

**DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING
OUTCOMES SPECIFIC ASSIGNMENT COVER SHEET
CVEG 4100 – Geotechnical Engineering Design Laboratory
FALL 2021**

Instructor: Md. Jobair Bin Alam, Ph.D., P.E.

Title of Assignment

Stress Distribution and Consolidation Settlement

Outcome Measured Using this Assignment

Outcome 7

An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Check the acquiring and applying engineering knowledge related to this assignment

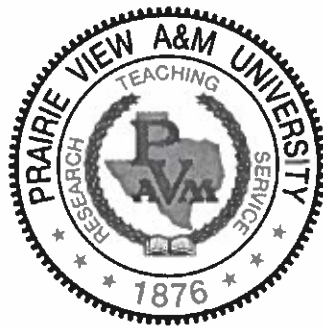
Assignment problem	
×	involves wide-ranging problem-solving issues
×	involves critical thinking in solving engineering and design problems
×	Involves real time design problems solution
×	involves identifying appropriate parameters for designing
×	Involves practicing application of engineering judgement
×	involves familiarizing with contemporary industry design and field investigation
Assignment problems will improve	
×	Ability to command basic and applied knowledge of mathematics, science, and engineering
×	Ability to identify, formulate, and solve geotechnical engineering problems by interpreting data and data analysis.
×	Ability to design a system, component, or process in geotechnical engineering to meet desired needs within realistic constraints such as economic, environmental, social, ethical, health and safety, manufacturability, and sustainability.
×	Ability to communicate effectively to understand the impact of geotechnical engineering solutions in a global, economic, environmental, and societal context.

Brief justification of the suitability of assignment for the outcome

This assignment will increase the students ability to determine the stress distribution into the soil due to structural loading and associated soil movement or settlement.

Sample of graded student's solution

Prairie View A&M University
Roy G Perry College of Engineering
Civil & Environmental Engineering Department



CVEG 4100 P81 – Geotechnical Engineering
Design Lab

Fall 2021

Homework #2

Submitter: *Johnathon Chevalier*

Grader: *Dr. J. Alam, MD*

Roster #4

Date Assigned: 21 September 2021

Date submitted: 29 September 2021

Problem 1

Given

- Full tank
of water

@ 10 m

@ 20 m

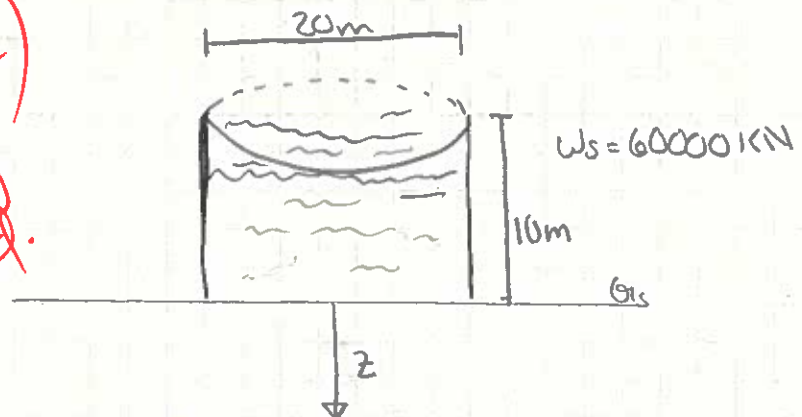
@ 30 m

$W_{self} = 60,000 \text{ kN}$

Question

Stress increase = ?

Solve



①

$W_{water} = \gamma V$

$$L = (1.81 \times \pi/4) (20^2 \times 10)$$

$$L = 30819.02 \text{ kN}$$

$$q = \frac{60000 + 30819.02}{(\pi/4 \times 20^2)}$$

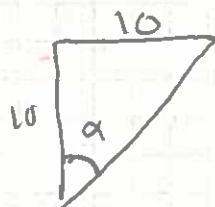
$$L = 289.1 \text{ kN/m}^2$$

②

@ $z = 10 \text{ m}$

$$\alpha = \tan^{-1}(\frac{10}{10}) =$$

$$L = 45^\circ$$



$$\sigma_z = (1 - \cos^2(45^\circ)) 289.1$$

$$L = 186.89 \text{ kN/m}^2$$

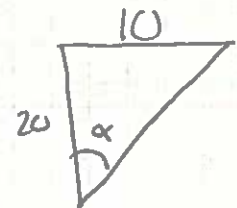
③ @ $z = 20 \text{ m}$

$$\alpha = \tan^{-1}(\frac{10}{20})$$

$$L = 26.56^\circ$$

$$\sigma_z = (1 - \cos^2(26.56^\circ)) 289.1$$

$$L = 82.237 \text{ kN/m}^2$$



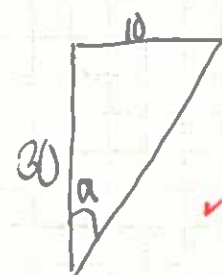
④ @ $z = 30 \text{ m}$

$$\alpha = \tan^{-1}(\frac{10}{30})$$

$$L = 18.43^\circ$$

$$\sigma_z = (1 - \cos^2(18.43^\circ)) 289.1$$

$$L = 42.262 \text{ kN/m}^2$$



Solution

@ $z = 10 \text{ m}$, 186.89 kN/m^2

@ $z = 20 \text{ m}$, 82.237 kN/m^2

@ $z = 30 \text{ m}$, 42.262 kN/m^2

(+2)
very good.

Problem 2

Given

rectangle
10 ft x 15 ft
450 kips
40 ft, 8 ft
depth

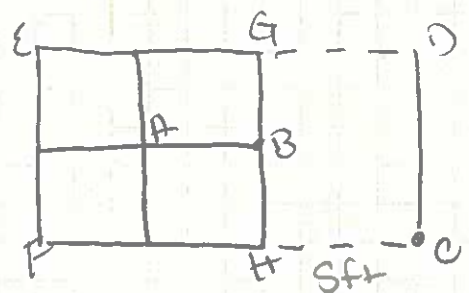
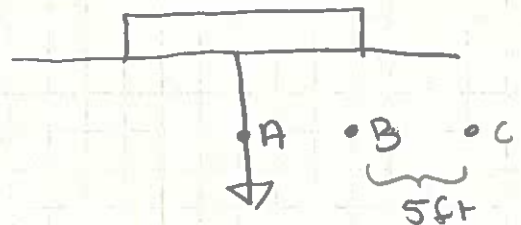
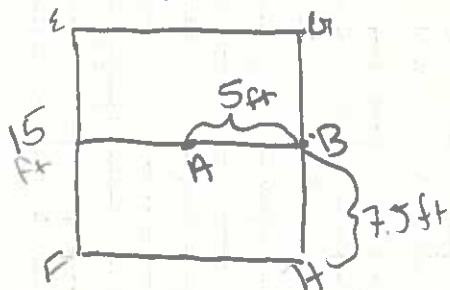
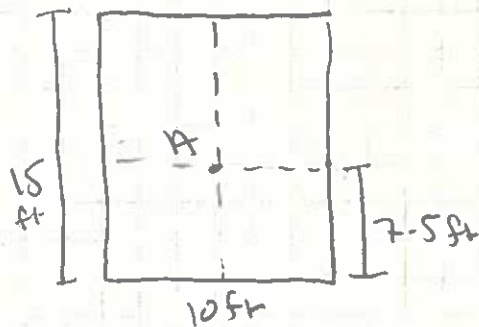
Solve

vertical stress

@ center, A,
B, C,

distribution
plot

Solve



$$z = 10 \text{ ft}$$

$$Q = 450 \text{ kips}$$

$$q = \frac{Q}{z \cdot B}$$

$$q = \frac{450}{10 \times 15}$$

$$q = 3 \text{ kips/ft}^2$$

$$m = \frac{B}{2} = \frac{x}{z}$$

$$m = \frac{10}{2} = 5$$

$$n = \frac{L}{2} = \frac{y}{z}$$

$$n = \frac{7.5}{2} = 3.75$$

$$I = 1.05$$

$$\sigma = 4 \times q \times I$$

$$\sigma = 4 \times 3 \times 1.05$$

$$\sigma = 1.26 \text{ kips/ft}^2$$

$$m = \frac{x}{z}$$

$$m = 10/10 = 1$$

$$n = \frac{y}{z}$$

$$n = 7.5/10 = .75$$

$$I = .158$$

$$\sigma = 4 \times 3 \times .158$$

$$\sigma = .948 \text{ kips/ft}^2$$

$$m = \frac{x}{z}$$

$$m = 15/10 = 1.5$$

$$n = \frac{y}{z}$$

$$n = 15/10 = 1.5$$

$$I = .22$$

$$m = \frac{x}{z}$$

$$m = 5/10 = .5$$

$$n = \frac{y}{z}$$

$$n = 15/10 = 1.5$$

$$I = .13$$

$$\sigma = 3 \times (I_1 - I_2)$$

$$\sigma = 3 \times (.22 - .13)$$

$$\sigma = .27 \text{ kips/ft}^2$$

$$(4)$$

$$\sigma = \frac{qBL}{(B+L)(L+2)}$$

$$\sigma = \frac{3 \times 15 \times 10}{(15+10)(10+10)}$$

$$\sigma = .9 \text{ kips/ft}^2$$

$$(5)$$

$$z = 8$$

$$m = \frac{x}{z}$$

$$m = 5/8$$

$$n = \frac{y}{z}$$

$$n = 7.5/8$$

$$I = .1301$$

$$\sigma = 4 \times 3 \times 1.301$$

$$\sigma = 1.632 \text{ kips/ft}^2$$

$$z = 16$$

$$m = .3125$$

$$n = .468$$

$$I = .045$$

$$\sigma = .54 \text{ kips/ft}^2$$

$$z = 24$$

$$m = .2$$

$$n = .31$$

$$I = .023$$

$$\sigma = .276 \text{ kips/ft}^2$$

$$z = 32$$

$$m = .15$$

$$n = .23$$

$$I = .008$$

$$\sigma = .11 \text{ kips/ft}^2$$

$$z = 40$$

$$m = .125$$

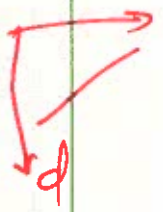
$$n = .187$$

$$I = 0$$

$$\sigma = 0$$

(-5)

Plot

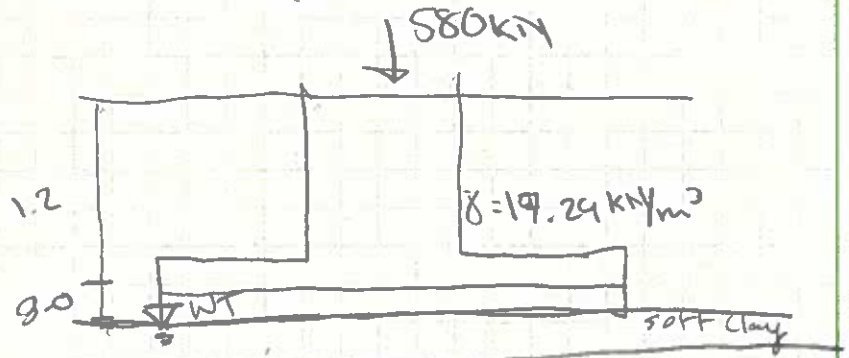


Problem 3

Given

- CS ≥ 40 mm
- 580 kN
- WT - 4.2 m
- soft clay
- $\gamma = 18.86$ $\gamma_{sat} = 29.6\%$
- $w_L = 50\%$ $G_s = 2.65$

Solve



Solve

Proportional
Square
factoring

$$P_0' = [3 + 12] [17.29] + \frac{4.5}{2} [18.86 - 9.807] = 93 \text{ kPa}$$

$$C_c = .009(w_L - 10)$$

$$L_c = .004(50 - 10) = .36$$

$$P_0 = w G_s = \frac{29.6}{100} (2.65)$$

$$L_c = .784$$

$$\Delta H = \frac{C_c H}{H L_c} \log \frac{P_0' + \Delta P}{P_0'}$$

$$L_c = \frac{.36(.45)}{1.784} \log \frac{93 + \Delta P}{93}$$

$$L_c = .91 \log \frac{93 + \Delta P}{93}$$

B = 2.4:

$$\Delta P = \frac{1}{3} (15/3) \left(\frac{.25 + .06}{2} + .13 + .08 \right)$$

$$L_c = \frac{.36}{3} = .1215 \text{ m} \quad 2.4$$

B = 4.8

$$\Delta P = \frac{1}{3} \left[\frac{.6 + .17}{2} + .4 + .25 \right] = .3446$$

B = 7.2

$$\Delta P = \frac{1}{3} \left[\frac{.77 + .21}{2} + .6 + .4 \right] = .5178$$

$$\Delta H_{2.4} = .91 \log \left(\frac{93 + 12}{93} \right)$$

$$L_c = .048 \text{ m}, 48 \text{ mm}$$

$$\Delta H_{4.8} = .91 \log \left(\frac{93 + 3.8}{93} \right)$$

$$L_c = .036 \text{ m}, 36 \text{ mm}$$

$$\Delta H_{7.2} = .91 \log \left(\frac{93 + 5.8}{93} \right)$$

$$L_c = .024 \text{ m}, 24 \text{ mm}$$

	B=2.4	D=4.8	B=7.2	
Dim	P/3	q/4	q/3	q/2
3	1.25	.25	.62	.6
4.5	1.87	.13	.94	.4
6.0	2.5	.08	1.25	.25
7.5	3.12	.06	1.50	.17

2.4

$$q_{2.4} = .12 \times \frac{580}{2.42}$$

$$L_c = 2.87 \text{ kPa or } 12 \text{ kPa}$$

$$q_{4.8} = .35 \times \frac{580}{4.82}$$

$$L_c = 42.116 \text{ or } 8.8 \text{ kPa}$$

$$q_{7.2} = .52 \times \frac{580}{7.22} = 41.77 \text{ or } 5.8 \text{ kPa}$$

Solution

B = 4 m

B = 2.4 m

Problem 4

Given

-shallow foundation

$$Q = 1500 \text{ kips}$$

$$\gamma = 17 \text{ kN/m}^3$$

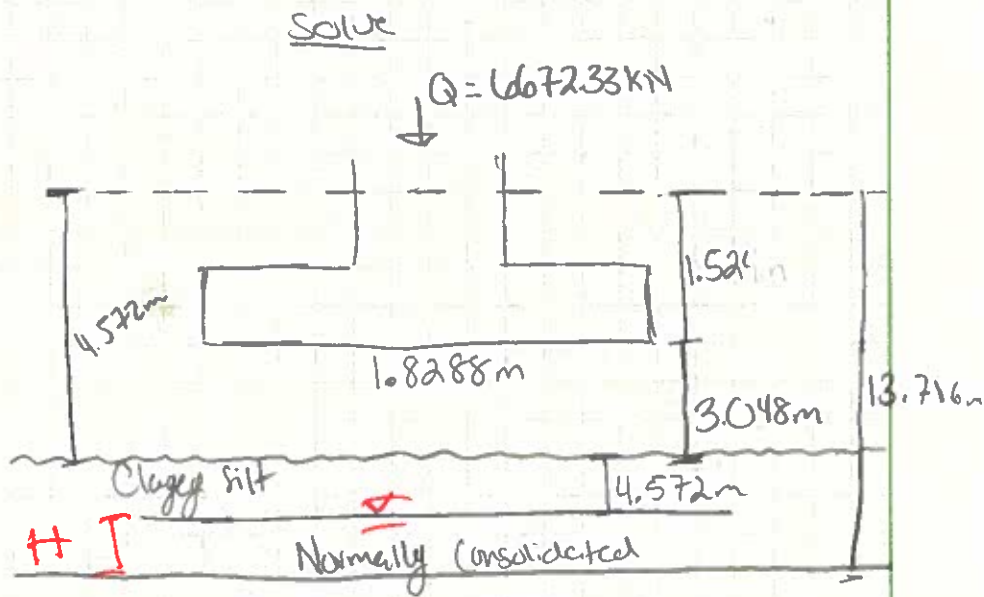
$$C_c = 0.25 \quad \gamma_{sat} = 16.85 \text{ kN/m}^3$$

$$e_0 = 0.9$$

$$\gamma_{water} = 15.8 \text{ kN/m}^3$$

Question

Consolidation Settlement = ?



$$z = (4.572 + 4.572) - 1.52$$

$$L = 7.62 \text{ m}$$

$$\sigma_0 A = (17 \times 4.572) + (15.8 \times 4.572)$$

$$L = 149.96 \text{ kN/m}^2$$

$$A_s = \frac{P}{A} = \frac{Q}{(z + 0)^2}$$

$$L = \frac{667233}{(0.18288 + 7.62)^2}$$

$$L = 24.73 \text{ kN/m}^2$$

$$AH = \frac{H_0}{H_0} C_c \log_{10} \left(\frac{\sigma_0 + A_s}{\sigma_0} \right)$$

$$L = \frac{4.572 \times 2}{1 + 0.9} \times 0.25 \times \log_{10} \left(\frac{149.96 + 24.73}{149.96} \right)$$

$$L = 0.211 \text{ m or } 211.88 \text{ mm}$$

Solution

$$AH = 0.211 \text{ m or } 211.88 \text{ mm}$$

(m,n) ⇒ method

(-5)

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CVEG 4100- Geotechnical Engineering Design

Homework #2

Shadaria Lynch

Problem 1

load = 60,000 kN

pressure (q) = $\frac{\text{load}}{\text{area}} = \frac{60,000}{\pi/4 (20)^2} = \frac{60,000}{314.2} = 191 \text{ kN/m}^2$

Stress increase (σ_z) = $q \left[1 - \frac{1}{1 + (R/z)^2} \right]^{3/2}$

radius (R) = 20/2 = 10m

z = depth

@ 10m depth:

$\sigma_z = 191 \left[1 - \frac{1}{1 + (10/10)^2} \right]^{3/2}$

= 67.5 kN/m²

@ 20m depth:

$\sigma_z = 191 \left[1 - \frac{1}{1 + (10/20)^2} \right]^{3/2}$

= 17.1 kN/m²

@ 30m depth:

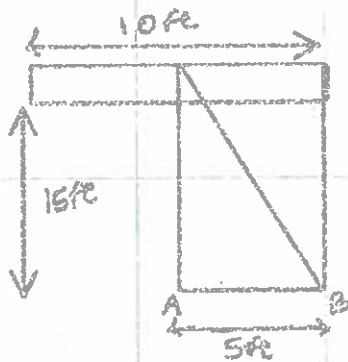
$\sigma_z = 191 \left[1 - \frac{1}{1 + (10/30)^2} \right]^{3/2}$

= 6.04 kN/m²

$q = \frac{60,000}{A} + \gamma_w h$

(5)

Problem 2



$$z = 10 \text{ ft}$$

$$Q = 450 \text{ kips}$$

a) vertical stress @ center of slab, point A

$$q = \frac{450}{10 \times 15} = 3 \text{ kips/ft}^2$$

$$m = \frac{b}{z} = \frac{5}{10} = 0.5 \quad n = \frac{L}{z} = \frac{7.5}{10} = 0.75$$

$$\text{vertical stress } \sigma_a = 4 \times q \times I_2$$

$$= 4 \times 3 \times 0.105 = 1.26 \text{ kips/ft}^2$$

b) at B

$$m = 10/10 = 1$$

$$n = 7.5/10 = 0.75$$

$$I_2 = 0.158$$

$$\sigma_b = 2 \times 3 \times 0.158 = 0.948 \text{ kips/ft}^2$$

c) at C

$$m = 15/10 = 1.5$$

$$n = 15/10 = 1.5$$

$$I_2 = 0.22 \text{ (CDEF)}$$

$$m = 5/10 = 0.5$$

$$n = 15/10 = 1.5$$

$$I_2 = 0.13 \text{ (CDGH)}$$

$$\sigma_c = 3 \times (0.22 - 0.13)$$

$$= 0.27 \text{ kips/ft}^2$$



d) Using approximate method

$$\sigma_c = \frac{qL}{(B+z)(L+z)} = \frac{3 \times 15 \times 10}{(15+10)(10+10)} = 0.9 \text{ kips/ft}^2$$

e) At $z = 8$

$$m = 5/8 = 0.625 \quad n = 7.5/8 = 0.9375$$

$$\sigma_z = 4 \times 3 \times 0.1361 = 1.6332$$

At $z = 16$

$$m = 0.3125 \quad n = 0.46875$$

$$\sigma_z = 4 \times 3 \times 0.045 = 0.54$$

At $z = 24$

$$m = 0.2 \quad n = 0.3125$$

$$\sigma_z = 4 \times 3 \times 0.023 = 0.276$$

At $z = 32$

$$m = 0.15 \quad n = 0.234375$$

$$\sigma_z = 0.10$$

At $z = 40$

$$m = 0.125 \quad n = 0.1875$$

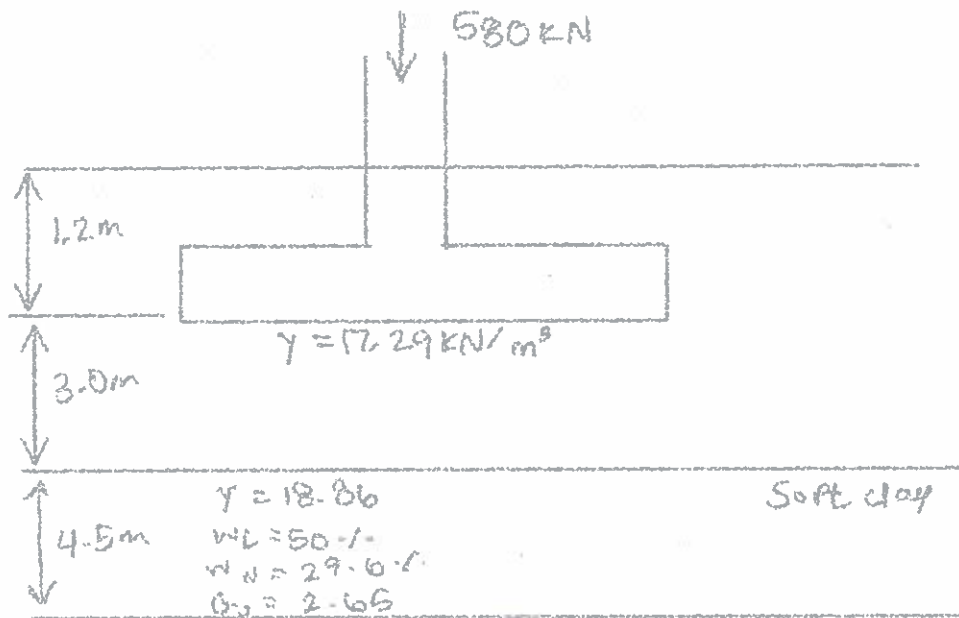
$$\sigma_z \approx 0$$

plot

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(-5)

