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Mt. Washington Summit Facility Design and Wastewater Plant Analysis

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Degree of Bachelor of Science

By

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1. Fire Protection
2. Structural Design
3. Wastewater Treatment

Abstract

The goal of this project was to design an environmental research facility with an adequate fire protection system and to improve the wastewater treatment on the summit. This project assessed building and wastewater treatment needs for the extreme weather conditions on the summit of Mount Washington in New Hampshire. Two separate structural frames using structural steel and concrete were designed, and the structural steel frame was recommended as the best option. An INERGEN® fire protection system was selected for the proposed research facility. The current package wastewater treatment plant's influent and effluent characteristics were analyzed. Recommendations were made to modify the processes of the current wastewater treatment plant and to improve influent characteristics.

Authorship

This project was written by Lillian Clark, Richard Emberley, and Joseph Vanni. The research facility structural steel and foundation designs were written by Joseph Vanni. The reinforced concrete structural design and fire protection designs were written by Richard Emberley. The wastewater treatment plant analysis and alternatives were completed by Lillian Clark.

Lillian Clark

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Capstone Design

This project fulfills the requirements of a major design experience. Through the demonstration of knowledge and experience acquired in earlier course work and independent learning and through the incorporation of engineering standards, this project addressed realistic constraints and design considerations including economics, constructability, environmentalism, and health and safety, as well as social and political aspects.

An important consideration for this project was the economic feasibility for the State Park. The costs associated with the project must be covered by revenue from the Park sales on the summit. It was important to minimize the costs using a cost analysis for both the building design and the wastewater treatment plant recommendations.

This project addressed the environmental concerns raised by the Park staff about the current wastewater effluent characteristics, especially nitrates, not meeting the NH discharge requirements. The project considered ways to improve the current treatment process to reduce effluent concentrations to meet the NH discharge requirements and to protect the sensitive alpine research area located downhill from the plant.

The constructability of the project addressed the feasibility of the design and construction of both the research facility and the wastewater treatment plant. The summit of Mount Washington presents a number of natural challenges to constructability including an extremely small construction season, cold temperatures, high winds and fog. This project addressed these conditions by considering the ease of construction when choosing building materials. The proposed research facility was designed to minimize excavation and alteration of the historic views of the mountain.

The social and political issues of constructing a building on the summit of Mt. Washington impacted height and aesthetics of the building. The building height was limited, as persons in surrounding towns do not want to see a tall structure on the summit. The State Park managers wanted the building to fit the natural surroundings of the summit and resemble the other buildings on the summit. This project incorporated all these constraints into the design of the facility.

In order to address health and safety considerations, a structural analysis of the research facility was performed in order to assure that the building is able withstand the harsh summit conditions. The building was designed to comply with the following safety and fire codes: *NFPA 101: Life Safety Code, NFPA 1: Fire Code 2009, International Building Code 2009, Building Code Requirements for Structural Concrete (ACI 318-05).*The wastewater treatment plant recommendations considered a need for increased safety of the Park managers traveling to the plant in the dangerous weather. Since local fire departments do not have access to the summit, a fire protection system was designed to extinguish a fire in the shortest time possible. NFPA documents used in the research and design were *NFPA 13: Automatic Sprinkler Systems Handbook 2010* and *NFPA 750: Standard on Water Mist Fire Protection Systems 2010.*

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1 Introduction

The Mount Washington summit in North Conway, NH is a popular attraction for hikers and tourists as well as a location for valuable research on the mountain's unique conditions and environment. While a large number of tourists visit the summit in the summer, extreme weather conditions prevent such visits during the winter. Providing a wastewater treatment system to accommodate variable visitor usage while meeting discharge requirements in the cold weather is a constant challenge for park staff. In addition, a new building to pursue the ongoing research on the mountain is much needed. A building on the summit must be able to withstand extreme precipitation and wind conditions. Fire protection systems are also important because there is no access for fire trucks on the Auto Road leading to the summit.

The purpose of this project was to design a two-story research facility to be constructed at the summit of Mount Washington as well as to analyze their current wastewater treatment plant and recommend solutions to help meet the current discharge permits.

This project was divided into two distinct sections: the building and the wastewater treatment plant. The building design includes the structural design of the beams, girders, floors, columns, and foundation along with a sprinkler system design. A variety of structural building materials were considered to combat the unique weather conditions of the summit, as well as the overall constructability of each design. The wastewater treatment plant design includes an analysis of various package wastewater treatment plants taking into account the summit's unique weather, as well as large seasonal and daily changes in flow. A recommendation for the building design and treatment plant design are provided based on cost, constructability, and maintenance.

2 Background

The location of the "World's Worst Weather" is on the summit of Mt. Washington in northern New Hampshire. With yearly snow accumulations over 300 inches and wind gust speeds over 200 mph along with the elevation and remoteness of the summit, the design of any facility on Mt. Washington needs to account for the unique features of the summit. The specific needs of the state park must be addressed in the building design in addition to the weather. This chapter discusses the history and needs of the State Park, as well as the design constraints for the proposed new research facility and wastewater treatment plant.

2.1 Mount Washington State Park

Mount Washington is located in northern NH about 90 miles northwest of Portland, Maine, 180 miles north of Boston and 210 miles southwest of Montreal (see Figure 1). The mountain is part of the Presidential Range, which forms a ridgeline about 12 miles long and includes the highest peak in the Northeast at 6,288 ft. It is the highest point in the United States east of the Mississippi River and north of the Carolinas with the only peak in the Northeast that exceeds 6,000 ft. (Mount Washington Observatory 2010b).

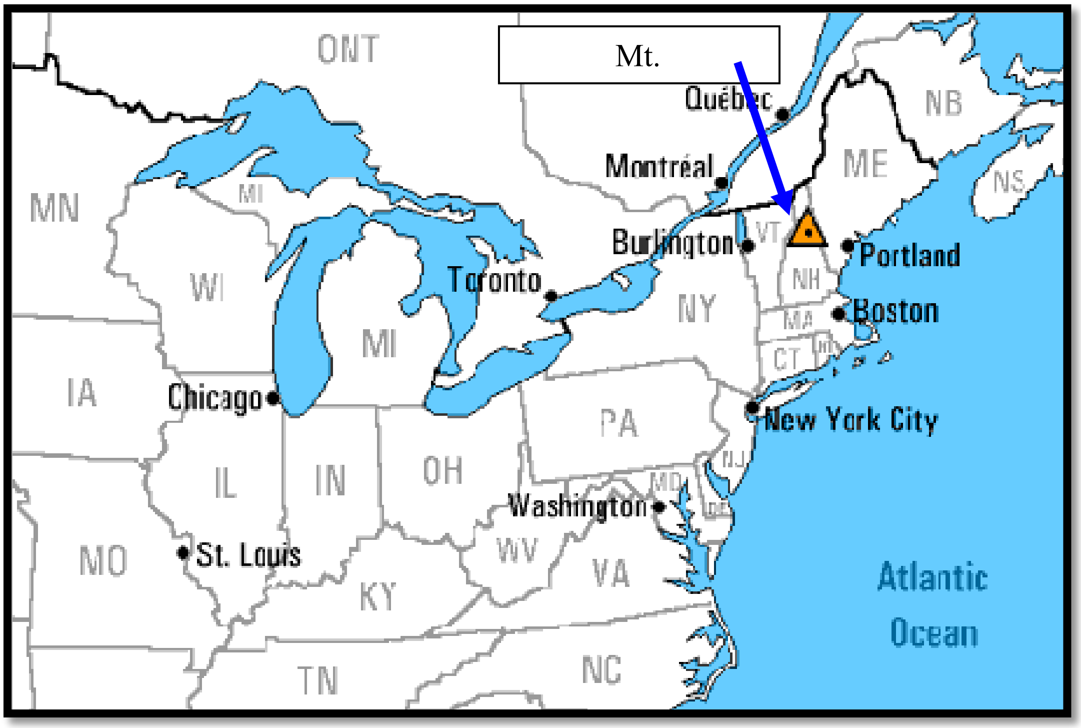

Figure 1: Mount Washington (Mount Washington Observatory 2010b)

As part of the Appalachian Trail, the mountain brings many hikers, some long distance, to enjoy the views the summit has to offer of the surrounding White Mountains, and of peaks in Maine, Vermont, Quebec, and even New York on a day with ideal conditions. The summit can also be reached by visitors by the Cog Railway, which is about 3 miles long, or via the 8 mile trip up the Auto Road (see Figure 2). On the top of the mountain there is the Sherman Adams Summit Building, the Tip Top house, the Yankee Building, the WMTW-TV Station and towers, and the Stage Office, as shown in Figure 3 (Mount Washington Observatory 2010b).

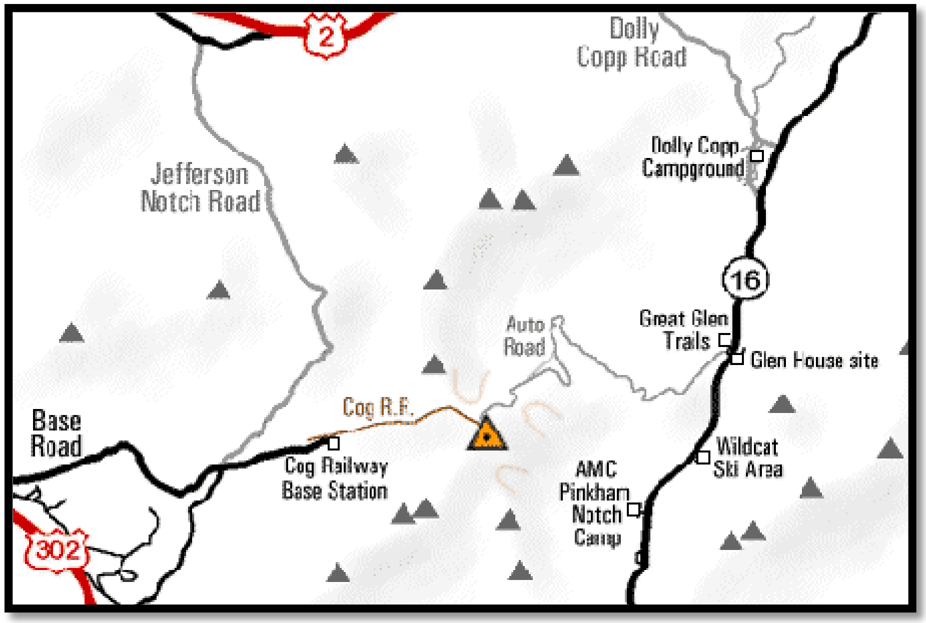

Figure 2: Map of Mount Washington (Mount Washington Observatory 2010b)

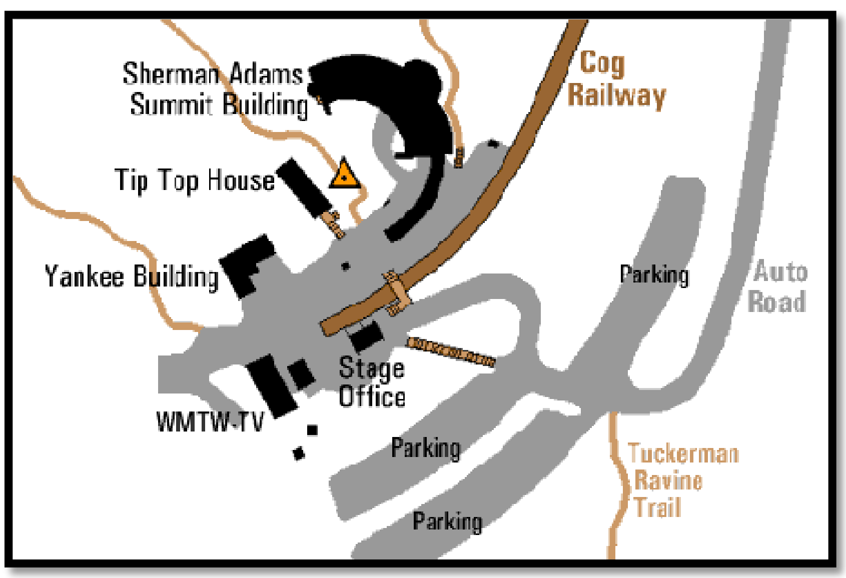

Figure 3: Map of Summit (Mount Washington Observatory 2010b)

2.1.1 History of the Park

Mount Washington has attracted many visitors since the first summit house was built in 1852. Soon after this house was built, the Carriage Road and the Cog Railway were constructed on opposite sides of the mountain to allow more visitors of all ages and abilities to reach the summit. With more visitors came more buildings, but not without the challenges due to the unique location and the weather conditions at the summit. For example, all of the buildings, besides the Tip Top House, burned in a fire in 1908 due to the lack of available water for firefighting. The Mount Washington Observatory, originally housed in the Stage Office and now in the Sherman Adams Building, was established in 1932 and has since kept a daily record of the weather.

On February 9, 2003, a fire broke out in a former WMTW television building. The building at the time of the fire also housed the WHOM radio station transmitters and other broadcasting equipment. The fire started in the WMTW building and then spread to the Yankee power building next to it. Both buildings were completely destroyed in the blaze (see Figure 4). Since the fire destroyed the electricity generator in the building, the electricity was cut off for the entire summit and every person had to be evacuated (Cheshire County DX ARC 2003).

Figure 4: WMTW Building after Fire (Cheshire County DX ARC 2003)

The summit sees about 300,000 people each summer. During the harsh winters, the number of visitors to the mountain is close to none, besides the park rangers who maintain the buildings and the wastewater treatment plant (Mount Washington Observatory 2010b).

2.1.2 Existing Buildings

Currently, there are four working buildings on the summit of Mount Washington, as shown in Figure 3. The Sherman Adams Summit Building was built in 1979 to replace the previous summit building (Mount Washington Observatory 2010a). It is made of concrete and serves as the mountain's main visitor center. The building includes many amenities for visitors including an observation tower, restroom facilities, a post office, a food court, water fountains, and a museum. The Sherman Adams Building also houses the Mount Washington Observatory and the living quarters of its crew (Mount Washington Observatory 2010a).

The Tip Top house was constructed in 1853 when it served as a hotel. Today, the stone building is the oldest building on the summit, and it was the only building that survived the 1908 fire. Recently renovated, the 2,350 square foot structure is open to the public where it serves as a reminder of the observatory's past (Mount Washington Observatory 2010a).

The current Stage Office was built in 1976 to replace its predecessor. The original Stage Office, which recorded the record wind speed of 231 miles per hour in 1934, served as the original home of the Mount Washington Observatory (Mount Washington Observatory 2010a). The current building was made as a likeness of its predecessor and is equipped with chains that help hold its roof in place during the intense storms that frequently hit the summit. The interior of the building houses restrooms and a gift shop for tourists.

The summit also has numerous broadcasting towers that serve several state and federal agencies, as well as two FM radio stations, WHOM and WPKQ. The Yankee Building houses the majority of the broadcast equipment (Mount Washington Observatory 2010a). One of the other broadcast buildings, the WMTW-TV building, burned down in the fire of 2003. Previously, it held the station's equipment, electrical generators and living quarters for WMTW staff.

2.1.3 Existing Wastewater Treatment Plant

The wastewater treatment plant for the mountain is located about 300 feet below the Sherman Adam's Visitor Center. During the tourist season of the summer, approximately 300,000 visitors come to this building, and this generates over 500,000 gallons of wastewater a year. Seasonal visitation trends have a large impact on wastewater flows. On a busy summer day, the average flow of wastewater is about 5,000 gallons. On a typical winter day, the only wastewater generated is from the few staff members on the mountain.

Prior to the 1940's, wastewater was disposed of via a pipe on the east side of the mountain. In the 1940's, an icing research laboratory was established on the mountain. During this time, waste from the mountain was put into a containment system consisting of wells and holding tanks that were periodically emptied by a tanker truck. Several decades later there was a need to improve this system because of increased numbers of tourists and waste. The New Hampshire Bureau of Public Works along with input from the New Hampshire Department of Environmental Services (DES) selected a package wastewater treatment plant from the company Lifewater Engineering, in Fairbanks, Alaska. This company was chosen based on the company's experience with extremely cold climates. The system is called the Extreme Sewage Treatment Plant, or ESTP (Personal communication, Pelchat 2010).

In the system designed for Mount Washington, the sewage flows from the Sherman Adams Building through heated pipes to the package treatment plant. The process begins with screening which removes the larger particles. This screened wastewater is then pumped to an anoxic tank to allow for denitrification. The anoxic tank has a mixer and a sensor, which measures the dissolved oxygen. In order to keep the dissolved oxygen concentration low, a carbon source called microCg is added. Microbial degradation of the microCg consumes oxygen and the microCg also provides a carbon source and electron donor for the denitrifying bacteria (Personal communication, Pelchat 2010).

After the anoxic tank, the wastewater is treated aerobically with an active sludge process in a bioreactor tank. The detention time in this tank is about 15 hours and there are sensors that monitor the dissolved oxygen, total suspended solids, and pH. The mixed liquor is then pumped through four tubular membrane filters in series. When about 600 gallons of treated water accumulates in the storage tanks at the end of the filters, the effluent is discharged in batches through a UV disinfection system and then onto the ground near the plant. Heated and insulated pipes make it possible to discharge the water in the winter. The excess sludge is either put into underground holding tanks to be removed by a truck or in a sludge bag. In addition, recirculation of the flow from some of the tanks in the treatment process is done in order to accommodate the large fluctuations in flow during the season and between seasons (Personal communication, Pelchat 2010).

2.1.3.1 Current Treatment Challenges

There are many challenges to treating wastewater at the summit. First, the plant experiences significant daily and seasonal variations in the flow of the wastewater due to visitation trends. The majority of visitors come to the summit in the summer months and there are barely any in the winter. In addition, during the summer months, a clear and relatively warm day will bring more visitors than a foggy and cold day. This poses a challenge for the living organisms in the treatment system because of changes in flow and organic matter concentrations.

The operation of the plant for 365 days a year is the responsibility of the four staff members on the summit, who must also manage the many other maintenance aspects on the top of the mountain. Maintenance is especially difficult in the winter months because the extremely strong winds and cold temperatures make the plant difficult to access. Much of the current maintenance involves filters clogging and pumps failing. According to Diane Holmes (2010), a park staff member, the filters need a lot of maintenance and must routinely be taken out and cleaned. If one of the pumps fails, there is no secondary pump that can be turned on and treatment must temporarily stop. If maintenance needs to be done, there is no fresh water available at the treatment system to clean the system or for the staff to clean up afterwards (Personal Communication, Holmes 2010).

The treatment plant is located about 300 ft. away from the laboratory on the summit. Collecting samples is dangerous during the stormy weather that occurs throughout the fall, winter, and spring months. Once samples are collected, they must be brought back up to the small make-shift laboratory in the Yankee Building. Effluent must be tested to make sure it is meeting discharge requirements from the NH Department of Environmental Protection. The current treatment plant does not always meet these requirements. When the effluent concentrations exceed the limits, they can have an impact on the alpine research area located below the treatment plant (Personal Communication, Holmes 2010).

2.1.4 Current Water Supply

The State Park currently has one working well to supply all the water needs for the summit. The well only draws a limited amount of water when in use. During the winter and spring, the well draws 3-5 gallons per minute (gpm); whereas during the summer and fall it draws 10-12 gpm. When flows are low as in the winter and spring, the well can only be run for short durations because the chances of drying up the well, damaging the pump, and/or contaminating the well are greater (Personal Communication, Emberley 2010). Typically, the water pump runs between 30 minutes and 8 hours at a time (Holmes 2010).

The summit stores water in several tanks to ensure that if flows from the well are low, water can still be provided to the buildings. Five tanks, each with a 2,470 gallon capacity (12,350 gallon total), are inside the Sherman Adams building. During the summer months when the weather is warmer, two outside tanks each with a 20,000 gallon capacity (40,000 gallons total) are used. Each of the inside and outside tanks is kept as full as possible at all times (Holmes 2010).

2.1.5 Needs of the Park

The State Park on the summit of Mount Washington is in need of a building to replace the old WMTM TV-8 building that was destroyed by fire. The new building would serve as an environmental research facility for the state park and would need to fit the footprint of the previous building (Personal Communication, Pelchat 2010).

The park has several requirements for this new building. A garage or airlock large enough for a snow cat to fit in will need to be linked to the new facility to allow for safe debarkation in the winter months. A kitchen, bathrooms, storage facilities and sleeping areas are required. Other areas within the building could include a lounge and study areas, as well as a conference room. Diane Holmes stated that the wastewater treatment laboratory should be located inside of this new building because the current laboratory is located in the Yankee building, which is too far from the current treatment plant. Due to problems with the treatment system in place on the summit, the staff has requested a new treatment facility to replace the old system and for it to be adjacent to or in the floor plan of this new building. The new facility should be simple for the park staff to maintain, while also reducing effluent concentrations to the acceptable limits as stated in the New Hampshire discharge permit. The treatment facility must also be able to operate under the extreme conditions on the summit (Personal Communication, Holmes 2010).

The building's roof should have space for radio and observatory equipment as well as an area for visitors to enjoy the views of the southern and western portions of the mountains. A ramp should be constructed to the roof so that visitors can access the observation area without having to walk through the interior of the building.

The park is also in need of a second observation tower in addition to the existing tower on top of the Sherman Adams building. Therefore, a second tower will be erected on the roof of the new building.

The fires of 1908 and 2003 are prime examples demonstrating the need for fire protection systems to be installed in the new building. Firefighting capabilities are minimal due to the weather on the summit, the limited availability of water, and the lack of personnel. In the event of fire, the state park rangers attempt to extinguish the fire. Only two fire fighter suits and breathing apparatuses are available to the crew. Fire hoses can help extinguish a fire in the Sherman Adams building but no hoses and water connections are available in the Yankee building. There is only one well on the summit that can be used for water and this well produces a flow that is too small to adequately fight a fire. Fire trucks cannot access to the summit because it is too hazardous for a truck to drive up the Auto Road, regardless of the weather. Fire protection systems need to be installed to protect the equipment being housed in the building and the people residing in the building (Personal Communication, Pelchat 2010).

2.2 Design Constraints

Design constraints help to focus a project. Constraints can include how much the sponsor or client is willing to spend on a new building to where the building is located and what it should look like. Other critical design constraints include building and fire codes and discharge permits. The codes and permits are standards established by the state to protect life and the environment from harm.

2.2.1 Budget

Through communication with Diane Holmes, acting Mt. Washington State Park Manager, a budget was established for the design of the environmental research facility and wastewater treatment plant. This budget was set at ten million dollars. This covers the entire cost of design and construction. However, NH legislation mandates that every New Hampshire State Park must be a self-supporting entity. Mt. Washington does not receive state funding to help with repairs or for upgrades. Revenue comes from food concessions, sales in the gift shop, and donations.

2.2.2 Building Code

Building codes are regulations that ensure the safe design and construction of a building. These mandatory codes provide the minimum design conditions. Because Mt. Washington is in the state of New Hampshire, the New Hampshire State Building Code governs the aspects of the design. The State of New Hampshire has adopted the *International Building Code* (IBC) 2009 as its current building code. The code went into effect in April 2010(Reed Construction 2010). Everything about a building from its design and construction to demolition and removal has to be done according to the provision of *IBC 2009* (State of New Hampshire 2002). Some *IBC* regulations include material types, building heights and areas, and means of egress (International Code Council Inc 2009).To incorporate realistic constraints on this project, the design of the building was completed according to the *IBC 2009*.

2.2.3 Fire Protection

The State of New Hampshire adopted *NFPA 1*, 2009 Edition, as its state fire code. As with the building codes, the fire code went into effect in April 2010(National Fire Protection Agency 2009). As stated in Chapter 1.2 of *NFPA 1*, “the purpose of this code is to prescribe minimum requirements necessary to establish a reasonable level of fire and life safety and property protection from the hazards created by fire, explosion, and dangerous conditions”(National Fire Protection Agency 2009).This statement reflects the desire of the state park to have a building with fire protection systems suitable to protection expensive equipment and lives that are housed in the building. The new building was designed with sufficient means of fire protection using *NFPA 1*.

2.2.4 Accessibility Guidelines for Buildings and Facilities

The Americans with Disabilities Act (ADA) was signed into law in 1990. The ADA requires all new construction after 1993 to be designed and constructed with certain public accommodations for people with disabilities (U.S. Architectural and Transportation Barriers Compliance Board 1991). The requirements for building design are listed in the Accessibility

Guidelines for Buildings and Facilities of ADA. The research facility was designed based on these requirements.

2.2.5 Discharge Permits

The groundwater discharge permit (Appendix B) from the Water Division of the New Hampshire Department of Environmental Services (NHDES) allows for the discharge and infiltration of up to 5,000 gallons per day of tertiary treated disinfected wastewater at the summit. The Mount Washington treatment plant cannot violate the groundwater Ambient Groundwater Quality Standards adopted by the DES at the boundary of the discharge zone. The discharge must also not cause any degradation to the groundwater. (NH DES 2009)

The treated effluent must meet the criteria in Table 1 before it is discharged. The continuous flow (gpd), ammonia, biological oxygen demand (BOD_5), total Kjeldahl nitrogen TKN), and total suspended solids (TSS) in the influent are required by the discharge permit to be monitored daily. Fecal coliform samples are taken weekly. If the treatment system fails to meet these discharge limits, then the two 5,000 gallon tanks on the site can be used for sewage storage.

Table 1: Wastewater Discharge Criteria (The State of New Hampshire Department of Environmental Services 2009)

Parameter	Effluent Limit	Frequency
pH	6.0 – 9.0	Weekly average
BOD_5	≤10 mg/l	Weekly average
Nitrate	≤10 mg/l	Weekly average
TSS	≤10 mg/l	Weekly average
Fecal Coliform	Zero counts/100 ml	Per sample

2.2.6 Summit Watershed

According to Seth Prescott of the State of New Hampshire Department of Resources and Economic Development, the old containment system was on US Forest Service land. One of the goals for the current package treatment system was to get the system off of that land and onto the park's land (Personal Communication, Prescott 2010). Another consideration that influenced the placement of the existing plant was which watershed would receive the effluent from the plant. The alpine garden was a concern for the current plant because that area is used for research. Figure 5 is a contour map, from Stantec Consulting Services, found in the application for the discharge permit for the current treatment system (The State of New Hampshire Department of Environmental Services 2009). As seen from the contours in the figure, the effluent from the current location of the treatment system will eventually reach the sensitive alpine research area. It is important to have the new treatment plant in a location where discharge is not affecting the alpine research area.

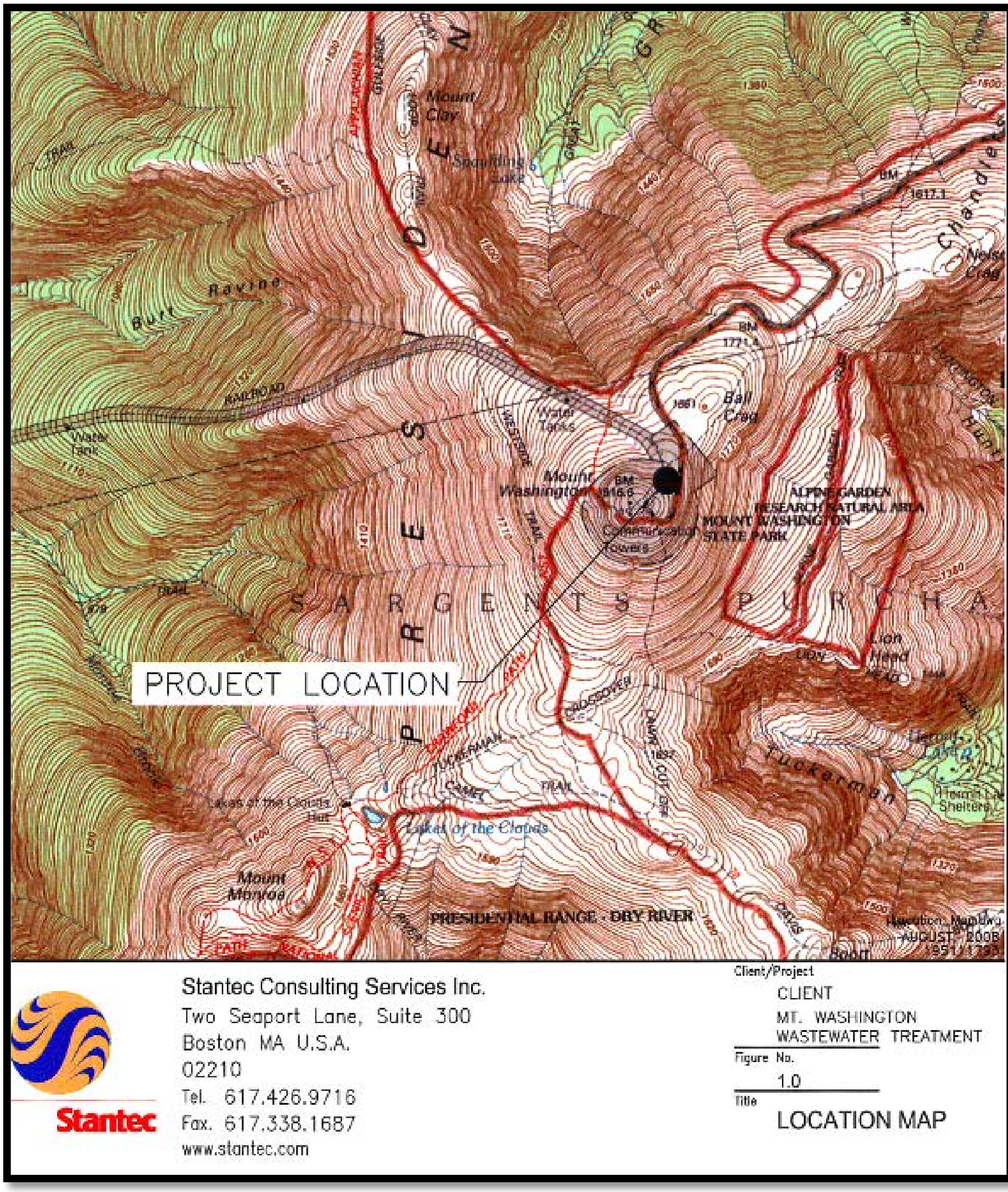

Figure 5: Lifewater Systems Treatment Location Contour Map (The State of New Hampshire Department of Environmental Services 2009)

2.2.7 Site Geology

Mount Washington, along with the other mountains in the Presidential Range, is a part of the White Mountain batholith. This large geological feature makes up most of the White Mountains in northern New Hampshire, covering over 1000 square kilometers. The structure of the basolith consists of igneous rock, 97 percent of which is granite, quartz syenites, or syenites. Mount Washington is located in the eastern portion of the batholith. The make-up of the rock in this area is mainly comprised of Moat volcanic rocks. These rocks include trachyte, tuff, breccias, alkali, rhyodyte and comendite, all of which are types of granite (Creasy and Fitzgerald 1999).

The geology of the summit of Mount Washington is important to consider in the design of the research facility. More specifically, the location of bedrock influences the design of the building's foundation. Bedrock lies at a depth of three to eight feet beneath the summit area of Mount Washington. The shallowest depths are located around the actual summit and near "Goofer Point," an area on the south side of the summit overlooking the Lake of the Clouds hut. Covering the bedrock is a layer of very large (one half to three cubic yards) boulders. This generality was confirmed during the construction of the Sherman Adams Building in the 1970s. Isolated pockets of sandy, stony, reworked glacial till known as "diamict" can also be found at bedrock level, although these are generally rare (Fowler 2010). Due to the relatively shallow depth of bedrock at the summit, only one story of the facility was designed to be below grade. To limit the amount of excavation work, the existing foundation hole from the previous building was used.

2.3 Weather Challenges

One of the major challenges in designing facilities for the summit of Mt. Washington is the weather. Weather affects everything from the flows of the wastewater treatment plant to the wind, snow, and impact loads on the structures. Table 2 is a summary of the effects weather has on building design and the indoor wastewater treatment system.

Table 2: Summary of Weather Effects

Type of Weather	Effect on Building Features	Effect on Building Design	Effect on Wastewater Treatment
Temperature	Insulation Type	Material choice	Bacterial Processes
Wind	Overhangs	Increases design loads	Not Applicable
Precipitation	Roof, materials	Increases design loads	Not Applicable
Rime	Effects negligible	Increases impact loads due to falling	Not Applicable
Fog	Effects negligible	Constructability	Not Applicable
Falling Ice	Window strength	Impact loads	Not Applicable

2.3.1 Temperatures

According to the Mount Washington Observatory, the average temperatures on the summit of the mountain during the year range from 5.2 to 48.7 degrees Fahrenheit, without accounting for wind chill (see Table 3).With the wind chill, values commonly drop below -100 degrees Fahrenheit. Summers average in the mid-forties, while winter temperatures are commonly in the single digits. The record low was recorded in 1934 as -47 degrees Fahrenheit. The cold temperatures are enhanced not only by the strong winds, but also by the amount of snow and fog that the mountain receives (Mount Washington Observatory 2010c).

Cold temperatures on the top of the mountain have an impact on building features as well as construction and design aspects. With the cold temperatures, it is important that the new research facility be properly insulated and designed to retain heat in the winter. During the construction phase, temperature extremes make it difficult to properly cure concrete. If the temperature is too close to freezing, then hydration of the concrete slows to nearly a standstill causing it to be weaker. Generally, the temperature should not drop below 50 degrees Fahrenheit while the concrete is curing (Portland Cement Association 2010; Uggerholt 2010).

Table 3: Temperatures (Fahrenheit) averaged over the period from 1971-2000(Mount Washington Observatory 2010c)

Month	Average Daily Maximum	Average Daily Minimum	Monthly Average	Record High (Year)	Record Low (Year)
January	14.0	-3.7	5.2	47 (1995)	-47 (1934)
February	14.8	-1.7	6.6	43 (1981,1999)	-46 (1943)
March	21.3	5.9	13.6	54 (1998)	-38 (1950)
April	29.4	16.4	22.9	60 (1976)	-20 (1995)
May	41.6	29.5	35.6	66 (1977)	-2 (1966)
June	50.3	38.5	44.4	72 (2003)	8 (1945)
July	54.1	43.3	48.7	71 (1953)	24 (2001)
August	53.0	42.1	47.6	72 (1975)	20 (1986)
September	46.1	34.6	40.4	69 (1999)	9 (1992)
October	36.4	24.0	30.2	59 (1938)	-5 (1939)
November	27.6	13.6	20.6	52 (1982)	-20 (1958)
December	18.5	1.7	10.1	47 (2001)	-46 (1933)
YEAR	33.9	20.4	27.2	72 (1975)	-47 (1934)

As a result of the extremely cold temperatures starting in beginning of the fall season, the numbers of hikers and tourists who visit the mountain decreases significantly from the summer months. The seasonal variations in the number of visitors result in large wastewater flow fluctuations between the summer and winter months at the summit. A treatment plant on the top of the mountain must be designed to accommodate these fluctuations. The current treatment plant handles these flow fluctuations by including re-circulating tanks in the system. In addition, the freezing temperatures in the winter decrease the effectiveness and efficiency of traditional biological treatment methods. Currently, the surface discharge from the treatment plant is able to melt the snow and infiltrate into the ground. The ability to have a surface discharge in the winter is necessary for this facility.

2.3.2 Wind

Mount Washington is located in the middle of converging storm tracks, mainly from the South Atlantic, the Gulf region, and the Pacific Northwest. The Presidential Range acts as a barrier to winds from the west. As a result of the temperature differences between the Northeast and the Atlantic Ocean, low-pressure systems develop along the coastline in the winter causing winds that exceed hurricane force almost one third of the days in a year. The average wind speeds on the mountain range from the mid 20's to mid 40's miles per hour. However, it is not uncommon to see peak gusts over 100 miles per hour, as shown in Table 4.Peak gusts occur from many different directions but the prominent wind direction is from the west (Mount Washington Observatory 2010c).

Table 4: Wind (MPH) averaged over the period from 1971-2000(Mount Washington Observatory 2010c)

Month	Mean Wind		Peak Gusts		
	Speed (MPH)	Predominant Direction	Speed	Year	Direction
January	46.3	W	173	(1985)	NW
February	44.5	W	166	(1972)	E
March	41.6	W	180	(1942)	W
April	36.1	W	231	(1934)	SE
May	29.7	W	164	(1945)	W
June	27.7	W	136	(1949)	NW
July	25.3	W	154	(1996)	W
August	25.1	W	142	(1954)	ENE
September	29.1	W	174	(1979)	SE
October	33.8	W	161	(1943)	W
November	39.7	W	163	(1983)	NW
December	44.8	W	178	(1980)	NW
YEAR	35.3	W	231	(1934)	SE

Extreme winds pose a significant challenge to building on the summit. Strong winds can exert significant loads on a building, and magnitudes of wind loads vary with geographical locations, heights above the ground, types of terrain surrounding the buildings, and other factors. The strong winds on Mount Washington come from many different directions, and this poses a design concern for features like the faces of the building and the roof. The final design must take into consideration strong winds from all directions and not just the predominant direction from the west. Extreme winds of hurricane force are capable of taking a roof off of a building. Wind forces also act as pressures on vertical surfaces facing the wind, and pressures or suction on sloping surfaces facing the wind. Suction occurs on flat, vertical, and sloping surfaces facing away from the wind. Various loads and combinations of loads could occur on the building. The largest wind load and effect that is predicted to occur in the worst case was used for analysis and design (McCormac 2008).

2.3.3 Precipitation

The summit of Mount Washington experiences various types of precipitation throughout the year. As seen in Table 5, the summit has a yearly average of 101.9 inches of total precipitation, with a high of 130.1 inches in 1969 and low of 71.34 inches in 1979. As shown in Table 6, in the winter the summit averages between 48 and 55 inches of snow or ice per month, and yearly snowfall averages 314.8 inches. The highest snowfall in one month was 172.8 inches in 1969 with a yearly total in 1968-69 of 566.4 inches. The record for snowfall in a twenty-four hour period is 49.3 inches (Mount Washington Observatory 2010c).

Table 5: Precipitation (water equivalent, inches) averaged over the period from 1971-2000(Mount Washington Observatory 2010c)

Month	Average	Maximum Monthly (Year)	Minimum Monthly (Year)	Maximum in 24 hours (Year)
January	8.52	18.23 (1958)	1.29 (1981)	4.85 (1986)
February	7.33	25.56 (1969)	0.98 (1980)	10.30 (1970)
March	9.42	15.98 (1977)	2.15 (1946)	6.45 (1999)
April	8.43	15.21 (1988)	2.19 (1959)	8.30 (1984)
May	8.21	19.00 (1997)	1.78 (1951)	4.60 (1967)
June	8.36	16.00 (1973)	2.43 (1979)	6.50 (1973)
July	8.02	16.59 (1996)	2.69 (1995)	7.37 (1969)
August	8.08	20.69 (1991)	2.46 (1996)	6.63 (1991)
September	8.55	15.47 (1994)	2.74 (1948)	5.38 (1985)
October	7.66	28.70 (2005)	0.75 (1947)	11.07 (1996)
November	10.49	19.56 (1983)	2.31 (1939)	6.07 (1968)
December	8.84	17.95 (1973)	1.49 (1955)	8.64 (1969)

The design considerations for precipitation center on the snow and rain roof loads for the structure. Roof snow loads are influenced by the quantity of snow that falls on Mount Washington during the course of the year. In addition to this base number, roof snow loads are influenced by the pitch of the roof as well as the roof's thermal qualities and exposure to precipitation (Steel Building Guide 2007). Snow drifting and sliding were considered as both produce variations in snow load values across the roof surface which could result in overloads on sections of the roof.

Table 6: Snow, ice pellets, hail (inches) averaged over the period from 1971-2000(Mount Washington Observatory 2010c)

Month	Record Mean	Maximum Monthly (Year)	Maximum in 24 Hours (Year)
January	50.4	94.6 (1978)	24.0 (1978)
February	48.2	172.8 (1969)	49.3 (1969)
March	51.0	98.0 (1970)	27.4 (1969)
April	40.8	110.9 (1988)	27.2 (1988)
May	11.3	95.8 (1997)	22.2 (1967)
June	1.2	8.1 (1959)	5.1 (1988)
July	Trace	1.1 (1957)	1.1 (1957)
August	0.3	2.5 (1965)	2.5 (1965)
September	2.2	7.8 (1949)	7.7 (1986)
October	14.0	78.9 (2005)	25.7 (2005)
November	40.4	86.6 (1968)	25.0 (1968)
December	55.0	103.7 (1968)	37.5 (1968)

Rain loads are also important to consider in the design of a structure. Since rain does not accumulate in the same manner as snow, it is necessary to design roofs to properly drain rain water. However, the roof should be designed to withstand loads from accumulated rain in the event that these drainage methods are block or disabled. Additionally, ponding, the accumulation of water due to the deflection of roofs, should be considered in the determination of rain loads.

The most important factor in considering the effects of precipitation in a design for the summit is the combined effects of both rain and snow. Often in late winter and early spring storms, snow storms can quickly change to rain storms. Since snow has accumulated on the roof, rainwater drainage systems will not operate optimally. In addition, rain will be absorbed by the snow, saturating it with water and increasing the overall load on the roof. Finally, ponding will be one of the major problems in these mixed precipitation storms. As rain falls onto water saturated snow, it puddles. This gathering of rainwater on top of the snow will increase the overall load on the roof of the structure. This combined load of the rain and snow will increase the deflection of the roof, further contributing to the ponding effect and possibly creating serious problems for the structural integrity of the facility.

2.3.4 Rime Ice

One unique type of precipitation that occurs at the summit is known as rime ice. Rime is a type of white or milky opaque white ice that forms on the outside of both natural and manmade structures. It closely resembles frost found inside of freezers (Federal Aviation Administration 1975). Usually found in aviation, rime is very common during the colder months at the summit, growing quite thick at times. The formation of rime ice happens when super cooled water droplets strike an object at or below the freezing temperature of water. Rime is most often caused by freezing drizzle or fog. Other conditions that aid in the formation of rime include small droplet size as well as the dispersion of fusion heat from the freezing water (Federal Aviation Administration 1975). Rime is unique in that it forms winwardly (into a blowing wind) rather than leewardly. While rime ice may grow thickly on buildings, its weight is negligible, causing no structural stress (Federal Aviation Administration 1975). The formation of rime ice is inevitable in the winter on the summit, but the formation of the rime ice on building features like the walls, roof, windows, and doors, were not considered for this building design. However, falling rime ice from the towers adjacent to the new building was considered because it may produce significant impact loads due to the high winds.

Figure 6: Rime Ice at the Summit

2.3.5 Falling Ice

Since Mount Washington is the second highest elevation on the Eastern seaboard, it serves as a radio transmitter for numerous entities, including the Secret Service, Department of Defense, and local and regional radio stations. Several radio towers, as shown in Figure 7,have been constructed on the summit for the purpose of rebroadcasting the radio signals further. However, during the winter, the radio towers pose a major threat. Rime ice builds up on the radio tower and their associated support wires. Ice can accumulate over a foot thick. During the frequent strong winds, ice chunks crack and fall down to the surrounding area underneath and around the tower. When the WMTW building was original constructed, the summit workers quickly found that the building was not designed adequately enough to support the impact of the falling ice from the towers. The falling ice slammed into the building, shook the building and even caved in portion of the roof. An I-beam was placed along the ridge of the roof to prevent further structural damage.

Figure 7: Radio Tower on Mt. Washington Summit

Since the proposed location of the environmental research facility is in the location of the old WMTW building adjacent to the two radio towers as seen in Figure 8, the impact loads from falling rime ice in strong wind were taken into account to ensure the structural integrity of the building and safety of the occupants. Building features such as canopies and types of windows and doors need to be taken into account for the safety of the people around the outside of and inside the building during the winter. However, design of doors and windows was not a part of the scope of this project.

Figure 8: Location of the Old WMTW Building and Proposed Location of the Research Facility

2.3.6 Fog

Fog occurs often on the summit. Mount Washington currently has 303 foggy days a year, which leaves approximately 60 days for construction (Court and Gerston 1966). This poses a major obstacle during the construction phase of this project. Many aspects of construction are affected by fog. The delivery of construction materials such as concrete and steel up the Mount Washington Auto Road poses a danger in foggy condition. Not only is the road narrow but a foggy day could cause accidents from driving off the road or motorists not seeing each other in the road. The use of cranes will be limited in foggy days as communication between crane operators and workers on the ground needs to be unimpeded to ensure the right placement of beams and the safety of the workers on the ground.

3 Methodology

This Major Qualifying Project focused on the preliminary design of a research facility building and a recommendation for wastewater treatment plant improvements for the top of Mount Washington. There was also a focus on fire protection aspects of the research facility due to the unique location of the prospective building.

3.1 Schedule

The project was conducted over a period of eight months, as shown in Figure 9. During the first three months, the background research was completed, including a site visit to the summit of Mount Washington on September 18, 2010. During this visit park managers Diane Holmes and Chris Uggerholt were interviewed to obtain information on the site layout and park needs. The project team was given a tour of the buildings as well as the wastewater treatment plant. Pictures were taken of the layout of the mountain and the site of the burned down building and the wastewater treatment plant. After the site visit, the scope of the project was determined. From October to January, the floor plan, structural, foundation, and fire protection designs for the research facility building were developed. Wastewater treatment options were also analyzed and compared. A cost analysis was performed on both the proposed building and treatment plant to ensure that the expenses were within the State Park’s budget. In February, the group finalized the report.

TASKS	A TERM							B TERM								C TERM							
Week	29-Aug	5-Sep	12-Sep	19-Sep	26-Sep	3-Oct	10-Oct	25-Oct	1-Nov	8-Nov	15-Nov	22-Nov	29-Nov	6-Dec	13-Dec	10-Jan	17-Jan	24-Jan	31-Jan	7-Feb	14-Feb	21-Feb	28-Feb
Background Reserch	■	■	■	■	■	■	■																
Write Proposal	■	■	■	■	■	■	■																
Floor Layout								■	■														
NFPA egress/ADA								■	■														
Create floorplan using Autocad								■	■														
Building Area/Room								■	■														
Structural Design									■	■	■	■	■	■	■	■	■	■	■	■	■		
Foundation Research																			■	■	■		
Foundation Design																			■	■	■	■	
Fire Protection										■	■	■	■	■	■	■	■	■	■	■			
Cost Analysis																				■	■		
Research WWTP																			■	■	■		
Personal Communication	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■					
WWTP Analysis											■	■	■	■	■	■	■						
Final Report Writing																■	■	■	■	■	■	■	■
Presentation/Poster																				■	■	■	■

Figure 9: MQP Schedule

3.2 Research Facility Building Design

The design of the environmental research facility building was completed in several sections. These sections include the floor layout of each level; the structural design of beams, girders, columns and floor slabs; foundation design; and fire protection design.

3.2.1 Floor Layout

The first phase of the design process for the summit research facility was to develop a floor plan for the building. The overall size of the building was fixed at 77 feet by 34 feet, as the new facility had to fit on the footprint of the previous building. Mike Pelchat, the Mount Washington State Park manager, provided a rough sketch of the building's layout and the types of rooms that would address the needs of the State Park.

The team then drafted floor layouts using AutoCAD 2010. The project team designed the room sizes according to the proportions in the initial sketch provided by Mr. Pelchat. The team also researched appropriate room sizes, corridor, stair, and ramp widths as well minimum egress and door requirements using the *NFPA 1: Fire Code*, *NFPA 101: Life Safety Code,* the *International Building Code 2009*, and the *Americans with Disabilities Act* (ADA). The floor plan was then used to facilitate the structural design through the designation of tributary areas as well as the appropriate placement of the building's girders and columns.

3.2.2 Design Process

The main summit research facility was designed as a two-story building. Residents in the communities surrounding Mount Washington prefer that buildings on the summit do not exceed one-story as taller structures would disrupt the look of the summit from the base. Based on this opinion, the building was designed so that one story is underground, leaving only a single story visible. Coring samples at the building location were not available. Therefore, it was assumed that bedrock lies at sufficient depth to allow for a single story below grade. The remains from the previous building's foundation are one story below the ground, allowing for the existing excavation to be used in the construction of the story below grade. A depth of 10 feet is needed to place one story below grade.

Two alternative designs were evaluated: reinforced concrete and non-composite structural steel. Each structural option was evaluated based on the 3 criteria: cost, transportation of materials to the summit, and constructability. Each criterion was ranked on a scale of one to five, with five being the highest. The design with the highest total number was the most appropriate and was recommended.

The building was designed in accordance with the *International Building Code* (IBC 2009) as well as *ASCE7-10.ASCE7-10* was adopted in the *IBC* as part of the structural design codes. *ASCE7-10*, as stated in the document's scope, "provides minimum load requirements for the design of buildings and other structures." *ASCE7-10* was followed to ensure that sufficient design loads were taken in account during the proportioning of all structural components of the facility (International Code Council Inc 2009).

The design process was as follows: the roof and observatory tower were designed first, followed by the first floor and garage. The foundation design for the structural steel frame was completed once all sections were designed.

3.2.2.1 Design Loads

Once the materials were selected, the first step in the structural design process was to determine the loads that apply forces onto the structural members of the building. There are seven different loads that could be applied to a building: dead (D), live (L), roof live (L_r), snow (S), rain (R), wind (W), and seismic (E). Falling ice was accounted for with an increase in live load.

Dead loads are the weight of all the materials of construction of the building. This includes the walls, roof, ceiling, mechanical, electrical, and plumbing (MEP).The different wall types and materials for the roof and first floor were selected first. The dead load values used for the building materials were determined from *Design of Wood Structures* (Breyer et al. 2007). The types of material used for the interior and exterior construction and their associated dead load values are listed in Table 7. The interior and exterior walls were designed for the same loads. Concrete block was added to the exterior walls dead load for added protection from the elements and windows.

Table 7: Dead Load Values

Component	Load (psf)	Material
Roof	2.4	galvanized steel-18 gage corrugated
	1.5	insulation fiberglass
	12	stone decking
Ceiling	6	Mechanical, Electrical, Plumbing
	1	drop ceiling (channel suspend system)
Floor	12	cement finish per inch
	6	Mechanical, Electrical, Plumbing
	1	drop ceiling
	1.5	insulation
Wall (wall area)	0.9	wood studs 16" on center
	5	gypsum wall board
	30	concrete block outside wall
	8	windows
	1.5	insulation

The snow loads were calculated using Equation 7.3-1 of *ASCE 7-10* as shown in Equation 1.

$$p_f = 0.7C_eC_tI_sp_g \quad \text{(Equation 1)}$$

where C_e=Exposure Factor, C_t=Thermal Factor, I_s=Importance Factor, and p_g=ground snow load.

The exposure factor and thermal factor were determined from Table 7-2 and 7-3 of *ASCE 7-10*, respectively. The importance factor was determined using Table 1.5-2 with the Risk Category from Table 1.5-1. The ground snow load in the area of Mt. Washington was a site-specific special case snow load according to *ASCE 7-10;* therefore no value was given. However, the US Army Corps of Engineers published a paper on specific ground snow loads for various locations in New Hampshire (Tobiasson et al. 2002) and these ground snow loads for Mt. Washington were used to calculate the snow load. Actual values can be seen in section 2.3.3 and spreadsheets can be seen in Appendix G.

The simplified approach to seismic loads was able to be used because Mt. Washington is located in region of the United States that experiences very few earthquakes and those earthquakes that occur are small in magnitude.

To calculate the seismic factor, first the site class was determined. Mt. Washington is considered site class A, hard rock, according to Table to 20.3-1 of *ASCE 7-10*. The risk category III based on the use of the building was determined from Table 1.5-1 of *ASCE 7-10*. Using the risk category, the importance factor (I_e), and the location of the building, USGS U.S. Seismic "DesignMap" Web Application was used to determine the maximum spectral response acceleration parameters (S_{MS} and S_{M1}), site coefficient (F_a ,F_v , F_{PGA}), mapped acceleration parameters (S_s and S_1), design spectral response acceleration parameters (S_{DS} and S_{D1}), and peak ground acceleration (PGA)(United States Geological Survey 2010).Using the given values and Table 11.6-1 and 11.6-2 of *ASCE 7-10*, the Seismic Design Category (SDC) was determined as A. This means that the earthquake lateral forces on the building are only a function of the weight of the building. Equation 1.4-1 from section 11.7 of *ASCE 7-10*was used to calculate the seismic force, F_x (see Equation 2).

$$F_x = 0.01W_x \quad \text{(Equation 2)}$$

where W_x is the dead load of each level of the structure. The values for all the variables can be seen in Appendix J. Because a SDC A building yields such small earthquake design loads compared to the wind and live loads, the combination equations incorporating earthquake loads were not used.

Design live loads for a structure are based on use of the building and the occupancy. *ASCE 7-10*, Table 4-1 of *ASCE 7-10* defines minimum uniformly distributed live loads for various building types and occupancies. To account for impact loads from ice and other debris on the roof of the structure, the roof live load was increased by 100%. A 100% increase in live load to account for impact loads is usually done for elevators and the dynamic effects that may result from them (section C4.6 in *ASCE 7-10*).

Winds loads were determined using the envelope procedure for enclosed low-rise buildings. The risk category, III, was determined from Table 1.5-1 of *ASCE 7-10*. Based on the maximum wind speed data (V) from Table 4, the basic wind speed of 185 mph was used. Then five wind load parameters were calculated as follows from the provisions of *ASCE 7-10*:

- K_d, wind directional factor: Table 26.6-1
- K_{zt}, exposure factor: Section 26.7
- Topographic factor: 26.8
- GC_{pi}, enclosure classification and internal pressure coefficient: Section 26.10 and 26.11
- Velocity pressure coefficient: Table 28.3-1 using the height of the building.

Using the above parameters and coefficients, the velocity pressure (q_z) was calculated using Equation 3:

$$q_h = .00256 K_z K_{zt} K_d V^2 \qquad \text{(Equation 3)}$$

Once the external pressure coefficient (GC_{pf}) from Fig. 28.4-1 was determined, the design wind pressure (p) was calculated using Equation 4:

$$p = q_h[(GC_{pf}) - (GC_{pi})] \qquad \text{(Equation 4)}$$

where q_h is the velocity pressure determined from Figure 28.4-1 for both load cases A and B. Input values can be seen in the spreadsheets in Appendix H.

Load and Resistance Factor Design (LRFD) was used for both the reinforced concrete and structural steel framing options. According to *ASCE 7-10*, seven different load combinations need to be analyzed, and the design of the structural elements is based on the combination producing the largest effect. The seven load combinations are listed below.

- 1.4D
- 1.2D +1.6L +0.5(L_R or S or R)
- 1.2D +1.6(L_R or S or R) + (L +0.5W)
- 1.2D +1.0W +L +0.5(L_R or S or R)
- 1.2D + 1.0E +L +0.2S
- 0.9D +1.0W
- 0.9D +1.0E

3.2.3 Concrete Structural Design

This section details the processes used to design the concrete structural frame of the environmental research facility. The frame includes the slabs of the first floor and roof, the beams for both levels, and the interior and exterior columns. The garage frame is also included in this section since it was solely designed as a concrete structure.

3.2.3.1 Floor and Roof Slabs

The roof and floor slabs were designed based on methods from *Reinforced Concrete Design* as shown in Figure10 (Wang et al. 2007). Each slab was designed as a one-way slab where reinforcement primarily runs in one direction in the concrete.

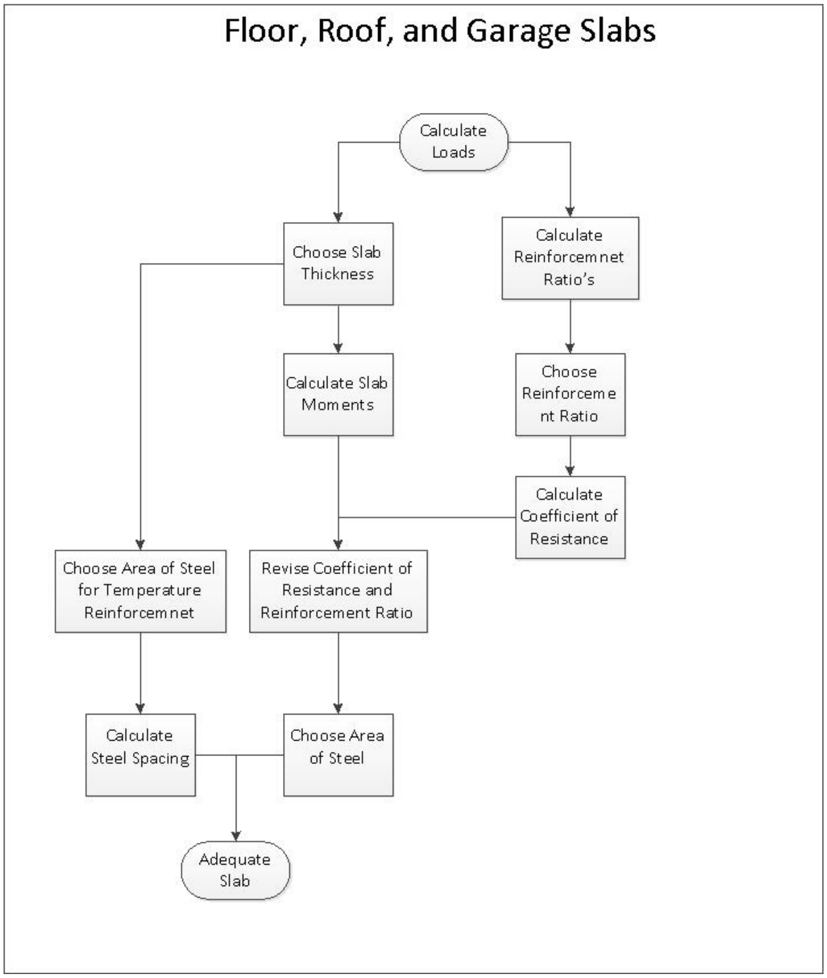

Figure 10: Roof Slab Design Flowchart

The first step was to determine the span length of each slab based on the girder spacing. Then values for concrete and steel strength (f'_c and f_y) were chosen. The values given in Table 8 show the strengths of the materials used in the design process. The concrete strength of 3000 psi was chosen to account for the batching of concrete on the summit in inclement weather. The steel strength value is an average steel strength value used in structural engineering.

After the loads were calculated as mentioned in Section 3.2.2.1, a slab thickness was chosen based on the minimum thickness of slab, h, which was determined from *ACI 318-05* Table 9.5(a). The limits of the reinforcement ratio (ρ) were calculated and a ρ value of one-half ρ_{max} was used to help control deflection. Deflection in beams is acceptable up to certain values which are given in Table 1604.3 of the *IBC* (International Code Council Inc 2009).Even with acceptable deflection limits, the bending of beams and the sway of a building can cause people to feel uncomfortable. This value was chosen to limit deflection while not overdesigning the beams and slabs.

Table 8: Material Strengths

Concrete Strength (f'_c)	3000 psi
Reinforcing Steel Strength (f_y)	60,000 psi

The dead and live loads were used to compute the moments in the slab at the support and midspan locations. The ACI coefficient method was used to calculate the moments in the slab. As an alternative to frame analysis. *ACI 318-05* Section 8.3 states that either method is an approved method for determining moments. Each position, support and middle, for slabs with one end and both ends continuous have various ACI moment coefficients used to determine the corresponding moments M_u. The ACI moment coefficients were taken from Table 8.4.1.of *Reinforced Concrete Design* (Wang et al. 2007; American Concrete Institute 2005).

The area of steel (A_s) calculated has to be greater than the minimum A_s or else the minimum area steel should be used as the design area value. The minimum area of steel ρ is taken from ACI 7.12.2.1. Using Table 3.9.6 from *Reinforced Concrete Design,* an area of steel larger than the calculated A_s is used (Wang et al. 2007).

Shrinkage and temperature reinforcing is needed in the concrete slab. This reinforcing is placed perpendicular to the main reinforcing. The area of steel is calculated in a similar manner to the minimum area of steel calculated in the above paragraph. The steel reinforcement and the concrete slabs were designed for ease of construction.

3.2.3.2 Beams

The next step in the building design process was to calculate the dimensions, areas of steel and the shear requirements for the beams that support the roof, first floor, and garage. The design process can be seen in Figure 11.ACI coefficients used to calculate the maximum positive and negative moment were taken from Table 8.4.1.of *Reinforced Concrete Design* (Wang et al. 2007). These calculated dead and live load moments were then factored to find M_u. After $M_u$was determined, the geometric dimensions (b,d) were chosen. Dimensions b and d were chosen such that the height of the beam (h) would be 1.5 or 2 times greater than b. The height, h is d plus a given amount of concrete cover and half the reinforcing beam diameter.

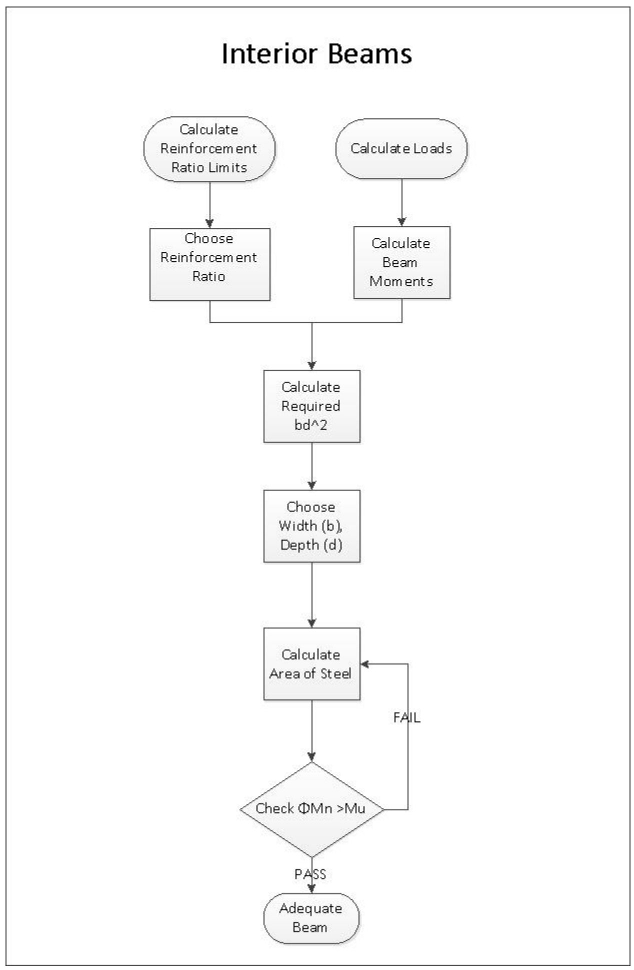

Figure 11: Interior Beam Design Flowchart

Once the required area of steel was calculated, the size of the bar and the number of bars per layer were specified so that the actual area of steel is close to the required area of steel that was calculated. Table 3.9.1 from *Reinforced Concrete Design* was used to aid in the selection of the appropriate steel section. The number of bars was checked to ensure they would fit the width of the beam with the appropriate cover. This was done with the aid Table 3.9.3 from *Reinforced Concrete Design* (Wang et al. 2007).

The beams were designed for shear reinforcement. The applied shear force and shear capacity of the concrete section were calculated, and the required shear capacity of steel was determined. From the required shear capacity of the steel, the spacing requirements for #3 vertical stirrups were calculated.

The design of the exterior beams was similar to the design of the interior beams in section. The design process can be seen in Figure 12. The lateral wind forces, dead loads, and live loads were entered into RISA 2D, and the negative and positive moments were calculated. RISA 2D is a computer program that calculates the axial, shear, and moment forces on a given set of members. Data on the loads applied to the member are entered, and the resulting support reactions and member forces are computed and graphed for the user. Using the computed moments along the major axis of the beam, the associated reinforcing area was calculated.

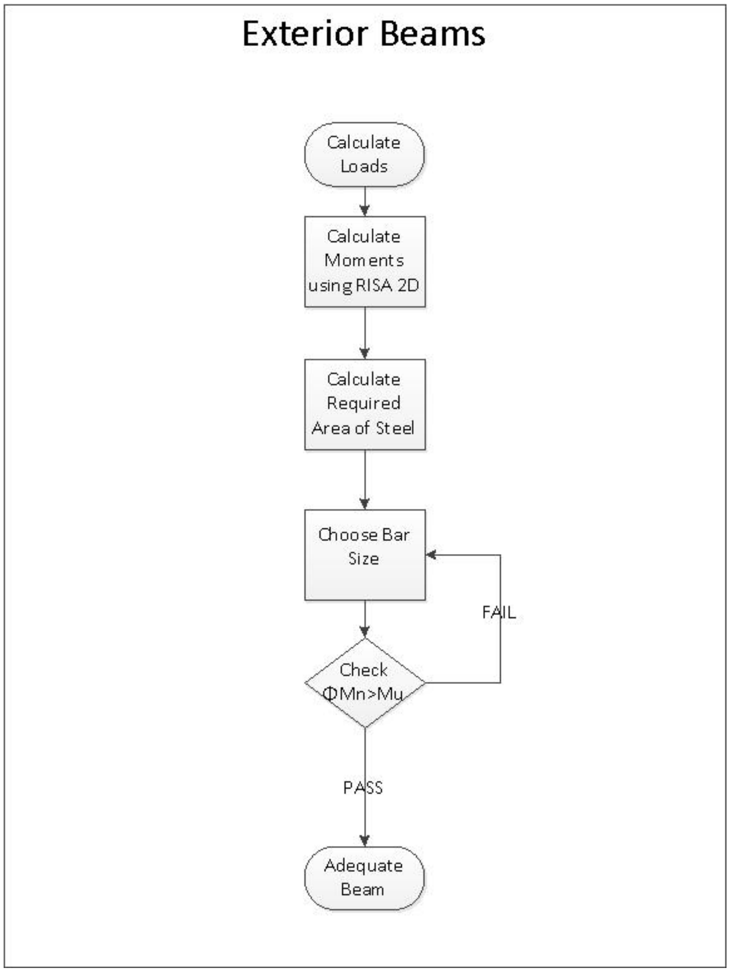

Figure 12: Exterior Beam Design Flowchart

As with the interior beams, each exterior beam was designed with shear reinforcing. The applied shear and shear capacity of the concrete beam were calculated, and the required shear capacity of steel was determined. From the required shear capacity of the steel, the spacing of the steel stirrups was calculated. A consistent steel stirrup size (3# bar) was used throughout the design.

