed areas such as roads and houses cause almost all of the rain to runoff and enter the pond. Another big factor is the type of soil present in the watershed. A clayey soil will not absorb much rain while a very sandy soil will drain very well. To determine the amount of runoff, both of these factors must be known. With the area of each land cover type and its corresponding soil group, a curve number can be determined. This will then be used in a computer program to determine the amount of runoff entering the pond.

The curve number dictates how much water is infiltrated into the ground and how much flows over the land cover present in the watershed. Curve numbers range from 0 up to 100. 0 means that all water is infiltrated into the ground and 100 means that no water is infiltrated into the ground (completely impervious). Each type of land cover has a specific curve numbers associated with it. Types of land cover in the Birch Mill Pond watershed area include: residential, road, pasture, forest, and the pond itself. Each land cover has four different curve numbers which depend on the soil present in those areas. These curve numbers are broken into groups and classified as A, B, C, or D. The classification is dependent upon how pervious the soil present is. Class A refers to soil with the most infiltration and class D refers to the most impervious.

The town of Essex's Geographic Information System (GIS) website was used to find the land cover and soil types of the watershed area. A map of the land cover for 2002 was saved and imported into Microstation and matched up with the perimeter of the watershed area. Since a small part of the watershed is in Westbrook and no GIS information is available, Google Earth was used to determine the land cover areas in that section. Each land cover type was boxed in and the area determined for each. To find the hydrologic soil groups for the watershed, a soils map was imported from Essex's GIS website. The provided soils map used NRCS classifications which are very location specific. The watershed had 14 different NRCS soil classifications. The hydrologic soil groups were determined by using an online document. The watershed only has two soil groups, B and C as seen in Appendix D. Since a small portion of the watershed is in Westbrook, soil group C was chosen for this area to provide a more conservative number. By superimposing the land cover and soil group areas, the area of each land cover and its corresponding soil group was found. This was then used to find the curve number for the entire watershed area.

If an area is only made up of one land cover and one soil type, then there is only one curve number associated with it. Since the watershed area surrounding Birch Mill Pond has 14 different types of soil and 5 different land covers, a Composite Curve Number needs to be calculated. A Composite Curve Number is the overall curve number associated with a watershed area. It takes the percentage of each separate land cover area compared to the overall watershed area. This number is then multiplied by its appropriate curve number. After doing this, the product of each section of the entire watershed area is summed up and that is the Composite Curve Number.

In the Birch Mill Pond watershed there are only soils with B and C classifications. The residential, pasture, and forest areas will be split up into areas with B soil and areas with C soil. The road area has a curve number of 98 and the pond area has a curve number of 100. The eight separated areas were broken up and a Composite Curve Number was calculated as follows:

<u>Composite CN</u> =

$$\left(\frac{8.5}{231}\right)*(98)+\left(\frac{18.42}{231}\right)*(79)+\left(\frac{14.27}{231}\right)*(68)+\left(\frac{15.22}{231}\right)*(74)+\left(\frac{14.11}{231}\right)*(61)+\left(\frac{66.67}{231}\right)*(70)+\left(\frac{82.33}{231}\right)*(55)+\left(\frac{12}{231}\right)*(100)=67.7$$

Time of Concentration

The time of concentration (T_c) is defined as the time it takes for a particle of water to flow from the most hydraulically secluded point of a watershed to the outlet. Within Inroads Site there is a hydrology application with a command called trickle. This command will show the path that rainwater will take as it runs downhill to the pond. Using this command the three longest paths were plotted, which were used in determining the time of concentration. The lengths and slopes of these lines were also determined which affect how quickly the water reaches the pond as seen in Appendix D. Using these values, the time of concentration was determined.

There are three different types of flow that contribute to the time of concentration. Runoff begins as sheet flow which occurs for a relatively short distance. Sheet flow is a very thin layer of overland flow that forms when infiltration can no longer take place. A flow length of 150 feet was used along with 0.4 for Manning's n-value. The average slope for this section of flow was 6.88% and 3.3 inches was entered for a 2-year 24 hour storm. Sheet flow then becomes shallow concentrated flow which has a greater depth and velocity than sheet flow. The flow length is 2414 feet of unpaved ground with an average slope of 3.5%. Channel flow is the final resultant of sheet and shallow concentrated flow. For this project open channel flow was used because the water flows through a stream before it ultimately reaches the spillway. Google Earth was used to determine the length of the stream. The inputs to this section of the program include the cross-sectional area, wetted perimeter, channel slope, Manning's n-value, and flow length. The wetted perimeter for this channel is the addition of its base and two sides. The total time of concentration is equal to the sum of the time it takes for the water to flow through each one of these three phases. A peak runoff of 528.69 cubic feet per second was reached at 12.4 hours.

Surveying

To propose any of the solutions to the spillway, the existing conditions must be known. The elevations and locations of the spillway and surrounding area were obtained using a TDS GTS-235W total station and a TDS Ranger data collector. An elevation for the spillway was assumed to be 50 ft and a back sight direction was also assumed. A total of 49 data points were taken on the existing spillway, the nearby house and topography of the surrounding area. These data points were then brought back to the office and downloaded from the data collector. They were then converted into a text file which included their coordinates, elevations and descriptions. This text file was then imported into Microstation using Inroads commands. The points were imported as random features which allowed them to retain their elevation data and the contour lines were then drawn. The existing spillway and edges of the pond were then drawn and a map was created showing the existing conditions.

With the existing conditions known and located on the map, the design alternative spillways were then drawn and positioned. A map of the existing conditions is located in Appendix A. Maps of the design alternative positions are located in the Appendix B and Appendix C.

Hydraulic Calculations

Manning's Equation is the most widely and often used equation by Hydraulic Engineers. It calculates the maximum amount of flow an open-channel can adequately handle. The following equation and roughness coefficient were obtained from Hydraulic Engineering[2]. Manning's equation is written as follows:

$$Q = \left(\frac{1.49}{n}\right) A R^{\frac{2}{3}} \mathrm{So}^{\frac{1}{2}}$$

Q → This refers to the amount of flow in a channel in cubic feet per second (ft^3/s). This is the maximum amount of flow a channel can handle before it is overtopped and flooding of the surrounding area occurs.

1.49 → This is entered in the equation when using English Units for measurements.

n → This is the roughness coefficient of the spillway. This value is based on the material of the spillway that the water will flow over. This is a tabulated value. The spillway at Birch Mill Pond is made out of concrete (wood forms and unfinished) and carries a n value equal to 0.015.

A → This variable refers to the cross-sectional area of the spillway. The Birch Mill Pond Spillway has a cross-sectional area equal to 7.8125 square feet (ft^2). Refer to Appendix A to see the cross-section.

$R^{\frac{2}{3}}$ → R is equal to the hydraulic radius of the spillway. The hydraulic radius is equal to ($\frac{cross\ sectional\ area}{wetted\ perimter}$). The area is the value determined above, 7.1825 ft^2.

The wetted perimeter is equal to the sum of the dimensions in the cross-sectional area that will get wet when flow occurs at a given depth. The wetted perimeter is equal to 10.9167 ft when the spillway flows full. Plugging these numbers into the R equation yields a hydraulic radius of 0.71565 ft.

$So^{\frac{1}{2}}$ → This refers to the slope of the spillway. Using Microstation and imported elevation points of the spillway, which were taken on site with a Totalstation, the slope was calculated to be 0.0369 (3.69%).

The following shows the maximum amount of flow for the Birch Mill Pond Spillway:

$$Q = \left(\frac{1.49}{0.015}\right) 7.8125 * 0.71565^{\frac{2}{3}} * 0.0369^{\frac{1}{2}} = \underline{119.3 \text{ ft}^3/\text{s}}$$

Hydraflow Express

The hydraulic calculations were verified through a computer program called Hydraflow Express. It was started by clicking on the "Channels" tab and entered the spillway properties. The program inputs include the spillway dimensions, slope, and Manning's n-value. The Manning's n-value is determined by how smooth or rough the water channel surface is. This value increases with increasing roughness. The same n-value as the hand calculations was entered into the program. It then displays the capacity, velocity, and cross sectional area of the spillway at various depths. The hand calculations matched the results of the program and were therefore deemed correct.

Spillway Results

The existing spillway can handle a flow up to, but not exceeding 119 ft^3/s. This was shown in the hydraulic calculations. The flow it needs to be able to handle is 530 ft^3/s, as shown in the TR-20 program results. There is no storage available in the Birch Mill Pond. The spillway is flowing most days out of the year, which means the water level of the pond is almost always at the elevation of the spillway. This means that the spillway will need to handle the entire amount of flow produced by the storm, because any rise in the water level will create some amount of flow over the spillway. Comparing the amount of flow produced by a 100 year storm to the maximum amount of flow the existing spillway can handle, it is significantly inadequate. The spillway is only 22.5% effective, which means that design alternatives must be considered or flooding and disaster will inevitably occur.

Design Alternative 1

Design alternatives needed to be investigated to handle the flow of a 100 year storm as the existing spillway is inadequate. The first design consists of adding an additional spillway next to the existing spillway (the layout can be seen in Appendix B). To blend in well with the existing spillway, the new design will be made of the same material, which is concrete (wood-formed and unfinished) giving a roughness coefficient of 0.015 and will be built at the same slope as the existing spillway, which is 3.69%. The maximum capacity will be taken as the 530 ft^3/s produced by the storm. The only missing data in the design is the cross sectional area of the spillway and the hydraulic radius of the spillway. The height of the spillway has been determined to be 14 inches. This height was chosen as this is the low point of the eastern edge of the pond, which is where the water naturally flows. Anything higher than this will cause flooding away from the spillway as the perimeter of the pond will be overtopped. This eliminates the costly need to build up any edges with retaining walls or berms. With the height known, the only variable that needs to be calculated is the length of the spillway and this was found as follows:

Rearranging Manning's Equation → $$\left(\frac{A^{\left(\frac{5}{3}\right)}}{P^{\left(\frac{2}{3}\right)}}\right) = \frac{Q*n}{1.49*0.0369^{0.5}}$$

With Q=530 ft^3/s, n=0.015, A= 1.167*L ft^2 , and P 2*1.167+L ft the above equation reduces to → $(14*L)^{(5/2)} - 27.77*L = 4098.24$ (L is in ft.)

Solving this equation yields a value of 25.5 ft for L.