Problem 3



$$\Delta H = \frac{C_c H \log \sigma_2 / \sigma_1}{1 + e_0}$$

$$C_c = 0.007(W_L - 10) = 0.28$$

$$H = 4.5 \text{ m}$$

$$e = \frac{G W_n}{S_d} = \frac{2.65 \times 0.296}{1} = 0.784$$

$$\sigma_1 = 17.29(3 + 1.2) + (18.86 - 9.81)(2.25) = 92.98 \text{ kN/m}^2$$

$$\sigma_2 = \sigma_1 + \Delta \sigma$$

$$\Delta \sigma = \frac{P}{(B + z)^2}$$

$$B = 2$$

$$z = 5.25 \text{ m}$$

$$C_c = 0.007(W_L - 10) = 0.28$$

$$\Delta H = \frac{0.28 \times 4.5 \log \sigma_2 / \sigma_1}{1 + 0.784} \Rightarrow \log \sigma_2 / \sigma_1 = 0.056$$

$$\frac{\sigma_2}{\sigma_1} = 1.13$$

$$\sigma_2 = 92.98 \times 1.13 = 105.1$$

$$\Delta \sigma = \sigma_2 - \sigma_1 = 105.1 - 92.98 = 12.12 \text{ kN/m}^2$$

$$12.12 = \frac{580}{(B + 5.25)^2} \Rightarrow (B + 5.25)^2 = 47.85$$

$$B + 5.25 = 6.9$$

$$B = 1.65 \text{ m}$$

(2)

$$B = 2.4 \text{ m}$$

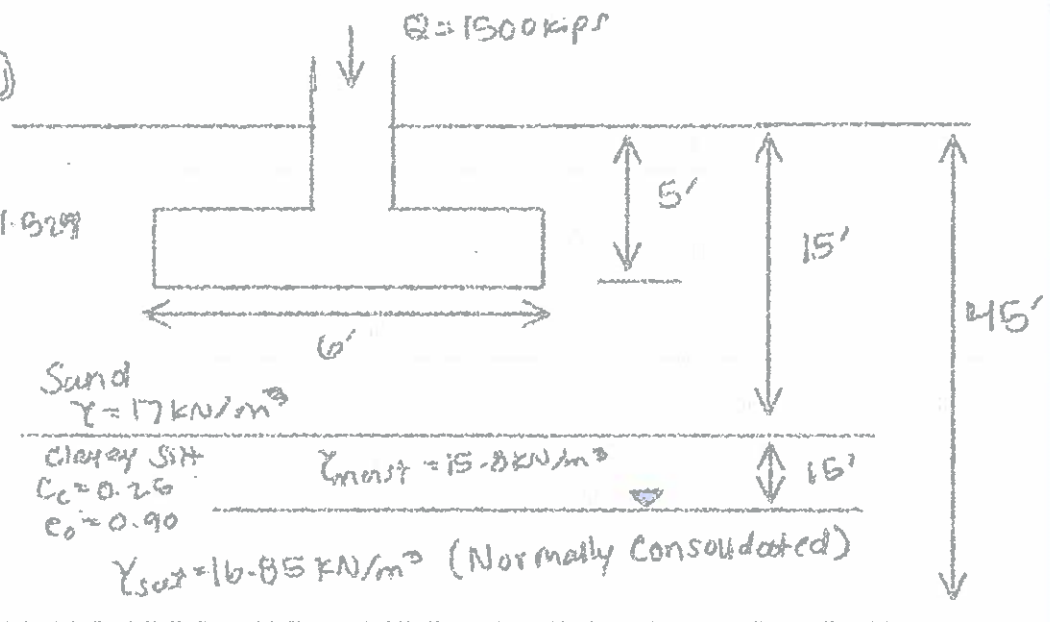
check

Problem 4

$$1 \text{ ft} = 0.3048 \text{ m}$$

$$B = 1.829 \text{ m}$$

$$Z = 2 \times 4.572 - 1.829 \\ = 7.62$$



$$Q = 1500 \text{ kips} \times \frac{4.448 \text{ kN}}{1 \text{ kips}} = 6672 \text{ kN}$$

$$\Delta H = \frac{H_0}{1 + e_0} C_c \log_{10} \left(\frac{\sigma_0 + \Delta \sigma}{\sigma_0} \right)$$

$$\sigma_0 = 17 \times 4.572 + 15.8 \times 4.572 = 149.96 \text{ kN/m}^2$$

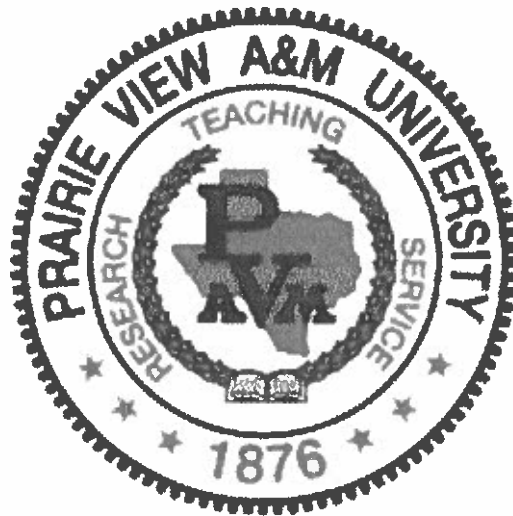
$$\Delta \sigma = \frac{Q}{(Z + B)^2} = \frac{6672}{(7.62 + 1.829)^2} = 74.73 \text{ kN/m}^2$$

$$\Delta H = \frac{4.572}{1 + 0.90} \times 0.25 \times \log \left(\frac{149.96 + 74.73}{149.96} \right)$$

$$= 0.211 \text{ m} = 211 \text{ mm}$$

(m, n) $\Rightarrow$ method

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PRAIRIE VIEW A&M UNIVERSITY



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CVEG 4100 P81 GEOTECHNICAL ENGINEERING
DESIGN

Homework #2

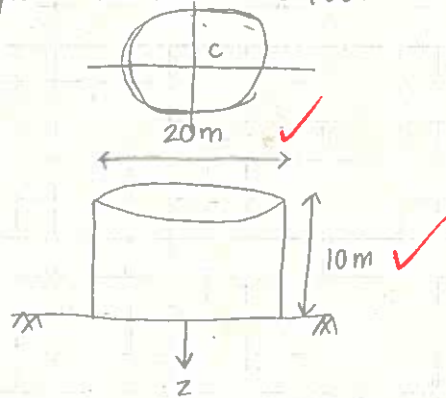
Perla Zaldivar (#10)

Given: September 22, 2021

Due: September 28, 2021

PROBLEM 1

Find the stress increase of the circular concrete water tank (when the tank is full of water) at 10m, 20m and 30m below the center of the tank. The self weight of the tank is 60,000 kN.



$$\text{pressure } (q_0) = \frac{\text{load}}{\text{area}} = \frac{60,000 \text{ kN}}{(\pi/4)(20\text{m})^2} = 191 \text{ kN/m}^2$$

$$\begin{aligned} \text{load} &= \frac{60,000}{\text{A}} + \gamma_w h \\ &= \frac{60,000}{\text{A}} + 9.81 \times 10 \\ &= \frac{60,000}{\text{A}} + 98.1 \text{ kN} \end{aligned}$$

$$\Delta \sigma = q_0 \left[1 - \frac{1}{1 + (R/z)^2} \right]^{3/2}$$

at 10m $R = 10\text{m}/2 = 10\text{m}$ $z = 10\text{m}$

$$\Delta \sigma = (191 \text{ kN/m}^2) \left[1 - \frac{1}{1 + \left(\frac{10}{10}\right)^2} \right]^{3/2} = 107.53 \text{ kN/m}^2$$

at 20m $R = 20\text{m}/2 = 10\text{m}$ $z = 20\text{m}$

$$\Delta \sigma = (191 \text{ kN/m}^2) \left[1 - \frac{1}{1 + \left(\frac{10}{20}\right)^2} \right]^{3/2} = 17.09 \text{ kN/m}^2$$

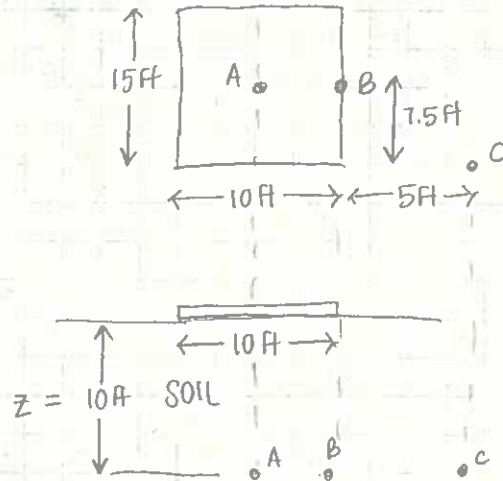
at 30m $R = 10\text{m}/2 = 10\text{m}$ $z = 30\text{m}$

$$\Delta \sigma = (191 \text{ kN/m}^2) \left[1 - \frac{1}{1 + \left(\frac{10}{30}\right)^2} \right]^{3/2} = 6.04 \text{ kN/m}^2$$

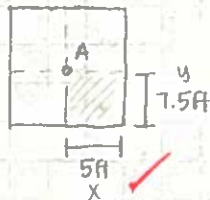
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PROBLEM 2

- A rectangular concrete slab, 10 x 15 ft, rests on the surface of a soil mass. The load on the slab is 450 kips. Determine the vertical stress increase at a depth of 10 ft. (a) under the center of the slab at point A (b) under point B (c) at distance of 5 ft from corner point C (d) compare the results from 'a' with an estimate using the approximate method (e) plot the distribution of stress increase at point A with depth till 40 ft depth with a depth increment of 8 ft (using m & n method)



PART A



$$m = x/z = 5/10 = 0.5$$

$$n = y/z = 7.5/10 = 0.75$$

$$450 \text{ kip} -$$

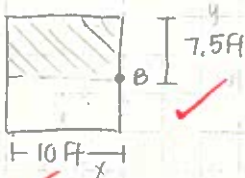
$$\Delta \sigma = 4Iq$$

$$q = \frac{Q}{A} = \frac{450 \text{ kip}}{(10 \text{ ft} \times 15 \text{ ft})} = 3 \text{ kip/ft}^2$$

$$I \text{ (from Fig 4)} = 0.107$$

$$\Delta \sigma = 4(0.107)(3 \text{ kip/ft}^2) = 1.284 \text{ kip/ft}^2$$

PART B



$$m = x/z = 10/10 = 1$$

$$n = y/z = 7.5/10 = 0.75$$

$$\Delta \sigma = 4Iq$$

$$q = \frac{Q}{A} = \frac{450 \text{ kip}}{(10 \text{ ft} \times 15 \text{ ft})} = 3 \text{ kip/ft}^2$$

$$I = 0.101$$

$$\Delta \sigma = 4(0.101)(3 \text{ kip/ft}^2) = 1.932 \text{ kip/ft}^2$$

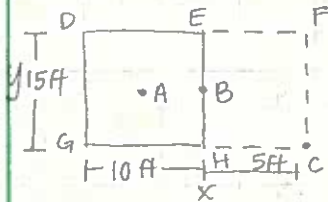
2

X

(-5)

PROBLEM 2 CONTINUE

PART C



for DFCG

$$m = x/z = 15/10 = 1.5$$

$$n = y/z = 15/10 = 1.5$$

$$I_1 = 0.218$$

$$I = (I_1 - I_2) \Delta q$$

$$I = (0.218 - 0.131)(3 \text{ kip/ft}^2)$$

$$0.261 \text{ kip/ft}^2$$

for EFCH

$$m = x/z = 5/10 = 0.5$$

$$n = y/z = 15/10 = 1.5$$

$$I_2 = 0.131$$

$$q = \frac{Q}{A} = \frac{450 \text{ kip}}{(10 \text{ ft} \times 15 \text{ ft})} = 3 \text{ kip/ft}^2$$

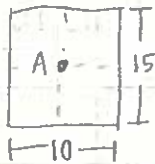
PART D

$$\Delta \sigma = \frac{q_0 B L}{(B+Z)(L+Z)} \quad (\text{eq 8.15})$$

$$q = \frac{Q}{A} = 3 \text{ kip/ft}^2$$

$$\Delta \sigma = \frac{(3 \text{ kip/ft}^2)(10 \text{ ft})(15 \text{ ft})}{(10 \text{ ft} + 10 \text{ ft})(15 \text{ ft} + 10 \text{ ft})} = 0.9 \text{ kip/ft}^2$$

PART E



$$q = \frac{Q}{A} = \frac{450 \text{ kips}}{10 \text{ ft} \times 15 \text{ ft}} = 3 \text{ kip/ft}^2$$

at $Z = 8 \text{ m}$

$$m = x/z = 5/8 = 0.625$$

$$n = y/z = 7.5/8 = 0.9375$$

$$I = 0.136$$

$$\Delta \sigma = 4 I q = 4(0.136)(3 \text{ kip/ft}^2) = 1.632 \text{ k/ft}^2$$

at $Z = 10 \text{ m}$

$$m = x/z = 5/10 = 0.5$$

$$n = y/z = 7.5/10 = 0.75$$

$$I = 0.055$$

$$\Delta \sigma = 4 I q = 4(0.055)(3 \text{ kip/ft}^2) = 0.66 \text{ k/ft}^2$$

Part E (continue)

at $z = 24 \text{ ft}$

$$m = x/z = 5/24 = 0.208$$

$$n = y/z = 7.5/24 = 0.3125$$

$$I = 0.028$$

$$\Delta\sigma = 4Iq_v = 4(0.028)(3 \text{ kip/ft}^2) = \boxed{0.336 \text{ kip/ft}^2}$$
 ✓

at $z = 32 \text{ ft}$

$$m = x/z = 5/32 = 0.156$$

$$n = y/z = 7.5/32 = 0.234$$

$$I = 0.011$$

$$\Delta\sigma = 4Iq_v = 4(0.011)(3 \text{ kip/ft}^2) = \boxed{0.132 \text{ kip/ft}^2}$$
 ✓

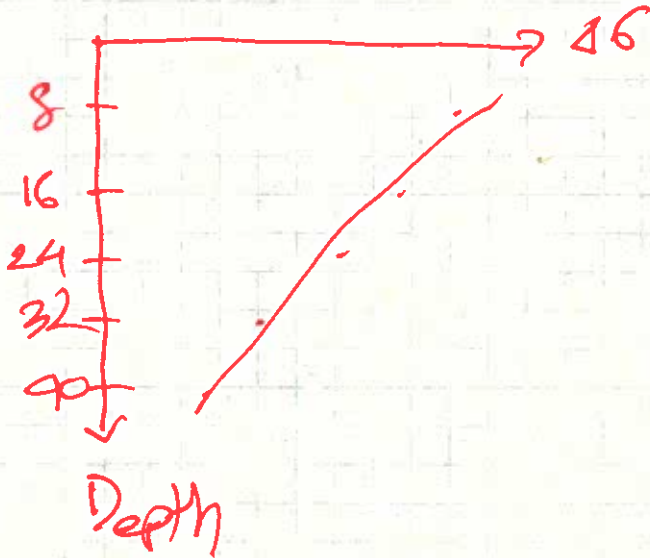
at $z = 40 \text{ ft}$

$$m = x/z = 5/40 = 0.125$$

$$n = y/z = 7.5/40 = 0.1875$$

$$I = 0.008$$

$$\Delta\sigma = 4Iq_v = 4(0.008)(3 \text{ kip/ft}^2) = \boxed{0.096 \text{ kip/ft}^2}$$
 ✓



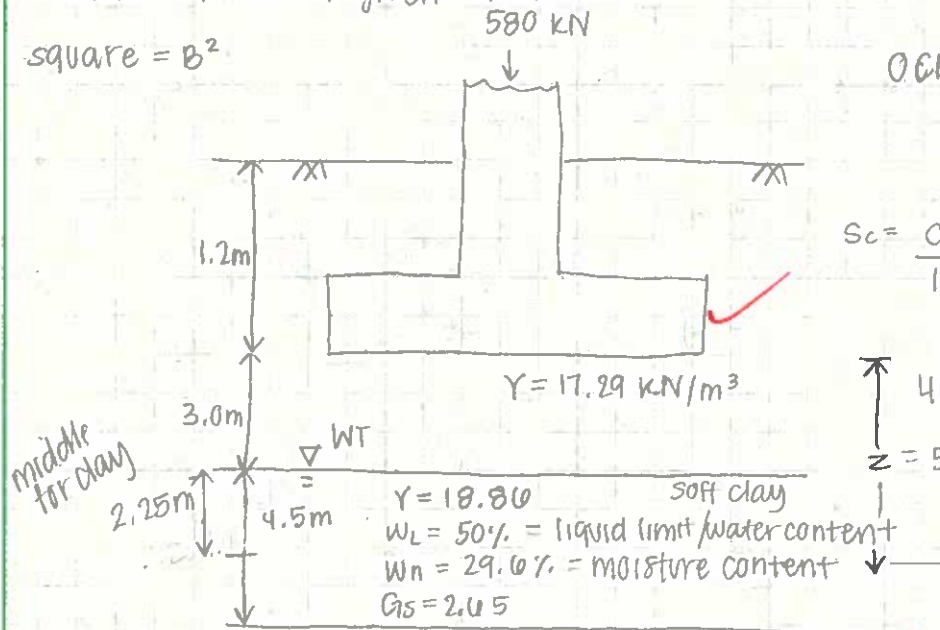
plot = ?

(-5)

PROBLEM 3

Proportion a square footing such that the consolidation settlement is not over 40mm for given conditions

square = B^2



$$OCR = \frac{\sigma'_b}{\sigma'_o}$$

$$S_c = \frac{C_c H}{1 + e_o} \log \left(\frac{\sigma'_o + \Delta \sigma'_o}{\sigma'_o} \right)$$

$$40 \text{ mm} \rightarrow 0.04 \text{ m}$$

$$z = 5.25$$

determine if its OC or NC

$$\sigma'_o = (1.2 + 3) \text{ m} (17.29 \text{ kN/m}^3) + (2.25 \text{ m}) (18.80 \text{ kN/m}^3 - 9.81 \text{ kN/m}^3)$$

$$\sigma'_o = 92.98 \text{ kPa} = 93 \text{ kPa}$$

$$e_o = W G_s = \frac{(29.6)(2.65)}{100} = 0.7844$$

$$(2.54) \quad CC = 0.009 (W_L - 10) = 0.009 (50 - 10) = 0.36$$

$$S_c = \frac{C_c H}{1 + e_o} \log \left(\frac{\sigma'_o + \Delta \sigma'_o}{\sigma'_o} \right) = \log \left(\frac{\sigma'_o}{\sigma'_o} \right) + \log \left(\frac{\Delta \sigma'_o}{\sigma'_o} \right)$$

$$0.04 = \frac{(0.36)(4.5)}{1 + 0.7844} \log \left(\frac{\Delta \sigma'_o}{93} \right)$$

$$0.04 = 0.907 \log \left(\frac{\Delta \sigma'_o}{93} \right)$$

$$10^{0.044} = \frac{\Delta \sigma'_o}{93}$$

$$1.106 = \frac{\Delta \sigma'_o}{93}$$

$$\Delta \sigma'_o = 102.93$$

$$\Delta \sigma'_o = \frac{q_o}{(B + z)^2}$$

$$102.93 = \frac{580 \text{ kN}}{(B + 5.25)^2}$$

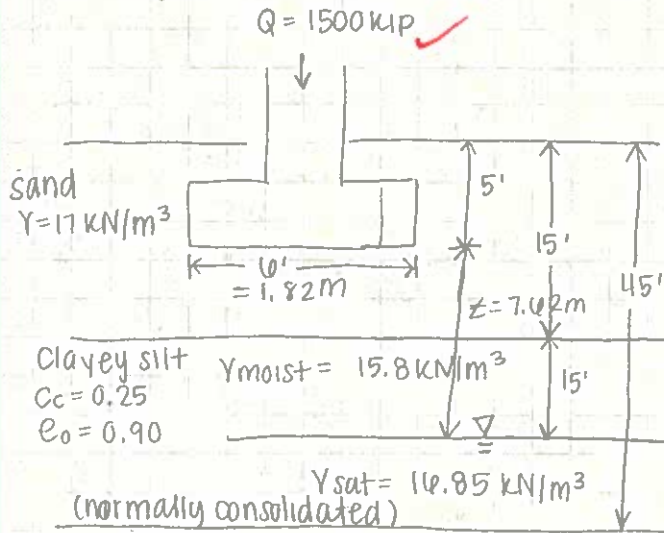
$$102.93 (B + 5.25)^2 = 580$$

$$\sqrt{(B + 5.25)^2} = \sqrt{5.63}$$

$$B + 5.25 = 2.37 \text{ m}$$

PROBLEM 4

A shallow foundation is to be constructed on a sandy soil layer underlain by clayey soil. Find the consolidation settlement for the footing.



$$\begin{aligned} 15' &= 4.5m \\ 5' &= 1.5m \\ 45' &= 13.7m \end{aligned}$$

$$NC \rightarrow S_c = \frac{C_c H}{1 + e_0} \log \left(\frac{\sigma'_0 + \Delta \sigma}{\sigma'_0} \right)$$

$$kip \rightarrow kN$$

$$6672.33 kN$$

mid point

$$+ 7.5 (16.85 - 9.81)$$

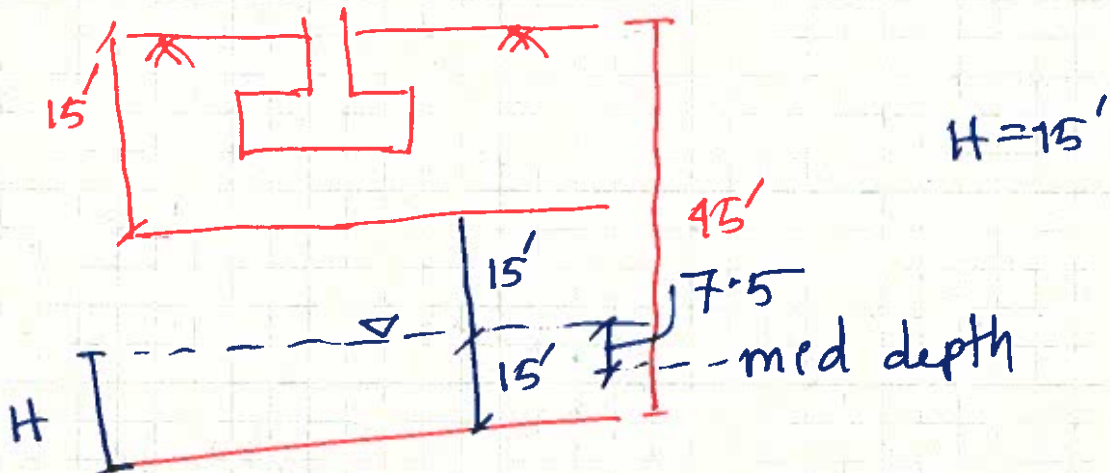
$$\sigma'_0 = (4.5m)(17 kN/m^3) + (4.5m)(15.8 kN/m^3) = 147.6 kN/m^2$$

eq
(8.15a)

$$\Delta \sigma = \frac{6672.33 kN}{(Area of shallow)} = \frac{6672.33 kN}{(9.44 m)^2} = 74.87 kN/m^2$$

$$S_c = \frac{0.25(9m)}{1 + 0.90} \log \left(\frac{147.6 kN/m^2 + 74.87 kN/m^2}{147.6 kN/m^2} \right)$$

$$S_c = 0.21m$$



(5)

**OUTCOME “7” SPECIFIC ASSIGNMENTS
USED TO ASSESS THE OUTCOME IN**

**CVEG 4472
SENIOR DESIGN & PROFESSIONALISM I**

DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING
CVEG 4472 Senior Design and Professionalism I
OUTCOMES SPECIFIC ASSIGNMENT COVER SHEET

FALL 2019

Instructor: Dr. R. Radha

Title of Assignment

**Information research for the project, determining needs,
understanding contemporary issues and to use the information
to implement in the project design**

Outcome Measured Using this Assignment

Outcome 7

**An ability to acquire and apply new knowledge as needed, using appropriate learning
strategies**

Check the outcome appropriate characteristics related to this assignment

Ability to Acquire new knowledge using the appropriate learning strategies Requires students to:	
X	Be knowledgeable of and use different learning strategies (<i>Instructor may provide information on different learning strategies</i>)
X	Identify and take advantage of learning opportunities available in the library, online resources, seminars, webinars, conferences, workshops and tutorials.
X	Be aware of the need for and are able to independently acquire additional knowledge and data needed for solving problem using appropriate learning strategies and tools.
Ability to apply new knowledge to solve problems Requires students to:	
X	Demonstrate appropriate use of the new knowledge to solve problems.