Each interior and exterior beam's deflection was checked was to see if it complied with Section 1604.3 of the *IBC* (International Code Council Inc 2009). Each beam needed to have a deflection that was within the limits specified in Table 1604.3 of the *IBC*. In this case the deflection had to be less than L/240, with L being the length of the beam. Just the concrete cross section was used to check deflection since adding steel rebar makes the beams stiffer in tension.

3.2.3.3 Columns

The function of the columns is to transfer dead, live, and other loads down into the foundation. The column design process is shown in Figure 13. Rectangular columns were used in this design. Column lateral dimensions (b,h) were determined from the width of the beams connected to each face of the column. The columns needed to be equal in width or wider than the beams since it facilitates formwork construction at beam-column joints and ensures that all of the longitudinal reinforcing steel in the beam can extend into the column for proper transfer of bending moment.

The interior columns are a part of the gravity system only and therefore only needed to be designed to withstand axial compression. The exterior columns were designed as part of the lateral force resisting system. To determine the size and reinforcement of those columns, the moments and axial loads were determined with RISA 2D. Column interaction equations were used to calculate the amount of steel reinforcement needed (MacGregor and Wight 2005). The shear capacity in the column was calculated and checked against the applied shear to ensure adequate shear resistance. Lateral ties serving as shear stirrups were placed throughout the length of the column. This was also completed for the Lateral Force Resisting System, which added lateral loads in the RISA 2D analysis.

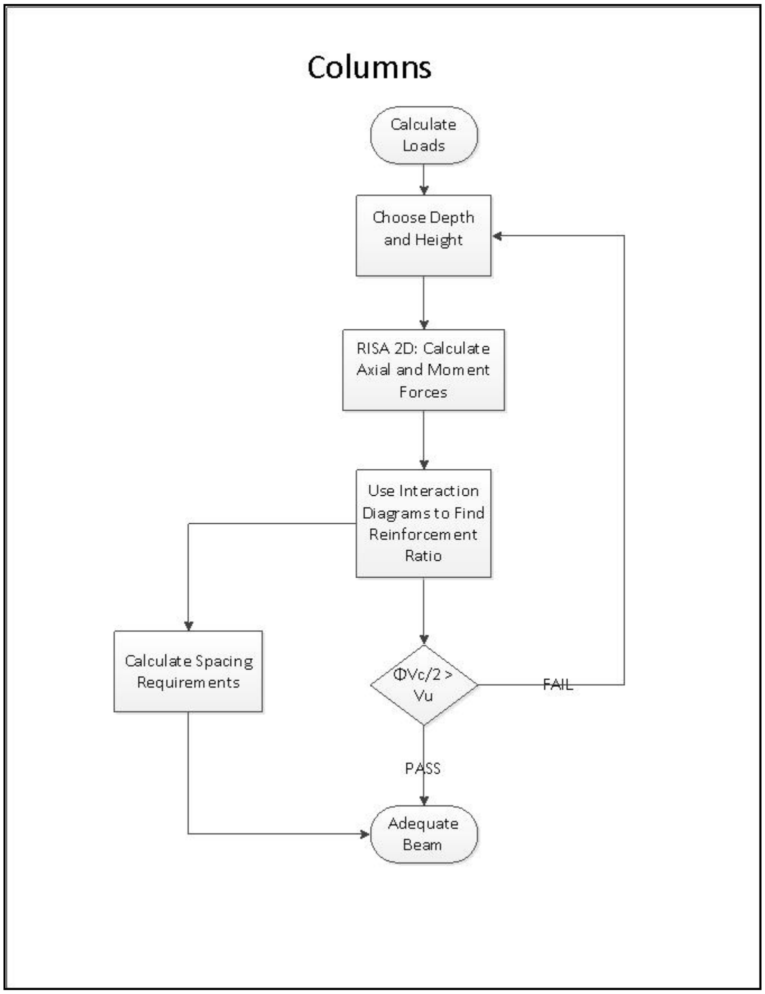

Figure 13: Column Design Flowchart

3.2.4 Steel Structural Design

The first component of the steel structure to be designed was the gravity resisting system. The gravity resisting system comprises the slab, beams and columns in the interior of the building. The system's primary job is to resist the gravitational loads of the building, enabling the building to be used safely. It was also important to design the roof slab to withstand potentially damaging impacts from falling ice.

3.2.4.1 Beams

A systematic approach was taken in the design of beams to resist gravity. As can be seen in the beam design flow chart (Figure 14), the beam layout and spacing needed to be created in order to evaluate the building's gravity loads. Next, gravity loads for the building were determined based on a combination of dead, live and snow loads. The beams' tributary areas were used to determine gravity loads in pounds per foot format to aid in easy calculation of shear, moment and deflection. Table3-2 in the AISC Manual, displaying beam's strength in bending, was consulted in the selection of a trial beam. Once the beam had been selected, it was checked to see if it had adequate strength in bending by comparing the beam's maximum allowable moment capacity to the actual moment force that it had to resist. Beams found to be inadequate were resized and checked a second time.

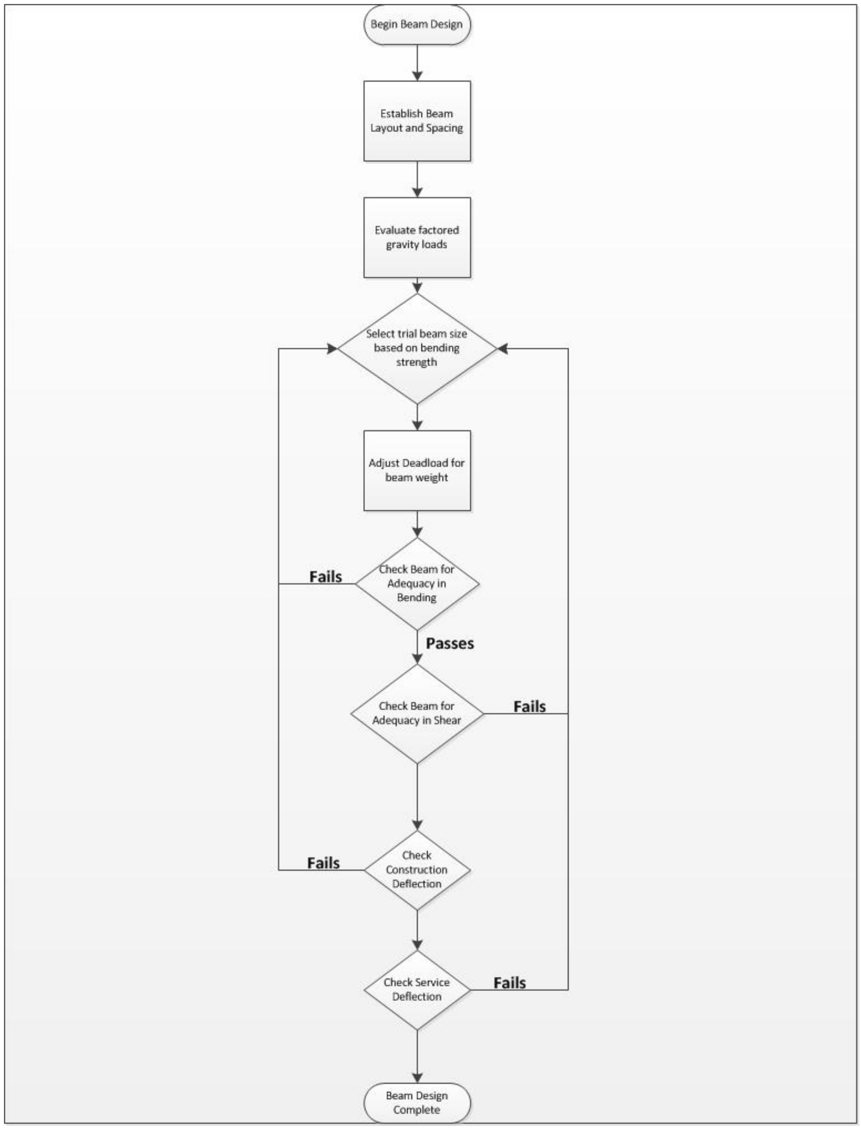

Figure 14: Steel Beam Design

If the beam was determined to have adequacy in bending resistance, it could then be checked to have adequacy in shear, as shown in the design flowchart. Table 3-2 was again consulted to determine a beam's shear capacity. If the beam's shear capacity was greater than its calculated shear load, then the beam could then be evaluated for adequacy in deflection.

Beams were checked for adequacy in both construction and service deflection. Construction deflection accounts for the unfactored loads subjected to the beam during the construction of the building, while service deflection includes the service (unfactored) live load that the beam would have to withstand. The beam could not deflect more than Length/360 inches or it was deemed unacceptable. Several beams failed this particular evaluation and thus needed to be resized as shown in the design flowchart. New sections were chosen based on their moment of inertia, as an increased moment of inertia helped to increase both deflection and bending resistance. Once a given beam was determined to have adequacy in bending, shear and deflection (both service and construction), the beam design was complete.

3.2.4.2 Columns

Columns in the gravity load resisting system are responsible for transferring gravitational loads axially to the building's foundation. Figure 15 outlines the steel column design. First, the column's tributary load was calculated by multiplying the tributary area by its tributary load in pounds per foot. The result was an axial force in pounds. A trial size column was then selected based upon the size of the load that is to be supported by the column. In selecting the column trial size, a slenderness ratio (KL/r) of 75 was assumed in order to get an approximate required area of steel. Based on this required area, a trial size for the column was selected. Once selected, the column's actual slenderness ratio was calculated using a K value of 1.0, in turn enabling an accurate calculation of the column's maximum axial load capacity. A K value of 1.0 was used because the gravity columns were part of a gravity resisting system rather than a moment resisting system. Table 4-22 of the AISC manual was consulted in order to determine the available strength for each column based upon the column's slenderness ratio and grade of steel. Once the column's maximum load capacity is established, it can be compared to the column's axial design load. If the column's capacity is sufficient, the design is complete. However, if this failed, columns needed to be resized and the process was repeated, as seen in the column design flowchart.

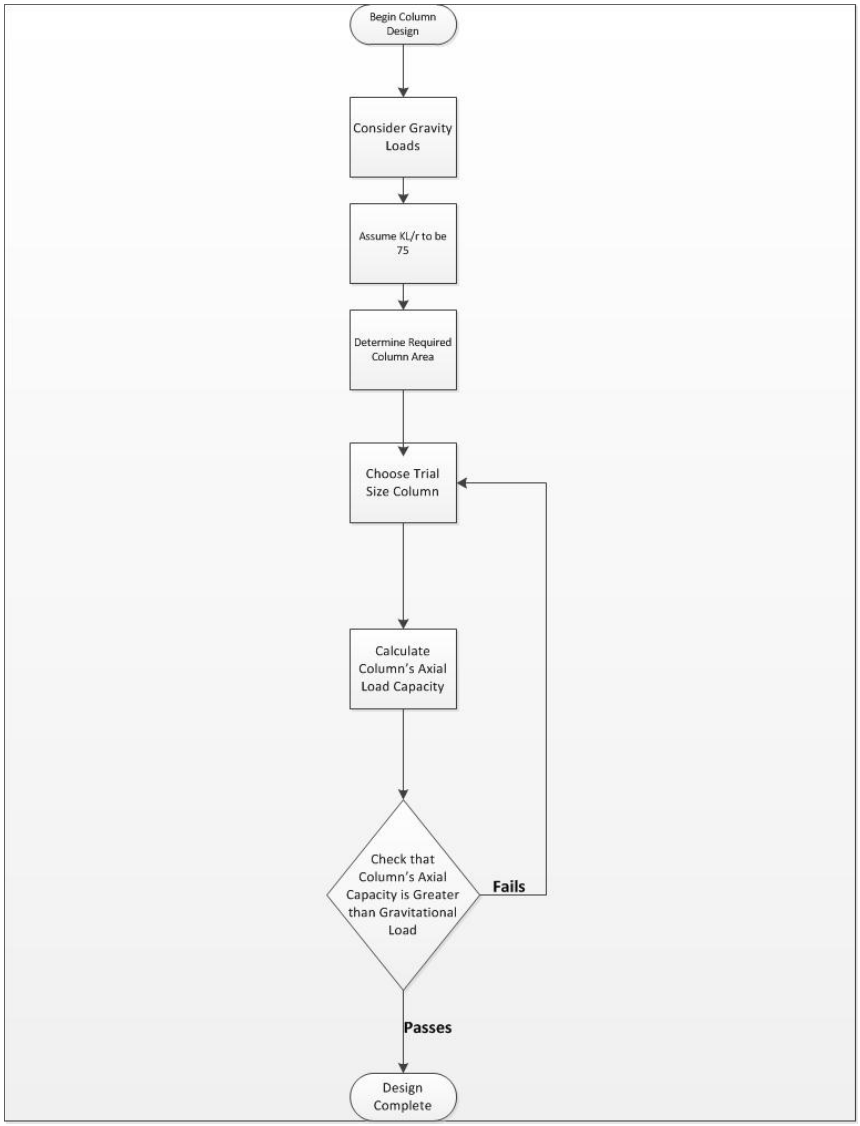

Figure 15: Steel Column Design

3.2.4.3 Lateral Design

Functionally, the intent of the Lateral Force Resisting System (LFRS) is to gather lateral forces acting on the building and transfer them to the building's supporting foundation. Some portions of the LFRS required certain considerations before design could begin. First, the type of LRFS had to be chosen. Given the steel frame structure, there were two possible options: a rigid, or moment frame and a laterally braced frame. A moment frame was selected to serve as the LRFS in order to maximize the functional space of the building, rather than losing some of the interior building space to bracing. Columns were assumed to be pinned to their footings. In the design of the moment frame, the initial requirement for the sizing of the members was their role in the gravity load resisting system; then, the effects of the lateral load were investigated. The intent of the design of the LFRS is to satisfy AISC requirements for building stability and strength.

The first step in the design of the LFRS, as seen in the design flow chart Figure 16, was to select trial members. Members selected had to have sufficient bending, shear and deflection capacity to support their designated gravity loads. Members chosen also had to be sufficiently rigid with relatively high moments of inertia to resist the lateral loads that the building would be subjected to on the summit of Mount Washington. In general, the columns in the LFRS were of more importance to the resistance of lateral forces than the corresponding girders, so sufficiently high moments of inertia were important in the selection of the frame's columns.

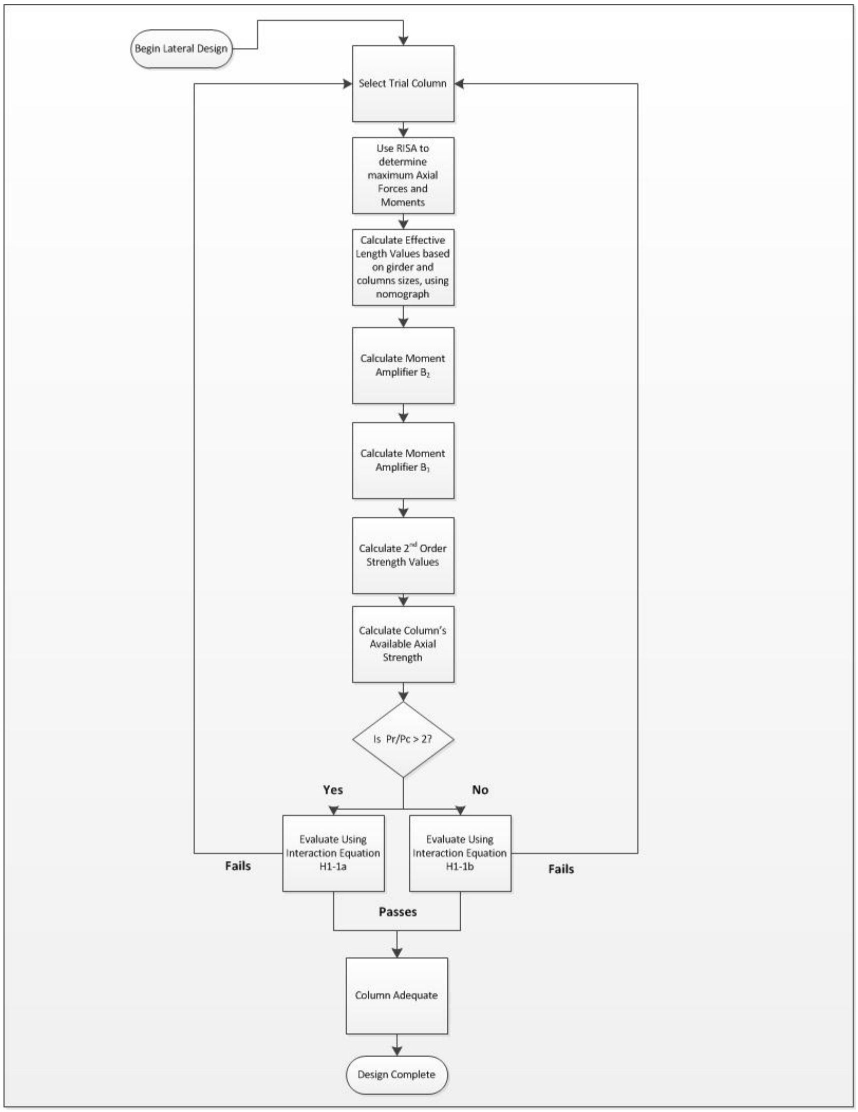

Figure 16: Lateral Force Resisting System Design

Once trial members were selected, the frame was analyzed using RISA-2D, a structural analysis computer program. The computer program yielded moment and axial forces in the frame's columns due to both gravitational forces and lateral forces. Lateral forces reflected the wind design loads appropriate to the summit of Mount Washington. Wind loads were chosen for the lateral loads over seismic forces, as the high winds on the summit created much larger loads than any potential loads due to seismic activity. Once the structural analysis was completed and the axial and moment forces were established for each column in the frame, the frame's analysis was continued according to the effective length method in order to determine second-order effects.

After the members were selected and structural analysis was compete, the frame's B_1 and B_2 moment amplifiers were calculated. The B_1 and B_2 amplifiers were calculated in place of a rigorous second order analysis, as allowed for by the AISC. The amplifiers were calculated simultaneously for each column in the frame using an Excel spreadsheet. Following the determination of the moment amplifiers, the required second-order strength values, P_r and M_r were calculated. These values reflected the required axial forces and amplified moments for the design of each column to resist the combined axial and lateral loads. The column's available axial strength could then be calculated using Table 4-1 of the AISC manual.

After calculating the member's axial compressive strength, evaluation of the story's columns could begin using the AISC interaction equations. First, the ratio of P_r/P_c was calculated in order to determine which of the two interaction equations to use. If the ratio was greater than or equal to 0.2, then equation H1-1a was to be used. If not, H1-1b would be used to evaluate the columns. This distinction can be seen in the LFRS design flowchart. The final step in the lateral design would be to evaluate the interaction equations using the information previously calculated in the effective length method as well as the column's axial and bending capacities. If the result of the interaction equation yielded a value less than 1, the design was satisfactory and no adjustments or resizing had to be made, as the flowchart outlines.

Finally, if the columns were deemed adequate by the interaction equations, they could be evaluated for sway. Column information was again added to RISA, and was once again subjected to lateral wind forces to determine the lateral sway of the building. If the sway was less than $1/400^{th}$ the height of the building, or 0.3 inches, the columns were adequate in sway.

While designing the LFRS, it was discovered that the design aids in Table 4-1 did not calculate the available strength in axial compression for any section smaller than W12x40. Therefore, using the sections provided in Table 4-1 would be excessive in this design due to the small design loads. Therefore, the column's strength in axial compression was manually calculated using information from Table 4-22 and Table 1-1. Also during the lateral design process, the initial column selections were unsatisfactory. W10x12s were initially chosen because the gravity loads were small and excessive compressive strength was not necessary. However, these initial sections did not have sufficient moment capacity to satisfy the requirements for combined axial and bending strength. As a result, larger sections needed to be selected and evaluated. After an iterative process, W10x22s were tested and found to be sufficient.

3.2.5 Observatory Tower Design

The observatory tower was designed using a similar process as that of a reinforced concrete beam. As shown in Figure 17, the first step in the process was to calculate the factored lateral and gravity loads and choose initial dimensions for the thickness of the wall and tower diameter. RISA 2D was then used to analyze the axial, shear, and moment forces acting on the tower. The combined stress equation for wall stresses was used to determine if the concrete had sufficient strength to withstand both axial and moment forces. Overall geometry of the wall was used to determine area and section modulus for evaluating stresses. Wall stresses need to be less than or equal to 0.3575 times the strength of the concrete (f'_c) (American Concrete Institute 2005).This value is based on the Empirical Design Method. If the stress calculation yields a result more than $0.3575f'_c$ then new dimensions need to be chosen. If it is less than $0.3575f'_c$ then the steel reinforcement needs to be calculated next. Minimum reinforcement was designed for since the concrete had greater amounts of strength than the axial and moment forces. *ACI 318-05* was used to calculate both vertical and horizontal reinforcing steel. The shear strength of both the concrete and the steel reinforcing also needed to satisfy certain limits. If the applied shear was greater than half the shear strength of the concrete, then steel shear reinforcement would have been needed. However, the shear strength of the concrete was more than adequate, so shear steel reinforcement was not needed.

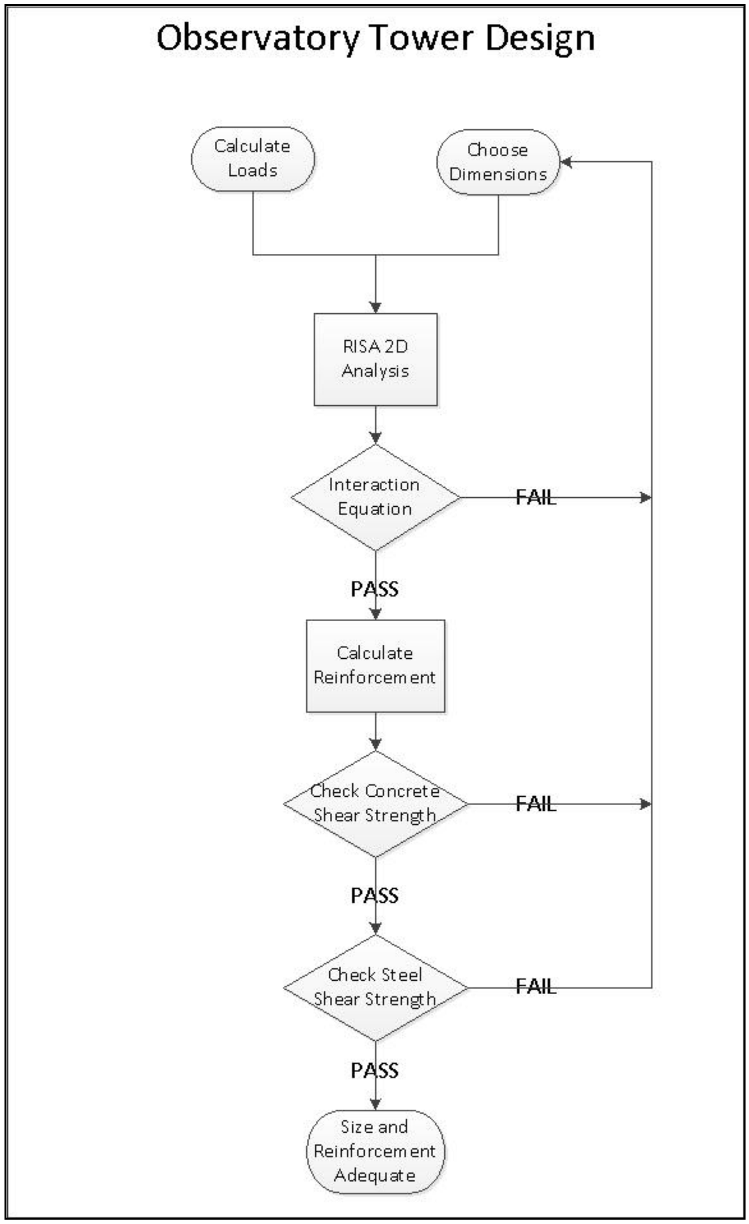

Figure 17: Observatory Tower Design

3.2.6 Foundation Design

A proper foundation for the building was part of the deliverables outlined in the project proposal. Given the relatively small loads created by the building and the geology at the summit, column base plates anchored to spread footings were deemed sufficient to act as a foundation.

3.2.6.1 Column Base plates

Column base plates aid in the transfer of the column's axial load to the foundation. The approach taken is outlined in the flowchart seen in Figure 18. First, a column was selected for the base plate to support. Next, the design load for the base plate is chosen based upon structural analysis and the computation of design loads. As seen in the flowchart, the next step was to determine the stress in the column using both the column's axial load and its area of steel. This stress can then be compared to the design aid in Table 4-22 of the AISC manual, showing critical stress in compression for the axial member. If the axial stress is more than the maximum allowable, the column should be resized. Next, the base plate area was calculated using an assumed ratio between the areas of the base plate pedestal. The baseplate size was approximated using bearing stresses. The bearing capacity of concrete beneath the baseplate was adjusted to reflect the beneficial confinement provided by the surrounding area of the footing. Once the baseplate area was established, the values B and N were calculated, yielding the dimensions of the baseplate. The B and N values correspond to the length and width of the column base plate, respectively. Following the establishment of the overall base plate geometry, the plate's required thickness was calculated to limit the plate bending stresses.

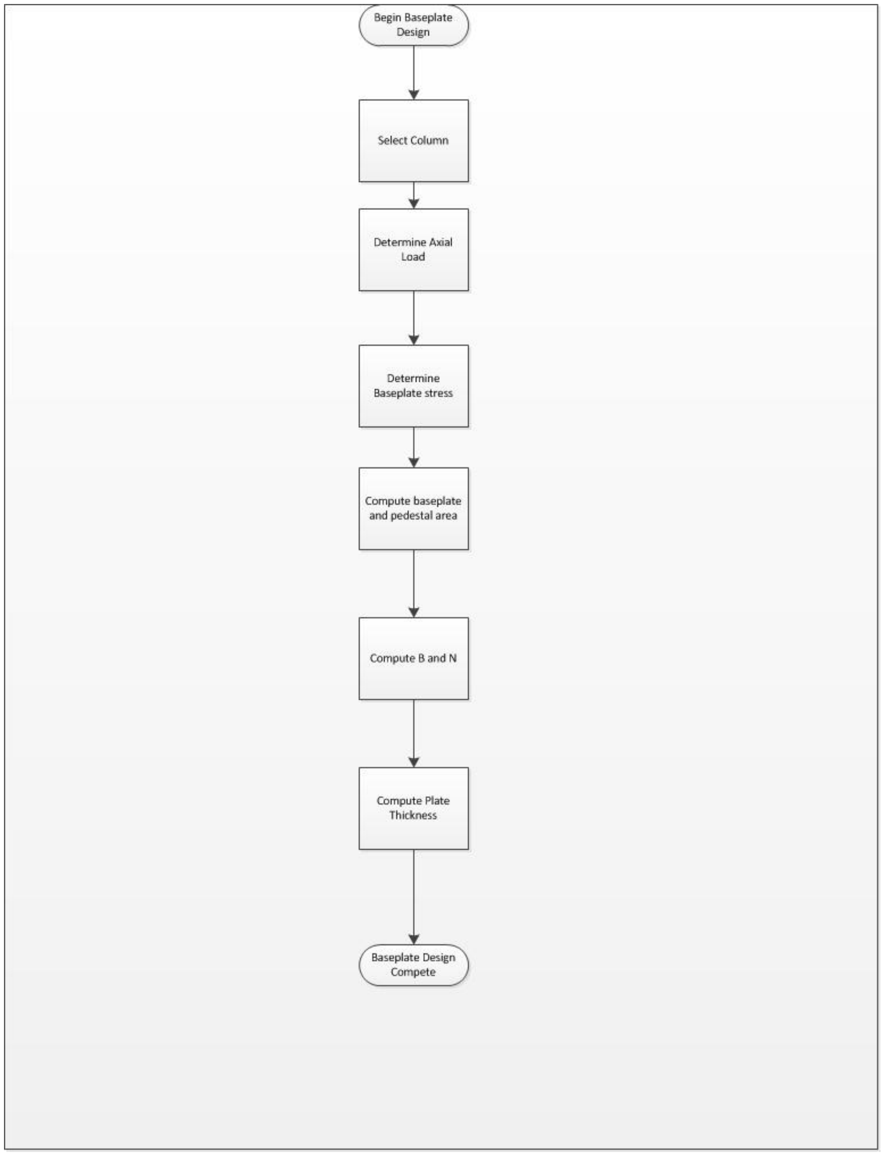

Figure 18: Column Baseplate Design

The goal in designing column baseplates for this building was to design one that would be considered typical for each column, meaning that only one baseplate would be designed that would satisfy the strength requirements for every column in the frame. Following this idea, W10x22 sections were chosen for the baseplate design as they were the largest columns in the structural frame. Additionally, the design load used was 90.2 kips, as this was the largest axial load found within the structural design.

3.2.6.2 Footings

The purpose of the building's footings is to transfer the total reaction forces from each column to the ground. The design of the footings used in this project is outlined in the flowchart in Figure 19. The required footing area was first calculated using the unfactored load carried by the column the footing is to support. Dimensions were chosen in order to create a square footing with adequate area. The footing designed was a square footing, so the length and width of the footing would be the same. Footing depth was chosen based upon a standard footing depth of 24 inches. Once the dimensions of the footing have been chosen, the depth was checked against both one and two way shear forces. As seen in the flowchart, the footing must be resized if it is found insufficient in either shear case. Upon the completion of the shear check, the footing must be also checked to ensure that the load from the column is being properly transferred to the footing. This calculation will also show if any excess axial force will need to be carried by reinforcement. As shown in the flowchart, the footing needs to also be designed for resistance to moment force. First, the moment force M_u and coefficient of resistant R_n were calculated. The moments calculated represent those in the footings created by the combination of upward acting forces from the earth beneath the footing as well as the downward acting axial force in the columns. The calculated moment forces are at their highest at footing's face. Using this moment force, both the required and minimum areas of steel were calculated. The final step in the design of the footings was to select the number of reinforcing steel bars to be placed within the footing in order to adequately protect against the moment force created by the column's axial load.

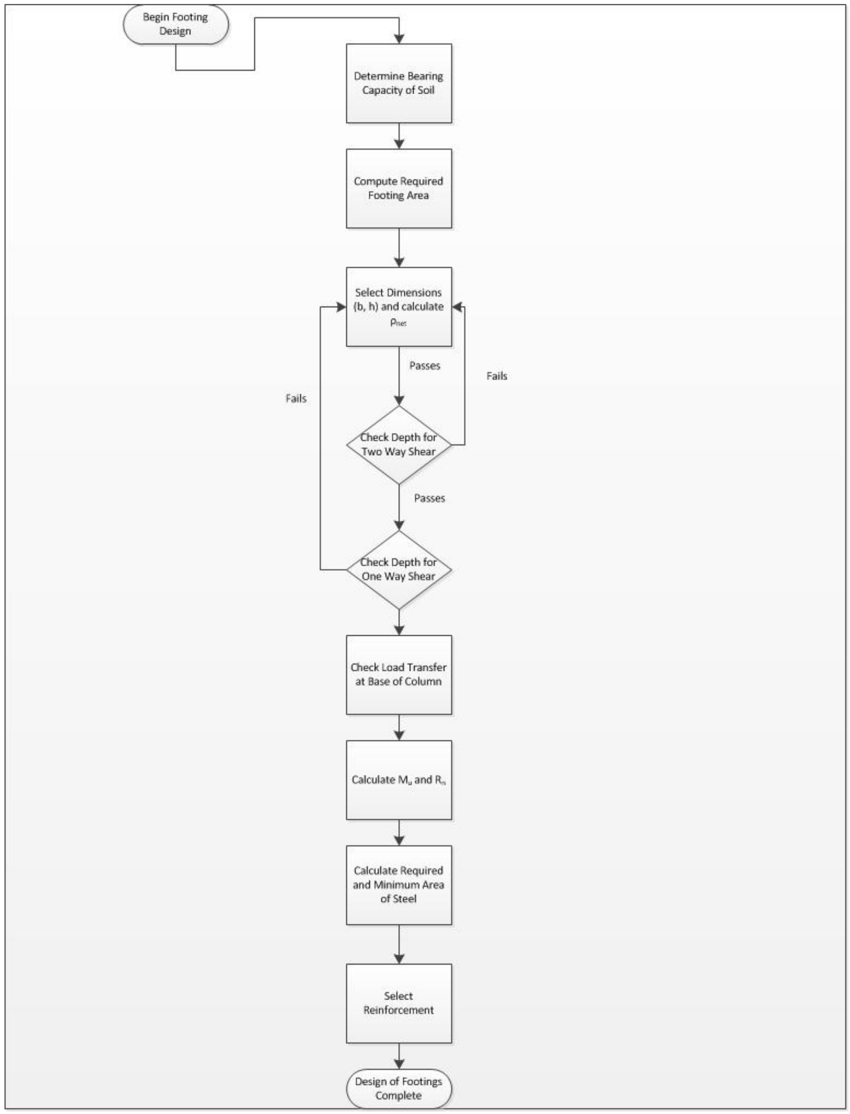

Figure 19: Footing Design

Similar to the design of a typical column base plate, the goal of the footings design process was to create a typical footing that could be used for every column in the structure. As a result, the highest axial force in the structure was used as a design load, like in the baseplate design. A pedestal was not needed in conjunction with the column baseplates because of the building's relatively small axial loads as well as the building's change in elevation. The typical baseplate size was however increased to a 13.5" square in order to better transfer the column's axial load to the footing. When calculating the required and minimum area of steel to resist moment forces, the required area was substantially lower than the minimum area of steel required. Thus, the minimum was used as a guide when selecting reinforcement.

3.2.7 Fire Protection

A fire protection system needed to be chosen to protect the new environmental research facility on Mt. Washington. The system needed to be able to extinguish a fire or suppress it long enough until the park rangers could extinguish it themselves. The layout of the building was designed first in order to know the exact area the sprinkler system needed to cover. Multiple fire suppression systems were researched specifically to minimize the usage of water on the summit. *NFPA 13: Automatic Sprinkler System Handbook* and *NFPA 750: Standard on Water Mist Fire Protection System* were used to research the requirements for standard and water mist fire protection systems respectively. Standard sprinkler systems use large droplets of water to extinguish the fire. Their primary means of suppression is to cool the fire and the surrounding combustibles. A water mist system uses extremely fine water droplets to cool the fire but also to push the oxygen away from the fire, thereby stifling it. The standard sprinkler system uses large amount of water, several hundred gallons a minute. A water mist system uses several hundred gallons or less over the entire time the system is in use, which is a minimum of 30 minutes.

In the process of researching the best fire protection system for the environmental research facility, several companies specializing in the design for water mist suppression systems were contacted. These companies and their recommendations of systems were researched online. Randy Edwards was contacted in regards to Marioff's HI-FOG Water Mist suppression system. Mr. Edwards is the Eastern Regional Manager of Marioff Inc. He was able to provide information about water mist fire suppression systems as well as the advantages and disadvantages of using them. Several manuals of the HI-FOG system were received by email and reviewed. Contact information for Mr. Edwards can be seen in Appendix C.

Steven Pelletier, an Engineered Systems Manager for Tyco Fire Suppression and Building Products, was contacted as well. He provided information about the Tyco Water Mist system Aquasonic. He also recommended the INERGEN® fire protection system as a less costly alternative to the water mist fire suppression systems. Through email he provided numerous data sheets, manuals, and brochures about the INERGEN® system. Contact information for Mr. Pelletier can be seen in Appendix C.

Fire protection systems costs were researched using email communication to Mr. Edwards and Mr. Pelletier. They were able to provide data sheets on their companies' respective systems as well as prices for the water mist and INERGEN® systems. The final fire protection analysis was completed using the 2010 INERGEN® Quick Quote spreadsheet given by Steven Pelletier.

3.2.8 Cost Analysis

The total cost of the structural framing and foundation materials, which included steel, concrete, and rebar, was calculated using the amount of material designed and the price per unit of material. The price per unit of material was found using *2009 National Construction Estimator.*

The interior finishing and construction cost estimates were completed using *Square Foot Costs 2008* by RSMeans and the layout of the building (RSMeans 2007). The research facility was to have the same kind of rooms that would be present in a residential home. These types of rooms include living room, kitchen, bedrooms, and bathrooms. Therefore, in *Square Foot Costs 2008,* the square foot values for a 2-story residential house were used. The exterior of the building was assumed to be made of concrete block for insulation and protection purposes.

Both the structural steel and concrete designs costs were totaled and the difference between the two was calculated to show which design was more cost effective.

3.3 Wastewater Treatment Plant

Gathering data and observations on the Lifewater ExtremeSTP™ was necessary to complete a data analysis and to gain a full understanding of the operational problems that the Park managers were experiencing with the plant. Information was gathered through personal communications with the Park managers, NH DES, and others. A correlation analysis was done on the treatment plant data using Excel to determine whether there were any relationships among monitored water quality parameters. Then, treatment recommendations were evaluated based effluent characteristics, cost, ability to be transported to the summit, and manageability.

3.3.1 Personal Communications

Personal communications were used to gather data on the current wastewater system. Richard H. Emberley, father of Richard Emberley, co-author of this MQP, and a wastewater treatment operator at Water System Operators Inc. in Henniker, NH, was contacted because of his knowledge of the plant on the summit and connections to individuals who are also knowledgeable about the plant. Richard H. Emberley and the project team visited the site on September 18, 2010. During the site visit, State Park Managers Diane Holmes and Chris Uggerholt were interviewed about the current Lifewater system. In addition to the contacts established on this site visit, Richard H. Emberley suggested interviewing others who are knowledgeable about the current system and who were responsible for the decision to purchase it for the State Park. Table 9is a list of people who were interviewed via phone or email communication. From these contacts, the team gathered information on the wastewater treatment plant and its function, as well as influent and effluent flows and water quality monitoring data. Full contact information and interview notes can be found in Appendix C.

Table 9: Interview Contacts

Contact	Company	Job Title	City, State
Richard H. Emberley	Water System Operators Inc.	Wastewater treatment operator	Henniker, NH
Kenneth Kessler	Department of Environmental Services	Operations, WWTF Technical Assistance, Complaint Response	Concord, NH
Mike Pelchat	Mount Washington State Park	State Park Manager	North Conway, NH
Diane Holmes	Mount Washington State Park	State Park Manager	North Conway, NH
Seth Prescott	Department of Resources and Economic Development	Public Works Manager	Concord, NH
Jobie Chase	Bureau of Public Works and Construction	Project Manager	Concord, NH
Dennis Tupick	White Mountain Communication Corporation	Contractor	Randolph, NH
RobertTsigonis	Lifewater Engineering	President	Fairbanks, Alaska

Data on the current Lifewater wastewater treatment plant were obtained from the NH Department of Environmental Services through Richard H. Emberley. Mr. Emberley and the DES have been in contact with the park staff while they have been learning to manage the new Lifewater plant. The information included the influent and effluent flows from November 2009 through October 2010 as well as water quality characteristics on days when samples were taken. Water quality parameters measured included pH, total suspended solids, fecal coliforms, biological oxygen demand, total nitrate, total nitrite, total ammonia, total Kjeldahl nitrogen, and mixed liquor suspended solids. There was also a section of notes for each month with comments from the State Park Managers related to the samples taken that day. In August 2010, data were obtained for the time period from the beginning of operation on the summit in November 2009 through August, 2010. Data from September and October 2010 were obtained in December 2010.

3.3.2 Discharge Permit Violations

The discharge permit for Mount Washington State Park was found on the NH Department of Environmental Services website (2009) and can be reviewed in Appendix B. Data from the current plant were used to determine the number of violations per month for each water quality parameter by comparing the data to the discharge permit requirements. The permit was also used to determine the wastewater treatment monitoring violations, like failure to take weekly or daily samples.

3.3.3 Treatment Plant Data Analysis

First, the data were received from the Department of Environmental Services (see Appendix D). They were graphed using Excel to determine whether there were any apparent trends between flows and water quality parameters. When no trends were observed, a correlation analysis was done using the Analysis Toolpak in Microsoft Excel to determine whether there were any quantitative relationships between the flow and water quality parameters in the data. Pearson's method of correlation analysis is a statistical test to determine a linear relationship between two pairs of data. The correlation coefficient, r, is a value of the linear relationship between the data pairs, and it ranges from -1.00 to 1.00, where the negative sign indicates a negative correlation and zero indicates no correlation. The α-value is a measure of the type 1 error, or the probability that a statistical test will generate a false-positive error. The value that is commonly used in research is 0.05, which is a 95% confidence level.

Each monitored parameter was evaluated for correlation to every other monitored parameter. The absolute values of the correlation coefficients from Excel were compared to the critical values of the Pearson Product-Moment correlation coefficient (see Table 10) based on the number of paired data points (n) and an α-value of 0.05 (A = α in Table 10). If the correlation coefficient from Excel was greater than or equal to the critical tabled value, the parameters were correlated.

Table 10: Critical Values of the Pearson Product Moment Correlation Coefficient

	A				
n	0.20	0.10	0.05	0.02	0.01
3	0.951	0.988	0.997	1.000	1.000
4	0.800	0.900	0.950	0.980	0.990
5	0.687	0.805	0.878	0.934	0.959
6	0.608	0.729	0.811	0.882	0.917
7	0.551	0.669	0.754	0.833	0.875
8	0.507	0.621	0.707	0.789	0.834
9	0.472	0.582	0.666	0.751	0.798
10	0.443	0.549	0.632	0.715	0.765
11	0.419	0.521	0.602	0.685	0.735
12	0.398	0.497	0.576	0.658	0.708
13	0.380	0.476	0.553	0.634	0.684
14	0.365	0.458	0.532	0.612	0.661
15	0.351	0.441	0.514	0.592	0.641
16	0.338	0.426	0.497	0.574	0.623
17	0.327	0.412	0.482	0.558	0.606
18	0.317	0.400	0.468	0.543	0.590
19	0.308	0.389	0.456	0.529	0.575
20	0.299	0.378	0.444	0.516	0.561
25	0.265	0.337	0.396	0.462	0.505
30	0.241	0.306	0.361	0.423	0.463
35	0.222	0.283	0.334	0.392	0.430
40	0.207	0.264	0.312	0.367	0.403
45	0.195	0.248	0.294	0.346	0.380
50	0.184	0.235	0.279	0.328	0.361
100	0.129	0.166	0.197	0.233	0.257
200	0.091	0.116	0.138	0.163	0.180

A nitrogen analysis was also done on the data to determine whether the season has an effect on the influent total Kjeldahl nitrogen. The dates of operation were graphed against influent and effluent total Kjeldahl nitrogen to determine whether there were any noticeable patterns with the seasons. Because of limitations in the number of data points, a correlation analysis could not be done on the data.

3.3.4 Evaluation of Treatment Alternatives

Various alternatives for improving wastewater treatment on Mount Washington were evaluated based on four criteria:

- Effluent characteristics
- Cost
- Manageability
- Transportation to the summit

First, effluent characteristics of the current plant were analyzed to determine whether any improvements were necessary. If a certain water quality parameter was not meeting the treatment plant discharge permit requirements, then improvements were suggested to improve that parameter. Other treatment systems were also evaluated based on their ability to reduce effluent concentrations and the cost of their product.

Funding for the treatment system must come from only the State Park revenues; therefore, the costs of improvements to the Lifewater system or a new treatment plant must be within the Park's operating budget. Costs of improvements to the current system were estimated based on whether they were high, medium, or low cost. Estimates for a new treatment plant were based off of previous costs estimates from bids in 2008, and by contacting companies with potentially feasible treatment systems. Another factor that was evaluated was costs associated with transporting system improvements or a new system to the summit because the transportation up the mountain road can be difficult and dangerous.

The plant must also be manageable for the park staff because they must balance running the State Park with running the plant. NH state law requires licensing of all wastewater operators who are responsible for a wastewater facility. The operator in charge oversees the daily operation of the wastewater treatment facility and is accountable for all plant operational duties, record keeping, and reporting(NH DES , 2010).The park staff were trained by the NH Department of

Resources and Economic Development (DRED) staff to be level 1 certified wastewater treatment operators, and the Department of Environmental Services (DES) provided the training to level 2 (Personal Communication, Prescott 2010). State law requires all wastewater operators who are responsible for of a wastewater facility to be licensed. Since the park managers are also managing the rest of the park year round, the plant must be simple to run. Information about the manageability of the current plant was obtained from interviews and email communication with Mr. Pelchat, Ms. Holmes, and Mr. Kessler.

Each treatment option was evaluated based on the four criteria ranked on a scale of one to three, with three being the best option. Alternatives with the higher total numbers were appropriate solutions.

3.4 Deliverables and Conclusions

Several deliverables were provided to the State Park as follows: a structural and foundation design; a sprinkler design recommendation; a recommendation for wastewater treatment modifications; a recommendation for alternative treatment plants; and an expected cost analysis of the entire design, building, and wastewater treatment solutions.

4 Results: Structural Design and Fire Protection

This section presents the results of the design and analysis work performed to complete this project. The criteria for determining the floor plan are detailed along with the reinforced concrete and structural steel building designs. Design layouts for each type of construction show sizes of beams and columns.

4.1 Structural Building Design

Two separate structural designs using either reinforced concrete or structural steel were completed. Each design used the same floor layout and had to support the same (dead load values will be different) gravity and lateral loads. This section summarizes the results for each design along with the floor layout and load analysis.

4.1.1 Floor Layout

The layout of the research facility was based upon a sketch provided by Mike Pelchat at Mount Washington. The sketch detailed the types of spaces needed in the new building. The layout was designed in accordance with the *International Building Code* (*IBC*), and addressed criteria for various aspects of the building. Compliance of the building layout with the *IBC*, *ADA*, and *NFPA 101*is summarized in Table 11.

Table 11: Building Layout Dimensional Criteria

Feature	Results	Reference
Ramps	Minimum slope of 1/12 (feet) Minimum width of 30”	IBC 1010.2
Corridors	No Obstructions Clear pathway from exit to exit Minimum height of 84” Minimum width 60”	IBC 1018.3 IBC 1018.6 NFPA 101:24.2.6.2 ADA A4.2.1
Doors	Minimum Height of 80” Minimum width of 32”	IBC 1008.1.1 NFPA 101:7.2.1.2.3.2
Landings	Must be at least the same width as corresponding stairs Minimum length of 44”	IBC 1008.1.6
Stairs	Minimum width of 48”	IBC 1009.1 ADA 4.3.11.3
Ceiling Height	Minimum height of 84”	NFPA 101: 7.1.5.1 NFPA 101:24.2.6.2
Number of Means of Escape	Two primary means No secondary means	NFPA 101: 26.2.1.3 NFPA 101: 24.2.2.1.2 (2)

The building was designed to provide sleeping accommodations for a maximum of 12 people. According to *NFPA 101: 26.1.1.1*, the building would be classified as a Lodging or Rooming House. The building was designed with two primary means of escape because each story has an area of more than 2000 ft^2 and the travel path for primary means of escape is more than 75 ft. (*NFPA 101:26.2.1.3*). Since the building was designed with an approved automatic sprinkler system, a secondary means of egress was not needed for each bedroom and living area (*NFPA 24.2.2.1.2 (2)*). Figures 20-23 show cross sections of the research facility design.

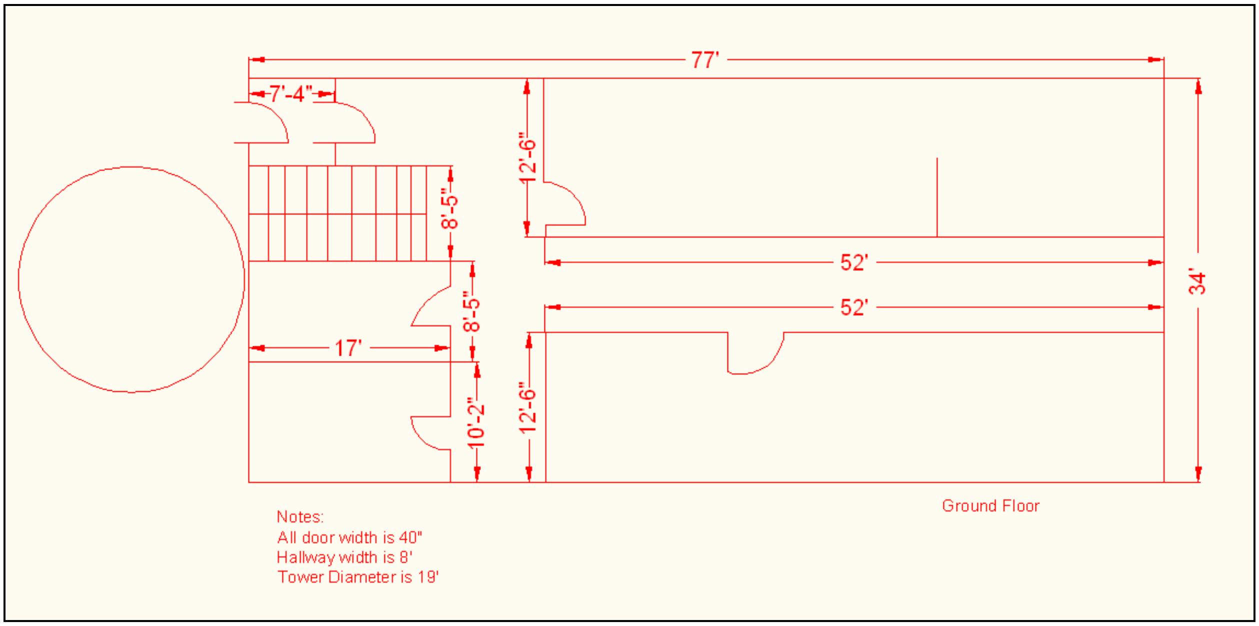

Figure 20: Basement Floor Layout

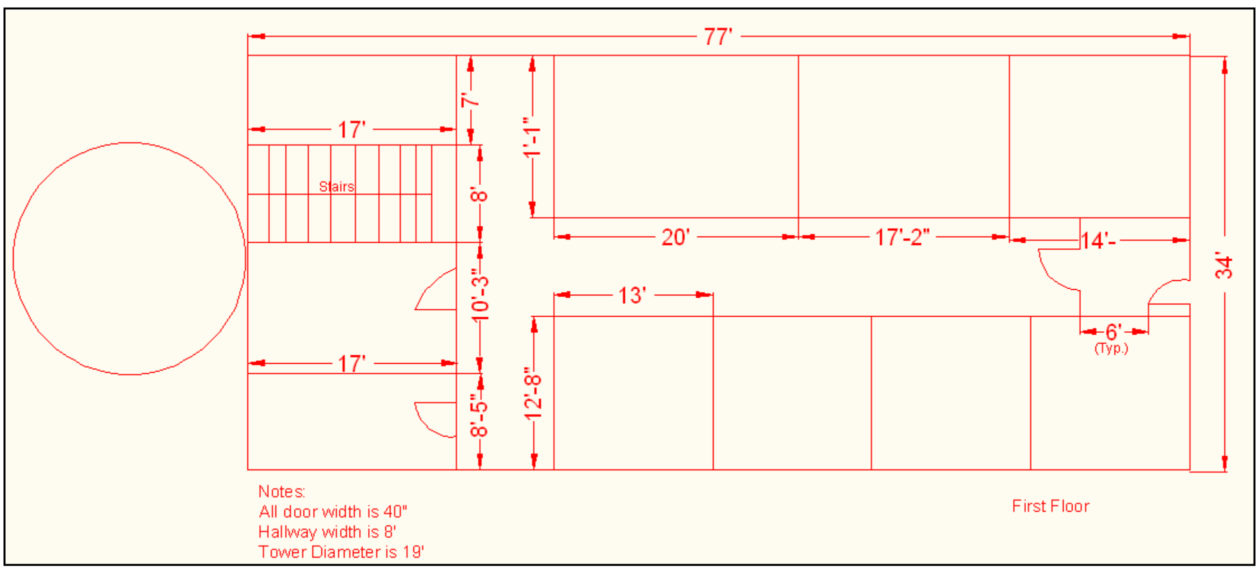

Figure 21: First Floor Layout

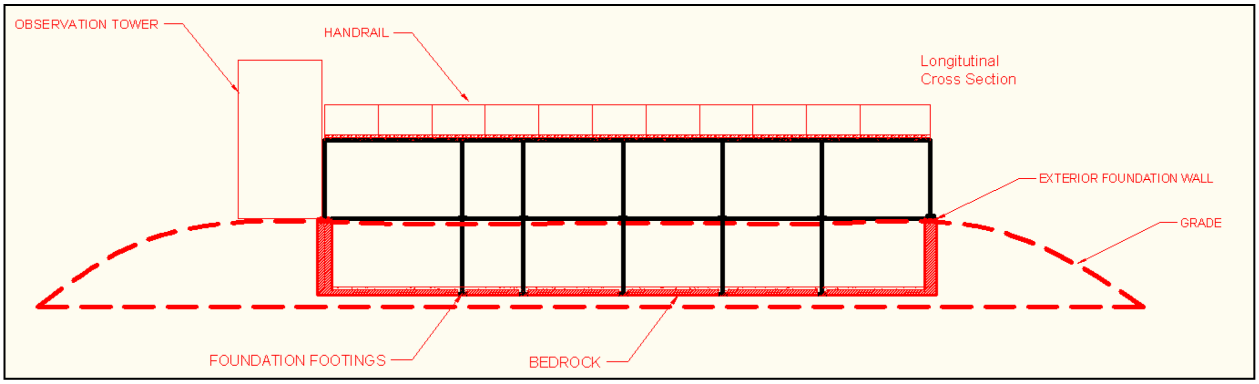

Figure 22: Longitudinal View

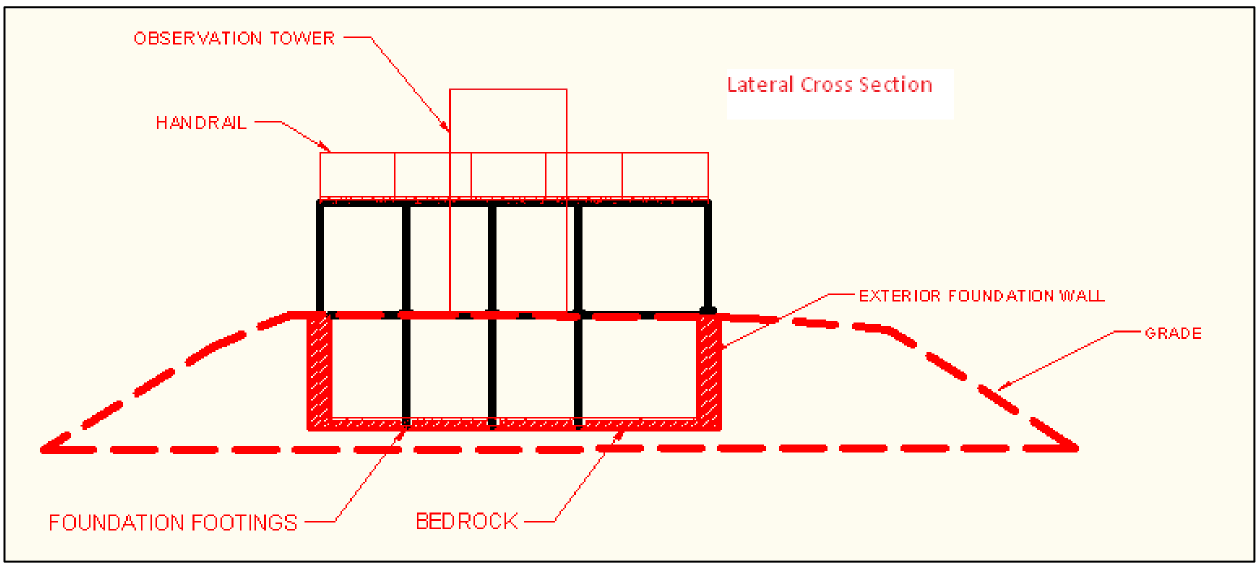

Figure 23: Lateral View

4.1.2 Design Loads

The dead load consisted of values such as the weight of the concrete slab and beams, the walls, and the insulation. A table of dead load values assumed in the design of the building is provided in Table 7. Each of these values was applied in the design of the various structural components. Dead load calculations can be seen in Appendix E.

Live loads were determined using *ASCE 7-10*: Table 4-1. Live loads for the floors and corridors were also taken as 100 psf since the building is to be used as a public building. Since the roof of the building was to be used as an observation deck, the live load value was also taken as 100 psf as an assembly area for a roof. The snow load value was calculated as 30.2 psf. According to the USGS, this value is low due to the strong winds on the summit (United States Geological Survey 2010). The wind does not allow the snow to remain on the roof for extended periods of time. Because this value was less than the roof live load value, the roof live load of 100 psf was used to design the roof support system. Live load and snow calculations can be seen in Appendix F and G.

The wind loads on the transverse and longitudinal sections of the building were calculated by means of *ASCE 7-10*: Section 28.4. The values and their associated areas of influence as determined by *ASCE 7-10*can be seen in Appendix H and I respectively. These values were inserted in the load combination equations to determine the maximum values. The maximum values were from the following combination equations

$$\text{Roof: } 1.2D + 1.6(L_R \text{ or } S \text{ or } R) + (L \text{ or } 0.5W)$$
$$\text{Ground Floor: } 1.2D + 1.6L + 0.5(L_R \text{ or } S \text{ or } R)$$

These equations governed because the roof live load and live load were almost double the wind load.

Since the earthquake loads were not as large as the live loads and winds loads, their associated load combinations were not consideration. Calculation of the earthquake loads can be seen in Appendix J.

4.1.3 Concrete Structural Design

Two structural designs for the summit research facility were completed using two separate materials: concrete and steel. The concrete structural design is discussed in the following sections, whereas the steel structural design is discussed in Section 4.1.4.

4.1.3.1 Concrete

Concrete is a mixture of cement, aggregates, water and admixtures. Concrete has a high compressive strength but weak tensile strength; therefore concrete needs to have steel reinforcing placed inside the beams and columns to provide sufficient tensile strength(Wang et al. 2007).Concrete is relatively inexpensive building material, easy to transport, and easy to make. Reinforced concrete has to be mixed either on-site or at a concrete mix plant and delivered to the construction site. When the Sherman Adams building was originally built, a concrete mixing plant was constructed on the summit to expedite the process of placed concrete (Pelchat 2010). Because concrete flows like a liquid it can be placed and formed in any shape desired. This makes it a desirable construction material. However concrete has to cure for 14 days before the forms holding the concrete in place can be removed and loads can be carried on it. Different admixtures can be added to the concrete mix design to ensure that it cures in any climate and temperature range (Wang et al. 2007). An important concrete characteristic is that it is fire-resistant. A building with a concrete structural frame will be structurally safe in the event of a fire. Concrete can be used throughout the structural frame for members including columns, beams, and slabs.

4.1.3.2 Slab

Each slab was designed to be a consistent thickness to minimize construction time. The overall slab thickness was 6.5 inches for the first floor and roof slabs and 7.5 inches for the garage slab. This was calculated based on the overall length the slab was spanning. This also provides a 3 hour fire resistance rating for the floors (*IBC2009: Table 721.2.2.1).* The cover for each slab was .75 inches. This is a 4 hour fire resistance rating (*IBC2009: Table 721.2.3(1)).* The area of steel was designed only using #3 bars to minimize the cost of materials. The spacing per foot width of the roof, first floor and garage slabs are shown in Tables 12. The location of the slab is identified by 4 letters and numbers corresponding to the 4 corners of the slab. The letters and numbers, and their locations can be seen in Figure 24 or 25. Since the beam layout is the same for both first floor and roof, Figure 24 applies to both. Temperature reinforcement was designed to run perpendicular to the direction of the reinforcing bars. Temperature reinforcing can be seen in Table 13. Figure 26 shows the location of the positive and negative reinforcing in each slab. The positive reinforcing is the top steel in the slab and the negative is bottom steel in the slab. Spreadsheets and sample calculations can be seen in Appendix K, L.

The garage building is located near the research facility. Column B5 of the research facility and column A1 of the garage are adjacent to each other. The buildings were designed as unconnected structures to allow for the construction of them to occur at different times.

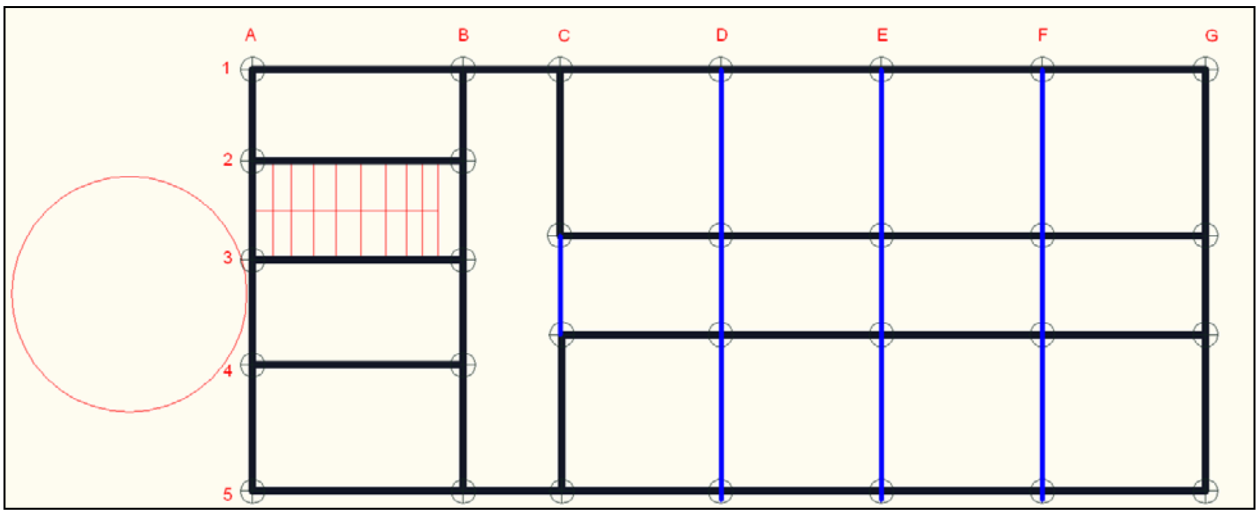

Figure 24: Building Grid Layout

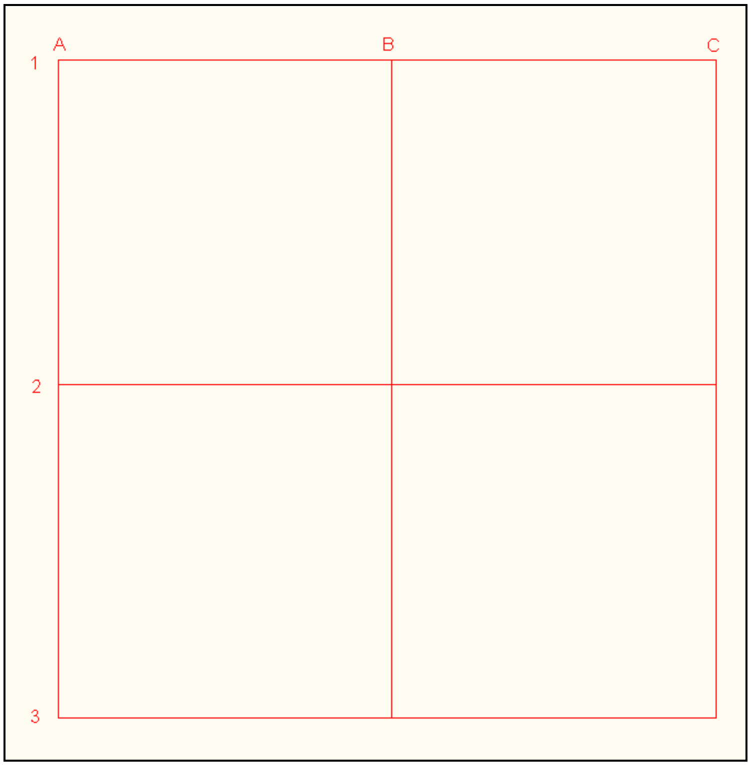

Figure 25: Garage Grid Layout

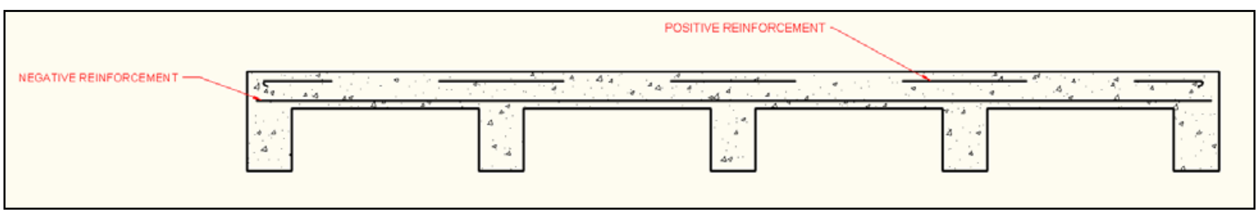

Figure 26: Slab Reinforcing Layout

Table 12: Spacing of#3 Rebar per Foot of Slab Width (in)

Component	Location	Spacing	
		Negative	Positive
Roof Slab	C1,G1,C3,G3	4.5	6
	C3,G3,C4,C4	9	9
	C4,G4,C5,G5	4.5	6
	B1,C1,B5,C5	9	9
	A1,B1,A2,B2	6	9
	A2,B2,A4,B4	9	9
	A4,B4,A5,B5	9	9
First Floor Slab	C1,G1,C3,G3	6	8
	C3,G3,C4,C4	9	9
	C4,G4,C5,G5	6	8
	B1,C1,B5,C5	9	9
	A1,B1,A2,B2	9	9
	A2,B2,A4,B4	9	9
	A4,B4,A5,B5	9	9
Garage Slab	A1,C1,A3,C3	8	5.5

Table 13: Spacing of #3 Temperature Reinforcing per Foot of Slab Width (in)

Temperature reinforcement	
Garage	Roof/First Floor
8	9

4.1.3.3 Beams

Two different zones of beams were calculated: interior and exterior. The only difference between the two is that exterior beams are part of the lateral force resisting system. Tables 14 and 15 summarize the results of the calculations of both the interior and exterior beams of the roof system. Table 16 summarizes the first floor beams, whereas Table 17 summarizes the garage beams. The cross-section dimensions, length, and the number and type of steel rebar for each beam are identified in each table. The identification numbers and letter can be seen in Figures 24 and 25. A cross section of a typical beam with the placement of the rebar is show in

Figure 27. The number of reinforcing bars changes from beam to beam but the general placement is the same throughout. b is the width of the beam, h is the height, and c is the cover. In all the beams the cover is 1.5 inches. This provides a 4 hour fire-resistance rating. The shear reinforcement spacing is given for each beam in Table 14-17. Figure 28 shows a side view of the beam with positive reinforcing on the top of the beam and negative reinforcing on the bottom of the beam. Spreadsheets and sample calculations can be seen in the Appendix M, N, O, and P.