Using a height of 14 inches, the new total area will be equal to:

$$\left(\frac{14}{12}\right) ft * (25.5) ft = 29.759\ ft^2$$

This will be the required area of both spillways combined. The area of the existing spillway at a height of 14 inches will need to be subtracted from this total. The area of the existing spillway with this new height was determined as follows:

$$A = \frac{9in*30in + 95in*5in}{144\frac{in^2}{ft^2}} = 5.17\ ft^2$$

This means that the area of the additional spillway will have to be 24.589 ft^2. With a height of 14 inches, the length will need to be 21 ft. These will be the dimensions of the new spillway. The new area will be 24.507 ft^2, the hydraulic radius will be 1.05027 ft, and the slope will remain the same at 0.0369. As a check to see what capacity the new spillway can handle, the following maximum Q was calculated:

$$Q = \left(\frac{1.49}{0.015}\right) 24.507 * 1.05027^{\frac{2}{3}} * 0.0369^{\frac{1}{2}} = \underline{483\ ft^3/s}$$

With the new height of 14 inches, the capacity of the existing spillway becomes:

$$Q = \left(\frac{1.49}{0.015}\right) 5.17 * 0.05044^{\frac{2}{3}} * 0.0369^{\frac{1}{2}} = \underline{63\ ft^3/s}$$

In Appendix D, diagrams were created using Hydroflow Express, a software designed to determine the capacity of spillways at various depths, and back these numbers exact. When summing the capacities of the two spillways, a maximum capacity of 546 ft^3/s was obtained. This capacity is enough to handle the flow of a hundred year storm with a 16 ft^3/s degree of safety.

Concrete Design Alternative 1

The proposed auxiliary spillway will be constructed of unfinished, wood formed concrete similar to the existing one. It will be constructed using normal weight concrete with 3/4" aggregate. Since this spillway is fully supported and has very little external force on it, it will only be reinforced to provide for temperature and shrinkage. The slab thickness was determined to be 10". The

American Concrete Institute 318-08 Code states that the minimum steel needed for temperature and shrinkage is $A_{s,min} = 0.0018bh$. When designing slabs, only a 12" wide section is designed and the minimum steel found for that section. The spacing is then determined and spread throughout the slab. For a slab height of 10" the minimum steel was calculated as

$$A_{s,min} = 0.0018bh = 0.0018 * 12*10 = 0.216 \ {}^{in^2}/_{ft}$$

To provide for this steel area, #5 bars were chosen spaced at 17" which gives a steel area of $0.219 \ {}^{in^2}/_{ft}$. This spacing was checked according to ACI 7.12.2.2 which allows a maximum spacing of 18".

Cost Analysis

To determine the approximate cost of each one of the design alternatives the 2004 Architects, Contractors, and Engineers Guide to Construction Costs was used. This manual is used to accurately establish the cost by giving a choice of 280 cost multipliers depending on which region of the country the site is in. For this project the New London\Norwich multiplier of 1.09 was used as it is the nearest listed city to Essex. There are five variables related to this project that contribute to its total cost. These include concrete, demolition, excavation, rebar, and riprap. Calculations for these values are provided in Appendices B and C. This cost analysis only includes costs related to the actual construction of the spillways. They do not include any costs associated with soil testing, engineering, or any unforeseen construction costs.

Design Alternative 1 Cost Analysis

The entire cost of concrete is divided into two subcategories which are labor and material. There are 23.52 cubic yards of $^3/_4$" aggregate concrete that will be required for Design Alternative 1. The cost for labor is $14.50 per cubic yard and material is $78.00 per cubic yard. The price of concrete for this design is then calculated to be $2,175.60.

The cost of demolition will only be required for Design Alternative 2 because this design involves removing the existing spillway. There are two costs related to demolition which include the cost of the machine and labor. It will cost $42 per cubic yard for the machine and $226 per cubic yard for labor.

Similar to demolition, the cost of the machine and labor contribute to the total cost of excavation. It amounts to $28.50 per cubic yard for labor and $4.00 per cubic yard for the machine. Excavation will be required where the new spillways and walls will be placed. The side slopes of the stream will also need to be set to the appropriate grade before riprap can be placed.

Rebar is available in various sizes. The costs of three different types that pertain to this project were evaluated. The cost of rebar is determined by the amount of linear feet required. The manual provides individual prices for both the material and labor. The slab was designed using #3, #4, and #5 bars to establish which would be most cost effective. #4 bars were determined to be the most cost effective at $0.21 per linear foot for both material and labor ($0.42 per linear foot total).

Riprap will be machine placed at a cost of $22.00 per cubic yard. It was determined that approximately 60 yards of riprap will be required to minimize erosion and velocity.

Design Alternative 2

Another viable option for the pond is to demolish the existing spillway and build a new one that will be adequate to drain the watershed during a 100-year storm on its own. There are many reasons for this, one of these being the limited space of the site. There is a limited amount of space to build the spillway, and given the fact that the current spillway can only handle about 22.5% of the design capacity implies that a spillway of adequate size would be much bigger than the original. Because of this, the space to build the spillway should be used as efficiently as possible.

Another reason would be that there is a small channel that runs straight after the existing spillway, into a pipe that drains under the nearby street. The flow out of the new spillway would need to be diverted into that original channel. The thinner the total width of the spillway, the fewer amounts of resources will be needed to compact the channel to its original size.

Finally, with a single spillway, the specifications are less strict than having to build an auxiliary spillway. With two spillways in place, the auxiliary spillway would have to be placed at the same elevation as the existing spillway, so that they can work together effectively. However, if there is only one spillway, there are more possibilities for how high or low to build it. Furthermore, the depth of the spillway will determine how wide the spillway would need to be built to handle the design flow.

Like the existing spillway, the new spillway would be made of concrete. The slope will remain the same as the existing spillway. Because the spillway sits on top of a narrow strip between the pond and the drop off leading to the channel, the slope of the channel should not be any greater than that of the existing spillway to ensure the spillway will not fall toward the drainage channel. Again, the placement of the spillway will determine how wide the spillway would need to be. So, Design Alternative 2 has three possible options.

For option 1, the spillway will be placed at the same elevation as the auxiliary spillway in Design Alternative 1. This will result in a maximum water height of 14 inches. By using Manning's equation to solve for the length, the spillway channel will need to be 23 feet wide. For option 2, the maximum water height will be 16 inches, resulting in a 19-foot wide spillway. And for option 3, the water height will be 18 inches, requiring a width of only 19 feet. The cost for this option 1 will be $10,450, while the costs for Options 2 and 3 will be $9750 and $9120, respectively (as shown in Appendix C)

As with the other spillways, 2-foot wide sidewalls will be placed on each side to create the spillway channel, as well as create a buffer against the soil. The height of the sidewalls will be two inches higher than the maximum water height for each option.

The bottom of the spillway will be a reinforced concrete slab 14 inches high, 16.7 feet long, and be wide enough to create the sufficient channel for each option plus 4 feet for the two sidewalls. The reinforcing bars will be placed both laterally and transversely to protect against temperature and shrinkage. The most efficient bars to use are #5 bars in each direction because they provide adequate protection using the least amount of bars. Also, shrinkage reinforcement spacing has to adhere to ACI 7.12.2.2, which stipulates that the maximum spacing for reinforcement shall not be greater than 18 inches. This explains why using larger bars would be impractical. For option 1, 18 #5 bars running parallel to the direction of the flow, spaced at 18 inches were selected. For option 2, 18 #5 bars spaced 15.5 inches apart will be necessary. For option 3, 16 #5 bars spaced 15 inches apart will be necessary.

In the other direction (from one sidewall to the other), the amount of reinforcing bars will be the same for all three options, because the length of the spillway is the same. In this direction, 13 #5 bars spaced 15 inches apart will be necessary.

The head walls will need to be demolished and rebuilt as well. Near the inlet, or approach of the spillway, the velocity of the water increases as it passes from an area the size of the pond, to a much smaller area such as the spillway. The head walls will provide erosion control as well as extra retention strength for the accelerating water.

The head walls will be poured together with the spillway, so the entire structure with me a monolith. The vast majority of concrete structures are built this way. Building the headwalls together with the spillway prevents seepage into the earth dam between the spillway and wall, where there would be a gap.

These head walls will extend 15 feet from each side of the spillway along the edge of the pond, 4 feet deep into the pond, and be 1 foot thick.

Building a rectangular chute spillway modeled after the existing spillway has many advantages. Because it is composed of all rectangular parts, the formwork is straightforward. Also this type of spillway uses a relatively small amount of building material (around 20 cubic yards for any given design alternative). Most importantly, a spillway similar to one that already exists there works well because it has been proven that such a design can last sitting atop of the earth dam. This design works better than another design, which would call for removing a lot of the earth dam just to fit the spillway.

Ogee Spillway

When designing the new single spillway, other designs were explored as options. One of them was an ogee-shaped weir. This type of spillway would drain the pond when the water level reaches a certain height like the rectangular chute spillways, but the water will flow down a curved path into the discharge channel instead of simply falling into it.

One of the advantages of having an ogee spillway is aesthetics. This spillway sits on private property and is surrounded by houses, one of them just 5 feet away. So aesthetics matters in this situation to those in the vicinity of the spillway, including the owner. One advantage of the ogee spillway over the rectangular spillway is that the water will be guided down to the discharge channel, which would make less noise than having the water fall down to the channel, slamming into the riprap below.

The flow through an ogee spillway can be expressed by the equation:

$$Q = LCH_e^{\frac{3}{2}}$$

Where L equals the length of the spillway. C equals a discharge constant, based on conditions of the site. H_e represents the effective head over the spillway. The effective head of the spillway is determined by the velocity of the approach of the spillway, as well as the design height of water on the spillway. The velocity of the approach was assumed to be about 7 miles per hour, or 10.3 feet per second. The velocity head equals the approach velocity squared, divided by two times the gravitational constant, or 32.2 feet per second per second.

Initial calculations showed that using the effective head at 14 inches, with no velocity head, yielded a necessary spillway length of over 100 feet. Because of this, it proved more effective to pick a reasonable length of the spillway, assume a low approach velocity, and solve for the piezometric head, H_o, which will equate to the height of water through the spillway. Assuming an approach velocity of 10.3 feet per second, and a length of 25 feet, the piezometric head needed was 1.62 feet, or about 20 inches.

The ogee spillway will be made of unfinished, wood-formed concrete. The ogee spillway will be made of 24 cubic yards of concrete. This value was found by using a standard equation for the curvature of the ogee spillway:

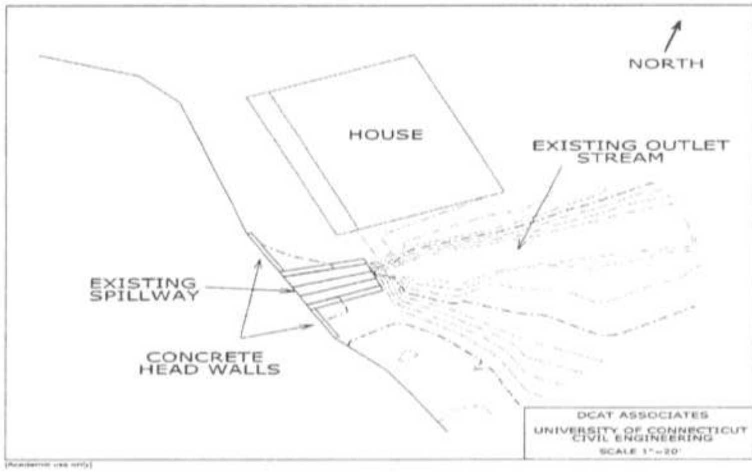
$$\frac{y}{H_o} = -K\left(\frac{X}{H_o}\right)^n$$

Where K was found to be .5, and N was determined to be 1.835. These values are based on the ratio of the difference in head from the middle of the pond and the approach, called h_o, divided by the piezometric head H_o. Adding the height difference between the top of the spillway and the discharge channel to the equation, and integrating the curve where it reaches 0 obtains the amount of concrete needed.