Brief justification of the suitability of assignment for the outcome

All students will be required to read reference materials and use library and web resources needed to perform the project. Literature review and reference documentation related to the project subtasks will have to be prepared and submitted

**CVEG 4472 Senior Design and Professionalism I
FALL 2019**

**ASSIGNMENT STATEMENT/QUESTIONS
GRADING SCHEME FOR ASSIGNMENT**

Literature search documentation	25 pts
Document use of new knowledge	25 pts
References listing and relevance statements	50 pts
Total:	100 pts

See below Student Sample for Crit. 7

Insert here Student Sample for Crit. 7

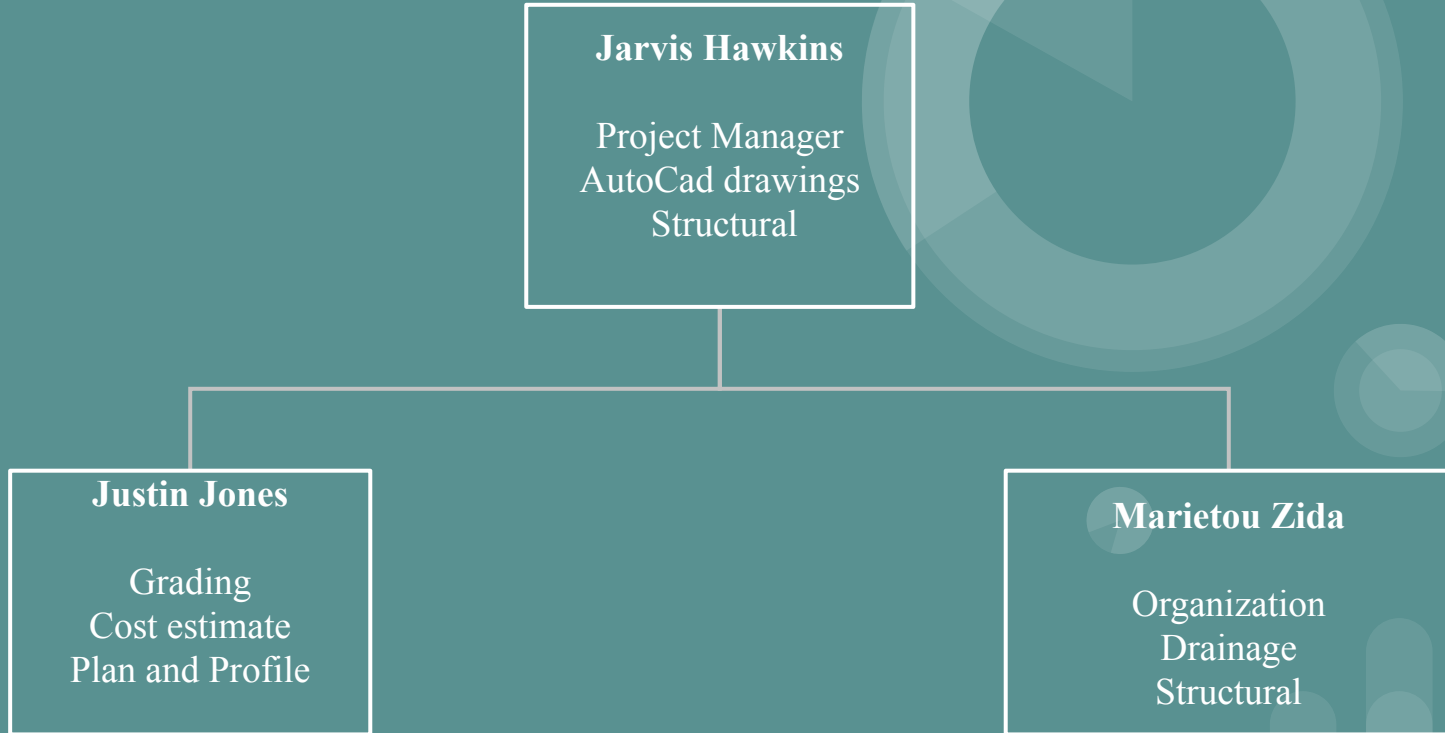
**CIVIL ENGINEERING DEPARTMENT
PRAIRIE VIEW A&M UNIVERSITY
CVEG 4472
FALL 2019**



Civil Engineering Firm

MARIETOU ZIDA
JUSTIN JONES
JARVIS HAWKINS

Organizational Chart

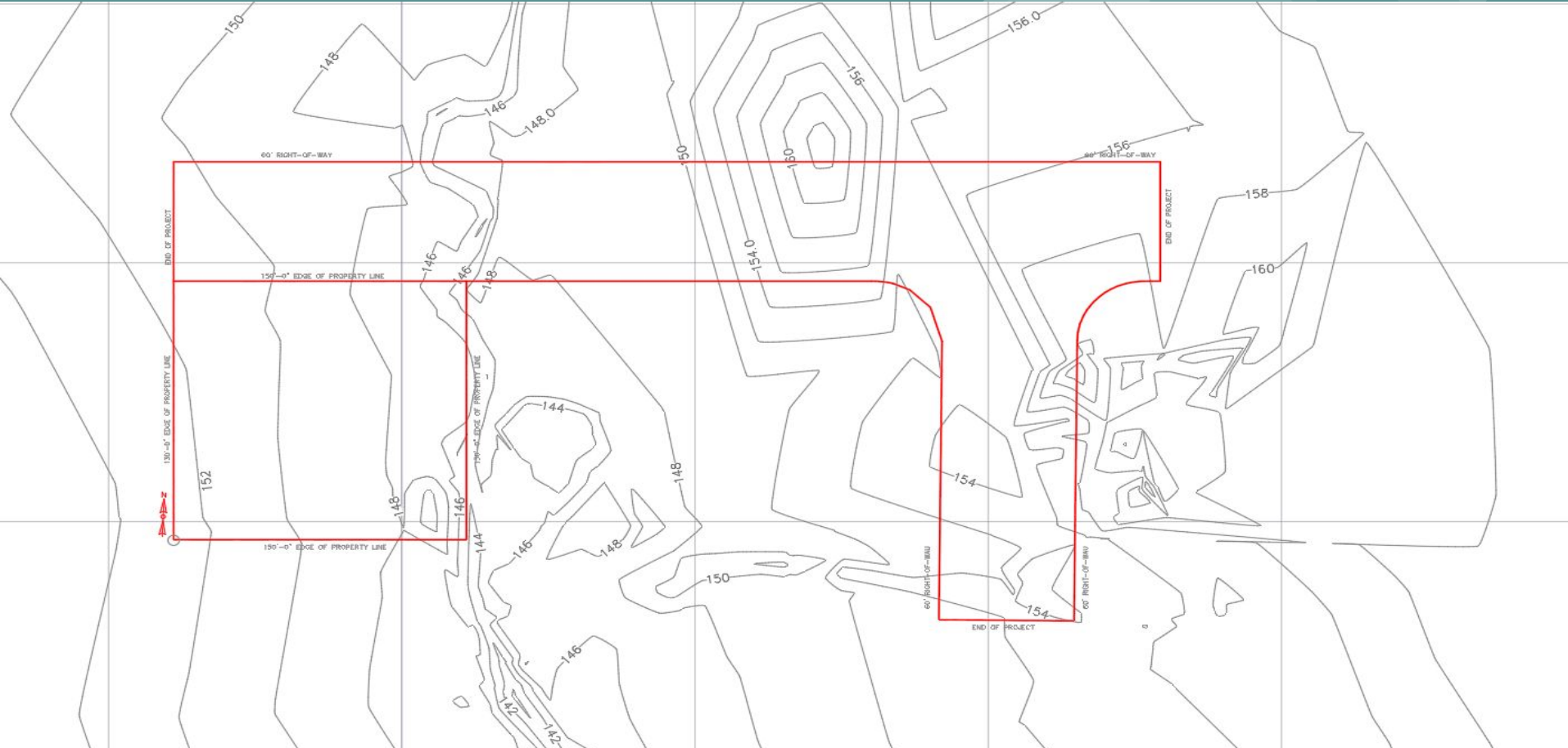


Meeting Times

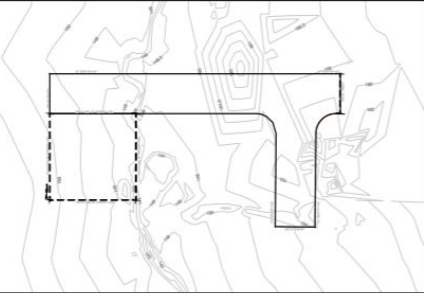
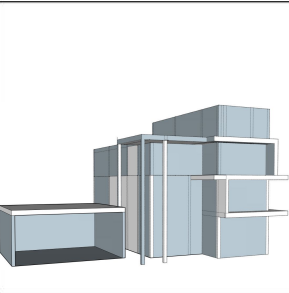
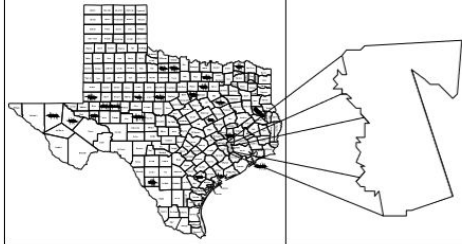
Meeting days	Meeting time	Group members	Task worked on
09/16/19	10-12pm	Marietou, Jarvis, Justin	site plan for proposed townhouse, building footprint
09/18/19	2-3pm	Marietou, Jarvis, Justin	driveway and sidewalk
09/23/19	10-12pm	Marietou, Jarvis, Justin	driveway and sidewalk
09/25/19	2-3pm	Marietou, Jarvis, Justin	building footprint
09/30/19	10-12pm	Marietou, Jarvis, Justin	site plan
10/07/19	2-3pm	Marietou, Jarvis, Justin	cross-section of driveway and site plan review
10/14/19	10-12pm	Jarvis, Justin	site plan
10/21/19	10-12pm	Marietou, Jarvis, Justin	drainage
10/25/19	5-7pm	Marietou, Jarvis	structural framing, dead load, live load
10/28/19	10-12pm	Marietou	drainage
10/28/19	10-12pm	Justin	grading
10/29/19	5-7pm	Marietou, Jarvis, Justin	structural framing, dead load, live load
11/4/19	10am-12pm	Marietou, Jarvis, Justin	structural framing, dead load, live load, wind load
11/04	12- 2pm	Marietou, Jarvis	wind load, structural layout on STAAD PRO
11/05/19	7pm - 9:30pm	Marietou	drainage, wind load
11/06/19	9am - 10am	Justin	cost estimates
11/06/19	5pm - 8pm	Marietou, Jarvis, Justin	Presentation, beam and columns sizing
11/06/19	8pm-10pm	Jarvis, Justin	Plan & Profile View
11/06/19	8am-11pm	Jarvis	Strucual Layout, Foundation Design

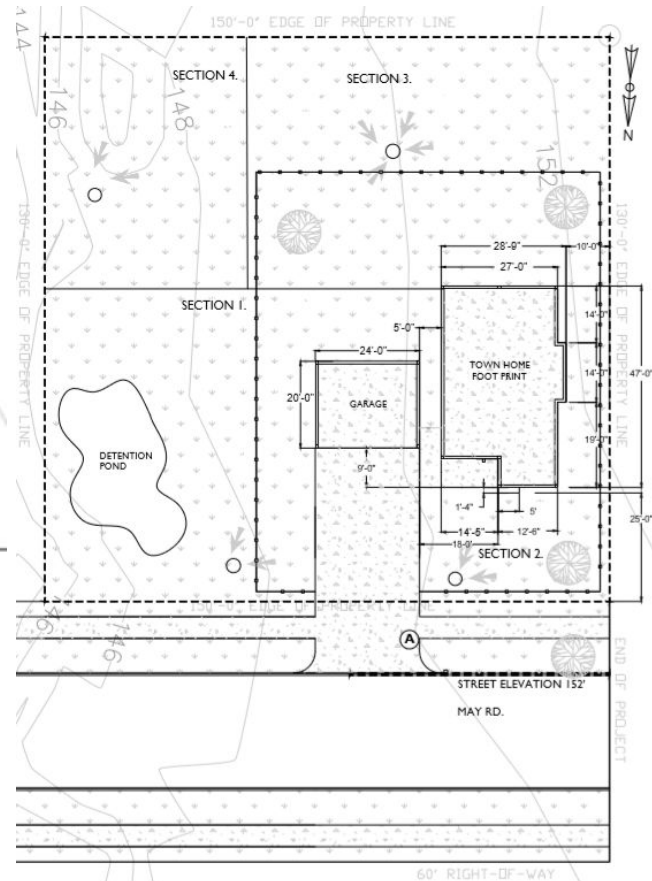
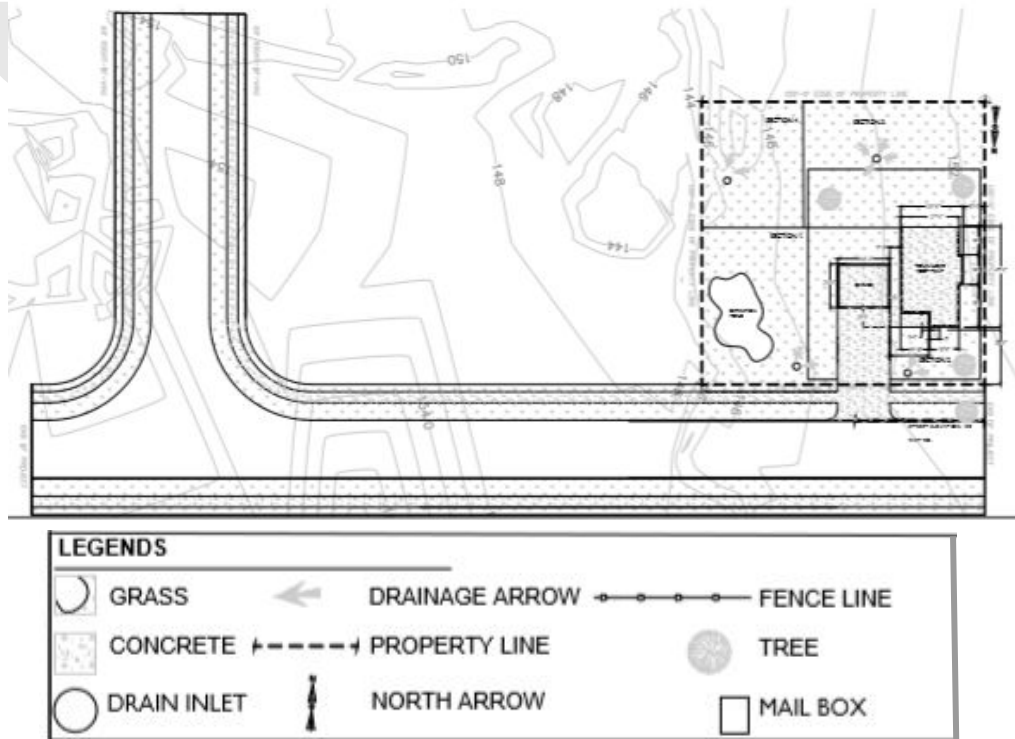
Existing Conditions

Lot size is a 130x130



Cover Sheet and Title Block

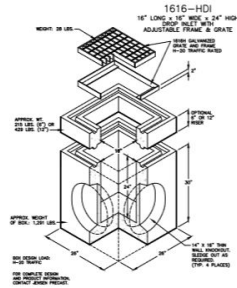
PRAIRIE VIEW GARDENS MASTERPLAN RESIDENTIAL COMMUNITY LOT ADDRESS: 2020 MAY RD. PRAIRIE VIEW, TX 77446		 CIVIL ENGINEER FIRM												
MJ² CIVIL ENGINEER FIRM	SITE PLAN: LOT SCALE: 1/64"= 1'- 0"	RENDERING:												
VICINITY MAP: PRAIRIE VIEW, TX														
	GENERAL NOTES LIST OF DRAWINGS SITE PLAN BUILDING FOOT PRINT DRIVEWAY AND SIDEWALK MISCELLANEOUS DETAILS SHADING AND DRAINAGE STORM WATER COLLECTION SYSTEM RETENTION POND DESIGN STRUCTURAL PLANS FOUNDATION DESIGN BUILDING DESIGN TRANSPORTATION CONNECTING LOT STREET DESIGN SIGNAGE LAYOUT REFERENCE SYMBOL ABBREVIATIONS													
	ENGINEERING TEAM PROJECT MANAGER: JARVIS HAWKINS PHONE: 832.771.6418 EMAIL: JARVIS@MJ2ENGINEERS.COM ENGINEERS: JUSTIN JONES PHONE: 214.286.7833 EMAIL: JONES@MJ2ENGINEERS.COM MARIETOU ZIDA PHONE: 832.272.1918 EMAIL: MARIETOU.ZIDA@GMAIL.COM LEGEND  NORTH ARROW  PROPERTY LINE CODE													
CLIENT JOHNNY GANT P.E. MJ² ENGINEERS MARIETOU ZIDA JARVIS HAWKINS JUSTIN JONES <table border="1" style="width: 100%; border-collapse: collapse; font-size: x-small;"> <thead> <tr> <th style="width: 10%;">REVISIONS</th> <th style="width: 40%;">DESCRIPTION</th> <th style="width: 50%;">INITIAL</th> </tr> </thead> <tbody> <tr> <td> </td> <td> </td> <td> </td> </tr> <tr> <td> </td> <td> </td> <td> </td> </tr> <tr> <td> </td> <td> </td> <td> </td> </tr> </tbody> </table>		REVISIONS	DESCRIPTION	INITIAL										CHECKED: APPROVED: DATE: LOT ADDRESS: 2020 MAY RD. PRAIRIE VIEW, TX 77446
REVISIONS	DESCRIPTION	INITIAL												
COVER SHEET		SHEET NO. : 1 OF 3												



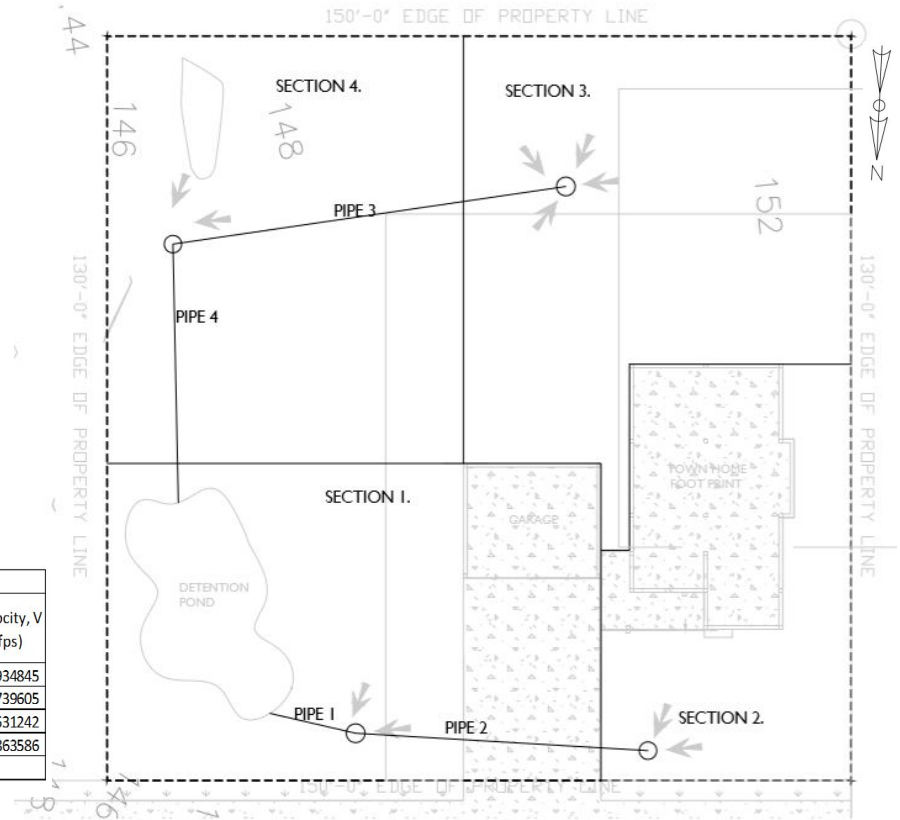
Drainage and Grading



Grading		
Area	Cut Volume (ft ³)	Fill Volume (ft ³)
Town House	0	2247.7
Section 1	316.9	0
Section 2	735.2	0
Section 3	722.5	0
Section 4	194.35	0

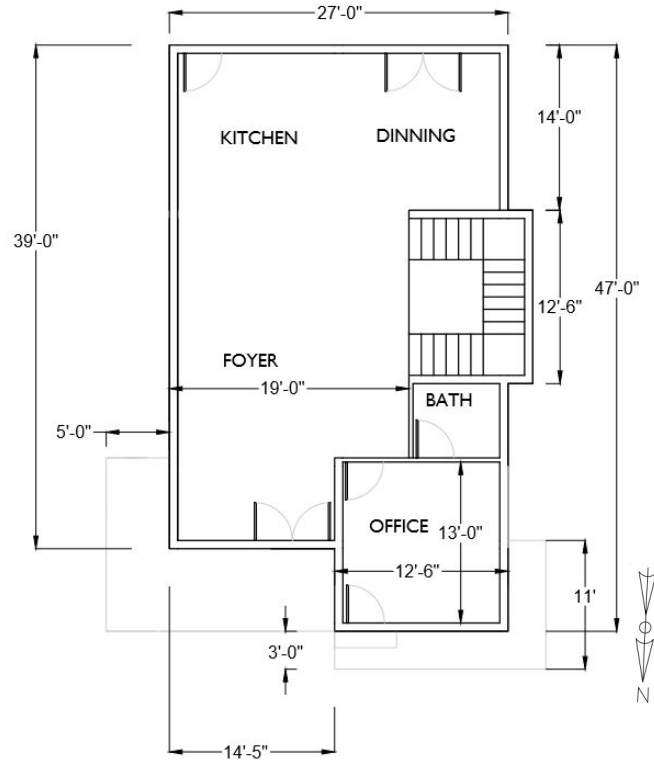


DRAINAGE AREA CALCULATIONS												
Inlet	Drainage area (acres)	Total drainage area (acres)	C factor	Time of concentration Tc	Intensity, I in/hr	flow Q (cfs)	Length L (ft)	Diameter (in)	Manning's n	slope %	Flow Q (cfs)	Velocity, V (fps)
1	0.11	0.18	0.200	21.779	3.645	0.080	15	20	0.012	0.02	0.198	0.0934845
2	0.07	0.07	0.457	21.261	3.687	0.118	51	17	0.012	0.02	0.118	0.0739605
3	0.1	0.1	0.200	21.667	3.654	0.073	69.5	16	0.012	0.02	0.073	0.0531242
4	0.11	0.21	0.200	21.779	3.645	0.080	45	18	0.012	0.02	0.153	0.0863586
OUT												