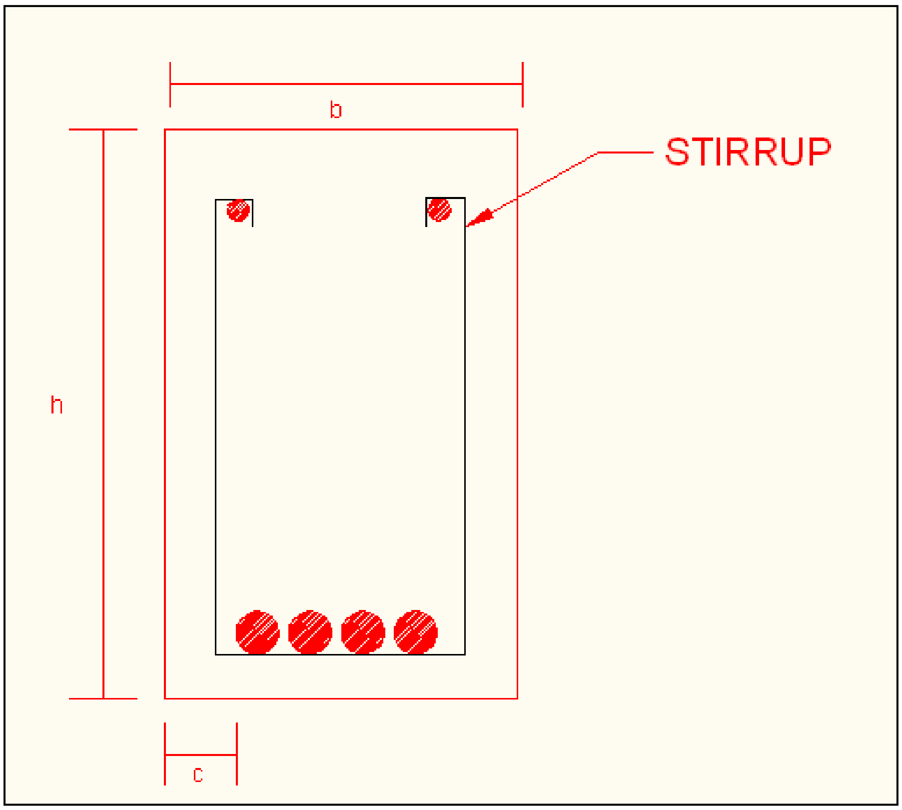

Figure 27: Typical Beam Cross Section

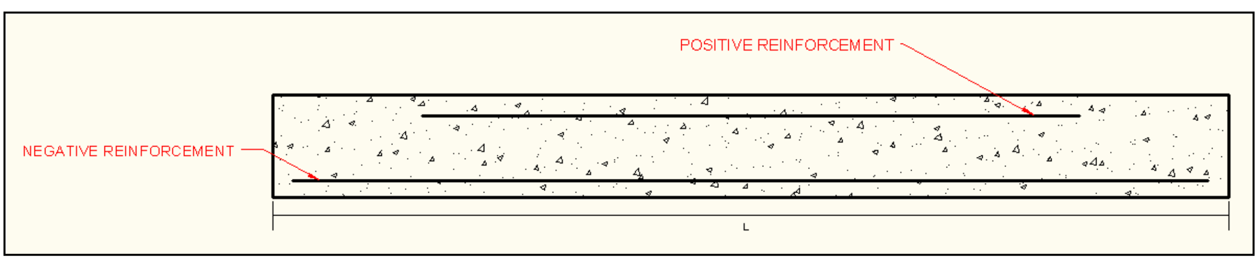

Figure 28: Beam Side View

Table 14: Roof Interior Beams

Member	Length (ft.)	Size(bxh)(in.)	Steel		Shear Stirrup
			Negative	Positive	Spacing (in)
F1-F3, E1-E3, D1-D3, F4-F5, D4-D5, E4-E5	13	8X18	2#8	2#8	3
D3-D4, E3-E4, F3-F4	8	8X12	2#6	2#6	3.5
D3-E3, E3-F3, D4-E4, E4-E5	13	8X16	2#8	2#8	3.5
C3-D3, F3-G3, C4-D4, F4-G4	13	10X16	2#8	2#8	4
C3-C4	8	6X12	2#5	2#5	4
C1-C3, C4-C5	13	10X16	3#6	2#6	4
B1-B2	7	8X12	2#6	2#6	5
B2-B3, B3-B4	8	8X14	2#7	2#7	5
B4-B5	11	10X16	2#7	2#7	4.5
A2-B2	17	10X18	2#8	2#8	6.5
A3-B3	17	10X18	2#9	2#9	5
A4-B4	17	10X20	2#9	2#9	5

Table 15: Roof Exterior Beams

Member	Length (ft.)	Size(bxh)(in.)	Steel		Shear Stirrup
			Negative	Positive	Spacing (in)
G1-G3	13	10X16	2#7	2#9	6.5
G3-G4	8	8X12	2#8	2#3	4.5
G4-G5	13	10X16	2#7	2#7	6.5
A5-B5	17	10X16	2#11	2#9	2.5
B5-C5	8	10X16	2#10	2#7	2
C5-D5	13	10X16	2#8	2#7	3.5
D5-E5	13	10X16	2#8	2#7	3.5
E5-F5	13	10X16	2#8	2#7	3.5
F5-G5	13	10X16	2#8	2#8	3
A1-A2	7	10X16	2#6	2#8	5
A2-A3	8	10X16	2#8	2#7	5
A3-A4	8	10X16	2#8	2#5	4.5
A4-A5	11	10X16	2#8	2#8	2.5
A1-B1	17	10X16	2#9	2#7	5.5
B1-C1	8	10X16	2#8	2#9	2
C1-D1	13	10X16	2#8	2#9	4
D1-E1	13	10X16	2#8	2#9	3
E1-F1	13	10X16	2#8	2#9	3.5
F1-G1	13	10X16	2#8	2#8	3

Table 16: First Floor Interior Beams

Member	Length (ft.)	Size(bxh)(in.)	Steel		Shear Stirrups
			Negative	Positive	Spacing (in)
F1-F3, E1-E3, D1-D3, F4-F5, D4-D5, E4-E5	13	10X20	2#8	2#8	4
D3-D4, E3-E4, F3-F4	8	8X12	2#6	2#6	3
D3-E3, E3-F3, D4-E4, E4-E5	13	10X16	2#8	2#8	3.5
C3-D3, F3-G3, C4-D4, F4-G4	13	10X18	2#8	2#8	4.5
C3-C4	8	8X14	2#5	2#5	6
C1-C3, C4-C5	13	10X18	2#6	2#6	4.5
B1-B2	7	8X12	2#6	2#6	4
B2-B3, B3-B4	8	10X16	2#7	2#7	8
B4-B5	11	10X18	2#7	2#7	4.5
A2-B2	17	12X20	2#8	2#8	7.5
A3-B3	17	10X18	2#9	2#9	4
A4-B4	17	10X20	2#9	2#9	4

Table 17: Garage Beam

Member		Length (ft.)	Size(bxh)(in.)	Steel		Shear Stirrups
				Negative	Positive	Spacing (in)
Exterior	A1-B1, B1-C1, C1-C2, C2-C3, A3-B3, B3-C3, A1-A2, A2-A3	15	10X18	2#8	2#8	4.5
Interior	B1-B2, B2-B3, A2-B2, B2-C2	15	10X18	2#7	2#9	2

4.1.3.4 Columns

The columns support the slab and beam system and transfer their associated forces into the foundation. The roof columns are separated into two zones as the beams were: interior and exterior. The interior columns span 2 stories: first floor and roof. The interior columns support the gravity loads, whereas the exterior columns support both the gravity and lateral loads. Tables 18, 19, and 20 show the column size, steel reinforcement, tie size, and tie spacing of the interior, exterior, basement and garage columns. Each of the basement columns, columns that support the first floor interior columns and the first floor slab, were determined to be identical to the first floor columns. Figure 24 and 25 shows the location of the column's corresponding to the member letters. A typical cross section of a column is shown in Figure 27. The width (b), length (h) and cover distance (c) are also shown in Figure 29. Three inches of cover was used for each column. The fire resistance rating for the column sizes of 10, 12, and 14 in^2 are 2, 3, and 4 hours respectively (*IBC2009: Table 721.2.4)*. Spreadsheet and sample calculations can be seen in the Appendix Q and R.

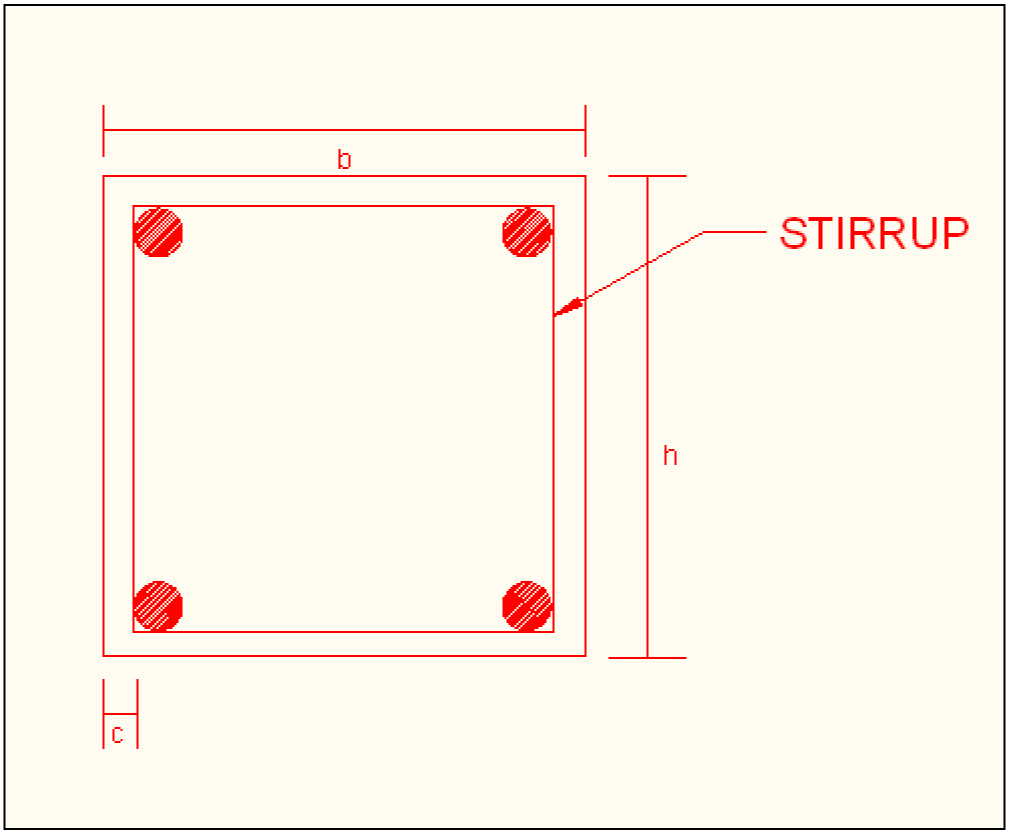

Figure 29: Typical Column Cross Section

Table 18: Interior and Basement Columns

Member	Size (bxH)(in.)	Reinforcing Steel	Ties	Tie Spacing(in.)
F3,F4,D3,D4	10X10	4#5	#4	10
E3,E4	10X10	4#5	#4	10
C3, C4	10X10	4#5	#4	10
B2	12X12	4#6	#4	12
B3	12X12	4#6	#4	12
B4	14X14	4#7	#4	14

Table 19: Exterior Columns

Member	Size (bxh)(in.)	Reinforcing Steel	Ties	Tie Spacing(in.)
G1	12X12	4#6	#4	10
G3	12X12	4#6	#4	10
G4	12X12	4#6	#4	10
G5	12X12	4#6	#4	10
F5	10X10	4#5	#4	10
E5	10X10	4#5	#4	10
D5	10X10	4#5	#4	10
C5	10X10	4#5	#4	10
B5	10X10	4#5	#4	10
A5	12X12	4#6	#4	10
A4	10X10	4#5	#4	10
A3	10X10	4#5	#4	10
A2	10X10	4#5	#4	10
A1	12X12	4#6	#4	10
B1	10X10	4#5	#4	10
C1	10X10	4#5	#4	10
D1	10X10	4#5	#4	10
E1	10X10	4#5	#4	10
F1	10X10	4#5	#4	10

Table 20: Garage Columns

Member	Size (bxh)(in.)	Reinforcing Steel	Ties	Tie Spacing (in.)
A1, B1, C1,A2, B2, C2, A3, B2, C3	14X14	4#7	#4	14

4.1.4 Steel Structural Design

When considering the design of the summit research facility, the structural steel framing has certain advantages and disadvantages. The advantages for selecting a steel framed structure are centered around construction considerations at the summit of Mount Washington. A steel structure is pre-fabricated, that is beams and columns are created to the project's specifications offsite and shipped to the construction zone. The actual construction of the steel framed building involves connecting the members. Thus, a steel frame structure can be erected relatively quickly; a major advantage in a setting that has an extremely short construction season. In addition, steel is the dominant building material in the northeastern United States so experienced steel fabricators and construction companies are relatively easy to find.

However, there are a few disadvantages to choosing a steel frame building. The first is that all the prefabricated members need to be transported to the building site, meaning they would have to be transported up a dangerous, windy mountain road. The second downside to choosing a steel frame is cost. Structural grade steel is more expensive than concrete, thus a steel frame building would have a higher material cost. In addition, transportation of steel members and the labor costs of erecting a steel frame structure at the summit of Mount Washington would further increase the overall cost of the project. However, disadvantages due to cost are offset in this particular situation by steel's construction speed in an environment that has a very small construction season.

4.1.4.1 Beams

Beams were designed according to the procedure outline in section 3.2.4.1 of this report. Shown below are structural layout drawings (Figures 30 and 31) depicting the beam selection and placement for the gravity force resisting system. Spreadsheet and sample calculations can be seen in Appendix S and T. Floor and roof slabs were poured onto metal decking that was puddle welded to the tops of the frame's beams.

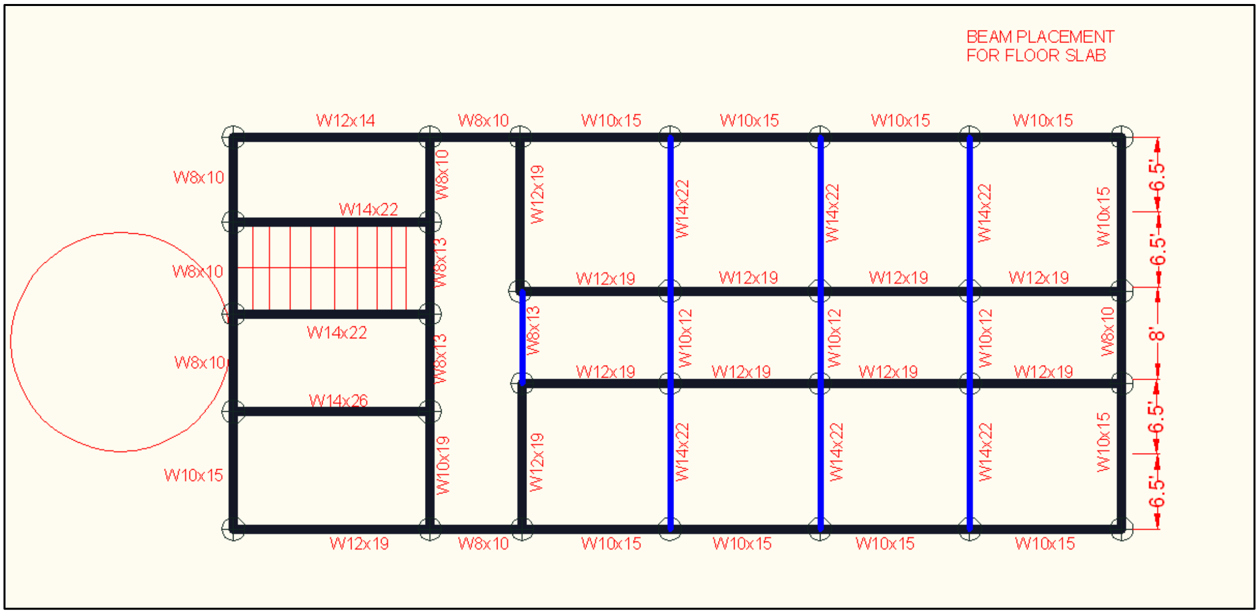

Figure 30: First Floor Steel Layout

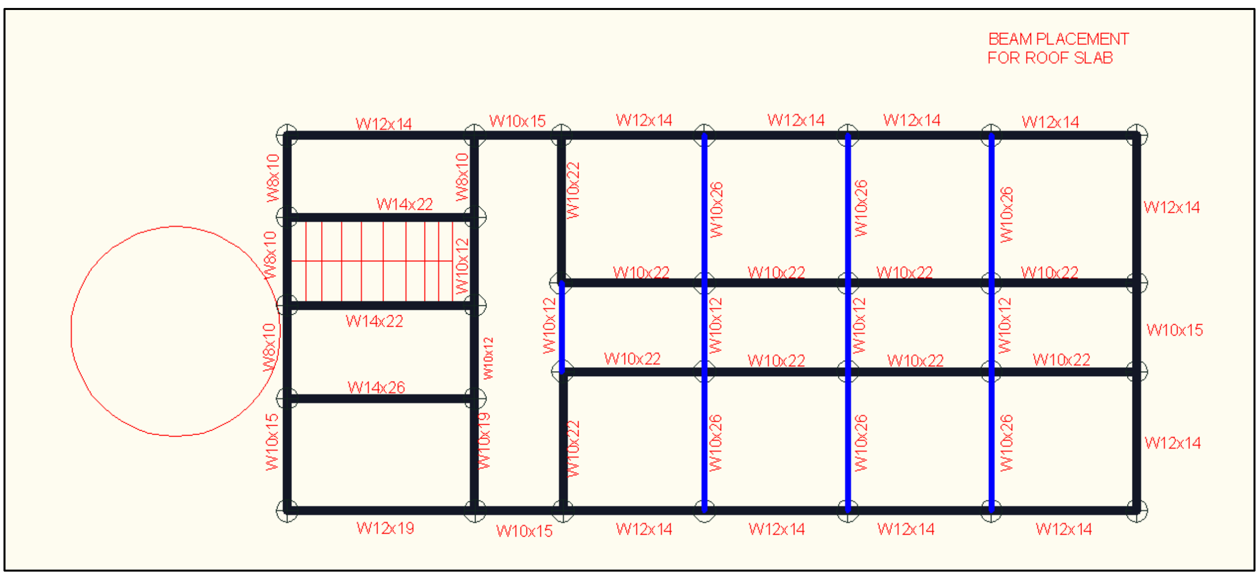

Figure 31: Roof Steel Layout

4.1.4.2 Columns

Columns in the gravity force resisting system were designed according to the procedure outlined in Section 3.2.4.2 of this report. Columns that were part of the moment frame lateral force resisting system were designed in accordance with the procedure outlined in Section 3.2.4.3 of the paper. Below are structural layout drawings (Figures 32 and 33) that show the selection and placement of all columns in the steel structure. Spreadsheet and sample calculations can be seen in Appendices U, V, and W. Additionally, the building's moment frames that served as its Lateral Forces Resisting System (LFRS) can be seen in Figures 34, 35, and 36.

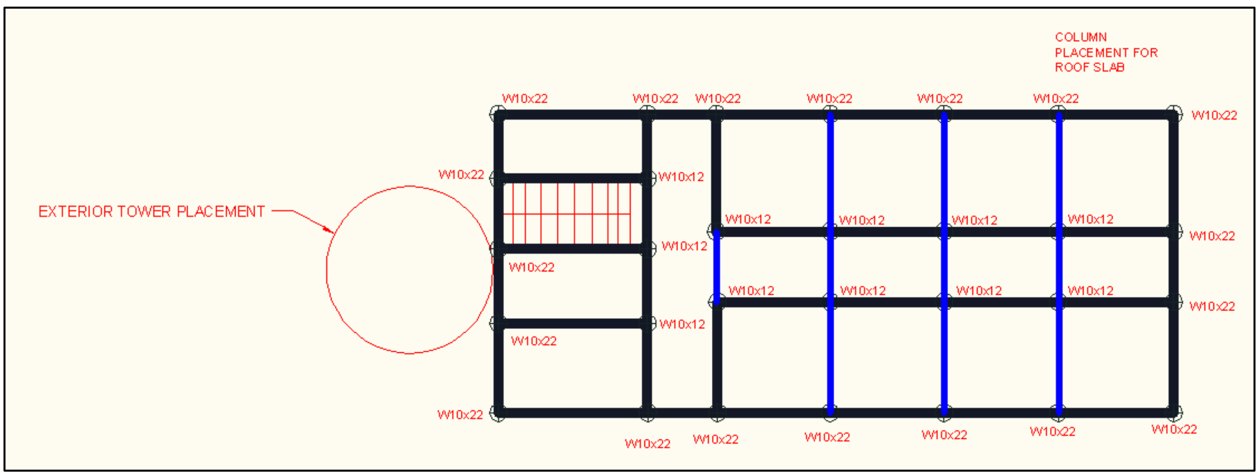

Figure 32: Roof Exterior and Interior Column Layout

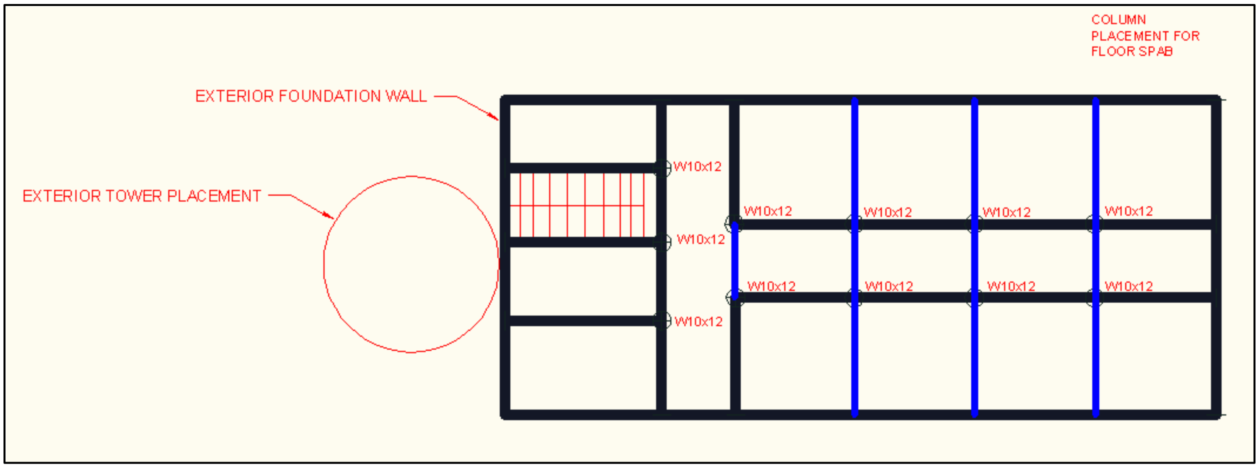

Figure 33: First Floor Interior Column Layout

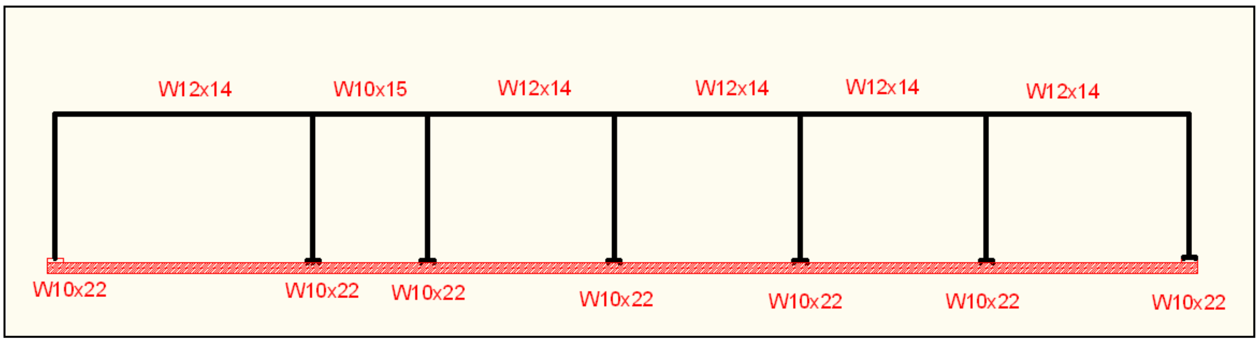

Figure 34: Longitudinal LFRS

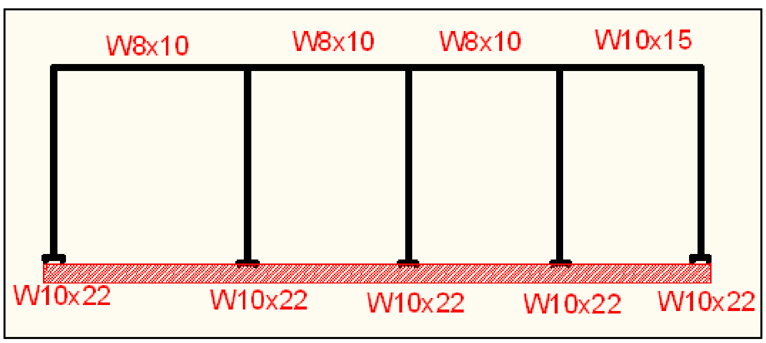

Figure 35: Latitudinal LFRS

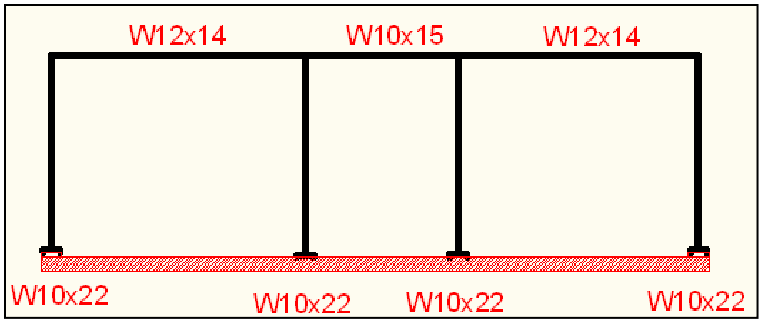

Figure 36: Alternate Latitudinal LFRS

4.1.5 Observatory Tower Design

The observatory tower was designed as a 20-ft tower with a 17-ft outside diameter. An overall cross section of the tower can be seen in Figure 37.The roof thickness and slab on grade thickness were both assumed to be 1ft thick with #3 rebar spaced 9 inches throughout. This was chosen because it was the same thickness as the walls and also it provides a 4 hour fire-resistance rating (*IBC 2009: Table 721.2.1.1)*. The walls were calculated to be 1-ft thick. This can be seen in Figure 38. According to *ACI 318-05* section 14.3.4, the reinforcing steel needs to be placed in two layers, with a minimum cover on either side of two inches. The horizontal and vertical reinforcing steel were calculated using *ACI 318-05*section 14.3.2 and 14.3.3 respectively. The reinforcing bars and spacing for vertical reinforcement shall be No. 3 spaced 10 inches apart; whereas the horizontal reinforcement shall be No. 3 spaced 6 inches apart. This can be seen in Figure 38. To satisfy section 14.3.7 of *ACI 318-05,* two No. 5 bars shall be placed around all windows and opening to ensure proper minimum reinforcing. Spreadsheet and sample calculations can be seen in Appendices X and Y.

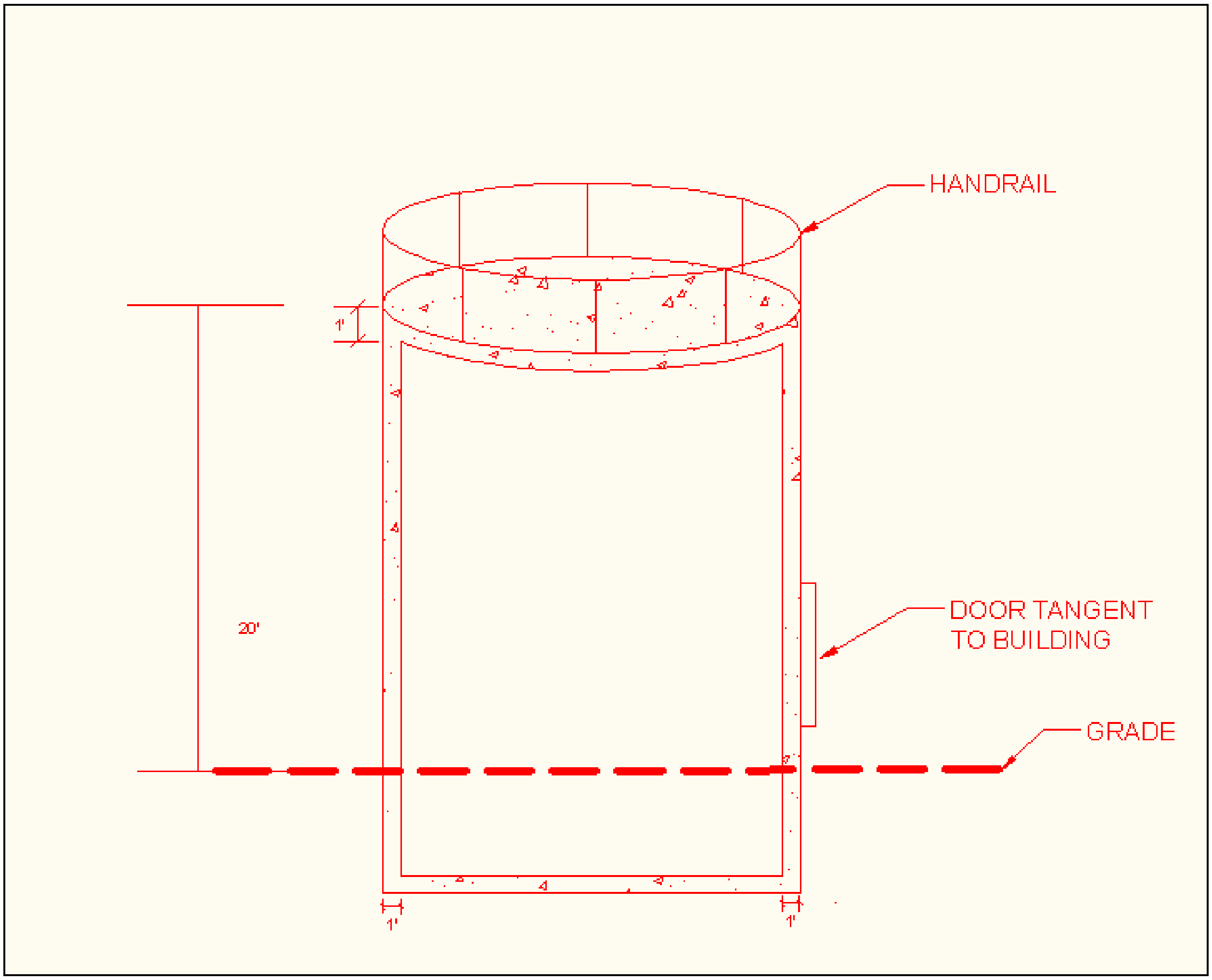

Figure 37: Observatory Tower Cross Section

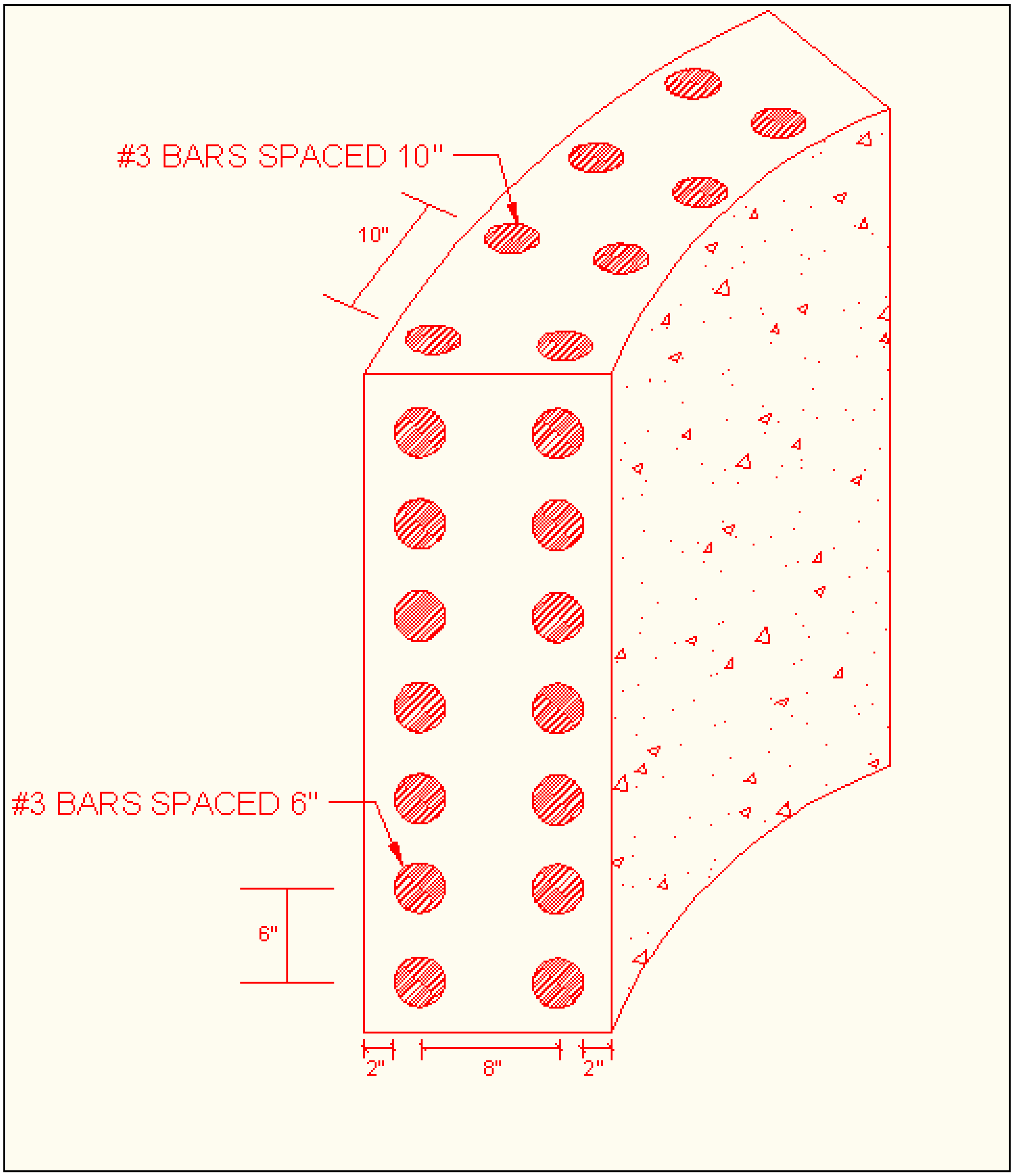

Figure 38: Cross Section of Observatory Tower Wall

4.1.6 Foundation Design

The design of the interior footings was done in accordance with Section 3.2.6.2 of this report. Shown below in Figures 39 and 40 are two design sketches of the footings including dimensions, reinforcement and spacing. Spreadsheet and sample calculations can be seen in

Appendix Z. Additionally, column baseplates were designed in accordance with Section 3.2.6.1 of this report. Their dimensions can be seen in the design sketch provided in Figure 40.

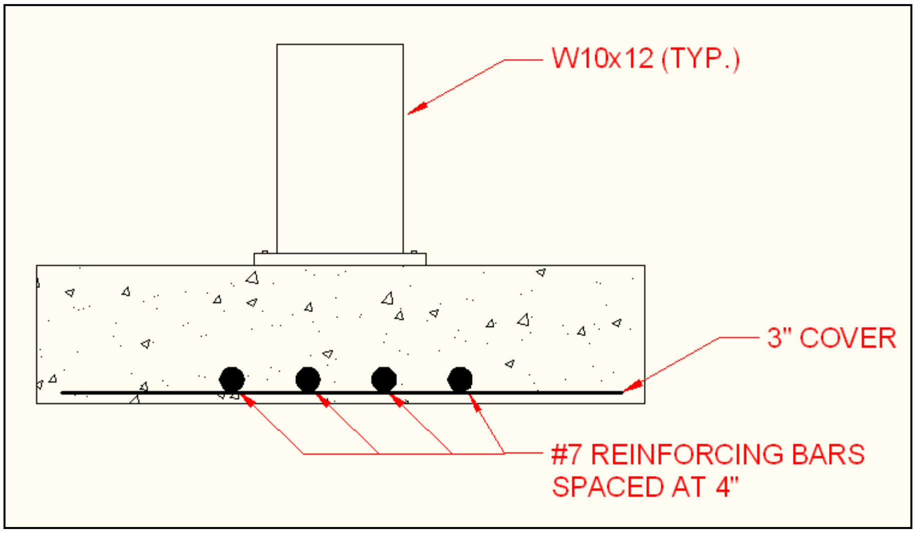

Figure 39: Typical Interior Footing

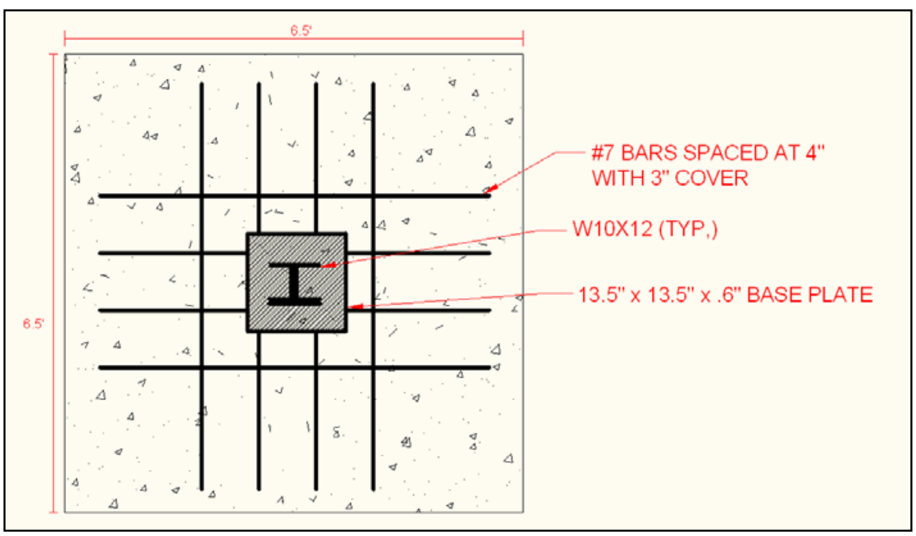

Figure 40: Typical Column Footing Plan View

4.1.7 Cost Analysis

After both the concrete and structural steel designs were completed, the cost analysis on each of the designs was performed. For the concrete design, the total volume of concrete used and the length of rebar imbedded in the concrete were calculated. The total volume was then multiplied by the cost per square yard of concrete (Craftsman Book Company 2008). The total length of rebar was also calculated for each size of beam and multiplied by the cost per linear foot of steel. These results can be seen in Table 21.The cost spreadsheets can be seen in Appendices AA and BB.

For the steel design, the total weight of all the W-shape sections was calculated. Also added in the cost of the steel was the steel decking used to support the concrete floors. The total weight of the steel was multiplied by the cost of steel per ton. The steel decking cost was calculated using the total area and the cost per square foot. The concrete cost of the floor was calculated using the volume of the concrete and the cost per cubic yard of concrete. The results can be seen in Table 21.The costs spreadsheets can be seen in Appendix CC.

The tower, foundation footings, and garage were all designed using concrete and therefore are identical in each design. The costs are exactly the same in for both the steel and concrete options in Table 21.The cost spreadsheets can be seen in Appendices DD, EE, AA, BB,

The total finishings (including construction and transportation) of the building were estimated using the *2008 Square Foot Costs* (RSMeans 2007).We assumed that the environmental research facility was best represented by a two-story residential house and this provided a base for estimating the finishing costs on that assumption. *2008 Square Foot Costs* only cover houses up to 3800 square feet and since the research facility has an area of 6500 square feet a trendline needed to be calculated to determine the cost of a building that size. Since the building was designed with a concrete block (see Table 7) exterior wall the cost per square foot column was used (as shown in Appendix JJ). The graph in Figure 41 was drawn using these data.

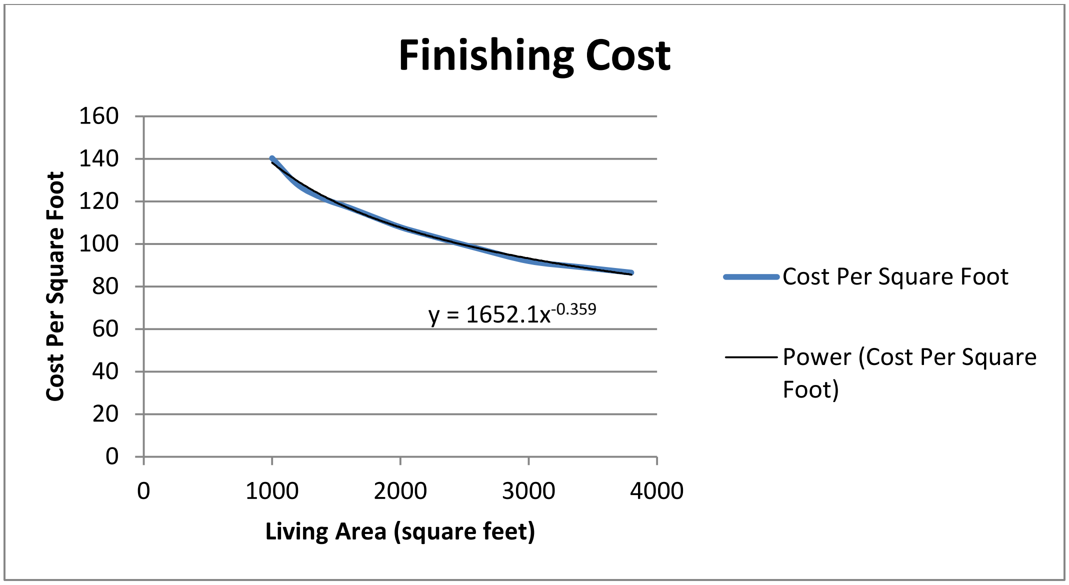

Figure 41: Finishing Cost Per Square Foot (RSMeans 2007)

A trendline was chosen that best fit the data and an equation of the line was calculated.

$$y = 1652.1x^{-0.359} \quad \text{(Equation 5)}$$

The square footage of the building (6500) was substituted for x and the square foot cost of the building was yielded as y. This was calculated as $70.66 per square foot. The total cost for the entire finishings was then calculated. The same volume was assumed for both the concrete and structural steel designs and can be seen in Figure 41.

Table 21: Cost Analysis of Concrete and Structural Steel Designs

Concrete Design		Structural Steel Design	
Tower	$9,000	Tower	$9,000
Garage	$4,000	Garage	$4,000
Rebar	$14,000	Rebar	$42,000
Concrete	$6,000	Concrete	$8,000
Finishings	$460,000	Finishings	$460,000
Foundation	$3,000	Foundation	$3,000
Total Cost	$496,000	Total Cost	$526,000
Location Multiplier	X5	Location Multiplier	X5
New Total Cost	$2,480,000	New Total Cost	$2,630,000

In an email communication Jobie Chase indicated that the cost of all construction the Mt. Washington summit is five times more expensive than elsewhere (Chase 2010). This is shown in the new total cost row of Table 21. The price difference between the two designs is $150,000.

4.1.8 Structural Design Evaluation

The structural steel and reinforced concrete structural designs were evaluated on four separate criteria: cost, transportation, weather factors, and constructability. Each criterion was ranked on a scale of one to five, with five being the best option available and one being the worst option. The design with the highest score would be the option recommended. The highest possible attainable score was a 15.

Table 22: Evaluation Matrix of Structural Designs

Designs	Cost	Transportation	Constructability	Total
Structural Steel	3	3	4	10
Reinforced Concrete	4	3	1	8

We are recommending the structural steel design based on the evaluation matrix in Table 22 and for several reasons. The first reason is that steel is able to be erected quicker than concrete and at full supporting strength as soon as it's put in place and connected. Concrete takes several days to cure to the strength that it can support its own weight and other loads. With buildable days being limited due to the extreme weather, a fast construction of the supporting frame is the most important consideration. Although, the cost of the steel frame is approximately $150,000 more, this is only a 6% cost increase and the time saved in construction may offset these material costs.

4.2 Fire Protection Design

A standard automatic sprinkler system was the first fire protection system researched to provide fire suppression for the environmental research laboratory. A standard automatic sprinkler system is one that requires a reliable water source to provide the flow rate and volume of water needed to suppress the fire. Most residential and city buildings with this type of sprinkler system use the city or town's water main. *NFPA 13* section 23.2.1.1 states that "a connection to a reliable waterworks system shall be a water supply source." The summit of Mt. Washington however, does not have a reliable water supply (see Section 2.1.4). As mentioned in Section 2.1.4, during the winter the well only provides 3-5 gallons per minute in the winter and can only be run for short durations in the winter (Personal Communication, Emberley 2010). Even though the summit may have the needed water supply at a given time, it cannot reliably provide the needed water supply all the time. If a fire were to ignite in the winter and the water supply were to run out, the fire could destroy the entire building. Therefore a standard automatic sprinkler system would not work in this building and location.

To try and minimize the amount of water used by the fire protection system in the environmental research facility, water mist systems were researched next. Water mist systems use around 90% less water than a standard automatic sprinkler system (Marioff Inc. 2011). Water mist systems use high pressures to create a fine mist of water that prevents oxygen from getting to the fire, prevents radiative heat from heating up the surrounding objects, and cools the temperature of the fire and the room. Water mist systems, such as Tyco Aquasonic and Marioff HI-FOG, use 50-800 gallons of water to suppress a fire. A standard sprinkler system uses anywhere between 500-8000 gallons depending on the size of the building to extinguish a fire. These systems each use water tanks, separate from the main water supply and can be easily stored in a building room (Edwards 2011; Pelletier 2011)

However, two problems arise with water mist systems. The first problem is that as of February 2011, water mist systems are only designed for a Light Hazard building classification. The environmental research facility was designed to be a multipurpose building with sleeping quarters, workshop area, library, and conference room, which classifies the building as an Ordinary Hazard classification. Steven Pelletier, Engineered Systems Manager, from Marioff Inc. indicated that in the next year an Ordinary Hazard water mist system was going to be on the market from Marioff Inc.(Personal Communication, Pelletier 2011)The second problem is that they are expensive, costing two to three times more than the INERGEN® system to be discussed next. With the State Park having to raise the money themselves with no help from the State, it is important that the system has the lowest possible cost while still providing sufficient protection. These two reasons make water mist systems not the best option for the State Park.

The final fire suppression system researched was the Ansul INERGEN® System. What makes this system different from the other two is that this system uses inert gases instead of water to suppress fires. The gases completely flood the room and extinguish the fire by the displacing oxygen. There are also many other factors that make this system the best choice for the environmental research facility on Mt. Washington. One factor is that the concentrations of the gases used in the INERGEN® System are safe for humans and the environment. The gas used to extinguish the fire is a combination of 40% argon, 52% nitrogen, and 8% carbon dioxide (Ansul 2006). These gases are already present in the air humans breathe at different concentrations. Once used for fire suppression, these gases easily disperse back into the environment. The second factor is that there is no property damage with the use of gases (Ansul 2008). With water-based suppression systems, property is damaged from the intentional and accidental activation of the sprinklers. With the INERGEN® System this is not the case. Although the INGERGEN® system only functions between 32°F and 130°F, this is not a problem since the buildings on the summit of Mt. Washington are insulated and heated throughout the winter.

The INERGEN® System incorporates a fire detection system called the AUTOPULSE®. Key features of this system are thermal heat and flame detectors, smoke detectors, and a computer unit to specifically determine the start of a fire and suppress it before it can grow (Ansul 2006). The INERGEN® system is a self-designed, proprietary system in that only representatives of Ansul design and install the INERGEN® system. When a system is bought, Ansul covers everything from the design process until the system is ready to be used by the building and the owner. This process and system is significantly less than a water mist system making it affordable for the State Park (Pelletier 2011).

4.2.1 Fire Protection System Cost Analysis

The INERGEN® system is a relatively inexpensive solution for fire protection. According to *NFPA 1* section 13.3.2.17.1 and 13.3.2.17.3, an automatic or alternative method of fire protection needs to be designed and installed throughout the entire building. The total square footage and volume of the building is 5,979 ft^2 and 55,608 ft^3 respectively. Using the 2010 INERGEN® Quick Quote spreadsheet given by Steven Pelletier, the following prices for design, installation and equipment were developed, as seen in Table 23.INERGEN® Quick Quote spreadsheets for First Floor, Basement, and Garage can be seen in Appendices FF, GG, and HH.

Table 23: Cost Analysis of INERGEN® Fire Protection System

INERGEN® System	$ 135,000
Turnkey Installation	$ 350,000
Total	$ 485,000

A turnkey installation refers to the hardware, design, submittals, installation, and miscellaneous materials for the installation of the INERGEN® system. The average cost of a turnkey installation is $6.25 per cubic foot of building volume (Pelletier 2011).

The 2010 INERGEN® Quick Quote spreadsheet required several pieces of information to be entered into it in order for the prices to be output. Data entered included:

- Area
- Volume
- Support measures for gas cylinders.
- Gas cylinder size
- Number of exits per room
- Type of detection and detector
- UL or ULC listed
- Heat Detector temperature

The data above is the only information necessary for the Quick Quote spreadsheet to be run. Values selected were based on the designed layout of the building. The area and volume refer to the size of the rooms being protected. The actual sizes and dimensions can be seen in Figure 20 and 21. The number of exits refers to the exits from each room. The support measures for the gas cylinders come in either single row or double. For this design, double rows none back to back were chosen to keep the cylinders confined to a small area. The gas cylinders size chosen was 439 ft^3 since that is the default size used. The number of cylinders to be used is 43. This system would need roughly 60 square feet of space. This could easily fit in one of the room in the basement of the new facility. Cross zone thermal detectors were chosen to help prevent accidental activation. This system's components are Underwrites Laboratory and FM Global listed and approved. The heat detectors temperature was chosen to be 140°F. No machinery or equipment that would raise the temperature of the room above 140 °F is expected to be placed in the facility.

A water mist system could have been used in this situation, however as stated in section 4.2, water mist systems are more expensive. They are around two to three times more expensive than the INERGEN® fire protection system. Based on the INERGEN® cost analysis, a water mist system in the same size building would cost close to $1.5 million. With cost being a major concern for the State Park, the INERGEN® system is the best choice for this scenario.

The INERGEN ® System recommended is an effective solution for fire protection for the research facility. Even with the lack of firefighting help from surrounding towns, the building will be safe from a devastating fire that would completely destroy the building, as in the case of the 2003 fire that destroyed the previous building.

5 Results: Wastewater Treatment

This section describes the operational problems and permit violations of the Lifewater treatment plant on the summit. The results of the data analysis and evaluation of the effluent nitrates are detailed. Wastewater improvement alternatives are also described to improve effluent wastewater characteristics and meet the New Hampshire discharge permit requirements.

5.1 Current Lifewater System

The following sections detail the Lifewater ExtremeSTP™ current wastewater treatment process on the summit of Mount Washington. Operational problems with the plant and discharge permit violations are discussed. Influent and effluent wastewater characteristics were analyzed to provide insight on the operational problems of the plant. Since the effluent nitrate concentrations were a concern for the NH DES and the Park Staff, the nitrate data were examined for apparent trends or correlations with other plant data.

5.1.1 <u>Description of Plant</u>

The ExtremeSTP™ sewage treatment plant for Mount Washington (see Figure 42) is a membrane bioreactor that is housed in a 40-foot long, insulated enclosure and can be remotely controlled. Wastewater flows by gravity from the Sherman Adams Building to the plant, where the process begins with fine screening. Next, the flow moves to the anoxic tank where denitrification takes place (T-1 in Figure 42). The flow into this tank comes from the fine screening and a metered flow off the membrane circulation loop. The anoxic tank is always kept at the same level of water, so when there is not enough flow from the fine screening, the flow from the membranes is increased. Therefore, keeping the anoxic tank at a constant level maintains constant flow to the bioreactor. Denitrification requires anoxic conditions. Since dissolved oxygen (DO) is high in both the flow from the screening and the membranes, a carbon source is added to the anoxic tank to increase the biological oxygen demand (BOD_5) and reduce the DO to less than 0.5 mg/L (Lifewater Engineering 2009).

The bioreactor (T-2 in Figure 42) is where the activated sludge process takes place. When the bioreactor is at full capacity, the excess mixed liquor will enter the surge tank (T-3). The purpose of the surge tank is to dampen the changes in flow. Aeration also takes place to prevent the solids from settling. During normal operation, the air is directed to the bioreactor tank rather than the surge tank. The aerobic zone is supposed to reduce the amount of carbon and nitrify the influent. The mixed liquor DO concentration decreases as it passes through the surge tank, which helps keep the DO concentration in the anoxic tank low when the mixed liquor is returned from the membrane loop (Lifewater Engineering 2009).

Next, the membrane pump sends the wastewater from the surge tank to four tubular membranes in series. Permeate from the membranes flows to the permeate tank (T-4), but most of the mixed liquor is sent back to the bioreactor, and a portion to the anoxic tank to be used for denitrification. After the membranes, a tank (T-4) is used to store the permeate before it is discharged. Some of the permeate is used to flush the fine screen at the beginning of the process, mix chemicals, and help suppress foam in the bioreactor. The excess permeate then moves to the UV disinfection unit (UV) and is then discharged (Lifewater Engineering 2009).

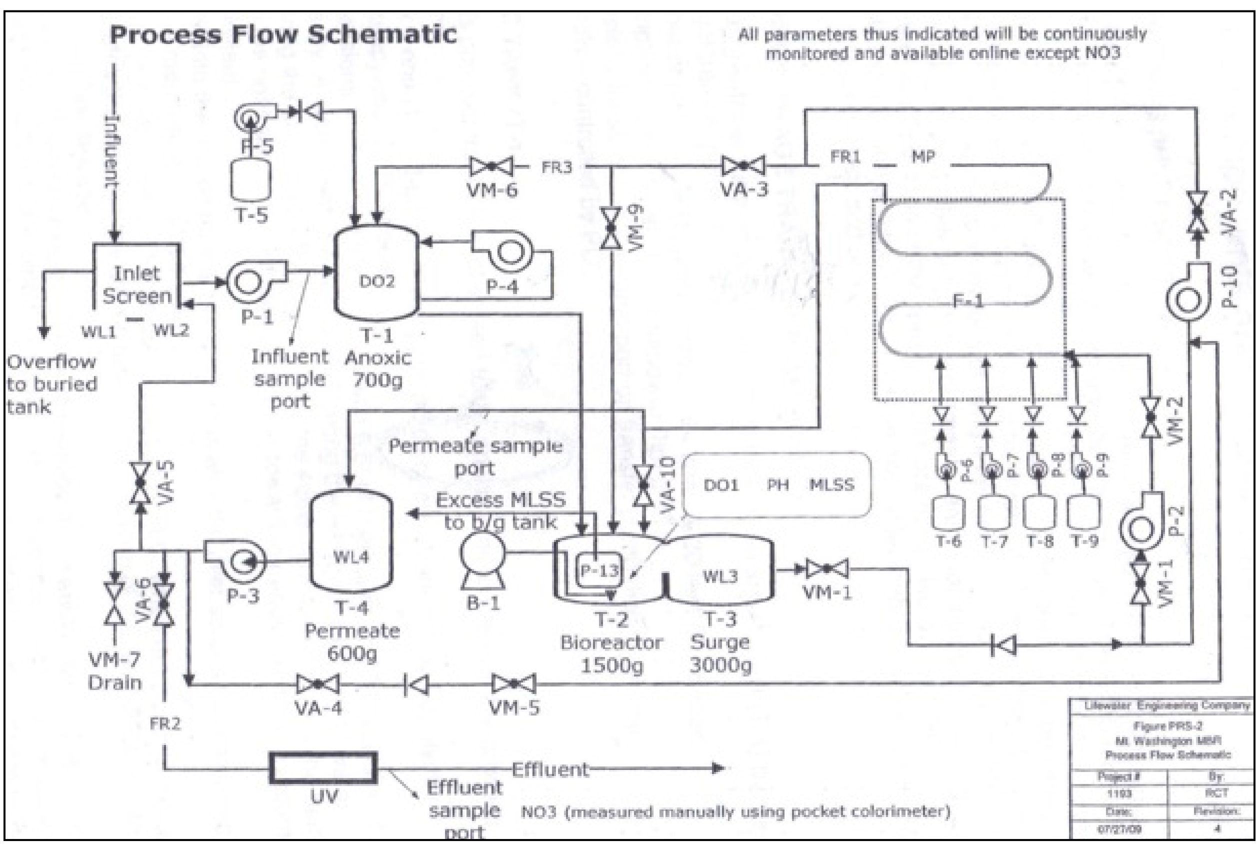

Figure 42: Process Flow Schematic (Lifewater Engineering 2009)

Tables 24 and 25 show expected influent and effluent characteristics of the Extreme STP™ plant according to the Operation and Maintenance manual provided by Lifewater.

Table 24: Expected Influent Loading to Extreme STP™ (Lifewater Engineering 2009).

Flow, Average (Summer)	2,000 GPD
Flow, Average (Winter)	200 to 300 GPD
Flow, Peak Daily	7,000 GPD
BOD_5	450 mg/L
TSS	300 mg/L
TKN	190 mg/L

Table 25: Expected Effluent Characteristics from Extreme STP™ (Lifewater Engineering 2009).

pH	6.5 – 8.0
Total Nitrogen	< 20 mg/L
Nitrates	< 10 mg/L
BOD_5	< 10 mg/L
TSS	< 10 mg/L
Fecal Coliform	0

5.1.2 Operational Problems

Through email and phone communication with Kenneth Kessler, the wastewater treatment facilities technical assistant (NHDES), the project team learned about difficulties with operation of the current treatment plant. According to Mr. Kessler, the plant has an overall lack of process control data. For example, recycling of the nitrified product back to the anoxic zone only occurs on an intermittent schedule when the surge tank reaches the preprogrammed level.

This means that denitrification happens intermittently as well (Personal Communication, Kessler 2010).

Mr. Kessler noted that another problem of this current system is the inability to gain access to the compartments of the treatment plant to check conditions. There is very little operational data about the conditions in the various tanks. Data tracking relies on fixed probes in the aerated zone (T-2)for monitoring DO, pH, and suspended solids. However, sometimes the probes give negative readings in the 100's, which are erroneous. The conditions in the anoxic zone are not monitored, and there is no practical way of obtaining the information while the system is operating. Mr. Kessler could only get into one of the access ports in the anoxic zone when the system was shut down. When the plant is operating, there is a thin layer of solids on the surface of the tank that would spill out if the tank was opened (Personal Communication, Kessler 2010).

Data from the current Lifewater wastewater treatment plant were obtained from the NH Department of Environmental Services through Richard H. Emberley. The information included the influent and effluent flows from November 2009 until October 2010 as well as water quality characteristics on days when samples were taken. Notes from the Park Managers related to any observations or failures were also included. Table 26 shows a compiled list of the relevant operational notes, the number of occurrences, and whether the occurrence was due to a failure, regular maintenance, or another reason.

Table 26: Compiled Operational Notes from Wastewater Treatment Plant November 2009 – October 2010

Note	Number of Occurances (days)		
	Plant Failure	**Regular Maintenance**	**Other**
Cleaned membrane filters	8	8	0
Plant offline	18	2	8
UV bulb fail	1	0	0
Auger motor fail due to toilet paper	2	0	0
Press screen and auger shaft replaced	1	0	0
Carbon pump replaced	1	0	0
Broken air compressor	2	0	0
Cleaned bioreactor DO probe	0	2	0

The Operation and Maintenance manual from Lifewater provides information on cleaning and maintenance of the plant. Cleaning the plant is recommended prior to an extended period of inactivity to increase the membrane productivity (Lifewater Engineering 2009).Regular maintenance includes the following (Lifewater Engineering 2005):

- Clean the UV bulb every 3 to 4 months
- Clean the fresh air filter every 3 to 4 months
- Check and replace the return air filter every 3 to 4 months
- Clean the blower housing every 3 to 4 months
- Replace the UV bulb every 1 to 2 years
- Pump sludge from the unit every 2 to 5 years

The manual indicates that the plant is simple to operate and requires minimal maintenance. According to the operational notes in Table 26, the plant was offline 28 times over a one-year period and 18 of these times was because of a failure. The 8 times that the treatment plant was offline for other reasons was due to a lightning storm and a resulting power outage after the storm for 8 days. The press screen, auger shaft, and the carbon pump were each replaced once. The UV bulb and the air compressor both failed once. It was also noted that the membranes were cleaned a total of 16 times since the plant's installation. Based on the operation notes from the park managers, it was estimated that 8 of these 16 cleanings were regular maintenance. Information about the membrane cleaning in the Operation and Maintenance manual for the Lifewater plant states that there is a clean-in-place system where pressurized water from the permeate tank is used to mix the chemicals needed to clean the membranes (Lifewater Engineering 2009). The manual does not mention the frequency of cleaning needed, but similar membranes of this type are cleaned every one to three months (Yacubowicz and Naworski 2005).

5.1.3 Permit Violations

Data on flow as well as influent and effluent characteristics were obtained for two months in 2009 and 10 months in 2010. Water quality parameters that were measured include pH, total suspended solids, fecal coliforms, biological oxygen demand, total nitrate, total nitrite, total ammonia, total Kjeldahl nitrogen, and mixed liquor suspended solids. These data are shown in Appendix D. The data were compared to the treatment plant discharge permit to determine the number of permit violations each month.

Mr. Kessler notes that the BOD, TSS, and fecal coliform measurements from the effluent have generally met the discharge requirements (Personal Communication, Kessler 2010). The main concern of the park staff and the NH Department of Environmental Services has been the inability of the plant to meet the discharge requirements for nitrogen removal. Data were available from November 2009 through October 2010. As shown in Table 27, the plant had 41 permit violations based on effluent quality, 24 of which were because the plant exceeded the nitrate limit of 10 mg/L. Water quality violations were highest in August 2010 with 11 violations, while September and October had the second highest number of violations, with 7 each. There were no violations of pH or BOD_5 during either of these years.

Table 27: Discharge Effluent Water Quality Violations 2009-2010

Month	Violations Per Month By Parameter						Total Violations per Month
	Flow	pH	BOD_5	Nitrate	TSS	Fecal Coliform	
November-09	0	0	0	2	1	0	**3**
December-09	0	0	0	2	1	1	**4**
January-10	0	0	0	1	1	1	**3**
February-10	0	ND	0	0	0	0	**0**
March-10	0	ND	0	1	0	0	**1**
April-10	0	ND	ND	ND	ND	ND	**0**
May-10	0	ND	ND	ND	ND	ND	**0**
June-10	0	0	0	1	0	1	**2**
July-10	1	0	0	0	0	2	**3**
August-10	5	0	0	6	0	0	**11**
September-10	1	0	0	5	ND	1	**7**
October-10	1	0	0	6	ND	0	**7**
November-10	ND	ND	ND	ND	ND	ND	**ND**
December-10	ND	ND	ND	ND	ND	ND	**ND**
Total	**8**	0	0	24	3	6	**41**

ND = No Data

In New Hampshire, when a wastewater treatment plant is not meeting the required limits set by the discharge permit, the Department of Environmental Services administers fines. First, the DES issues a Notice of Proposed Fine informing the violator and proposing a dollar amount for the fine. Next, the violator must either pay the fine within the date specified on the notice, which is no less than 25 days from the notice of the proposed fine, or s/he has the opportunity to have a hearing and settle the case to reduce or eliminate the fine. At this hearing, the violator explains why the fine should not be imposed. The Commissioner of the Department of Environmental Services decides whether the fine should be imposed based on the evidence presented by the hearing officer on the rationales against the fine. The fine can be reduced in certain circumstances, including if the violations occurred despite good faith efforts to comply. If a fine is still imposed after the hearing, the violator will need to pay the fine within 30 days of the commissioner's decision, or according to the date specified in the decision (NH DES 2006).