The ogee spillway also needs retaining walls to contain the outflow. They will be poured at the same time as the spillway, and will slope down linearly on each side of the spillway at an angle of 45 degrees. The walls will be 7 feet long, 3 feet high and 1 foot wide.

Even though constructing the ogee spillway uses a similar amount of concrete as any of the rectangular spillway options but building the ogee spillway has many disadvantages. One of the reasons is the channel height. The channel height is 20 inches, 2 inches lower than the lowest of the rectangular spillway options. This means the maximum depth will be at least 6 inches lower than the current depth. Because aesthetics are important, the client may not want to lower the overall depth of the spillway. Another disadvantage to building an ogee spillway is the complicated formwork. Creating formwork for a parabolic curve is much more difficult than creating rectangular formwork. But perhaps the biggest disadvantage to the spillway is trying to fit it into the site. The ogee spillway acts is meant to act as a dam as well, which means the earth dam would have to be partially, if not totally removed for 25 feet, to place the concrete spillway. This means extremely high excavation costs that will result in thousands of dollars more to invest in this design alternative.

Construction Concerns



There are various issues that need to be addressed before construction can take place. This is a fairly compact site that poses several unique problems.

As depicted above there are two rather narrow entrances to the construction site, one along each corner of the house. This will pose a significant problem as to how to get the necessary equipment on the site. Crossing the existing outlet stream via an existing driveway bridge and cutting a path through the woods will be required, if both entrances prove to be too narrow. This will therefore increase the cost of the project and add to its duration. If the equipment is able to pass one of these narrow entrances the next concern is crossing the existing spillway with heavy equipment. The strength of the existing spillway is unknown and placing a heavy load, such as machinery, may cause it to crack. This won't be an issue for Design Alternative 2 since it involves completely removing the existing spillway but is of concern for Design Alternative 1 since it will be utilized in this design.

Another major concern is temporarily removing water from the edge of the pond where the new spillways and head walls will be constructed. Dry site conditions must exist in order to properly place the concrete. One way this can be achieved is by opening the valve in the pipe below the existing spillway and lowering the water level of the entire pond. Another possibility would be to construct a temporary retaining wall to keep pond water out away from the construction site and then remove the wall when finished. Opening the valve is clearly the most cost effective method, but significantly lowering the level of the pond (minimum of 3+ feet for the head walls) could pose several environmental threats. Decreasing this water level by 3+ feet could take quite some time using a 12 inch diameter pipe.

Permits

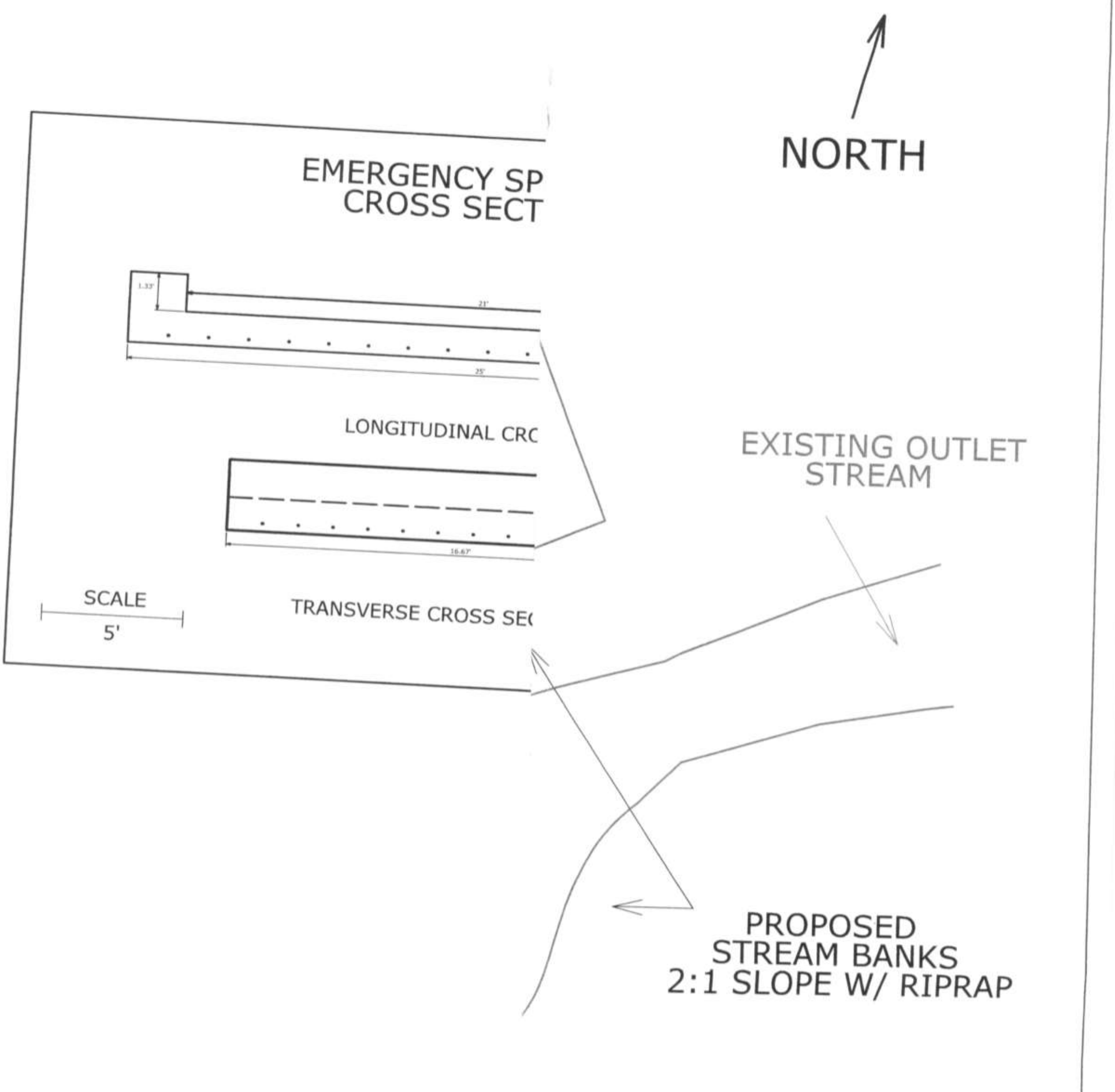
There are undoubtedly many permits that will need to be pulled from the Connecticut Department of Environmental Protection in order to construct this project. We were unable to contact Jim Sangivanni (CT DEP) in time to establish what permits would be required, but this is clearly an issue that will need to be resolved. Design Alternative 2 might involve a stricter permit process since it calls for removing the existing structure instead of simply adding another one adjacent to it.

Our Decision

We chose Design Alternative 1 as the best solution for several reasons. The project's budget is of significant concern to the Birch Mill Pond homeowner association and Design Alternative 1 is the most cost effective of the four. The existing spillway is incorporated into this design and therefore won't need to be removed allowing the pond to drain in the event that a storm occurs during construction. Options 2 and 3 of Design Alternative 2 involve decreasing the level of the pond which could be less aesthetically pleasing than the current height. Modifying the pond in such a way can lead to additional issues with the CT DEP. Design Alternative 1 was chosen because it is the cheapest, least invasive, and least problematic of the four.

<u>Sources & References</u>

1. A Guide to SCS Runoff Procedures. Department of Water Resources, July 1985.
2. Roberson, Cassidy, and Chaudhry. *Hydraulic Engineering*. 2nd Edition. Wiley, 1998.
3. Chow. *Applied Hydrology*. 1st Edition. McGraw-Hill, 1998.
4. http://host.appgeo.com/essexct/
5. 2004 Architects, Contractors, and Engineers Guide to Construction Costs. Volume 35. USA: Design & Construction Resources, 2004.
6. Hydraflow Express Software.
7. Hydraflow Hydrographs, 2002.
8. Design of Small Dams. 3rd Edition, 1987.



PROPOSED EMERGENCY SPILLWAY

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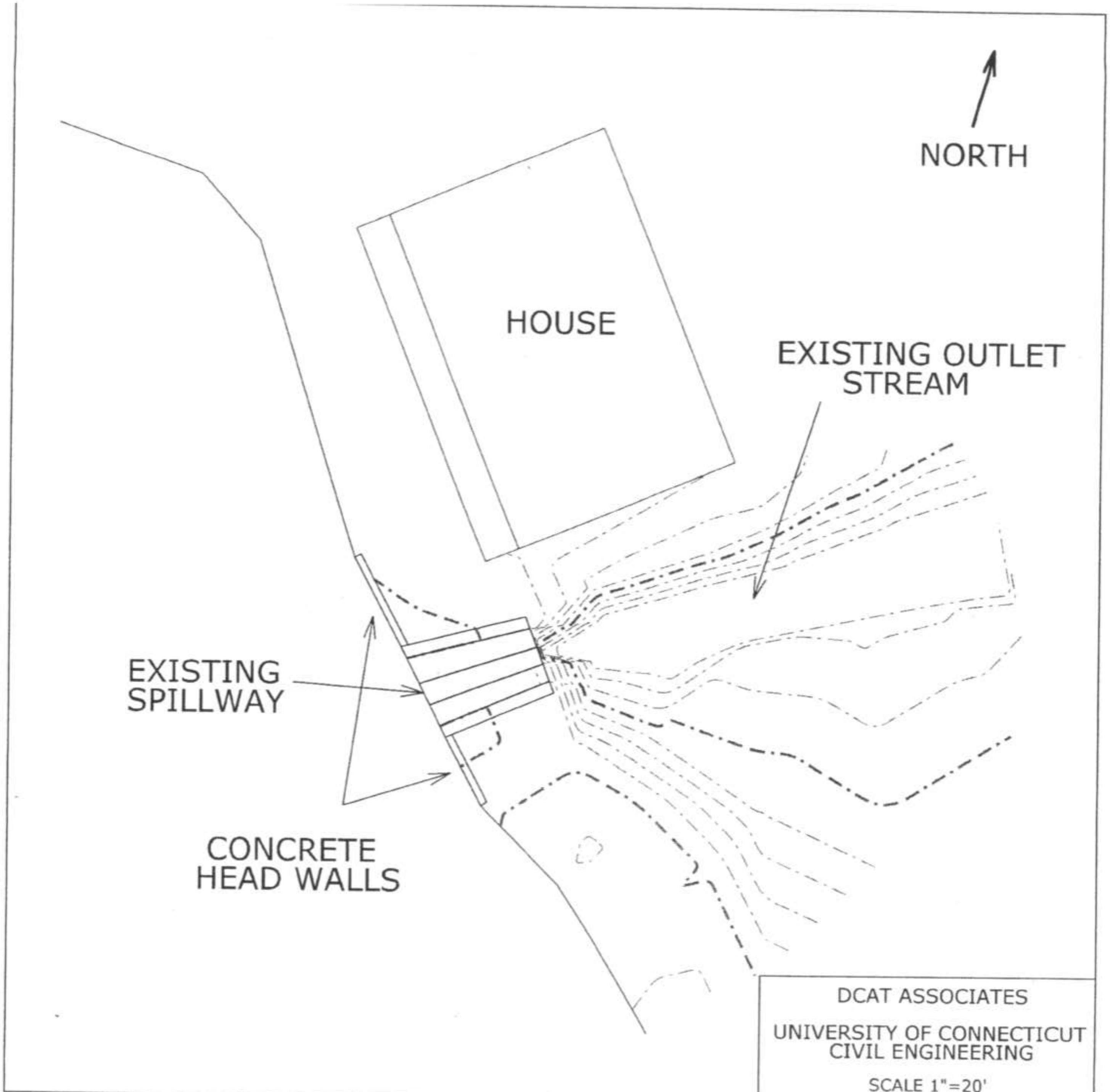
CIVIL ENGINEERING