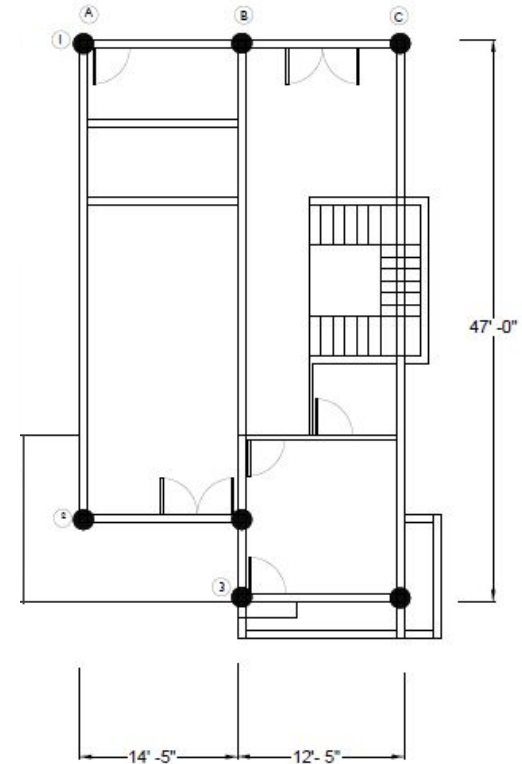


First Floor

Floor plan

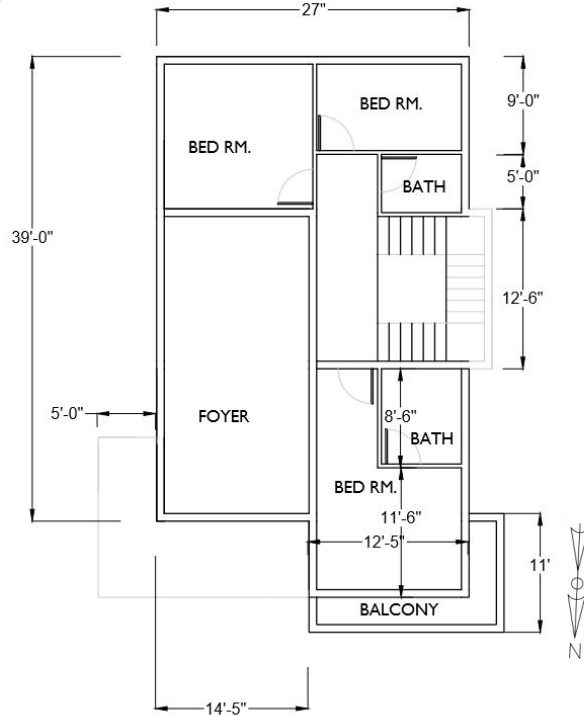


Steel Design

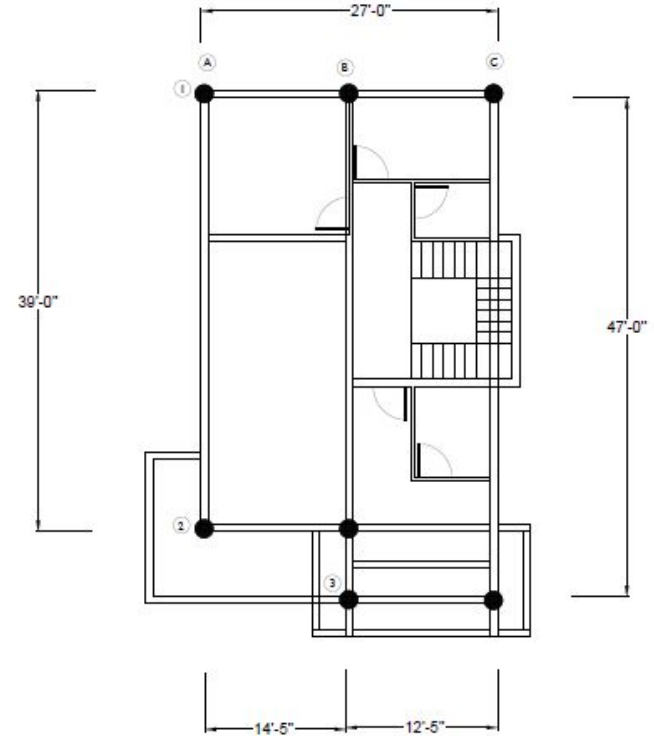


Second Floor

Floor plan

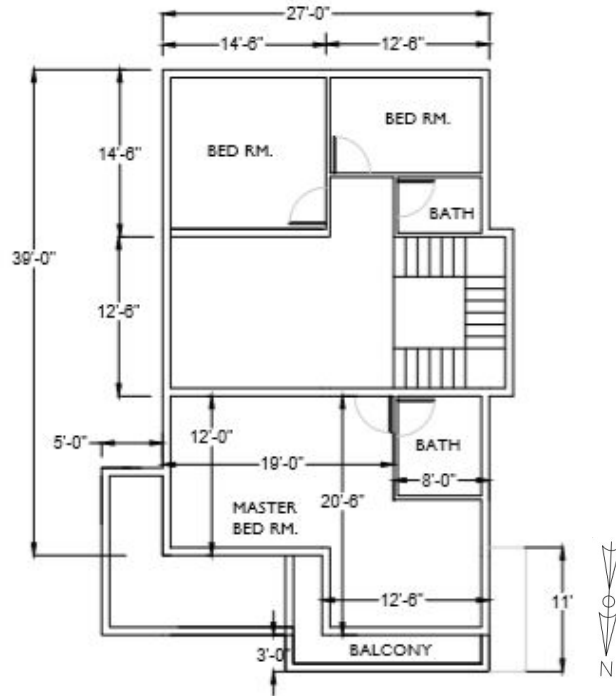


Steel Design

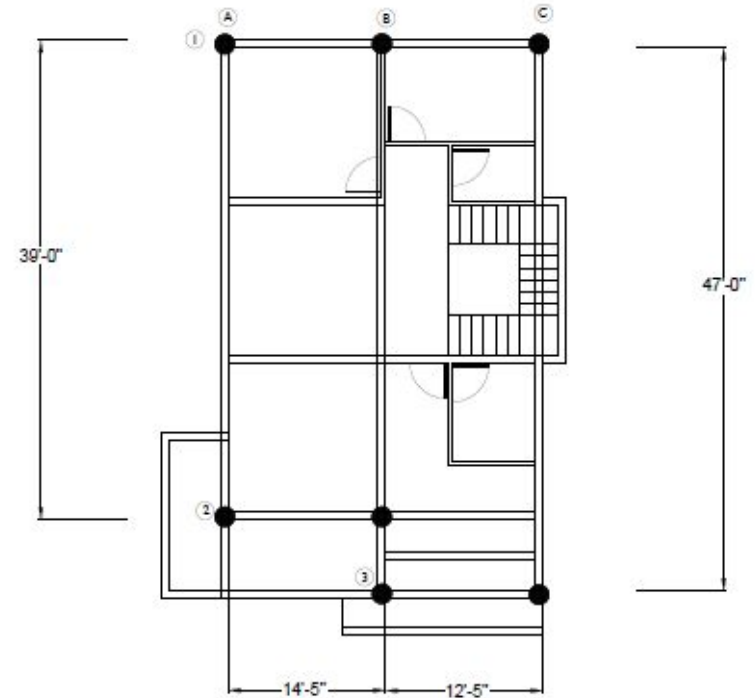


Third Floor

Floor plan

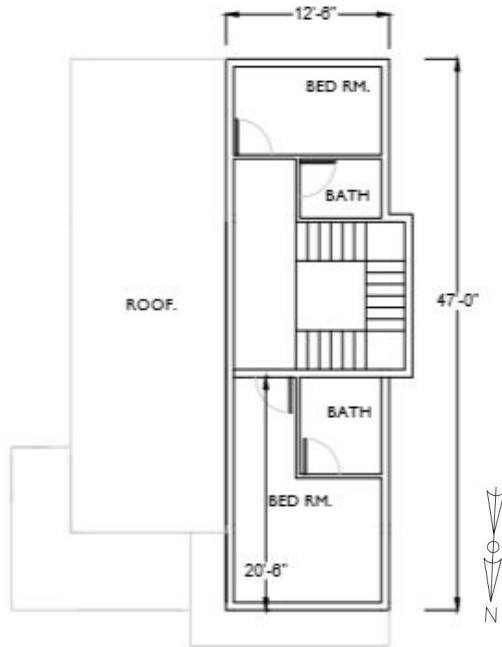


Steel Design

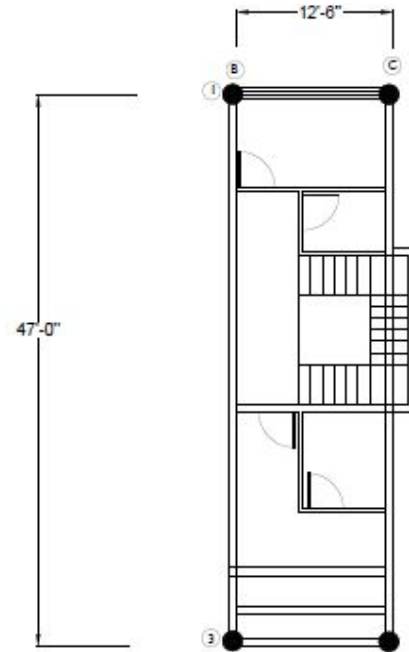


Fourth Floor Plan

Floor plan



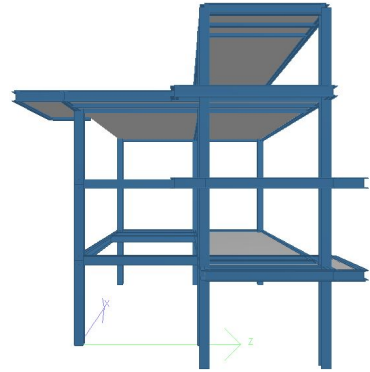
Steel Design



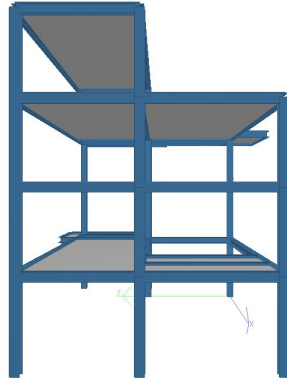
Staad Pro (ISOMETRIC VIEW)



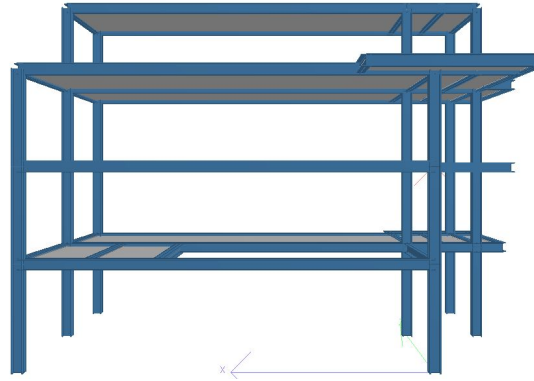
Staad Pro Elevation



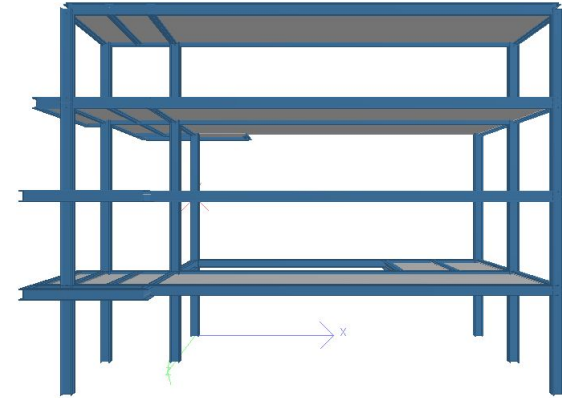
NORTH
ELEVATION



SOUTH
ELEVATION

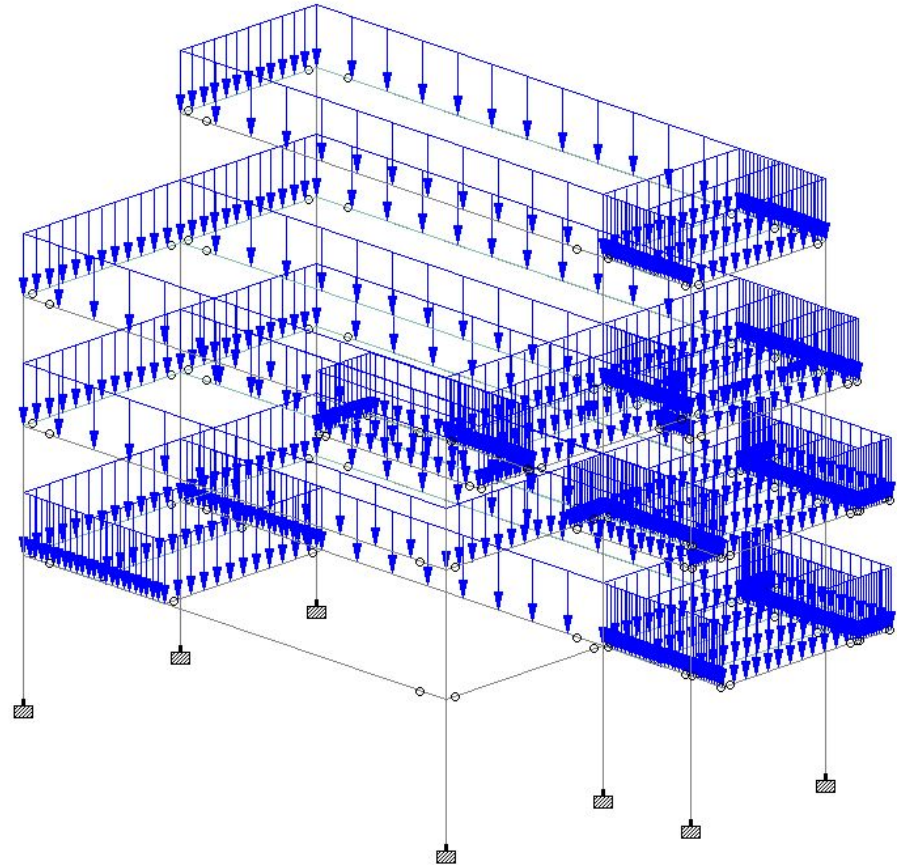


EAST
ELEVATION

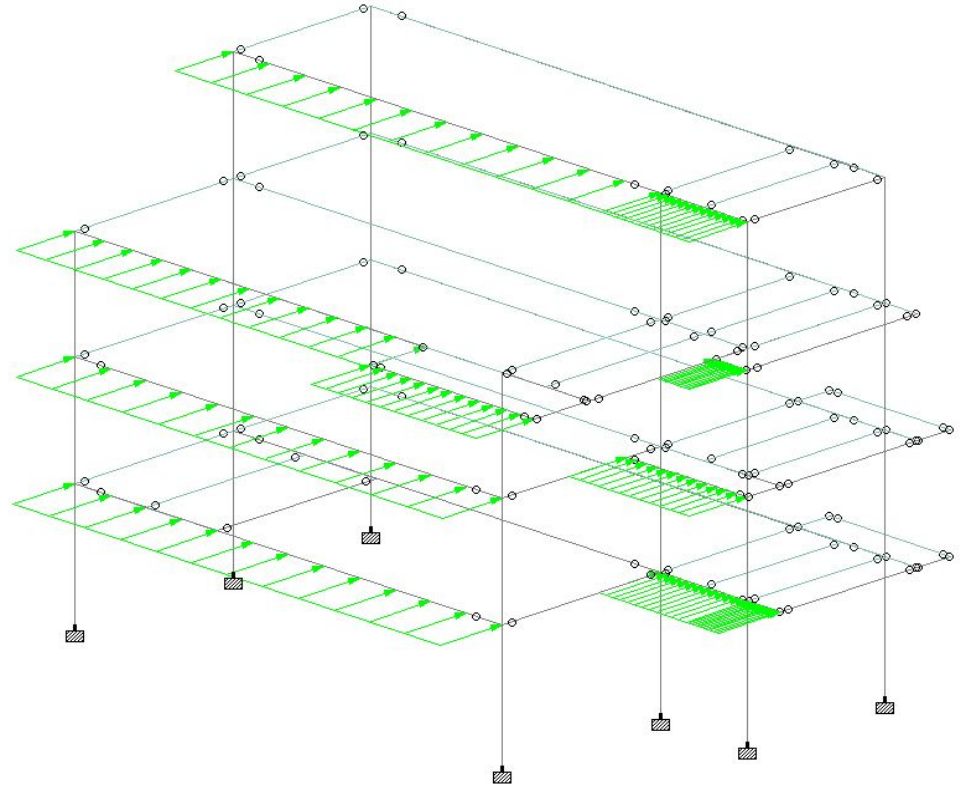


WEST
ELEVATION

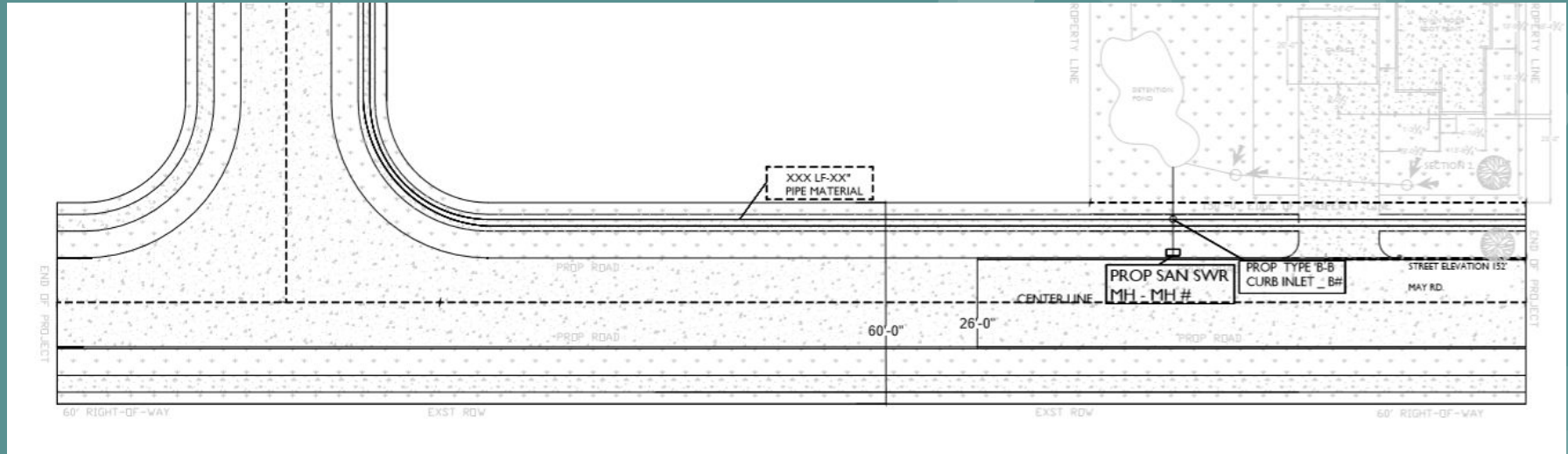
Dead Load and Live Load



Wind Load



May Rd. Plan View



Next Stage

Structural plans

- Foundation Design

Transportation Plans

- Finish Plan & Profile View

Quantity Takeoff

- Finalize Cost Estimates





Thank You!

Done by Marietou Zida

checked by:

Done by Marietou
checked by Justin and
Jarvis

Impervious Area calculations

- Townhome :

$$① 26.79 \times 13.0625 = 349.94$$

$$② 28.75 \times 13.73 = 394.74$$

$$③ 26.79 \times 5.875 = 157.39$$

$$④ 6.54 \times 13.73 = 89.79$$

$$⑤ 12.75 \times 12.42 = 158.31$$

$$= 1150.17 \text{ SF}$$

$$\text{Garage} = 480 \text{ SF}$$

$$\text{walkway} = (5 \times 13.73) + (13.0625 \times 6.54) = 154.1 \text{ SF}$$

$$\text{Driveway} = 24 \times 35.33 = 848 \text{ SF}$$

$$\text{Total impervious Area} = \frac{2632.27 \text{ SF}}{43560} = 0.06 \text{ Acre}$$

Drainage Calculations

Done by Navietou
checked by Justin and Jarvis

$$\text{Lot Size} = 130 \times 130$$

$$\text{Lot Area} = 130 \times 130 = \frac{16,900 \text{ SF}}{43560} = 0.39 \text{ Acre}$$

$$\text{Impervious Area} = 0.06 \text{ Acre}$$

$$\text{Pervious Area} = 0.39 - 0.06 = 0.33 \text{ Acre}$$

Calculation of the runoff coefficient, C

$$C = 0.6 I_a + 0.2$$

$$= 0.6 \left(\frac{0.06}{0.39} \right) + 0.2 = 0.29$$

Time of concentration, T_c

$$T_c = 10 A^{0.1761} + 15$$

$$T_c = 10 (0.39)^{0.1761} + 15 = 23.47 \text{ min}$$

Rainfall intensity, i

$$i = \frac{b}{(d + t_c)^e} = \frac{75.01}{(16.2 + 23.47)^{0.8315}} = 3.52 \text{ in/hr}$$

Calculation of the total runoff, Q

$$Q = CIA$$

$$= 0.29 \times 0.39 \times 3.52 = 0.398 \approx 0.4 \text{ cfs}$$

$$Q = 0.4 \text{ cfs}$$

Done by Marietou
checked by Jarvis and
Justin

Detention Pond Calculations

Total detention volume required is =

$$V_T = [43,560 \times (0.20 \times A_{ii})]$$

A_{ii} = Area of impervious surface in Acre

$$V_T = [43,560 \times (0.20 \times 0.06)] + [43,560 \times (0.20 \times 0.39)]$$

$$V_T = 522.72 \text{ ft}^3 + 3397.68 \text{ ft}^3$$

$$V_T = 3920.4 \text{ ft}^3$$

Done by Marielou
Checked by Jarvis and Justin

Pipe sizing

$$\text{Impervious area} = 1304.27 \text{ SF} \\ = 0.03 \text{ acre}$$

Drainage area 1

$$\text{Area} = \frac{3017.7 \text{ SF}}{43560} = 0.07 \text{ Acre}$$

$$C = 0.6 I_a + 0.2$$

$$= 0.6 \left(\frac{0.03}{0.07} \right) + 0.2 = 0.46$$

$$T_c = 10 A^{0.1761} + 15$$

$$= 10 (0.07)^{0.1761} + 15$$

$$T_c = 21.26 \text{ min}$$

$$i = \frac{b}{(d + t_c)^e} = \frac{75.01}{(16.2 + 21.26)^{0.2315}} = 3.69 \text{ in/hr}$$

$$Q = CIA = 0.46 \times 3.69 \times 0.07$$

$$Q_2 = 0.12 \text{ cfs}$$

$$\text{Perimeter} = 310.38 \text{ ft}$$

$$D = \left(\frac{4^{5/3} \times 0.12 \times (310.38)^{2/3} \times 0.013}{\pi^{5/3} \times 1.49 \times 0.02} \right)^{3/10} = 1.48' \times 12 = 17.61'' \approx 18''$$

Done by Marietou

Checked by Justin and
Jarvis

Drainage area 2

$$\text{Area} = \frac{4776.22}{43560} = 0.11 \text{ acre}$$

$$\text{impervious area} = 1328 \text{ S.F.} \\ = 0.03 \text{ acre}$$

$$C = 0.2 + 0.6 I_a = 0.2 + 0.6 \left(\frac{0.03}{0.11} \right) = 0.37$$

$$T_c = 10 A^{0.1761} + 15 = 10 (0.11)^{0.1761} + 15 = 21.78 \text{ min}$$

$$i = \frac{b}{(d + t_c)^e} = \frac{75.01}{(16.2 + 21.78)^{0.8315}} = 3.65 \text{ in/hr}$$

$$Q = CIA$$

$$= 0.37 \times 3.65 \times 0.11 = 0.08 \text{ cfs}$$

$$\text{Perimeter} = 290.25 \text{ ft}$$

$$Q = 0.08 + 0.12 = 0.2$$

$$D = \left(\frac{4^{5/3} \times 0.2 \times (290.25)^{2/3} \times 0.013}{\pi^{5/3} \times 1.49 \times 0.02} \right)^{3/10} = 1.69' \times 12 = 20.25 \approx 20''$$

Drainage Area 3

$$\text{Area} = \frac{44,657.75 \text{ ft}^2}{43,560} = 0.1 \text{ Acre}$$

Done by Narjetou
Checked by Jarvis and Justin

$$C = 0.2$$

$$T_c = 10 A^{0.1761} + 15$$
$$= 10 (0.1)^{0.1761} + 15 = 21.67 \text{ min}$$

$$i = \frac{b}{(d + t_c)^e} = \frac{75.01}{(16.2 + 21.67)^{0.8315}} = 3.65 \text{ in/hr}$$

$$Q = CIA$$

$$= 0.2 \times 3.65 \times 0.1$$

$$Q_3 = 0.07 \text{ cfs}$$

$$\text{Perimeter} = 439.695 \text{ ft}$$

$$D = \left(\frac{4^{5/3} \times 0.07 \times (439.695)^{2/3} \times 0.013}{\pi^{5/3} \times 1.49 \times 0.02} \right)^{3/10} = 1.34' \times 12 = 16.08 \approx 16 \text{ in}$$

Drainage area 4

Done by Marietou Zida

$$\text{Area} = \frac{4645.88}{43560} = 0.11 \text{ acre}$$

checked by Justin and Jarvis

$$C = 0.2$$

$$T_c = 10 A^{0.1761} + 15$$

$$T_c = 10 (0.11)^{0.1761} + 15 = 21.78 \text{ min}$$

$$i = \frac{b}{(d + t_c)^e} = \frac{75.01}{(16.2 + 21.78)^{0.8315}} = 3.65 \text{ in/hr}$$

$$Q = CIA$$

$$= 0.2 \times 3.65 \times 0.11$$

$$Q_4 = 0.0803 \text{ cfs}$$

$$\text{Perimeter} = 2 \times (62.25 + 74.6) = 273.7 \text{ ft}$$

Pipe size using Manning's equation ($n = 0.013$)

$$Q = \frac{1.49}{n} \times A R^{2/3} \sqrt{S} \quad R = \frac{A}{P}$$

$$Q = \frac{1.49}{n} \times \frac{A^{5/3}}{P^{2/3}} \sqrt{S} \quad A = \frac{\pi}{4} D^2$$

$$Q = \frac{1.49}{n} \times \left(\frac{\pi}{4} D^2 \right)^{5/3} \sqrt{S}$$

$$Q = Q_3 + Q_4 = 0.07 + 0.0803 = 0.15 \text{ cfs}$$

$$D = \left(\frac{4^{5/3} Q \times P^{2/3} \times n}{\pi^{5/3} \times 1.49 \times \sqrt{S}} \right)^{3/10}$$

$$D = \left(\frac{4^{5/3} \times 0.15 \times (273.7)^{2/3} \times 0.013}{\pi^{5/3} \times 1.49 \times 0.02} \right)^{3/10} = 1.53' \times 12 = 18.35'' \approx 18 \text{ in}$$

use 18 in pipe in drainage area 4

CVEG 4472

Fall 2019

Group 5

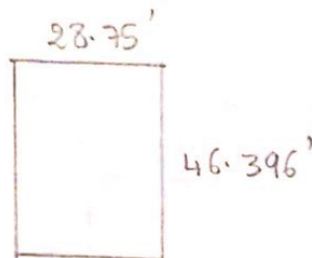
Zida, Marielou

Hawkins, Jarvis

Jones, Justin

i) Building Foot print

1. Dimensions



2. Finish Floor Elevation is = 154'

3. Square Footage

- First Floor = 1,234 SF
- Second Floor = 842 SF
- Third Floor = 1,184 SF
- Fourth Floor = 484 SF

4. Distances from the property lines

using City of Houston Code of ordinances and the constraints given in the scope of work, the setback along the front of the lot is 25 feet and the setback along the back and the sides of the lot is 10 feet.