Since the installation of the Lifewater system on Mount Washington in 2009, the New Hampshire Department of Environmental Services has not fined the State Park for the violations of the discharge permit. This is due to the unique conditions on the mountain and the time required for the staff to learn how to operate the plant successfully through trial and error. In addition to the effluent limits, the permit also requires weekly testing, but this is physically difficult to do during the winter months because of the weather. Mr. Kessler noted that the DES could issue an administrative order for the State Park to conduct a study on the treatment plant and take action complying with the requirements of the permit with a proposed timeframe for compliance. Therefore, if the Lifewater plant continues to produce effluent in violation of the discharge permit requirements, there are three possible scenarios. First, the State Park could be fined and pay the fines. However, Mr. Kessler notes that the DES is unlikely to impose a monetary fine on the Park due to the unique conditions of the plant and the location. Second, the State Park could implement upgrades to the treatment system or install an alternative system. Third, the State Park could present a study that is convincing to the DES that the requirements of the current permit are unreasonable and that the discharge is not negatively impacting the environment as they are currently operating.

5.1.4 Treatment Plant Data Analysis

Data on the Lifewater treatment plant on the summit of Mount Washington were analyzed to determine whether there are any apparent trends or correlations among the data. Flow, influent wastewater quality, and effluent wastewater quality data were obtained from the NH Department of Environmental Services for November 2009 through October 2010. The influent flow to the treatment plant was compared to each of the water quality parameters by graphing these data over time and qualitatively observing trends. An example graph of influent flow and effluent nitrates is shown in Figure 43. The remaining graphs are shown in Appendix II. These graphs do not demonstrate any apparent trends between water quality characteristics and influent flow. This may be because of large gaps in the data due to the difficulty of obtaining samples. For example, considering flow and nitrogen in Figure 43, there are 302 data points for the flow over a 10-month period in 2010, but there are only 33 data points for effluent nitrates.

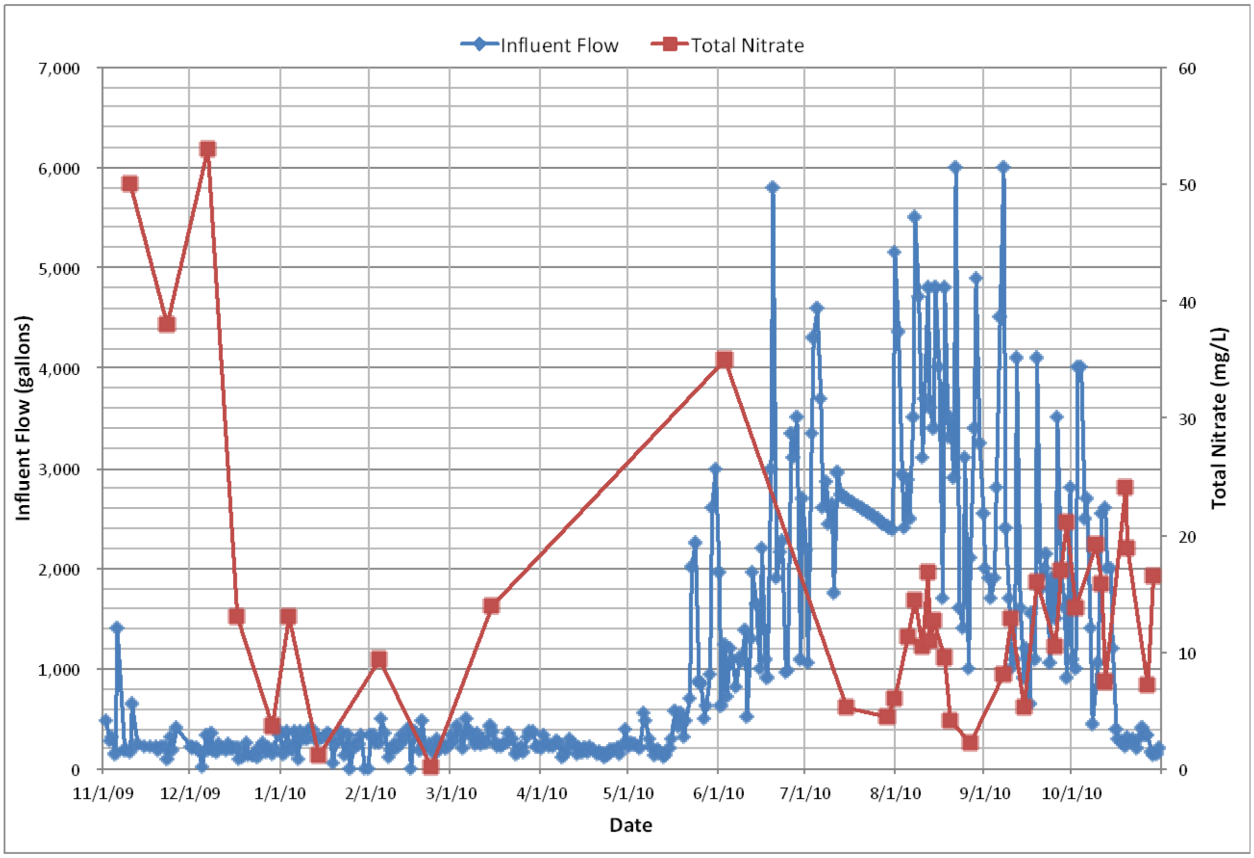

Figure 43: Lifewater ESTP Treatment Influent Flow vs. Effluent Nitrates

A correlation analysis was performed on the data collected from the treatment plant to determine if the water quality parameters were statistically related to one another. There were forty-five possible correlations. Table 28 shows the number of pairs of data for each set of variables. Flow in and flow out had 351 paired data points. However, there were large gaps in many other variables, and the number of paired data points ranged from 1 to 82 (NA indicates that a correlation is not applicable where the parameter is being correlated with itself).Table 29 shows the critical correlation coefficients, which are based on the number of paired data points and the alpha value (0.05).A minimum of two paired data points is necessary to determine a critical value. A correlation analysis was performed in Excel and Table 30 shows the output. The absolute values of the correlation coefficients were compared to the critical values. The eight paired parameters that were statistically correlated are highlighted in yellow in Table 30: flow in and out of the treatment system; flow in and pH out; flow out and pH out; fecal coliform and pH out; BOD_5 in and total suspended solids in; BOD_5 out and flow in; and BOD_5 out and flow out.

The only parameters that were inversely correlated were flow out of the treatment system and total nitrates.

Table 28: Pairs of Data for Correlation Analysis

	Flow in	*Flow out*	*pH in*	*pH out*	*TSS in*	*TSS out*	*FC*	*BOD in*	*BOD out*	*Tot. Nitrate*
Flow in	NA									
Flow out	351	NA								
pH in	16	15	NA							
pH out	81	82	1	NA						
TSS in	11	10	1	6	NA					
TSS out	13	13	1	5	8	NA				
FC	18	18	3	9	10	13	NA			
BOD in	13	13	3	8	10	10	13	NA		
BOD out	18	18	5	9	10	13	18	13	NA	
Tot. Nitrate	37	37	3	28	9	12	17	12	17	NA

NA = Not Applicable

Table 29: Critical Correlation Coefficients Based on Pairs of Data

	Flow in	*Flow out*	*pH in*	*pH out*	*TSS in*	*TSS out*	*FC*	*BOD in*	*BOD out*	*Tot. Nitrate*
Flow in	NA									
Flow out	0.138	NA								
pH in	0.497	0.514	NA							
pH out	0.228	0.227	NA	NA						
TSS in	0.602	0.632	NA	0.811	NA					
TSS out	0.553	0.553	NA	0.878	0.707	NA				
FC	0.468	0.468	0.997	0.666	0.632	0.553	NA			
BOD in	0.553	0.553	0.997	0.707	0.632	0.632	0.553	NA		
BOD out	0.468	0.468	0.878	0.666	0.632	0.553	0.468	0.553	NA	
Tot. Nitrate	0.325	0.325	0.997	0.375	0.666	0.576	0.482	0.576	0.482	NA

NA = Not Applicable

Table 30: Correlation Analysis for Existing Treatment Plant Data

	Flow in	*Flow out*	*pH in*	*pH out*	*TSS in*	*TSS out*	*FC*	*BOD in*	*BOD out*	*Tot. Nitrate*
Flow in	1.000									
Flow out	0.830	1.000								
pH in	-0.065	-0.088	1.000							
pH out	0.355	0.418	1.000	1.000						
TSS in	-0.129	-0.200	1.000	0.563	1.000					
TSS out	-0.429	-0.489	-1.000	0.099	0.382	1.000				
FC	0.332	0.216	-0.637	0.837	0.421	-0.198	1.000			
BOD in	0.285	0.125	0.871	0.677	0.905	0.341	0.177	1.000		
BOD out	0.511	0.473	-0.350	0.305	0.042	-0.216	0.362	-0.170	1.000	
Tot. Nitrate	-0.285	-0.332	-0.570	-0.279	-0.182	-0.067	-0.190	-0.128	-0.028	1.000

5.1.5 Evaluation of Nitrate Problem

Mr. Kessler indicated that the nitrate discharge violations might be due to the food service business on the summit in the Sherman Adams Building (Personal Communication, Kessler 2010). From May through October, there are 300,000 visitors to the top of the mountain. The business uses “Santimine 150”, a quaternary ammonia and benzyl methyl ammonium chloride monohydrate compound to clean and disinfect the pots, pans, dishes and utensils. This process involves filling and draining a three-compartment sink filled with these chemicals. According to Diane Holmes, Park Manager, 14 to 21 of these tablets can be used in a day during the summer months depending on how busy food service is that day(Personal Communication, Kessler 2010).

Quarternary compounds such as cleaning disinfectants are toxic to all living organisms, such as those in the activated sludge process. Alkyldimethylbenzel ammonium chloride is widely used in cleaning products and is a strong catalyst that speeds up the hydrolysis of esters and amides, both of which are found in living organisms(Cogent Solutions , 2010)Mr. Kessler suggests that the use of the Santimine product in the Sherman Adam’s kitchen may be the cause of the high nitrates in the effluent during the summer months because the compound contains nitrogen and because it kills the microorganisms in the treatment plant. The project team attempted to gather information on the chemical make-up and nitrogen content of Santamine 150. However, Santimine and Poison Control could not disclose detailed information on the nitrogen content of these tablets because the information is proprietary.

Data from the Department of Environmental Services were analyzed to determine whether there are any apparent trends among influent and effluent total Kjeldahl nitrogen (TKN) and the dates of operation (see Figure 44). No trends between the time of year and influent TKN were observed. This may be due to the few data points available. Based on the wastewater characterization in the 2008 Advanced Design Engineering Report for the treatment plant, the influent TKN was expected to be 190 mg/L. However, the average TKN from the monitoring data is 212 mg/L and the median value is 215 mg/L (Stantec 2008).

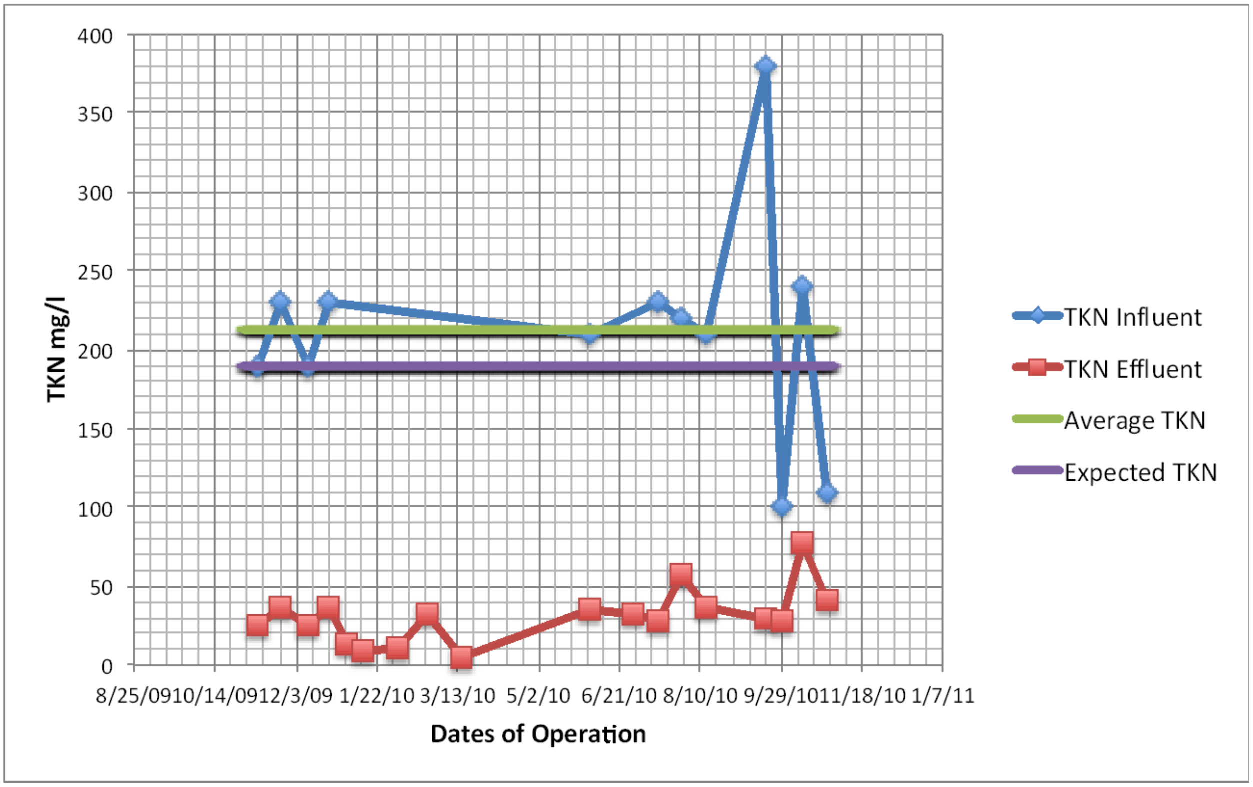

Figure 44: Lifewater ESTP Treatment Total Kjeldahl Nitrogen v. Dates of Operation

As seen in Figure 44, 8 of the 12 data points for the influent are higher than 200 mg/L and therefore higher than the predicted wastewater characterization for the current Lifewater design and operation. Higher TKN values in the influent may be due to a design error and an underestimation of the influent TKN.

5.2 Wastewater Improvement Alternatives

The main concern of the Department of Environmental Services in NH and the park managers on Mount Washington is the nitrogen concentration in the wastewater treatment plant effluent. Therefore, alternatives were investigated for improving the current nitrogen removal process, and for monitoring in the Lifewater treatment plant. According to the NH DES, one alternative is that the State Park could present a convincing study to the DES that the requirements of the current permit are unreasonable and that the discharge is not negatively impacting the environment as they are currently operating (NH DES 2006).

Other alternatives include dilution of the influent, changes to the configuration of the tanks in the plant, additional monitoring of the treatment facility, and environmentally friendly disinfectants. Each of these alternatives is discussed in the following sections.

5.2.1 Dilution

The influent TKN values may be large because of the low water flow entering the plant and the use of the nitrogen containing disinfectant for washing dishes in the Sherman Adam's building. The treatment plant was designed to treat 190 mg/L of TKN but the average summer influent is about 213 mg/L. The average summer influent summer flow is about 2,230 gallons a day and the 213 mg/L of TKN would need to be diluted by 11% to meet the design value of 190 ml/L. To accomplish this, an additional 264 gallons/day on average would be needed. Dilution would also increase the amount of water that the system would need to process and therefore decrease detention times in the various tanks. However, diluting that influent is not recommended. Fixtures have already been installed to minimize the water use on the summit because there can only be minimal withdrawals from the well. Diluting the influent would reduce the concentration of TKN entering the plant; however, it is not practical for the Park.

5.2.2 Alternative Treatment Configuration

A second option is to increase the retention time in the anoxic tank to allow for more denitrification. This could be accomplished by an arrangement known as the Bardenpho process, proposed by Dr. James L. Barnard in1970, who has designed many nutrient removal plants for South Africa and Canada (van Haandel and van der Lubbe 2007). The current configuration of the Lifewater plant is an anoxic tank leading to an aerobic tank with recycle loops back to the anoxic tank for further denitrification. In the Bardenpho process, an anoxic tank is placed before and after the aerobic (bioreactor) to remove nitrogen, like the current configuration, as seen in Figure 45. Most of the nitrate is removed in the first anoxic reactor, and the remaining nitrate, which would normally leave the plant if not recycled back to the first anoxic tank, is further reduced in the second anoxic tank. After the second anoxic tank, the water passes to an optional second aerobic tank, and then to the settler. The optional aerobic reactor is smaller than the other tanks, and its purpose is to provide re-aeration so that the sludge remains aerated and the excess nitrogen is removed (van Haandel and van der Lubbe 2007).

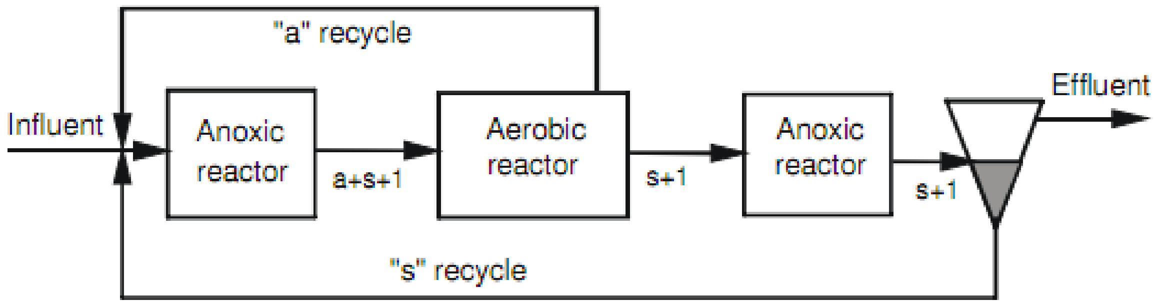

Figure 45: Bardenpho Configuation (van Haandel and van der Lubbe 2007)

This process was installed in a 1.4 million gallon per day treatment plant in Palmentt, Florida in 1979 (EIMCO Water Technologies 2010). It was the first Bardenpho process treatment facility in North America. The plant has experienced ranges in flow from 0.89 to 1.6 million gallons a day and changed in influent concentrations but the plant has still produced high quality effluent (EIMCO Water Technologies 2010)

A disadvantage of the Bardenpho configuration is that it can be difficult to balance the amount of organic material with the nitrate concentration so that there is the least amount of either in the effluent. Another disadvantage to this process would be the addition of another tank in the small and already complicated layout of the existing plant. The Park Managers do not have the time to monitor a complicated treatment process. The final disadvantage of this configuration is the cost of a new tank. There has already been over $500,000 invested into the current treatment process and modifications could be costly. However, modifications will be less costly than purchasing a new treatment system.

5.2.3 Improved Monitoring

Before a decision is made on improvements to the wastewater treatment system, more comprehensive data on the current system should be obtained. The current wastewater discharge permit requires daily monitoring of the influent flow, weekly monitoring of the influent and effluent ammonia, BOD_5, TKN, and TSS, as well weekly monitoring of effluent fecal coliforms. According to data from the DES, flow is monitored most days, but monitoring for water quality parameters is not done weekly, as required by the discharge permit. Better monitoring capabilities would provide more accurate data for analysis and would aid in future decisions regarding the plant. Water quality monitoring recommendations can be seen in Table 31

Table 31: Water Quality Monitoring Recommendations

Parameter	Permit Requirement	Current Monitoring	Ideal Monitoring
pH	Not specified	≈ 2 samples/week	Daily
BOD_5	Weekly	≈ 1 sample/month	Weekly
Nitrate	Weekly	≈ 1 sample/week	Weekly
TSS	Weekly	≈ 1 sample/month	Weekly
Fecal Coliform	Weekly	≈ 1 sample/month	Weekly

First, moving the package plant so that it is adjacent to the proposed research facility would ensure that the physical monitoring of the Lifewater plant could continue in dangerous winter conditions, and the effluent would not be discharging to the sensitive alpine region. Currently, the samples that are collected by the Park managers are shipped off the mountain to laboratory for analysis because the Park lacks the equipment and space to test on site. To address this issue, a laboratory is included in the research building design and will allow for space to carry out on-site testing. Therefore, the Park managers could not only access and monitor the treatment plant in bad weather, but they could also collect more data to meet the discharge permit requirements for monitoring. The Park would also be helping to protect the sensitive alpine research area, which is currently downhill of the surface discharge of the Lifewater plant.

If the Lifewater plant was located adjacent to the proposed research facility, the complicated treatment process would be easier to constantly monitor by a Park staff member. The plant was designed to be simple to run in theory but the treatment is complicated because of the unconventional design and recycle loops. Actual operation on the Mount Washington's summit has required the Park staff to spend many hours learning and monitoring the process, while also managing all other aspects of running the State Park. Therefore another suggestion is to acquire an additional Park staff member with wastewater experience to run the plant.

A more complete analysis could be accomplished with better ways to monitor the supplemental of carbon (microCg), water quality parameters throughout the treatment, recycle rates, and sludge waste. High TKN values in the effluent may occur because there is not enough biological mass or carbonaceous material in the influent to fully convert the ammonia that enters the plant. Better monitoring and knowledge of when to increase the amount of microCg would improve denitrification and reduce TKN concentrations in the effluent. Increased denitrification could also be accomplished by increasing the recycle rate from the bioreactor back to the anoxic tank. However, too much recycle could add too much dissolved oxygen into the anoxic tank and prevent further denitrification. Therefore, it would be beneficial to monitor this recycled stream with a dissolved oxygen probe. It would also be helpful for the Park managers to be able to determine the amount of sludge to remove or waste, and how often to do this.

5.2.4 Natural Disinfectants

A final option for managing the high influent TKN would be to use an alternative disinfectant method in the Sherman Adams building kitchen. The current disinfectant that is being used to clean the dishes in the summer months contains nitrogen, which adds to the influent levels, and the product contains quaternary ammonia, which is toxic to the microorganisms in the treatment process. According to the Food Safety Division of the New Hampshire Department of Health and Human Services there are several acceptable alternatives to the current disinfectant. These include chlorine at 50 – 100 parts per million (ppm), or iodine at 12.5 – 25 ppm (New Hampshire Department of Health and Human Services 2010). These alternatives would decrease the influent nitrogen content because they do not contain nitrogen. However, these practices would still kill the microorganisms in the plant that are needed for the denitrification process. An alternative method of disinfecting is storing the dishes and utensils in heated drawers at 160° F for 15 seconds, or 140° F for 10 minutes to disinfect. Boiling utensils and dishware would also safely disinfect and would produce no nitrogen.

5.3 Treatment Plant Alternatives

If resources allowed, the State Park could purchase an entirely new package treatment plant to replace the Lifewater plant. This option would be more costly for the Park than the modifications and recommendations detailed in Section 5.2 due to the remote location of the site, the limited access of the Auto Road, and the difficult weather. According to Mr. Chase, a project manager at the Bureau of Public Works and Construction, work and materials for a construction project on the summit can cost up to five times more than a project elsewhere (Chase 2010). Bids from the previous treatment plant project ranged from $497,400 to $1,055,000, which included the package plant and construction costs (Chase 2010). It is suggested that further treatment plants be researched only if the minor modifications recommended in Section 5.2 have been made to the current plant accompanied by well-documented data and observations, but the results show that there are no improvements in effluent characteristics (Chase 2010)(Chase 2010).

5.3.1 SaniBrane

SaniBrane was one of the companies considered in 2008 when the wastewater treatment plant project was up for bid. The SaniBrane® Membrane Bioreactor was developed by Sanitherm, Inc. and the company has successfully installed over 300 plants. According to the website, the treatment systems have been successful in "remote, hostile and unforgiving sites" all over North America (Sanibrane 2009). The company is based in Canada but there are representatives in both the United States and Canada.

The company has a container treatment system that was previously researched for Mount Washington. The container system is a compact and self-contained treatment system. It can be set up and operating within a few hours of installation, and no building is required. According to Sanibrane, the system is very low maintenance and in most cases produces an effluent that is of better quality than the regulated effluent values. The size options for containers include 4,000, 8,000, 12,000, and 16,000 gallons per day. The container size that would be most appropriate for the summit's flow of about 6,000 gallons a day in the summer would be the company's 8,000 gallon per day tank (30 m^3/d), which is a 48-foot long container. The container system comes with flow equalization, treatment tanks, heat, lights, and controls. There are also other options available depending on the mountain's requirements. The approximate cost of this system, based on the prices from 2008, is $495,000 - $545,000 and this cost does not include costs associated with transporting the plant and installing it (Sanibrane 2009).

5.3.2 Enviroquip

Enviroquip, located in Austin TX, was another company that was considered in 2008 for the summit. The MPAC System is a pre-engineered Enviroquip® membrane bioreactor system. The approximate cost of the plant, not including transportation and installation costs in 2008 was between $495,000 and $545,000. According to the company website, the plant is easy to operate and maintain and it provides reliable treatment. The plant uses Kubota® membrane products which have been used in over 2,500 installations around the world. Remote control capabilities for monitoring and optimization are also available. The MPAC model comes with fine screening, an anoxic zone, a pre-aeration zone, a MBR zone, equipment skid, control panels, aeration systems, and recycle and permeate pump systems. The company also provides after sale support by staying in contact with operators, and providing ongoing technical training through workshops and site visits (Enviroquip 2009).Table 32 shows the treatment's achievable values according to the website. These values are below those of the current NH groundwater discharge permit for the Park.

Table 32: Enviroquip MPAC Treated Effluent Quality (Enviroquip 2009)

Parameters	Achievable Values
BOD_5	Not Detectable
Total Nitrogen	< 3.0 mg/L
Ammonia	< 0.3 mg/L
Phosphorus	< 0.03 mg/L
Fecal Coliforms	Not Detectable
Total Suspended Solids	Not Detectable

5.3.3 Seapoint

Seapoint, located in Boxford, MA, produces pre-engineered, wastewater treatment package plants for municipal, commercial, government, marine and military use. The Seapoint Container Unit (C-Series) is a self-contained treatment system that produces effluent that is high quality and reusable. The sizes of the treatment system range from 5,000 to 30,000 gallons per day, so the Park could purchase a plant of a similar size to the current Lifewater plant. The plant is a membrane bioreactor with ultraviolet disinfection, a PLC control system, insulation, duplexed plumps and blowers. Similar to the current plant, the Seapoint workspace in the container can be heated. According to the Seapoint website, the plant can achieve the limits listed in Table 33, which are below the NH groundwater discharge permit for the Park (Seapoint 2010).The cost of this treatment plant would be $25-$30 per gallon for a small 6,000 gallon tank with an additional 0.50 cents per gallon for heating in a cold climate. That would make the total price of the plant in the range of $153,000-$183,000 (Personal Communication, Seapoint 2011). Table 33 shows the treatment's achievable values according to the website.

Table 33: Seapoint Treated Effluent Quality (Seapoint 2010)

Parameter	Achievable Value
BOD_5	≤ 5 mg/L
Total Suspended Solids	≤ 5 mg/L
Total Nitrogen	≤ 10 mg/L
Fecal Coliform	Not Detectable

5.4 Evaluation of Wastewater Alternatives

The proposed options for improving the wastewater system for the Park were evaluated based on their ability to meet the evaluation criteria established in section 3.3.4. These criteria were the ability to improve effluent characteristics, cost, and manageability for the Park managers, as well as the ability for the option to be transported to the summit. The criteria were ranked on a scale from 1 to 3, with 3 being comparatively a better option and 1 being a lesser option. Thus, the highest attainable score was 12. The matrix can be seen in Table 34.

Table 34: Evaluation Matrix for Wastewater Alternatives

Recommendations	Effluent Characteristics	Cost	Manageability	Transportation	Totals
Dilution	2	3	2	3	10
Alternative Configuration	3	2	1	2	8
Improved Monitoring	3	3	3	3	12
Alternative Disinfectants	2	3	3	3	11
Sanibrane Plant	3	1	2	1	7
Enviroquip Plant	3	1	2	1	7
Seapoint Plant	3	1	2	1	7

According to the evaluation matrix criteria, improved monitoring is highly recommended for the State Park with an overall score of 12. Better monitoring would provide more accurate operational and effluent readings, providing the Park managers and the DES with a better understanding of how to meet the discharge permit and if there are further steps that need to be taken to reduce the effluent more. The cost of this recommendation is very low in comparison to some of the other recommendations. Improved monitoring would make managing the plant easier and less time consuming for the Park managers. More monitoring equipment could be easily brought up the mountain Auto Road. Additionally, if more monitoring was used in conjunction with using alternative disinfectants in the Sherman Adams food service kitchen, this would be a minimal cost solution until further analysis could be done on more data.

If monitoring was improved and an alternative disinfectant was also used, but no significant changes to the effluent quality were noticed, then the Park should possibly consider an alternative configuration. A different configuration, like the Bardenpho, would be more costly than the solutions described above, but it would be less costly than purchasing an entirely new treatment plant. The purchase of a new plant is not recommended unless improved monitoring, accurate testing, and less costly modifications are done and there is no significant change to the discharge quality or manageability of the current plant.

6 Conclusions and Recommendations

Two separate structural designs for the environmental research facility were completed using reinforced concrete and structural steel. The structural steel design was chosen as the recommended design for its constructability characteristics. Buildable days on the summit of Mt. Washington are limited to approximate 60 days a year so rapid construction is necessary. A structural steel frame is the easiest to construct in these conditions. With the steel design, interior footings will be used as a foundation along with the existing exterior retaining wall. In addition to the research facility, an observatory tower and garage were designed as reinforced concrete structures. It is recommended that the retaining wall be rehabilitated due to the fire damage.

Due to the lack of a reliable source of water, an INERGEN® fire protection system is recommended for the facility. The INERGEN® system uses a mixture of environmentally safe gases to extinguish a fire. Unlike water suppression, gas suppression will not damage property inside the building and the concentration of the gases is low enough that people inside the building will not be harmed during activation of the system.

The operational data from the current Lifewater treatment plant on the summit were analyzed to determine correlations among water quality parameters. Treatment alternatives were discussed to improve effluent nitrate characteristics. The most cost effective and manageable suggestion to reduce the effluent nitrate concentrations was determined to be an alternative disinfectant in the food service kitchen, increased monitoring, and more accurate testing during operation of the plant.

The total cost analysis for each recommendation is shown in Table 35. The total cost is $3,115,000. This is approximately $7 million under the estimated $10 million budget proposed by the State Park. The cost of the building includes the cost of the reinforced concrete tower and garage.

Table 35: Total Cost Analysis

Component	Recommended Alternatives	Cost
Building	Structural Steel Frame	$2,630,000
Fire Protection System	INERGEN®	$ 485,000
Wastewater Treatment	Monitoring and Disinfectant Change	Negligible
Total		$3,115,000

The following suggestions include future studies, related to this project, which would be beneficial to the State Park. Due to the fire damage, the foundation may not be structurally safe to use for the designed building. A study should be conducted on the feasibility of reusing the existing foundation. An analysis of the impact loads on the summit structures could be completed to determine the exact increase in loads on the structural frame. Other alternatives such as foaming extinguishing agents could be researched for fire protection.

Research on the effects of quatinary ammonia on the wastewater treatment process would help determine if the disinfectant used in the kitchen facilities in the Sherman Adams Building is a major factor in the high nitrate levels in the effluent wastewater. Finally, the Park could conduct a study investigating the effects of the effluent discharge on the alpine research area downhill from the current location of the wastewater treatment plant.

7 References

American Concrete Institute. (2005). *Building Code Requirements for Structural Concrete and Commentary.* American Concrete Institute, Michigan.

Ansul. (2008). "Priceless Protection: Inergen Clean Agent Fire Suppression Systems.".

Ansul. (2006). "INERGEN 150-Bar Systems Design, Installation, Recharge and Maintenance Manual." .

Breyer, D. E., Fridley, K. J., Cobeen, K. E., and Pollock, D. G. (2007). *Design of Wood Structures.* MaGraw-Hill Companies, Inc., New York.

Chase, J. (2010). Department of Administrative Services, Bureau of Public Works Design & Construction: Electronic Correspondence Regarding WWTP. Personal Communication.

Cheshire County DX ARC. (2003). "Fire on Mt. Washington: "The Rock Pile" goes dark." http://www.ccdx.org/scrapbook/MtWash/MTW.htm (accessed September 29, 2010).

Cogent Solutions. "Detergent Enzymes: How safe are they?" http://www.ecogent.ca/enviro/env_enzyme.htm (12/13, 2010).

Court, A., and Gerston, R. D. (1966). "Fog Frequency in the United States." *Geogr.Rev.,* 56(4), pp. 543-550.

Craftsman Book Company. (2008). *2009 National Construction Estimator.* Craftsman Book Company, California.

J. W. Creasy, and Fitzgerald, J. P. (1999). "Bedrock Geology of the Eastern White Mountain Batholith, North Conway, New Hampshire." Available online at: http://abacus.bates.edu/acad/depts/geology/jcreasy.WM.html .

Edwards, R. (2011). Eastern Regional Manager, Marioff Inc., Shrewsbury, MA. Personal Communication.

EIMCO Water Technologies. (2010). "Bardenpho Process." http://www.itepro.cl/ (2/14, 2011).

Emberley, R. H. (2010). Wastewater treatment operator, Water System Operators Inc., Henniker, NH. Personal Communication (8/10 - 12/10).

Enviroquip. (2009). "Enviroquip." http://enviroquip.com/ (2/14, 2011).

Federal Aviation Administration. (1975). "Structural Icing." Federal Aviation Administration, Washington, DC.

Fowler, B. K. (2010). Electronic Correspondence Regarding Bedrock at Summit of Mount Washington. Personal Communication.

Holmes, D. (2010). Mount Washington State Park Manager II. Personal Communication: Interview at the Summit of Mount Washington 9/18/10.

International Code Council Inc. (2009). *International Building Code.* International Code Council, Inc, Illinois.

Kessler, K. (2010). NH Department of Environmental Services: Electronic Correspondence Regarding WWTP. Personal Communication (September - December).

Lifewater Engineering. (2009). "Extreme STP Sewage Treatment Plant Operation & Maintenance Manual." Revision 2.0.

Lifewater Engineering. (2005). "ExtremeSTP Cold Climate Sewage Treatment Plants from Internet Archive Wayback Machine." http://web.archive.org/web/20080528045405/http://lifewaterengineering.com/Overview.htm (12/13, 2010).

MacGregor, J. G., and Wight, J. K. (2005). *Reinforced Concrete Design: Mechanics and Design.* Pearson Education, Inc, New Jersey.

Marioff Inc. (2011). "What is HI-FOG?" http://www.marioff.com/hi-fog/en_GB/what_is/ (February 11, 2011).

McCormac, J. C. (2008). "Computing Combined Loads with LRFD Expressions." *Structural Steel Design,* Pearson Education, Upper Saddle River, NJ, .

Mount Washington Observatory. (2010a). "History of Mount Washington." http://www.mountwashington.org/about/visitor/history/ (accessed September 17, 2010).

Mount Washington Observatory. (2010b). "Mount Washington Observatory." http://www.mountwashington.org/ (accessed September 17, 2010).

Mount Washington Observatory. (2010c). "Normals, Means and Extremes." http://www.mountwashington.org/weather/normals.php (accessed September 12, 2010).

National Fire Protection Agency. (2009). *NFPA 1: Fire Code 2009.* National Fire Protection Agency, Massachusetts.

New Hampshire Department of Health and Human Services. (2010). "Division of Public Health Services." http://www.dhhs.nh.gov/dphs/index.htm .

NH DES. (2009). "NH Department of Environmental Services Groundwater Discharge Permit; NO. GWP-19907077-S-003.".

NH DES. (2006). "Environmental Fact Sheet: Administrative Fines of the Department of Environmental Services." http://des.nh.gov/organization/commissioner/pip/factsheets/co/documents/co-2.pdf (12/6, 2010).

NH DES. "Wastewater Operations Certification, Training, and Technical Assistance." http://des.nh.gov/organization/divisions/water/wweb/opcert.htm (12/9, 2010).

Pelchat, M. (2010). Mount Washington State Park Manager I. Personal Communication: Interview at the Summit of Mount Washington 9/18/10.

Pelletier, S. M. (2011). " Engineered Systems Manager, Tyco Fire Suppression and Building Products , North Smithfield, RI . Personal Communication (Jan/11- Feb/11) " .

Portland Cement Association. (2010). "Cement and Concrete Basics." http://www.cement.org/basics/concretebasics_faqs.as (accessed September 15, 2010).

Prescott, S. (2010). Department of Resources and Economic Development, Office of the Commissioner Design Development and Maintenance Section. Personal Communication.

Reed Construction. (2010). "New Hampshire Building Codes." www.reedconstructiondata.com/building-codes/new-hampshire (accessed May 16, 2010).

RSMeans. (2007). *2008 Square Foot Costs.* Reed Construction Data, Inc., Massachusetts.

Sanibrane. (2009). "Sanibrane." http://www.sanibrane.com/wastewater-treatment/container-systems.aspx (2/14, 2011).

Seapoint. (2011). Seapoint: Phone Correspondence Regarding WWTP Costs. Personal Communication.

Seapoint. (2010). "Seapoint: Pre-engineered, Wastewater Treatment Package Plants." http://www.seapointinc.com (2/14, 2011).

Stantec. (2008). "Wastewater Treatment Plant Membrane Bioreactor for the Summit of Mt. Washington, NH: Advanced Design Engineering Report.".

State of New Hampshire. (2002). "Title XII: Public Safety and Welfare Chapter 155-A: New Hampshire Building Code." 155-A:1-155-A:12.

Steel Building Guide. (2007). "A Discussion of Snow and Rain Loads on Steel Buildings." Available online at: http://www.steelbuildingguide.com/Rain_Snow_Loads.htm .

The State of New Hampshire Department of Environmental Services. (2009). "Groundwater Discharge Permit." GWP-199007007-S-003.

Tobiasson, W., Buska, J., Greatorex, A., Tirey, J., Fisher, J., and Johnson, S. (2002). "Ground Snow Loads for New Hampshire." *Rep. No. ERDC/CRREL TR-02-6,* US Army Corps of Engineers, Virginia.

U.S. Architectural and Transportation Barriers Compliance Board. (1991). "Accessibility Requirements." http://www.access-board.gov/publications/adafactsheet/a13.html (accessed Oct 6, 2010).

Uggerholt, C. (2010). Mount Washington State Park Staff. Personal Communication: Interview at the Summit of Mount Washington 9/18/10.

United States Geological Survey. (2010). "U.S. Seismic "Designmaps" Web Application." https://geohazards.usgs.gov/secure/designmaps/us/application.php (November 13, 2010).

A. van Haandel, and van der Lubbe, J. (2007). "Wastewater Handbook: Nitrogen Removal." http://www.wastewaterhandbook.com/webpg/th_nitrogen_40intro.htm (01/22, 2011).

Wang, C., Salmon, C. G., and Pincheira, J. A. (2007). *Reinforced Concrete Design.* John Wiley & Sons, Inc, New Jersey.

Yacubowicz, H., and Naworski, S. (2005). "Sequence of Operations.".

Appendices

Appendix A: Proposal

Project Number: LDA-1106

JYP-1001

Summit Research Facility

A Major Qualifying Project Proposal

submitted to the Faculty

of

WORCESTER POLYTECHNIC INSTITUTE

in partial fulfillment of the requirements for the

Degree of Bachelor of Science

By

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Lillian Clark

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Richard Emberley

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Joseph Vanni

Date: October 14, 2010

Approved:

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Professor Leonard Albano, Advisor

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Professor Jeanine Plummer, Advisor

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1 Problem Statement

Mount Washington's summit is a popular attraction for hikers and tourists as well as a location for valuable research on the mountain's unique conditions and environment. Extreme weather conditions cause a large amount of tourists to visit in the summer and close to none in the winter. Providing a wastewater treatment system to accommodate these flow variations while meeting discharge requirements in the cold weather is a constant challenge for park staff. In addition, a new building to pursue the ongoing research on the mountain is needed. A building on the summit must be able to withstand the loads such as precipitation and wind. Consideration for the building's fire protection is also important due to no access for fire trucks on the Auto Road.

2 Objective

The purpose of this project is to design a two-story research facility to be constructed at the summit of Mount Washington as well as to design a working wastewater treatment plant, also to be housed on the mountain's summit. A variety of structural building materials will be considered to combat the unique weather conditions of the summit, as well as the overall constructability of each design. The wastewater treatment plant's design will also consider the summit's unique weather, as well as large seasonal changes in flow. The project will make recommendations for the final design and construction of each design based upon economic feasibility, constructability and maintenance.

3 Scope of Work

This project is split up into two distinct sections: the building and the wastewater treatment plant. The building design will include the structural design of the beams, girders, floors, columns, and foundation. A sprinkler system design will also be included in the building design. Analysis of various package wastewater treatment plants will incorporate the wastewater treatment plant section. Both sections will be included within a cost analysis section. Each group member will contribute to each section of this project.

4 Background

The location of the "World's Worst Weather" is on the summit of Mt. Washington in northern New Hampshire. With yearly snow accumulations over 300 inches and wind gust speeds over 200 mph along with the elevation and remoteness of the summit, the design of any facility on Mt. Washington needs to account for the unique features of the summit. The specific needs of the state park must be addressed in the building design in addition to the weather. This chapter will discuss the history and needs of the State Park, as well as the design constraints for the proposed new research facility and wastewater treatment plant.

4.1 Mount Washington State Park

Mount Washington is located in northern NH about 90 miles northwest of Portland, Maine, 180 miles north of Boston and 210 miles southwest of Montreal (see Figure 1). The mountain is part of the Presidential Range, which forms a ridgeline about 12 miles long and includes the highest peak in the Northeast at 6,288 ft. It is the highest point in the United States east of the Mississippi River and north of the Carolinas with the only peak in the Northeast that exceeds 6,000 ft (Mount Washington Observatory 2010b).

Figure 1: Mount Washington (Mount Washington Observatory 2010b)

As part of the Appalachian Trail, the mountain brings many hikers, some long distance, to enjoy the views the summit has to offer of the surrounding White Mountains, and of peaks in Maine, Vermont, Quebec, and even New York on a day with ideal conditions. The summit can also be reached by visitors by the Cog Railway, which is about 3 miles long, or via the 8 mile trip up the Auto Road (see Figure 2). On the top of the mountain there is the Sherman Adams Summit Building, the Tip Top house, the Yankee Building, the WMTW-TV Station and towers, and the Stage Office, as shown in Figure 3 (Mount Washington Observatory 2010b).

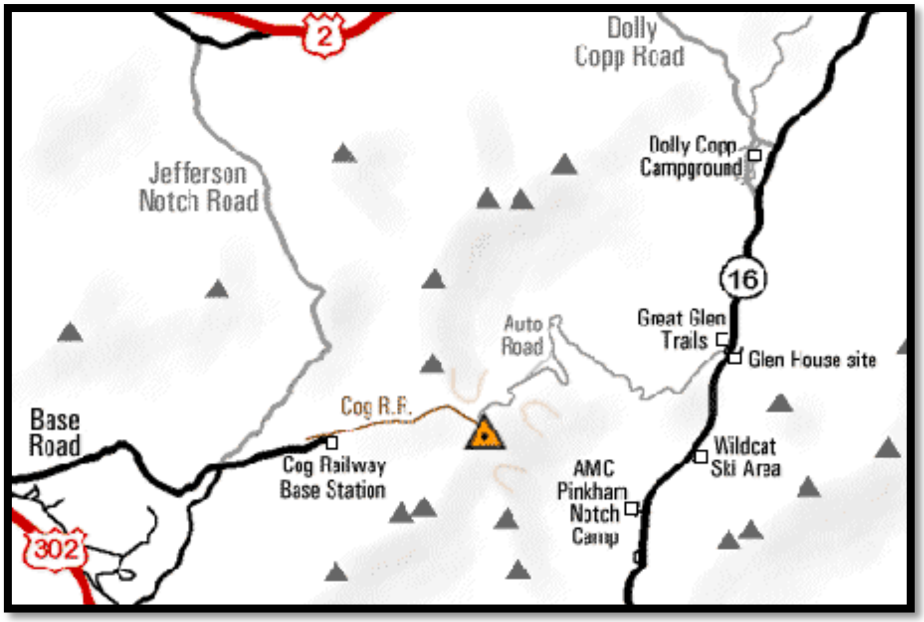

Figure 2: Map of Mount Washington (Mount Washington Observatory 2010b)

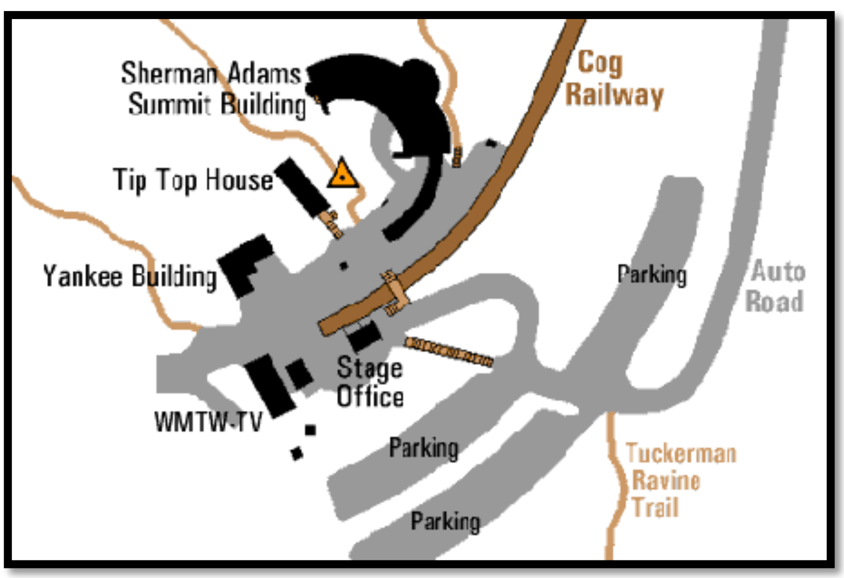

Figure 3: Map of Summit (Mount Washington Observatory 2010b)

4.1.1 <u>History of the Park</u>

Mount Washington has attracted many visitors since the first summit house was built in 1852. Soon after this house was built, the Carriage Road and the Cog Railway were constructed on opposite sides of the mountain to allow more visitors of all ages and abilities to reach the summit. With more visitors came more buildings, but not without the challenges due to the unique location and the weather conditions at the summit. For example, all of the buildings, besides the Tip Top House, burned in a fire in 1908 due to the lack of available water for fire fighting. The Mount Washington Observatory, originally housed in the Stage Office and now in the Sherman Adams Building, was established in 1932 and has since kept a daily record of the weather.

On February 9, 2003, a fire broke out in a former WMTW television building. The building at the time of the fire also housed the WHOM radio station transmitters and other broadcasting equipment. The fire started in the WMTW building and then spread to the Yankee power building next to it. Both buildings were completely destroyed in the blaze (see Figure 4). Since the fire destroyed the electricity generator in the building, the electricity was cut off for the entire summit and every person had to be evacuated (Cheshire County DX ARC 2003).

Figure 4: WMTW Building After Fire (Cheshire County DX ARC 2003)

The summit sees about 300,000 people each summer. During the harsh winters, the number of visitors to the mountain are close to none, besides the park rangers who maintain the buildings and the wastewater treatment plant (Mount Washington Observatory 2010b).

4.1.2 Existing Buildings

Currently, there are four working buildings on the summit of Mount Washington, as shown in Figure 3. The Sherman Adams Summit Building was built in 1979 to replace the previous summit building (Mount Washington Observatory 2010a). It is made of concrete and serves as the mountain's main visitor center. The building includes many amenities for visitors including an observation tower, restroom facilities, a post office, a food court, water fountains, and a museum. The Sherman Adams Building also houses the Mount Washington Observatory and the living quarters of its crew (Mount Washington Observatory 2010a).

The Tip Top house was constructed in 1853 when it served as a hotel. Today, the stone building is the oldest building on the summit, and it was the only building that survived the 1908 fire. Recently renovated, the 2,350 square foot structure is open to the public where it serves as a reminder of the observatory's past (Mount Washington Observatory 2010a).

The current Stage Office was built in 1976 to replace its predecessor. The original Stage Office, which recorded the record wind speed of 231 miles per hour in 1934, served as the original home of the Mount Washington Observatory (Mount Washington Observatory 2010a). The current building was made as a likeness of its predecessor. It is owned and operated by the Mount Washington Auto Road, and is equipped with chains that help hold its roof in place during the intense storms that frequently hit the summit. The interior of the building houses restrooms and a gift shop for tourists.

The summit also has numerous broadcasting towers that serve several state and federal agencies, as well as two FM radio stations, WHOM and WPKQ. The Yankee Building houses the majority of the broadcast equipment (Mount Washington Observatory 2010a). One of the other broadcast buildings, the WMTW-TV building, burnt down in the fire of 2003. Previously, it held the station's equipment, electrical generators and living quarters for WMTW staff.

4.1.3 Existing Wastewater Treatment Plant

The wastewater treatment plant for the mountain is located about 300 feet below the summit Sherman Adam's Visitor Center. During the tourist season of the summer, approximately 300,000 visitors come to this building, and this generates over 500,000 gallons of wastewater a year. Seasonal visitation trends have a large impact on wastewater flows. On a busy summer day, the average flow of wastewater is about 5,000 gallons. On a typical winter day, the only wastewater generated is from the few staff members on the mountain.

Prior to the 1940's, wastewater was disposed of via a pipe on the east side of the mountain. In the 1940's, an icing research laboratory was established on the mountain. During this time, waste from the mountain was put into a containment system consisting of wells and holding tanks that were periodically emptied by a tanker truck. Several decades later there was a need to improve this system because of increased numbers of tourists and waste. The New Hampshire Bureau of Public Works along with input from the New Hampshire Department of

Environmental Services (DES) selected a package wastewater treatment plant from the company LIFEWATER Engineering, in Fairbanks, Alaska. This company was chosen based on the company's experience with extremely cold climates. The system is called the Extreme Sewage Treatment Plant, or ESTP (Personal Communication, Pelchat 2009).

In the system designed for Mount Washington, the sewage flows from the Sherman Adams Building through heated pipes to the package treatment plant. The process begins with screening which removes the larger particles. This screened wastewater is then pumped to an anoxic tank to allow for denitrification. The anoxic tank has a mixer and a sensor, which measures the dissolved oxygen. In order to keep the dissolved oxygen concentration low, a carbon source called microCg is added. Microbial degradation of the microCg consumes oxygen and the microCg also provides a carbon source and electron donor for denitrifying the bacteria (Personal Communication, Pelchat 2009).

After the anoxic tank, the wastewater is treated aerobically with an active sludge process in a bioreactor tank. The detention time in this tank is about 15 hours and there are sensors that monitor the dissolved oxygen, total suspended solids, and pH. The mixed liquor is then pumped through four tubular membrane filters in series. When about 600 gallons of treated water accumulates in the storage tanks at the end of the filters, the effluent is discharged in batches through a UV disinfection system and then onto the ground near the plant. Heated and insulated pipes make it possible to discharge the water in the winter. The excess sludge is either put into underground holding tanks to be removed by a truck or in a sludge bag. In addition, recirculation of some of the tanks in the treatment process is done in order to accommodate the large fluctuations in flow during the season and between seasons (Personal Communication, Pelchat 2009).

4.1.3.1 Current Treatment Challenges

There are many challenges to treating wastewater at the summit. First, the plant experiences significant daily and seasonal variations in the flow of the wastewater due to visitation trends. The majority of visitors come to the summit in the summer months and there are barely any in the winter. In addition, during the summer months, a clear and relatively warm day will bring more visitors than a foggy and cold day. This poses a challenge for the living organisms in the treatment system because of changes in flow and organic matter concentrations.

The operation of the plant for 365 days a year is the responsibility of the four staff members on the summit, who must also manage the many other maintenance aspects on the top of the mountain. Maintenance is especially difficult in the winter months because the extremely strong winds and cold temperatures make the plant difficult to access. Much of the current maintenance involves filters clogging and failing pumps. According to Diane Holmes (2010), a park staff member, the filters need a lot of maintenance and must routinely be taken out and cleaned. If one of the pumps fails, there is no secondary pump that can be turned on and treatment must temporarily stop. If maintenance needs to be done, there is no fresh water available at the treatment system to clean the system or for the staff to clean up afterwards (Personal Communication, Holmes 2010).

The treatment plant is located about 300 ft away from the laboratory on the summit. Collecting samples is dangerous during the stormy weather that occurs throughout the fall, winter, and spring months. Once samples are collected, they must be brought back up to the small make-shift laboratory in the Yankee Building. Effluent must be tested to make sure it is meeting discharge requirements from the Department of Environmental Protection. The current treatment plant is often finding it difficult to meet these requirements. When the effluent concentrations exceed the limits, they can have an impact on the alpine research area located below the treatment plant (Personal Communication, Holmes 2010).

4.1.4 Needs of the Park

The State Park on the summit of Mount Washington is in need of a building to replace the old WMTM TV-8 building that was destroyed by fire. The new building would serve as an environmental research facility for the state park and would need to fit the footprint of the previous building.

The park has several requirements for this new building. A garage or airlock large enough for a snow cat to fit in will need to be linked to the new facility to allow for safe debarkation in the winter months. A kitchen, bathrooms, storage facilities and sleeping areas are required. Other areas within the building could include a lounge and study areas, as well as a conference room. Diane Holmes stated that mentioned the need for the wastewater treatment laboratory should be located inside of this new building because the current laboratory is located in the Sherman Adams building, which is too far from the current treatment plant. Due to problems with the treatment system in place on the summit, the staff has requested a new treatment facility to replace the old system and for it to be adjacent to or in the floor plan of this new building. The new facility should be simple to maintain for the park staff while also reducing their effluent concentrations to the acceptable limits as stated in the New Hampshire discharge permit. The treatment facility must also be able to operate under the extreme conditions on the summit. (Personal Communication, Holmes 2010)

The building's roof should have space for radio and observatory equipment as well as an area for visitors to enjoy the views of the southern and western portions of the mountains. A ramp should be constructed to the roof so that visitors can access the observation area without having to walk through the interior of the building.

The park is also in need of a second observation tower in addition to the existing tower on top of the Sherman Adams building. Therefore, a second tower will be erected on roof of the new building.

The fires of 1908 and 2003 are prime examples demonstrating the need for fire protection systems to be installed in the new building. Fire fighting capabilities are minimal due to the weather on the summit and the lack of personnel. In the event of fire, the state park rangers attempt to extinguish the fire. Only two fire fighter suits and breathing apparatuses are available to the crew. Fire hoses can help extinguish a fire in the Sherman Adams building but no hoses and water connections are available in the Yankee building. There is no fire truck access to the summit because it is too hazardous for a truck to drive up the Auto Road, regardless of the weather. Fire protection systems need to be installed to protect the equipment being housed in the building and the people residing in the building. (Personal Commication, Pelchat 2010)

4.2 Design Constraints

Design constraints help to focus a project. Constraints can include how much the sponsor or client is willing to spend on a new building to where the building is located and what it should look like. Other critical design constraints include building and fire codes and discharge permits.

The codes and permits are standards established by the state to protect life and the environment from harm.

4.2.1 Budget

Through communication with Diane Holmes, acting Mt. Washington State Park Manager, a budget was established for the design of the environmental research facility and wastewater treatment plant. This budget was set at ten million dollars. However, NH legislation mandated that every New Hampshire State Park must be a self-supporting entity. Mt. Washington does not receive state funding to help with repairs or for upgrades. Revenue comes from food concessions, gift shop, and donations.

4.2.2 Building Code

Building codes are regulations that ensure the safe design and construction of a building. These mandatory codes provide the absolute minimum design conditions. Because Mt. Washington is in the state of New Hampshire, the New Hampshire State Building Code governs the aspects of the design. The State of New Hampshire has adopted the International Building Code (IBC) 2009 as its current building code. The code went into effect in April 2010 (Reed Construction). Everything about a building from its design and construction to demolition and removal has to be done according to the provision of IBC 2009 (State of New Hampshire 2002). Some IBC regulations include material types, building heights and areas, and means of egress (International Code Council 2009). To incorporate realistic constraints on this project, the design of the building will be completed according to the IBC 2009.

4.2.3 Fire Protection

The State of New Hampshire adopted NFPA 1, 2009 Edition, as its state fire code. As with the building codes, the fire code went into effect in April 2010 (National Fire Protection Agency 2009). As stated in Chapter 1.2 of NFPA 1, "the purpose of this code is to prescribe minimum requirements necessary to establish a reasonable level of fire and life safety and property protection from the hazards created by fire, explosion, and dangerous conditions" (National Fire Protection Agency 2009). This statement reflects the desire of the state park to have a building with fire protection systems suitable to protection expensive equipment and lives that are housed in the building. The new building will be designed with sufficient means of fire protection using NFPA 1.

4.2.4 Accessibility Guidelines for Buildings and Facilities

The Americans with Disabilities Act (ADA) was signed into law in 1990. The ADA requires all new construction after 1993 to be designed and constructed with certain public accommodations for people with disabilities (U.S. Architectural and Transportation Barriers Compliance Board 1991). The requirements for building design are listed in the Accessibility Guidelines for Buildings and Facilities of ADA. The research facility will be designed based on these requirements.

4.2.5 Discharge Permits

The groundwater discharge permit (GWP-199007007-S-003) from the Water Division of the New Hampshire Department of Environmental Services allows for the discharge and infiltration of up to 5,000 gallons per day of tertiary treated disinfected wastewater at the summit. The Mount Washington treatment plant cannot violate the Ambient Groundwater Quality Standards adopted by the Department in the groundwater, at the boundary of the discharge zone. The discharge must also not cause any degradation to the groundwater. (The State of New Hampshire Department of Environmental Services 2009).

The treated effluent must meet the criteria in Table 1 before it is discharged. The continuous flow (gpd), ammonia, biological oxygen demand (BOD_5), total kjeldahl nitrogen (TKN), and total suspended solids (TSS) in the influent are monitored daily and weekly. Fecal coliform samples are taken weekly. If the treatment system fails to meet these limits, then the two 5,000 gallon tanks on the site can be used for sewage storage.

Table 1: Wastewater Discharge Criteria (The State of New Hampshire Department of Environmental Services 2009)

Parameter	Effluent Limit
pH	6.0 – 9.0 (average weekly)
BOD_5	≤10 mg/l (average weekly)
Nitrate	≤10 mg/l (average weekly)
TSS	≤10 mg/l (average weekly)
Fecal Coliform	Zero counts/100 ml

4.2.6 Summit Watershed

According to Seth Prescott, State of New Hampshire Department of Resources and Economic Development, the old containment system was on US Forest Service land. One of the goals for the current package treatment system was to get the system off of that land and onto the park's land (Personal Communication, Prescot 2010). Another consideration that influenced the placement of the existing plant was which watershed would receive the effluent from the plant. The alpine garden was a concern for the current plant because that area is used for research. Figure 5 is a contour map, from Stantec Consulting Services, found in the application for the discharge permit for the current treatment system (The State of New Hampshire Department of Environmental Services 2009). As seen from the contours in the figure, the effluent from the current location of the treatment system will eventually reach the sensitive alpine research area. It is important to have the new treatment plant in a location where discharge is not affecting the alpine research area.

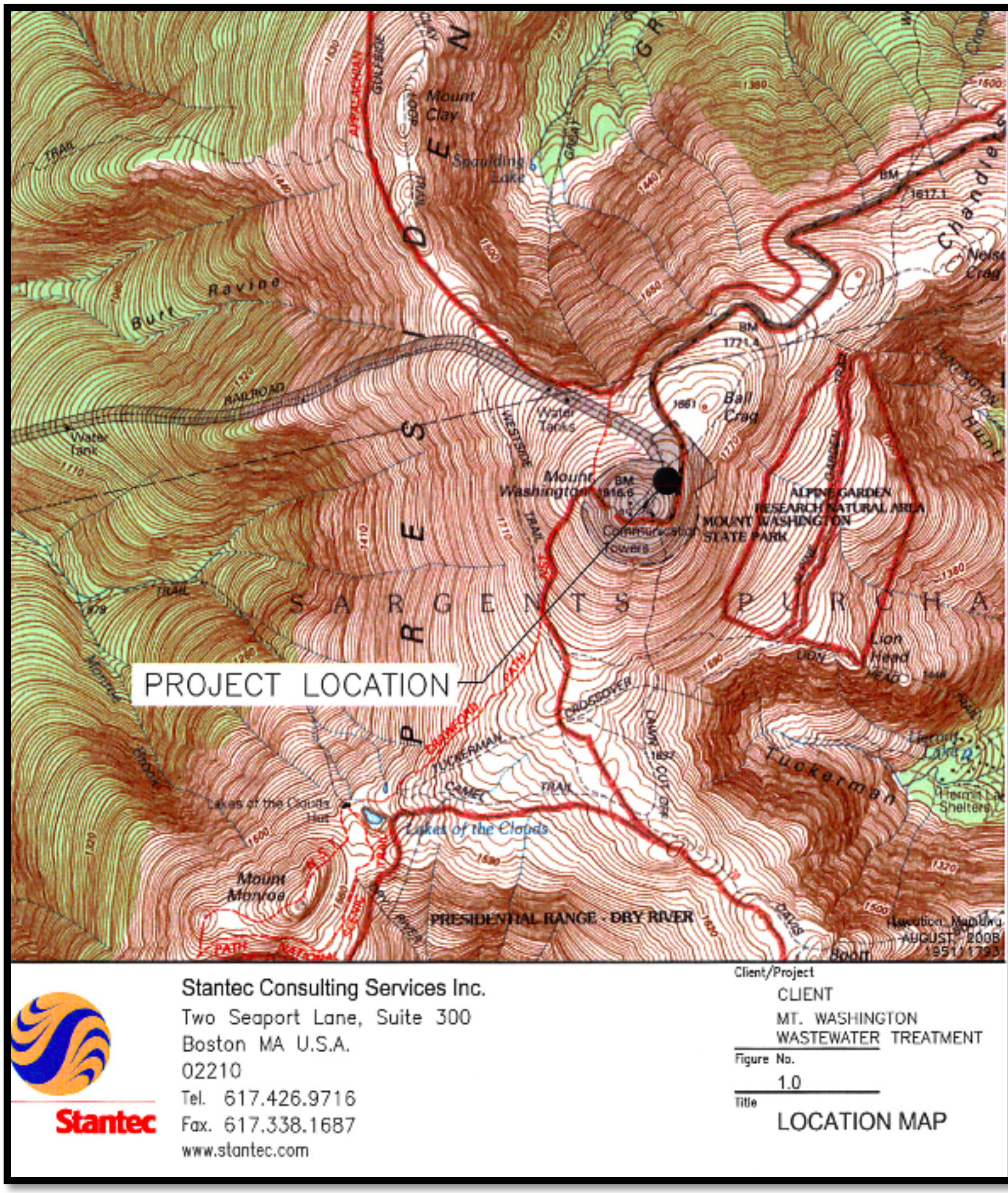

Figure 5: LifeWater Systems Treatment Location Contour Map (The State of New Hampshire Department of Environmental Services 2009)

4.2.7 Site Geology

Mount Washington, along with the other mountains in the Presidential Range, is a part of the White Mountain batholith. This large geological feature makes up most of the White Mountains in northern New Hampshire, covering over 1000 square kilometers. The structure of the basolith is made up of igneous rock, 97 percent of which is either granite, quartz syenites, or syenites. Mount Washington is located in the eastern portion of the batholith. The make-up of the rock in this area is mainly comprised of Moat volcanic rocks. These rocks include trachyte, tuff, breccias, alkali, rhyodyte and comendite, all of which are types of granite (Creasy and Fitzgerald 1999).

The geology of the summit of Mount Washington will be important to consider in the design of the research facility. More specifically, the location of bedrock will influence the design of the building's foundation. Bedrock lies at depth of three to eight feet beneath the summit area of Mount Washington. The shallowest depths are located around the actual summit and near "Goofer Point," an area on the south side of the summit overlooking the Lake of the Clouds hut. This generality was confirmed during the construction of the Sherman Adams Building during the 1970s. Isolated pockets of sandy, stony, reworked glacial till known as "diamict" can also be found at bedrock level, although these are generally rare (Fowler 2010).

4.3 Weather Challenges

One of the major challenges in designing facilities for the summit of Mt. Washington is the weather. Weather affects everything from the flows of the wastewater treatment plant to the wind, snow, and impact loads on the structures. Table 2 is a summary of the effects weather has on building design and the indoor wastewater treatment system.

Table 2: Summary of Weather Effects

Type of Weather	Effect on Building Features	Effect on Building Design	Effect on Wastewater Treatment
Temperature	Insulation Type	Material choice	Bacterial Processes
Wind	Overhangs	Increases design loads	Not Applicable
Precipitation	Roof, materials	Increases design loads	Not Applicable
Rime	Effects negligible	Increases impact loads due to falling	Not Applicable
Fog	Effects negligible	Constructability	Not Applicable
Falling Ice	Window strength	Impact loads	Not Applicable

4.3.1 Temperatures

According to the Mount Washington Observatory, the average temperatures on the summit of the mountain during the year range from 5.2 to 48.7 degrees Fahrenheit, without accounting for wind chill (see Table 3). With the wind chill, values commonly drop below -100 degrees Fahrenheit. Summers average in the mid forties, while winter temperatures are commonly in the single digits. The record low was recorded in 1934 as -47 degrees Fahrenheit. The cold temperatures are enhanced not only by the strong winds, but also by the amount of snow and fog that the mountain receives (Mount Washington Observatory 2010c).