SCALE 1"=15'

Appendix A

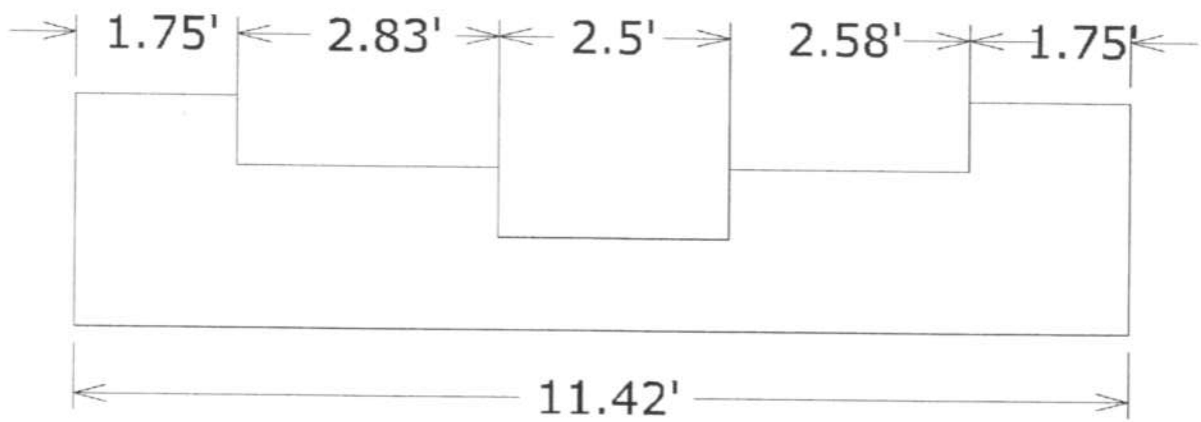


[Academic use only]

Drawn by: DEH

Checked by: TJC

EXISTING SPILLWAY DIMENSIONS



CROSS SECTIONAL AREA = 7.8125 SQR. FT.

DCAT ASSOCIATES

UNIVERSITY OF CONNECTICUT
CIVIL ENGINEERING

SCALE 1"=2'

Drawn by: DEH

Checked by: [illegible]

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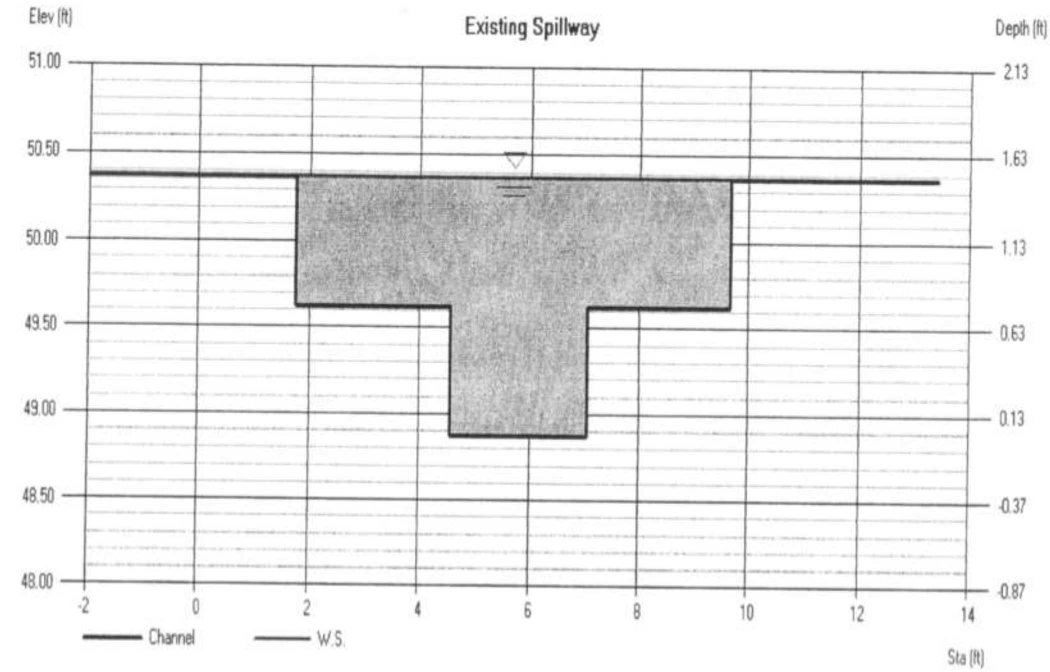
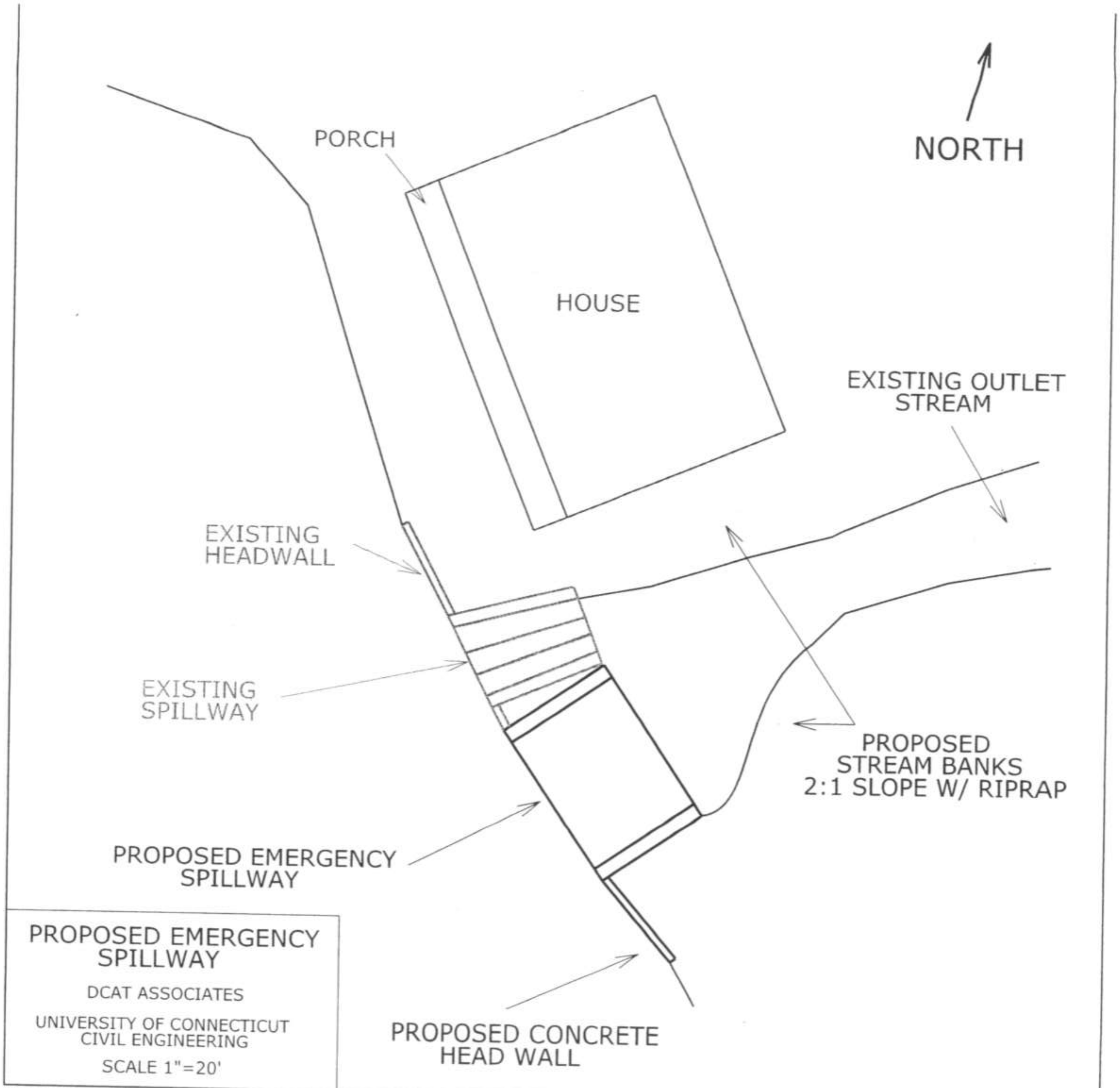