Ethics Quiz

Fall 2019

CVEG 4472

Name: Zida ⁶⁰
Last Marielou
First

Answer all Questions below by circling the correct answer:

D 1. What is the direct result of ethical behavior?

- A. Your reputation will be enhanced.
- B. You will be rewarded economically.
- ☒ C. You will feel good about yourself.
- D. Neither a, b, or c

2. Complete the sentence: "if you check the calculations for a licensed (registered) friend who has gone into a consulting business for himself/herself,

- A. "you should be paid for your work."
- ☒ B. "your friend's client should be told of your involvement."
- C. "you do not need to be licensed or registered yourself."
- D. "your friend assumes all the liability for your work."

C 3. What does it mean when a design professional accepts a punishment for an unethical act from his technical society "with prejudice?"

- A. The professional's race, creed, and national origin were Considered in deciding on the punishment.
- B. The professional's race, creed, and national origin were Not considered in deciding on the punishment.
- C. Even after the sentence is served or punishment is completed, there may be further actions taken.
- ☒ D. The professional is held in bad report for the period of prejudice.

B 4. While supervising a construction project in a developing country, an Engineer discovers that his client's project manager is treating laborers in an unsafe and inhumane manner (but for that country, legal). When he protests, the Engineer is told by the company executives that the company has no choice if it wishes to remain competitive in the regions, and he should accept this as the way things are. What would Ethics require the Engineer to do?

A. Take no action – the company is acting in a perfectly legal manner.

B. Withdraw from the project, returning any fees he may have already received.

☒ C. Report the company to the proper authorities for its human rights abuses.

D. Assist the laborers in organizing a strike to obtain better working conditions.

5. Two engineers submitted sealed bids to a prospective client for a design project. The client told Engineer A how much Engineer B had bid and invited Engineer A to beat that amount. Engineer A really wants the project and honestly believes he can do a better job than Engineer B. What should he do?

A. He should submit another quote, but only if he can perform the work adequately at the reduced price.

B. He should withdraw from consideration for the project.

☒ C. He should remain in consideration for the project, but not change his bid.

D. He should bargain with the client for the cost of the work.

6. You are a city Engineer in charge of receiving bids on behalf of the city council. A contractor's bid arrives with two tickets to a professional football game. The bid is the lowest received. What should you do?

- ☒ A. Return the tickets and accept the bid.
- B. Return the tickets and reject the bid.
- C. Discard the tickets and accept the bid.
- D. Discard the tickets and reject the bid.

7. The first and foremost obligation of registered professional engineers is to:

- ☒ A. The public welfare
- B. Their employer
- C. The government
- D. The engineering profession

8. Registered professional engineers should undertake services for clients only when:

- A. They really need the fees
- B. Their own bid is the lowest one
- ☒ C. They are fully technically competent to carry out the services
- D. Carrying out the services would not involve excessive time or effort

9. The Model Rules of Professional Conduct require registered engineers to conform to all but one of the following rules. Which rule is not required?

- ☒ A. Do not charge excessive fees
- B. Do not compete unfairly with others
- C. Perform services only in the areas of their competence
- D. Avoid conflicts of interest

- C 10. You are a quality control engineer of a completely produced U.S. made product compliance. You notice one subcontractor used foreign-made bolts. The customer urgently needs this product. What should you do?
- A. Say nothing and deliver hoping no one notices
 - B. Find, or invent, some equivalent violation of contract where the customer is responsible. Tell them you will ignore the violation if they ignore your violation
 - C. Tell the customer and let them decide
 - ☒ D. Put all efforts into trying to find a legal loophole in the original specs.

**CIVIL ENGINEERING DEPARTMENT
PRAIRIE VIEW A&M UNIVERSITY
CVEG 4472
FALL 2019**



Civil Engineering Firm

MARIETOU ZIDA
JUSTIN JONES
JARVISHAWKINS

GROUP 5

References

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<https://www.jensenprecast.com/Drainage-Inlets-Catch-Basins/Curb-Inlets-p14780/>
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3. Street Paving Design Requirements <https://www.houstonpermittingcenter.org>
4. Live Load and Dead Load
Chapter 3, Design Loads for Residential Buildings, Residential Structural Design Guide.
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DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING
CVEG 4472 Senior Design and Professionalism I
OUTCOMES SPECIFIC ASSIGNMENT COVER SHEET

FALL 2020

Instructor: Dr. R. Radha

Title of Assignment

**Information research for the project, determining needs,
understanding contemporary issues and to use the information
to implement in the project design**

Outcome Measured Using this Assignment

Outcome 7

**An ability to acquire and apply new knowledge as needed, using appropriate learning
strategies**

Check the outcome appropriate characteristics related to this assignment

Ability to Acquire new knowledge using the appropriate learning strategies Requires students to:	
X	Be knowledgeable of and use different learning strategies <i>(Instructor may provide information on different learning strategies)</i>
X	Identify and take advantage of learning opportunities available in the library, online resources, seminars, webinars, conferences, workshops and tutorials.
X	Be aware of the need for and are able to independently acquire additional knowledge and data needed for solving problem using appropriate learning strategies and tools.
Ability to apply new knowledge to solve problems Requires students to:	
X	Demonstrate appropriate use of the new knowledge to solve problems.

Brief justification of the suitability of assignment for the outcome

All students will be required to read reference materials and use library and web resources needed to perform the project. Literature review and reference documentation related to the project subtasks will have to be prepared and submitted

ASSIGNMENTS FOR OUTCOME “7”

An ability to acquire and apply new knowledge as needed, using appropriate learning strategies

DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING
CVEG 4200 Senior Design and Professionalism I
OUTCOMES SPECIFIC ASSIGNMENT COVER SHEET

FALL 2021

Instructor: Dr. Md Jobair Bin Alam

Title of Assignment

**Information research for the project, determining needs,
understanding contemporary issues and to use the information
to implement in the project design**

Outcome Measured Using this Assignment

Outcome 7

**An ability to acquire and apply new knowledge as needed, using appropriate learning
strategies**

Check the outcome appropriate characteristics related to this assignment

Ability to Acquire new knowledge using the appropriate learning strategies Requires students to:	
X	Be knowledgeable of and use different learning strategies (<i>Instructor may provide information on different learning strategies</i>)
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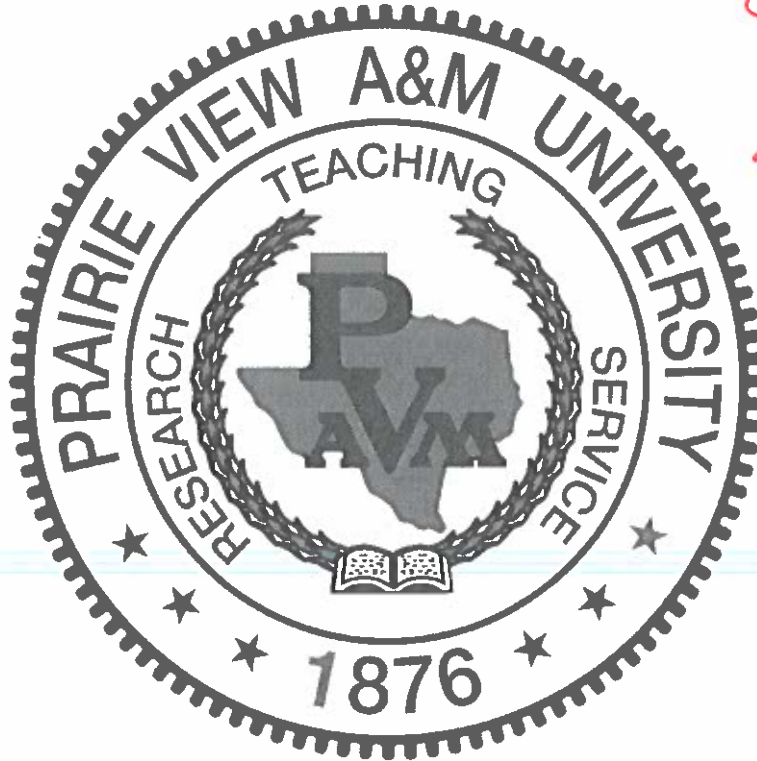
**CVEG 4200 Senior Design and Professionalism I
FALL 2021**

**ASSIGNMENT STATEMENT/QUESTIONS
GRADING SCHEME FOR ASSIGNMENT**

Literature search documentation	25 pts
Document use of new knowledge	25 pts
References listing and relevance statements	50 pts
Total:	100 pts

Insert here Student Sample for Crit. 7

**Prairie View A&M University
Roy G. Perry College of Engineering
Civil & Environmental Engineering Department**



88

CVEG 4200: Senior Design

Section: P01

Course Number: 17739

Title: Final Semester Report

Submitted By: Abram Auguste, Armando Gomez, Alex Martinez, Nathaniel Smith –

G.A.M.S. Engineering

Submitted To: Dr. Alam, Md Jobair Bin Ph.D., P.E.

Due Date: December 01, 2021, 1:00 P.M.

Executive Summary

Prepared by

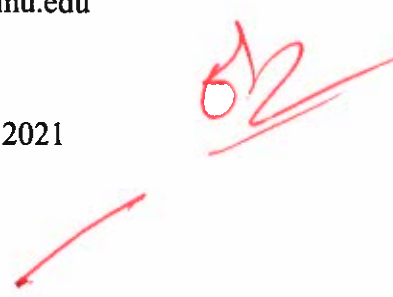
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Nathaniel Smith
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Armando Gomez
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November 17, 2021

A red handwritten signature, possibly "AJ", is located to the right of the date. A red arrow points from the signature towards the date.

Summary

The proposed project is the development of a 400 acre lot for Amazon. This new development is located near the city of Brenham in Washington County, Texas. G.A.M.S Engineering is to develop and design Amazon distribution center, IT Hub, Office space, convention center, wastewater treatment facility, storm water ditch (to connect to a major lake), parking lots, roads, intersection and a highway extension that will accommodate the new facilities. G.A.M.S Engineering is to provide details on progress and milestones with completion dates for thus scope of work.

Geotechnical Engineering

The following report summarizes G.A.M.S. Engineering, Inc's Geotechnical Evaluation for the proposed Amazon Hub, located in Washington County, Texas. This report includes information regarding the field and laboratory testing analysis, the subsurface conditions encountered, and discussion related to building construction in relationship to the subsurface conditions at the site. The analysis was performed in general accordance with CVEG 3023 and 4100 processes and formulaic assessment.

At this time, the project consists of constructing a two five-story commercial office building, a steel structure warehouse, and a three-story convention center building with a footprint of approximately 30,000 to 50,000 square feet based on historical data. The building is proposed to be constructed at grade (i.e. without subsurface floors) with a finished floor elevation of approximately 340 feet.

On August 26, 2021, two (2) Standard Penetration Test (SPT) borings were performed using CME 75 drill rigs with 8" test hole diameter in the vicinity of the proposed Amazon hub building location to depths at 75 feet below the existing ground surface. Beneath a surface layer, the subsurface conditions observed can be described as lean to fat clay with varying amounts of silt to the extent of the test boring logs. Based on the assessment of the subsurface conditions and information exchanged to and between the G.A.M.S. Engineering team, the following comments and recommendations are made: The proposed building construction could not be supported on a conventional shallow foundation system and slab-on-grade nor a Matt foundation. However, it

was determined that Pile foundations could be designed for a maximum allowable bearing pressure of 560 pounds per square foot (psf). Total foundation settlement is estimated to be on the order of 1.34 inch or less, and a differential settlement on the order of a ½ inch or less; Groundwater was observed in the test borings performed at the site at depths approximately 7.5 feet below the existing ground surface. Based on the groundwater depths observed during soil assessment, it is likely that groundwater will be encountered during foundation construction. Therefore, the best course of action would be a deep pile system suitable to carry the load of the Amazon facility.

Structural Engineering

The scope of work for the structural engineering portion of the project is to provide designs for the Amazon distribution center warehouse, five story IT Hub and office building, and three story civic center. It is to include the location of where the buildings are to be built. The location of the buildings will be coordinated with geotechnical engineers and water resources engineers to provide the best location for the foundation design and on grade slab of the building. As well as the watershed that could cause flooding to the buildings.

The warehouse is to be designed with reinforced concrete step footings that will support the load of the building. Anchors bolts for the columns will be set in the concrete footings. Steel H-beams with base plates will be used for the load bearing column of the buildings. The spacing of the building columns is to utilize and provide the most floor space possible. To roof supports for the building will be that of I beams and joist that will run perpendicular to the beam. The connection joints to be determined depending on shear and moment of the location. The dead, live, and wind loads for the buildings will be calculated using the Load and Resistance Factor Design (LRFD). The live, dead and wind loads that meet the requirements given in the International Building Code. The information will be imputed into STADD pro modeling for all four buildings. To provide output results of the given bending moments, and shear and axial loads. The STADD report is to be utilized for design purposes of the buildings. As the warehouse design, the multistory buildings will also be of steel structure meeting all International Building Code (IBC) guidelines and local ordinances. The building's footing will be dependent on the



geotechnical report and could require pile footing to support the structures. Autocad will be used to provide a detailed design of the building's footing, floor layout, column and beam locations, dimensions of building and building materials that are to be used.

Water Resources

In the water resources portion project the tasks included determining the location of a storm water ditch, the rainfall intensity based on the 100-year rainfall investigation period, calculating the quantity of water and designing the ditch based on the rainfall study. The ditch was assumed to be an unlined trapezoidal channel and was designed by using hydrologic and hydraulic methods. One of The hydrologic methods used was the "Tractive Force based Unlined Channel Design Method " to get the design dimensions for the ditch/channel. One of the first things done was determining the runoff based on the rainfall intensity by using the Rational Method. Next, the Manning's roughness coefficient and the sediment size were determined based on the surrounding land. The slope of the land was then determined. Moving forward the design depth of the was calculated and the value of side slope was assumed. The area and perimeter were then set up as equations where the base was unknown.

After everything that could be determined was calculated, the runoff, Manning's roughness coefficient, area, perimeter, and the slope of the land were all put into an equation to determine the base of the ditch/channel. The design velocity and the Kennedy equation velocity were then calculated. The design velocity would need to be greater than the Kennedy equation velocity in order for the design to be sufficient. If the Kennedy equation velocity was greater, then the design calculations would have to be done again by assuming a different side slope until the design velocity is greater.

Transportation Engineering

The transportation engineering part of this project include the task to design a roadway layout for the entire project site including a connecting road with the nearby highway 290, create an interchange design, design a parking lot for entire facilities, locate signals and related traffic

studies, and provide a plan and profile as well as a pavement design cross section for a typical local road in the development.

Within the roadway layout of the project site there are to be two entrances required into the site. One entrance on the east side and one entrance on the west side of the project site. One entrance must be regulated by a traffic signal in order to direct traffic. The traffic signal setup will be a simple 3 way intersection signal that will help people from the Amazon hub exit the site safely and in a timely manner. Furthermore, within the parking layout there is to be service truck parking for the warehouse that is separate from visiting cars of the office buildings for amazon. The parking for the service trucks are found on the west portion of the project facility near an existing Farm to Market road which will make it efficient for the trucks to come in and out of the facility. In addition, sidewalks will be placed throughout the project site especially around the business offices and convention center. These sidewalks will help connect parking lots to the respective buildings as well as creating an easy path from building to building. Lastly, all roadway designs for this project must meet Texas Department of Traffic (TxDOT) and US DOT requirements and specifications. For all the transportation parts of the project that require design, the software AutoCAD will be used to create and portray these ideas in a professional manner.

Environmental Engineering

In the environmental engineering portion of this project the ~~tasks~~ included calculating the estimated wastewater quantity, determining the location of a wastewater treatment plant, a schematic of the treatment plant, an approach to treat the wastewater, and to choose a reliable dumping location for the disposal of the wastewater. The scope of work for this portion of the project is to be completed in the following semester.

Recommendations

Geotechnical: There are currently no recommendations at this time.

Structural: There are currently no recommendations at this time.

Water Resources: There are currently no recommendations at this time.

Transportation: there are currently no recommendations at this time

Environmental: There are currently no recommendations at this time

Table of Contents

1. **Geotechnical Survey**
2. **Structural Engineering**
3. **Water Resources**
4. **Transportation Engineering**
5. **Environmental Engineering**

X

table of content
must be elaborated

Geotechnical Survey

Introduction

This report is a representation of the subsurface performed for the design and construction of the proposed Amazon Hub in Washington County, Near the city of Brenham, Texas. It is understood that the overall project has been split into four (4) phases, with separate engineers working on each phase, and each phase being constructed within different construction periods. The four phases, and corresponding project periods, are as follows:

Table 1. Project Phasing

Phase	Project Area	Development Period
A	Geotechnical Survey	4 weeks
B	Structural Design	8 weeks
C	Hydrology Design	4 weeks
D	Environmental/Traffic	5 weeks

This investigation was performed for Phase A, which is for the 400-acre segment that is located adjacent to the Interstate-290 and Southwest of the City of Brenham. Information provided by the coursework scope, it is understood that the proposed Amazon Hub will consist of an The specific scope of the project will include Civil Engineering Development and Design services for the entire site which will include two five-story commercial office building, a steel structure warehouse, a three-story convention center, parking lots. The students will also perform new road network development, engineering design of pavement and pavement subgrade, intersections, sidewalks, driveways, and extension of major highways/service road and connecting local road with highway, a storm water ditch connecting a major lake, a municipal solid waste and a temporary recyclables disposal facility, and wastewater treatment process and facility. The facilities will be designed for 20,000 people or based on population projection for 15 years., and road connections to I-290. Phase A project alignment, which will interconnect with the existing drainage systems and interstate roads.

1.1 Existing Site Conditions

The project site encompasses an approximately 400 square foot long area along the southwestern bank of the city of Brenham on the southwest side of the Interstate-290, Texas. Brenham is a city in east-central Texas in Washington County, United States, with a population of 15,716 according to the 2010 U.S. census. It is the county seat of Washington County. The elevation is approximately (341') and the city has an area: 13.03 mi². Brenham is located at 30°9'43"N 96°23'49"W (30.161901, -96.397004). Industrial properties and Blinn Community College facilities are located along the northeast side of the proposed space, and it is presumed that the land is baron and free of residential buildings. Pond Creek sits just southwest of the proposed space in the town of Wesley, Texas.

Design Location (Theory)

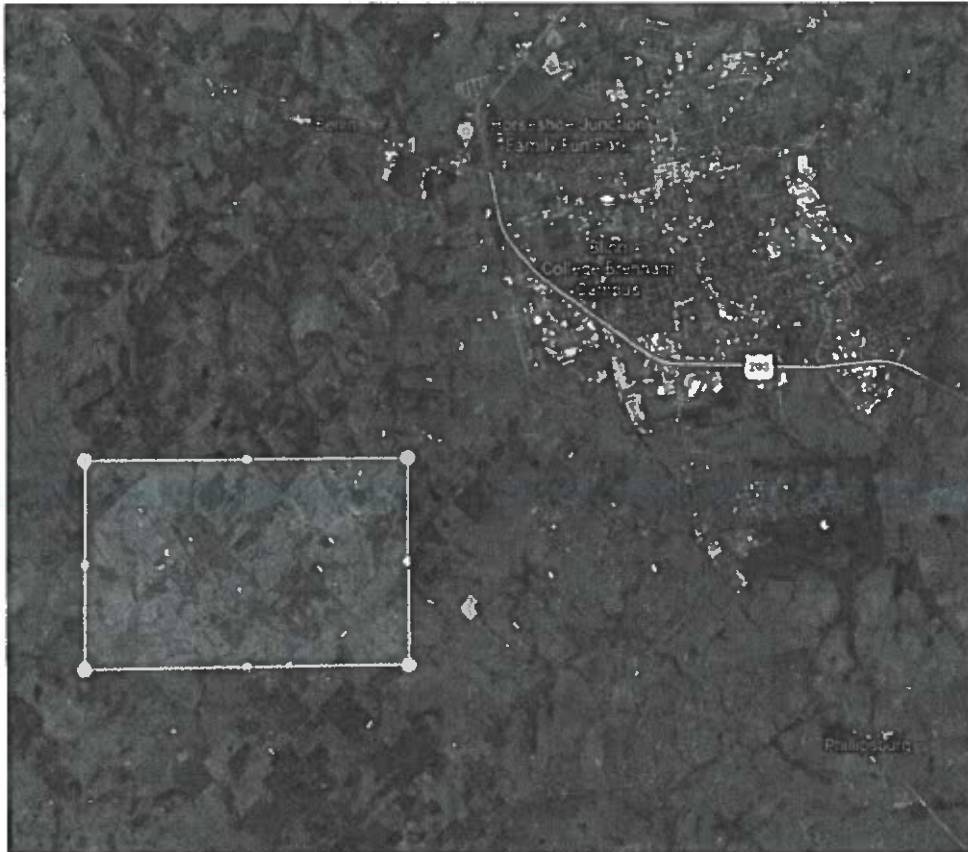


Figure 1: 400 Acre near Brenham (Washington County)

Figure 1: 400 Acre near Brenham (Washington County)

1.2 Site Geology

Washington County is in the Blackland Prairies region of southeast central Texas. The center of the county is at 30°14' north latitude and 96°24' west longitude. Brenham, the seat of government, is near the county's center and seventy-five air miles east of Austin. The county was named for George Washington, the first president of the United States. Washington County encompasses 611 square miles of gently rolling land with elevations ranging between 200 to 500 feet above sea level. Sloping generally southeasterly, the area drains into the Brazos River, which runs along the eastern border. Other prominent streams include New Year's Creek, East Fork Mill Creek, Doe Run Creek, Wolf Creek, and Yegua Creek,

which forms the county's northern border. Soils along the Brazos River are brownish to reddish, cracking and clayey or loamy; in most of the rest of the county, shallow to deep clayey soils cover a bed of chalk. Subterranean water reservoirs include the Catahoula, Oakville, and Lagarto formations. Washington County, located in the post oak belt, is well timbered, and elms, ashes, hackberries, hickories, pecans, cottonwoods, red cedar, mulberry, and other trees grow in its forests. The county's climate is subtropical and humid, with an average annual precipitation of forty inches. Temperatures range from an average low of 39° F in January to an average high of 96° F in July; the growing season lasts 277 days. The principle mineral resources include oil, natural gas, lignite, brick clay, salt and sulphur. The county is linked to the rest of the state by U.S. Highway 290, which crosses east to west, and by the Burlington Northern Santa Fe Railroad, which runs north-south.