Cold temperatures on the top of the mountain have an impact on building features as well as construction and design aspects. With the cold temperatures, it is important that the new research facility be properly insulated and designed to retain heat in the winter. During the construction phase, temperature extremes make it difficult to properly cure concrete. If the temperature is too close to freezing, then hydration of the concrete slows to nearly a standstill causing it to be weaker. Generally, the temperature should not drop below 50 degrees Fahrenheit while the concrete is curing (Portland Cement Association 2010; Uggerholt 2010)

Table 3: Temperatures (Fahrenheit) averaged over the period from 1971-2000 (Mount Washington Observatory 2010c)

Temperatures (Fahrenheit)					
	Average Daily Maximum	Average Daily Minimum	Monthly Average	Record High (Year)	Record Low (Year)
January	14.0	-3.7	5.2	47 (1995)	-47 (1934)
February	14.8	-1.7	6.6	43 (1981,1999)	-46 (1943)
March	21.3	5.9	13.6	54 (1998)	-38 (1950)
April	29.4	16.4	22.9	60 (1976)	-20 (1995)
May	41.6	29.5	35.6	66 (1977)	-2 (1966)
June	50.3	38.5	44.4	72 (2003)	8 (1945)
July	54.1	43.3	48.7	71 (1953)	24 (2001)
August	53.0	42.1	47.6	72 (1975)	20 (1986)
September	46.1	34.6	40.4	69 (1999)	9 (1992)
October	36.4	24	30.2	59 (1938)	-5 (1939)
November	27.6	13.6	20.6	52 (1982)	-20 (1958)
December	18.5	1.7	10.1	47 (2001)	-46 (1933)
YEAR	33.9	20.4	27.2	72 (1975)	-47 (1934)

As a result of the extremely cold temperatures starting in beginning of the fall season, the numbers of hikers and tourists who visit the mountain decreases significantly from the summer months. The seasonal variations in the number of visitors result in large wastewater flow fluctuations between the summer and winter months at the summit. A treatment plant on the top of the mountain must be designed to accommodate these fluctuations. The current treatment plant accommodates for these flow fluctuations by having re-circulating tanks in the system. In addition, the freezing temperatures in the winter decrease the effectiveness and efficiency of traditional biological treatment methods. Currently, the surface discharge from the treatment plant is able to melt the snow and infiltrate into the ground. The ability to have a surface discharge in the winter is necessary for this facility.

4.3.2 Wind

Mount Washington is located in the middle of converging storm tracks, mainly from the South Atlantic, the Gulf region, and the Pacific Northwest. The Presidential Range acts as a barrier to winds from the west. As a result of the temperature differences between the Northeast and the Atlantic Ocean, low-pressure systems develop along the coastline in the winter causing winds that exceed hurricane force almost one third of the days in a year. The average wind speeds on the mountain range from the mid 20's to mid 40's miles per hour. However, it is not uncommon to see peak gusts over 100 miles per hour, as shown in Table 4. Peak gusts occur from many different while the prominent wind direction is from the west (Mount Washington Observatory 2010c).

Table 4: Wind (MPH) averaged over the period from 1971-2000 (Mount Washington Observatory 2010c)

Wind (MPH)				
	Mean Speed	Predominant Direction	Peak Gust (Year)	Direction
January	46.3	W	173 (1985)	NW
February	44.5	W	166 (1972)	E
March	41.6	W	180 (1942)	W
April	36.1	W	231 (1934)	SE
May	29.7	W	164 (1945)	W
June	27.7	W	136 (1949)	NW
July	25.3	W	154 (1996)	W
August	25.1	W	142 (1954)	ENE
September	29.1	W	174 (1979)	SE
October	33.8	W	161 (1943)	W
November	39.7	W	163 (1983)	NW
December	44.8	W	178 (1980)	NW
YEAR	35.3	W	231 (1934)	SE

Extreme winds pose a significant challenge to building on the summit. Strong winds can exert significant loads on a building, and magnitudes of wind loads vary with geographical locations, heights above the ground, types of terrain surrounding the buildings, and other factors. The strong winds on Mount Washington come from many different directions, and this poses a design concern for features like the faces of the building and the roof. The final design must take into consideration strong winds from all directions and not just the predominant west. Extreme winds of hurricane force are capable of taking a roof off of a building. Wind forces also act as pressures on vertical surfaces facing the wind, and pressures or suction on sloping surfaces facing the wind. Suction occurs on flat, vertical, and sloping surfaces facing away from the wind. Various loads and combinations of loads could occur on the building. The largest wind load and effect that is predicted to occur in the worst case will be used for analysis and design (McCormac 2008).

4.3.3 Precipitation

The summit of Mount Washington experiences various types of precipitation throughout the year. As seen in Table 5, the summit has a yearly average of 101.9 inches of total precipitation, with a high of 130.1 inches in 1969. As shown in Table 5, in the winter the summit averages between 48 and 55 inches of snow or ice per month, with a high of 172.8 inches in a month. The record for snowfall in a twenty-four hour period is 49.3 inches with most other all time twenty-four hour totals between 22 and 27 inches (Mount Washington Observatory 2010c).

Table 5: Precipitation (water equivalent, inches) averaged over the period from 1971-2000

(Mount Washington Observatory 2010c)

Precipitation (Water Equivalent, inches)				
	Average	Maximum Monthly (Year)	Minimum Monthly (Year)	Maximum in 24 hours (Year)
January	8.52	18.23 (1958)	1.29 (1981)	4.85 (1986)
February	7.33	25.56 (1969)	0.98 (1980)	10.30 (1970)
March	9.42	15.98 (1977)	2.15 (1946)	6.45 (1999)
April	8.43	15.21 (1988)	2.19 (1959)	8.30 (1984)
May	8.21	19.00 (1997)	1.78 (1951)	4.60 (1967)
June	8.36	16.00 (1973)	2.43 (1979)	6.50 (1973)
July	8.02	16.585 (1996)	2.69 (1995)	7.37 (1969)
August	8.08	20.69 (1991)	2.46 (1996)	6.63 (1991)
September	8.55	15.47 (1994)	2.74 (1948)	5.38 (1985)
October	7.66	28.70 (2005)	0.75 (1947)	11.07 (1996)
November	10.49	19.56 (1983)	2.31 (1939)	6.07 (1968)
December	8.84	17.95 (1973)	1.49 (1955)	8.64 (1969)
YEAR		Maximum Yearly (Year)	Minimum Yearly (Year)	
	101.91	130.14 (1969)	71.34 (1979)	11.07 (1996)

The design considerations for precipitation center on the snow and rain roof loads for the structure. Roof snow loads are influenced by the quantity of snow that falls on Mount Washington during the course of the year. In addition to this base number, roof snow loads are influenced by the pitch of the roof as well as the roof's thermal qualities and exposure to precipitation (Steel Building Guide 2007). Snow drifting and sliding will also have to be considered.

Table 6: Snow, ice pellets, hail (inches) averaged over the period from 1971-2000(Mount Washington Observatory 2010c)

Snow, Ice Pellets, Hail (inches)			
	Record Mean	Maximum Monthly (Year)	Maximum in 24 Hours (Year)
January	50.4	94.6 (1978)	24.0 (1978)
February	48.2	172.8 (1969)	49.3 (1969)
March	51.0	98.0 (1970)	27.4 (1969)
April	40.8	110.9 (1988)	27.2 (1988)
May	11.3	95.8 (1997)	22.2 (1967)
June	1.2	8.1 (1959)	5.1 (1988)
July	Trace	1.1 (1957)	1.1 (1957)
August	0.3	2.5 (1965)	2.5 (1965)
September	2.2	7.8 (1949)	7.7 (1986)
October	14.0	78.9 (2005)	25.7 (2005)
November	40.4	86.6 (1968)	25.0 (1968)
December	55.0	103.7 (1968)	37.5 (1968)
YEAR		Maximum Season Total	
	314.8	566.4 (1968-69)	

Rain loads are also important to consider in the design of a structure. Since rain does not accumulate in the same manner as snow, it is necessary to design roofs to properly drain rain water. However, the roof should be designed to withstand loads from accumulated rain in the event that these drainage methods are block or disabled. Additionally, ponding, the accumulation of water due to the deflection of roofs, should be considered in the determination of rain loads.

The most important factor in considering the effects of precipitation in a design for the summit is the combined effects of both rain and snow. Often in late winter and early spring storms, snow storms can quickly change to rain storms. Since snow has accumulated on the roof, rainwater drainage systems will not operate optimally. In addition, rain will be absorbed by the snow, saturating it with water and increasing the overall load on the roof. Finally, ponding will be one of the major problems in these mixed precipitation storms. As rain falls onto water saturated snow, it puddles. This gathering of rainwater on top of the snow will increase the overall load on the roof of the structure. This combined load of the rain and snow will increase the deflection of the roof, further contributing to the ponding effect and possibly creating serious problems for the structural integrity of the facility.

4.3.4 Rime Ice

One unique type of precipitation that occurs at the summit is known as rime ice. Rime is a type of white or milky opaque white ice that forms on the outside of both natural and manmade structures. It closely resembles frost found inside of freezers (Federal Aviation Administration 1975). Usually found in aviation, rime is very common during the colder months at the summit, growing quite thick at times. The formation of rime ice happens when super cooled water droplets strike an object at or below the freezing temperature of water. Rime is most often caused by freezing drizzle or fog. Other conditions that aide in the formation of rime include small droplet size as well as the dispersion of fusion heat from the freezing water (Federal Aviation Administration 1975). Rime is unique in that it forms winwardly (into a blowing wind) rather than leewardly. While rime ice may grow thickly on buildings, its weight is negligible, causing no structural stress (Federal Aviation Administration 1975). The formation of rime ice is inevitable in the winter on the summit, but the formation of the rime ice on building features like the walls, roof, windows, and doors, will not be a consideration for this building design. However, falling rime ice from the towers adjacent to the new building will be a consideration because these may produce significant impact loads due to the high winds.

Figure 6: Rime Ice at the Summit

4.3.5 Falling Ice

Since Mount Washington is the second highest elevation on the Eastern seaboard, it serves as a radio transmitter for numerous entities, including the Secret Service, Department of Defense, and local and regional radio stations. Several radio towers, as can be seen in Figure 7, have been constructed on the summit for the purpose of rebroadcasting the radio signals further. However, during the winter, the radio towers pose a major threat. Rime ice builds up on the radio tower and their associated support wires. Ice can accumulate over a foot thick. During the frequent strong winds, ice chunks crack and fall down to the surrounding area underneath and around the tower. When the WMTW building was original constructed, the summit workers quickly found that the building was not designed adequately enough to support the impact of the falling ice from the towers. The falling ice slammed into the building, shook the building and even caved in portion of the roof. An I-beam was placed along the ridge of the roof to prevent further structural damage.

Figure 7: Summit Radio Tower

Figure 8: Location of the Old WMTW Building and Proposed Location of the Research Facility

Since the proposed location of the environmental research facility is in the location of the old WMTW building adjacent to the two radio towers as seen in Figure 8, the impact loads from falling rime ice in strong wind will need to be taken into account to ensure the structural integrity of the building and safety of the occupants. Building features such as canopies and types of windows and doors need to be taken into account for the safety of the people around the outside of and inside the building during the winter.

4.3.6 Fog

Fog occurs often on the summit. Mount Washington currently has 303 foggy days a year, which leaves approximately 60 days for construction (Court and Gerston 1966). This poses a major obstacle during the construction phase of this project. Many aspects of construction are affected by fog. The delivery of construction materials such as concrete and steel up the Mount Washington Auto Road poses a danger in foggy condition. Not only is the road narrow but a foggy day could cause accidents from driving off the road or motorists not seeing each other in the road. The use of cranes will be limited in foggy days as communication between crane operator and workers on the ground needs to be unimpeded to ensure the right placement of beams and the safety of the workers on the ground.

4.4 Capstone Design

This project fulfills the requirements of the culmination of a major design experience. Through the demonstration of the knowledge and experience acquired in earlier course work and the incorporation of engineering standards, this project address realistic constraints and design considerations including economics, constructability, sustainability, environmentalism, ethics, health and safety, as well as social and political aspects.

4.4.1 Economic

An important consideration for this project will be the economic feasibility for the mountain. Since the costs associated with the project will only be covered by revenue from the state park, it will be important to minimize the costs for the building design and the treatment plant. A cost analysis of the designs and materials will be done to minimize these costs and to provide a feasible solution for the park.

4.4.2 Environmental

This project will address the environmental concerns raised by the park staff about the current wastewater effluent not meeting the NH discharge requirements. The project will also take the location of the discharge into consideration because of the sensitive alpine research area located downhill from the current treatment plant. In addition to the environmental concerns of the wastewater treatment, the proposed research facility will be designed to minimize the amount of excavation and altering of the historic views of the mountain.

4.4.3 Sustainability

Sustainability is a major issue for the state park. One way that this project will incorporate sustainability will be in regards to reusing the wastewater treatment plant effluent to help ease the usage of the one existing well that is on the summit. With only one clean well on the summit and with that well pumping out minimal flows, innovative ways to re-use water is needed for the new facility.

4.4.4 Constructability

The constructability of the project will address the feasibility of the design and construction of both the research facility and the wastewater treatment plant. The summit of Mount Washington presents a number of natural challenges to constructability including an extremely small construction season, cold temperatures, high winds and fog. This project will address these conditions by considering the ease of construction when choosing building materials and researching the most practical methods for construction at the mountain's summit.

4.4.5 Ethical

Ethics and ethical discussions are a part of every design process. This project will be completed to the high standard of ethical integrity that WPI requires of its students. Ethical decisions will need to be made concerning what is in the best interest of the state park, environment on the summit, and the surrounding towns.

4.4.6 Health and Safety

In order to address health and safety considerations, a structural analysis of the research facility will be performed in order to assure that the building can withstand the harsh summit conditions. Additionally, all windows, doors and walls will be designed to withstand the impact of high velocity ice projectiles. The wastewater treatment plant will be designed to ensure that all chemicals are properly stored and protected, and that all codes and discharge permits are being followed.

4.4.7 Social and Political

This project will deal with the social and political issues of constructing a building on the summit of Mt. Washington. Constraints that will need to be examined and followed are regarding the height and aesthetics of the building. The height of the design cannot be too large as the surrounding towns do not want to see a tall structure on the summit. The state park wants the building to fit the natural decorum of the summit and resemble the other buildings on the summit. This project will incorporate all these constraints into the design of the facility.

5 Methodology

This Major Qualifying Project will focus on the design of a research facility building and a recommendation for a wastewater treatment plant for the top of Mount Washington. There will also be a focus on fire protection aspects of the research facility due to the unique location of the prospective building.

5.1 Schedule

The project will take place over a period of eight months. During the first three months, the background research was completed, including a trip to the summit of Mount Washington to gain firsthand experience and insight of the site layout and park needs. The scope of the project was also determined during this time. Throughout the months of October, November, December, and January, the floor plan, structural, foundation, and fire protection designs for the research facility building will be done. Various package treatment plants will also be analyzed and compared. A cost analysis will be done on both the proposed building and treatment plant to ensure that the expenses are within the state park's budget. In C term, the group will finalize the report. A detailed timeline can be seen in Figure 9.

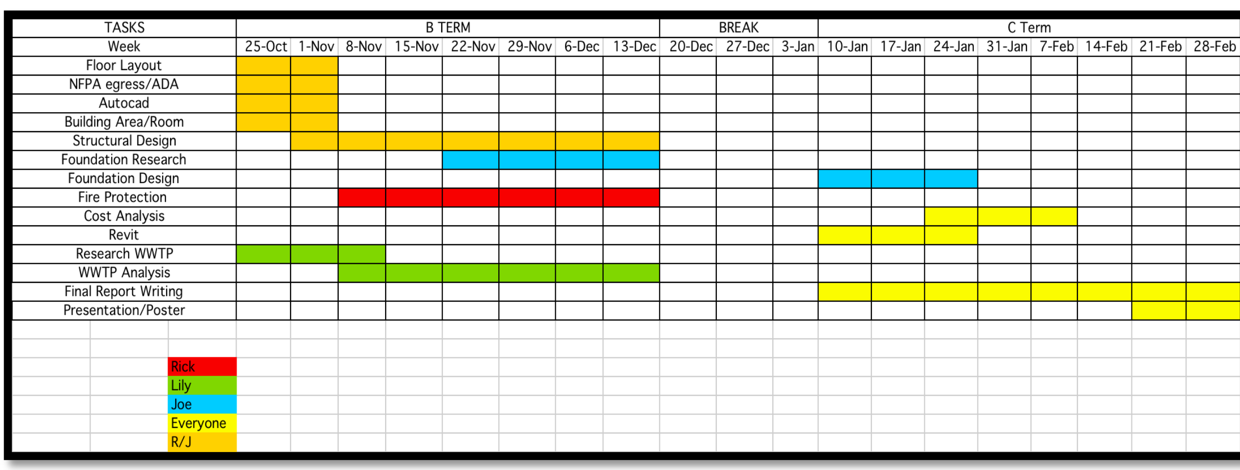

Figure 9: MQP Schedule for B and C Term

5.2 Research Facility Building Design

The design of the environmental research facility building will be done in several sections. These sections include the floor layout of each level, the structural design of beams, girders, columns and floor slabs, foundation design, and fire protection design. Once the entire facility has been designed, a 3D model of the building will be drawn up using Revit.

5.2.1 Floor Layout

The first phase in the process of designing the research facility is to develop a floor layout of the new building. The size of the building has already been determined for us by the state park manager, Mike Pelchat. He has requested the building to be designed on the same foundational footprint of the previous building. Mike has provided us with a preliminary sketch of the type of rooms and layout that he would like to see. This initial sketch will be placed into Autocad.

The design of the exact layout of the room and their dimensions based on three building codes: *NFPA 1: Fire Code, International Building Code 2009,* and the *Americans with Disablilites Act* (ADA). These codes will allow the project team to properly design the buildings layout with the proper means of egress and dimension of rooms to accommodate people with disabilities.

5.2.2 Structural Design

The main summit research facility will be designed as a two story building. However, due to recent political pressure from communities surrounding Mount Washington, the building will be designed so that one story will lie underground, leaving only a single story visible. It should be noted that at this time, coring samples do not exist, so it will be assumed that bedrock lies at sufficient depth to allow for a story below grade.

The building will be designed in accordance with the International Building Code (IBC 2009) as well as ASCE 7. The project will encompass several alternative designs. These designs are necessary to both explore the cost alternatives of the design as well as to determine the design most feasible for construction at the summit. A reinforced concrete design, as well as both composite and non-composite structural steel designs will be delivered.

5.2.3 Foundation Design

The design of a working foundation will be a part of the overall structural design delivered by the project. The principles of foundations designs will be explored through research with a goal of understanding the fundamentals of a foundation's function and design methods. Alternative design formats will be discussed. A final foundation type will be selected and designed based upon the unique needs of the facility as well as the constraints provided by the building's location.

5.2.4 Fire Protection

The project team will be designing the new building with a fire sprinkler system. This fire sprinkler system will need to be designed to extinguish the fire or suppress it long enough until the park rangers can extinguish it themselves. This sprinkler system will be designed according to *NFPA 13: Automatic Sprinkler Systems Handbook.* The layout of the building will need to be designed first in order to know the exact area the sprinkler system will need to suppress. We will also be looking into alternatives of fire suppressing agents and sprinkler systems. Research will need to be done on the available water supply at the summit and alternatives in suppressing agents of sprinkler systems for cold and extreme weather locations.

5.2.5 Revit

As a visualization aid for the state park managers, Revit will be used to create a 3D model of our building and wastewater treatment plant layout. These models can be used for future presentations that the park managers will give to show exact what the new building will look like in relation to other structures on the summit.

5.3 Wastewater Treatment Plant

Research will be done to determine the best package wastewater treatment plant option for the summit of Mount Washington. It will be important to contact those responsible for choosing the current treatment option from LIFEWATER Systems to learn of other options that were possibly considered during the process. It will also be useful to investigate different treatment options that are used on other mountains with some of the same characteristics as Mount Washington.

Various package treatment plants will be analyzed based on how effective they are at reducing effluent concentrations to meet the New Hampshire discharge permit requirements. Input from the park staff about the manageability of the plant will also be important to consider when choosing the best treatment solution for the park since the staff will be in charge of the operations of the plant once it is installed.

5.4 Cost Analysis

The costs of the research facility and the treatment plant will have to be within an estimated ten million dollar budget from the state park. Costs for the building will include those for materials, transportation of materials up to the summit, excavation, and labor. RSMeans is a publisher of reference books that contain costs of construction data. This will be used to estimate the costs of the construction of the proposed research facility. Costs for the treatment plant will be largely for the actual package plant, but there will also be some costs required to make the foundation.

5.5 Deliverables and Conclusions

Since the state park will be using this project as a base for which to start the process of design and construction of an environmental research facility, several deliverables need to be completed at the end of this project. These deliverables are as follows: a structural and foundation design; a sprinkler design layout and recommendations on the type of system; a recommendation for the best wastewater treatment option; a Revit 3D model of the facility; and an expected cost analysis of the entire design. These deliverables will make the process of constructing the building on the summit hopefully easier for the state park.

6 References

Cheshire County DX ARC. (2003). "Fire on Mt. Washington: "The Rock Pile" goes dark." http://www.ccdx.org/scrapbook/MtWash/MTW.htm (September 29, 2010).

Court, A., and Gerston, R. D. (1966). "Fog Frequency in the United States." *Geogr.Rev.,* 56(4), pp. 543-550.

J. W. Creasy, and Fitzgerald, J. P. (1999). "Bedrock Geology of the Eastern White Mountain Batholith, North Conway, New Hampshire." Available online at: http://abacus.bates.edu/acad/depts/geology/jcreasy.WM.html .

Federal Aviation Administration. (1975). "Structural Icing." *Aviation Weather for Pilots and Flight Operations Personnel,* Federal Aviation Administration, Washington, DC, .

Fowler, B. K. (2010). Electronic Correspondence Regarding Bedrock at Summit of Mount Washington. Personal Communication.

Holmes, D. (2010). Mount Washington State Park Manager II. Personal Communication: Interview at the Summit of Mount Washington 9/18/10.

International Code Council, I. (2009). *International Building Code.* International Code Council, Inc, Illinois.

McCormac, J. C. (2008). "Computing Combined Loads with LRFD Expressions." *Structural Steel Design,* Pearson Education, Upper Saddle River, NJ, .

Mount Washington Observatory. (2010a). "History of Mount Washington." http://www.mountwashington.org/about/visitor/history/ (September 17, 2010).

Mount Washington Observatory. (2010b). "Mount Washington Observatory." http://www.mountwashington.org/ .

Mount Washington Observatory. (2010c). "Normals, Means and Extremes." http://www.mountwashington.org/weather/normals.php (September 12, 2010).

National Fire Protection Agency. (2009). *NFPA 1: Fire Code 2009.* National Fire Protection Agency, Massachusetts.

Pelchat, M. (2010). Mount Washington State Park Manager I. Personal Communication: Interview at the Summit of Mount Washington 9/18/10.

Pelchat, M. (2009). "Wastewater Treatment Operations at the "Home of the World's Worst Weather", Mt Washington State Park, elev. 6,288'." *The Collector,* December.

Portland Cement Association. (2010). "Cement and Concrete Basics." http://www.cement.org/basics/concretebasics_faqs.as (September 15, 2010).

Prescot, S. (2010). Department of Resources and Economic Development, Office of the Commissioner Design Development and Maintenance Section. Personal Communication.

Reed Construction. "New Hampshire Building Codes." www.reedconstructiondata.com/building-codes/new-hampshire (May 16, 2010).

State of New Hampshire. (2002). "Title XII: Public Safety and Welfare Chapter 155-A: New Hampshire Building Code." 155-A:1-155-A:12.

Steel Building Guide. (2007). "A Discussion of Snow and Rain Loads on Steel Buildings." available online at: http://www.steelbuildingguide.com/Rain_Snow_Loads.htm .

The State of New Hampshire Department of Environmental Services. (2009). "Groundwater Discharge Permit." GWP-199007007-S-003.

U.S. Architectural and Transportation Barriers Compliance Board. (1991). "Accessibility Requirements." http://www.access-board.gov/publications/adafactsheet/a13.html (Oct/6, 2010).

Uggerholt, C. (2010). Mount Washington State Park Staff. Personal Communication: Interview at the Summit of Mount Washington 9/18/10.

Appendix B: Mt. Washington Wastewater Discharge Permit

The State of New Hampshire
Department of Environmental Services

Thomas S. Burack, Commissioner

May 6, 2009

SETH PRESCOTT
N.H. DEPARTMENT OF RESOURCES AND ECONOMIC DEVELOPMENT
DIVISION OF PARKS AND RECREATION
P.O. BOX 1856
CONCORD, NH 03302

GROUNDWATER DISCHARGE PERMIT

SUBJECT: Sargents Purchase - Mount Washington State Park, Sherman Adams Building, Summit Observatory, Groundwater Discharge Permit

Site# 199007007 / RSN# 2137 / Activity# 142777

Dear Mr. Pelchat:

Please find enclosed Groundwater Discharge Permit Number GWP-199007007-S-003, approved by the Water Division of the Department of Environmental Services (Department), for the discharge and infiltration of up to 5,000 gallons per day of tertiary treated disinfected wastewater at the subject facility.

This permit is issued with an approved waiver from installing groundwater monitoring wells and sampling from dedicated monitoring wells (Env-Wq 402.09). Due to the extreme seasonal conditions and potential environmental damage monitoring well installation would cause, the permit relies on operational sampling to verify wastewater meets ambient groundwater quality standards prior to discharge to the ground. The existing water supply well on-site is currently sampled under the public water supply rules to assure groundwater meets drinking water quality.

This permit includes the following conditions and changes relative to the treatment, sampling, and wastewater quality for discharges at the Mount Washington State Park, Summit Observatory:

- Condition # 11 identifies quality standards for wastewater discharges to the ground.
- Condition #12 identifies the operational sampling requirements for discharged wastewater. These include frequency, parameters for sampling, and sampling locations. Winter sampling shall be conducted at the same frequency to track and identify any problems with treatment system operations under adverse conditions. After the first year of operations, a review of the system operations will determine if future sampling can be modified.

- Condition # 14 requires preparations and submission of monthly operational reports (MORs) to DES's Wastewater Engineering Bureau - Operations Section. The reports will include sampling results and discharge volumes as required in the permit. (A blank MOR is attached). The reports will track and verify treatment works efficiency and compliance. Contact the Operations Section at ((603) 271-3325 with questions or for additional information.

Additionally, electronic submissions of reports and data are encouraged and accepted at the Department. To submit information electronically via e-mail, it must be formatted as outlined in the Department's Electronic Submittal Guidance found at the following link: *http://des.nh.gov/organization/divisions/waste/orcb/documents/electronic_submittal_guidelines*. Information submitted electronically to the Department that is not formatted according to the guidance must also be:

1. Faxed to this office at (603) 271-0656) or
2. Followed up by a hard copy mailed to DES (*Groundwater Permits Coordinator, 29 Hazen Dr., PO Box 95, Concord, NH 03302-0095*).

Another option is to use the Site Remediation Program Upload (SRP) method (a.k.a., OneStop Data Providers). For additional information on this upload method please contact Brett Rand at brett.rand@des.nh.gov or call (603) 271-7379.

Should you have any questions, please contact me at (603) 271-2858 or by e-mail at *mitchell.locker@des.nh.gov*

Sincerely,

Mitchell Locker, P.G.
Drinking Water & Groundwater Bureau

MDL/mdl/h:\swp\uic1\2009mdl\permits\199007007-S-003pmt Mt Wash Observatory
Enclosure
c: Rene Pelletier, Assistant Director, WD
Steve Roy, DWGB
Paul Heirtzler, Administrator, WEB
Mike Pelchat, Park manager, PO Box D, Gorham, NH 03581
Jobi Chase, NH Admin. Svcs.
Mary Ellen Parkman – Stantec
File

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

The

NEW HAMPSHIRE DEPARTMENT OF ENVIRONMENTAL SERVICES

WATER DIVISION

hereby issues this

GROUNDWATER DISCHARGE PERMIT

NO. GWP-199007007-S-003

to the permittee

NH DEPARTMENT OF RESOURCES AND ECONOMIC DEVELOPMENT

DIVISION OF PARKS AND RECREATION

for the discharge of up to 5,000 gallons per day

of tertiary treated disinfected wastewater

in SARGENTS PURCHASE, N.H.

to the groundwater via infiltration as depicted on the drawings titled

"State of New Hampshire State Park – Mount Washington

Wastewater Treatment Facility Site Plan"

prepared by

Stantec Consulting Services, Inc.

TO: N.H. DEAPRTMENT OF RESOURCES AND ECONOMIC DEVELOPMENT
DIVISION OF PARKS AND RECREATION
P.O. BOX 1856
CONCORD, NH 03302
ATTN: MR. SETH PRESCOTT

Date of Issuance: May 6, 2009
Date of Expiration: May 5, 2014

(continued)

Pursuant to authority in N.H. RSA 485-A:13, I(a), the New Hampshire Department of Environmental Services (Department), hereby grants this permit to discharge up to 5,000 gallons per day of tertiary treated disinfected wastewater to the groundwater via infiltration at the above described site, subject to the following conditions:

STANDARD DISCHARGE PERMIT CONDITIONS

1. The permittee shall not violate Ambient Groundwater Quality Standards adopted by the Department (N.H. Admin. Rules, Env-Wq 402) in the groundwater, at the boundary of the Groundwater Discharge Zone, as shown on the referenced site plan.

2. The permittee shall not cause groundwater degradation, which results in a violation of the surface water quality standards (N.H. Admin. Rules, Env-Wq 1700), in any surface water body at the boundary of the Groundwater Discharge Zone, designated as the property line, as shown on the referenced site plan.

3. The permittee shall allow an authorized member of the Department staff, or its agent, to enter the property covered by this permit for the purpose of collecting information, examining records, collecting samples, or undertaking other action associated with the permit.

4. The permittee shall apply for renewal of this permit at least 90 days prior to its expiration date. The permittee shall continue to comply with all conditions in this permit until the permit is renewed or the facility is closed in accordance with all applicable requirements, regardless of whether a renewal application is filed.

5. This permit is transferable only upon written request to, and approval of, the Department. Compliance with the existing permit shall be established prior to ownership transfer. Transfer requests shall include the name and address of the person to whom the permit transfer is requested, signature of the current permittee, and a summary of all monitoring results to date.

6. The Department reserves the right, under N.H. Admin. Rules, Env-Wq 402, to require additional hydrogeologic studies and/or remedial measures if the Department receives information indicating a need for such work.

7. All federal, state, and local permits required for this activity shall be obtained and kept current.

8. The permittee shall submit an operations manual (owners manual) to the Department for the wastewater treatment and disposal system within 180 days of the issuance of this permit.

9. The wastewater treatment facility shall be operated and maintained by qualified operators, licensed by the Department under the requirements of the N.H. Administrative Rules, Env-Ws 901.

10. Issuance of this permit is based on the Groundwater Discharge Permit application dated March 10, 2008, submitted supporting information and the information in the DES file under Site# 199007007

11. Treated effluent shall meet the following criteria prior to discharge:

Parameter	Effluent limit
pH	6.0 – 9.0 standard units
BOD_5	≤10 mg/l (average weekly)
Nitrate	≤10 mg/l (average weekly)
TSS	≤10 mg/l (average weekly)
Fecal Coliform	Zero counts/100 ml

12. The facility shall conduct operational sampling of the treatment system according to the following table to verify wastewater quality and disinfection:

Treatment works:

Monitoring Locations	Sampling Frequency	Parameters
Influent(1)	Daily Weekly	Continuous Flow (gpd), Ammonia, BOD_5, TKN, TSS
Effluent(2)	Weekly	BOD5, Nitrate, TKN, TSS, & Fecal Coliform

(1) Influent sampling shall be taken at headworks.
(2) Effluent sampling shall be taken from outfall or a sample tap located after all treatment

An annual summary of water quality data shall be submitted to the Department's Groundwater Discharge Permits Coordinator in the month of January using a format acceptable to the Department.

13. Public accessibility to the treatment works, outfall pipe, and discharge area(s) shall be restricted.

14. The permittee shall submit completed Monthly Operations Reports (MOR) to the Department's Wastewater Engineering Bureau, Operations Section.

15. If system malfunction or breakdown causes exceedances in the permit limits the permittee shall notify the Department's Groundwater Discharge Permits Coordinator within 10 days and prepare a response plan (in accordance with N.H. Administrative Rules, Env-Wq 402) within 60 days of notifying the Department to ensure that groundwater quality criteria are not violated at the boundary of the Groundwater Discharge Zone. The permittee shall implement the response plan within 30 days of Department approval.

16. The permittee shall submit as-built plans subsequent to construction completion, system improvements or expansions, or any other construction activity related to the wastewater system.

(continued)

17. The permittee shall notify the Department's Groundwater Discharge Permits Coordinator in writing of alteration to, or abandonment of the system or discharge areas.

18. The facility shall keep and maintain the two (5,000 gallon) tanks on site as identified in the permit application. The tanks will be used for sewage storage if the treatment system fails to meet the permit limits. The two 5,000 gallon tanks used for system overflow or breakdown shall be watertight.

19. Sludge and solids generated at the treatment works shall be collected and disposed of at an approved facility. No on-site discharge of sludge or solids is permitted.

Rene Pelletier, PG, Assistant Director
Water Division

Under RSA 21-0:14 and 21-0:7-IV, any person aggrieved by any terms or conditions of this permit may appeal to the Water Council in accordance with RSA 541-A and N.H. Admin. Rules, Env-WC 200. Such appeal must be made to the Council within 30 days and must be addressed to the Chairman, Water Council, 29 Hazen Drive, PO Box 95, Concord, NH 03302-0095.

Appendix C: Contact Information

Contact	Company	Job Title	City, State	Email	Phone #
Richard H. Emberley	Waster System Operators Inc.	Wastewater Treatment Operator	Henniker, NH	REmber1776@msn.com	603-899-4012
Kenneth Kessler	Department of Environmental Services	Operations, WWTF Technical Assistance, Complaint Response	Concord, NH	Kenneth.Kessler@des.nh.gov	603-271-3549
Mike Pelchat	Mount Washington State Park	State Park Manager	North Conway, NH	mike.pelchat@dred.state.nh.us	603-466-3347
Diane Holmes	Mount Washington State Park	State Park Manager	North Conway, NH	diane.holmes@dred.state.nh.us	603-466-3347
Seth Prescott	Department of Resources and Economic Development	Pubic Works Manager	Concord, NH	sprescott@dred.state.nh.us	603-271-2606
Jobie Chase	Bureau of Public Works and Construction	Project Manager	Concord, NH	jlchase@dot.state.nh.us	603-271-7934
Dennis Tupick	White Mountain Communication Corporation	Contractor	Randolph, NH	dmtupick@ne.rr.com	
Robert Tsigonis	Lifewater Engineering	President	Fairbanks, AK	bob@lifewaterengineering.com	
Steven M. Pelletier	Tyco Fire Suppression and Building Products	Engineered Systems Manager	North Smithfield, RI	stpelletier@tycoint.com	401-762-8110
Randy Edwards	Marioff Incorporated	Eastern Regional Manager	Shrewsbury, MA	randy.edwards@fs.utc.com	508-241-3116

Appendix D: New Hampshire DES Wastewater Treatment Plant Data

NH DES Wastewater Engineering Bureau - Operations Section
P.O. Box 95, 29 Hazen Drive
Concord, New Hampshire 03302-0095

Facility: Mt. Washington State Park Wastewater Disposal Facility
Permit #: GWP-199007007-S-003
Chief Operator: Mike Pelchat
Signature:
Year: 2009
Month: Nov

Date and Day of Week	R= S=	Rain or Snow (in.)	Wastewater Flow In (Gallons) INF. TOTAL	Wastewater Flow In (Gallons) EFF. TOTAL	pH INF. SU	pH EFF. SU	Total T.S.S. (1) INF. mg/L	Total T.S.S. (1) EFF. mg/L	Fecal Coliform EFF. #/100ml	BOD5 (1) INF. mg/L	BOD5 (1) EFF. mg/L	Total Nitrate as N (1) EFF. mg/L	Total Nitrite as N (1) EFF. mg/L	Total Ammonia as N (1) INF. mg/L	Total Ammonia as N (1) EFF. mg/L	TKN (1) INF. mg/L	TKN (1) EFF. mg/L	MLSS Bio-Tank mg/L	Additional Information: Record special analyses, equipment breakdowns, sludge wasting, unusual events, etc.
1 [S]																			
2 (M)			475	0															Solids Bagged = 20#
3 (T)			275	0															Clean BioReactor DO Probe w/sir surge
4 (W)			310	585															
5 [T]			160	0															Reboot 8 PM
6 (F)			1,400	610															No Internet
7 (S)				0															
8 [S]			195	0															
9 (M)			185	0															
10 (T)			170	614			340	0	0	570.0	2.9	50.00	2.60	29.0		190.0	25.0		Sample testing DES lab
11 (W)			645	610															
12 [T]				0															BioReactor pH 5.0 / hand held
13 (F)			240	0															BioReactor temp. 69 on meter 65
14 (S)																			
15 [S]			225																
16 (M)				0															
17 (T)			220	297															
18 (W)				0															Plant OFF line
19 [T]			220	0		6.8													Adjust Anoxic pump from 30 to 50 rpm
20 (F)			180	0															
21 (S)			220	0															
22 [S]			225	0															
23 (M)			100	0	8.0	6.9	400	12	0	490.0	4.4	38.00		210.0		230.0	37.0		Sample testing DES lab
24 (T)			310	1,151															
25 (W)			180	0															Dump black water
26 [T]			410	554		5.2													
27 (F)				0															
28 (S)				0															
29 [S]				450															
30 (M)				548		4.6													
(T)																			
Maximum	R=	0	1,400	**1,151**	8.0	**6.9**	400	**12**		570.0	**4.4**	**50.00**	2.60	210.0		230.0	37.0		(1) 0.0 value used in calculations when result is below
Min or (*total*)			6,345	5,419	8.0	**4.6**	340			490.0	2.9	38.00	2.60	29.0		190.0	25.0		detection limits:
Averages	S=	0	317	**201**			370	6	0	530.0	3.7	44.00	**2.60**	119.5		210.0	31.0		Detection Limits:
PERMIT MAX				**5,000**		**9.0**	**week**	**10**	**0**	**week**	**10**	**10.00**							Ammonia = 0.05 mg/L
MIN						**6.0**													BOD = 1 mg/L TKN = 0.5 mg/L
FREQ					1/discharge		1/wk	1/wk	1/wk	1/wk	1/wk	1/wk		1/wk		1/wk	1/wk		Nitrate = 0.5 mg/L TSS = 1 mg/L

NOTE: Send by 15th of following month to NH Water Supply & Pollution Control Commission

NH DES Wastewater Engineering Bureau - Operations Section
P.O. Box 95, 29 Hazen Drive
Concord, New Hampshire 03302-0095

Facility: Mt. Washington State Park Wastewater Disposal Facility
Permit #: GWP-199007007-S-003
Chief Operator: Mike Pelchat Signature:
Year: 2009 Month: Dec

Date and Day of Week	R= S=	Rain or Snow (in.)	Wastewater Flow In (Gallons) INF. TOTAL	EFF. TOTAL	pH INF. SU	pH EFF. SU	Total T.S.S. (1) INF. mg/L	EFF. mg/L	Fecal Coliform EFF. #/100ml	BOD5 (1) INF. mg/L	EFF. mg/L	Total Nitrate as N (1) EFF. mg/L	Total Nitrite as N (1) EFF. mg/L	Total Ammonia as N (1) INF. mg/L	EFF. mg/L	TKN (1) INF. mg/L	EFF. mg/L	MLSS Bio-Tank mg/L	Additional Information: Record special analyses, equipment breakdowns, sludge wasting, unusual events, etc.
1 (T)			220	0															
2 (W)			200	0															
3 [T]			200	0															
4 (F)			180	278		5.2													Cleaned membrane filters psi / 179
5 (S)			30	0															
6 [S]			330	0															
7 (M)			190	312		6.3		0	0		2.7	53.00					2.3		Sample testing DES lab
8 (T)			350	0															
9 (W)			180	0															
10 [T]			170	611															
11 (F)			250	0															
12 (S)			200	0															
13 [S]			180	0		6.6													Sugar 25 g
14 (M)			250	315															
15 (T)			200	0															
16 (W)			200	221															
17 [T]			200	92			1600	19	0	780.0	2.9	13.00		93.0		240.0	9.5		Sample testing DES lab
18 (F)			100	1,127															
19 (S)			120	0															
20 [S]			260	0															
21 (M)			140	0															
22 (T)			130	0															
23 (W)			130	0															
24 [T]			120	0															
25 (F)			200	0															
26 (S)			270	0															
27 [S]			170	293															
28 (M)			205	570															
29 (T)			155	0			920	0	2	510.0	1.2	3.60				320.0	3.4	5,100	Sample testing DES lab
30 (W)			200	0															
31 [T]			400	0															
Maximum	R=	0	400	**1,127**		**6.6**	1600	**19**	**2**	780.0	**2.9**	**53.00**		93.0		320.0	9.5	5,100	(1) 0.0 value used in calculations when result is below
Min or (*total*)			6,130	3,819		**5.2**	920			510.0	1.2	3.60		93.0		240.0	2.3	5,100	detection limits:
Averages	S=	0	198	**123**			1,260	6	1	645.0	2.3	23.20		93.0		280.0	5.1	5,100	Detection Limits:
PERMIT	MAX			**5,000**		**9.0**	**week**	**10**	**0**	**week**	**10**	**10.00**							Ammonia = 0.05 mg/L
	MIN					**6.0**													BOD = 1 mg/L TKN = 0.5 mg/L
	FREQ				1/discharge		1/wk	1/wk	1/wk	1/wk	1/wk	1/wk		1/wk		1/wk	1/wk		Nitrate = 0.5 mg/L TSS = 1 mg/L

NOTE: Send by 15th of following month to NH Water Supply & Pollution Control Commission

NH DES Wastewater Engineering Bureau - Operations Section
P.O. Box 95, 29 Hazen Drive
Concord, New Hampshire 03302-0095

Facility: Mt. Washington State Park Wastewater Disposal Facility
Permit #: GWP-199007007-S-003
Chief Operator: Mike Pelchat
Signature:
Year: 2010
Month: Jan

Date and Day of Week	R= S=	Rain or Snow (in.)	Wastewater Flow In (Gallons) INF. TOTAL	Wastewater Flow EFF. TOTAL	pH INF. SU	pH EFF. SU	Total T.S.S. (1) INF. mg/L	Total T.S.S. (1) EFF. mg/L	Fecal Coliform EFF. #/100ml	BOD5 (1) INF. mg/L	BOD5 (1) EFF. mg/L	Total Nitrate as N (1) EFF. mg/L	Total Nitrite as N (1) EFF. mg/L	Total Ammonia as N (1) INF. mg/L	Total Ammonia as N (1) EFF. mg/L	TKN (1) INF. mg/L	TKN (1) EFF. mg/L	MLSS Bio-Tank mg/L	Additional Information: Record special analyses, equipment breakdowns, sludge wasting, unusual events, etc.
1 (F)	S=	1.90	340	0															
2 (S)	S=	3.00	160	313															
3 [S]	S=	3.60	365	852															
4 (M)	S=	0.10	245	318								13.00					13.0		DES lab test results
5 (T)	S=	Tr	180	0															
6 (W)			370	318															
7 [T]			100	633															
8 (F)	S=	Tr	370	1,200															
9 (S)			300	0		7.3													nitrate reading hand held 18.0 eff
10 [S]			300	0															
11 (M)	S=	0.20	400	298															
12 (T)			400	291															
13 (W)			300	299															
14 [T]			325	575				11	2		3.3	1.20					8.9	2,800	DES lab test results
15 (F)	S=	Tr	300	0															
16 (S)			325	1,146															nitrate reading hand held 40.0 mg/L eff
17 [S]	S=	Tr	350	560															
18 (M)	S=	1.10	340	289															
19 (T)	S=	1.70	60	0															
20 (W)	S=	1.80	240	0															
21 [T]			280	292															clean sugar/water tank, moldy
22 (F)			365	288															
23 (S)			130	284															
24 [S]	S=	0.10	335	0															
25 (M)	S=	0.10	0	0															
26 (T)	S=	1.10	210	0															
27 (W)	S=	1.10	270	0															
28 [T]	S=	2.50	250	0															
29 (F)	S=	Tr	340	1,920															
30 (S)			0	0															
31 [S]	S=	0.10	0	0															
Maximum	*R=*	*0*	400	**1,920**		**7.3**		**11**	**2**		**3.3**	**13.00**					13.0	2,800	(1) 0.0 value used in calculations when result is below
Min or (*total*)			7,950	9,876		**7.3**		11	2		3.3	1.20					8.9	2,800	detection limits:
Averages	*S=*	*18.4*	256	**319**				11	2		3.3	7.10					11.0	2,800	Detection Limits:
PERMIT MAX				**5,000**		**9.0**	**week**	**10**	**0**	**week**	**10**	**10.00**							Ammonia = 0.05 mg/L
MIN						**6.0**													BOD = 1 mg/L TKN = 0.5 mg/L
FREQ					1/discharge		1/wk	1/wk	1/wk	1/wk	1/wk	1/wk		1/wk		1/wk	1/wk		Nitrate = 0.5 mg/L TSS = 1 mg/L

NOTE: Send by 15th of following month to NH Water Supply & Pollution Control Commission

NH DES Wastewater Engineering Bureau - Operations Section
P.O. Box 95, 29 Hazen Drive
Concord, New Hampshire 03302-0095

Facility: Mt. Washington State Park Wastewater Disposal Facility
Permit #: GWP-199007007-S-003
Chief Operator: Mike Pelchat
Signature:
Year: 2010
Month: Feb

Date and Day of Week		R= S=	Rain or Snow (in.)	Wastewater Flow In (Gallons) INF. TOTAL	Wastewater Flow EFF. TOTAL	pH INF. SU	pH EFF. SU	Total T.S.S. (1) INF. mg/L	Total T.S.S. (1) EFF. mg/L	Fecal Coliform EFF. #/100ml	BOD5 (1) INF. mg/L	BOD5 (1) EFF. mg/L	Total Nitrate as N (1) EFF. mg/L	Total Nitrite as N (1) EFF. mg/L	Total Ammonia as N (1) INF. mg/L	Total Ammonia as N (1) EFF. mg/L	TKN (1) INF. mg/L	TKN (1) EFF. mg/L	MLSS Bio-Tank mg/L	Additional Information: Record special analyses, equipment breakdowns, sludge wasting, unusual events, etc.
1	(M)	S=	1.80	330	0															
2	(T)	S=	0.20	340	576															
3	(W)	S=	1.80	260	578															
4	[T]	S=	0.70	270	0				10	0		3.0	9.40					11.0		DES lab test results
5	(F)			500	370															
6	(S)			360	278															
7	[S]	S=	Tr	110	568															
8	(M)	S=	1.00	180	284															
9	(T)			250	441															
10	(W)	S=	0.30	210	295															
11	[T]			250	294															
12	(F)	S=	Tr	340	0															
13	(S)	S=	Tr	300	0															
14	[S]	S=	1.70	410	285															
15	(M)	S=	0.40	0	0															
16	(T)	S=	0.30	370	0															
17	(W)	S=	0.40	360	0															
18	[T]	S=	0.80	190	296															
19	(F)	S=	0.80	480	280															
20	(S)			210	1,110															
21	[S]	S=	1.80	240	1,402															
22	(M)	S=	Tr	200	0				0	0		4.0	0.18					33.0		DES lab results
23	(T)	S=	Tr	160	0															cleaned membrane filters
24	(W)	S=	7.70	300	0															restart plant
25	[T]	S=	7.50	200	587															
26	(F)	S=	7.80	240	0															
27	(S)	S=	8.70	200	0															
28	[S]	S=	1.10	240	0															
	(M)																			
	(T)																			
	(W)																			
Maximum		R=	0	500	**1,402**				**10**			**4.0**	**9.40**					33.0		
Min or (*total*)				7,500	7,644							3.0	0.18					11.0		
Averages		S=	44.8	268	**273**				5	0		3.5	4.79					22.0		
PERMIT	MAX				**5,000**		**9.0**	**week**	**10**	**0**	**week**	**10**	**10.00**							
	MIN						**6.0**													
	FREQ					1/discharge		1/wk	1/wk	1/wk	1/wk	1/wk	1/wk		1/wk		1/wk	1/wk		

(1) 0.0 value used in calculations when result is below detection limits:

Detection Limits:
Ammonia = 0.05 mg/L
BOD = 1 mg/L
Nitrate = 0.5 mg/L
TKN = 0.5 mg/L
TSS = 1 mg/L

NOTE: Send by 15th of following month to NH Water Supply & Pollution Control Commission

NH DES Wastewater Engineering Bureau - Operations Section
P.O. Box 95, 29 Hazen Drive
Concord, New Hampshire 03302-0095

Facility: Mt. Washington State Park Wastewater Disposal Facility
Permit #: GWP-199007007-S-003
Chief Operator: Mike Pelchat Signature:
Year: 2010 Month: Mar

Date and Day of Week	R= S=	Rain or Snow (in.)	Wastewater Flow In (Gallons) INF. TOTAL	Wastewater Flow EFF. TOTAL	pH INF. SU	pH EFF. SU	Total T.S.S. (1) INF. mg/L	Total T.S.S. (1) EFF. mg/L	Fecal Coliform EFF. #/100ml	BOD5 (1) INF. mg/L	BOD5 (1) EFF. mg/L	Total Nitrate as N (1) EFF. mg/L	Total Nitrite as N (1) EFF. mg/L	Total Ammonia as N (1) INF. mg/L	Total Ammonia as N (1) EFF. mg/L	TKN (1) INF. mg/L	TKN (1) EFF. mg/L	MLSS Bio-Tank mg/L	**Additional Information:** Record special analyses, equipment breakdowns, sludge wasting, unusual events, etc.
1 (M)	S=	8.20	335	0															
2 (T)			280	0															
3 (W)			430	0															
4 [T]	S=	0.30	360	312															
5 (F)			200	314															
6 (S)			495	322															
7 [S]			380	312															
8 (M)			315	0															
9 (T)			245	314															
10 (W)			360	309															
11 [T]			240	453															
12 (F)	S=	Tr	290	1,499															
13 (S)			265	297															
14 [S]	S=	7.20	425	288															
15 (M)	S=	10.40	380	0				8	0		3.0	14.00					5.0		DES lab results
16 (T)			260	0															
17 (W)			220	288															
18 [T]			230	1,048															
19 (F)			250	0															
20 (S)			260	584															
21 [S]	S=	Tr	350	306															
22 (M)			305	0															
23 (T)	S=	1.00	160	615															
24 (W)	S=		195	282															
25 [T]			230	0															
26 (F)			170	898															
27 (S)			315	0															
28 [S]			380	0															
29 (M)			365	0															
30 (T)			230	1,466															
31 (W)			225	0															
Maximum	R=	*0*	495	**1,499**				**8**			**3.0**	**14.00**					5.0		(1) 0.0 value used in calculations when result is below
Min or (*total*)			9,145	9,907				8			3.0	14.00					5.0		detection limits:
Averages	S=	*27.1*	295	**320**				8	0		3.0	14.00					5.0		Detection Limits:
PERMIT MAX				**5,000**		**9.0**	**week**	**10**	**0**	**week**	**10**	**10.00**							Ammonia = 0.05 mg/L
MIN						**6.0**													BOD = 1 mg/L TKN = 0.5 mg/L
FREQ					1/discharge		1/wk	1/wk	1/wk	1/wk	1/wk	1/wk		1/wk		1/wk	1/wk		Nitrate = 0.5 mg/L TSS = 1 mg/L

NOTE: Send by 15th of following month to NH Water Supply & Pollution Control Commission

NH DES Wastewater Engineering Bureau - Operations Section
P.O. Box 95, 29 Hazen Drive
Concord, New Hampshire 03302-0095

Facility: Mt. Washington State Park Wastewater Disposal Facility
Permit #: GWP-199007007-S-003
Chief Operator: Mike Pelchat   Signature:
Year: 2010   Month: Apr

Date and Day of Week		R= S=	Rain or Snow (in.)	Wastewater Flow In (Gallons) INF. TOTAL	EFF. TOTAL	pH INF. SU	EFF. SU	Total T.S.S. (1) INF. mg/L	EFF. mg/L	Fecal Coliform EFF. #/100ml	BOD5 (1) INF. mg/L	EFF. mg/L	Total Nitrate as N (1) EFF. mg/L	Total Nitrite as N (1) EFF. mg/L	Total Ammonia as N (1) INF. mg/L	EFF. mg/L	TKN (1) INF. mg/L	EFF. mg/L	MLSS Bio-Tank mg/L	Additional Information: Record special analyses, equipment breakdowns, sludge wasting, unusual events, etc.
1	[T]	S=	0.08	200	604															
2	(F)			340	228															
3	(S)			265	255															
4	[S]			225	0															
5	(M)			225	309															
6	(T)	S=	Tr	285	309															
7	(W)	S=	0.49	255	621															
8	[T]	S=	0.22	120	0															
9	(F)	S=	0.02	150	310															
10	(S)	S=	3.40	200	299															
11	[S]	S=	0.90	300	0															
12	(M)	S=	1.90	270	191															
13	(T)			150	0															
14	(W)			210	597															
15	[T]			170	303															
16	(F)			200	290															
17	(S)	S=	7.90	170	289															
18	[S]	S=	4.30	225	0															
19	(M)	S=	3.00	190	288															
20	(T)	S=	0.26	155	289															
21	(W)	S=	Tr	170	0															
22	[T]	S=	0.01	150	279															
23	(F)	S=	1.60	120	0															
24	(S)			160	295															
25	[S]			190	288															
26	(M)			180	0															
27	(T)	S=	0.11	200	0															Membranes plugged removed for cleaning
28	(W)	S=	1.16	150	0															Membranes being clean manually
29	[T]	S=	28.00	250	0															Membranes being clean manually
30	(F)			400	0															Membranes being clean manually
	(S)																			
Maximum		R=	0	400	**621**															(1) 0.0 value used in calculations when result is below
Min or (*total*)				6,275	6,044															detection limits:
Averages		S=	53.35	209	**201**															Detection Limits:
PERMIT		MAX			**5,000**		**9.0**	**week**	**10**	**0**	**week**	**10**	**10.00**							Ammonia = 0.05 mg/L
		MIN					**6.0**													BOD = 1 mg/L TKN = 0.5 mg/L
		FREQ				1/discharge		1/wk	1/wk	1/wk	1/wk	1/wk	1/wk		1/wk		1/wk	1/wk		Nitrate = 0.5 mg/L TSS = 1 mg/L

NOTE: Send by 15th of following month to NH Water Supply & Pollution Control Commission

NH DES Wastewater Engineering Bureau - Operations Section
P.O. Box 95, 29 Hazen Drive
Concord, New Hampshire 03302-0095

Facility: Mt. Washington State Park Wastewater Disposal Facility
Permit #: GWP-199007007-S-003
Chief Operator: Mike Pelchat
Signature:
Year: 2010
Month: May

Date and Day of Week	R= / S=	Rain or Snow (in.)	Wastewater Flow In (Gallons) INF. TOTAL	Wastewater Flow EFF. TOTAL	pH INF. SU	pH EFF. SU	Total T.S.S. (1) INF. mg/L	Total T.S.S. (1) EFF. mg/L	Fecal Coliform EFF. #/100ml	BOD5 (1) INF. mg/L	BOD5 (1) EFF. mg/L	Total Nitrate as N (1) EFF. mg/L	Total Nitrite as N (1) EFF. mg/L	Total Ammonia as N (1) INF. mg/L	Total Ammonia as N (1) EFF. mg/L	TKN (1) INF. mg/L	TKN (1) EFF. mg/L	MLSS Bio-Tank mg/L	Additional Information: Record special analyses, equipment breakdowns, sludge wasting, unusual events, etc.
1 (S)			233	0															Membranes being cleaned manually
2 [S]			257	0															Membranes being cleaned manually
3 (M)	R=	Tr	238	0															Membranes being cleaned manually
4 (T)	S=	0.03	228	0															Membranes being cleaned manually
5 (W)	S=	0.13	200	0															Membranes reinstalled / plant on line
6 [T]			560	527															
7 (F)	S=	1.20	490	0															Switched to MicroC-G from cane sugar
8 (S)	S=	0.01	300	0															No remote control of PLC - Lightning hit
9 [S]	S=	2.20	220	0															No remote control of PLC - new router being obtained
10 (M)	S=	2.70	130	0															No remote control of PLC - new router being obtained
11 (T)			185	0															No remote control of PLC - new router being obtained
12 (W)			170	0															No remote control of PLC - new router being obtained
13 [T]			110	0															No remote / Hand held Nitrate 57.64 mg/L
14 (F)			140	0															No remote control of PLC - new router being obtained
15 (S)	S=	0.30	198	0															
16 [S]	S=	1.00	292	0															Hand held Nitrate 94.60 / Increased MicroC-G
17 (M)			570	1,305															
18 (T)			420	325															
19 (W)			550	310															Hand held Nitrate 145.2 mg/L - Test Strips Nitrate 50 - Nitrite 3.0 - Ammonia 6.0
20 [T]	R=	0.38	310	466															Filled hypochlorite tank
21 (F)	S=	Tr	490	861															
22 (S)			700	401															System on AUTO for summer
23 [S]			2,020	2,225															Nitrate 9.4
24 (M)			2,250	2,202															UV off-line, reset
25 (T)			870	547															Hand Held Nitrate 145.2, Increased MicroC-G to 6 min/hr
26 (W)			860	1,626															
27 [T]			510	553															
28 (F)			640	517															Cleaned membrane filters, gpm now 179.0 : UV bulb failed - ordered new one
29 (S)			950	517															Nitrate 4.6 :)
30 [S]			2,600	2,844															
31 (M)			3,000	2,867															
Maximum	*R=*	*0.38*	3,000	**2,867**															
Min or (*total*)			20,691	18,093															
Averages	*S=*	*7.57*	667	**584**															
PERMIT MAX				**5,000**		**9.0**	**week**	**10**	**0**	**week**	**10**	**10.00**							
PERMIT MIN						**6.0**													
PERMIT FREQ					1/discharge		1/wk	1/wk	1/wk	1/wk	1/wk	1/wk		1/wk		1/wk	1/wk		

(1) 0.0 value used in calculations when result is below detection limits:

Detection Limits:
Ammonia = 0.05 mg/L
BOD = 1 mg/L
TKN = 0.5 mg/L
Nitrate = 0.5 mg/L
TSS = 1 mg/L

NOTE: Send by 15th of following month to NH Water Supply & Pollution Control Commission

NH DES Wastewater Engineering Bureau - Operations Section
P.O. Box 95, 29 Hazen Drive
Concord, New Hampshire 03302-0095

Facility: Mt. Washington State Park Wastewater Disposal Facility
Permit #: GWP-199007007-S-003
Chief Operator: Mike Pelchat
Signature:
Year: 2010
Month: Jun

Date and Day of Week		R= / S=	Rain or Snow	Wastewater Flow In (Gallons)		pH		Total T.S.S. (1)		Fecal Coliform	BOD5 (1)		Total Nitrate as N (1)	Total Nitrite as N (1)	Total Ammonia as N (1)		TKN (1)		MLSS (1)		Additional Information: Record special analyses, equipment breakdowns, sludge wasting, unusual events, etc.
				INF.	EFF.	INF.	EFF.	INF.	EFF.	EFF.	INF.	EFF.	EFF.	EFF.	INF.	EFF.	INF.	EFF.	INF.	EFF.	
			(in.)	TOTAL	TOTAL	SU	SU	mg/L	mg/L	#/100ml	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	
1	(T)	R=	0.00	1,950	1,035																Auger motor tripped out, toilet paper clog, back on line
2	(W)	R=	0.52	630	466																Press zone screen bent, Auger shaft displaced, Auger and Screen taken offline and directed influent to outside storage tanks. Rest of plant online.
3	[T]	R=	0.00	1,240	420	6.60				3	210.0	6.0	35.00		170.0		210.0	35.0	230.0	0	Parts on order to correct equipment failure of Press Zone and Auger Shaft. Influent/Effluent samples sent to DES lab. Screen damaged, bypass plant to outside
4	(F)	R=	0.53	730	0																Hand held pH 5.4 bioreactor eff nitrate 31.1 add 12# NaOH mixed with 5gal H2O to bioreactor pH 10.3
5	(S)	R=	0.00	1,200	0																Repaired screen back on line 2PM
6	[S]	R=	0.88	1,100	2,074	8.30															hand held nitrate 6.5
7	(M)	R=	1.28	820	524																
8	(T)	S=	Tr	1,110	1,322																
9	(W)	S=	0.40	1,070	786	7.94															hand nitrate 145.2, increased MicorCG from 3min/hr to 6min/hr
10	[T]	S=	Tr	1,380	1,563	7.65															Hach DR2800 nitrate 9.46 pH 7.0
11	(F)	S=	Tr	520	524																
12	(S)	R=	0.36	1,300	1,331	6.40															hand nitrate 33.2, add NaOH to bioreactor 0.9#
13	[S]	R=	0.01	1,950	2,048																
14	(M)	R=	0.00	1,650	1,550																
15	(T)	R=	0.14	1,000	1,034																
16	(W)	R=	0.00	2,200	2,353	7.10															Hach 2800 nitrate 8.61
17	[T]	R=	0.00	1,100	1,001																
18	(F)	R=	0.98	900	1,058																bypass plant to outside holding tanks
19	(S)	R=	0.00	3,000	2,316	7.60															membranes run 24hrs straight
20	[S]	R=	Tr	5,800	2,518	7.60															cleaned membrane filters, pumped surge to 1.5 inches, pumped bioreactor 20min to dose tank to hold sludge
21	(M)	R=	0.85	1,900	508																
22	(T)	R=	0.00	2,160	2,240	7.65															press zone screen /auger failure again, toilet paper not moving through, compacted and hard as a rock. bypass plant into outside tanks until further notice
23	(W)	R=	0.05	2,265	0	7.50															Hach 2800 nitrate <3.25, cleaning cycle reprogrammed by Jason at Lifewater used in PM
24	[T]	R=	0.52	955	0	7.60															
25	(F)	R=	0.86	980	3,070	7.10															Hach nitrate 10.6
26	(S)	R=	Tr	3,350	1,414																black plastic water pipe 1" diameter installed in holding tanks with sump pump to feed ESTP a 4gpm
27	[S]	R=	0.22	3,100	4,189	6.60															decreased feed water from holding tanks to 2gpm
28	(M)	R=	0.04	3,500	2,524																
29	(T)	R=	1.00	1,100	2,353			60	0	0	210.0	3.0		11.00	140.0	19.0		33.0			
30	(W)	R=	0.10	2,700	2,684	7.00															Hach nitrate 13.8, COD 72.0, hand held pH 6.87, increased MicroCG to 7min/hr
	[T]																				
Maximum		R=	8.34	5,800	**4,189**	8.3		60		**3**	210.0	**6.0**	**35.00**	11.00	170.0	19.0	210.0	35.0			(1) 0.0 value used in calculations when result is below detection limits:
Min or (*total*)				52,660	42,905	6.4		60			210.0	3.0	35.00	11.00	140.0	19.0	210.0	33.0			
Averages		S=	0.4	1,755	**1,430**			60	0	2	210.0	4.5	35.00	**11.00**	155.0	19.0	210.0	34.0		0	Detection Limits:
PERMIT		MAX			**5,000**		**9.0**	**week**	**10**	**0**	**week**	**10**	**10.00**								Ammonia = 0.05 mg/L
		MIN					**6.0**														BOD = 1 mg/L; TKN = 0.5 mg/L
		FREQ				1/discharge		1/wk	1/wk	1/wk	1/wk	1/wk	1/wk		1/wk		1/wk	1/wk			Nitrate = 0.5 mg/L; TSS = 1 mg/L

NOTE: Send by 15th of following month to NH Water Supply & Pollution Control Commission

NH DES Wastewater Engineering Bureau - Operations Section
P.O. Box 95, 29 Hazen Drive
Concord, New Hampshire 03302-0095

Facility: Mt. Washington State Park Wastewater Disposal Facility
Permit #: GWP-199007007-S-003
Chief Operator: Mike Pelchat
Signature:
Year: 2010
Month: Jul