Depth (ft)	Q (cfs)	Area (ft^2)	Velocity (ft/s)
1.50	119.23	7.82	15.26

Created by: CMM

Checked by: OJR

Appendix B



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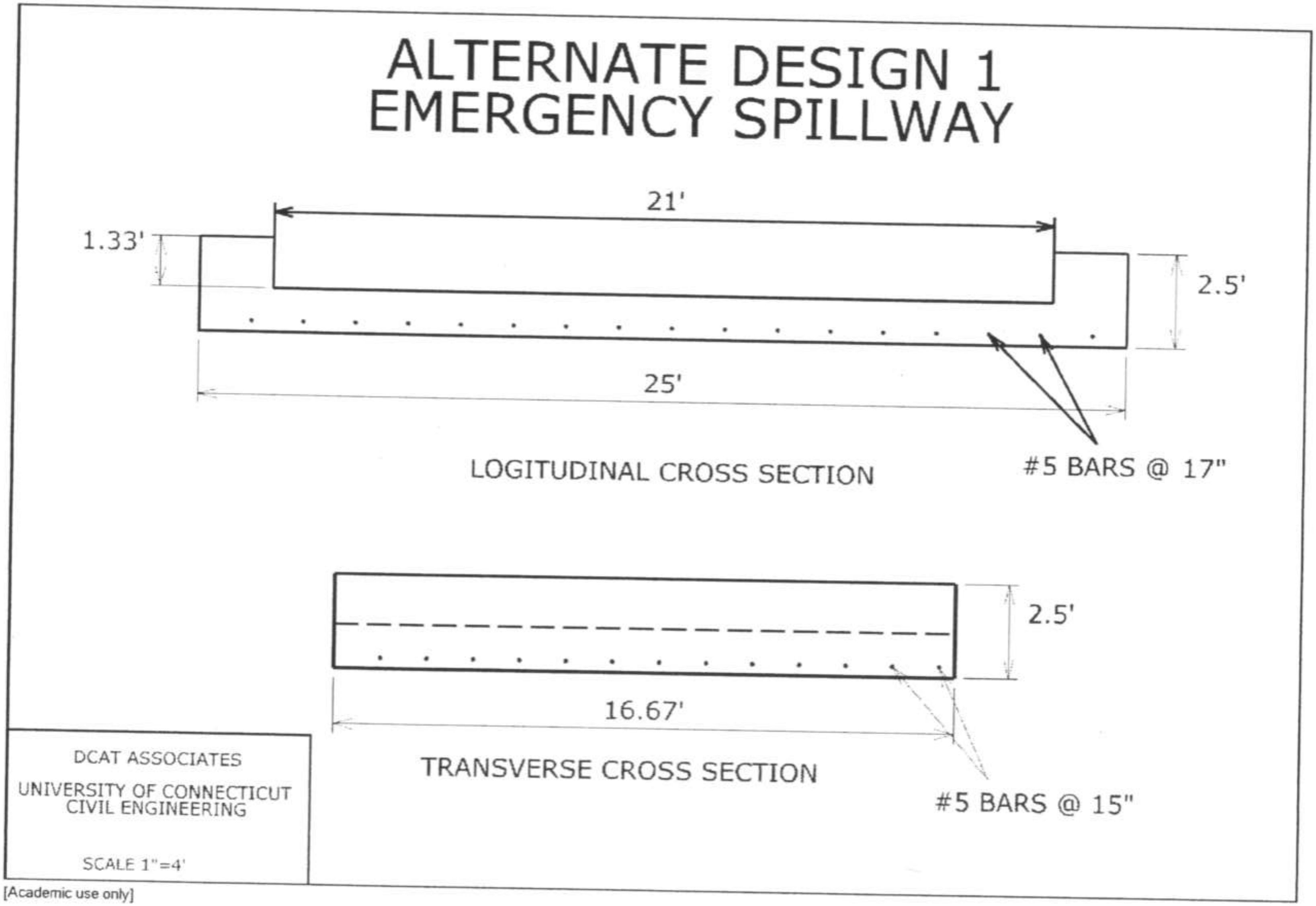
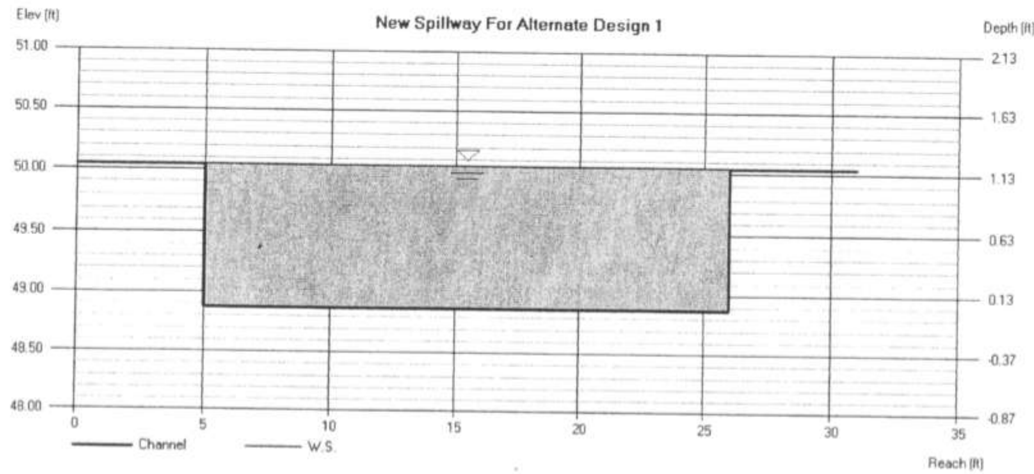


[Academic use only]

Drawn by: DEH

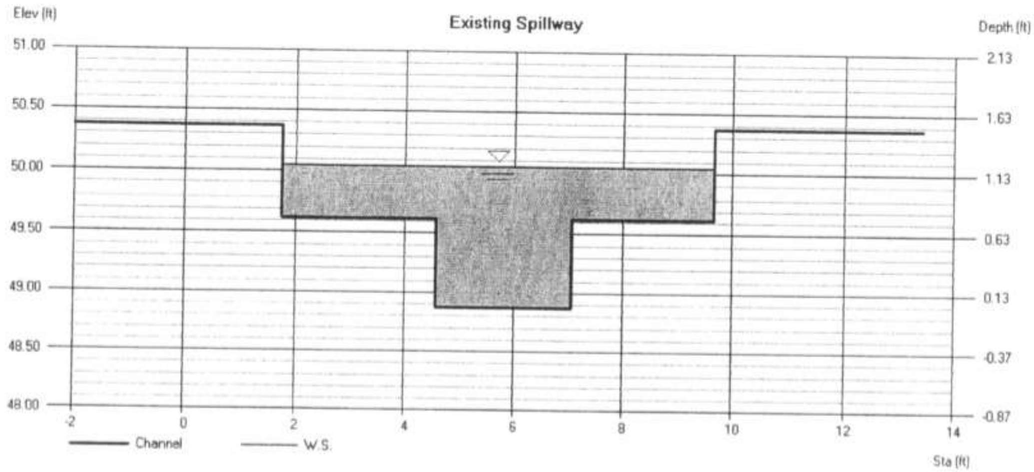
Checked by: JR, CMM



Depth (ft)	Q (cfs)	Area (sqft)	Veloc (ft/s)	Wp (ft)	Yc (ft)	TopWidth (ft)	Energy (ft)
0.12	11.09	2.46	4.52	21.23	0.01	21.00	0.43
0.23	34.98	4.91	7.12	21.47	0.21	21.00	1.02
0.35	68.26	7.37	9.26	21.70	0.45	21.00	1.68
0.47	109.48	9.83	11.14	21.94	0.70	21.00	2.40
0.59	157.69	12.29	12.84	22.17	0.95	21.00	3.15
0.70	212.21	14.74	14.39	22.40	1.17	21.00	3.92
0.82	272.49	17.20	15.84	22.64	1.17	21.00	4.72
0.94	338.10	19.66	17.20	22.87	1.17	21.00	5.54
1.05	408.66	22.11	18.48	23.11	1.17	21.00	6.36
1.17	**483.86**	**24.57**	**19.69**	**23.34**	**1.17**	**21.00**	**7.20**

Created by: CMM

Checked by: JR



Depth (ft)	Q (cfs)	Area (sqft)	Veloc (ft/s)	Wp (ft)	Yc (ft)	TopWidth (ft)	Energy (ft)
0.03	0.136	0.07	1.81	2.56	0.01	2.50	0.08
0.06	0.425	0.15	2.83	2.62	0.05	2.50	0.18
0.09	0.822	0.23	3.65	2.68	0.10	2.50	0.30
0.12	1.308	0.30	4.36	2.74	0.15	2.50	0.42
0.15	1.871	0.38	4.99	2.80	0.21	2.50	0.54
0.18	2.500	0.45	5.55	2.86	0.26	2.50	0.66
0.21	3.187	0.52	6.07	2.92	0.32	2.50	0.78
0.24	3.929	0.60	6.55	2.98	0.37	2.50	0.91
0.27	4.718	0.68	6.99	3.04	0.43	2.50	1.03
0.30	5.551	0.75	7.40	3.10	0.49	2.50	1.15
0.33	6.424	0.83	7.79	3.16	0.54	2.50	1.27
0.36	7.334	0.90	8.15	3.22	0.59	2.50	1.39
0.39	8.278	0.97	8.49	3.28	0.65	2.50	1.51
0.42	9.254	1.05	8.81	3.34	0.70	2.50	1.63
0.45	10.26	1.13	9.12	3.40	0.87	2.50	1.74
0.48	11.29	1.20	9.41	3.46	0.89	2.50	1.86
0.51	12.35	1.27	9.69	3.52	0.92	2.50	1.97
0.54	13.43	1.35	9.95	3.58	0.94	2.50	2.08
0.57	14.54	1.42	10.20	3.64	0.97	2.50	2.19
0.60	15.66	1.50	10.44	3.70	0.99	2.50	2.30
0.63	16.81	1.58	10.67	3.76	1.01	2.50	2.40
0.66	17.97	1.65	10.89	3.82	1.04	2.50	2.51
0.69	19.16	1.72	11.11	3.88	1.06	2.50	2.61
0.72	20.36	1.80	11.31	3.94	1.08	2.50	2.71
0.75	21.57	1.88	11.50	4.00	1.11	2.50	2.81
0.78	14.80	2.11	7.01	9.48	1.13	7.92	1.54
0.81	17.60	2.35	7.49	9.54	1.00	7.92	1.68
0.84	20.58	2.59	7.95	9.60	1.05	7.92	1.82
0.87	23.73	2.83	8.40	9.66	1.11	7.92	1.97
0.90	27.04	3.06	8.83	9.72	1.17	7.92	2.11
0.93	30.50	3.30	9.24	9.78	1.23	7.92	2.26
0.96	34.11	3.54	9.64	9.84	1.29	7.92	2.40
0.99	37.86	3.78	10.03	9.90	1.35	7.92	2.55
1.02	41.74	4.01	10.40	9.96	1.41	7.92	2.70
1.05	45.76	4.25	10.76	10.02	1.47	7.92	2.85
1.08	49.90	4.49	11.12	10.08	1.50	7.92	3.00
1.11	54.17	4.73	11.46	10.14	1.50	7.92	3.15
1.14	58.55	4.96	11.80	10.20	1.50	7.92	3.30
1.17	**63.05**	**5.20**	**12.12**	**10.26**	**1.50**	**7.92**	**3.45**

created by: CMM
checked by: JM

Cost Analysis: Design Alternative 1

Multiplier for New London/Norwich, CT = 1.09

Concrete

-23.52 cubic yards of total concrete

Labor: $23.52\ cu\ yd\ \times \$14.50\ per\ cu\ yd = \$341.04$

Material: $23.52\ cu\ yd\ \times \$78.00\ per\ cu\ yd = \$1834.56$

Total: $\$341.04 + \$1834.56 = \mathbf{\$2175.60}$

Demolition

-only pertains to Design Alternative 2

Excavation

-Head walls = 4.44 yd

-Spillway and downstream side slopes = 133.33 yd

Labor: $138\ yd \times \$28.50 = \$3{,}933$

Machine: $138\ yd \times \$4.00 = \$552$

Total: $\$3{,}933 + \$552 = \mathbf{\$4{,}485}$

Rebar

Rebar #	Material (lf)	Labor (lf)	Total (lf)
3	$0.15	$0.16	$0.31
4	$0.21	$0.21	$0.42
5	$0.33	$0.31	$0.64