The Blackland Prairies region is named for the deep, fertile black soils that characterize the area. Blackland Prairie soils once supported a tallgrass prairie dominated by tall-growing grasses such as big bluestem, little bluestem, indiangrass, and switchgrass. Because of the fertile soils, much of the original prairie has been plowed to produce food and forage crops. The average annual rainfall ranges from 28 to 40 inches. May is the peak rainfall month for the northern end of the region; however, the south-central part has a fairly uniform rainfall distribution throughout the year. Typically, soils are uniformly dark-colored alkaline clays, often referred to as "black gumbo," interspersed with some gray acidic sandy loams. The landscape is gently rolling to nearly level, and elevations range from 300 to 800 feet above sea level. Crop production and cattle ranching are the primary agricultural industries.

2.0 SUBSURFACE INVESTIGATION

On September 1, 2021, a total of two (2) borings, designated as B-1 and B-2, were drilled at the locations illustrated on the boring plan provided in Appendix I and summarized in Table 2 (Appendix III) below. The borings were drilled to a completion depth of 68.0 feet each below the existing ground surface.

The boring locations were determined and field located by G.A.M.S. personnel. During the field reconnaissance, G.A.M.S. personnel documented the existing site conditions. Ground surface elevations at the boring locations were determined using topographic mapping information provided by the United States Soil and Conservation Services (USSCS). The borings were drilled with a drilling machine, utilizing a hollow stem auger to advance the holes. Standard penetration test (SPT) were performed at 6-inch intervals to a depth of 68.0 feet below the ground surface. Driving resistance is recorded on the boring logs in terms of blows per 6.0-inch interval of the driving distance. The second and third intervals are added to obtain the number of blows per foot (N). SPT blow counts aid in determining soil properties applicable in foundation system design.

3.0 SUBSURFACE PROFILE

Interpreted engineering logs have been prepared based on the field logs, visual interpretation of samples and chart analysis. Classification follows the current USCS specifications. The following is a summary of what was found in the test borings and what is represented on the boring logs.

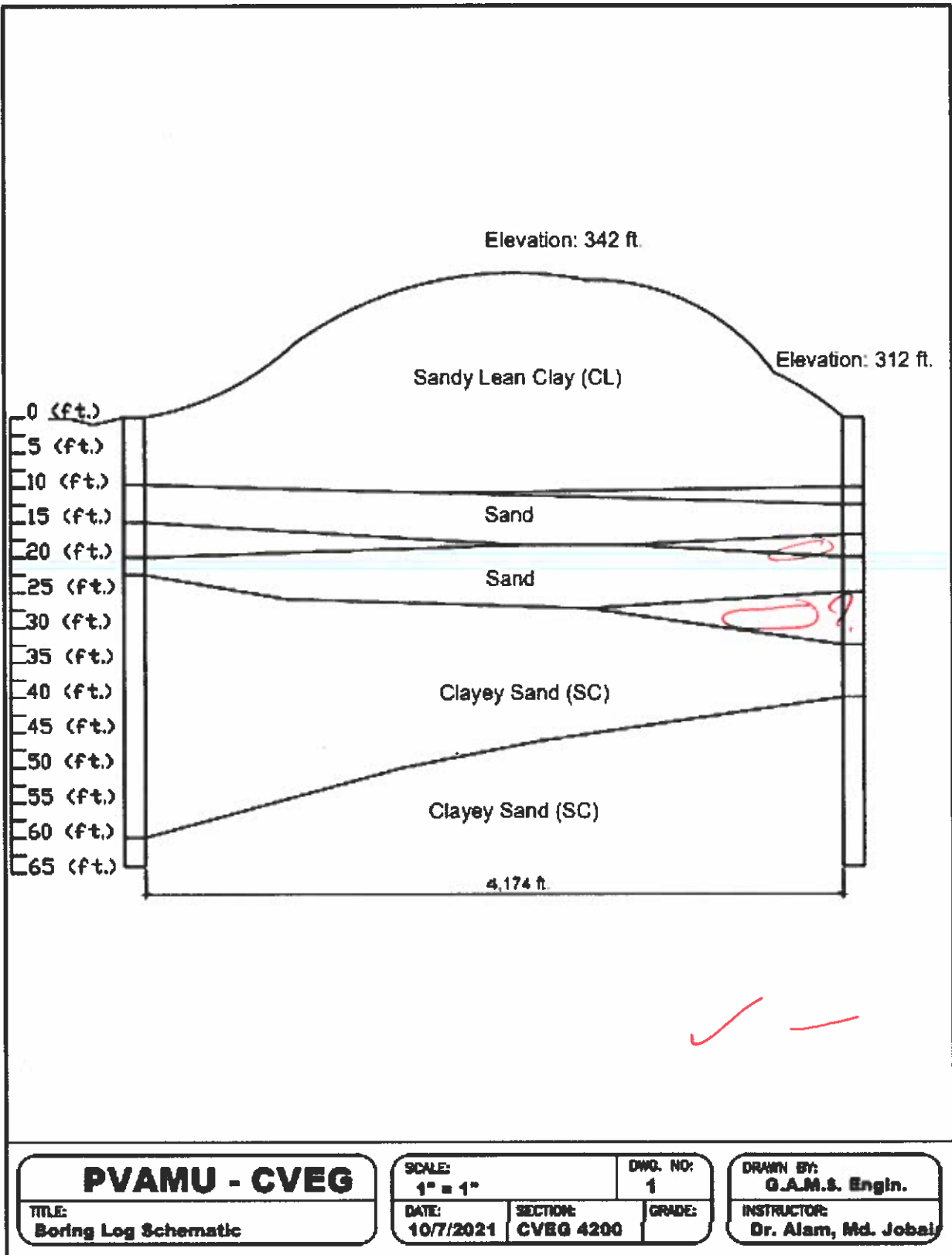
Boring 1										Assume Gravel 0
SPT-Values	Depth (Feet)	LL	PL	Plastic Index, PI	Sieve No. 200	Water Content, %	Plasticity Chart	Coarse Fraction, %	Classification	N
3,3,4	2.5	43	16	27	71	14	CL	29%	Sandy Lean Clay	7
3,5,5	7.5	47	19	28	81	12	CL	19%	Sandy Lean Clay	10
4,8,7	9	-	-	-	20	6	-	80%	Sand	15
3,7,8	15	51	24	27	69	13	CH	31%	Sandy Fat Clay	15
8,10,10	20	-	-	-	16	8	-	84%	Sand	20
9,12,13	30	62	30	32	80	15	CH	20%	Sandy Fat Clay	25
11,18,21	40	62	27	35	79	13	CH	21%	Sandy Fat Clay	31
13,22,31	50	69	28	41	83	17	CH	17%	Sandy Fat Clay	53
17,26,34	60	71	33	38	72	18	CH	28%	Sandy Fat Clay	60
18,39,50	68	69	34	35	79	19	MH	21%	Sandy Elastic Silt	89

Boring 2										
SPT-Values	Depth (Feet)	LL	PL	Plastic Index, PI	Sieve No. 200	Water Content, %	Plasticity Chart	Coarse Fraction, %	Classification	N
4,4,4	2.5	48	20	28	54	13	CL	46	Sandy Lean Clay	8
5,5,5	5	51	32	19	69	14	MH	31	Sandy Elastic Silt	10
6,8,8	10	-	-	-	-	8	-	-	Sand	16
8,8,9	12.5	46	19	27	74	18	CL	26	Sandy Lean Clay	17
8,10,10	17	-	-	-	-	10	-	-	Sand	20
10,12,12	20	32	16	16	54	13	CL	46	Sandy Lean Clay	24
-	25	60	31	29	81	21	MH	19	Sandy Elastic Silt	24
10,12,12	30	72	31	41	82	20	CH	18	Sandy Fat Clay	24
13,26,28	40	68	34	34	62	4	MH	38	Sandy Elastic Silt	54
16,20,22	50	80	39	41	69	18	MH	31	Sandy Elastic Silt	44
14,34,38	60	68	34	34	84	20	MH	16	Sandy Elastic Silt	72
13,48,50	68	-	-	-	-	-	-	-	-	98

Table 2: Soil Classification Summary

3.1 Subsurface Soils

The below CAD drawing displays the layers of the soil types found in the Boring samples . Bedrock was not encountered for this investigation.



PVAMU - CVEG

TITLE:
Boring Log Schematic

SCALE:
1" = 1"

DATE:
10/7/2021

SECTION:
CVEG 4200

DWG. NO:
1

GRADE:

DRAWN BY:
G.A.M.S. Engin.

INSTRUCTOR:
Dr. Alam, Md. Jobal

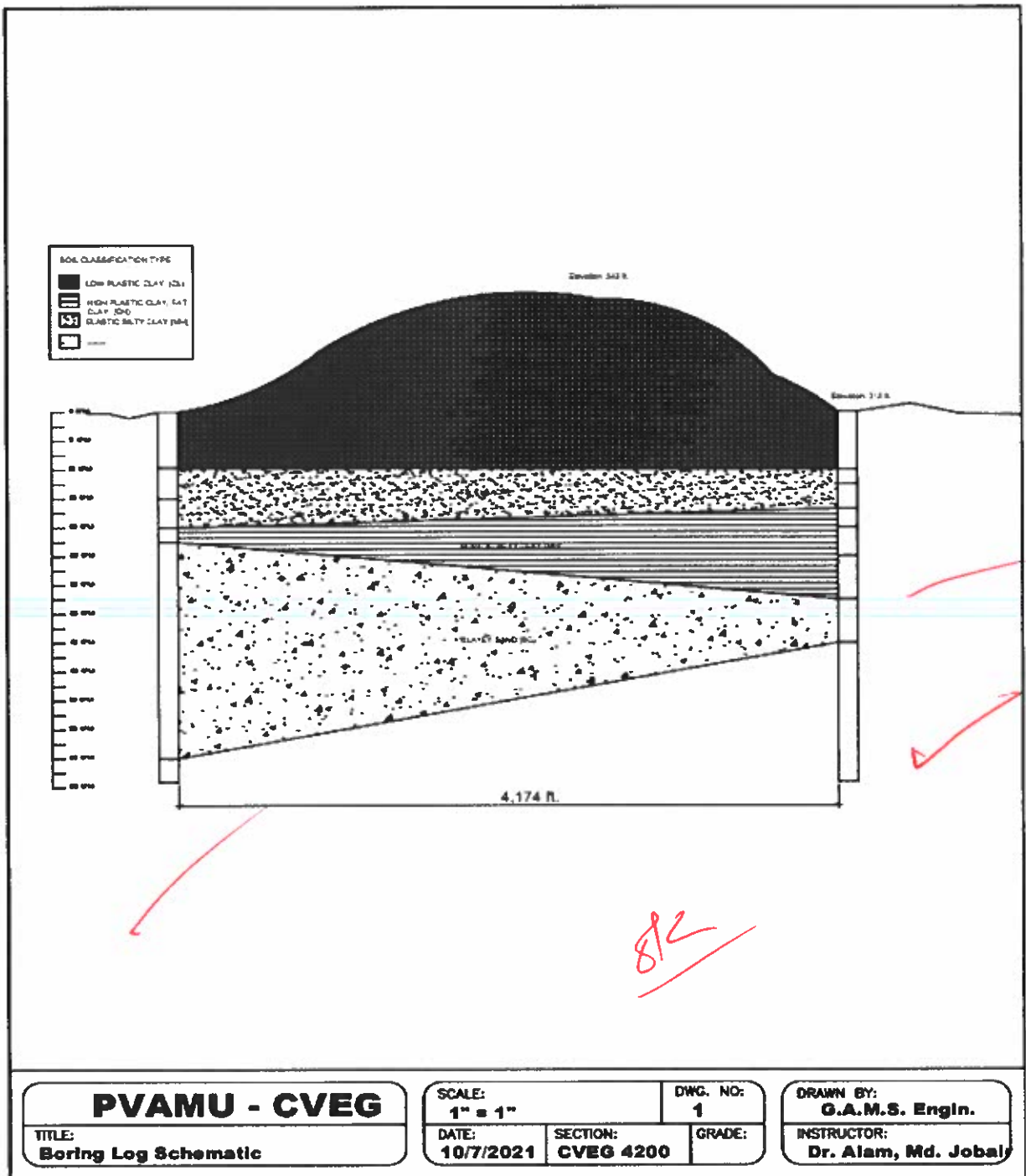


Figure 2. Soil Profile

Note: The Hatch not a clear depiction of the Cad version since not to scale. Some disorientation!

SOIL CLASSIFICATION

TABLE 2.7 AASHTO Soil Classification System

General classification		Granular materials (35% or less of total sample passing No. 200 sieve)					
Group classification	A-1		A-3	A-2			
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7
Sieve analysis (% passing)							
No. 10 sieve	50 max						
No. 40 sieve	30 max	50 max	51 min				
No. 200 sieve	15 max	25 max	10 max	35 max	35 max	35 max	35 max
For fraction passing No. 40 sieve							
Liquid limit (LL)				40 max	41 min	40 max	41 min
Plasticity index (PI)		6 max	Nonplastic	10 max	10 max	11 min	11 min
Usual type of material	Stone fragments, gravel, and sand		Fine sand	Silty or clayey gravel and sand			
Subgrade rating	Excellent to good						

General classification		Silt-clay materials (More than 35% of total sample passing No. 200 sieve)			
Group classification	A-4	A-5	A-6	A-7	
Sieve analysis (% passing)					
No. 10 sieve					
No. 40 sieve					
No. 200 sieve	36 min	36 min	36 min		36 min
For fraction passing No. 40 sieve					
Liquid limit (LL)	40 max	41 min	40 max		41 min
Plasticity index (PI)	10 max	10 max	11 min		11 min
Usual types of material	Mostly silty soil		Mostly clayey soil		
Subgrade rating	Fair to poor				

^aIf $PI \leq LL - 30$, the classification is A-7-5.

^bIf $PI > LL - 30$, the classification is A-7-6.

Table 3: AASHTO Soil Classification

Applying Group index, $GI = (F-35) \times [0.2 + 0.005 \times (LL-40)] + 0.01 \times (F-15) \times (PI-10)$, F IS % OF PASSING #200

3.1 ULTIMATE BEARING CAPACITY SCHEMATIC

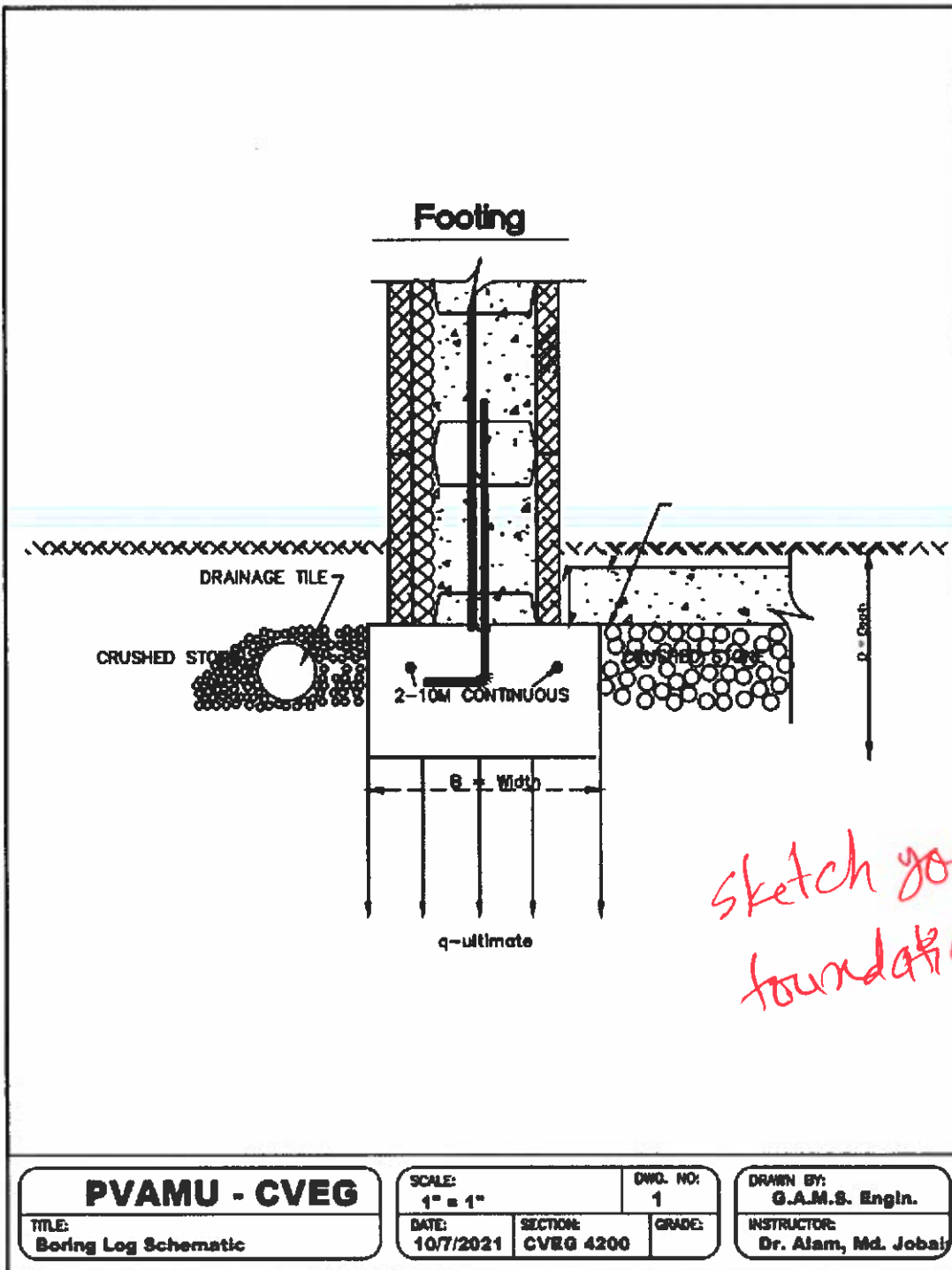
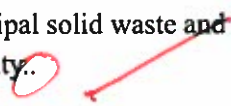


Figure 3. Footing Diagram

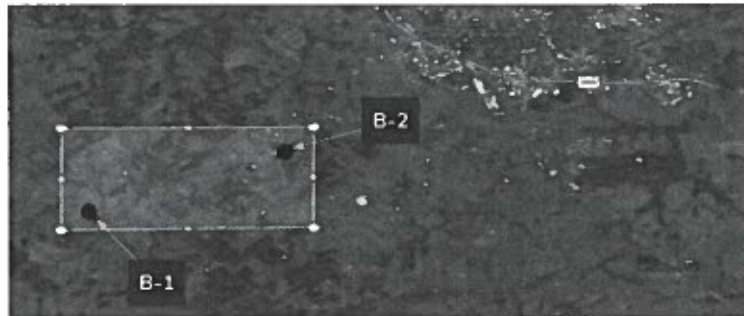
4.0 CONCLUSIONS AND RECOMMENDATIONS

Data obtained from the drilling and testing program have been used to determine foundation, structural systems, and pipe support capabilities for the soil encountered at the site. These parameters have been used to provide guidelines for the design of the foundation systems, as well as the construction of the detention basin, the pipe bedding and general earthwork recommendations. Allowable bearing capacity considers the gross loading, which includes weight of foundation concrete for elements placed below the existing ground and the loading from the superstructure. Based on plan information provided by G.A.M.S. Engineering, it is understood that the proposed Amazon hub site will support the two five-story commercial office building, a steel structure warehouse, a three-story convention center, parking lots, road network development, engineering design of pavement and pavement subgrade, intersections, sidewalks, driveways, and extension of major highways/service road and connecting local road with highway, a storm water ditch connecting a major lake, a municipal solid waste and a temporary recyclables disposal facility, and wastewater treatment process and facility..



APPENDIX I

Boring Locations



Topography Map



APPENDIX II

BORING LOGS

Definitions of Abbreviations

AS = Auger sample

HP = Unconfined compressive strength as determined by a hand penetrometer (tons per square foot)

LOI = Percent organic content (by weight) as determined by ASTM D2974 (loss on ignition test)

PID = Photo-ionization detector reading (parts per million)

QR = Unconfined compressive strength of intact rock core sample as determined by ASTM D2938
(pounds per square inch)

QU = Unconfined compressive strength of soil sample as determined by ASTM D2166 (pounds per square foot)

RC = Rock core sample

REC = Ratio of total length of recovered soil or rock to the total sample length, expressed as a percentage

RQD = Rock quality designation – estimate of the degree of jointing or fracture in a rock mass, expressed as a percentage:

$$\sum \frac{\text{segments equal to or longer than 4.0 inches}}{\text{Core Run Length}} \times 100$$

S = Sulfate content (parts per million)

SPT = Standard penetration test blow counts, per ASTM D1586. Driving resistance recorded in terms of blows per 6-inch interval while letting a 140-pound hammer free fall 30 inches to drive a 2-inch outer diameter (O.D.) split spoon sampler a total of 18 inches. The second and third intervals are added to obtain the number of blows per foot (Nm).

N_{60} = Measured blow counts corrected to an equivalent (60 percent) energy ratio (ER) by the following equation: $N_{60} = N_m * (ER/60)$

SS = Split spoon sample

2S = For instances of no recovery from standard SS interval, a 2.5 inch O.D. split spoon is driven the full length of the standard SS interval plus an additional 6.0 inches to obtain a representative sample. Only the final 6.0 inches of sample is retained. Blow counts from 2S sampling are not correlated with N_{60} values.

3S = Same as 2S, but using a 3.0 inch O.D. split spoon sampler.