Date and Day of Week		R= S=	Rain or Snow (in.)	Wastewater Flow In (Gallons) INF. TOTAL	Wastewater Flow In (Gallons) EFF. TOTAL	pH INF. SU	pH EFF. SU	Total T.S.S. (1) INF. mg/L	Total T.S.S. (1) EFF. mg/L	Fecal Coliform EFF. #/100ml	BOD5 (1) INF. mg/L	BOD5 (1) EFF. mg/L	Total Nitrate as N (1) EFF. mg/L	Total Nitrite as N (1) EFF. mg/L	Total Ammonia as N (1) INF. mg/L	Total Ammonia as N (1) EFF. mg/L	TKN (1) INF. mg/L	TKN (1) EFF. mg/L	MLSS (1) INF. mg/L	MLSS (1) EFF. mg/L	Record special analyses, equipment breakdowns, sludge wasting, unusual events, etc.
1	[T]	S=	0.20	2,180	2,678																
2	(F)	R=	0.01	1,050	968		6.50														Nitrate 33.4
3	(S)	R=	0.00	3,350	2,698																
4	[S]	R=	0.00	4,300	3,486																
5	(M)	R=	0.00	4,600	4,519																
6	(T)	R=	0.00	3,700	5,500		7.22														
7	(W)	R=	0.00	2,600	4,988		6.99														Nitrate 17.0, increase MicroCG to 8min/hr
8	[T]	R=	0.00	2,860	4,253		7.05														
9	(F)	R=	0.00	2,440	2,924		7.13														Nitrate 16.8, Install/put on line new auger/press zone screen
10	(S)	R=	0.00	2,650	2,981																waste sludge 20 min
11	[S]	R=	1.34	1,750	1,411																
12	(M)	R=	0.00	2,960	3,367																
13	(T)	R=	0.00	2,742	3,529																
14	(W)	R=	0.58	2,722	3,562		7.33														Nitrate 4.27
15	[T]	R=	0.06	2,702	3,595	8.30	7.16	1900	0	2	980.0	6.0	5.30		43.0	16.0	230.0	28.0			
16	(F)	R=	0.01	2,683	3,628																Clean membrane filters
17	(S)	R=	0.00	2,663	3,661		7.30														Nitrate 1.56, COD 22.0
18	[S]	R=	0.10	2,643	3,693		7.30														Nitrate 33, carbon pump failed, replaced
19	(M)	R=	0.00	2,623	3,726		7.87														Nitrate 33.0, carbon pump failed prior day
20	(T)	R=	0.34	2,604	3,759		7.03														Nitrate 25.7, waste sludge 10 min
21	(W)	R=	0.48	2,584	3,792		7.84														waste sludge 10 min, membranes plugged, switch to outside settling tanks
22	[T]	R=	1.17	2,564	3,825		7.75														
23	(F)	R=	0.74	2,545	3,858																
24	(S)	R=	0.05	2,525	3,891																
25	[S]	R=	0.17	2,505	3,924																
26	(M)	R=	0.31	2,485	3,957		7.51														
27	(T)	R=	0.00	2,466	3,990																
28	(W)	R=	0.00	2,446	4,023		7.79														
29	[T]	R=	0.21	2,426	4,056		7.20	110	0	2	260.0	6.0	4.40		120.0		220.0	57.0	2300		Nitrate 8.44, ammonia 65.6
30	(F)	R=	0.25	2,407	4,089		7.10														Nitrate 4.42, COD 1134?
31	(S)	R=	0.00	2,387	4,122																
Maximum		*R=*	*5.82*	4,600	**5,500**	8.3	**7.9**	1900		**2**	980.0	**6.0**	**5.30**		120.0	16.0	230.0	57.0			(1) 0.0 value used in calculations when result is below detection limits:
Min or (*total*)				83,162	112,454	8.3	**6.5**	110		2	260.0	6.0	4.40		43.0	16.0	220.0	28.0			
Averages		*S=*	*0.2*	2,683	**3,628**			1,005	0	2	620.0	6.0	4.85		81.5	16.0	225.0	42.5			Detection Limits:
PERMIT			MAX		**5,000**		**9.0**	**week**	**10**	**0**	**week**	**10**	**10.00**								Ammonia = 0.05 mg/L
			MIN				**6.0**														BOD = 1 mg/L; TKN = 0.5 mg/L
			FREQ			1/discharge		1/wk	1/wk	1/wk	1/wk	1/wk	1/wk		1/wk		1/wk	1/wk			Nitrate = 0.5 mg/L; TSS = 1 mg/L

NOTE: Send by 15th of following month to NH Water Supply & Pollution Control Commission

NH DES Wastewater Engineering Bureau - Operations Section
P.O. Box 95, 29 Hazen Drive
Concord, New Hampshire 03302-0095

Facility: Mt. Washington State Park Wastewater Disposal Facility
Permit #: GWP-199007007-S-003
Chief Operator: Mike Pelchat
Signature:
Year: 2010
Month: Aug

Date and Day of Week		R= S=	Rain or Snow (in.)	Wastewater Flow In (Gallons) INF. TOTAL	Wastewater Flow EFF. TOTAL	pH INF. SU	pH EFF. SU	Total T.S.S. (1) INF. mg/L	T.S.S. EFF. mg/L	Fecal Coliform EFF. #/100ml	BOD5 (1) INF. mg/L	BOD5 EFF. mg/L	Total Nitrate as N (1) EFF. mg/L	Total Nitrite as N (1) EFF. mg/L	Total Ammonia as N (1) INF. mg/L	Ammonia EFF. mg/L	TKN (1) INF. mg/L	TKN EFF. mg/L	MLSS Bio-Tank mg/L	Additional Information: Record special analyses, equipment breakdowns, sludge wasting, unusual events, etc.
1	[S]	R=	0.00	5,150	3,347		7.03						6.02			58.6				In house lab results
2	(M)	R=	0.00	4,360	4,961		7.81													waste 10 min.
3	(T)	R=	1.44	2,940	6,486		7.50													waste 10 min.
4	(W)	R=	0.89	2,400	2,598		7.50													waste 10 min.
5	[T]	R=	0.85	2,875	2,717		6.85						11.30			44.8				In house lab results
6	(F)	R=	0.03	2,500	2,994															
7	(S)	R=	0.02	3,500	3,243															
8	[S]	R=	0.00	5,500	3,558		6.70						14.50			42.8				In house lab results, highest volume Inf. Day
9	(M)	R=	0.01	4,700	5,656															
10	(T)	R=	0.43	3,100	5,026		7.20						10.50			44.4				Cleaned Membrane Filters, 167 gpm, In house lab results
11	(W)	R=	Tr	3,700	3,439		7.22													
12	[T]	R=	0.00	4,800	3,900		7.00						16.80			26.6				In house lab results
13	(F)	R=	0.00	3,600	4,250		6.60	28	0	0	350.0	6.0	11.00		90.0	53.0	210.0	37.0		DES Lab Report, in house nitrate test 17.0, DES test 11.0
14	(S)	R=	0.00	3,400	3,164		6.70						12.70			27.3				In house lab results
15	[S]	R=	0.00	4,800	3,439															Membrane rate down to 131gpm
16	(M)	R=	0.02	4,000	4,801		7.11													
17	(T)	R=	0.20	1,700	3,283															
18	(W)	R=	0.00	4,800	2,785		6.60						9.49			30.1				cleaned membranes, 169 gpm, In house lab results
19	[T]	R=	0.00	3,300	4,546		7.90													Membrane rate down to 144 gpm
20	(F)	R=	0.01	3,500	5,786		6.20						4.20			32.5				In house lab results
21	(S)	R=	0.00	2,900	4,884															
22	[S]	R=	0.00	6,000	3,382															membrane rate 131, Largest water volume
23	(M)	R=	0.97	1,600	4,631		7.47													waste sludge 5 min
24	(T)	R=	0.43	1,400	1,036		7.31													waste sludge 5 min
25	(W)	R=	Tr	3,100	2,835		7.30													
26	[T]	R=	1.02	1,000	1,549															DES Lab Report Pending
27	(F)	R=	0.10	2,100	2,334		6.90						2.20			14.4				In house lab results
28	(S)	R=	Tr	3,400	2,607															
29	[S]	R=	0.00	4,900	3,128															
30	(M)	R=	0.00	3,250	5,146															
31	(T)	R=	0.00	2,550	2,398		7.26													
Maximum		R=	6.42	6,000	**6,486**		**7.9**	28			350.0	**6.0**	**16.80**		90.0	58.6	210.0	37.0		
Min or (*total*)				106,825	113,909		**6.2**	28			350.0	6.0	2.20		90.0	14.4	210.0	37.0		
Averages		S=	0	3,446	**3,674**			28	0	0	350.0	6.0	9.87		90.0	37.5	210.0	37.0		
PERMIT	MAX				**5,000**		**9.0**	**week**	**10**	**0**	**week**	**10**	**10.00**							
	MIN						**6.0**													
	FREQ					1/discharge		1/wk	1/wk	1/wk	1/wk	1/wk	1/wk		1/wk		1/wk	1/wk		

(1) 0.0 value used in calculations when result is below detection limits:

Detection Limits:
Ammonia = 0.05 mg/L
BOD = 1 mg/L
TKN = 0.5 mg/L
Nitrate = 0.5 mg/L
TSS = 1 mg/L

NOTE: Send by 15th of following month to NH Water Supply & Pollution Control Commission

NH DES Wastewater Engineering Bureau - Operations Section
P.O. Box 95, 29 Hazen Drive
Concord, New Hampshire 03302-0095

Facility: Mt. Washington State Park Wastewater Disposal Facility
Permit #: GWP-199007007-S-003
Chief Operator: Mike Pelchat Signature:
Year: 2010 Month: Sep

Date and Day of Week		R= S=	Rain or Snow (in.)	Wastewater Flow In (Gallons) INF. TOTAL	Wastewater Flow In (Gallons) EFF. TOTAL	pH INF. SU	pH EFF. SU	Total T.S.S. (1) INF. mg/L	Total T.S.S. (1) EFF. mg/L	Fecal Coliform EFF. #/100ml	BOD5 (1) INF. mg/L	BOD5 (1) EFF. mg/L	Total Nitrate as N (1) EFF. mg/L	Total Nitrite as N (1) EFF. mg/L	Total Ammonia as N (1) INF. mg/L	Total Ammonia as N (1) EFF. mg/L	TKN (1) INF. mg/L	TKN (1) EFF. mg/L	MLSS Bio-Tank mg/L	Additional Information: Record special analyses, equipment breakdowns, sludge wasting, unusual events, etc.
1	(W)			2,000	2,231		7.3													
2	[T]			1,900	2,095															
3	(F)			1,700	1,815		6.5													
4	(S)	R=	2.08	1,900	1,875		6.2													
5	[S]	R=	0.63	2,800	1,719															
6	(M)	R=	0.21	4,500	3,786															
7	(T)	R=	0.09	6,000	4,361		7.4						8.11							
8	(W)	R=	0.04	2,400	5,660															
9	[T]	R=	0.11	1,700	2,359		6.5													
10	(F)	R=	1.42	1,000	820		6.2						12.80							
11	(S)	R=	0.05	1,100	1,046		7.0													
12	[S]			4,100	3,254															
13	(M)	R=	0.02	1,600	2,762		6.7													Pump Obs Black Water Tank
14	(T)	R=	0.13	900	1,838		7.4						5.33							
15	(W)	R=	0.42	1,200	1,487		6.6													
16	[T]	R=	0.21	650	290															
17	(F)	R=	0.50	1,550	1,998															
18	(S)	R=	0.16	1,100	1,152		6.6													Air Compressor brake down. Plant shut down to fix for 3+ hours. Clean Micro CG tank and refilled
19	[S]			4,100	3,044		7.5		ND	2	1200.0	3.0	16.00		160.0	25.0	380.0	30.0		DES Lab Report. In house Lab: nitrate 7.92. wasted 5 min sludge, 2 min TSS
20	(M)			1,800	2,519		6.8													samples to DES Lab, waiting for results
21	(T)			2,000	2,155		6.4													
22	(W)			2,150	2,470		6.4													
23	[T]	R=	0.07	1,050	1,124		6.9													PLC failure - Reboot Computer, fixes problems
24	(F)	R=	tr	1,900	1,923															Sludge bagger @ 7.5 psi up from 3 psi when put online, wasted 5 min sludge, 2 min TSS
25	(S)	R=	0.47	1,500	850		7.0						10.50							
26	[S]			3,500	3,621		7.0													
27	(M)	R=	0.01	2,000	2,644		7.1						16.90							
28	(T)	R=	0.25	1,600	1,430		6.4													
29	(W)	R=	0.53	900	1,153		6.9		ND	0	420.0	3.0	21.00		210.0	24.0	100.0	28.0		DES Lab Report. In house Lab: nitrate 22.3 wasted 5 min sludge, 2 min TSS
30	[T]	R=	0.01	2,800	2,268															
	(F)																			
Maximum		R=	7.41	6,000	**5,660**		**7.5**			**2**	1200.0	**3.0**	**21.00**		210.0	25.0	380.0	30.0		(1) 0.0 value used in calculations when result is below detection limits:
Min or (*total*)				63,400	65,749		**6.2**				420.0	3.0	5.33		160.0	24.0	100.0	28.0		
Averages		S=	0	2,113	**2,192**					1	810.0	3.0	12.95		185.0	24.5	240.0	29.0		Detection Limits:
PERMIT	MAX				**5,000**		**9.0**	**week**	**10**	**0**	**week**	**10**	**10.00**							Ammonia = 0.05 mg/L
	MIN						**6.0**													BOD = 1 mg/L TKN = 0.5 mg/L
	FREQ					1/discharge		1/wk	1/wk	1/wk	1/wk	1/wk	1/wk		1/wk		1/wk	1/wk		Nitrate = 0.5 mg/L TSS = 1 mg/L

NOTE: Send by 15th of following month to NH Water Supply & Pollution Control Commission

NH DES Wastewater Engineering Bureau - Operations Section
P.O. Box 95, 29 Hazen Drive
Concord, New Hampshire 03302-0095

Facility: Mt. Washington State Park Wastewater Disposal Facility
Permit #: GWP-199007007-S-003
Chief Operator: Mike Pelchat
Signature:
Year: 2010
Month: Oct

Date and Day of Week	R= / S=	Rain or Snow (in.)	Wastewater Flow In (Gallons) INF. TOTAL	Wastewater Flow In (Gallons) EFF. TOTAL	pH INF. SU	pH EFF. SU	Total T.S.S. (1) INF. mg/L	Total T.S.S. (1) EFF. mg/L	Fecal Coliform EFF. #/100ml	BOD5 (1) INF. mg/L	BOD5 (1) EFF. mg/L	Total Nitrate as N (1) EFF. mg/L	Total Nitrite as N (1) EFF. mg/L	Total Ammonia as N (1) INF. mg/L	Total Ammonia as N (1) EFF. mg/L	TKN (1) INF. mg/L	TKN (1) EFF. mg/L	MLSS Bio-Tank mg/L	Additional Information: Record special analyses, equipment breakdowns, sludge wasting, unusual events, etc.
1 (F)	R=	1.69	1,100	1,951															waste 7 min, pump obs balck water tank, MicroCg @ 8 min/hr
2 (S)	R=	2.30	1,000	838		6.9						13.80			20.9				
3 [S]			4,000	3,064		6.9													
4 (M)			4,000	5,478		6.2													
5 (T)	R=	0.03	2,500	4,279		6.4													
6 (W)	R=	0.04	2,700	210		6.4													power outage @ 9:46 am
7 [T]	R=	0.09	1,400	1,672															
8 (F)	R=	0.45	450	0															PLC failure, all pumps in off postion, microCg in 0/gpm. Restarted all pumps, reset MicroCg to 8/gpm. to clear all problems had to reboot ESTP computer clearing previous
9 (S)	S=	0.80				6.9						19.10							lack of data due to previous day of resetting PLC
10 [S]			1,050	0		7.0													
11 (M)			2,550	0		7.2						15.80			27.0				
12 (T)			2,600	867		6.8	92	ND	0	350.0	3.2	7.40		220.0	23.0	240.0	77.0		DES Lab Report, Ken Kessler onsite visit. Eff: Alk. 100. Inf: PH 7.89, nitrate 7.21, ammonia<3.5. Alk. Anoxic tank: PH 8.08, nitrate 2.10. Alk.Bioreactor tank: PH 7.33.
13 (W)			2,000	3,313		6.5													
14 [T]			2,000	2,681															
15 (F)	S=	0.20	1,200	2,489															
16 (S)	S=	5.30	400	0															
17 [S]	S=	2.80	300	0															
18 (M)	S=	0.60	265	0															
19 (T)			225	535		6.6						24.10			13.5				MicroCG @ 7/min/hr
20 (W)			325	0		6.8						18.90							
21 [T]			285	558															MicroCg @ 6/min/hr
22 (F)	S=	1.60	300	0															
23 (S)	S=	0.80	205	0															
24 [S]			305	527															
25 (M)	S=	Tr	415	1,131		6.4													
26 (T)	R=	0.49	330	2,569		6.5													Clean probes
27 (W)	R=	0.39	345	3,084		6.7	140	ND	0	530.0	2.0	7.10		210.0	42.0	110.0	41.0		Samples to DES Lab
28 [T]	R=	0.21	170	3,306		6.5													
29 (F)			130	3,947		7.1						16.40			30.7				
30 (S)	S=	2.20	150	240															
31 [S]	S=	2.30	200	0															
Maximum	R=	5.69	4,000	**5,478**		**7.2**	140			530.0	**3.2**	**24.10**		220.0	42.0	240.0	77.0		(1) 0.0 value used in calculations when result is below detection limits:
Min or (*total*)			32,900	42,739		**6.2**	92			350.0	2.0	7.10		210.0	13.5	110.0	41.0		
Averages	S=	16.6	1,097	**1,425**			116		0	440.0	2.6	15.33		215.0	26.2	175.0	59.0		Detection Limits:
PERMIT MAX				**5,000**		**9.0**	**week**	**10**	**0**	**week**	**10**	**10.00**							Ammonia = 0.05 mg/L
MIN						**6.0**													BOD = 1 mg/L; TKN = 0.5 mg/L
FREQ					1/discharge		1/wk	1/wk	1/wk	1/wk	1/wk	1/wk		1/wk		1/wk	1/wk		Nitrate = 0.5 mg/L; TSS = 1 mg/L

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Appendix E: Dead Loads

Roof		
0.0024	ksf	galvanized steel-18 gage corrigated
0.0015	ksf	insulation fiberglass
0.012	ksf	stone decking
Ceiling		
0.006	ksf	MEP
0.001	ksf	drop ceiling (channel susppend system)
Floor		
0.012	ksf	cement finish per inch
0.006	ksf	MEP
0.001	ksf	drop ceiling
0.0015	ksf	insulation
Wall		
0.0009	ksf	wood studs 16" on center
0.005	ksf	gypsum wall board
0.03	ksf	concrete block outside wall
0.008	ksf	windows
0.0015	ksf	insulation

Appendix F: Live-Impact Loads

floors

Increase Roof Live Load by 100%

Lo 100 psf no reduction because of rooms

No reduction based on Assembly Table 4-1

ROOF LIVE LOADS

L	200	psf	Table 4-1, assembly purposes	8 foot wide hallway
				17ft rooms

Corridors

Lo 100 psf

Will be used for multiple beams, girders, and columns,

7	ft
8	ft
8 1/2	ft
10 1/4	ft

Appendix G: Snow Loads

ASCE 7.3 Flat Roof Snow Loads

pg	56	psf	senh.org
Ce	0.7		fully exposed above treeline in windswept mountainous areas
Ct	1		All structures
Is	1.1		Risk Category
pf	30.184	psf	

Appendix H: Wind Loads

least width of building	34	ft			
height of building	10	ft		a	3.4
Step 1				2a	6.8
Risk Category	3	Table 1.5-1			
Step 2					
V (basic wind speed)	185	mph	based on .0027V^2		
Step 3					
Kd	0.85	Table 26.6-1			
Kd tower	0.95	Table 26.6-1			
Exposure Category	C	Secton 26.7			
Kzt	1	Section 26.8, Figure 26.8-1			
Exclosure Classification	Enclosed	Section 26.10	Enclosed building		
Gcpi	0.18	Table 26.11-1			
	-0.18				
Step 4					
zg	900	Table 26.9-1			
alpha	9.5	Table 26.9-1			
Kz	0.779429	Table 28.3-1			
Step 5					
qz=qh (building)	58.04689	Secton 26.3			

Gcpi

Load Case A

	1	2	3	4	1E	2E	3E	4E	
0<5	0.4	-0.69	-0.37	-0.29	0.61	-1.07	-0.53	-0.43	
p	12.77	-50.501	-31.93	-27.282	24.96	-72.56	-41.2	-35.4	positive Gcpi
p	33.67	-29.604	-11.03	-6.3852	45.86	-51.66	-20.3	-14.5	negative Gcpi

Load Case B

	1	2	3	4	5	6	1E	2E	3E	4E	5E	6E	
0<90	-0.45	-0.69	-0.37	-0.45	0.4	-0.29	-0.48	-1.07	-0.53	-0.48	0.61	-0.43	
p	-36.57	-50.501	-31.93	-36.57	12.77	-27.28	-38.3	-72.6	-41.21	-38.31	24.96	-35.4086	positive Gcpi
p	-15.67	-29.604	-11.03	-15.673	33.67	-6.385	-17.4	-51.7	-20.32	-17.41	45.857	-14.5117	negative Gcpi

p should not be less than 16 lb/ft^2

Load Case A

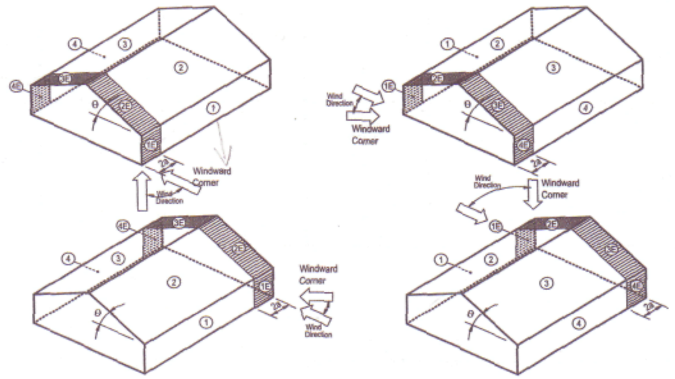
1	2	3	4	1E	2E	3E	4E	
33.67	-51	-31.93	-27.282	45.857	-72.559	-41.21	-35.41	psf

Load Case B

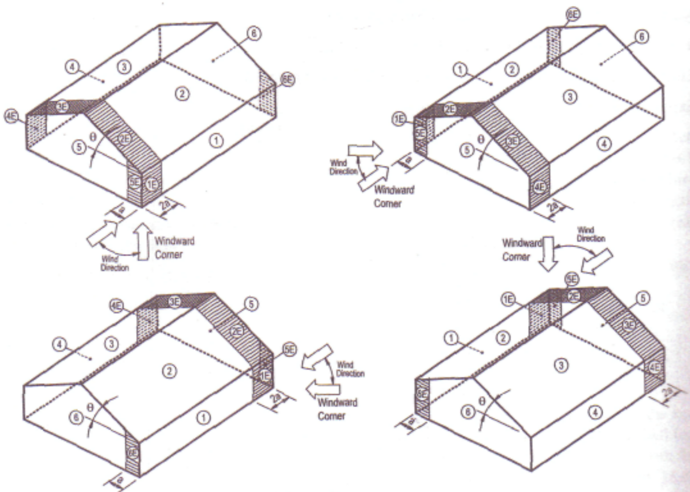
1	2	3	4	5	6	1E	2E	3E	4E	5E	6E	
-36.6	-51	-31.93	-36.57	33.667	-27.282	-38.31	-72.56	-41.2	-38.3	45.857	-35.41	psf

Appendix I: Load Case Drawings

Main Wind Force Resisting System – Part 1		h ≤ 60 ft.
Figure 28.4-1	**External Pressure Coefficients (GC_{pf})**	**Low-rise Walls & Roofs**
Enclosed, Partially Enclosed Buildings		



Load Case A



Load Case B

Basic Load Cases

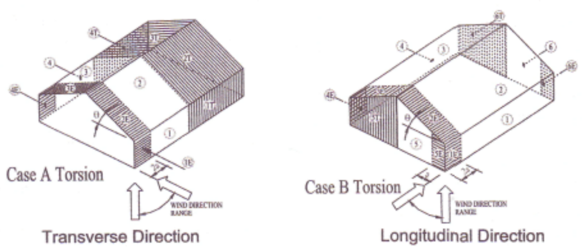
Main Wind Force Resisting System – Part 1		$h \leq 60$ ft.
Figure 28.4-1 (cont.)	External Pressure Coefficients (GC_{pf})	Low-rise Walls & Roofs
Enclosed, Partially Enclosed Buildings		

Roof Angle θ (degrees)	LOAD CASE A							
	Building Surface							
	1	2	3	4	1E	2E	3E	4E
0-5	0.40	-0.69	-0.37	-0.29	0.61	-1.07	-0.53	-0.43
20	0.53	-0.69	-0.48	-0.43	0.80	-1.07	-0.69	-0.64
30-45	0.56	0.21	-0.43	-0.37	0.69	0.27	-0.53	-0.48
90	0.56	0.56	-0.37	-0.37	0.69	0.69	-0.48	-0.48

Roof Angle θ (degrees)	LOAD CASE B											
	Building Surface											
	1	2	3	4	5	6	1E	2E	3E	4E	5E	6E
0-90	-0.45	-0.69	-0.37	-0.45	0.40	-0.29	-0.48	-1.07	-0.53	-0.48	0.61	-0.43

Notes:

1. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
2. For values of θ other than those shown, linear interpolation is permitted.
3. The building must be designed for all wind directions using the 8 loading patterns shown. The load patterns are applied to each building corner in turn as the Windward Corner.
4. Combinations of external and internal pressures (see Table 26.11-1) shall be evaluated as required to obtain the most severe loadings.
5. For the torsional load cases shown below, the pressures in zones designated with a "T" (1T, 2T, 3T, 4T, 5T, 6T) shall be 25% of the full design wind pressures (zones 1, 2, 3, 4, 5, 6).
   Exception: One story buildings with h less than or equal to 30 ft (9.1m), buildings two stories or less framed with light frame construction, and buildings two stories or less designed with *flexible diaphragms need not be designed for the torsional* load cases.
   Torsional loading shall apply to all eight basic load patterns using the figures below applied at each Windward Corner.
6. For purposes of designing a building's MWFRS, the total horizontal shear shall not be less than that determined by neglecting the wind forces on the roof.
   Exception: This provision does not apply to buildings using moment frames for the MWRFS.
7. For flat roofs, use θ = 0° and locate the zone 2/3 and zone 2E/3E boundary at the mid-width of the building.
8. The roof pressure coefficient *(GC_{pf})*, when negative in Zone 2 and 2E, shall be applied in Zone 2/2E for a distance from the edge of roof equal to 0.5 times the horizontal dimension of the building parallel to the direction of the MWFRS being designed or 2.5 times the eave height at the windward wall, whichever is less; the remainder of Zone 2/2E extending to the ridge line shall use the pressure coefficient *(GC_{pf})* for Zone 3/3E.
9. Notation:
   a: 10 percent of least horizontal dimension or 0.4h, whichever is smaller, but not less than either 4% of least horizontal dimension or 3 ft (0.9 m).
   h: Mean roof height, in feet (meters), except that eave height shall be used for θ ≤ 10°.
   θ: Angle of plane of roof from horizontal, in degrees.



Torsional Load Cases

Appendix J: Earthquake Loads

Importance Factor		Table 1.5-2	Risk Categroy 3		
Ic	1.25				
Seismic Force-Resisting System					
			R	Omega	Cd
Ordinary Concrete Shear Walls			5	2.5	4.5
Steel Frame					
Using the USGS U.S. Seismic "DesignMap" Web Application					
Ss	0.27	Figure 22-1			
S1	0.09	Figure 22-2			
Site Class A		Table 11.4-1,2			
Fa	0.8				
Fv	0.8				
Sms	0.216	Eq 11.4-1			
Sm1	0.072	Eq 11.4-2			
Sds	0.144	Eq 11.4-3			
Sd1	0.048	E1 11.4-4			
Design Response Spectrum					
TL	6	seconds			
Maximum Earthquake Geometric Meam					
PGA	0.15	Figure 22.7			
Fpga	0.8	From Table 11.8-1			
PGAm	0.12				
Table 11.6-2					
Seismic Deisgn Category		A			
Only apply Section 1.4		Section 11.7			
Use Equation 1.4-1					
Wx		Weight of each story			
Fx	0				

Appendix K: Slab Spreadsheet

Slab Reinforments

floor

f'c	3000	psi
fy	60000	psi
L	13	ft
dl factor	1.2	
ll factor	1.6	
live load	100	psf
theta	0.9	
bar dia	0.375	in
cover	0.75	in

h(2SI)	6.5	in
h(2S2,2S3)	5.5714	in
assume h	6.5	in
assume beam thick	12	in
assume b	12	in
d	5.5625	in

wu	0.3366	kips/ft^2
weight	0.0813	kips/ft^2
wd	0.1766	kips/ft^2
wl	0.1600	kips/ft^2
clear span	12.0000	ft
Mu without moment coefficient	48.4675	ft-kips

B1	0.85	
pb	0.0214	
pmax	0.0155	
.50pmax	0.0077	
m	23.5294	
Rn	422.1649	psi

shear strength theta	0.75	
Max Shear Vu	2.3224	kips/ft of width
theta Vc	5.4841	kips/ft of width
stirrups?	no	

		ASI			AS2			AS3		
	support	middle	support	support	middle	support	support	middle	support	
ACI coff	-24	14	-10	-11	16	-11	-11	16	-11	
Mu	-2.0195	3.4620	-4.8468	-4.4061	3.0292	-4.4061	-4.4061	3.0292	-4.4061	ft-kips
Rn	72.5199	124.3198	174.0477	158.2252	108.7798	158.2252	158.2252	108.7798	158.2252	psi
required rho	0.0013	0.0023	0.0032	0.0029	0.0020	0.0029	0.0029	0.0020	0.0029	
required As	0.1404	0.1522	0.2130	0.1937	0.1404	0.1937	0.1937	0.1404	0.1937	in^2
table 3.9.6 pg 72 As	0.15	0.17	0.22	0.22	0.15	0.22	0.22	0.15	0.22	in^2

min As	0.1404	in^2
Max Spacing	19.5000	

Shrinkage and Temperate Reinforments

	rho					
Grade 60 bars	0.0018			As	0.1404	in^2
				Max Spacing	32.5000	or 18 in
		table 3.9.6 pg 72	As	0.15	in^2	

Appendix L: Slab Sample Calculations

Roof Slab sample calcs - Slab B

$f'_c = 3000psi$

$f_{y_{steel}} = 60{,}000psi$

S1 $L = 13 ft$

S2 $L = 8 ft$

ACI - Table 9.5a

2S1 min $h = \frac{L}{24} = \frac{13(12)}{24} = 6.5''$

2S2 min $h = \frac{L}{28} = \frac{13'(12')}{28} = 5.6''$

S1 = one side continuous

S2,S3 = two side continuous

assume $h = 6.5''$ - same height of slab for ease of construction

assume beam thickness = 12''

Load Factors

$w_u = 1.2D + 1.6L$

$L = 100\ psf$

$D = 150\ pcf\left(h = 6.5''/12\right) = 81.25\ psf$

$w_u = 1.2\left(81.25\ psf/1000\right) + 1.6\left(100/1000\right)$

$\boxed{w_u = .2575\ kips/ft^2}$

clear span of slab S1

$L - \frac{\text{beam th.}}{12} = 13 - \frac{12}{12} = 12'$

clear span of slab S2

$8 - \frac{12}{12} = 7'$

reinforcement ratio ρ_b

$$\rho_b = \frac{0.85\beta_1 f'_c}{f_y}\left(\frac{87{,}000}{87{,}000+f_y}\right)$$

then

if $f'_c > 4000$ $\beta_1 = 0.85 - 0.05\left(\frac{f'_c - 4000}{1000}\right) \geq 0.65$

since $f'_c = 3000$ psi

use $\beta_1 = 0.85$

$$\rho_b = \frac{0.85(0.85)(3000)}{60000}\left(\frac{87{,}000}{87000+60000}\right)$$

$\rho_b = .02138$

$$\rho_{max} = \frac{0.003 + \frac{f_y}{29000000}}{.007}\left(\rho_b\right.$$

$\rho_{max} = 0.0155$

for reasonable deflection control use $\frac{1}{2}\rho_{max}$

$\rho^* = .0077$

$$R_n^* = \rho^* f_y\left(1 - \frac{1}{2}\rho^* m\right)$$

where $m = \frac{f_y}{0.85 f'_c}$

$m = 23.53$

$\therefore$

$R_n^* = .0077(60000)\left(1 - \frac{1}{2}(0.0077)(23.53)\right)$

$R_n^* = 422.16$ psi — based on material properties

M_u without ACI moment coefficients

S1 $\quad w_u L^2 = (.2575)(12')^2 = 37.08$ ft-kips/ft of width

L = clearspan

S2 = $w_u L^2 = (.2575)(7^2) = 12.6175$ ft-kips/ft of width

ACI moment coefficients

S1

	support	middle	support	
	-24	14	-10	
M_u =	-1.545	2.65	-3.708	ft-kips/ft of width

$$M_u = \frac{M_u \text{ without coeff}}{\text{ACI coefficient}}$$

S2

	support	middle	support	
	-11	16	-11	
M_u =	-1.15	.789	-1.15	ft-kips/ft of width

$$R_n = \text{abs}\left[\frac{M_u \times 12000}{\phi(\text{ft of slab})(d)^2}\right]$$

$$d = h - \frac{\text{assume bar } \phi}{2} - \text{clear cover}$$

bar $\phi = .375''$ ⇒ #3 bar

cover $= .75''$ ACI 7.7.1 (c)

$$d = 6.5'' - .375/2 - .75 = 5.56''$$

based on geometry of slab

	support	middle	support	
S1 R_n =	55.48	95.11	133.15	psi
S2 R_n =	41.19	28.3	41.9	psi

required ρ

$$\rho = \frac{(R_n)(\rho^*)}{R_n^*} = \frac{R_n(.0077)}{422.16 \text{ psi}}$$

	support	middle	support
S1 ρ	.0010	.0017	.0024
S2 ρ	.0008	.0005	.0008

$A_s = (\varphi)(\text{ft of width})(d) = \varphi(12")(5.56")$

min $A_s = \varphi(\text{ft of width})(d)$

for Grade 60 steel $\varphi = .0018$ - ACI 7.12.2.1

min $A_s = (.0018)(12")(5.56") = .1404\ in^2$

use A_s if larger then min A_s

S1

	support	middle	support
A_s =	$.0667\ in^2$ ∴ use $.1404\ in^2$	$.1134\ in^2$ ∴ use $.1404\ in^2$	$.1630\ in^2$

S2

	support	middle	support
A_s =	$.05\ in^2$ ∴ use $.1404\ in^2$	.03 ∴ use $.1404\ in^2$	$.05\ in^2$ ∴ use $.1404\ in^2$

based on required A_s choose A_s from table 3.9.6 of Reinforced Concrete Design by Wang, Salmon, Pincheira

max spacing = $3(h) = 3(6.5) = 19.5''$

Shrinkage and Temperature Reinforcements

$A_s = \rho b h = .1404 \text{ in}^2$

$\rho = .0018$ for Grade 60 steel
b = foot of width of slab
$h = 6.5$

use table 3.9.6 to select steel size

max spacing $s = 5(h) = 5(6.5) = 32''$ or $18''$ whichever is less - ACI 7.12.2.2

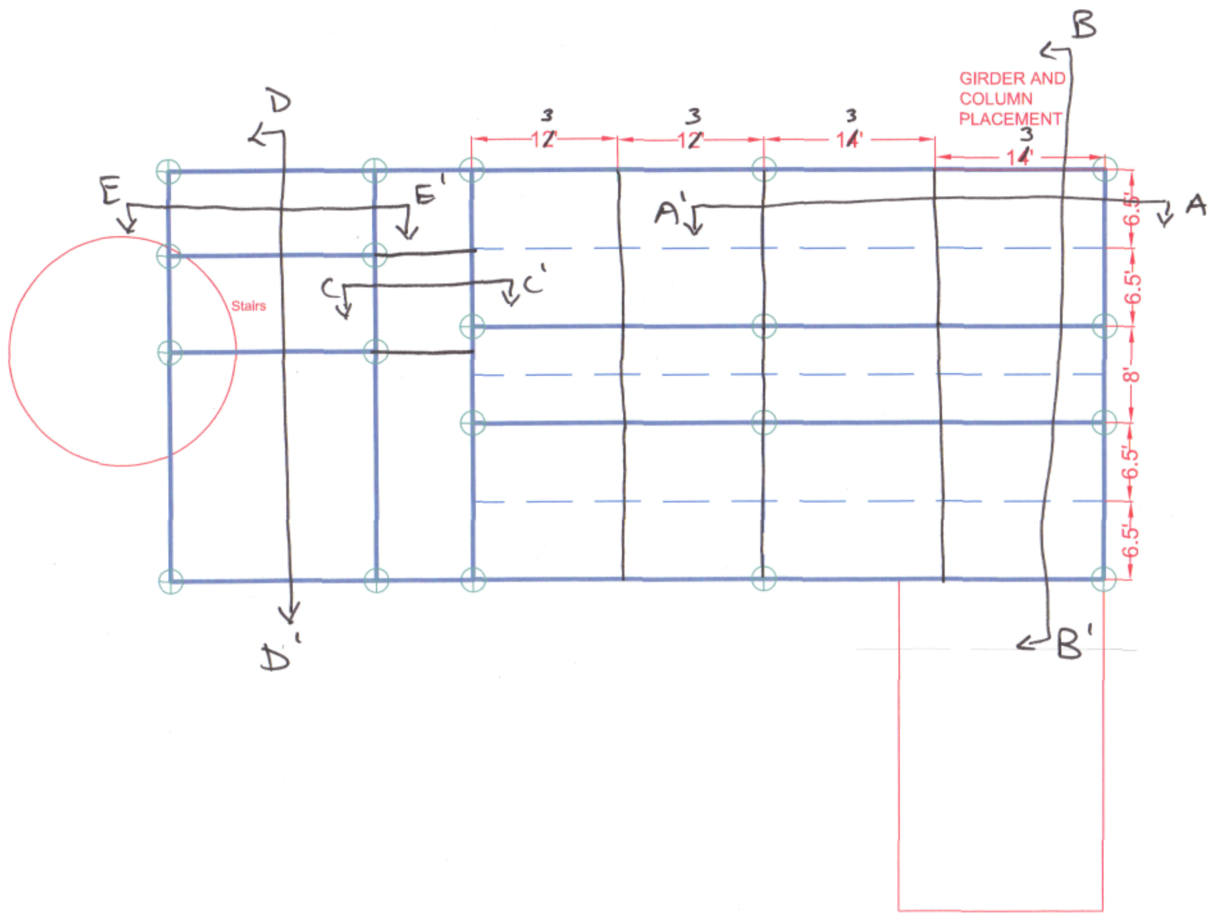
∴ use 18" spacing

Use same method to analyze

section AA', BB', CC', DD', EE'

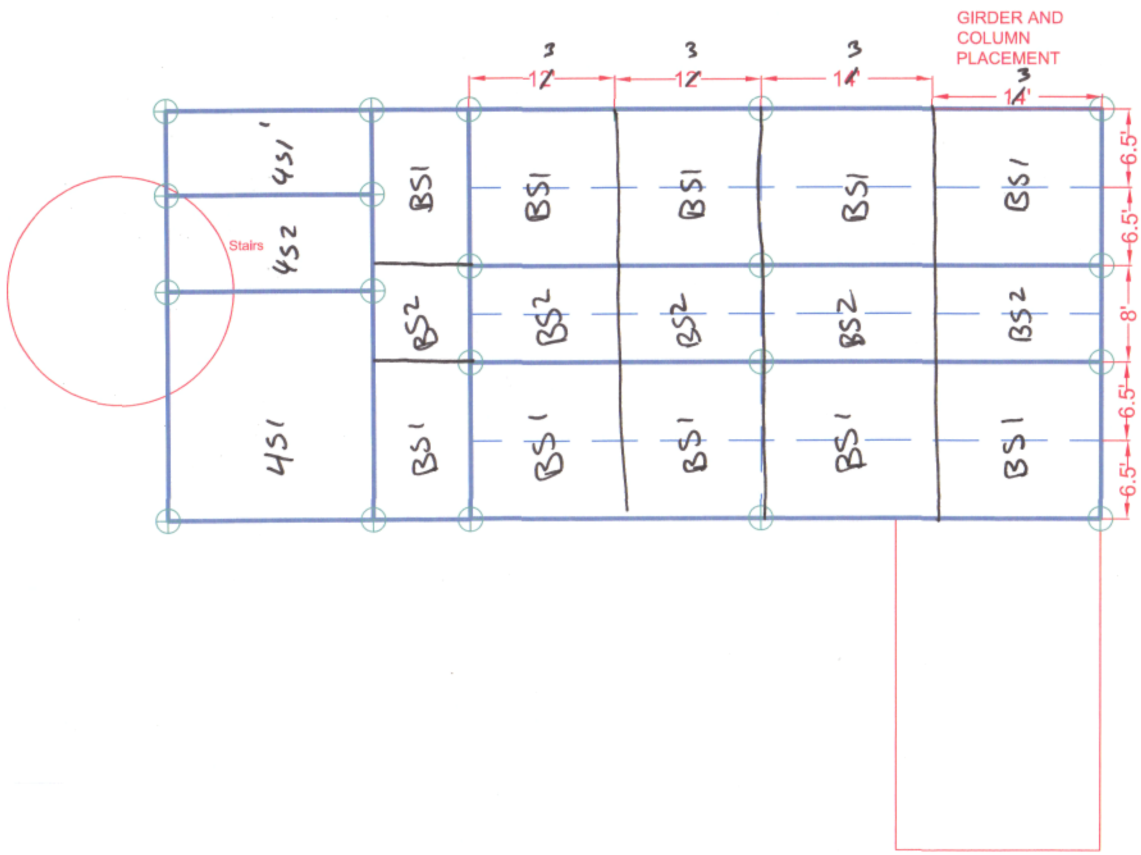
Each Roof Slab Section has a corresponding
Excel table labeled A, B, C, D, E.

To limit spacing differences of beams we chose slab B & D
designs.



GIRDER AND
COLUMN
PLACEMENT
12'
12'
14'
14'
3
3
3
3
6.5'
6.5'
8'
6.5'
6.5'
Stairs
A
A'
B
B'
C
C'
D
D'
E
E'

SlAB LAYOUT



GIRDER AND
COLUMN
PLACEMENT
12'
12'
14'
14'
3
3
3
3
6.5'
6.5'
8'
6.5'
6.5'
Stairs
4S1
4S2
4S1
BS1
BS2
BS1
BS1
BS2
BS1

Appendix M: Beam Spreadsheets

	floor				
girder width	10	in			
L	13	ft	rho b	0.02138	
f'c	3000	psi	rho max	0.015482	
fy	60000	psi	rho min	0.003333	
ecu	0.003				
Es	29000000	psi	m	23.52941	
B1	0.85		Rn	741.1765	psi
rho	0.015		Mu	42.03705	psi
theta	0.9		require Mn	46.70784	psi
Ln	12.16667	ft	required bd^2	756.2221	in^3
Md factor	1.2				
Ml factor	1.6				
cover	1.5	in			
bar diamet	1	in			
stirrup dia	0.375	in			
slabDL factored	0.17658	kips/ft^2			
Slab length	13				
D. Load	2.29554	kips/ft	Max Positive M		
L Load	4.16	kips/ft	ACI coeff	24	
asmd beam weight	0.36	kips/ft			
Md	16.3789	ft-kips			
Ml	25.65815	ft-kips			

Check strength

T	47.4	kips	es	0.020493	tension	theta	0.9
a	1.858824	in	theta Mn	57.57532	check		
Mn	63.97257	ft-kips					
s max	8.5625		use 6.5" spacing after 5 feet through out for shear reinforcement				

b	d	h	
10	8.6961	11.571	fall between 1.5 to 2 times b
12	7.9384	10.813	
14	7.3495	10.225	
8	9.7225	12.598	

b	10	h fall between 1.5 to 2 times b	
h	20	min h	8.432432

revised w	0.25	kips/ft
revised Md	15.7	ft-kips
revised Mu	41.359	ft-kips
revised Mn	45.954	ft-kips
actual d	17.125	
required Rn	188.04	
approx rho	0.0038	
approx As	0.6517	

Actual As	0.8	1#8 bar	check spacing	6.375	check
dia bar	1				

Shear Requirement

phi	0.75		Av	0.11	in^2
wu	6.70554	kips/ft	fy	40	ksi
Vu midspan	6.326667				
Vu support	40.79204		Vs max	75.03799	

simplified method

x	Vu(kips)	phiVc(kip	Vs(kips)	s(in)
1.8438	35.49657	16.432	19.06	3.9523
3	32.17569	16.432	15.74	4.7859
4	29.30358	16.432	12.87	5.8538
5	26.43146	16.432	10	7.5352
6	23.55935	16.432	7.128	10.571
7	20.68724	16.432	4.256	17.706
7.5	19.25118	16.432	2.82	26.725

Appendix N: Beam Sample Calculations

Beam Sample Calcs

D.L = 1.62 $\quad L_n = 12.166 = 13\text{ft} - \text{column with } 10''$

L.L = 4.16

assume beam weight = .36

$$M_d = \frac{D.L + \text{beam weight}\,(L_n^2)}{\text{ACI coeff.}} = \frac{(1.62 + .36)(12.166^2)}{24}$$

$$M_d = 12.24$$

$$M_\ell = \frac{L.L\,(L_n^2)}{\text{ACI coeff}} = \frac{(4.16)(12.166^2)}{24} = 25.69$$

$$\rho_b = \frac{(.85)(f'_c)}{f_y}\,\beta_1\left(\frac{\epsilon_{cu}}{\epsilon_u + \frac{f_y}{E_S}}\right) = 0.02138$$

$f'_c = 3000$ psi
$f_y = 60000$ psi
$\epsilon_{cu} = .003$
$E_s = 29000000$ psi

$$\rho_{max} = \frac{.003 + \frac{f_y}{E_S}}{.007\ \rho_b}\,\rho_b = .015$$

$$\rho_{min} = \frac{3\left(f_c^{\frac{1}{2}}\right)}{f_y},\ \frac{200}{f_y} \Leftarrow \text{greater of 2}$$

$$= \frac{200}{f_y} = .0033\ \checkmark$$

$$= \frac{3f_c^{1/2}}{f_y} = .0027$$

choose ρ between values $\Rightarrow \rho = .015$

$m = \frac{f_y}{.85 f'_c} = 23.5$

$R_n = \rho f_y(1 - .5\rho m) = 741.2 psi$

$M_u = M_d + M_e = 37.9$ psi

requir $M_n = \frac{M_u}{\phi} = \frac{37.9}{.9} = 42.1$ psi

required $bd^2 = \frac{M_u \times 12000}{\phi R_n} = 681.7931 in^3$

choose b and calculate d^2 from bd^2

$8'' = b \quad d = 9.23$

Choose 8" and choose d = 18" ⇒ for strength check

revise weight with new size

$1.2\left[\frac{(bh)}{144} \times \rho\right] = weight = .18$ kips/ft

$\rho = .15$

new $M_d = \left[\frac{DL + \text{revised weight}}{\text{ACI coeff.}}\right]\left[L_n^2\right] =$

$\left[\frac{1.624 + .18}{24}\right]\left[12.16^2\right] = 11.11$ ft-kips revised M_u = M_c + revised M_d = 36.8 ft-kips

revised M_n = 40.88

actual d = h - cover - bar radius - stirrup ϕ

cover = 1.5"
bar radius = 1"
stirrup ϕ = .375"

h = 18

d = 15.125

$$\text{require } R_n = \frac{M_n \times 12000}{h \times d} = 268.03\text{ psi}$$

$$\rho = \text{original } \rho \left(\frac{\text{required } R_n}{\text{original } R_n}\right) = .015\left(\frac{268.03}{741.18}\right) = .005$$

$$A_s = \rho b d = .005(8)(15.125) = .656 \text{ in}$$

choose area of steel larger than A_s

Check strength

$$T = \frac{\text{area of steel} \times f_y}{1000} = 47.4 \text{ kips}$$

$$a = \frac{T}{(.85)\left(\frac{f'_c}{1000}\right)(b)} = 2.32"$$

$$M_n = \frac{T\left(d - \frac{a}{2}\right)}{12} = 55.15 \text{ ft-kips}$$

$$\phi M_n = \phi = .9 \times 53.15 = 49.64 \text{ ft-kips}$$

$$\phi M_n > M_u \quad \checkmark$$

Appendix O: Exterior Beam Spreadsheet

Long Exterior Girder

	L	13	ft
Negative	M comb	46.647	ft-kips
Positive	M3	43.691	ft-kips

cover	1.5	in
bar dia	1.128	in
stirrup dia	0.375	in

beam	inches	column
b	10	10
h	16	10
d	12.997	

Negative Moment

As	0.911507	in^2	
use	2#7		
As	1.2	in^2	
T	72	k	
a	2.823529		
Mn	69.51141	ft-kips	
phi Mn	55.60913	ft-kips	checks
es	0.008738	checks	

Positive Moment

As	0.853745	in^2
use	1# 9	
As	1	in^2
T	60	
a	2.352941	
Mn	59.10265	
phi Mn	47.28212	checks
es	0.064906	checks

column wic	10	ft
f'c	3000	psi

Shear Requirement

phi	0.75	Av	0.11	in^2
		fy	40	ksi
Vu midspan	3.336			
Vu support	24.461	Vs max	56.95	

simplified method

x	Vu(kips)	phiVc(kips)	Vs(kips)	s(in)
1.49975	21.82082	13.14534	8.675474	6.591778
3	19.17975	13.14534	6.034409	9.476786
4	17.41933	13.14534	4.273992	13.38018
5	15.65892	13.14534	2.513575	22.75118
6	13.8985	13.14534	0.753159	75.92929
7	12.13808	13.14534	-1.00726	-56.7747
7.5	11.25788	13.14534	-1.88747	-30.2982

s max 6.4985 throughout

Appendix P: Exterior Beam Calculations

Exterior Beams

RISA = Negative & Positive Moments

choose b, h = 10", 10"

cover = 1.5"
bar ϕ = 1.128"
stirrup ϕ = 0.375"

d = h - cover - bar ϕ - stirrup ϕ

d = 12.997

process for both negative & positive reinforcement

$$A_s = \left[\frac{M_u}{(.9)(60)(.975)(d)}\right]\left[12\right] = 0.911\ in^2$$

M_u = 46.647 ft-kips

Choose A_s larger than 0.911 in^2

$A_s = 1.2\ in^2$

Check moment capacity

$T = A_s \times 60 = 72^k$

$$a = \frac{T}{(0.85)\left(\frac{f'_c}{1000}\right)(b)} = 2.82''$$

$$M_n = \frac{T\left(d - \frac{a}{2}\right)}{12} = 61.5\ \text{ft-kips}$$

$\phi M_n = 0.9(61.5) = 55.61$ ft-kips

$\phi M_n > M_u$ ✓

Appendix Q: Column Spreadsheets

CORNERS

in frame							
	Pu	145.857	kips	slenderness ratios			
RISA 2D	M1	-16.238	ft-kips				
	M2	16.339	ft-kips	bending in frame			
clear spacing	lu	10	ft				
					k	0.5	
perpendicular	b	10	in		r	3	
in frame	h	10	in		ratio	20	column short
	d	7	in				
	cover	3	in		34-12(m1/m2)	45.92582	
perpendicular				bending perpendicular to frame			
RISA 2D	M1	-23.933	ft-kips				
	M2	23.933	ft-kips		k	0.5	
					r	3	
					ratio	20	column short
					34-12*(m1/m2)	46	

Coordinates for ACI interaction curves

Pu/Ag	1.45857	kips/in^2
e	1.344248	in
(Pn/Ag)*(e/h)	0.196068	

estimate yh= 7.5 in
y 0.75

Ast 1 in^2

use 4#5bar bar As=1.24 | bar dia 0.625 in

use table to find rho
rho 0.01

max spacing of ties

tie dia 0.5 in

use least of

1) 10 in
2) 24 in
3) 10 in

max spacing 10 in

ties
use #4 10 in

f'c 3000 psi

Shear			checks			checks
	frame			perpendicular		
Vu	3.2577	kips		Vu	4.7866	
Vc	13.26036	kips		Vc	13.26036	
phi	0.85			phi	0.85	
phiVc/2	5.635652	kips		phiVC/2	5.635652	

Appendix R: Column Sample Calculations

Column Design (Interior & Exterior)
(parallel & perpendicular)

from Risa 2D

P_u, M_1, M_2

$M_1 = -11.23$ ft-kips
$M_2 = 22.451$ ft-kips

$l_u = 10'$

$d = h - \text{cover} = 10 - 3 = 7''$

$k = 0.5$ for fixed top & bottom of column.

$r = 0.3(h) = 3$

ratio $= \dfrac{(0.5)(l_u/12)}{r} = 20$

$34 - 12\dfrac{M_1}{M_2} = 40.00$

because $20 < 40.00$ = column is short

use interaction diagrams to get $\rho = .01$

$A_{steel} = \rho bh = (.01)(10)(10)$

$A_{steel} = 1\ in^2$

choose A_s greater than $1\ in^2$

bar $\phi = .625$
tie $\phi = .5$

tie spacing least of
1) $16(\text{bar } \phi) = 10''$
2) $48(\text{tie } \phi) = 24''$
3) smallest of $b, h = 10''$

spacing $= 10''$

Check Shear $P_u = 68.874$ kips

$$V_u = \frac{M_2 + abs(M_1)}{l_u} = 3.37 \text{ kips}$$

$$\frac{\phi V_c}{2} = \frac{(0.85)\left(2 \times \left(1 + \left(\frac{P_u \times 1000}{(2000)(b)(h)}\right)\right) * \frac{f_c'^{\frac{1}{2}}}{1000} \times b \times d\right)}{2}$$

$$\frac{\phi V_c}{2} = 4.38 \text{ kips}$$

$$\frac{\phi V_c}{2} > V_u \checkmark$$

Appendix S: Steel Design Simple Beam Spreadsheet

Beam Design						
Parameters						
tributary width	13	ft				
Length (span)	13	ft				
Slab Thickness	4	in				
DeckThickness	0.5	in				
Deck rib widths	2.5	in				
MEP	6	psf				
Insulation	5	psf				
Ceiling/Stone Decking	13	psf				
Concrete Weight	145	lb/ft^3				
DL	1.003166667	k/ft				
LL	2.6	k/ft				
Construction LL	20	psf				
DL factor	1.2					
LL factor	1.6					
f'_c	3	ksi				
f_y	50	ksi				
b_e	39					
b_e	156					
LRFD						
w_u	5.3638	k/ft				
M_u	113.3	ft-k				
a. Select steel beam for composite action						
Refer to table 3-2 and choose beam with a φMpx value higher than Mu						
Beam Chosen	W10 x 26					
A	7.61	in^2				
d	10.3	in				
t_w	0.26	in				
ΣQ_n	380.5	k				
a req'd	3.83	in	<	4	in	checks
φbMpx	117	ft-k				
Check for Local Buckling/Compact Criteria						
FLB = bf/2tf (Table 1-1 AISC)	6.56		<	9.2		Checks
WLB = h/tw (Table 1-1 AISC)	34		<	90.5		Compact
Recalculate DL including selected beam weight						
Beam Weight	26.0	lbs/ft				
DL	1.029	k/ft				
Recalculate LRFD Loading Conditions						
w_u	5.40	k/ft				
M_u	114.0	ft-k				
φbMn interp.	117.0	ft-k	>	114.0	ft-k	checks
c. Check Strength of W Section Before Concrete Hardens						
Assume that the wet concrete is a LL during construction, and also add a 20psf construction live load						
Concrete wt	776.3	lbs/ft				
Other DL	26	lb/ft				
LRFD	802.3	lbs/ft				
w_u	1.69	k/ft				
M_u	35.7	ft-k	<	117.0	ft-k	checks
d. Service Load Deflection Before Concrete Hardens. (AISC Table 1-1)						
I_x	144	in^4			1.9797E+11	5wDL^4
Use w_D	1.06	k/ft			1.60358E+12	384EIx
M_D	22.4	ft-k			0.123454534	Delta
Deflection = (5wL^4)/(384EIx)	0.123454534	in				
	0.12	in	<	0.433333	in	checks
e. Service LL Deflection Post Construction						
Live Load	2.6	ft-k	2600			
Ix	144	in^4				
Δ = (5wL^4)/(384EIx)	0.400100216	in	<	0.433333		Checks
f. Check Shear						
LRFD						
w_u	5.395	k/ft				
V_u	35.1	k				
ϕV_n from AISC T3-6	140	k	>	35.1	k	checks
h. Cost Estimate						
Beam weight	0.013	ton/ft				
Beam spacing	13	ft				
Beam span	13	ft				
Cost structural steel	$2,500					
Cost ($/sf)	**$ 2.50**	**per sf**				

Appendix T: Steel Beam Sample Calculations

Example Hand Calculation For the Design of a gravity resisting beam.

Corresponds w/ spreadsheet B1, Roof Beam

Tributary width = 13'

Beam Span = 13'

Slab Thickness = 4"

MEP = 6 psf

Insulation = 5 psf

Ceiling + Stone Roof Decking = 13 psf

Concrete weight = 145 lb/ft³

$$\text{Dead load} = \frac{\left((6\text{ psf})(13') + (5\text{psf} \times 13') + (13\text{ psf} \times 13') + (145\text{ lb/ft}^3 \times 13' \times 4/12')\right) \times 1.1}{1000}$$

Dead load = 1.003 k/ft

Live Load = 200 psf

$$\text{Live load} = \frac{(200)(13)}{1000} = 2.6\text{ k/ft}$$

Construction LL = 20 psf

Factored Load = 1.2D + 1.6L

= 1.2 (1.003) + 1.6(2.6) = 5.3638 k/ft = W_u

$$M_u = \frac{W_u L^2}{8} = \frac{(5.3638)(13\text{ ft})^2}{8} = \boxed{113.3\text{ ft-k}}$$

a) Select W section form Table 3-2 AISC steel Construction Manual

Section Chosen: W10x26

$\phi_b M_{px}$ = 117 ft-k (Table 3-2)

Check for compactness

FLB = $b_f/2t_f$ = 6.56 (T1-1 AISC) 6.56 < 9.2

WLB = h/t_w = 34 (T1-1 AISC) 34 < 90.4

} Section is compact

Recaculate M_u with selected beam weight

Beam wt. = 26 plf

New DL = $\left(\frac{26}{1000}\right) + 1.003$ k/f

New DL = 1.029 k/f

Recalculate LRFD loading Conditions

New factored load = $1.2D + 1.6L = 1.2(1.029) + 1.6(2.6) = 5.4$ k/f

New moment = 114 ft-K

$\phi_b M_{Px} = 117$ ft-kips > 114 ft-k ($\phi_b M_n$) OK

Check Strength during Construction

- wet concrete is a Live Load
- add 20 psf construction L.L.

Concrete weight = $(145 \text{ lbs/ft}^3)(13' \times 4/12)(1.1) = 776.3$ lbs/ft

other DL = 26 lb/ft

Total DL = 802.3 lbs/ft

$W_u = 1.2(.026) + 1.6(776.3 + 260) = 1.657$ k/ft

Construction $M_u = \frac{(1.657)(13)^2}{8} = 35.7$ ft-k < 117 ft-k OK

Check Deflection - Construction

$I_x = 144 \text{ in}^4$ (T1.1 AISC)

W = 802.3 lbs/ft

Deflection = $\frac{5wL^4}{384EI_x} = \frac{5(802.3/12)(13 \times 12)^4}{384(29 \times 10^6)(144)} = .1234''$

Acceptable Deflection = $L/360 = (13 \times 12)/360 = .433$ in

.1234" < .433" OK

Service Deflection

Live Load = 2.6 K-ft

$w = 2.6 \times 1000 = 2{,}600$ lbs

$I_x = 144$ in^4

$$\Delta = 5wL^4 / 384EI_x = \frac{5(2600/12)(13 \times 12)^4}{384(29 \times 10^6)(144)} = .4 \text{ in} < .433 \text{ inches}$$

OK

Check Shear

$W_u = 5.4$ K/ft

$$V_u = \frac{wL}{2} = \frac{(5.4)(13)}{2} = 35.1 \text{ Kips}$$

ϕV_n for 13' W10x26, Table 3-6 AISC } $\phi V_n = 140$ Kips $>$ 35.1 Kips

OK

Appendix U: Steel Column Design Spreadsheet

Gravity Load-Interior Roof Column Design

Tributary Area	136.5	sq. ft.				
Concrete Slab Thickness	4	in				
Deck Thickness	0.5	in				
Deck Rib Width	2.5	in				
MEP	6	psf				
Insulation	5	psf				
Ceiling/Stone Decking	13	psf				
Concrete Weight	145	lb/ft^3				
Dead Load	10.53325	kips				
Live Load	200	psf				
Live Load (Calc.)	27.3	kips				
Dead Load Factor	1.2					
Live Load Factor	1.6					
f'_c	3	ksi				
f_y	50	ksi				
Length	10	feet				
b_e	409.5					
b_e	0					
LRFD						
Pu	56.3199	kips				
Load Contributed from Above Floor	0	kips				
Total Pu	56.3199	kips				
Initial selection of Section						
Assume (KL/r) = 75	75					
ΦcFcr	29.8	From Table 4-22 AISC				
Area Rqd	1.88992953	square inches				
Choose Initial Section						
Section	W10x12					
K	1	(Not a part of moment resisting frame)				
Area	3.54	square inches				
rx	3.9	in				
ry	1.74	in				
(KL/r)x	30.76923077					
(KL/r)y	68.96551724	Larger, Governs				
ΦcFcr (Table 4-22 AISC)	31.812	ksi				
ΦcPn	112.61448	kips	>	56.3199	Kips	Checks
Verify Initial Section	(Moment Resisting Frame Only)					
Calculate K						
Node A-Column	N/A					
Ix	N/A	in^4				
Node A-Girders	N/A		**Girder Length**	13	ft	
Ix	118	in^4				
GA	#VALUE!					
Node B-Columns	N/A					
Ix	53.8	in^4				
Node B-Girders	N/A		**Girder Length**	13	ft	
Ix	130	in^4				
GB	N/A					
New K	N/A	Alignment Chart, Sidesway Uninhibited				
(KL/r)x	76.92307692					
ΦcFcr (Table 4-22 AISC)	N/A	ksi				
ΦcPn	#VALUE!	kips	>	56.3199	**OK**	

Appendix V: Gravity Column Sample Calculations

Gravity Resiting Column

Tributary Area = 136.5 ft²

Concrete Slab Thickness = 4"

MEP = 6 psf

Insulation = 5 psf

Ceiling/Stone Decking = 13 psf

Concrete weight = 145 lbs/ft³

$$\underline{\text{Dead load}} = \frac{(13\ \text{psf} \times 136.5\ \text{ft}^2) + (5 \times 136.5) + (6 \times 136.5) + (136.5 \times 4/12 \times 145) \times 1.1}{1000}$$

$$= \boxed{10.53\ \text{Kips}}$$

$$\text{Live load} = (200\ \text{psf})(136.5\ \text{ft}^2) = 27.3^{K}$$

$$\text{Factored Load} = 1.2D + 1.6L = 1.2(10.53) + 1.6(27.3) = 56.39\ \text{Kips}$$

$\boxed{P_u = 56.39\ \text{Kips}}$ → no load contributed from above floor since this column supports roof.