#3 Bars:

$49\ bars \times 194" = 9506"$

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$$33\ bars \times 294'' = 9702''$$

$$\frac{(9506+9702)}{12''} = 1600.67' \times \$0.31 = \mathbf{\$496.21}$$

#4 Bars:

$$27\ bars \times 194'' = 5238''$$

$$18\ bars \times 294'' = 5292''$$

$$\frac{(5238+5292)}{12''} = 877.5' \times \$0.42 = \mathbf{\$368.55}$$

#5 Bars:

$$18\ bars \times 194'' = 3492''$$

$$12\ bars \times 294'' = 3528''$$

$$\frac{(3492+3528)}{12''} = 585' \times \$0.64 = \mathbf{\$374.40}$$

Riprap

-Machine Placed = $22.00 per cubic yd

$$\$22.00 \times 60\ yd = \mathbf{\$1,320}$$

Total = $8,400

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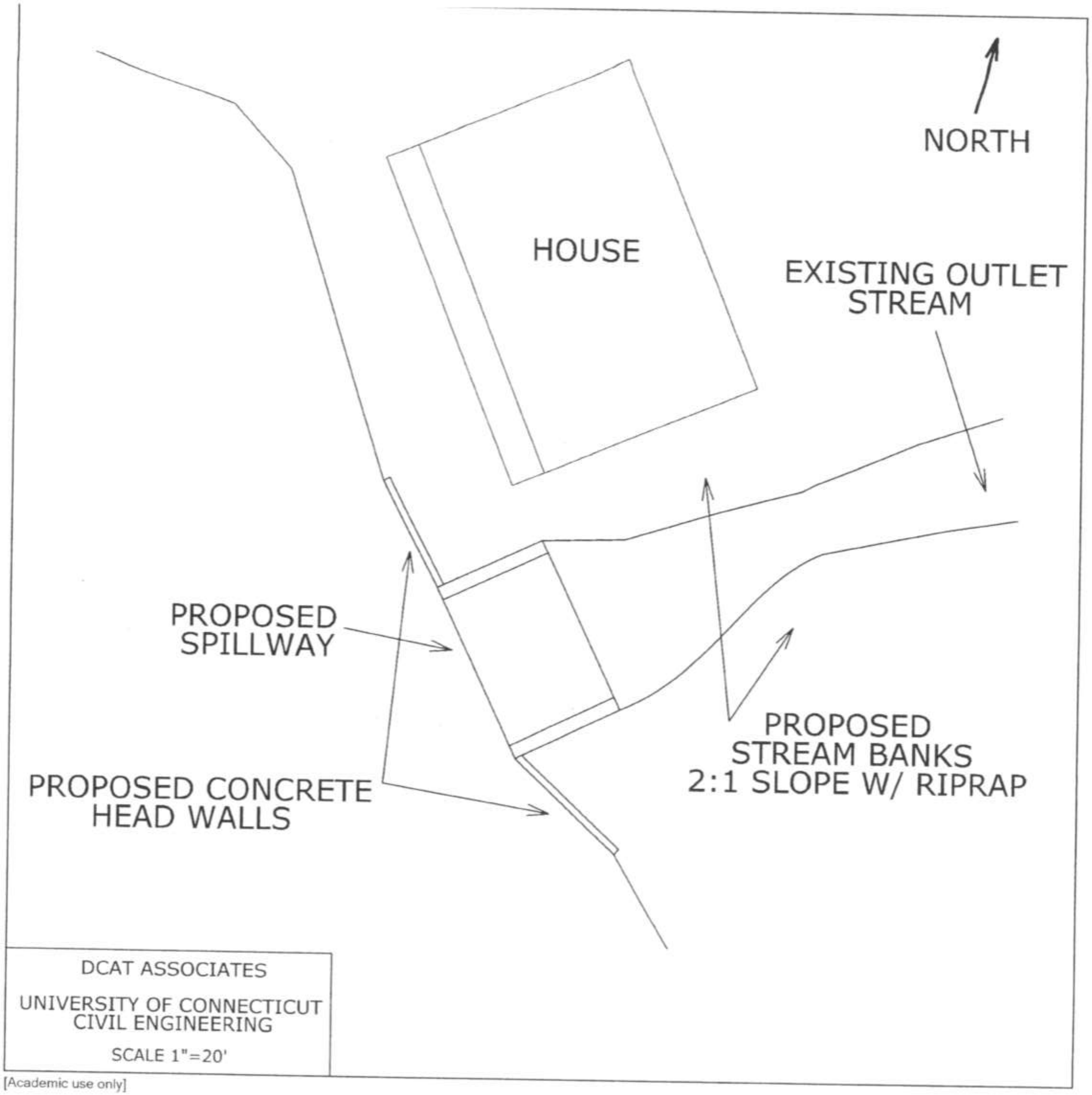
Appendix C



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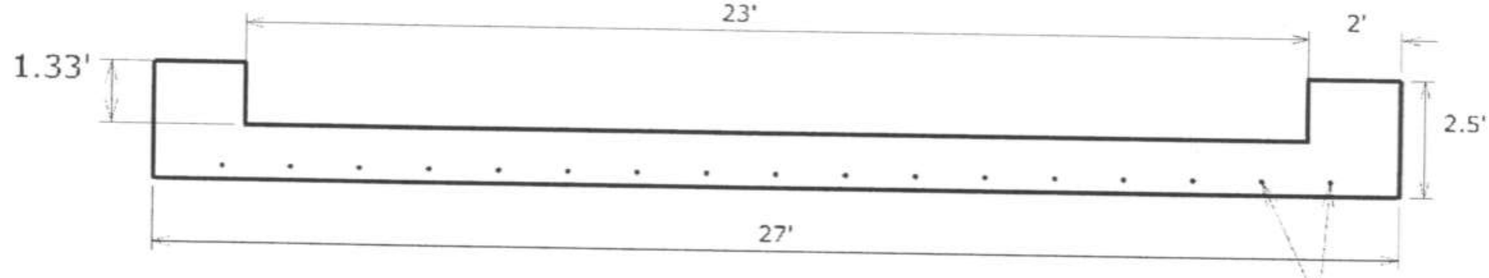
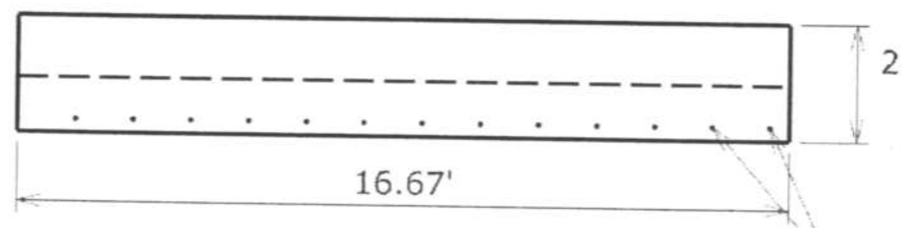
Checked By: AS

ALTERNATE DESIGN 2
SCENARIO 1



LOGITUDINAL CROSS SECTION

#5 BARS @ 18"



TRANSVERSE CROSS SECTION

#5 BARS @ 15"

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SCALE 1"=4'

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Checked by: CAHM

OGEE Spillway

$$Q = LCH_e^{3/2}$$

$$H_e = H_o + \frac{V_o^2}{2(32.2)} = H_o + 1.647$$

V_o = approach velocity, assumed to be 7mph or 10.3 feet per second.

C was chosen to be 3.6 based on site conditions

L = 25 feet

Q = 530 cubic feet per second

H_o = maximum water heigh in the spillway

$$530 = (25)(3.6)(H_o + 1.647)^{1.5}$$

For a 25-foot spillway, the design height H_o must be 1.62 feet or 20"

Dimensions

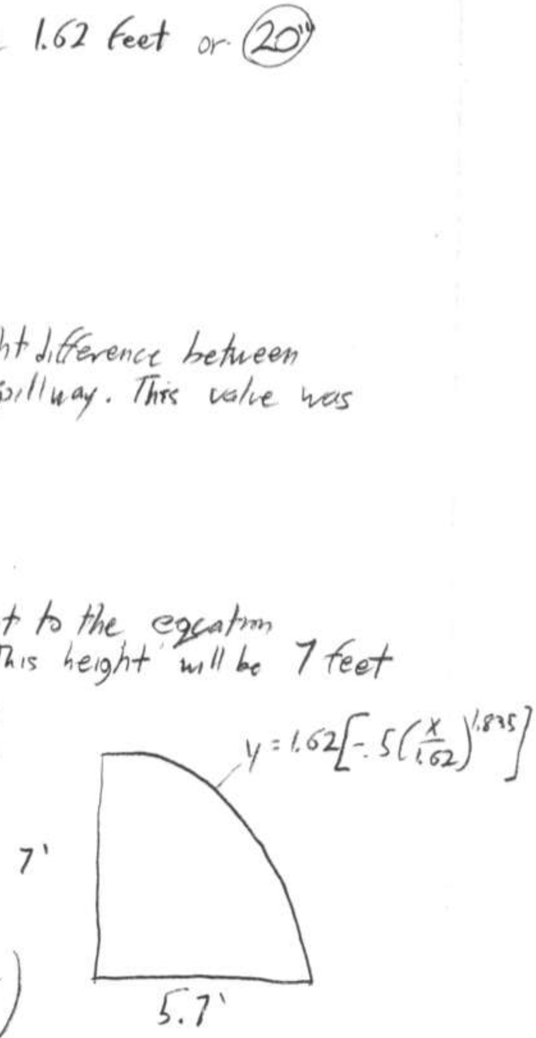
$$\frac{Y}{H_o} = -k\left(\frac{X}{H_o}\right)^n = y = 1.62\left[-k\left(\frac{x}{1.62}\right)^n\right]$$

k, n are based on the ratio $\frac{h_a}{H_o}$, where h_a is the height difference between a location in the center of the pond and the height at the spillway. This value was is 2", based on observation of the site.