TR = Top of rock

USCS = Unified Soil Classification System per ASTM D2487

W = Initial water level measured during drilling

▼ = Water level measured at completion of drilling

Classification Test Data

Gradation (as defined on Description of Soil Terms):

GR = % Gravel

SA = % Sand

SI = % Silt

CL = % Clay

Atterberg Limits:

LL = Liquid limit

PL = Plastic limit

PI = Plasticity Index

WC = Water content (%)

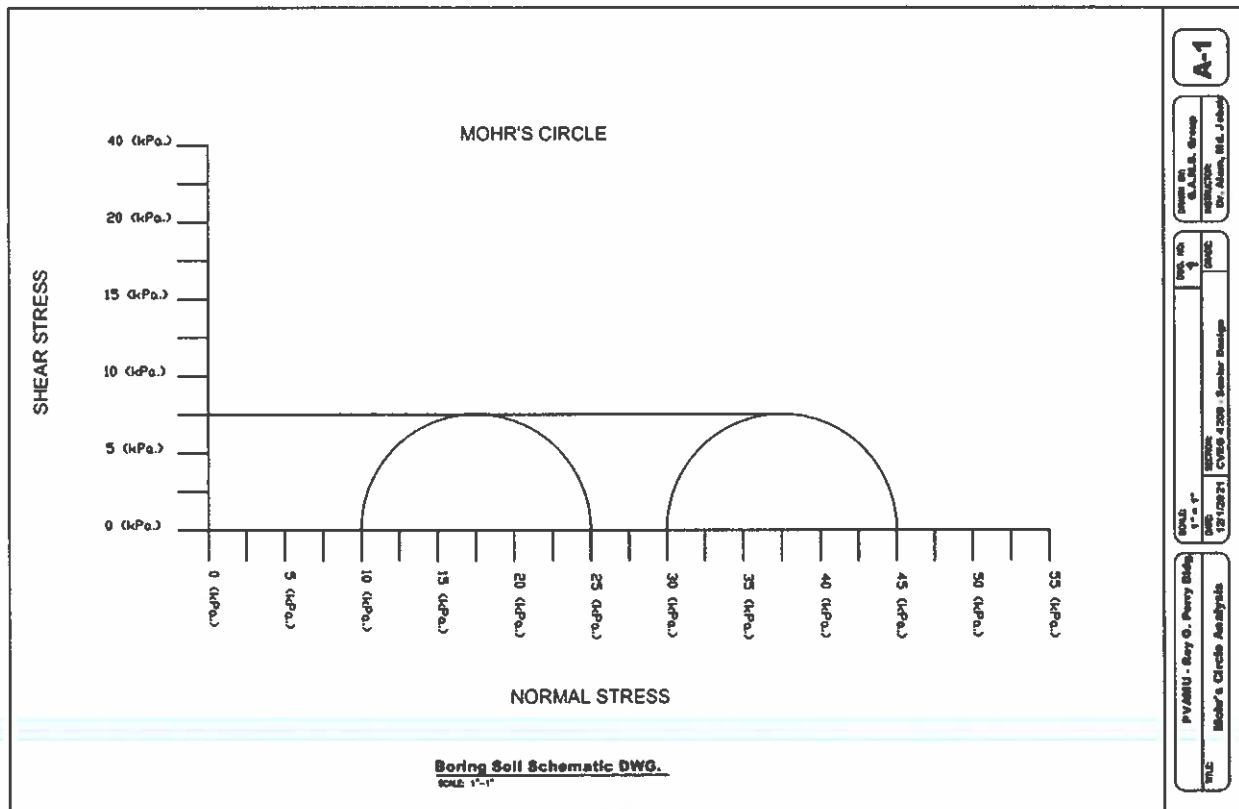


Figure 5. Mohr's Circle - of UU test → cor) from what depth

Determining Bearing Capacity Factors

Step 1:

Test 1: $\sigma_1 = \sigma_3 + \Delta\sigma_d \leftrightarrow \Delta\sigma_d = \sigma_1 - \sigma_3 = 25 \text{ kPa} - 10 \text{ kPa} = 15 \text{ kPa}$

Test 2: $\sigma_1 = \sigma_3 + \Delta\sigma_d \leftrightarrow \Delta\sigma_d = \sigma_1 - \sigma_3 = 45 \text{ kPa} - 30 \text{ kPa} = 15 \text{ kPa}$

Step 2:

$$\tau = c + \sigma_1 \tan(\phi) = 7.5 \text{ kPa} + 25 \text{ kPa} \times \tan(0) = 7.5 \text{ kPa} + 0 = 7.5 \text{ kPa}$$

Thus,

$$\begin{aligned} Q_{ult.} &= \text{Bearing Capacity}(BC) = 1.3 \times c \times N_c + q \times N_q + 0.4 \times \gamma \times B \times N_\gamma \\ &= 1.3 \times 7.5 \text{ kPa} \times 5.14 + q \times 1 + 0.4 \times \gamma \times B \times 0 \text{ (Table 4.2 in Appendix)} \\ &= 1.3 \times 7.5 \text{ kPa} \times 5.14 + q \times 1 \end{aligned}$$

Where, $q = \gamma \times D_f$

The “specific gravity” of soils and soil solids refers to the mass of solids in the soil compared to the mass of water at the same volume. The specific gravity of soil is actually an average of the specific gravity of all included soil particles. In general, the specific gravity tends to fall between 2.65 and 2.80, with coarser soils generally having lower specific gravities than finer soils.

font size is not consistent

A soil’s specific gravity largely depends on the density of the minerals making up the individual soil particles. However, as a general guide, some typical values for specific soil types are as follows:

- The specific gravity of the solid substance of most inorganic soils varies between 2.60 and 2.80.
- Tropical iron-rich laterite, as well as some lateritic soils, usually have a specific gravity of between 2.75 and 3.0 but could be higher.

- Sand particles composed of quartz have a specific gravity ranging from 2.65 to 2.67.
- Inorganic clays generally range from 2.70 to 2.80.
- Soils with large amounts of organic matter or porous particles (such as diatomaceous earth) have specific gravities below 2.60. Some range as low as 2.00.

In solving for the saturated unit clay we apply the below equation taking $w=12\%=0.12$ (at 7.5 feet) where G_s (Specific gravity) = 2.68

Next, we apply the SPT to the dry unit weight relationship to find the Degree of Saturation.

Table 21. Relationship among relative density, penetration resistance, dry unit weight, and angle of internal friction of cohesionless soils (after Duncan and Buchignani, 1976)

Descriptive Relative Density	Relative Density ..	Standard Penetration Resistance N_1 (see Note) *	Static Cone Resistance q_c	Angle of Internal Friction ϕ	Dry Unit Weight
	%	blows/foot	tsf or kgf/cm ²	degrees	KN/m ³
Very Loose	< 15	< 4	< 50	< 30	< 14
Loose	15 - 35	4 - 10	50 - 100	30 - 32	14 - 16
Medium Dense	35 - 65	10 - 30	100 - 150	32 - 35	16 - 18
Dense	65 - 85	30 - 50	150 - 200	35 - 38	18 - 20
Very Dense	85 - 100	> 50	> 200	> 38	> 20

* N_1 = N-value corrected to an effective vertical overburden pressure of 1.0 tsf or 100 kPa

** Freshly deposited, normally consolidated sand

Note: As originally proposed, this correlation used the uncorrected SPT blowcount, N_1 . However, hammers delivering 60% of the theoretical energy have been the most commonly used hammers for SPT tests, and it seems likely that the data on which the correlation was based was obtained primarily from tests with such hammers. It therefore seems logical to use $N_{1,60}$ with this correlation, and it is the recommendation of this report that this be done.

Note: $1 \frac{kN}{ft^3} = 6.366 \frac{lb}{ft^3} \rightarrow 16 \frac{kN}{ft^3} = 101.854 \frac{lb}{ft^3}$

Boring 1						Assume Gravel 0				
SPT-Values	Depth (Feet)	LL	PL	Plastic Index, PI	Sieve No. 200	Water Content, %	Plasticity Chart	Coarse Fraction, %	Classification	N
3,3,4	2.5	43	16	27	71	14	CL	29%	Sandy Lean Clay	7
3,5,5	7.5	47	19	28	81	12	CL	19%	Sandy Lean Clay	10
4,8,7	9	-	-	-	20	6	-	80%	Sand	15
3,7,8	15	51	24	27	69	13	CH	31%	Sandy Fat Clay	15
8,10,10	20	-	-	-	16	8	-	84%	Sand	20
9,12,13	30	62	30	32	80	15	CH	20%	Sandy Fat Clay	25
11,18,21	40	62	27	35	79	13	CH	21%	Sandy Fat Clay	31
13,22,31	50	69	28	41	83	17	CH	17%	Sandy Fat Clay	53
17,26,34	60	71	33	38	72	18	CH	28%	Sandy Fat Clay	60
18,39,50	68	69	34	35	79	19	MH	21%	Sandy Elastic Silt	89

Boring 2						Assume Gravel 0				
SPT-Values	Depth (Feet)	LL	PL	Plastic Index, PI	Sieve No. 200	Water Content, %	Plasticity Chart	Coarse Fraction, %	Classification	N
4,4,4	2.5	48	20	28	54	13	CL	46	Sandy Lean Clay	8
5,5,5	5	51	32	19	69	14	MH	31	Sandy Elastic Silt	10
6,8,8	10	-	-	-	-	8	-	-	Sand	16
8,8,9	12.5	46	19	27	74	18	CL	26	Sandy Lean Clay	17
8,10,10	17	-	-	-	-	10	-	-	Sand	20
10,12,12	20	32	16	16	54	13	CL	46	Sandy Lean Clay	24
-	25	60	31	29	81	21	MH	19	Sandy Elastic Silt	-
10,12,12	30	72	31	41	82	20	CH	18	Sandy Fat Clay	24
13,26,28	40	68	34	34	62	4	MH	38	Sandy Elastic Silt	54
16,20,22	50	80	39	41	69	18	MH	31	Sandy Elastic Silt	44
14,34,38	60	68	34	34	84	20	MH	16	Sandy Elastic Silt	72
13,48,50	68	-	-	-	-	-	-	-	-	98

$$e \times s = G_s \times w \rightarrow e = \frac{G_s \times w}{s} = \frac{2.68 \times 0.12}{1} = 0.3216$$

Therefore, the saturated unit of clay is given by the below where

$$\gamma_w = 62.4 \frac{lb}{ft^3}$$

$$\gamma_{sat} = \frac{G_s \times (1+e)}{1+e} \times \gamma_w = \frac{2.68 + 0.3216}{1 + 0.3216} \times 62.4 \frac{lb}{ft^3} = 141.505 \frac{lb}{ft^3}$$

X too high not possible

Next, we calculate the dry density using the following equation:

$$\gamma_{dry} = \frac{\gamma_{sat}}{w+100} \times 100 \rightarrow \gamma_{sat} = \frac{\gamma_{dry} \times (w+100)}{100} = \frac{101.854 \frac{lb}{ft^3} \times (13+100)}{100} =$$

$$\gamma_{sat} = 115.095 \frac{lb}{ft^3} \quad \text{and} \quad \gamma_{dry} = 101.854 \frac{lb}{ft^3}$$

where:

γ_{dry} = dry unit weight, in pcf of compacted soil

γ_{sat} = wet unit weight, in pcf of compacted soil

w = percentage of moisture in the specimen

Bearing Capacity Equations (INCOMPLETE)

MEYERHOF EQUATION (Bearing Capacity):

Example: 6.1 Find the allowable, $Q_u = ?$

Approach:

$$\tau = c + \sigma_1 \tan(\phi) = 7.5 \text{ kPa} + 25 \text{ kPa} \times \tan(0) = 7.5 \text{ kPa} + 0 = 7.5 \text{ kPa}$$

Thus,

$$\begin{aligned} Q_{ult.} &= \text{Bearing Capacity}(BC) = 1.3 \times c \times N_c + q \times N_q + 0.4 \times \gamma \times B \times N_\gamma \\ &= 1.3 \times 7.5 \text{ kPa} \times 5.14 + q \times 1 + 0.4 \times \gamma \times B \times 0 \\ &= 1.3 \times 7.5 \text{ kPa} \times 5.14 + q \times 1 \end{aligned}$$

From Table 6.2, for $\phi = 0^\circ$, $N_c = 5.14$, $N_q = 1$, $N_\gamma = 0$

Also, Assuming foundation will be positioned at 7 feet.

$$q(\text{pressure}) = \gamma \times D_f = \gamma_{dry} \times D_f = 115.095 \frac{lb}{ft^3} \times 5 \text{ ft.} = 575.475 \frac{lb}{ft^2} = 27.554 \text{ kPa}$$

By simplification and direct substitution we obtain

$$Q_{ult.} = \text{Bearing Capacity}(BC) = 1.3 \times 7.5 \text{ kPa} \times 5.14 + 27.554 \text{ kPa} \times 1 = 77.669 \text{ kPa} = 1622.151 \frac{lb}{ft^2}$$

Next, $Q_{Allowable}$ is given by the below equation with a given Factor of safety at 3

$$Q_{\text{Allowable}} = \frac{Q_{\text{ult}}}{F.S.} = \frac{1622.151 \frac{\text{lb}}{\text{ft}^2}}{3} = 540.717 \frac{\text{lb}}{\text{ft}^2} \quad (Q = \text{Load; } q = \text{pressure } B \leq 485 \text{ good. If larger then increase foundation})$$

In order to Solve for B= ??? (Ny=0,)

We know the load applied, Q = (From ARMANDO GOMEZ) = $400 \frac{\text{lb}}{\text{ft}^2}$ (Should be pounds) and Area (Square) = B^2 . The stress developed at the footing base is given by the below where $S = Q_{\text{Allowable}}$

$$S = \frac{Q}{A} = \frac{400 \frac{\text{lb}}{\text{ft}^2}}{B^2} = \frac{400 \frac{\text{lb}}{\text{ft}^2}}{5^2} = 16 \frac{\text{lb}}{\text{ft}^2}$$

(Footing must be greater than Column size- coordinate with structural engineer. Can play with Df value. If the foundation size is greater than required then we are good.)

MATT FOUNDATION DESIGN

Matt Foundations on saturated Clays ($\phi = 0$) and a vertical loading condition ($=0$) the net ultimate bearing capacity

$$\begin{aligned} q_{\text{ult.}} &= c_u \times N_n \times F_m \times F_{cd} \times q \\ &= 5.14 \times C_u \times \left(1 + \frac{0.195 \times B}{L}\right) \times \left(1 + 0.4 \times \frac{D_f}{B}\right) + q \\ &= 5.14 \times C_u \times \left(1 + \frac{0.195 \times 5}{L}\right) \times \left(1 + 0.4 \times \frac{D_f}{B}\right) + q \end{aligned}$$

$$q_{\text{allowable net}} = \frac{q}{F.S.} = 1.713 \times C_u \times \left(1 + \frac{0.195 \times B}{L}\right) \times \left(1 + 0.4 \times \frac{D_f}{B}\right) + q$$

Or, the load-bearing capacity can be obtained based on Standard Penetration Test (SPT) and may be expressed as:

$$q_{\text{allowable net}} \left(\frac{\text{kip}}{\text{ft}^2} \right) = 0.25 \times N_{60} \left[1 + 0.33 \left(\frac{D_f}{B} \right) \right] [S_e (\text{in.})] \leq 0.33 \times N_{60} [S_e (\text{in.})]$$

<http://site.iugaza.edu.ps/ymadhoun/files/2016/09/Chapter-08.pdf>

SOLUTION: Using Meyerhof's Equation (Table 6.4 and Equation 6.19)

$$q_u = C \times N_c \times F_{cs} \times F_{cd} \times F_{ci} + q \times N_q \times F_{qs} \times F_{qd} \times F_{qi} + \frac{1}{2} \times \gamma \times B \times N_\gamma \times F_{\gamma s} \times F_{\gamma d} \times F_{\gamma i}$$

From Table 6.2, for $\phi = 0^\circ$, $N_c = 5.14$, $N_q = 1$, $N_\gamma = 0$

Also, Assuming foundation will be positioned at 7 feet.

$$q = \gamma \times D_f = \gamma_{dry} \times D_f = 144.332 \frac{lb}{ft^3} \times 7 ft. = 1,010.3245 \frac{lb}{ft^2}$$

Next, go to table 6.3 (equation table)

$$F_{cs} = 1 + \frac{B}{L} \times \frac{N_q}{N_c} = 1$$

$$F_{qs} = 1 + \frac{B}{L} \times \tan \phi = 1 + 0 \times \tan \phi = 1$$

$$F_{\gamma s} = 1 - 0.4 \times \frac{B}{L} = 1 - 0.4 \times 0 = 1$$

Table 6.3

$$\frac{D_f}{B} = \frac{1.5}{2} = 0.75 \leq 1$$

$$F_{qd} = 1 + 2 \times \tan \phi' (1 - \sin \phi')^2 \times \frac{D_f}{B} = 1 + 2 \times \tan 26^\circ (1 - \sin 26^\circ)^2 \times 0.75 = 1.23$$

$$F_{cd} = F_{qd} - \frac{1 - F_{qd}}{N_c \times \tan \phi} = 1.23 - \frac{1 - 1.23}{22.5 \times \tan 26^\circ} = 1.25$$

Since $\beta = 0^\circ$, we assumed $F_{ci} = F_{qi} = F_{\gamma i} = 1$

$$q_u = 931.8 \text{ kN/m}^2 \quad \text{and} \quad q_{allowable} = \frac{q_u}{F.S.} = \frac{931.8}{3} = 310.6 \text{ kN/m}^2$$

Next,

$$Q_{Allowable} = q_{allowable} \times \text{Area} = 310.6 \text{ kN/m}^2 \times 2m = 621 \text{ kN/m}$$

$$e = \frac{E_s}{E_c}$$

SETTLEMENT

Given:

$$\gamma_{sat} = 120 \text{ pcf}$$

$$e_o = 1.1173$$

$$\sigma'_c = 1.1 \text{ tsf} \quad \checkmark$$

$$C_c = 0.478 \quad \checkmark$$

$$C_s = 0.041 \quad \checkmark$$

Find:

$$S_c = ?$$

SOLUTION:

$$OCR = \frac{\sigma'_c}{\sigma'_o} \quad \checkmark$$

$$\sigma'_o = 6 \times 118 + 112(120 - 62.4) + 5(120 - 62.4) = 1,687.2 \text{ psf}$$

$$OCR = \frac{1.1 \times 2,000}{1,687.2} = 1.3 > 1 \text{ (Therefore soil is OC)} \quad \checkmark$$

Next, check if a Case 1 or Case 2

$$\sigma'_o + \Delta\sigma$$

$$X = 2, Y = 2$$

$$m = \frac{x}{2} = \frac{2}{17} = 0.118 \quad \checkmark$$

$$n = \frac{y}{2} = \frac{2}{17} = 0.118 \quad \checkmark$$

$$\Delta\sigma = 4 \times l \times q$$

Where

$$q = \frac{Q}{A} = \frac{14}{4 \times 4} = 0.94 \text{ tsf} = 1880 \text{ psf}$$

$$\Delta\sigma = 4 \times l \times q = 4 \times 0.014 \times 1880 = 105.28 \text{ psf}$$

$$\sigma'_o + \Delta\sigma = 1687.2 + 105.28 = 1792.48 \quad \checkmark$$

$$\sigma'_0 = 1.1 \times 2,000 = 2,200 \text{ psf}$$

CASE 2:

$$\sigma'_0 + \Delta\sigma < \sigma'_c$$

CASE 2:

$$S_c = \frac{c_s \times H}{4 \times 4} \times \log \log \left(\frac{\sigma'_0 + \Delta\sigma}{\sigma'_0} \right) = 0.058 \text{ ft} = 0.69 \text{ inches} < 1$$

Since the parameter is met then the soil is good and we are okay!

SHALLOW FOUNDATION DESIGN

DEEP FOUNDATION DESIGN (pg. 463 Ch. 12 Notes 10/20/2021)

$$\text{Total Capacity, } Q_u = Q_p + Q_s$$

Where

$$Q_p = \text{Tip Resistance/End Bearing} = A_p \times N_c \times C_u = 9 \times C_u \times A_p =$$

$$= 9 \times 7.5 \text{ kPa} \times (\text{Base} \times \text{Width})$$

$$= 9 \times 156.6407570477925 \text{ psf} \times (\text{Base} \times \text{Width})$$

$$= 9 \times 156.6407570477925 \text{ psf} \times (\text{Base} \times \text{Width})$$

$$Q_s = f \times P \times \Delta L = \alpha \times (2 \times \text{Base} + 2 \times \text{width}) \times L =$$

$$= f \times P \times \Delta L = \alpha \times C_u \times (2 \times \text{Base} + 2 \times \text{width}) \times L =$$

Note: 1 kilopascal = 20.88543423315 pounds per square foot

$$\gamma_1 - 0.4 \times \frac{B}{L} = 1 - 0.4 \times 0 = 1 \rightarrow \rightarrow$$

CAPACITY CURVES

need revision

Table 1a: Boring 1 Analysis for Circular Pile

Depth (ft)	Qp (lb)	Qs (lb)	Qu (lb)
0	0	0	0
2.5	6361.725204	2544.690082	8906.415286
7.5	9542.587807	12087.27789	21629.86569
9	0	12087.27789	12087.27789
15	14137.16712	35177.98419	49315.15131
20	0	35177.98419	35177.98419
30	24033.18411	96062.05059	120095.2347
40	36756.63451	207148.7682	243905.4027
50	49480.08492	394073.5335	443553.6184
60	56548.66848	650427.4973	706976.1658
68	74220.12738	1031754.018	1105974.146

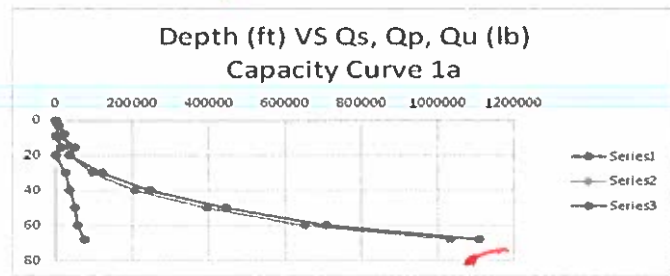
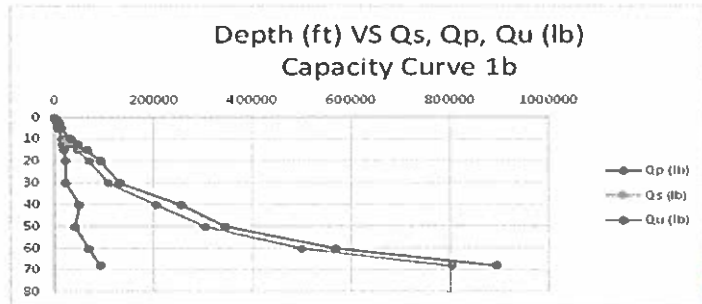


Table 1b: Boring 1 Analysis for Square Section Pile

Depth (ft)	Qp (lb)	Qs (lb)	Qu (lb)
0	0	0	0
2.5	7068.58356	1675	8743.58356
5	9083.129875	5594.25	14677.37988
10	15197.45465	15914.25	31111.70465
12.5	16081.0276	29279.875	45360.9026
15	18873.11811	45700.375	64573.49311
20	22619.46739	70660.375	93279.84239
30	22619.46739	108100.375	130719.8424
40	50186.94328	204660.375	254847.3183
50	40997.78465	303260.375	344258.1597
60	67858.40218	499100.375	566958.7772
68	92598.44464	801972.375	894570.8196



distorted table. put figures in different pages.