Selection of Section

Assume $\left(\frac{KL}{r}\right)_y = 75$ for $\phi_c F_{cr} = 29.8$ Kips (Table 4-22 AISC) aid in selection.

$$\text{Area Required} = \frac{P_u}{\phi_c F_{cr}} = \frac{56.39}{29.8} = \underline{1.889\ \text{in}^2}$$

Choose W10x12 (Area = 3.54 in², Table 1-1 AISC)

K = 1 (Gravity Load only, not part of moment resisting frame)

$A = 3.54\ \text{in}^2$ $r_x = 3.9$ $r_y = 1.74$

$$\left(\frac{KL}{r}\right)_x = \frac{(1)(10)}{3.9} \qquad \left(\frac{KL}{r}\right)_y = \frac{(1)(10)}{1.74}$$

$$\left(\frac{KL}{r}\right)_x = 30.76 \qquad \boxed{\left(\frac{KL}{r}\right)_y = 68.96} \Rightarrow \text{governs}$$

50 Ksi Steel | 50 Ksi steel ②

$\phi_c F_{cr}$ for $\frac{KL}{r} = 68 \Rightarrow 32.1$ ksi $\phi_c F_{cr}$ for $\frac{KL}{r} = 69 \Rightarrow 31.8$ ksi

Interpolation

$$\frac{32.1 - 31.8}{68 - 69} = -.3(.96) = -.288$$

$\phi_c F_{cr}$ for $\frac{KL}{r} = 68.96 \longrightarrow 31.812$ ksi

$\phi_c P_n = \phi_c F_{cr} \times \text{Area} = (31.812)(3.54) = 112.61$ Kips

$\phi_c P_n = 112.61$ Kips $> P_u = 56.319$ Kips

OK

Appendix W: Lateral Design Spreadsheet

Exterior Beam Top

Column 1

W10x22			
Ix	118	in^4	
K2	1.33		
Length	10	ft	
Pnt	18.26	kips	
Plt	0.182	kips	
Mnt	-36.647	ft-kips	
Mlt	2.725	ft-kips	
M1	17.253	ft-kips	
E	29000	ksi	
α	1	LRFD	
Ky	1		
Kx	1.33		
Rx	4.27	inches	
Ry	1.33	inches	
Pe2	**1325.907548**		
ΣPe2	10148.35333		
ΣPnt	208.63	kips	
B2 Amplifier			
B2	1.020989518		
B1 Amplifier			
Cm = .6 ± .4(M1/M2)	0.411684449		
Pe1 = Π^2EI/(K1L)^2	2345.397861		
Pr = Pnt +B2xPlt	18.44582009	kips	
B1 = Cm/1-(αPr/Pe1)	0.414947884	B1 < 1 so B1 = 1.0	
	1		
Required 2nd Order Strength Values			
Pr = Pnt + B2xPlt	18.44582009		
Mr = B1xMnt + B2xMlt	39.42919644	ft-kips	
	39.42919644		

Interaction Equations

KyL/Ry	90.22556391	Governs	
KxL/Rx	37.37704918		
KyL	10	Feet	
Available Axial Strength	ΦcPn = Pc		
ΦcPn = Pc	159.36	kips	AISC Table 4-22 and Table 1-1
Pr/Pc	0.115749373	Use Equation H1-1b	
Mrx	39.42919644	ft-kips	
Mcx	76.184	Interpolate Strength Value through Interpolation of Lp, Lr	
Mry	0	No bending about minor axis; beam oriented within plane	
Mcy	0		
Equation H1-1b			
Pr/2Pc + (Mrx/Mcx + Mry/Mcy) ≤ 1	0.517915365	≤ 1 OK	
Sway (From RISA)	0.125	inches	

Column 2

W10x22			
Ix	118	in^4	
K2	1.27		
Length	10	ft	
Pnt	36.074	kips	
Plt	0.15	kips	
Mnt	22.429	ft-kips	
Mlt	3.254	ft-kips	
M1	-11.891	ft-kips	
E	29000	ksi	
α	1	LRFD	
Ky	1		
Kx	1.3		
Rx	4.27		
Ry	1.33		
Pe2	**1454.15**		
ΣPe2	10148.35		
ΣPnt	208.63	kips	
B2 Amplifier			
B2	1.02099		
B1 Amplifier			
Cm = .6 + - .4(M1/M2)	0.387935		
Pe1 = Π^2EI/(K1L)^2	2345.398		
Pr = Pnt +B2xPlt	36.22715		
B1 = Cm/1-(αPr/Pe1)	0.394021	B1 < 1 so B1 = 1.0	
	1		
Pr = Pnt + B2xPlt	36.22715		
Mr = B1xMnt + B2xMlt	25.7513	ft-kips	
	25.7513		
KyL/Ry	90.22556	Governs	
KxL/Rx	36.53396		
Available Axial Strength	ΦcPn = Pc		
ΦcPn = Pc	159.36	kips	AISC Table
Pr/Pc	0.227329	Use Equation H1-1a	
Mrx	25.7513	ft-kips	
Mcx	76.184	Interpolate Strength V	
Mry	0	No bending about mir	
Mcy	0		
Equation H1-1a			
Pr/Pc +(8/9)* (Mrx/Mcx + Mry/Mcy) ≤ 1	0.301884	≤ 1 OK	
Sway (From RISA)	0.125	inches	

Column 3

W10x22		
Ix	118	in^4
K2	1.26	
Length	10	ft
Pnt	30.483	kips
Plt	-0.141	kips
Mnt	-10.735	ft-kips
Mlt	3.245	ft-kips
M1	4.788	ft-kips
E	29000	ksi
α	1	LRFD
Ky	1	
Kx	1.29	
Rx	4.27	
Ry	1.33	
Pe2	**1477.322916**	
ΣPe2	10148.35333	
ΣPnt	208.63	kips
B2 Amplifier		
B2	1.020989518	
B1 Amplifier		
Cm = .6 + - .4(M1/M2)	0.42159292	
Pe1 = Π^2EI/(K1L)^2	2345.397861	
Pr = Pnt +B2xPlt	30.33904048	
B1 = Cm/1-(αPr/Pe1)	0.427117931	B1 < 1 so B1 = 1.0
	1	
Pr = Pnt + B2xPlt	30.33904048	
Mr = B1xMnt + B2xMlt	14.04811099	ft-kips
KyL/Ry	90.22556391	Governs
KxL/Rx	36.2529274	
Available Axial Strength	ΦcPn = Pc	
ΦcPn = Pc	159.36	kips AISC Table 4-1
Pr/Pc	0.190380525	Use Equation H1-1b
Mrx	14.04811099	ft-kips
Mcx	76.184	Interpolate Strength Value through Interpolation of Lp, Lr
Mry	0	No bending about minor axis; beam oriented within plane
Mcy	0	
Equation H1-1a		
Pr/2Pc + (Mrx/Mcx + Mry/Mcy) ≤ 1	0.184994459	≤ 1 OK
Sway (From RISA)	0.125	inches

Column 4

W10x22		
Ix	118	in^4
K2	1.25	
Length	10	ft
Pnt	35.936	kips
Plt	0.021	kips
Mnt	-17.652	ft-kips
Mlt	3.245	ft-kips
M1	9.221	ft-kips
E	29000	ksi
α	1	LRFD
Ky	1	
Kx	1.25	
Rx	4.27	in
Ry	1.33	in
Pe2	**1501.055**	
ΣPe2	10148.35	
ΣPnt	208.63	kips
B2 Amplifier		
B2	1.02099	
B1 Amplifier		
Cm = .6 + - .4(M1/M2)	0.391049	
Pe1 = Π^2EI/(K1L)^2	2345.398	
Pr = Pnt +B2xPlt	35.95744	kips
B1 = Cm/1-(αPr/Pe1)	0.397138	B1 < 1 so B1 = 1.0
	1	
Pr = Pnt + B2xPlt	35.95744	
Mr = B1xMnt + B2xMlt	20.96511	ft-kips
KyL/Ry	90.22556	Governs
KxL/Rx	35.12881	
Available Axial Strength	ΦcPn = Pc	
ΦcPn = Pc	159.36	kips AISC Table 4-22
Pr/Pc	0.225637	Use Equation H1-1a
Mrx	20.96511	ft-kips
Mcx	76.184	Interpolate Strength Value through Interpola
Mry	0	No bending about minor axis; beam orientec
Mcy	0	
Equation H1-1a		
Pr/Pc +(8/9)* (Mrx/Mcx + Mry/Mcy) ≤ 1	0.24603	≤ 1 OK
Sway (From RISA)	0.125	inches

Column 5			Column 6			Column 7		
W10x22			**W10x22**			**W10x22**		
Ix	118	in^4	Ix	118	in^4	Ix	118	in^4
K2	1.25		K2	1.25		K2	1.3	
Length	10	ft	Length	10	ft	Length	10	ft
Pnt	34.898	kips	Pnt	36.752	kips	Pnt	16.227	kips
Plt	0.009	kips	Plt	0.099	kips	Plt	-0.32	kips
Mnt	17.739	ft-kips	Mnt	-20.736	ft-kips	Mnt	27.051	ft-kips
Mlt	3.67	ft-kips	Mlt	4.119	ft-kips	Mlt	3.902	ft-kips
M1	-8.216	ft-kips	M1	11.082	ft-kips	M1	-12.508	ft-kips
E	29000	ksi	E	29000	ksi	E	29000	ksi
α	1	LRFD	α	1	LRFD	α	1	LRFD
Ky	1		Ky	1		Ky	1	
Kx	1.25		Kx	1.25		Kx	1.3	
Rx	4.27	in	Rx	4.27	in	Rx	4.27	in
Ry	1.33	in	Ry	1.33	in	Ry	1.33	in
Pe2	**1501.055**		**Pe2**	**1501.055**		**Pe2**	**1387.809**	
ΣPe2	10148.35		**ΣPe2**	10148.35		**ΣPe2**	10148.35	
ΣPnt	208.63	kips	**ΣPnt**	208.63	kips	**ΣPnt**	208.63	kips
B2 Amplifier			**B2 Amplifier**			**B2 Amplifier**		
B2	1.02099		**B2**	1.02099		**B2**	1.02099	
B1 Amplifier			**B1 Amplifier**			**B1 Amplifier**		
Cm = .6 + - .4(M1/M2)	0.414736		**Cm = .6 + - .4(M1/M2)**	0.386227		**Cm = .6 + - .4(M1/M2)**	0.415046	
Pe1 = Π^2EI/(K1L)^2	2345.398		**Pe1 = Π^2EI/(K1L)^2**	2345.398		**Pe1 = Π^2EI/(K1L)^2**	2345.398	
Pr = Pnt +B2xPlt	34.90719	kips	**Pr = Pnt +B2xPlt**	36.85308	kips	**Pr = Pnt +B2xPlt**	15.90028	kips
B1 = Cm/1-(αPr/Pe1)	0.421002	B1 < 1 so B1 = 1.0	**B1 = Cm/1-(αPr/Pe1)**	0.392392	B1 < 1 so B1 = 1.0	**B1 = Cm/1-(αPr/Pe1)**	0.417879	B1 < 1 so B1 = 1.0
	1			1			1	
Pr = Pnt + B2xPlt	34.90719		**Pr = Pnt + B2xPlt**	36.85308		**Pr = Pnt + B2xPlt**	15.90028	
Mr = B1xMnt + B2xMlt	17.739	ft-kips	**Mr = B1xMnt + B2xMlt**	24.94146	ft-kips	**Mr = B1xMnt + B2xMlt**	31.0349	ft-kips
KyL/Ry	90.22556	Governs	**KyL/Ry**	90.22556	Governs	**KyL/Ry**	90.22556	Governs
KxL/Rx	35.12881		**KxL/Rx**	35.12881		**KxL/Rx**	36.53396	
Available Axial Strength	ΦcPn = Pc		**Available Axial Strength**	ΦcPn = Pc		**Available Axial Strength**	ΦcPn = Pc	
ΦcPn = Pc	161.6	kips AISC Table 4-1	**ΦcPn = Pc**	161.6	kips AISC Table 4-1	**ΦcPn = Pc**	161.6	kips
Pr/Pc	0.21601	Use Equation H1-1a	**Pr/Pc**	0.228051	Use Equation H1-1a	**Pr/Pc**	0.098393	Use Equation H1-1b
Mrx	17.739	ft-kips	**Mrx**	24.94146	ft-kips	**Mrx**	31.0349	ft-kips
Mcx	76.184	Interpolate Strength Value through Interpola	**Mcx**	76.184	Interpolate Strength Value throug	**Mcx**	76.184	
Mry	0	No bending about minor axis; beam orientec	**Mry**	0	No bending about minor axis; bea	**Mry**	0	
Mcy	0		**Mcy**	0		**Mcy**	0	
Equation H1-1b			**Equation H1-1b**			**Equation H1-1b**		
Pr/Pc +(8/9)* (Mrx/Mcx + Mry/Mcy) ≤ 1	0.208309	≤ 1 OK	**Pr/Pc +(8/9)* (Mrx/Mcx + Mry/Mcy) ≤ 1**	0.29242	≤ 1 OK	**Pr/2Pc + (Mrx/Mcx + Mry/Mcy) ≤ 1**	0.407672	≤ 1 OK
Sway (From RISA)	0.125	inches	**Sway (From RISA)**	0.125	inches	**Sway (From RISA)**	0.125	inches

Appendix X: Circular Tower Design

		f'c	3000	psi			
		thickness	1	ft	stress	6.261674	k/ft^2
		d	17	ft	fcritical	154.44	k/ft^2
		A	25.905	ft^2			
		Sx	103.8105	ft^3	checks		
		P	95.3316	k			
		M	268	k-ft			
		cover	2	in			
		b	12	in			
		d	8	in			
ACI	14.3.2	rho	0.0012		Vertical Reinforcement		
		MinAs	0.1152		No. 3 Bar spaced 10" apart		
ACI	14.3.3	rho	0.002		Horizontal Reinforcement		
		MinAs	0.192		No 3 Bar spaced 6 inches apart		
ACI	14.3.7	2 No. 5 bars around door opening					
		2 feet of opening					

shear capacity

phi	0.75		
shear cap	306.4771	kips	
shear at base	26.8	kips	from RISA
checks			

Total	518.1	19.18889	CY

Appendix Y: Tower Design Sample Calculations

Circular Tower Design

$D.L. = .12 \frac{k}{ft^2}$ $\quad A = \frac{\pi}{4}(17')^2 = 226.98\ ft^2$

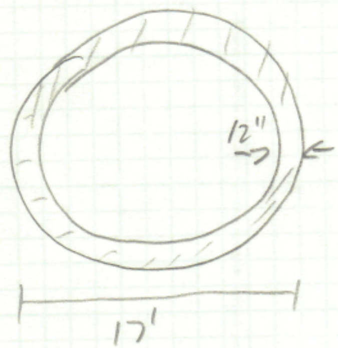
$L.L = .3\ {}^{k}/_{ft^2}$

factored
$D.L = 27.24^k$
$L.L = 68.094^k$
$w = 1.339975 \frac{k}{ft}$ over entire length

RISA 2D Analysis

$Axial = 95.332^k$

$Moment = -268\ k\text{-}ft$



$A = \frac{\pi}{4}(17^2 - 16^2) = 25.9181\ ft^2$

$S_x = 103.863\ ft^3$

$f'_c = 3000\ psi$

$\sigma_{cr} = .3575\,(f'_c) = 1072.5\ ksi$

$\sigma_{cr} = 154.4\ \frac{k}{ft^2}$

$$\frac{P}{A} + \frac{M}{S_x} \le \sigma_{cr}$$

$$\frac{95.332^k}{25.9181\ ft^2} + \frac{268\ k\text{-}ft}{103.863\ ft^3} \le 154.4\ {}^{k}/_{ft^2}$$

$$6.25851\ \frac{k}{ft^2} \le 154.4\ \frac{k}{ft^2}\ ✓$$

2" of cover either side

thickness = 12" - based on table 3.9.6 per
b = 12" foot of width of Wang & Salmon
$d = 12" - 2(2") = 8"$ Concrete Design

vertical reinforcing	horizontal reinforcing
ACI 318-05	ACI 318-05
- 14.3.2 (a)	-14.3.3(a)
$\rho = .0012$	$\rho = .0020$
$A_{s\,min} = \rho(b)(d)$	$A_{s\,min} = \rho(b)(d)$
$A_{s\,min} = 0.1152$	$A_{s\,min} = 0.192$
No. 3 Bar spaced 10" apart	No. 3 Bar spaced 6" apart.

Shear capacity

$\phi 2\sqrt{f'_c}\, A = V_c$

Area of concrete = $25.92\ ft^2$

$\phi = 0.75$

$f'_c = 3000$

$(0.75)(2)(\sqrt{3000})(25.92\,ft^2)(144\,\frac{in^2}{ft^2}) = V_c$

✓ $V_c = 306^k \geq 26.8^k$ => Shear from RISA 2D

Appendix Z: Foundation Design Sample Calculations

Design of Footings

bearing capacity of rock: 541.2 ksi x 144 = 77,904 ksf

$f'c = 3$ ksi
fy = 50 ksi (steel)

LL = 13.65 kips
DL = 10.055
Other Load = 56.32 kips

- 11 inche base plate
- 13.5 inch pedestal

– Pe

1) Rqd Area = $\frac{79.42}{4.0}$ = 19.85 sq. ft

Try 5' square footing = 25 sq. ft.

$P_u = 1.2(10.05) + 1.6(13.65) + 56.32$ (already factored)

$P_u = 90.2265$ kips

$q_{net} = \frac{90.2265}{25} = 3.61$ ksf

2) Depth based on Shear – 2 way Action

– Assume thickness of 24 inches

Averge $d = 24 - 3(\text{cover}) - 1(\text{bar}) \approx 20$ in

$V_u = (q_{net})(\text{area}) = 3.61[5(5) - (3)(3)] = 57.76$ kips

ACI - 11.12.2.1, $\beta_c \le 2$ and $b_o/d \le 20$ for a 4 sided critical section

$b_o/d = 4(13.5 + 20)/20 = 6.7 \le 20$ ok

$V_c = 4\sqrt{f'c}\, b_o d = 4\sqrt{3000}\,[4(13.5+20)](20)\left(\frac{1}{1000}\right) = 587.15$

$\phi V_c = (.75)(587.15) = 440$ kips > 57.76 kips ok

No Shear Reinforcement required

One way Shear

$V_u = 3.61(.270)(5) = 4.87$ kips

ACI- 11.12.1.1. and 11.3.1.1,

$V_c = 2\sqrt{f'c}\, b_w d = 2\sqrt{3000}(5)(12)(20)\left(\frac{1}{1000}\right) = 131.43$ kips

$\phi V_c = (.75)(131.43) = \boxed{98.58 \text{ kips} > 4.87 \text{ kips}}$ ok

c) Check that load transfer at base of column.

$A_g = 13.5^2 = 182.25 \text{ in}^2$

$\phi P_n = \phi(.85f'c)A_g = (.65)(.85)(3)(182.25) = \boxed{302.0 \text{ kips}}$

$\boxed{\phi P_n > \phi P_u = 90.2265}$ ok

-No excess load to be carried by dowells

min $A_s = .005(A_g) = .005(182.25) = \boxed{.911 \text{ in}^2}$

Use 3 #5 bars, area = $\boxed{.93 \text{ in}^2}$

Develop Dowells

$L_{dc} = .02 f_y d_b / \sqrt{f'c}$

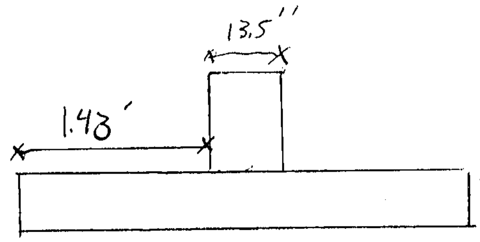
$= \frac{.02(50{,}000)(1.0)}{\sqrt{3000}} = 18.257$ in

~~Not Less than~~

$L_{dc} = .0003 f_y d_b = .0003(50{,}000)(1.0) = 15$ in

24" Thick footing is adequate for straight dowells

1) Design for bending moments



$$M_u = \frac{1}{2}(3.61)(4)(1.48)^2 = 14.76 \text{ ft-K}$$

$$R_n = \frac{M_u}{\phi b d^2} = \frac{14.76}{(.9)(48)(20)^2} = 10.25 \text{ psi}$$

Equation 3.8.5

$$\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2mR_n}{f_y}}\right) \; ; \; m = \frac{f_y}{.85 f'_c} = \frac{50{,}000}{(.85)(3{,}000)} = \boxed{19.6}$$

$$\rho = \frac{1}{19.6}\left(1 - \sqrt{1 - \frac{2(19.6)(10.25)}{50{,}000}}\right) = 2.05 \times 10^{-4}$$

required $A_s = \rho b d = (2.05 \times 10^{-4})(48)(20) = \boxed{.197 \text{ in}^2}$

min $A_s = (.002)(48)(22) = \boxed{2.112 \text{ in}^2}$

Use 4 #7 bars; $A = \boxed{2.4 \text{ in}^2}$

Develop reinforcement

$$L_d = \left(\frac{3}{40}\frac{f_y}{\sqrt{f'_c}}\frac{\psi_t \psi_s \psi_e \lambda}{\left(\frac{C_b + K_{tr}}{d_b}\right)}\right) d_b$$

- 4" Spacing

- bottom + side cover = 1.5 + .4375 = 1.9875 in

one half spacing = $\frac{4}{2}$ = 2 in

$C_b = 1.9375$, $K_{tr} = 0$ (no stirrups)

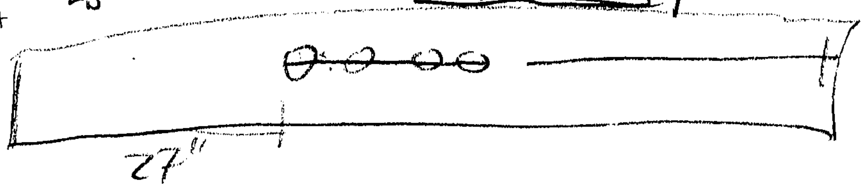
$$\frac{c_b + K_{tr}}{d_b} = \frac{1.9375+0}{.875} = 2.214$$

$$L_d = \left(\frac{3}{40} \frac{50{,}000}{\sqrt{3000}} \frac{(1.0)(1.0)(1.0)(1.0)}{2.214}\right)(.875) = 27.05 \text{ in}$$

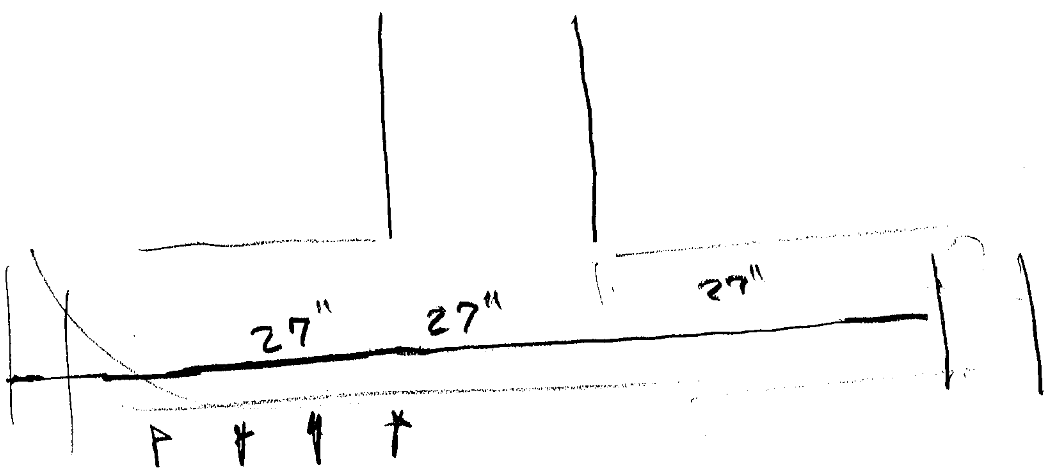
New Footing Dimension

27.05" + 15.5 + 27.05" +6" = 72.6" = **6.5' X 6.5'** **42.25 ft²**

27.05" ↓ L_D ; 15.5 ↓ reinforcement + spacing ; 27.05" ↓ L_D ; 6" ↳ Total cover



5.5



1) Column : W10x22 → $A = 6.49\ in^2$, $r_x = 4.27\ in$, $d = 10.2$; $b_f = 5.75\ in$

2) Load : 90.2265 Kips

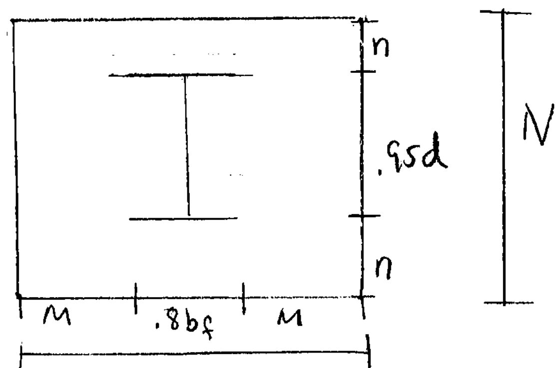
3) $\frac{90.2265}{6.49} = 13.90\ ksi$

From Table 4-22 AISC $\phi_c F_{cr} = 42.4\ psi$

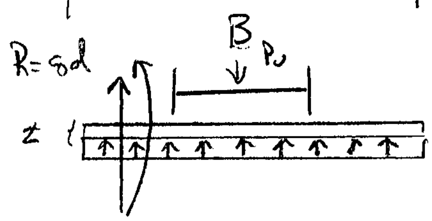
$K = 1.0$ (assume) $\quad \frac{Kl}{r} = 28.1$

$l = 10 \times 12 = 120''$

$r = 4.27$



$q_u = \frac{P_u}{B_u} \leq \phi P_p$



$M = q_u l\left(\frac{l}{2}\right) = q_u\left(\frac{l^2}{2}\right)$

For bending : $\frac{M}{Z} \leq \phi_b F_y$, $\phi_b = .9$

Assume

- $\sqrt{\frac{A_2}{A_1}} = 1.1 \qquad f'_c = 4\ ksi$

- Pedestal Area = 2.5 times wider than base plate.

$A_1 = \frac{P_u}{\phi_c(.85 f'_c)\sqrt{\frac{A_2}{A_1}}}$ so $A_1 = \frac{(90.2265)(1.6)}{(.6)(.85 \times 4)(1.1)} = 64.33 =$ **65 inches**

Baseplate = 11" X 6"
Pedestal = 13.5" x 8.5"

$A_2 \to 1.1 = \sqrt{\frac{A_2}{65}}$; $A_2 = 78.65 =$ **79 inches** $\quad \sqrt{\frac{79}{65}} = 1.10$

Compute B & N

$\Delta = \frac{.95d - .8b_f}{2} = \frac{(.95 \times 10.2) - (.8 \times 5.75)}{(2)} = 2.545$

$N = \sqrt{A_1} + \Delta \to \sqrt{65} + 2.545 = 10.65 =$ **11"** $\qquad B = \frac{A_1}{N} = \frac{65}{11} = 5.90 \approx$ **6"**

Plate Thickness

$$M = \frac{N - .95d}{2} = \frac{11-(.95 \times 10.2)}{2} = .655$$

$$n = \frac{B - .85 \times b_f}{2} = \frac{6-(.85 \times 5.75)}{2} = .556$$

} aprox. equal

$$n' = \frac{\sqrt{d \times b_f}}{4} = \frac{\sqrt{10.2 \times 5.75}}{4} = 1.91 \text{ inches}$$

$\ell = n' = 1.91$ inches (largest)

$$t_{req} = \ell\sqrt{\frac{2P_u}{.9F_y BN}} = 1.91\sqrt{\frac{2(144.36)}{(.9)(50)(11 \times 6)}} = .595 \text{ inches Thick}$$

Appendix AA: Rebar Cost Analysis Spreadsheet

TOTAL	$15,364.90	FF/ROOF	$13,132.98	GARAGE	$2,231.92

ROOF SLAB

		Size	Cost/ft	1 length	ft	spacing	#bars	length (ft)	Cost Total
BSI	support	3	0.28	3.25	52	0.75	69.33333333	225.3333333	63.09333333
BSI	middle	3	0.28	13	52	0.5	104	1352	378.56
BSI	support	3	0.28	3.25	52	0.375	138.6666667	450.6666667	126.1866667
BS2	support	3	0.28	2	52	0.75	69.33333333	138.6666667	38.82666667
BS2	middle	3	0.28	8	52	0.75	69.33333333	554.6666667	155.3066667
BS2	support	3	0.28	2	52	0.75	69.33333333	138.6666667	38.82666667
BSI	support	3	0.28	3.25	52	0.75	69.33333333	225.3333333	63.09333333
BSI	middle	3	0.28	13	52	0.5	104	1352	378.56
BSI	support	3	0.28	3.25	52	0.375	138.6666667	450.6666667	126.1866667
CS3	support	3	0.28	2	34	0.75	45.33333333	90.66666667	25.38666667
CS3	middle	3	0.28	8	34	0.75	45.33333333	362.6666667	101.5466667
CS3	support	3	0.28	2	34	0.75	45.33333333	90.66666667	25.38666667
DS1	support	3	0.28	1.25	17	0.75	22.66666667	28.33333333	7.933333333
DS1	middle	3	0.28	7	17	0.75	22.66666667	158.6666667	44.42666667
DS1	support	3	0.28	1.25	17	0.5	34	42.5	11.9
DS2	support	3	0.28	2	17	0.75	22.66666667	45.33333333	12.69333333
DS2	middle	3	0.28	8	17	0.75	22.66666667	181.3333333	50.77333333
DS2	support	3	0.28	2	17	0.75	22.66666667	45.33333333	12.69333333
DS2	support	3	0.28	2	17	0.75	22.66666667	45.33333333	12.69333333
DS2	middle	3	0.28	8	17	0.75	22.66666667	181.3333333	50.77333333
DS2	support	3	0.28	2	17	0.75	22.66666667	45.33333333	12.69333333
DS1'	support	3	0.28	2.75	17	0.75	22.66666667	62.33333333	17.45333333
DS1'	middle	3	0.28	11	17	0.75	22.66666667	249.3333333	69.81333333
DS1'	support	3	0.28	2.75	17	0.75	22.66666667	62.33333333	17.45333333
							Total	6579.5	1842.26

FIRST FLOOR SLAB

		Size	Cost/ft	1 length	ft	spacing	#bars	length (ft)	Cost Total
BSI	support	3	0.28	3.25	52	0.75	69.33333333	225.3333333	63.09333333
BSI	middle	3	0.28	13	52	0.666666667	78	1014	283.92
BSI	support	3	0.28	3.25	52	0.5	104	338	94.64
BS2	support	3	0.28	2	52	0.75	69.33333333	138.6666667	38.82666667
BS2	middle	3	0.28	8	52	0.75	69.33333333	554.6666667	155.3066667
BS2	support	3	0.28	2	52	0.75	69.33333333	138.6666667	38.82666667
BSI	support	3	0.28	3.25	52	0.5	104	338	94.64
BSI	middle	3	0.28	13	52	0.666666667	78	1014	283.92
BSI	support	3	0.28	3.25	52	0.75	69.33333333	225.3333333	63.09333333
CS3	support	3	0.28	2	34	0.75	45.33333333	90.66666667	25.38666667
CS3	middle	3	0.28	8	34	0.75	45.33333333	362.6666667	101.5466667
CS3	support	3	0.28	2	34	0.75	45.33333333	90.66666667	25.38666667
DS1	support	3	0.28	1.25	17	0.75	22.66666667	28.33333333	7.933333333
DS1	middle	3	0.28	7	17	0.75	22.66666667	158.6666667	44.42666667
DS1	support	3	0.28	1.25	17	0.75	22.66666667	28.33333333	7.933333333
DS2	support	3	0.28	2	17	0.75	22.66666667	45.33333333	12.69333333
DS2	middle	3	0.28	8	17	0.75	22.66666667	181.3333333	50.77333333
DS2	support	3	0.28	2	17	0.75	22.66666667	45.33333333	12.69333333
DS2	support	3	0.28	2	17	0.75	22.66666667	45.33333333	12.69333333
DS2	middle	3	0.28	8	17	0.75	22.66666667	181.3333333	50.77333333
DS2	support	3	0.28	2	17	0.75	22.66666667	45.33333333	12.69333333
DS1'	support	3	0.28	2.75	17	0.75	22.66666667	62.33333333	17.45333333
DS1'	middle	3	0.28	11	17	0.75	22.66666667	249.3333333	69.81333333
DS1'	support	3	0.28	2.75	17	0.75	22.66666667	62.33333333	17.45333333
							Total	5664	1585.92

GARAGE SLAB

		Size	Cost/ft	1 length	ft	spacing	#bars	length (ft)	Cost Total
AS1	support	3	0.28	3.75	30	0.666666667	45	168.75	47.25
AS1	middle	3	0.28	15	30	0.458333333	65.45454545	981.8181818	274.9090909
AS1	support	3	0.28	3.75	30	0.333333333	90	337.5	94.5
AS1	support	3	0.28	3.75	30	0.333333333	90	337.5	94.5
AS1	middle	3	0.28	15	30	0.458333333	65.45454545	981.8181818	274.9090909
AS1	support	3	0.28	3.75	30	0.666666667	45	168.75	47.25
							Total	2976.136364	833.3181818

ROOF TEMPERATURE SLAB

	Size	Cost/ft	1 length	ft	spacing	#bars	length (ft)	Cost Total
AS1	3	0.28	69	34	1.5	22.66666667	1564	437.92
CS1	3	0.28	34	8	1.5	5.333333333	181.3333333	50.77333333
						Total	1745.333333	488.6933333

FF TEMPERATURE SLAB

	Size	Cost/ft	1 length	ft	spacing	#bars	length (ft)	Cost Total
AS1	3	0.28	69	34	1.5	22.66666667	1564	437.92
CS1	3	0.28	34	8	1.5	5.333333333	181.3333333	50.77333333
						Total	1745.333333	488.6933333

GARAGE TEMPERATURE SLAB

	Size	Cost/ft	1 length	ft	spacing	#bars	length (ft)	Cost Total
AS1	3	0.28	30	30	0.67	45	1350	378

ROOF Beams

#			ft	size	#	cost/ft	cost
6	B1	support	3.25	8	2	1.7	66.3
6	B1	middle	13	8	2	1.7	265.2
6	B1	support	3.25	8	2	1.7	66.3
3	B2	support	2	6	2	0.91	10.92
3	B2	middle	8	6	2	0.91	43.68
3	B2	support	2	6	2	0.91	10.92
4	B3	support	3.25	8	2	1.7	44.2
4	B3	middle	13	8	2	1.7	176.8
4	B3	support	3.25	8	2	1.7	44.2
4	B4	support	3.25	8	2	1.7	44.2
4	B4	middle	13	8	2	1.7	176.8
4	B4	support	3.25	8	2	1.7	44.2
1	B5	support	2	5	2	0.66	2.64
1	B5	middle	8	5	2	0.66	10.56
1	B5	support	2	5	2	0.66	2.64
2	B6	support	3.25	6	2	0.91	11.83
2	B6	middle	13	6	2	0.91	47.32
2	B6	support	3.25	6	3	0.91	17.745
1	B7	support	1.75	6	2	0.91	3.185
1	B7	middle	7	6	2	0.91	12.74
1	B7	support	1.75	6	2	0.91	3.185
2	B8	support	2	7	2	1.51	12.08
2	B8	middle	8	7	2	1.51	48.32
2	B8	support	2	7	2	1.51	12.08
1	B9	support	2.75	7	2	1.51	8.305
1	B9	middle	11	7	2	1.51	33.22
1	B9	support	2.75	7	2	1.51	8.305
1	B10	support	4.25	8	2	1.7	14.45
1	B10	middle	17	8	2	1.7	57.8
1	B10	support	4.25	8	2	1.7	14.45
1	B11	support	4.25	9	2	2.53	21.505
1	B11	middle	17	9	2	2.53	86.02

ROOF Exterior Beams

#			ft	size	#	cost/ft	cost
1	B1	support	3.25	7	2	1.51	9.815
1	B1	middle	13	9	2	2.53	65.78
1	B1	support	3.25	7	2	1.51	9.815
1	B2	support	2	8	2	1.7	6.8
1	B2	middle	8	3	2	0.28	4.48
1	B2	support	2	8	2	1.7	6.8
1	B3	support	3.25	7	2	1.51	9.815
1	B3	middle	13	7	2	1.51	39.26
1	B3	support	3.25	7	2	1.51	9.815
1	B4	support	4.25	11	2	3.95	33.575
1	B4	middle	17	9	2	2.53	86.02
1	B4	support	4.25	11	2	3.95	33.575
1	B5	support	2	10	2	3.2	12.8
1	B5	middle	8	7	2	1.51	24.16
1	B5	support	2	10	2		0
1	B6	support	3.25	8	2	1.7	11.05
1	B6	middle	13	7	2	1.51	39.26
1	B6	support	3.25	8	2	1.7	11.05
1	B7	support	3.25	8	2	1.7	11.05
1	B7	middle	13	7	2	1.51	39.26
1	B7	support	3.25	8	2	1.7	11.05
1	B8	support	3.25	8	2	1.7	11.05
1	B8	middle	13	7	2	1.51	39.26
1	B8	support	3.25	8	2	1.7	11.05
1	B9	support	3.25	8	2	1.7	11.05
1	B9	middle	13	8	2	1.7	44.2
1	B9	support	3.25	8	2	1.7	11.05
1	B10	support	1.75	6	2	0.91	3.185
1	B10	middle	7	8	2	1.7	23.8
1	B10	support	1.75	6	2	0.91	3.185
1	B11	support	2	8	2	1.7	6.8
1	B11	middle	8	7	2	1.51	24.16

1	B11	support	4.25	9	2	2.53	21.505
1	B12	support	4.25	9	2	2.53	21.505
1	B12	middle	17	9	2	2.53	86.02
1	B12	support	4.25	9	2	2.53	21.505
						Total	1572.635

FIRST FLOOR BEAMS

#			ft	size	#	cost/ft	cost
6	B1	support	3.25	8	2	1.7	66.3
6	B1	middle	13	8	2	1.7	265.2
6	B1	support	3.25	8	2	1.7	66.3
3	B2	support	2	6	2	0.91	10.92
3	B2	middle	8	6	2	0.91	43.68
3	B2	support	2	6	2	0.91	10.92
4	B3	support	3.25	8	2	1.7	44.2
4	B3	middle	13	8	2	1.7	176.8
4	B3	support	3.25	8	2	1.7	44.2
4	B4	support	3.25	8	2	1.7	44.2
4	B4	middle	13	8	2	1.7	176.8
4	B4	support	3.25	8	2	1.7	44.2
1	B5	support	2	5	2	0.66	2.64
1	B5	middle	8	5	2	0.66	10.56
1	B5	support	2	5	2	0.66	2.64
2	B6	support	3.25	6	2	0.91	11.83
2	B6	middle	13	6	2	0.91	47.32
2	B6	support	3.25	6	3	0.91	17.745
1	B7	support	1.75	6	2	0.91	3.185
1	B7	middle	7	6	2	0.91	12.74
1	B7	support	1.75	6	2	0.91	3.185
2	B8	support	2	7	2	1.51	12.08
2	B8	middle	8	7	2	1.51	48.32
2	B8	support	2	7	2	1.51	12.08
1	B9	support	2.75	7	2	1.51	8.305
1	B9	middle	11	7	2	1.51	33.22

1	B11	support	2	8	2	1.7	6.8
1	B12	support	2	8	2	1.7	6.8
1	B12	middle	8	5	2	0.66	10.56
1	B12	support	2	8	2	1.7	6.8
1	B13	support	2.75	8	2	1.7	9.35
1	B13	middle	11	8	2	1.7	37.4
1	B13	support	2.75	8	2	1.7	9.35
1	B14	support	4.25	9	2	2.53	21.505
1	B14	middle	17	7	2	1.51	51.34
1	B14	support	4.25	9	2	2.53	21.505
1	B15	support	2	8	2	1.7	6.8
1	B15	middle	8	9	2	2.53	40.48
1	B15	support	2	8	2	1.7	6.8
1	B16	support	3.25	8	2	1.7	11.05
1	B16	middle	13	9	2	2.53	65.78
1	B16	support	3.25	8	2	1.7	11.05
1	B17	support	3.25	8	2	1.7	11.05
1	B17	middle	13	9	2	2.53	65.78
1	B17	support	3.25	8	2	1.7	11.05
1	B18	support	3.25	8	2	1.7	11.05
1	B18	middle	13	9	2	2.53	65.78
1	B18	support	3.25	8	2	1.7	11.05
1	B19	support	3.25	8	2	1.7	11.05
1	B19	middle	13	8	2	1.7	44.2
1	B19	support	3.25	8	2	1.7	11.05
						Total	1229.45

1	B9	support	2.75	7	2	1.51	8.305
1	B10	support	4.25	8	2	1.7	14.45
1	B10	middle	17	8	2	1.7	57.8
1	B10	support	4.25	8	2	1.7	14.45
1	B11	support	4.25	9	2	2.53	21.505
1	B11	middle	17	9	2	2.53	86.02
1	B11	support	4.25	9	2	2.53	21.505
1	B12	support	4.25	9	2	2.53	21.505
1	B12	middle	17	9	2	2.53	86.02
1	B12	support	4.25	9	2	2.53	21.505
						Total	1572.635

GARAGE columns Beams

#		size	length	#	cost/ft	cost
9	C1	7	10	4	1.51	543.6
					Total	543.6

Interior/Basement Columns Beams

#		size	length	#	cost/ft	cost
1	I	6	10	4	0.91	36.4
1	II	6	10	4	0.91	36.4
1	III	6	10	4	0.91	36.4
1	IV	6	10	4	0.91	36.4
1	V	5	10	4	0.66	26.4
1	VI	5	10	4	0.66	26.4
1	VII	5	10	4	0.66	26.4
1	VIII	5	10	4	0.66	26.4
1	IX	5	10	4	0.66	26.4
1	X	6	10	4	0.91	36.4
1	XI	5	10	4	0.66	26.4
1	XII	5	10	4	0.66	26.4
1	XIII	5	10	4	0.66	26.4
1	XIV	6	10	4	0.91	36.4
1	XV	5	10	4	0.66	26.4
1	XVI	5	10	4	0.66	26.4
1	XVII	5	10	4	0.66	26.4
1	XVII	5	10	4	0.66	26.4
1	XIX	5	10	4	0.66	26.4
					Total	561.6

Interior/Basement Columns Beams

#		size	length	#	cost/ft	cost
8	C1	5	20	4	0.66	422.4
4	C2	5	20	4	0.66	211.2
4	C3	5	20	4	0.66	211.2
2	C4	6	20	4	0.91	145.6
2	C5	6	20	4	0.91	145.6
2	C6	7	20	4	1.51	241.6
					Total	1377.6

GARAGE INTERIOR BEAMS

#			ft	size	#	cost/ft	cost
4	B1	support	3.75	7	2	1.51	45.3
4	B1	middle	15	9	2	2.53	303.6
4	B1	support	3.75	7	2	1.51	45.3
						Total	394.2

GARAGE Exterior Beams

#			ft	size	#	cost/ft	cost
8	B1	support	3.75	8	2	1.7	102
8	B1	middle	15	8	2	1.7	408
8	B1	support	3.75	8	2	1.7	102
						Total	612

allow for 2 in wrap on either side.

ROOF INTERIOR BEAM STIRRUPS										
#	Beam	height	width	Spacing(in)	length (ft)	#	length	size	cost/ft	Cost
6	B1	8	18	4.75	3.166666667	32.84210526	13	3	0.28	174.7
3	B2	8	12	3	2.666666667	32	8	3	0.28	71.68
4	B3	8	16	4.55	3	34.28571429	13	3	0.28	115.2
4	B4	10	16	4.9	3.333333333	31.83673469	13	3	0.28	118.9
1	B5	6	12	4.4	2.333333333	21.81818182	8	3	0.28	14.25
2	B6	10	16	5.4	3.333333333	28.88888889	13	3	0.28	53.93
1	B7	8	12	4.5	2.666666667	18.66666667	7	3	0.28	13.94
2	B8	8	14	5.4	2.833333333	17.77777778	8	3	0.28	28.21
1	B9	10	16	5.5	3.333333333	24	11	3	0.28	22.4
1	B10	10	18	7	3.5	29.14285714	17	3	0.28	28.56
1	B11	10	18	6.4	3.5	31.875	17	3	0.28	31.24
1	B12	10	20	6.25	3.666666667	32.64	17	3	0.28	33.51
									Total	706.5

FF INTERIOR BEAM STIRRUPS

#	ea	height	width	pacing(ir	length (ft)	#	length	size	cost/ft	Cost
6	B1	10	20	5.25	3.66666667	29.71428571	13	3	0.28	183.04
3	B2	8	12	3.75	2.66666667	25.6	8	3	0.28	57.344
4	B3	10	16	4.55	3.33333333	34.28571429	13	3	0.28	128
4	B4	10	18	5	3.5	31.2	13	3	0.28	122.304
1	B5	8	14	4.5	2.83333333	21.33333333	8	3	0.28	16.92444444
2	B6	10	18	5.5	3.5	28.36363636	13	3	0.28	55.59272727
1	B7	8	12	4.3	2.66666667	19.53488372	7	3	0.28	14.58604651
2	B8	10	16	5.5	3.33333333	17.45454545	8	3	0.28	32.58181818
1	B9	10	18	5.5	3.5	24	11	3	0.28	23.52
1	31(	12	20	7.5	4	27.2	17	3	0.28	30.464
1	31:	10	18	5.9	3.5	34.57627119	17	3	0.28	33.88474576
1	31:	10	20	5.8	3.66666667	35.17241379	17	3	0.28	36.11034483
									Total	734.352127

GARAGE INTERIOR BEAM STIRRUPS

#	ea	height	width	pacing(ir	length (ft)	#	length	size	cost	
4	B1	10	18	4.3	3.5	41.86046512	15	3	0.28	164.0930233
									Total	164.0930233

GARAGE EXTERIOR BEAM STIRRUPS

	Bea	height	width	pacing(ir	length (ft)	#	length	size	cost	
8	B1	10	18	6.05	3.5	29.75206612	15	3	0.28	233.2561983
									Total	233.2561983

ROOF EXTERIOR BEAM STIRRUPS

#	Beam	height	width	Spacing(in)	ength (ft	#	length	size	cost/ft	Cost
1	B1	10	16	6.5	3.3333	24	13	3	0.28	22.4
1	B2	8	12	4.5	2.6667	21	8	3	0.28	15.92888889
1	B3	10	16	6.5	3.3333	24	13	3	0.28	22.4
1	B4	10	16	4.5	3.3333	45	17	3	0.28	42.31111111
1	B5	10	16	1.5	3.3333	64	8	3	0.28	59.73333333
1	B6	10	16	5.15	3.3333	30	13	3	0.28	28.27184466
1	B7	10	16	5.15	3.3333	30	13	3	0.28	28.27184466
1	B8	10	16	5.15	3.3333	30	13	3	0.28	28.27184466
1	B9	10	16	4.8	3.3333	33	13	3	0.28	30.33333333
1	B10	10	16	5.75	3.3333	15	7	3	0.28	13.63478261
1	B11	10	16	5.5	3.3333	17	8	3	0.28	16.29090909
1	B12	10	16	4.5	3.3333	21	8	3	0.28	19.91111111
1	B13	10	16	6	3.3333	22	11	3	0.28	20.53333333
1	B14	10	16	4	3.3333	51	17	3	0.28	47.6
1	B15	10	16	1.5	3.3333	64	8	3	0.28	59.73333333
1	B16	10	16	5	3.3333	31	13	3	0.28	29.12
1	B17	10	16	5	3.3333	31	13	3	0.28	29.12
1	B18	10	16	5	3.3333	31	13	3	0.28	29.12
1	B19	10	16	4.75	3.3333	33	13	3	0.28	30.65263158
									Total	573.6383017

COLUMN STIRRUPS

#	Column	height	width	Spacing(in)	ength (ft	#	length	size	cost/ft	Cost
8	C1	10	10	10	2.8333	12	10	3	0.28	76.16
4	C2	10	10	10	2.8333	12	10	3	0.28	38.08
4	C3	10	10	10	2.8333	12	10	3	0.28	38.08
2	C4	12	12	12	3.3333	10	10	3	0.28	18.66666667
2	C5	12	12	12	3.3333	10	10	3	0.28	18.66666667
2	C6	14	14	14	3.8333	8.6	10	3	0.28	18.4
1	I	12	12	10	3.3333	12	10	3	0.28	11.2
1	II	12	12	10	3.3333	12	10	3	0.28	11.2
1	III	12	12	10	3.3333	12	10	3	0.28	11.2
1	IV	12	12	10	3.3333	12	10	3	0.28	11.2
1	V	10	10	10	2.8333	12	10	3	0.28	9.52
1	VI	10	10	10	2.8333	12	10	3	0.28	9.52
1	VII	10	10	10	2.8333	12	10	3	0.28	9.52
1	VIII	10	10	10	2.8333	12	10	3	0.28	9.52
1	IX	10	10	10	2.8333	12	10	3	0.28	9.52
1	X	12	12	10	3.3333	12	10	3	0.28	11.2
1	XI	10	10	10	2.8333	12	10	3	0.28	9.52
1	XII	10	10	10	2.8333	12	10	3	0.28	9.52
1	XIII	10	10	10	2.8333	12	10	3	0.28	9.52
1	XIV	12	12	10	3.3333	12	10	3	0.28	11.2
1	XV	10	10	10	2.8333	12	10	3	0.28	9.52
1	XVI	10	10	10	2.8333	12	10	3	0.28	9.52
1	XVII	10	10	10	2.8333	12	10	3	0.28	9.52
1	XVII	10	10	10	2.8333	12	10	3	0.28	9.52
1	XIX	10	10	10	2.8333	12	10	3	0.28	9.52
9	GC1	14	14	14	3.8333	8.6	10	3	0.28	82.8
									Total	481.8133333

Appendix BB: Concrete Cost Analysis Spreadsheet

Roof Interior Beams					
#	Base	Height	Length	cub ft	cub y
6	8	18	13	13	2.888889
3	8	12	8	5.333333	0.592593
4	8	16	13	11.55556	1.711934
4	10	16	13	14.44444	2.139918
1	6	12	8	4	0.148148
2	10	16	13	14.44444	1.069959
1	8	12	7	4.666667	0.17284
2	8	14	8	6.222222	0.460905
1	10	16	11	12.22222	0.452675
1	10	18	17	21.25	0.787037
1	10	18	17	21.25	0.787037
1	10	20	17	23.61111	0.874486
					12.08642

Roof Interior Columns					
#	Base	Height	Length	cub ft	cub y
4	10	10	10	6.944444	1.028807
2	10	10	10	6.944444	0.514403
2	10	10	10	6.944444	0.514403
1	12	12	10	10	0.37037
1	12	12	10	10	0.37037
1	14	14	10	13.61111	0.504115
					3.302469

Garage Interior Beams					
#	Base	Height	Length	cub ft	cub y
4	10	18	15	18.75	2.777778
Garage Exterior Beams					
#	Base	Height	Length	cub ft	cub y
8	10	18	15	18.75	5.555556
Garage Columns					
#	Base	Height	Length	cub ft	cub y
9	14	14	10	13.61111	4.537037

Roof Slab			
L	W	Thick	Cub Yd
77	34	0.541667	4.131173

FF SLAB				
W	L	Thick	Cub Ft	Cub Yd
77	34	0.541667	10	0.37037

Exterior Beams					
#	Base	Height	Length	cub ft	cub y
1	10	16	13	14.44444	0.534979
1	8	12	8	5.333333	0.197531
1	10	16	13	14.44444	0.534979
1	10	16	17	18.88889	0.699588
1	10	16	8	8.888889	0.329218
1	10	16	13	14.44444	0.534979
1	10	16	13	14.44444	0.534979
1	10	16	13	14.44444	0.534979
1	10	16	13	14.44444	0.534979
1	10	16	7	7.777778	0.288066
1	10	16	8	8.888889	0.329218
1	10	16	8	8.888889	0.329218
1	10	16	11	12.22222	0.452675
1	10	16	17	18.88889	0.699588
1	10	16	8	8.888889	0.329218
1	10	16	13	14.44444	0.534979
1	10	16	13	14.44444	0.534979
1	10	16	13	14.44444	0.534979
1	10	16	13	14.44444	0.534979
					9.004115

Exterior Columns					
#	Base	Height	Length	cub ft	cub y
1	12	12	10	10	0.37037
1	12	12	10	10	0.37037
1	12	12	10	10	0.37037
1	12	12	10	10	0.37037
1	10	10	10	6.944444	0.257202
1	10	10	10	6.944444	0.257202
1	10	10	10	6.944444	0.257202
1	10	10	10	6.944444	0.257202
1	10	10	10	6.944444	0.257202
1	12	12	10	10	0.37037
1	10	10	10	6.944444	0.257202
1	10	10	10	6.944444	0.257202
1	10	10	10	6.944444	0.257202
1	12	12	10	10	0.37037
1	10	10	10	6.944444	0.257202
1	10	10	10	6.944444	0.257202
1	10	10	10	6.944444	0.257202
1	10	10	10	6.944444	0.257202
1	10	10	10	6.944444	0.257202
					5.565844

Total Roof	34.09002	CY
Total Garage	12.87037	CY
Total First	15.75926	CY
Concrete/CY	$118.00	
TOTAL GARAGE	$1,518.70	
TOTAL COST	$7,400.92	

FF Interior Beams					
#	Base	Height	Length	cub ft	cub y
#		20	13	13	2.888889
6	10	12	8	5.333333	0.592593
3	8	16	13	11.55556	1.711934
4	10	18	13	14.44444	2.139918
4	10	14	8	4	0.148148
1	8	18	13	14.44444	1.069959
2	10	12	7	4.666667	0.17284
1	8	16	8	6.222222	0.460905
2	10	18	11	12.22222	0.452675
1	10	20	17	21.25	0.787037
1	12	18	17	21.25	0.787037
1	10	20	17	23.61111	0.874486
1	10				12.08642

FF Interior Columns					
#	Base	Height	Length	cub ft	cub y
4	10	10	10	6.944444	1.028807
2	10	10	10	6.944444	0.514403
2	10	10	10	6.944444	0.514403
1	12	12	10	10	0.37037
1	12	12	10	10	0.37037
1	14	14	10	13.61111	0.504115
					3.302469

Appendix CC: Steel Cost Analysis Spreadsheet

BEAMS

ROOF

lbs/ft	ft	lbs	
14	17	238	
10	8	80	
15	13	195	
15	13	195	
15	13	195	
15	13	195	
15	13	195	
10	8	80	
15	13	195	
15	13	195	
15	13	195	
15	13	195	
15	13	195	
10	8	80	
19	17	323	
15	11	165	
10	8	80	
10	8	80	
10	7	70	
10	7	70	
13	8	104	
13	8	104	
19	11	209	
19	13	247	
13	8	104	
19	13	247	
12	8	96	
12	8	96	
12	8	96	
19	13	247	
19	13	247	
19	13	247	
19	13	247	
19	13	247	
19	13	247	
19	13	247	
19	13	247	
		6495	
		$2,990.00	/ton
		$9,710.03	

ROOF

lbs/ft	ft	lbs	
22	17	374	
22	17	374	
26	17	442	
22	13	286	
22	13	286	
22	13	286	
22	13	286	
22	13	286	
22	13	286	
		2906	
		$1,920.00	/ton
		$2,789.76	

FIRST FLOOR

lbs/ft	ft	lbs	
14	17	238	
15	8	120	
14	13	182	
14	13	182	
14	13	182	
14	13	182	
14	13	182	
15	8	120	
14	13	182	
14	13	182	
14	13	182	
14	13	182	
14	13	182	
15	8	120	
19	17	323	
15	11	165	
10	8	80	
10	8	80	
10	7	70	
10	7	70	
12	8	96	
12	8	96	
19	11	209	
12	8	96	
12	8	96	
12	8	96	
12	8	96	
		3991	
		$2,990.00	/ton
		$5,966.55	

FIRST FLOOR

lbs/ft	ft	lbs	
22	17	374	
22	17	374	
26	17	442	
22	13	286	
22	13	286	
26	13	338	
26	13	338	
26	13	338	
26	13	338	
26	13	338	
26	13	338	
22	13	286	
22	13	286	
22	13	286	
22	13	286	
22	13	286	
22	13	286	
22	13	286	
22	13	286	
22	13	286	
		6364	
		$1,920.00	/ton
		$6,109.44	

COLUMNS FF and ROOF

#	lbs/ft	ft	lbs	
1	22	10	220	
2	22	10	220	
3	22	10	220	
4	22	10	220	
5	22	10	220	
6	22	10	220	
7	22	10	220	
8	22	10	220	
9	22	10	220	
10	22	10	220	
11	22	10	220	
12	22	10	220	
13	22	10	220	
14	22	10	220	
15	22	10	220	
16	22	10	220	
17	22	10	220	
18	22	10	220	
19	22	10	220	
			4180	
			$1,920.00	/ton
			$4,012.80	

COLUMNS FF and ROOF

	lbs/ft	ft	lbs	
1	12	10	120	
2	12	10	120	
3	12	10	120	
4	12	10	120	
5	12	10	120	
6	12	10	120	
7	12	10	120	
8	12	10	120	
9	12	10	120	
10	12	10	120	
11	12	10	120	
12	12	10	120	
13	12	10	120	
14	12	10	120	
15	12	10	120	
16	12	10	120	
17	12	10	120	
18	12	10	120	
19	12	10	120	
20	12	10	120	
21	12	10	120	
22	12	10	120	
			2640	
			$2,990.00	/ton
			$3,946.80	

Total Beams and Columns
$32,535.37

Decking
$ 9,896.04

Concrete
$7,627.75

DECKING

SF	$/SF	Cost
5236	1.89	$ 9,896.04

CONCRETE ON DECKING

Thick	L	W	#	CY	
0.333333	77	34	2	64.64198	
				$118.00	/CY
				$7,627.75	

Appendix DD: Foundation Cost Analysis Spreadsheet

CONCRETE					
#	L	W	H	CF	CY
11	2	4	4	32	13.037037
					$118.00 /CY
					$ 1,538.37

REBAR							
	Size	Cost/ft	1 length	#bars	length (ft)	Cost Total	# of ftings
H	7	1.51	4	4	16	24.16	11
V	7	1.51	4	4	16	24.16	
						$ 531.52	

TOTAL FOOTING COST
$ 2,069.89

Appendix EE: Tower Cost Analysis Spreadsheet

CONCRETE			
	CF	CY	
Roof/Base	453.9598	16.813324	
Walls	518.1	19.188889	
		$ 118.00	/CY
	Total	$ 4,248.26	

REBAR								
	layers	size	spacing	length	height	#	Total L (ft)	
Vert	2	3	0.8333333	20	110	132	5280	
Horz	2	3	0.5	110	20	40	8800	
Roof/Base	4	3	0.75	17	N/A	22.66667	1541.333	
							0.28	$/ft
						Total	$4,373.97	

Appendix FF: 2010 INERGERN® Garage Price Spreadsheet

This form is for calculating a single hazard area or multiple hazard areas discharged simultaneously from a single bank of cylinders.

System based on required bill of materials given. Because design analysis and quantity calculations were not performed to verify proper system design, hardware supplied may not be sufficient for proper protection. Please verify equipment selected is equipment required for application.

INSTRUCTIONS FOR USE

1) Information Sheet

- Fill in all information in the bold cells on the information sheet.
- Do not fill in the area or volume, they will be calculate automatically.
- If only the volume is known, fill in the specified volume. The height will default to 10 ft., and the length will be 2 times the width.
- The temperature will default to 65, 75 and 70 degrees F. If other temperatures are required, replace the default temperatures with the required temperatures.

Pick one type of bracketing.

Examples:

S = single row

MRS = main & reserve single row

- enter the number of exits for each hazard
- enter whether single or cross zone detection is required and the type of detectors
- enter voltage
- **Select UL or ULC listing**

2) IG QTY Calc Sheet

- Select the size cylinder desired (yellow shaded box) and verify minimum and maximum concentrations are within the design concentrations acceptable using the selected cylinder size.
- If you are protecting an area with a false ceiling, check the estimated nozzle size to make certain the size is not larger then 1 1/2". If it is, increase the number of nozzles to reduce the size required.
- Check Estimate Union Orifice Pipe Size does not show the warning Larger than 4". If the warning appears you may have to split the systems to allow a available orifice size to be picked. If this is not corrected, a false bill of materials will be created without a pressure reducer.
- Tank size is automatically selects a 439 cu. Ft., if a different size is required please select a tank size that is available.

3) B.O.M.

- Input discount and any addition discount that may apply. If no discount is entered, the pricing will be at suggest list.
- Input any additional equipment that is required and does not have a quantity automatically associated with it, add quantity of item(s) in QTY column.
- Cell that show up red are suggestions for products to use. Other products maybe a better choice. Please refer to the products manual.
- Click on the drop down arrow in the QTY column and scroll to "nonblanks" and click. This will eliminate any items that are not automatically chosen and will provide a bill of materials for only the items requested or required.

INERGEN & DETECTION & CONTROL INFORMATION SHEET

DATE: 2/22/2011
QUOTE/JOB NUMBER: Mt Washington MQP
CUSTOMER: Mt Washington MQP

HAZARD INFORMATION	AREA 1	AREA 2	AREA 3	AREA 4	AREA 5	AREA 6
Area Name:	Garage					
Length (ft.):	30.00					
Width (ft.):	30.00					
Height (ft.):	10.00					
Area (sq. ft.):	900.0					
Volume (cu. ft.):	9000					
Specified Volume (cu. ft.):						
Structural Reductions (cu. ft.):						
Minimum Ambient Temp.:	65.0					
Maximum Ambient Temp.:	75.0					
Normal Ambient Temperature:	70.0					
Altitude Correction:	6288					

Bracketing: D **Type**

Single	S, MRS	Double	D, MRD
Single B-To-B	SBB, MRSBB	Double B-to-B	DBB, MRDBB

Uprights: Y — Y = Yes, Blank = No

	AREA 1	AREA 2	AREA 3	AREA 4	AREA 5	AREA 6
Nozzle type (180 or 360):	360					
Deflector Shield (Y or N):	Y					
Maximum Wall Strength:						

Main/Reserve System: Y — Y or N

DETECTION & CONTROL

	AREA 1	AREA 2	AREA 3	AREA 4	AREA 5	AREA 6
Area Name:	Garage					
General Alarm? Y or N:	Y					
Predischarge Alarm? Y or N:	Y					
System Fired Alarm? Y or N:	Y					
Number of Exits:	2					
Abort? Y or N:	Y					
Type Alarm:	bell					
Output dBA:	92					
Ambient Sound Level:	60					
Type Detection: S = single, X = cross zone	X					
Type Detector: I=Ion, P=Photo, T=Thermal, B=both Ion & Photo	T					

Type Panel:	Z10	Z10 or 542R or IQ318 or IQ636X-2
Voltage:	120	120 or 240
Wiring Type	B	A or B
Explosion Proof	N	Y or N
Number of Release Zones		1 through 10 (Number Depends on the panel)
Main/Reserve System	N	Y or N
Disable Switch	Y	Y or N
ULC Listed	UL	UL or ULC

INERGEN DESIGN CALCULATION WORKSHEET

DATE: 2/22/2011
QUOTE/JOB NUMBER: Mt Washington MQP
CUSTOMER: Mt Washington MQP

VOLUME CALCULATIONS:	AREA 1	AREA 2	AREA 3	AREA 4	AREA 5
Area Name:	Garage				
Length (ft.):	30.00				
Width (ft.):	30.00				
Height (ft.):	10.00				
Area (sq. ft.):	900.00				
Volume (cu. ft.):	9000.00				
Specified Volume (cu. ft.):					
Volume Reductions:					
Structural Reductions (cu. ft.):					
Reduced Volume:	9000.00				
(Volume - Structural Reductions)					
Movable Object Reductions (cu. ft.):					
(If More Than 25% of Reduced Volume)					
Total Reduced Volume (cu. ft.):	9000.00				
(Reduced Volume - Movable Object Reductions)					
ROOM MINIMUM AMBIENT TEMP.:	65.0				
DESIGN CONCENTRATION:	34.20	34.20	34.20	34.20	34.20
FLOODING FACTOR:	0.423				
(From Table)					
INITIAL INERGEN QUANTITY CALC.:	3804.30				
INERGEN Quantity (cu. ft.):	3804.30				
(Total Reduced Volume x Flooding factor) or (Formula from Design Manual)					
ALTITUDE CORRECTION:					
Height Above or Below Sea Level:	6288				
Factor:	0.77				
(From Design Manual Table)					
ACTUAL INERGEN QTY (cu. ft.):	2948.13				
(Initial Inergen Quantity x Altitude Correction Factor)					
TOTAL INERGEN QTY (cu. ft.):	2948.13				
(Sum of all Actual INERGEN qty's)					
TOTAL INERGEN QTY (cu. ft.):	2948.13				
(From Page 1)					

CYLINDER REQUIREMENTS:		TOTAL CYLINDER CAPACITY:
(Total INERGEN qty. ÷ Cylinder Capacity rounded to next highest whole number)		*(Cyl. qty. x Cyl. cap.)*
575 cu. ft. Cylinders:	6	3432
439 cu. ft. Cylinders:	7	3073
355 cu. ft. Cylinders:	9	3195
266 cu. ft. Cylinders:	12	3192
205 cu. ft. Cylinders:	15	3075

CYLINDER SIZE SELECTED:	439
INERGEN AGENT SUPPLIED:	3073

(Cylinder qty. x Cylinder capacity)

ACTUAL INERGEN AGENT PER AREA:	3073.00				

((Actual Inergen Qty. ÷ Total Inergen Qty.) x INERGEN Agent Supplied)

ACTUAL INERGEN FLOODING FACTOR:	0.44				

[(Actual INERGEN Agent per Area ÷ Alt. Correction Factor) ÷ Total Reduced Volume]

CONCENTRATION RANGE CHECK:
(Design Conc. Must be Between 32.4% - 52% For Occupied Spaces)

Room Max. Ambient Temp.:	75.0				
Design Concentration at Max. Temp:	35.90				

(Locate Actual INERGEN Conc. at Max. Temp. on Table, or Use Calc. in Design Manual)

DISCHARGE TIME:

Normal Ambient Temperature:	70.0				
Design Concentration at Ambient Temp.:	35.63				

(Locate Actual INERGEN Conc. at Amb. Temp. on Table, or Use Calc. in Design Manual)

90% of Agent Discharge Time (Sec.):	55.04				
90% of Agent Discharge Time (Min):	0.92				

ESTIMATED FLOW RATES:

Estimated System Flow Rate:	3015

[(INERGEN Agent Supplied x .9) ÷ 90% Discharge Time (Min.)]

Estimated Orifice Union Pipe Size:	1.25

(Refer to Pipe Sizing Chart)

Nozzle Quantity:	1				
Estimated Nozzle Flow Rate:	3014.78				

Estimated Nozzle Pipe Size:

Pipe Length Factor (S = Short, L = Long):	S	S	S	S	S
Pipe Size:	1.25	#N/A	#N/A	#N/A	#N/A

Allowable Enclosure Strength (PSF):					
Estimated Peak Flow Rate:					
Venting (sq. in.):					

Total Venting (sq. in.)