$\frac{h_a}{H_o} = .1$, $k = .5$, $n = 1.835$

A unit area of concrete can be found by adding a constant to the equation representing the height necessary to place the spillway. This height will be 7 feet

Integrating over $y = \left[1.62\left(-.5\left(\frac{x}{1.62}\right)^{1.835}\right] + 7 = \underline{24\ ft^2}$



Amount of concrete $= (24 ft^2) \cdot (25 ft) \left| \frac{1\ yd^3}{27 ft^3} \right|$

$= \underline{22.2\ yd^3}$ (use $24\ yd^3$ to account for foundation)

Cost: Design Alternative 2

Cost multiplier for New London/ Norwich: 1.09

Option 1

Concrete

Labor: 22.7 cu. yd. X $14.50 per cu. yd. = $329.15

Material: 22.7 cu. yd. X $78.00 per cu. yd. = $1770.60

Total: $2099.75

Demolition

Labor: 7.61 cu. yd. X $42.00 per cu. yd. = $319.62

Machine: 7.61 cu. yd. X $226.00 per cu. yd. = $1719.86

Total: $2039.48

Excavation

Labor: 133.4 cu. yd. X $28.50 per cu. yd. = $3801.90

Machine: 133.4 cu. yd. X $4.00 per cu. yd. = $533.6

Total: $4335.50

Rebar

#5: 16.2 feet at $.32 per foot X 18 bars = $93.32

#5: 26 feet at $.32 per foot X 18 bars = 149.76

Riprap

60 cu. yd. at $22.00 per cu. yd. = $1320.00

Walls

4.44 cu. yd at $92.50 per cu.yd (materials + labor) = $410.70

Total: $10,443.51

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Option 2

Concrete

Labor: 20.3 cu. yd. X $14.50 per cu. yd. = $294.35

Material: 20.3 cu. yd. X $78.00 per cu. yd. = $1583.40

Total: $1877.75

Demolition

Labor: 7.61 cu. yd. X $42.00 per cu. yd. = $319.62

Machine: 7.61 cu. yd. X $226.00 per cu. yd. = $1719.86

Total: $2039.48

Excavation

Labor: 118.4 cu. yd. X $28.50 per cu. yd. = $3374.40

Machine: 118.4 cu. yd. X $4.00 per cu. yd. = $473.60

Total: $3848.00

Rebar

#5: 16.2 feet at $.32 per foot X 18 bars = $93.32

#5: 22 feet at $.32 per foot X 18 bars = 126.72

Riprap

60 cu. yd. at $22.00 per cu. yd. = $1320.00

Walls

4.44 cu. yd at $92.50 per cu.yd (materials + labor) = $410.70

Total: $91716.00

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Option 3

Concrete

Labor: 18.6 cu. yd. X $14.50 per cu. yd. = $269.70

Material: 18.6 cu. yd. X $78.00 per cu. yd. = $1450.80

Total: $1720.50

Demolition

Labor: 7.61 cu. yd. X $42.00 per cu. yd. = $319.62

Machine: 7.61 cu. yd. X $226.00 per cu. yd. = $1719.86

Total: $2039.48

Excavation

Labor: 106.2 cu. yd. X $28.50 per cu. yd. = $3026.70

Machine: 106.2 cu. yd. X $4.00 per cu. yd. = $424.80

Total: $3451.50

Rebar

#5: 16.2 feet at $.32 per foot X 18 bars = $93.32

#5: 19 feet at $.32 per foot X 13 bars = 79.04

Riprap

60 cu. yd. at $22.00 per cu. yd. = $1320.00

Walls

4.44 cu. yd at $92.50 per cu.yd (materials + labor) = $410.70

Total: $9114.54

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CHECKED BY: DEH

Cost: Ogee spillway

Concrete

Labor: 24 cu. yd. X $14.50 per cu. yd. = $348.00

Material: 24 cu. yd. X $78.00 per cu. yd. = $1872.00

Total: $2220.00

Demolition

Labor: 7.61 cu. yd. X $42.00 per cu. yd. = $319.62

Machine: 7.61 cu. yd. X $226.00 per cu. yd. = $1719.86

Total: $2039.48

Excavation

Labor: 175 cu. yd. X $28.50 per cu. yd. = $4990

Machine: 175 cu. yd. X $4.00 per cu. yd. = $700

Total: $5690.00

Riprap

75 cu.yd at $22 per cu.yd = $1650

Side Walls

1.56 cu. yd at $92.50 per cu.yd (materials + labor) = $143.90

Walls

4.44 cu. yd at $92.50 per cu.yd (materials + labor) = $410.70

Total: 15,241.30

Created by: AS

CHECKED BY: DEA

Appendix D

Time of Concentration & Storm Flow

Time of Concentration Inputs:

Sheet Flow
Manning's N-value = .40
Flow Length = 150 ft.
2 yr. 24 hr. Storm = 3.3 in.
Land Slope = 6.88%

Shallow Concentrated Flow
Flow Length = 2414 ft.
Water Course Slope = 3.50%
Surface = unpaved

Channel Flow
Cross Sectional Area = 5 ft^2
Wetted Perimeter = 7 ft.
Channel Slope = 9.62%
Manning's N-value = .04
Flow Length = 1279 ft.

T_c = 33.5 min. → calculated in TR-20 computer program

Length, Slope, & Surface variables were found using Microstation

Storm Flow: (found using computer program)

Using our Composite Curve Number, Time of Concentration (T_c), Watershed Area, Type III rainfall event, & a 100 yr. storm (7.1 in.) the following peak flow was obtained:

Q_p = 530 cfs

Created by: CMM

Checked by: DEH

Curve Number

Total Acres = 231
-Pond = 12 ac.
-Road = 8.5 ac.
-Residential = 32.69 ac.
-Pasture/Rangeland = 29.33 ac.
-Forest = 149 ac.

Soils: Hydrologic Soil Groups

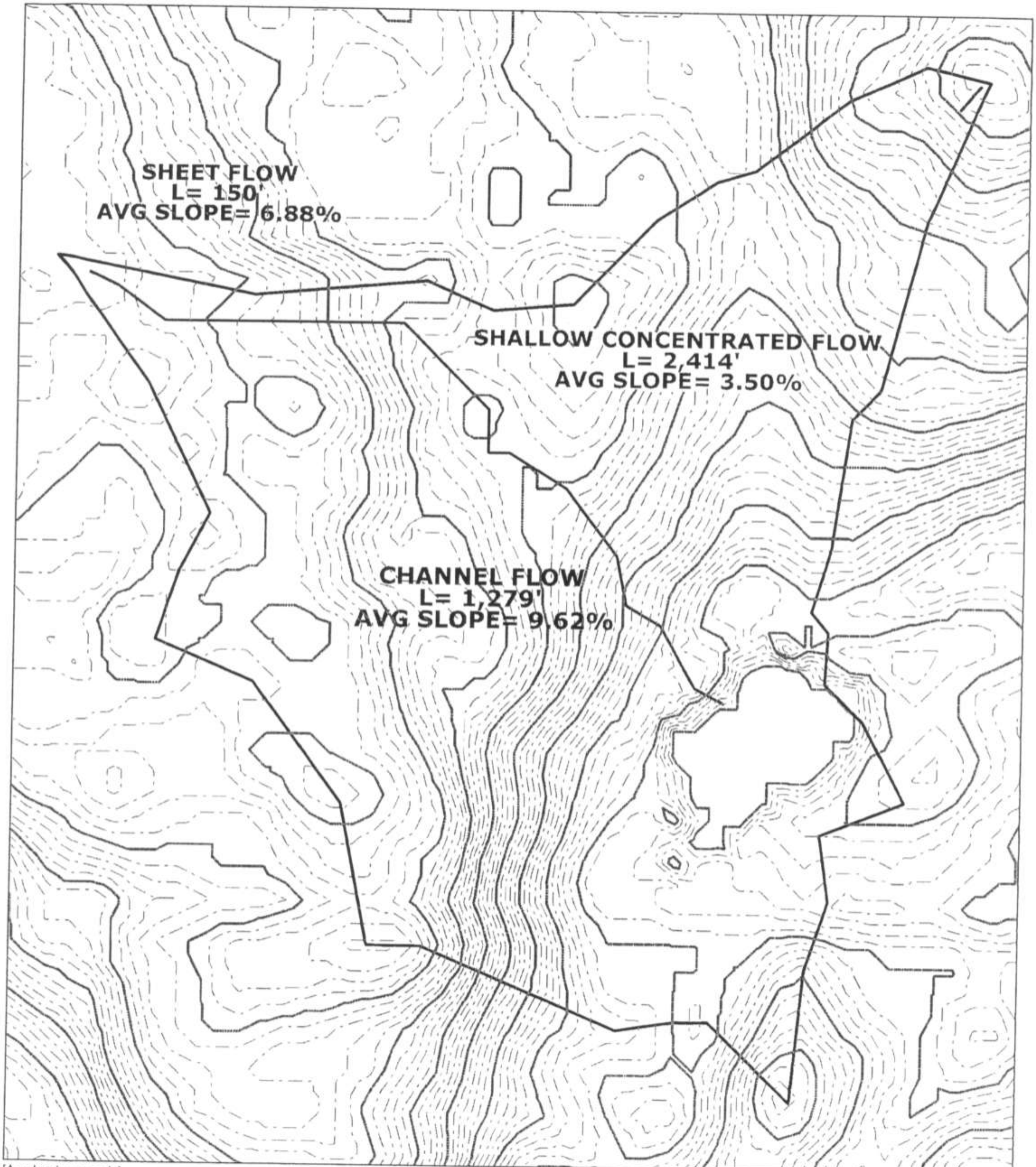
Agawam (29A)	= B
Canton & Charlton (62C)	= B
Canton & Charlton (62D)	= B
Charlton – Chatfield Complex (73C)	= B
Charlton – Chatfield Complex (73E)	= B
Paxton & Montauk (85B)	= C
Paxton & Montauk (85C)	= C
Paxton & Montauk (86C)	= C
Paxton & Montauk (86D)	= C
Ridgebury, Leicester (3)	= C
Rippawam (103)	= B
Timakwa & Natchaug (17)	= B
Walpole (13)	= C
Woodbridge (47C)	= C

Land Cover	Area (ac.)	Curve Number
Pond	12	100
Road	8.5	98
Residential (B)	14.27	68
Residential (C)	18.42	79
Pasture/Rangeland (B)	14.11	61
Pasture/Rangeland (C)	15.22	74
Forest (B)	82.33	55
Forest (C)	66.67	70