DETECTION & CONTROL
ALARM REQUIREMENTS

DATE: 2/22/2011
QUOTE/JOB NUMBER: Mt Washington MQP
CUSTOMER: Mt Washington MQP

	AREA 1	AREA 2	AREA 3	AREA 4	AREA 5	AREA 6
Area Name:	Garage					
Length:	30.00					
Width:	30.00					
Height:	10.00					
Area:	900.00					
Total AllAreas:	900.00					

DESIGN INFORMATION

	AREA 1	AREA 2	AREA 3	AREA 4	AREA 5	AREA 6
General Alarm? Y or N:	Y					
Predischarge Alarm? Y or N:	Y					
System Fired Alarm? Y or N:	Y					
Number of Exists:	2					
Abort? Y or N:	Y					

ALARM INFORMATION

	AREA 1	AREA 2	AREA 3	AREA 4	AREA 5	AREA 6
Type Alarm:	bell					
Output dBA:	92					
Ambient Sound Level:	60					
Linear Distance:	40					
Longest side of rectangle:	79.00					

NUMBER OF ALARMS

	AREA 1	AREA 2	AREA 3	AREA 4	AREA 5	AREA 6
bells:	1					
general alarm strobes:						
horn/strobes:	1					
strobes:	2					
manual releases:	2					
aborts:	2					
Total Bells	1					
Total Horn/Strobes	1					
Total Strobes	2					
Total Manual Releases	2					
Total Aborts	2					

DETECTION & CONTROL
DETECTOR REQUIREMENTS

DATE: 2/22/2011
QUOTE/JOB NUMBER: Mt Washington MQP
CUSTOMER: Mt Washington MQP
PROJECT:

	AREA 1	AREA 2	AREA 3	AREA 4	AREA 5	AREA 6
Area Name:	Garage					
Length:	30					
Width:	30					
Height:	10					
Area:	900.00					
Total All Areas:	900.00					

NUMBER OF DETECTORS

	AREA 1	AREA 2	AREA 3	AREA 4	AREA 5	AREA 6
Length:	2					
Width:	2					
Area Total:	4					
Total All Areas	4					
Width:	2					
Length:	2					
AreaTotal:	4					
Total All Areas	4					
Detectors Required Per Area:	4					
Detectors Required All Areas:	4					
Type Detection: S = single, X = cross zone	X					
Type Detector: I=Ion, P=Photo, T=Thermal, B=both Ion & Photo	T					
Ion						
Photo						
Thermal	4					
Total Ion:						
Total Photo:						
Total Thermal:	4					
Total Smoke Detectors:						

INERGEN BILL OF MATERIALS

Quote No.:	Mt Washington MQP		Date:	2/22/2011
Customer Name:	Mt Washington MQP		Page:	1 of 1
Customer Address:			Product Line:	Inergen
			List Price Discount:	
			Additional Discount:	
Phone No.:			Project:	
Fax No.:				
Contact Name:				

QTY	PART #	DESCRIPTION	UNIT PRICE	TOTAL PRICE
14	426150	435 CU. FT CYLINDER W/ CV98 VALVE-EN	$1,930.00	$27,020.00
14	427082	DISCHARGE HOSE	$133.00	$1,862.00
2	73327	HF ELECTRIC ACTUATOR	$540.00	$1,080.00
2	428949	BOOSTER ACTUATOR	$396.00	$792.00
2	70846	LEVER ACTUATOR	$280.00	$560.00
1	416680	1 1/4" NPT ORIFICE UNION	$241.00	$241.00
1	46250	PNEUMATIC SWITCH DPST	$353.00	$353.00
1	41942	NAMEPLATE - "MAIN"	$12.10	$12.10
1	41943	NAMEPLATE - "RESERVE"	$12.10	$12.10
2	416265	WARNING PLATE - INSIDE W/ ALARM	$16.60	$33.20
2	416266	WARNING PLATE - OUTSIDE W/ ALARM	$14.90	$29.80
1	417365	1 1/4" NPT INERGEN NOZZLE (360 Degree)	$121.00	$121.00
1	417717	1 1/4" INERGEN DEFLECTOR SHIELD	$88.00	$88.00
2	41549	1.1/4" CHECK VALVE - THREADED	$969.00	$1,938.00
2	79640	BACK FRAME ASSEMBLY (4 CYLINDER)	$226.00	$452.00
2	418503	27" CARRIAGE BOLT & NUT (DBL ROW 435)	$18.50	$37.00
2	73091	CYLINDER CLAMP (2 CYLINDER)	$51.00	$102.00
2	73257	UPRIGHT (USED FOR EITHER SIDE)	$98.50	$197.00
1	73555	DOUBLE ROW BRACKET FOOT (LEFT SIDE)	$60.50	$60.50
1	73556	DOUBLE ROW BRACKET FOOT (RIGHT SIDE)	$60.50	$60.50
2	71682	WEIGH RAIL SUPPORT-DOUBLE ROW	$115.00	$230.00
1	430525	AUTOPULSE Z-10 Control System, Red, 120/240 VAC	$998.00	$998.00
2	433940	Abort Switch, Flush Mount	$107.00	$214.00
1	430565	Heat Detector 135F ROR ULI	$29.00	$29.00
1	430567	2-Wire Base w/LED DRIVER ULI	$10.30	$10.30
1	4727	Detector, Heat, Rate Compensated, 140 deg.F, Vert.	$204.00	$204.00
2	435471	Pull Station, AUTOPULSE, NBG-12LR	$90.00	$180.00
2	418990	SB-10 SURFACE BACKBOX	$20.30	$40.60
1	417805	Bell, 24 VDC, 6 in.	$71.50	$71.50
2	433352	Strobe, Multi-Candela, AGENT, Red	$109.00	$218.00
1	433356	Horn/Strobe, Multi Candela, FIRE, Red	$143.00	$143.00
1	417692	Battery Pack, 7 AH, 24 VDC (2-12 VDC Batteries)	$151.00	$151.00
	TOTAL WEIGHT:	3,878.05	TOTAL PRICE:	$37,540.60
			ENGINEERING FEE:	
			TOTAL:	$37,540.60

NOTES:

1.Pricing is per information supplied and includes only the items listed. Equipment list could vary after design.

2.All terms are per the Ansul Distributor Contract.

3.No design or engineering is included unless noted.

4.No onsite checkout or supervision is included.

5. No installation material is included (i.e. wire, conduit, hangers and electrical connections.)

DISTRIBUTOR NAME
DISTRIBUTOR ADDRESS
DESTRIBUTOR CITY, STATE & ZIP CODE

PHONE
FAX

Appendix GG: 2010 INERGERN® First Floor Price Spreadsheet

This form is for calculating a single hazard area or multiple hazard areas discharged simultaneously from a single bank of cylinders.

System based on required bill of materials given. Because design analysis and quantity calculations were not performed to verify proper system design, hardware supplied may not be sufficient for proper protection. Please verify equipment selected is equipment required for application.

INSTRUCTIONS FOR USE

1) Information Sheet

- Fill in all information in the bold cells on the information sheet.
- Do not fill in the area or volume, they will be calculate automatically.
- If only the volume is known, fill in the specified volume. The height will default to 10 ft., and the length will be 2 times the width.
- The temperature will default to 65, 75 and 70 degrees F. If other temperatures are required, replace the default temperatures with the required temperatures.

  Pick one type of bracketing.

  Examples:

  S = single row

  MRS = main & reserve single row
- enter the number of exits for each hazard
- enter whether single or cross zone detection is required and the type of detectors
- enter voltage
- **Select UL or ULC listing**

2) IG QTY Calc Sheet

- Select the size cylinder desired (yellow shaded box) and verify minimum and maximum concentrations are within the design concentrations acceptable using the selected cylinder size.
- If you are protecting an area with a false ceiling, check the estimated nozzle size to make certain the size is not larger then 1 1/2". If it is, increase the number of nozzles to reduce the size required.
- Check Estimate Union Orifice Pipe Size does not show the warning Larger than 4". If the warning appears you may have to split the systems to allow a available orifice size to be picked. If this is not corrected, a false bill of materials will be created without a pressure reducer.
- Tank size is automatically selects a 439 cu. Ft., if a different size is required please select a tank size that is available.

3) B.O.M.

- Input discount and any addition discount that may apply. If no discount is entered, the pricing will be at suggest list.
- Input any additional equipment that is required and does not have a quantity automatically associated with it, add quantity of item(s) in QTY column.
- Cell that show up red are suggestions for products to use. Other products maybe a better choice. Please refer to the products manual.
- Click on the drop down arrow in the QTY column and scroll to "nonblanks" and click. This will eliminate any items that are not automatically chosen and will provide a bill of materials for only the items requested or required.

INERGEN & DETECTION & CONTROL INFORMATION SHEET

DATE: 2/22/2011
QUOTE/JOB NUMBER: Mt Washington MQP
CUSTOMER: Mt Washington MQP

HAZARD INFORMATION	AREA 1	AREA 2	AREA 3	AREA 4	AREA 5	AREA 6
Area Name:	FF 1	FF 2	Hallway	Tower	FF 3	FF 4
Length (ft.):	52.00	52.00	36.18	17.00	17.00	17.00
Width (ft.):	13.00	13.00	18.09	8.00	11.00	8.00
Height (ft.):	8.00	8.00	10.00	16.00	8.00	8.00
Area (sq. ft.):	676.0	676.0	654.6	283.8	187.0	136.0
Volume (cu. ft.):	5408	5408	6546	4540	1496	1088
Specified Volume (cu. ft.):			6546.00	4540.00		
Structural Reductions (cu. ft.):						
Minimum Ambient Temp.:	65.0	65.0	65.0	65.0	65.0	65.0
Maximum Ambient Temp.:	75.0	75.0	75.0	75.0	75.0	75.0
Normal Ambient Temperature:	70.0	70.0	70.0	70.0	70.0	70.0
Altitude Correction:	6288	6288	6288	6288	6288	6288

Bracketing:	DBB	**Type**	
Single	S, MRS	Double	D, MRD
Single B-To-B	SBB, MRSBB	Double B-to-B	DBB, MRDBB

Uprights: Y — Y = Yes, Blank = No

Nozzle type (180 or 360):	360	360	360	360	360	360
Deflector Shield (Y or N):	Y	Y	Y	Y	Y	Y
Maximum Wall Strength:						
Main/Reserve System	Y	Y or N				

DETECTION & CONTROL

	AREA 1	AREA 2	AREA 3	AREA 4	AREA 5	AREA 6
Area Name:	FF 1	FF 2	Hallway	Tower	FF 3	FF 4
General Alarm? Y or N:	Y	Y	Y	Y	Y	Y
Predischarge Alarm? Y or N:	Y	Y	Y	Y	Y	Y
System Fired Alarm? Y or N:	Y	Y	Y	Y	Y	Y
Number of Exits:	1	1	2	2	1	1
Abort? Y or N:	Y	Y	Y	Y	Y	Y
Type Alarm:	bell	bell	bell	bell	bell	bell
Output dBA:	92	92	92	92	92	92
Ambient Sound Level:	60	60	60	60	60	60
Type Detection: S = single, X = cross zone	X	X	X	X	X	X
Type Detector: I=Ion, P=Photo, T=Thermal, B=both Ion & Photo	T	T	T	T	T	T

Type Panel:	Z10	Z10 or 542R or IQ318 or IQ636X-2
Voltage:	120	120 or 240
Wiring Type	B	A or B
Explosion Proof	N	Y or N
Number of Release Zones		1 through 10 (Number Depends on the panel)
Main/Reserve System	N	Y or N
Disable Switch	Y	Y or N
ULC Listed	UL	UL or ULC

INERGEN DESIGN CALCULATION WORKSHEET

DATE: 2/22/2011
QUOTE/JOB NUMBER: Mt Washington MQP
CUSTOMER: Mt Washington MQP

VOLUME CALCULATIONS:	AREA 1	AREA 2	AREA 3	AREA 4	AREA 5
Area Name:	FF 1	FF 2	Hallway	Tower	FF 3
Length (ft.):	52.00	52.00	36.18	17.00	17.00
Width (ft.):	13.00	13.00	18.09	8.00	11.00
Height (ft.):	8.00	8.00	10.00	16.00	8.00
Area (sq. ft.):	676.00	676.00	654.60	283.75	187.00
Volume (cu. ft.):	5408.00	5408.00	6546.00	4540.00	1496.00
Specified Volume (cu. ft.):			6546.00	4540.00	
Volume Reductions:					
Structural Reductions (cu. ft.):					
Reduced Volume:	5408.00	5408.00	6546.00	4540.00	1496.00
(Volume - Structural Reductions)					
Movable Object Reductions (cu. ft.):					
(If More Than 25% of Reduced Volume)					
Total Reduced Volume (cu. ft.):	5408.00	5408.00	6546.00	4540.00	1496.00
(Reduced Volume - Movable Object Reductions)					
ROOM MINIMUM AMBIENT TEMP.:	65.0	65.0	65.0	65.0	65.0
DESIGN CONCENTRATION:	34.20	34.20	34.20	34.20	34.20
FLOODING FACTOR:	0.423	0.423	0.423	0.423	0.423
(From Table)					
INITIAL INERGEN QUANTITY CALC.:	2285.96	2285.96	2766.99		
INERGEN Quantity (cu. ft.):	2285.96	2285.96	2766.99	1919.06	632.36
(Total Reduced Volume x Flooding factor) or (Formula from Design Manual)					

ALTITUDE CORRECTION:	
Height Above or Below Sea Level:	6288
Factor:	0.77
(From Design Manual Table)	

ACTUAL INERGEN QTY (cu. ft.):	1771.50	1771.50	2144.27	1487.17	490.04
(Initial Inergen Quantity x Altitude Correction Factor)					

TOTAL INERGEN QTY (cu. ft.): 8020.87
(Sum of all Actual INERGEN qty's)

TOTAL INERGEN QTY (cu. ft.): 8020.87
(From Page 1)

CYLINDER REQUIREMENTS: *(Total INERGEN qty. ÷ Cylinder Capacity rounded to next highest whole number)*		**TOTAL CYLINDER CAPACITY:** *(Cyl. qty. x Cyl. cap.)*
575 cu. ft. Cylinders:	15	8580
439 cu. ft. Cylinders:	19	8341
355 cu. ft. Cylinders:	23	8165
266 cu. ft. Cylinders:	31	8246
205 cu. ft. Cylinders:	40	8200

CYLINDER SIZE SELECTED: 439
INERGEN AGENT SUPPLIED: 8341
(Cylinder qty. x Cylinder capacity)

ACTUAL INERGEN AGENT PER AREA:	1842.20	1842.20	2229.85	1546.52	509.60
((Actual Inergen Qty. ÷ Total Inergen Qty.) x INERGEN Agent Supplied)					
ACTUAL INERGEN FLOODING FACTOR:	0.44	0.44	0.44	0.44	0.44

[(Actual INERGEN Agent per Area ÷ Alt. Correction Factor) ÷ Total Reduced Volume]

CONCENTRATION RANGE CHECK:
(Design Conc. Must be Between 32.4% - 52% For Occupied Spaces)

Room Max. Ambient Temp.:	75.0	75.0	75.0	75.0	75.0
Design Concentration at Max. Temp:	35.83	35.83	35.83	35.83	35.83

(Locate Actual INERGEN Conc. at Max. Temp. on Table, or Use Calc. in Design Manual)

DISCHARGE TIME:

Normal Ambient Temperature:	70.0	70.0	70.0	70.0	70.0
Design Concentration at Ambient Temp.:	35.56	35.56	35.56	35.56	35.56

(Locate Actual INERGEN Conc. at Amb. Temp. on Table, or Use Calc. in Design Manual)

90% of Agent Discharge Time (Sec.):	54.34	54.34	54.34	54.34	54.34
90% of Agent Discharge Time (Min):	0.91	0.91	0.91	0.91	0.91

ESTIMATED FLOW RATES:

Estimated System Flow Rate: 8288

[(INERGEN Agent Supplied x .9) ÷ 90% Discharge Time (Min.)]

Estimated Orifice Union Pipe Size: 2.5

(Refer to Pipe Sizing Chart)

Nozzle Quantity:	2	2	2	1	1
Estimated Nozzle Flow Rate:	915.30	915.30	1107.90	1536.78	506.39

Estimated Nozzle Pipe Size:

Pipe Length Factor (S = Short, L = Long):	S	S	S	S	S
Pipe Size:	0.75	0.75	0.75	1	0.5

Allowable Enclosure Strength (PSF):					
Estimated Peak Flow Rate:					
Venting (sq. in.):					

Total Venting (sq. in.)

DETECTION & CONTROL
ALARM REQUIREMENTS

DATE: 2/22/2011
QUOTE/JOB NUMBER: Mt Washington MQP
CUSTOMER: Mt Washington MQP

	AREA 1	AREA 2	AREA 3	AREA 4	AREA 5	AREA 6
Area Name:	FF 1	FF 2	Hallway	Tower	FF 3	FF 4
Length:	52.00	52.00	**36.18**	17.00	17.00	17.00
Width:	13.00	13.00	18.09	8.00	11.00	8.00
Height:	8.00	8.00	10.00	16.00	8.00	8.00
Area:	676.00	676.00	654.60	136.00	187.00	136.00
Total AllAreas:	2465.60					

DESIGN INFORMATION

General Alarm? Y or N:	Y	Y	Y	Y	Y	Y
Predischarge Alarm? Y or N:	Y	Y	Y	Y	Y	Y
System Fired Alarm? Y or N:	Y	Y	Y	Y	Y	Y
Number of Exists:	1	1	2	2	1	1
Abort? Y or N:	Y	Y	Y	Y	Y	Y

ALARM INFORMATION

Type Alarm:	bell	bell	bell	bell	bell	bell
Output dBA:	92	92	92	92	92	92
Ambient Sound Level:	60	60	60	60	60	60
Linear Distance:	40	40	40	40	40	40
Longest side of rectangle:	79.00	79.00	79.00	79.00	79.00	79.00

NUMBER OF ALARMS

bells:	1	1	1	1	1	1
general alarm strobes:						
horn/strobes:	1	1	1	1	1	1
strobes:	1	1	2	2	1	1
manual releases:	1	1	2	2	1	1
aborts:	1	1	2	2	1	1
Total Bells	6					
Total Horn/Strobes	6					
Total Strobes	8					
Total Manual Releases	8					
Total Aborts	8					

DETECTION & CONTROL
DETECTOR REQUIREMENTS

DATE: 2/22/2011
QUOTE/JOB NUMBER: Mt Washington MQP

CUSTOMER: Mt Washington MQP
PROJECT:

	AREA 1	AREA 2	AREA 3	AREA 4	AREA 5	AREA 6
Area Name:	FF 1	FF 2	Hallway	Tower	FF 3	FF 4
Length:	52	52	36.18286887	17	17	17
Width:	13	13	18.09143444	8	11	8
Height:	8	8	10	16	8	8
Area:	676.00	676.00	654.60	136.00	187.00	136.00
Total All Areas:	2465.60					

NUMBER OF DETECTORS

	AREA 1	AREA 2	AREA 3	AREA 4	AREA 5	AREA 6
Length:	4	4	3	2	2	2
Width:	1	1	1	1	1	1
Area Total:	4	4	3	2	2	2
Total All Areas	17					
Width:	1	1	2	1	1	1
Length:	4	4	2	1	1	1
AreaTotal:	4	4	4	1	1	1
Total All Areas	15					
Detectors Required Per Area:	4	4	3	1	1	1
Detectors Required All Areas:	14					
Type Detection: S = single, X = cross zone	X	X	X	X	X	X
Type Detector: I=Ion, P=Photo, T=Thermal, B=both Ion & Photo	T	T	T	T	T	T
Ion						
Photo						
Thermal	4	4	4	2	2	2

Total Ion:	
Total Photo:	
Total Thermal:	18
Total Smoke Detectors:	

INERGEN BILL OF MATERIALS

Quote No.:	Mt Washington MQP	Date:	2/22/2011
Customer Name:	Mt Washington MQP	Page:	1 of 1
Customer Address:		Product Line:	Inergen
		List Price Discount:	
		Additional Discount:	
Phone No.:		Project:	
Fax No.:			
Contact Name:			

QTY	PART #	DESCRIPTION	UNIT PRICE	TOTAL PRICE
38	426150	435 CU. FT CYLINDER W/ CV98 VALVE-EN	$1,930.00	$73,340.00
38	427082	DISCHARGE HOSE	$133.00	$5,054.00
2	73327	HF ELECTRIC ACTUATOR	$540.00	$1,080.00
2	428949	BOOSTER ACTUATOR	$396.00	$792.00
2	70846	LEVER ACTUATOR	$280.00	$560.00
4	31809	16" ACTUATION HOSE	$20.00	$80.00
4	32334	MALE ELBOW (for use with part no. 73236)	$7.60	$30.40
2	418359	MALE TEE (for use with part no. 73236)	$5.20	$10.40
6	73236	PILOT VALVE ACTUATION ADAPTOR	$4.10	$24.60
1	426823	2 1/2" THREADED ORIFICE FLANGE ASSEMBLY	$548.00	$548.00
1	46250	PNEUMATIC SWITCH DPST	$353.00	$353.00
1	41942	NAMEPLATE - "MAIN"	$12.10	$12.10
1	41943	NAMEPLATE - "RESERVE"	$12.10	$12.10
12	416265	WARNING PLATE - INSIDE W/ ALARM	$16.60	$199.20
8	416266	WARNING PLATE - OUTSIDE W/ ALARM	$14.90	$119.20
2	417362	1/2" NPT INERGEN NOZZLE (360 Degree)	$95.00	$190.00
6	417363	3/4" NPT INERGEN NOZZLE (360 Degree)	$103.00	$618.00
1	417364	1" NPT INERGEN NOZZLE (360 Degree)	$113.00	$113.00
2	417708	1/2" INERGEN DEFLECTOR SHIELD	$65.00	$130.00
6	417711	3/4" INERGEN DEFLECTOR SHIELD	$68.00	$408.00
1	417714	1" INERGEN DEFLECTOR SHIELD	$79.50	$79.50
2	40656	2 1/2" CHECK VALVE - THREADED	$3,095.00	$6,190.00
4	79641	BACK FRAME ASSEMBLY (5 CYLINDER)	$270.00	$1,080.00
6	418503	27" CARRIAGE BOLT & NUT (DBL ROW 435)	$18.50	$111.00
2	73091	CYLINDER CLAMP (2 CYLINDER)	$51.00	$102.00
2	73092	CYLINDER CLAMP (3 CYLINDER)	$62.50	$125.00
2	73257	UPRIGHT (USED FOR EITHER SIDE)	$98.50	$197.00
2	73555	DOUBLE ROW BRACKET FOOT (LEFT SIDE)	$60.50	$121.00
2	73556	DOUBLE ROW BRACKET FOOT (RIGHT SIDE)	$60.50	$121.00
2	423027	WEIGH RAIL SUPPORT-DBL ROW BACK TO BACK	$167.00	$334.00
1	430525	AUTOPULSE Z-10 Control System, Red, 120/240 VAC	$998.00	$998.00
8	433940	Abort Switch, Flush Mount	$107.00	$856.00
1	430565	Heat Detector 135F ROR ULI	$29.00	$29.00
1	430567	2-Wire Base w/LED DRIVER ULI	$10.30	$10.30
1	4727	Detector, Heat, Rate Compensated, 140 deg.F, Vert.	$204.00	$204.00
8	435471	Pull Station, AUTOPULSE, NBG-12LR	$90.00	$720.00
8	418990	SB-10 SURFACE BACKBOX	$20.30	$162.40
6	417805	Bell, 24 VDC, 6 in.	$71.50	$429.00
8	433352	Strobe, Multi-Candela, AGENT, Red	$109.00	$872.00
6	433356	Horn/Strobe, Multi Candela, FIRE, Red	$143.00	$858.00
1	417692	Battery Pack, 7 AH, 24 VDC (2-12 VDC Batteries)	$151.00	$151.00

TOTAL WEIGHT:	10,385.36	TOTAL PRICE:	$97,424.20
		ENGINEERING FEE:	
		TOTAL:	$97,424.20

NOTES:

1.Pricing is per information supplied and includes only the items listed. Equipment list could vary after design.

2.All terms are per the Ansul Distributor Contract.

3.No design or engineering is included unless noted.

4.No onsite checkout or supervision is included.

5. No installation material is included (i.e. wire, conduit, hangers and electrical connections.)

DISTRIBUTOR NAME
DISTRIBUTOR ADDRESS
DESTRIBUTOR CITY, STATE & ZIP CODE

PHONE
FAX

Appendix HH: 2010 INERGERN® Basement Price Spreadsheet

This form is for calculating a single hazard area or multiple hazard areas discharged simultaneously from a single bank of cylinders.

System based on required bill of materials given. Because design analysis and quantity calculations were not performed to verify proper system design, hardware supplied may not be sufficient for proper protection. Please verify equipment selected is equipment required for application.

INSTRUCTIONS FOR USE

1) Information Sheet

- Fill in all information in the bold cells on the information sheet.
- Do not fill in the area or volume, they will be calculate automatically.
- If only the volume is known, fill in the specified volume. The height will default to 10 ft., and the length will be 2 times the width.
- The temperature will default to 65, 75 and 70 degrees F. If other temperatures are required, replace the default temperatures with the required temperatures.

  Pick one type of bracketing.

  Examples:

  S = single row

  MRS = main & reserve single row
- enter the number of exits for each hazard
- enter whether single or cross zone detection is required and the type of detectors
- enter voltage
- **Select UL or ULC listing**

2) IG QTY Calc Sheet

- Select the size cylinder desired (yellow shaded box) and verify minimum and maximum concentrations are within the design concentrations acceptable using the selected cylinder size.
- If you are protecting an area with a false ceiling, check the estimated nozzle size to make certain the size is not larger then 1 1/2". If it is, increase the number of nozzles to reduce the size required.
- Check Estimate Union Orifice Pipe Size does not show the warning Larger than 4". If the warning appears you may have to split the systems to allow a available orifice size to be picked. If this is not corrected, a false bill of materials will be created without a pressure reducer.
- Tank size is automatically selects a 439 cu. Ft., if a different size is required please select a tank size that is available.

3) B.O.M.

- Input discount and any addition discount that may apply. If no discount is entered, the pricing will be at suggest list.
- Input any additional equipment that is required and does not have a quantity automatically associated with it, add quantity of item(s) in QTY column.
- Cell that show up red are suggestions for products to use. Other products maybe a better choice. Please refer to the products manual.
- Click on the drop down arrow in the QTY column and scroll to "nonblanks" and click. This will eliminate any items that are not automatically chosen and will provide a bill of materials for only the items requested or required.

INERGEN & DETECTION & CONTROL INFORMATION SHEET

DATE: 2/22/2011
QUOTE/JOB NUMBER: Mt Washington MQP
CUSTOMER: Mt Washington MQP

HAZARD INFORMATION	AREA 1	AREA 2	AREA 3	AREA 4	AREA 5	AREA 6
Area Name:	Basement 1	Basement 2	Hallway	Stairs	Basement 3	Basement 4
Length (ft.):	52.00	52.00	36.18	17.00	17.00	17.00
Width (ft.):	13.00	13.00	18.09	8.00	11.00	8.00
Height (ft.):	8.00	8.00	10.00	16.00	8.00	8.00
Area (sq. ft.):	676.0	676.0	654.6	136.0	187.0	136.0
Volume (cu. ft.):	5408	5408	6546	2176	1496	1088
Specified Volume (cu. ft.):			6546.00			
Structural Reductions (cu. ft.):						
Minimum Ambient Temp.:	65.0	65.0	65.0	65.0	65.0	65.0
Maximum Ambient Temp.:	75.0	75.0	75.0	75.0	75.0	75.0
Normal Ambient Temperature:	70.0	70.0	70.0	70.0	70.0	70.0
Altitude Correction:	6288	6288	6288	6288	6288	6288

Bracketing: DBB **Type**

Single	S, MRS	Double	D, MRD
Single B-To-B	SBB, MRSBB	Double B-to-B	DBB, MRDBB

Uprights: Y — Y = Yes, Blank = No

	AREA 1	AREA 2	AREA 3	AREA 4	AREA 5	AREA 6
Nozzle type (180 or 360):	360	360	360	360	360	360
Deflector Shield (Y or N):	Y	Y	Y	Y	Y	Y
Maximum Wall Strength:						
Main/Reserve System	Y	Y or N				

DETECTION & CONTROL

	AREA 1	AREA 2	AREA 3	AREA 4	AREA 5	AREA 6
Area Name:	Basement 1	Basement 2	Hallway	Stairs	Basement 3	Basement 4
General Alarm? Y or N:	Y	Y	Y	Y	Y	Y
Predischarge Alarm? Y or N:	Y	Y	Y	Y	Y	Y
System Fired Alarm? Y or N:	Y	Y	Y	Y	Y	Y
Number of Exits:	1	1	2	2	1	1
Abort? Y or N:	Y	Y	Y	Y	Y	Y
Type Alarm:	bell	bell	bell	bell	bell	bell
Output dBA:	92	92	92	92	92	92
Ambient Sound Level:	60	60	60	60	60	60
Type Detection: S = single, X = cross zone	X	X	X	X	X	X
Type Detector: I=Ion, P=Photo, T=Thermal, B=both Ion & Photo	T	T	T	T	T	T

Type Panel:	Z10	Z10 or 542R or IQ318 or IQ636X-2
Voltage:	120	120 or 240
Wiring Type	B	A or B
Explosion Proof	N	Y or N
Number of Release Zones		1 through 10 (Number Depends on the panel)
Main/Reserve System	N	Y or N
Disable Switch	Y	Y or N
ULC Listed	UL	UL or ULC

INERGEN DESIGN CALCULATION WORKSHEET

DATE: 2/22/2011
QUOTE/JOB NUMBER: Mt Washington MQP
CUSTOMER: Mt Washington MQP

VOLUME CALCULATIONS:	AREA 1	AREA 2	AREA 3	AREA 4	AREA 5
Area Name:	Basement 1	Basement 2	Hallway	Stairs	Basement 3
Length (ft.):	52.00	52.00	36.18	17.00	17.00
Width (ft.):	13.00	13.00	18.09	8.00	11.00
Height (ft.):	8.00	8.00	10.00	16.00	8.00
Area (sq. ft.):	676.00	676.00	654.60	136.00	187.00
Volume (cu. ft.):	5408.00	5408.00	6546.00	2176.00	1496.00
Specified Volume (cu. ft.):			6546.00		
Volume Reductions:					
Structural Reductions (cu. ft.):					
Reduced Volume:	5408.00	5408.00	6546.00	2176.00	1496.00
(Volume - Structural Reductions)					
Movable Object Reductions (cu. ft.):					
(If More Than 25% of Reduced Volume)					
Total Reduced Volume (cu. ft.):	5408.00	5408.00	6546.00	2176.00	1496.00
(Reduced Volume - Movable Object Reductions)					
ROOM MINIMUM AMBIENT TEMP.:	65.0	65.0	65.0	65.0	65.0
DESIGN CONCENTRATION:	34.20	34.20	34.20	34.20	34.20
FLOODING FACTOR:	0.423	0.423	0.423	0.423	0.423
(From Table)					
INITIAL INERGEN QUANTITY CALC.:	2285.96	2285.96	2766.99		
INERGEN Quantity (cu. ft.):	2285.96	2285.96	2766.99	919.80	632.36
(Total Reduced Volume x Flooding factor) or (Formula from Design Manual)					
ALTITUDE CORRECTION:					
Height Above or Below Sea Level:	6288				
Factor:	0.77				
(From Design Manual Table)					
ACTUAL INERGEN QTY (cu. ft.):	1771.50	1771.50	2144.27	712.79	490.04
(Initial Inergen Quantity x Altitude Correction Factor)					
TOTAL INERGEN QTY (cu. ft.):	7246.50				
(Sum of all Actual INERGEN qty's)					
TOTAL INERGEN QTY (cu. ft.):	7246.50				
(From Page 1)					

CYLINDER REQUIREMENTS:
(Total INERGEN qty. ÷ Cylinder Capacity rounded to next highest whole number)

TOTAL CYLINDER CAPACITY:
(Cyl. qty. x Cyl. cap.)

575 cu. ft. Cylinders:	13	7436
439 cu. ft. Cylinders:	17	7463
355 cu. ft. Cylinders:	21	7455
266 cu. ft. Cylinders:	28	7448
205 cu. ft. Cylinders:	36	7380

CYLINDER SIZE SELECTED:	439
INERGEN AGENT SUPPLIED:	7463

(Cylinder qty. x Cylinder capacity)

ACTUAL INERGEN AGENT PER AREA:	1824.42	1824.42	2208.34	734.09	504.69

((Actual Inergen Qty. ÷ Total Inergen Qty.) x INERGEN Agent Supplied)

ACTUAL INERGEN FLOODING FACTOR:	0.44	0.44	0.44	0.44	0.44

[(Actual INERGEN Agent per Area ÷ Alt. Correction Factor) ÷ Total Reduced Volume]

CONCENTRATION RANGE CHECK:
(Design Conc. Must be Between 32.4% - 52% For Occupied Spaces)

Room Max. Ambient Temp.:	75.0	75.0	75.0	75.0	75.0
Design Concentration at Max. Temp:	35.55	35.55	35.55	35.55	35.55

(Locate Actual INERGEN Conc. at Max. Temp. on Table, or Use Calc. in Design Manual)

DISCHARGE TIME:

Normal Ambient Temperature:	70.0	70.0	70.0	70.0	70.0
Design Concentration at Ambient Temp.:	35.29	35.29	35.29	35.29	35.29

(Locate Actual INERGEN Conc. at Amb. Temp. on Table, or Use Calc. in Design Manual)

90% of Agent Discharge Time (Sec.):	51.46	51.46	51.46	51.46	51.46
90% of Agent Discharge Time (Min):	0.86	0.86	0.86	0.86	0.86

ESTIMATED FLOW RATES:

Estimated System Flow Rate:	7831

[(INERGEN Agent Supplied x .9) ÷ 90% Discharge Time (Min.)]

Estimated Orifice Union Pipe Size:	2.5

(Refer to Pipe Sizing Chart)

Nozzle Quantity:	2	2	2	1	1
Estimated Nozzle Flow Rate:	957.24	957.24	1158.67	770.32	529.60

Estimated Nozzle Pipe Size:

Pipe Length Factor (S = Short, L = Long):	S	S	S	S	S
Pipe Size:	0.75	0.75	1	0.75	0.5
Allowable Enclosure Strength (PSF):					
Estimated Peak Flow Rate:					
Venting (sq. in.):					

Total Venting (sq. in.)

DETECTION & CONTROL
ALARM REQUIREMENTS
DATE: 2/22/2011
QUOTE/JOB NUMBER: Mt Washington MQP
CUSTOMER: Mt Washington MQP

	AREA 1	AREA 2	AREA 3	AREA 4	AREA 5	AREA 6
Area Name:	Basement 1	Basement 2	Hallway	Stairs	Basement 3	Basement 4
Length:	52.00	52.00	**36.18**	17.00	17.00	17.00
Width:	13.00	13.00	18.09	8.00	11.00	8.00
Height:	8.00	8.00	10.00	16.00	8.00	8.00
Area:	676.00	676.00	654.60	136.00	187.00	136.00
Total AllAreas:	2465.60					

DESIGN INFORMATION

General Alarm? Y or N:	Y	Y	Y	Y	Y	Y
Predischarge Alarm? Y or N:	Y	Y	Y	Y	Y	Y
System Fired Alarm? Y or N:	Y	Y	Y	Y	Y	Y
Number of Exists:	1	1	2	2	1	1
Abort? Y or N:	Y	Y	Y	Y	Y	Y

ALARM INFORMATION

Type Alarm:	bell	bell	bell	bell	bell	bell
Output dBA:	92	92	92	92	92	92
Ambient Sound Level:	60	60	60	60	60	60
Linear Distance:	40	40	40	40	40	40
Longest side of rectangle:	79.00	79.00	79.00	79.00	79.00	79.00

NUMBER OF ALARMS

bells:	1	1	1	1	1	1
general alarm strobes:						
horn/strobes:	1	1	1	1	1	1
strobes:	1	1	2	2	1	1
manual releases:	1	1	2	2	1	1
aborts:	1	1	2	2	1	1
Total Bells	6					
Total Horn/Strobes	6					
Total Strobes	8					
Total Manual Releases	8					
Total Aborts	8					

DETECTION & CONTROL
DETECTOR REQUIREMENTS
DATE: 2/22/2011
QUOTE/JOB NUMBER: Mt Washington MQP

CUSTOMER: Mt Washington MQP
PROJECT:

	AREA 1	AREA 2	AREA 3	AREA 4	AREA 5	AREA 6
Area Name:	Basement 1	Basement 2	Hallway	Stairs	Basement 3	Basement 4
Length:	52	52	36.18286887	17	17	17
Width:	13	13	18.09143444	8	11	8
Height:	8	8	10	16	8	8
Area:	676.00	676.00	654.60	136.00	187.00	136.00
Total All Areas:	2465.60					

NUMBER OF DETECTORS

Length:	4	4	3	2	2	2
Width:	1	1	1	1	1	1
Area Total:	4	4	3	2	2	2
Total All Areas	17					
Width:	1	1	2	1	1	1
Length:	4	4	2	1	1	1
AreaTotal:	4	4	4	1	1	1
Total All Areas	15					
Detectors Required Per Area:	4	4	3	1	1	1
Detectors Required All Areas:	14					
Type Detection: S = single, X = cross zone	X	X	X	X	X	X
Type Detector: I=Ion, P=Photo, T=Thermal, B=both Ion & Photo	T	T	T	T	T	T
Ion						
Photo						
Thermal	4	4	4	2	2	2

Total Ion:	
Total Photo:	
Total Thermal:	18
Total Smoke Detectors:	

INERGEN BILL OF MATERIALS

Quote No.:	Mt Washington MQP		Date:	2/22/2011
Customer Name:	Mt Washington MQP		Page:	1 of 1
Customer Address:			Product Line:	Inergen
			List Price Discount:	
			Additional Discount:	
Phone No.:			Project:	
Fax No.:				
Contact Name:				

QTY	PART #	DESCRIPTION	UNIT PRICE	TOTAL PRICE
34	426150	435 CU. FT CYLINDER W/ CV98 VALVE-EN	$1,930.00	$65,620.00
34	427082	DISCHARGE HOSE	$133.00	$4,522.00
2	73327	HF ELECTRIC ACTUATOR	$540.00	$1,080.00
2	428949	BOOSTER ACTUATOR	$396.00	$792.00
2	70846	LEVER ACTUATOR	$280.00	$560.00
4	31809	16" ACTUATION HOSE	$20.00	$80.00
4	32334	MALE ELBOW (for use with part no. 73236)	$7.60	$30.40
2	418359	MALE TEE (for use with part no. 73236)	$5.20	$10.40
6	73236	PILOT VALVE ACTUATION ADAPTOR	$4.10	$24.60
1	426823	2 1/2" THREADED ORIFICE FLANGE ASSEMBLY	$548.00	$548.00
1	46250	PNEUMATIC SWITCH DPST	$353.00	$353.00
1	41942	NAMEPLATE - "MAIN"	$12.10	$12.10
1	41943	NAMEPLATE - "RESERVE"	$12.10	$12.10
12	416265	WARNING PLATE - INSIDE W/ ALARM	$16.60	$199.20
8	416266	WARNING PLATE - OUTSIDE W/ ALARM	$14.90	$119.20
2	417362	1/2" NPT INERGEN NOZZLE (360 Degree)	$95.00	$190.00
5	417363	3/4" NPT INERGEN NOZZLE (360 Degree)	$103.00	$515.00
2	417364	1" NPT INERGEN NOZZLE (360 Degree)	$113.00	$226.00
2	417708	1/2" INERGEN DEFLECTOR SHIELD	$65.00	$130.00
5	417711	3/4" INERGEN DEFLECTOR SHIELD	$68.00	$340.00
2	417714	1" INERGEN DEFLECTOR SHIELD	$79.50	$159.00
2	40656	2 1/2" CHECK VALVE - THREADED	$3,095.00	$6,190.00
4	79641	BACK FRAME ASSEMBLY (5 CYLINDER)	$270.00	$1,080.00
6	418503	27" CARRIAGE BOLT & NUT (DBL ROW 435)	$18.50	$111.00
2	73091	CYLINDER CLAMP (2 CYLINDER)	$51.00	$102.00
2	73092	CYLINDER CLAMP (3 CYLINDER)	$62.50	$125.00
2	73257	UPRIGHT (USED FOR EITHER SIDE)	$98.50	$197.00
2	73555	DOUBLE ROW BRACKET FOOT (LEFT SIDE)	$60.50	$121.00
2	73556	DOUBLE ROW BRACKET FOOT (RIGHT SIDE)	$60.50	$121.00
2	423027	WEIGH RAIL SUPPORT-DBL ROW BACK TO BACK	$167.00	$334.00
1	430525	AUTOPULSE Z-10 Control System, Red, 120/240 VAC	$998.00	$998.00
8	433940	Abort Switch, Flush Mount	$107.00	$856.00
1	430565	Heat Detector 135F ROR ULI	$29.00	$29.00
1	430567	2-Wire Base w/LED DRIVER ULI	$10.30	$10.30
1	4727	Detector, Heat, Rate Compensated, 140 deg.F, Vert.	$204.00	$204.00
8	435471	Pull Station, AUTOPULSE, NBG-12LR	$90.00	$720.00
8	418990	SB-10 SURFACE BACKBOX	$20.30	$162.40
6	417805	Bell, 24 VDC, 6 in.	$71.50	$429.00
8	433352	Strobe, Multi-Candela, AGENT, Red	$109.00	$872.00
6	433356	Horn/Strobe, Multi Candela, FIRE, Red	$143.00	$858.00
1	417692	Battery Pack, 7 AH, 24 VDC (2-12 VDC Batteries)	$151.00	$151.00
TOTAL WEIGHT:		9,329.61	TOTAL PRICE:	$89,193.70
			ENGINEERING FEE:	
			TOTAL:	$89,193.70

NOTES:

1.Pricing is per information supplied and includes only the items listed. Equipment list could vary after design.

2.All terms are per the Ansul Distributor Contract.

3.No design or engineering is included unless noted.

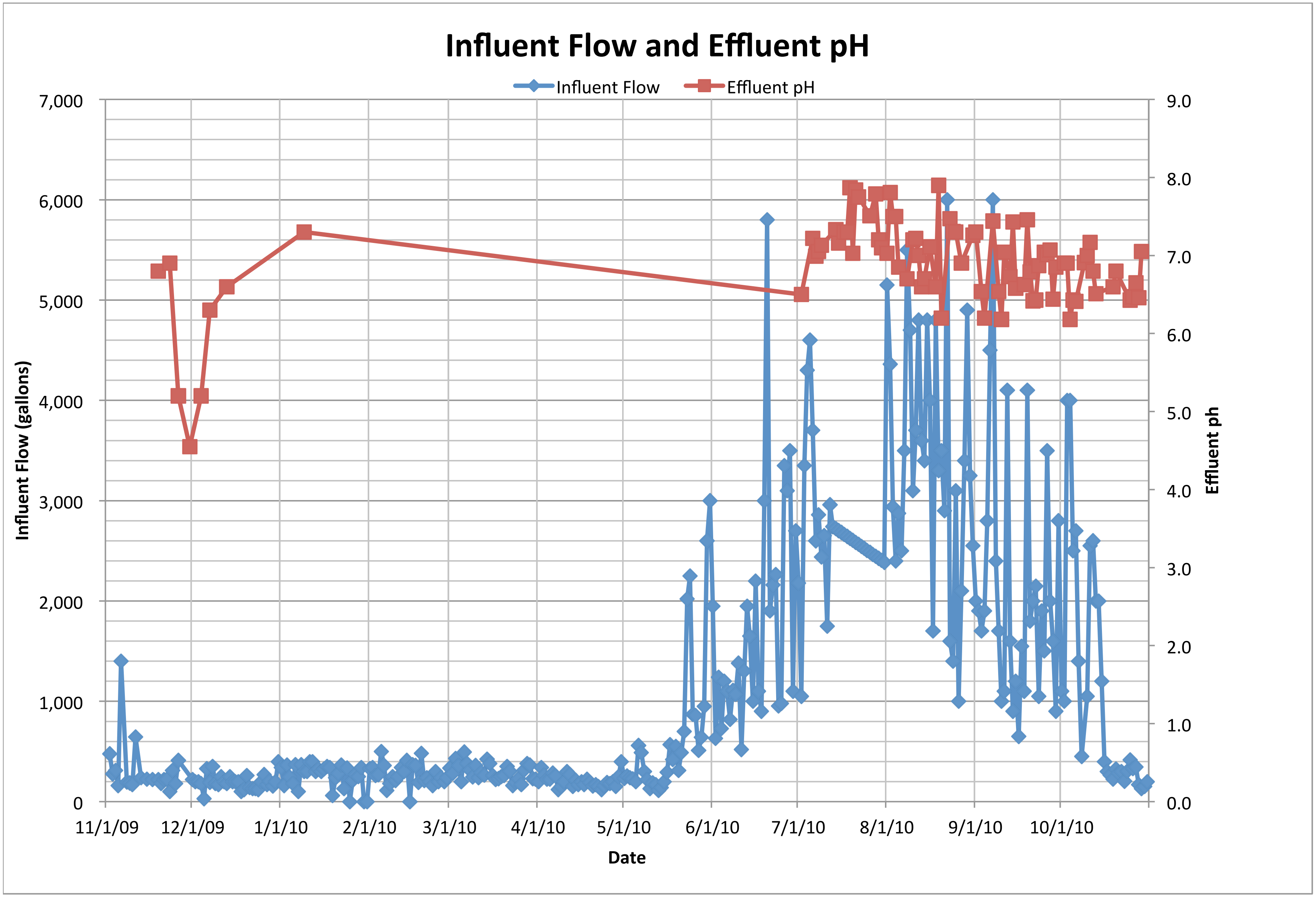
4.No onsite checkout or supervision is included.

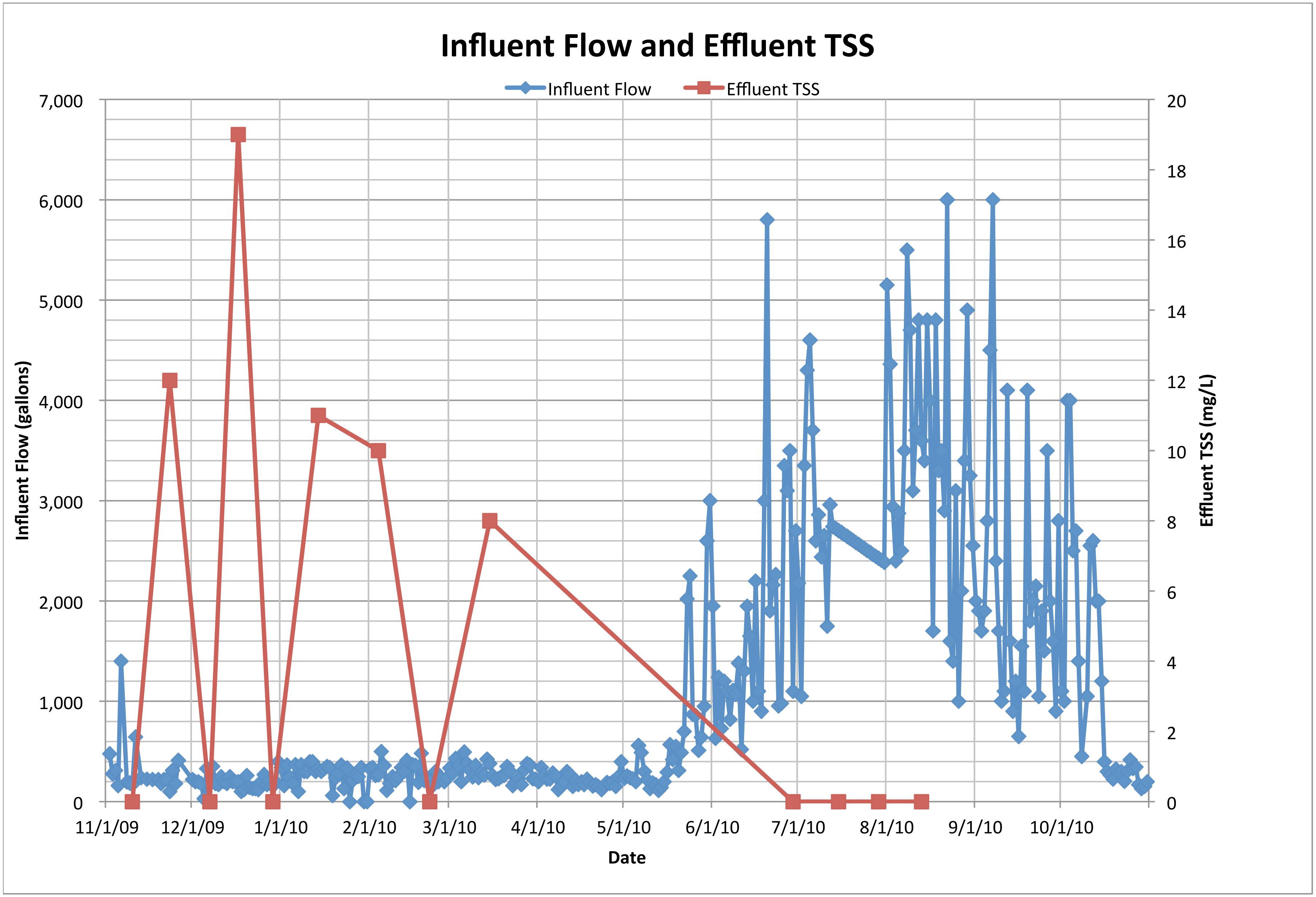
5. No installation material is included (i.e. wire, conduit, hangers and electrical connections.)

DISTRIBUTOR NAME
DISTRIBUTOR ADDRESS
DESTRIBUTOR CITY, STATE & ZIP CODE

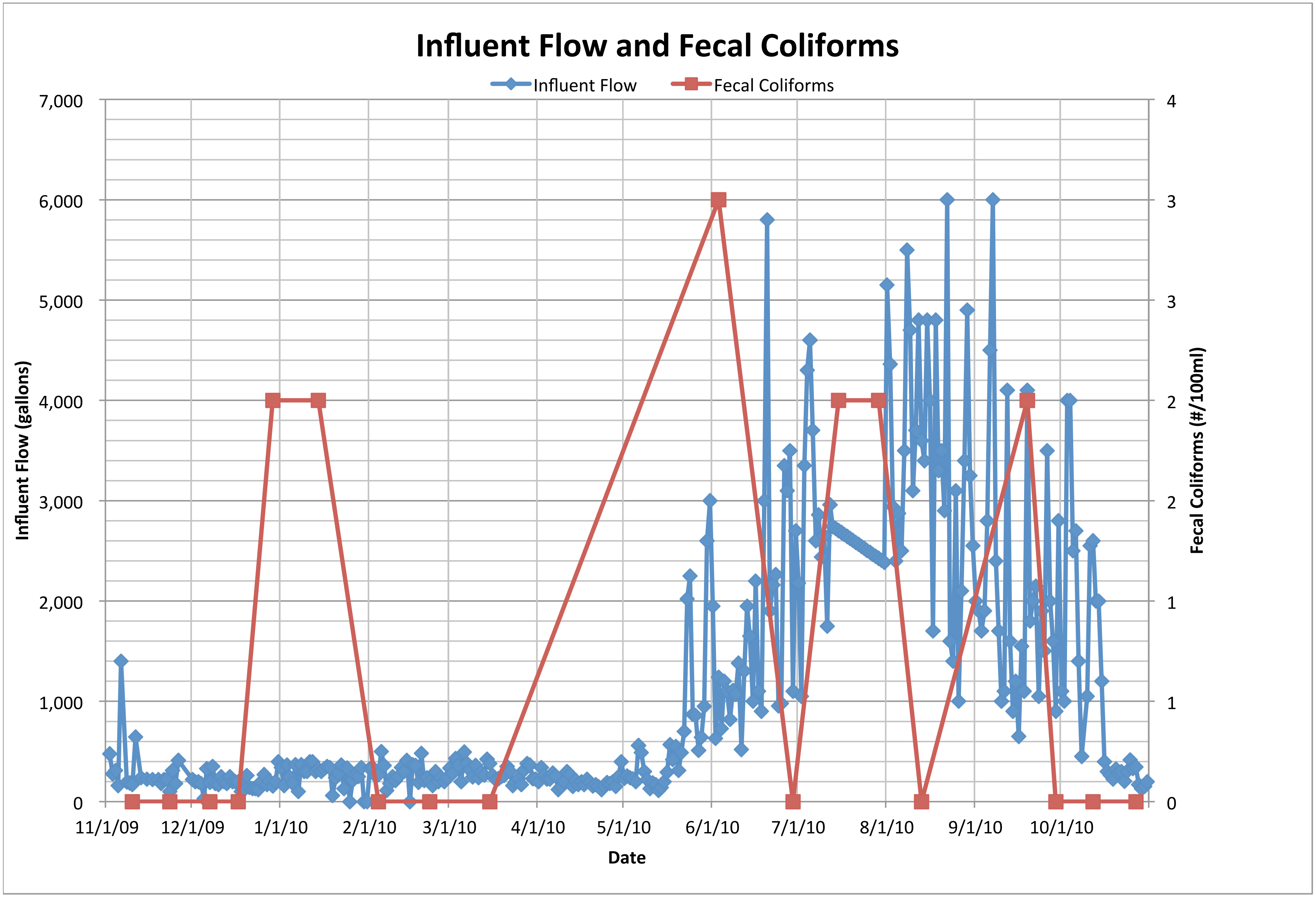
PHONE
FAX

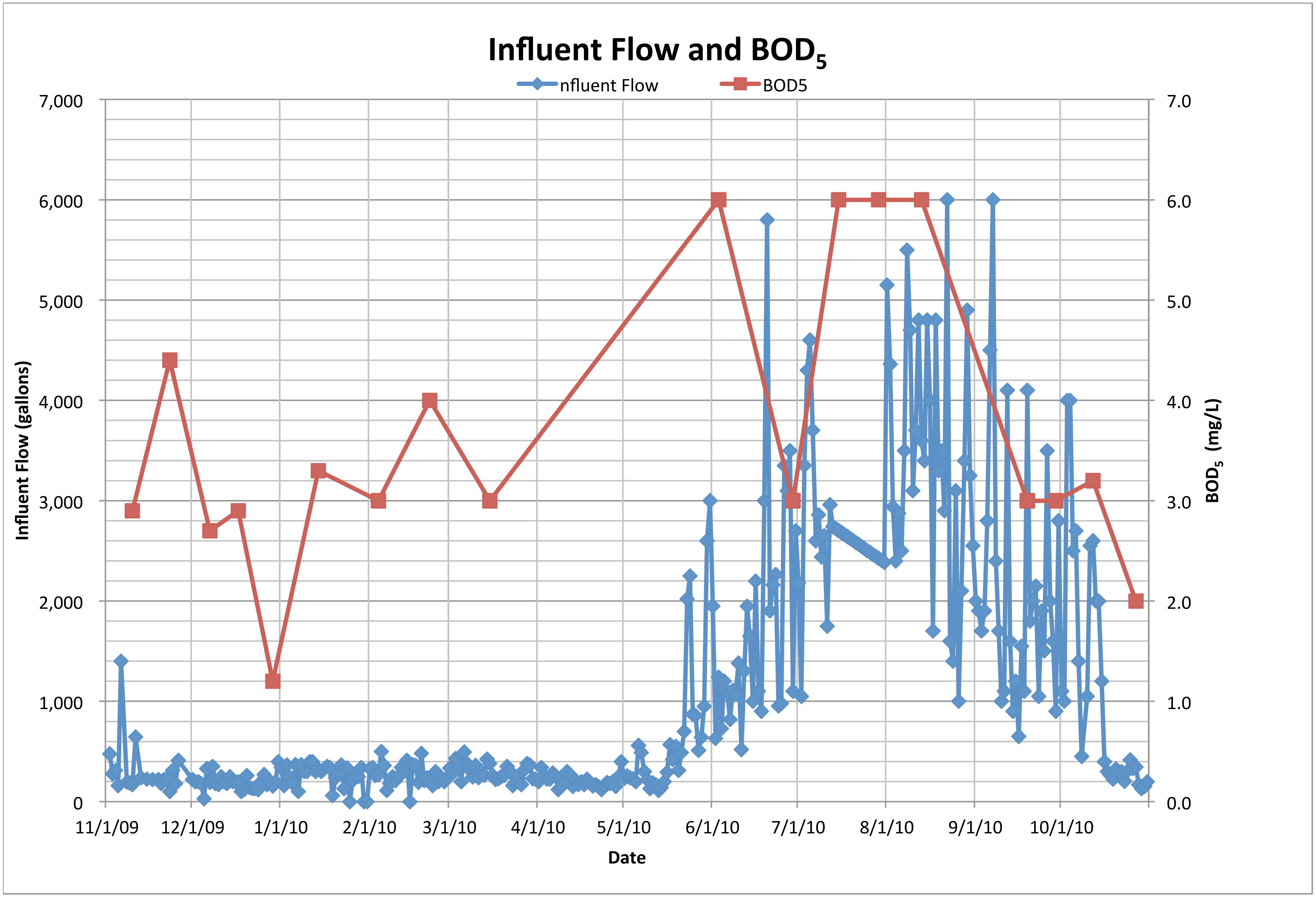
Appendix II: Wastewater Treatment Graphs

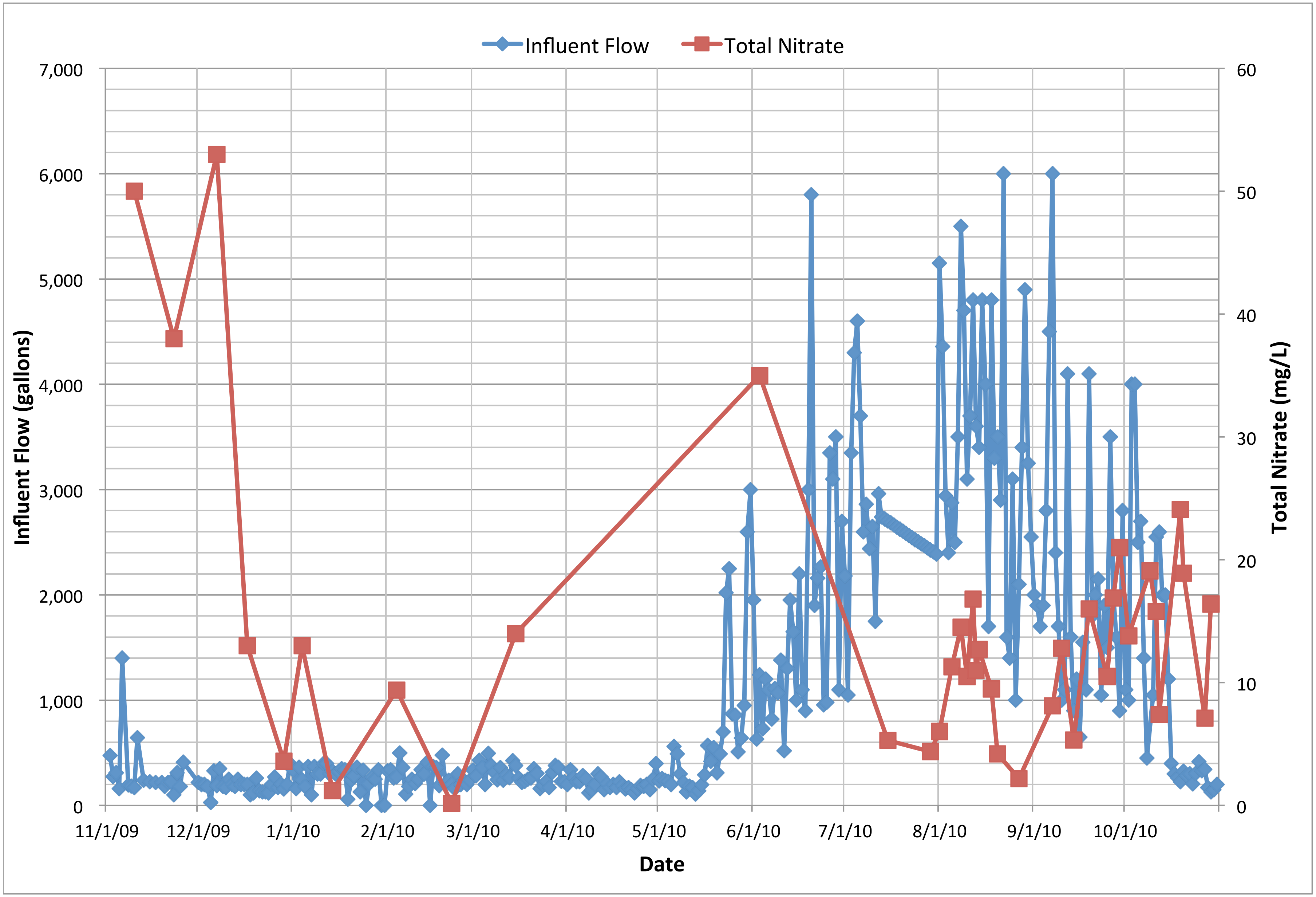

Influent Flow and Effluent pH
Influent Flow
Effluent pH
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Influent Flow (gallons)
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Effluent ph
11/1/09
12/1/09
1/1/10
2/1/10
3/1/10
4/1/10
5/1/10
6/1/10
7/1/10
8/1/10
9/1/10
10/1/10
Date



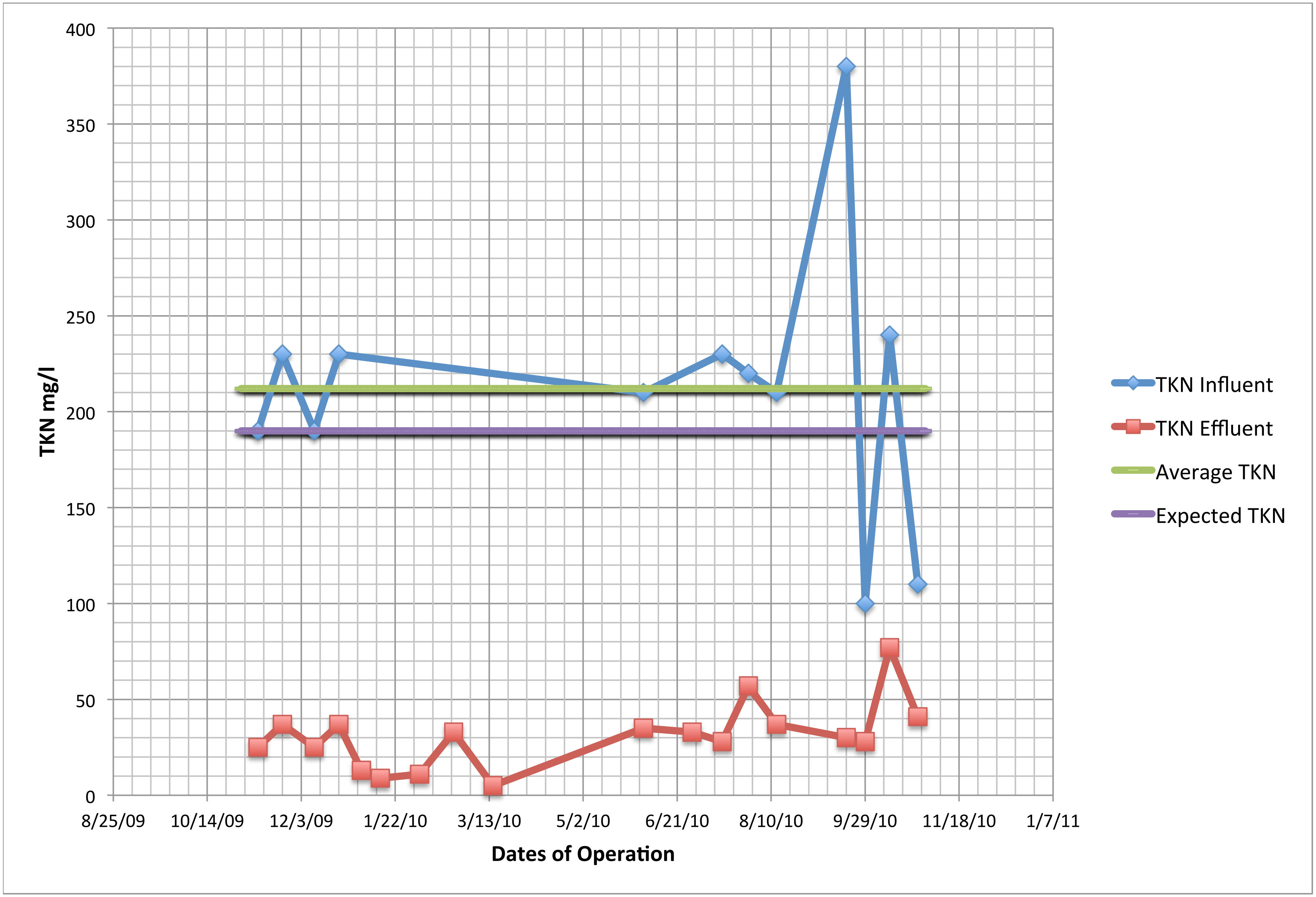
Influent Flow and Effluent TSS
Influent Flow
Effluent TSS
Influent Flow (gallons)
Effluent TSS (mg/L)
Date
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
0
2
4
6
8
10
12
14
16
18
20
11/1/09
12/1/09
1/1/10
2/1/10
3/1/10
4/1/10
5/1/10
6/1/10
7/1/10
8/1/10
9/1/10
10/1/10


Influent Flow and Fecal Coliforms
Influent Flow
Fecal Coliforms
Influent Flow (gallons)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Fecal Coliforms (#/100ml)
4
3
3
2
2
1
1
0
11/1/09
12/1/09
1/1/10
2/1/10
3/1/10
4/1/10
5/1/10
6/1/10
7/1/10
8/1/10
9/1/10
10/1/10
Date


Influent Flow and BOD_5
nfluent Flow
BOD5
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Influent Flow (gallons)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
BOD_5 (mg/L)
11/1/09
12/1/09
1/1/10
2/1/10
3/1/10
4/1/10
5/1/10
6/1/10
7/1/10
8/1/10
9/1/10
10/1/10
Date



Influent Flow
Total Nitrate
Influent Flow (gallons)
Total Nitrate (mg/L)
Date
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
60
50
40
30
20
10
0
11/1/09
12/1/09
1/1/10
2/1/10
3/1/10
4/1/10
5/1/10
6/1/10
7/1/10
8/1/10
9/1/10
10/1/10



400
350
300
250
200
150
100
50
0
TKN mg/l
8/25/09
10/14/09
12/3/09
1/22/10
3/13/10
5/2/10
6/21/10
8/10/10
9/29/10
11/18/10
1/7/11
Dates of Operation
TKN Influent
TKN Effluent
Average TKN
Expected TKN