Composite Curve Number:

$$\frac{(12*100)+(8.5*98)+(14.27*68)+(18.42*79)+(14.11*61)+(15.22*74)+(82.33*55)+(66.67*70)}{231} = 67.7$$

Created by: CMM
Checked by: OJM



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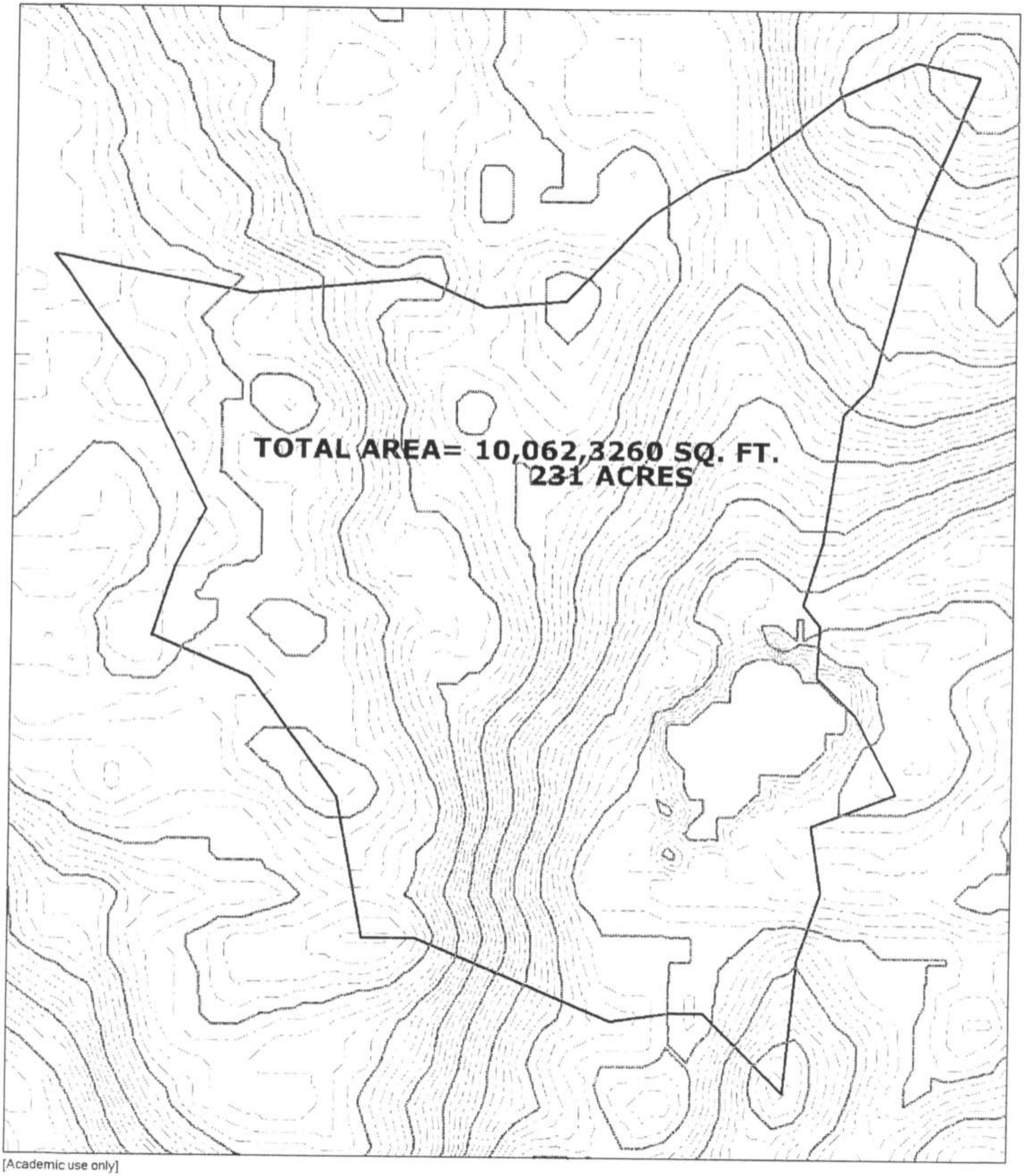

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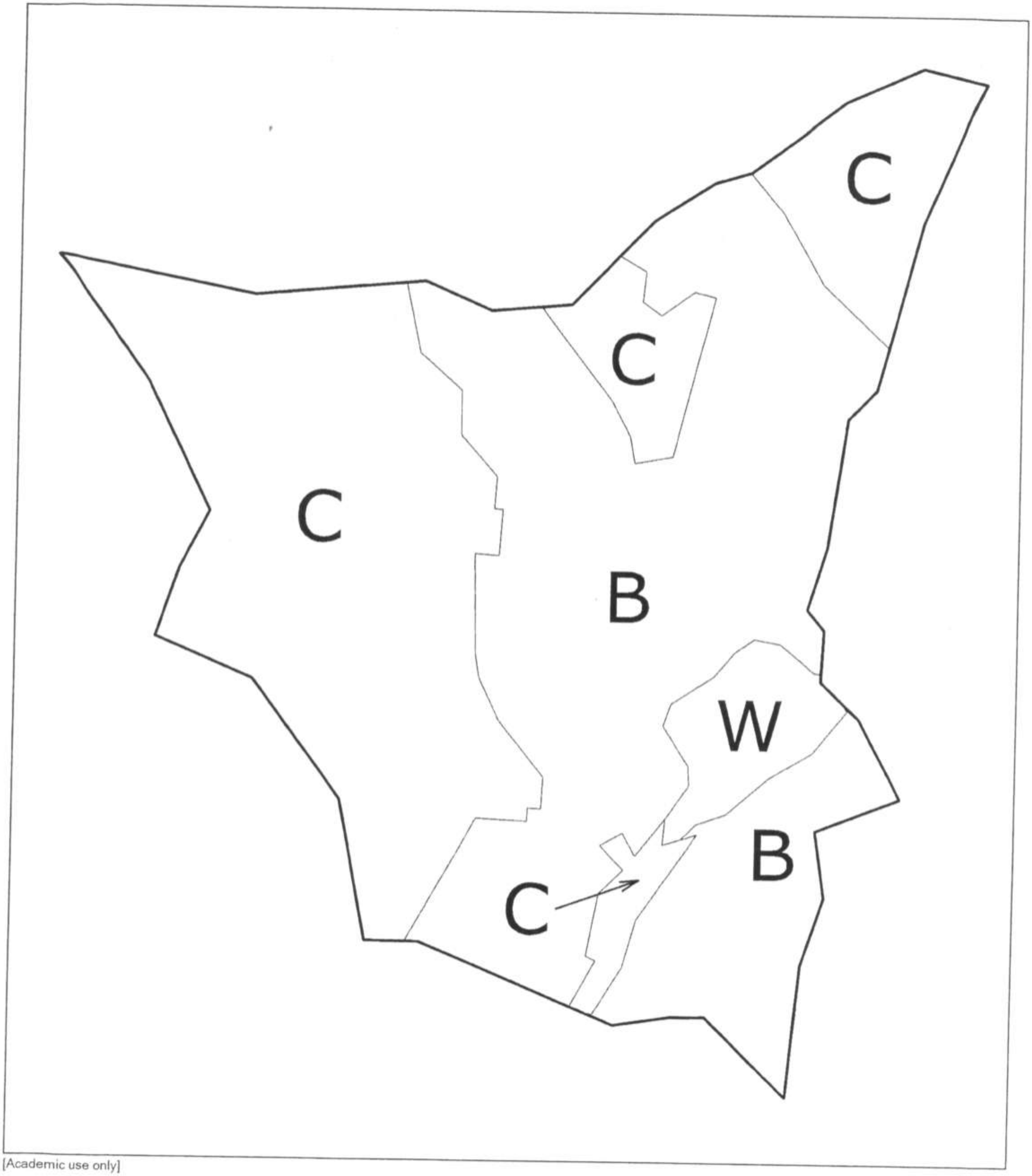

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Created by: DBH

Checked by: TM

Appendix E

Time Sheet:

Daniel Hoffman:

- Drove to the site three times (October 10, November 10, November 17) → 6 hours
- Work at the site (surveying, measuring, brainstorming) → 4 hours
- Initial proposal and presentation→ 8 hours
- Microstation land cover and soils → 4 hours
- Curve Number Calculations with Colin Mucci and Tsambikos Marasiotis → 5 hours
- Microstation time of concentration→ 2 hours
- Hydrologic Software Calculations with Colin Mucci and Daniel Hoffman (Sheet flow, Channel flow, Shallow Concentrated Flow) → 2.5 hours
- Downloading and importing surveying points→ 1.5 hours
- Alternate Design 1 with Colin Mucci and Tsambikos Marasiotis→ 6 hours
- Preparing maps and slides for final presentation→ 15 hours
- Typing and Finalizing Report → 9 hours

Time Sheet:

Tsambikos Marasiotis:

- Drove to the site four times (October 10, October 21, November 10, November 17) → **8 hours**
- Work at the site (Measuring, Surveying, Brainstorming Designs) → **4.5 hours**
- Initial Proposal → **8 hours**
- Hydraulic Hand Calculations and Software Check → **3.5 hours**
- Curve Number Calculations with Colin Mucci and Daniel Hoffman → **7 hours**
- Hydrologic Software Calculations with Colin Mucci and Daniel Hoffman (Sheet flow, Channel flow, Shallow Concentrated Flow) → **4 hours**
- Design Alternative 1 with Colin Mucci and Daniel Hoffman → **7 hours**
- Preparation for Final Presentation → **10 hours**
- Typing and Finalizing Report → **17 hours**

Time Sheet:

Colin Mucci:

- Went to the site five times (September 27, October 10, October 21, November 10, November 17) → **10 hours**
- Work at the site → **5.5 hours**
- Initial Proposal → **8 hours**
- Hydraulic Software Check → **3 hour**
- Curve Number Calculations with Tsambikos Marasiotis and Daniel Hoffman → **7 hours**
- Hydrologic Software Calculations with Tsambikos Marasiotis and Daniel Hoffman (Sheet flow, Channel flow, Shallow Concentrated Flow) → **4 hours**
- Design Alternative 1 with Tsambikos Marasiotis and Daniel Hoffman→ **7 hours**
- Presentation → **10 hours**
- Typing and Finalizing Report → **16 hours**

TIME SHEET – Anthony Santiago

Trips to the Site (Sept 27, Oct 21, Nov 10, Nov 17) Plus a meeting with Charles Elias at Uconn	13 hours
Draft Proposal	5 hours
Design Alternative 2	15 hours
Ogee Spillway Design	10 hours
Preparing for Final Presentation	10 hours
Typing and Finalizing Report	13 hours