Table 2a. Boring 1 Analysis for Circular Pile

Depth (ft)	Qp (lb)	Qs (lb)	Qu (lb)
0	0	0	0
2.5	7,069	1675	8,743.58
5	9,083	5594.25	14,677.38
10	15,197	15,914.25	31,112
12.5	16,081	29,279.88	45,360.90
15	18,873	45,700.38	64,573.49
20	22,619.47	70,660.38	93,279.84
30	22619.46739	108100.375	130719.8424
40	50,187	204660.375	254,847.32
50	40,998	303260.375	344,258.16
60	67,858	499100.375	566,958.78
68	92598.44464	801972.375	894570.8196

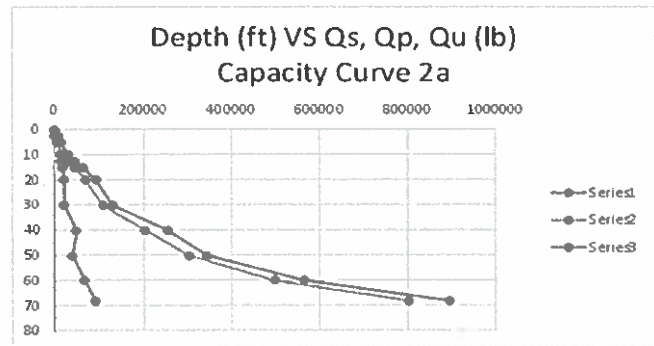
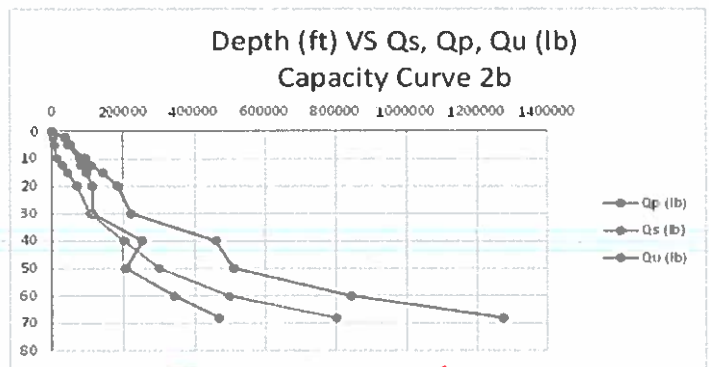


Table 2b. Boring 1 Analysis for Square Section Pile

Depth (ft)	Qp (lb)	Qs (lb)	Qu (lb)
0	0	0	0
2.5	36,000	1675	37,675.00
5	46,260	5594.25	51,854.25
10	77,400	15,914.25	93,314
12.5	81,900	29,279.88	111,179.88
15	96,120	45,700.38	141,820.38
20	115,200.00	70,660.38	185,860.38
30	115200	108100.375	223300.375
40	255,600	204660.375	460,260.38
50	208,800	303260.375	512,060.38
60	345,600	499100.375	844,700.38
68	471,600	801972.375	1,273,572.38



capacity curve
need revision

GEOTECHNICAL APPENDIX

APPENDIX III

BORING LOG DATA



CVEG 4200 Sr. Design and Professionalism										FIELD BORING LOG																																																																																																																																																																																																																																																																																																																											
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PROJECT: Business Center for Amazon					LOCATION: <u>South Texas</u>					DATE STARTED: _____																																																																																																																																																																																																																																																																																																																											
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DRILL LOG: <u>CME 75</u>					TEST HOLE DIAMETER (IN): <u>8"</u>					GROUND WATER DATA:																																																																																																																																																																																																																																																																																																																											
DRILLING METHOD: <u>Hollow Stem</u>					TOTAL DEPTH (ft): <u>70'</u>					DATE: <u>8/26/11</u>																																																																																																																																																																																																																																																																																																																											
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CVEG 4200 Sr. Design and Professionalism										FIELD BORING LOG					
PROJECT ID: CVEG 4200					TEST HOLE #2					SHEET NUMBER 1 of 1					
PROJECT: Business Center for Amazon					LOCATION: South Texas					DATE STARTED					
CLIENT: AMAZON					CLIENT: AMAZON					DATE FINISHED					
					CONTACT: Dr. Alan					DRILLER					
										LOGGER					
										REVIEWED BY					
DRILL RIG: CME-75					TEST HOLE DIAMETER (in): 8"					GROUND WATER DATA:					
DRILLING METHOD: HSA					TOTAL DEPTH (ft): 70'					DATE: 8/26					
										TIME: 7:5					
										WATER DEPTH (ft):					
										REMARKS:					
DEPTH (FEET)	SAMPLE	STANDARD PENETRATION			T-DOOT CONE				RECOVERY (%)	R.O.D. (ft)	HAND PEN	SOIL DESCRIPTION			
		4"	8"	12"	Tip	Sleeve	Friction	1"				2"	3"	4"	
5	4	4	4	4								48	20	59	13
10	5	6	5	5								67	32	69	14%
15	6	8	5	5											8%
15-15.5	8	8	9									46	31	74	18%
20	10	12	12												10%
25	10	12	12									32	16	59	13%
30	10	12	12									60	31	81%	21%
35	10	12	12									71	31	82%	20%
40	13	24	28									68	39	62%	4%
45	16	20	22									80	39	69%	18%
50	14	31	36									68	34	84%	20%
60	13	24	28												
65	13	24	28												
70															
75															
80															
85															
90															
95															
100															

Boring Log Classification

Boring 1					Assume Gravel 0					
SPT-Values	Depth (Feet)	LL	PL	Plastic Index, PI	Sieve No. 200	Water Content, %	Plasticity Chart	Coarse Fraction, %	Classification	N
8,3,4	2.5	43	16	27	71	14	CL	29%	Sandy Lean Clay	7
8,5,5	7.5	47	19	28	81	12	CL	19%	Sandy Lean Clay	10
4,8,7	9	-	-	-	20	6	-	80%	Sand	15
3,7,8	15	51	24	27	69	13	CH	31%	Sandy Fat Clay	15
8,10,10	20	-	-	-	16	8	-	84%	Sand	20
9,12,13	30	62	30	32	80	15	CH	20%	Sandy Fat Clay	25
11,18,21	40	62	27	35	79	13	CH	21%	Sandy Fat Clay	31
13,22,31	50	69	28	41	83	17	CH	17%	Sandy Fat Clay	53
17,26,34	60	71	33	38	72	18	CH	28%	Sandy Fat Clay	60
18,39,50	68	69	34	35	79	19	MH	21%	Sandy Elastic Silt	89

Boring 2										
SPT-Values	Depth (Feet)	LL	PL	Plastic Index, PI	Sieve No. 200	Water Content, %	Plasticity Chart	Coarse Fraction, %	Classification	N
4,4,4	2.5	48	20	28	54	13	CL	46	Sandy Lean Clay	8
5,5,5	5	51	32	19	69	14	MH	31	Sandy Elastic Silt	10
6,8,8	10	-	-	-	-	8	-	-	Sand	16
8,8,9	12.5	46	19	27	74	18	CL	26	Sandy Lean Clay	17
8,10,10	17	-	-	-	-	10	-	-	Sand	20
10,12,12	20	32	16	16	54	13	CL	46	Sandy Lean Clay	24
-	25	60	31	29	81	21	MH	19	Sandy Elastic Silt	-
10,12,12	30	72	31	41	82	20	CH	18	Sandy Fat Clay	24
13,26,28	40	68	34	34	62	4	MH	38	Sandy Elastic Silt	54
16,20,22	50	80	39	41	69	18	MH	31	Sandy Elastic Silt	44
14,34,38	60	68	34	34	84	20	MH	16	Sandy Elastic Silt	72
13,48,50	68	-	-	-	-	-	-	-	-	98

Table No?
Title.

TABLE 2.3 Relationships for γ , γ_d , and γ_{sat}

Unit weight relationship	Dry unit weight	Saturated unit weight
$\gamma = \frac{(1+w)G_s\gamma_w}{1+e}$	$\gamma_d = \frac{\gamma}{1+w}$	$\gamma_{sat} = \frac{(G_s+e)\gamma_w}{1+e}$
$\gamma = \frac{(G_s+Se)\gamma_w}{1+e}$	$\gamma_d = \frac{G_s\gamma_w}{1+e}$	$\gamma_{sat} = [(1-n)G_s+n]\gamma_w$
$\gamma = \frac{(1+w)G_s\gamma_w}{1+\frac{wG_s}{S}}$	$\gamma_d = G_s\gamma_w(1-n)$	$\gamma_{sat} = \left(\frac{1+w}{1+wG_s}\right)G_s\gamma_w$
$\gamma = G_s\gamma_w(1-n)(1+w)$	$\gamma_d = \frac{G_s}{1+\frac{wG_s}{S}}\gamma_w$	$\gamma_{sat} = \left(\frac{e}{w}\right)\left(\frac{1+w}{1+e}\right)\gamma_w$
	$\gamma_d = \frac{eS\gamma_w}{(1+e)w}$	$\gamma_{sat} = \gamma_d + n\gamma_w$
	$\gamma_d = \gamma_{sat} - n\gamma_w$	$\gamma_{sat} = \gamma_d + \left(\frac{e}{1+e}\right)\gamma_w$
	$\gamma_d = \gamma_{sat} - \left(\frac{e}{1+e}\right)\gamma_w$	

TABLE 2.4 Specific Gravities of Some Soil

Type of soil	G_s
Quartz sand	2.64–2.66
Silt	2.67–2.73
Clay	2.70–2.90
Chalk	2.60–2.75
Loess	2.65–2.73
Peat	1.30–1.90
Mine tailings	2.80–4.50

these things go to
appendix

Table 4.2 Bearing Capacity Factors

ϕ'	N_c	N_q	N_γ	ϕ'	N_c	N_q	N_γ
0	5.14	1.00	0.00	16	11.63	4.34	3.06
1	5.38	1.09	0.07	17	12.34	4.77	3.53
2	5.63	1.20	0.15	18	13.10	5.26	4.07
3	5.90	1.31	0.24	19	13.93	5.80	4.68
4	6.19	1.43	0.34	20	14.83	6.40	5.39
5	6.49	1.57	0.45	21	15.82	7.07	6.20
6	6.81	1.72	0.57	22	16.88	7.82	7.13
7	7.16	1.88	0.71	23	18.05	8.66	8.20
8	7.53	2.06	0.86	24	19.32	9.60	9.44
9	7.92	2.25	1.03	25	20.72	10.66	10.88
10	8.35	2.47	1.22	26	22.25	11.85	12.54
11	8.80	2.71	1.44	27	23.94	13.20	14.47
12	9.28	2.97	1.69	28	25.80	14.72	16.72
13	9.81	3.26	1.97	29	27.86	16.44	19.34
14	10.37	3.59	2.29	30	30.14	18.40	22.40
15	10.98	3.94	2.65	31	32.67	20.63	25.99

(continued)

Table 4: Bearing Capacity Factors

Structural Engineering

Introduction

The structural design is part of phase B of the project. The Amazon Hub in Washington County encompasses the structural design of two five-story commercial office buildings, a single-story steel Amazon warehouse, and a three-story convention center building. The Amazon distribution center will be a single story warehouse with a total gross area of one million square feet. Its design requirements are that of a single story with a steel frame. One of the five-story commercial buildings will be utilized as office space for Amazon. The second five-story building is to be designed as an IT Hub. The last building will be a convention center and will be three stories steel structure design.

Building Geometry and Utilization

The initial step taken in the structural design process is to have a good understanding of what the structure is to be utilized and its geometric design. The Amazon warehouse is to be the central hub for distribution. Is to be rectangular to be able to accommodate large space for storage that will be utilized as a distribution center. The length of the building is to be 2000ft lby 500ft for a total of 1M square feet facility. The floor layout then would require large open spacing for use storage and for equipment machinery to move around freely. Minimizing then the amount of columns supporting the structure would utilize the floor layout to its fullest potential and storage space. As standard storage racks are 48in in depth. The average height of the racks are 20-28ft. The rack heights need to be taken into account as to have plenty of ceiling space for the rack heights for storing the packages that would later be transported to their final destination.

The Amazon five-story buildings for the IT hub and office space have a different set of requirements that would need to be taken into account in its design. The buildings are to twins of each other as they will both be identail in design of each other. Its rectangular design is to

provide ample work space. The dimensions are to be 300ft by 200ft for a total of 60,000ft² per floor having a total floor space of 300,000ft² per building. Utilizing spacing between the columns for optimal office and IT space.

The convention center design will be required to follow standards for its design. As this building will be a mixed use facility and would need to adhere to them. The building will be that of a three-story building with the dimension of 500ft by 300ft for a total of 150,000ft² per floor and a building total of 450,000ft². This building will also utilize columns optimal spacing to achieve the most spacing for the convention center to utilize for occupancy and accommodate large open spaces for convention center events

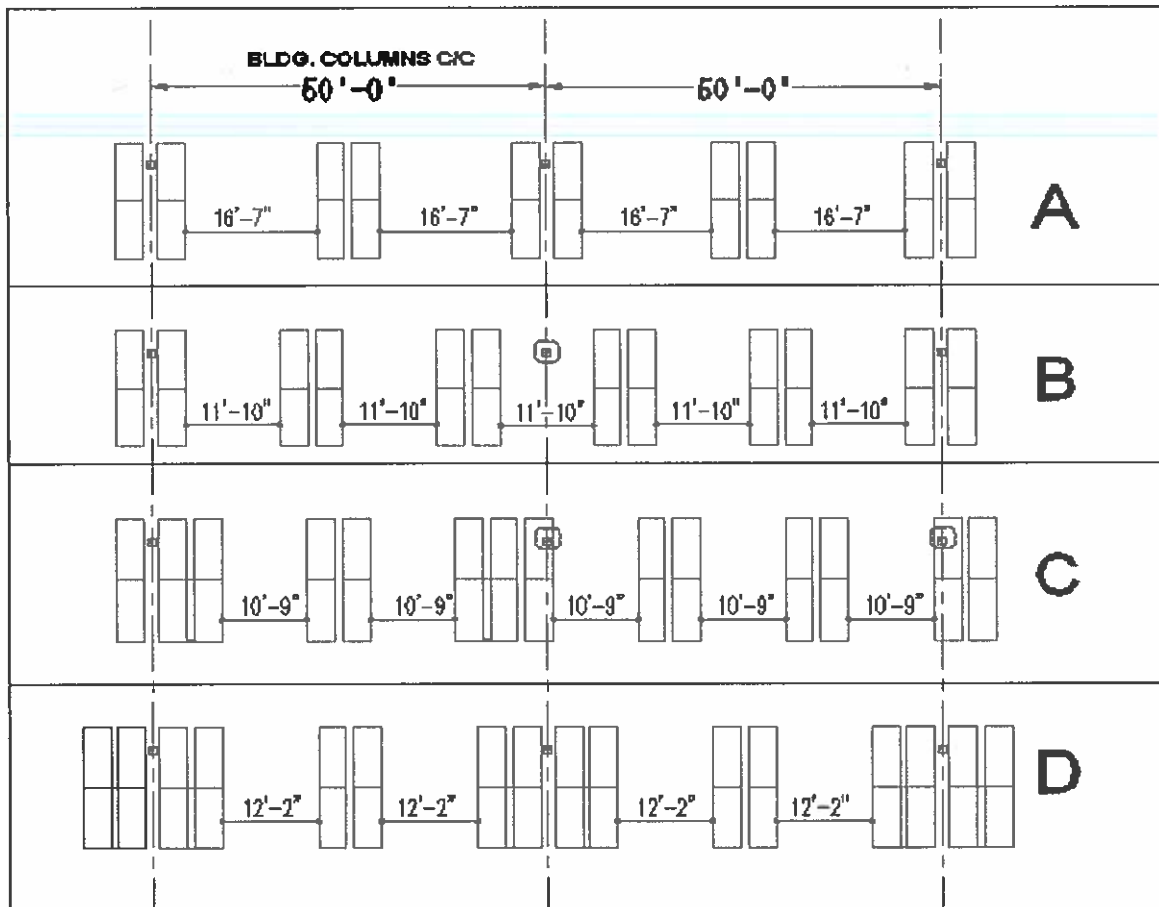


Figure 01: 50ft Column Spacing to maximize storage bays

Loading and standards

It is important when designing the building that all loads are considered so the building can withstand them. The loads that are applied are broken down into dead loads, live loads, and environmental loads (wind loads, snow loads, etc.). This is an important part of the design phase as to be able to anticipate the loads the structures would endure. Depending on the building use different sets of guidelines would be followed in order to accommodate its use as the environmental loads depending on its location. As in some areas are more prone to different weather patterns that need to be taken into consideration during the design stage.

Dead loads

Dead Loads consist of the permanent loads that are affixed to the structure itself. These include the self-weight of the structure, architectural features, fixed service equipment such as heating and air-conditioning systems, sprinkler systems, and utility services. (Williams).

Live loads Live loads are defined in ASCE 7 Sec. 4.1 as loading on a floor produced by the occupancy or use of the building that does not include construction loads, dead loads, or environmental loads. (Williams)

Wind Loads

Wind loads are loads that impact the exterior of the building produced by the wind. The wind exerts forces that can tear roofs from buildings. The building's roof overhang can have air build up a force and cause an uplift. There are three types of wind forces: uplift load, shear load and lateral load.

Load and Resistance Factor design (LRFD)

For the design of the buildings the use of the LRFD will be used to provide the load calculation of the buildings.

Load Types

Loads used in design load equations are given letters by type:

D = dead load

L = live load

L_r = live roof load

W = wind load

S = snow load

E = earthquake load

R = rainwater load or ice water load

T = effect of material & temperature

H = hydraulic loads from soil

F = hydraulic loads from fluids

ASCE-7 (2010) combinations of factored nominal loads:

1. $1.4D$
2. $1.2D + 1.6L + 0.5(L, \text{ or } S \text{ or } R)$
3. $1.2D + 1.6(L, \text{ or } S \text{ or } R) + (L \text{ or } 0.5W)$
4. $1.2D + 1.0W + L + 0.5(L, \text{ or } S \text{ or } R)$
5. $1.2D + 1.0E + L + 0.2S$
6. $0.9D + 1.0W$
7. $0.9D + 1.0E$

When *F* loads are present, they shall be included with the same load factor as dead load *D* in 1 through 5 and 7.

When *H* loads are present, they shall have a load factor of 1.6 when adding to load effect, or 0.9 when resisting the load when permanent.

Figure 01: ASCE-7 Combination of factored nominal loads

Occupancy or Use		Uniform (psf)	Concentrated (lbs)
Access Floor Systems	Office Use	50	2000
	Computer Use	100	2000
Roof	Roof Area not intended for occupancy	20	---
	Roof area used for other occupancy	Same as occupancy served	---
	Primary Roof Members Exposed to a work floor		

Roof	Single panel point of lower chord of roof trusses of any point along primary structural member supporting roofs over manufacturing, storage warehouse, and repair garages	---	2000
	All other Primary Roof Members	---	300
Storage Warehouse (Shall be designed for heavier loads if required for anticipated storage)	Heavy	250	---
	Light	150	---

Figure 03: Table 1607.1 Minimum Uniformly Distributed Live Loads

Building Layout

The building's floor plan was critical in the design process of the building. This is dependent on the use of each individual building. Designation of beam sizes and types is subject to change once it has been run through STAAD Pro its output.

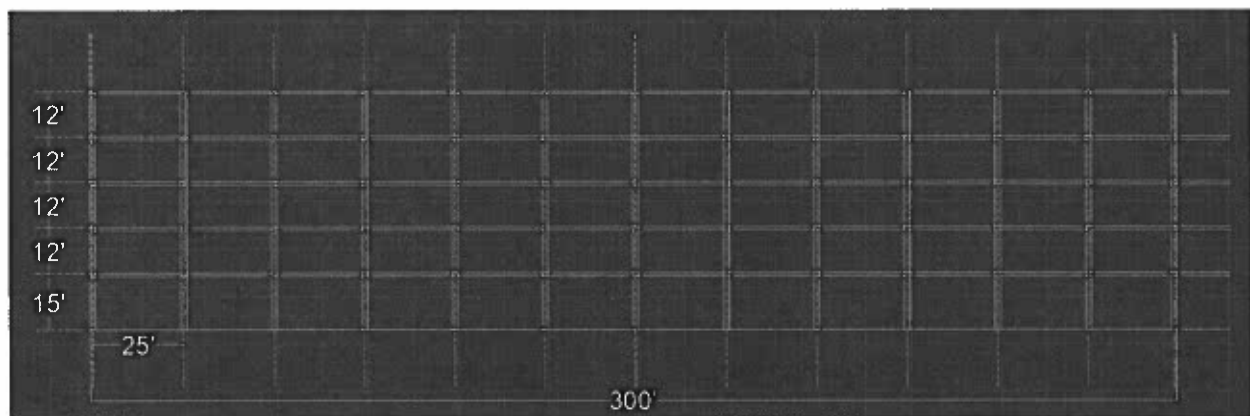


Figure 04: IT Hub and office space building side view

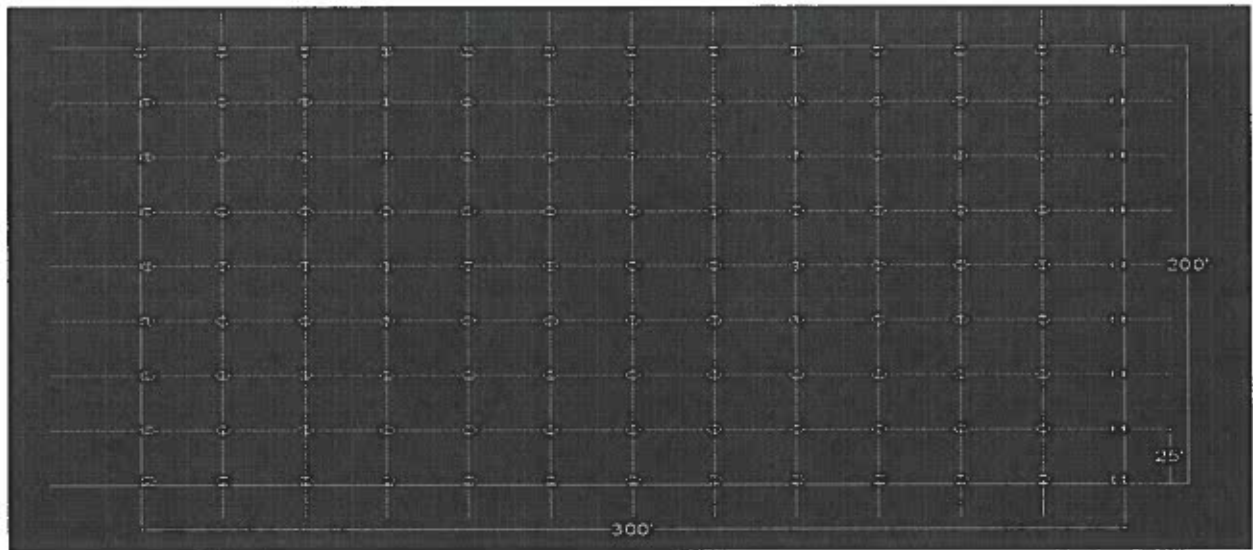


Figure 05: IT Hub and office space building top view of a typical floor

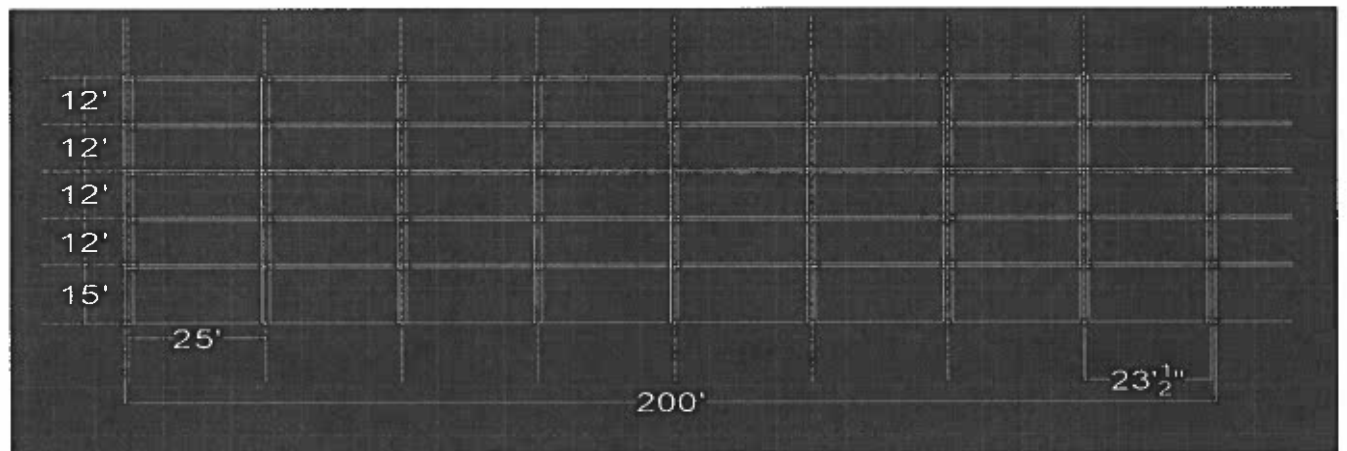


Figure 06: IT Hub and office space building view of front of building

check with structural faculty.

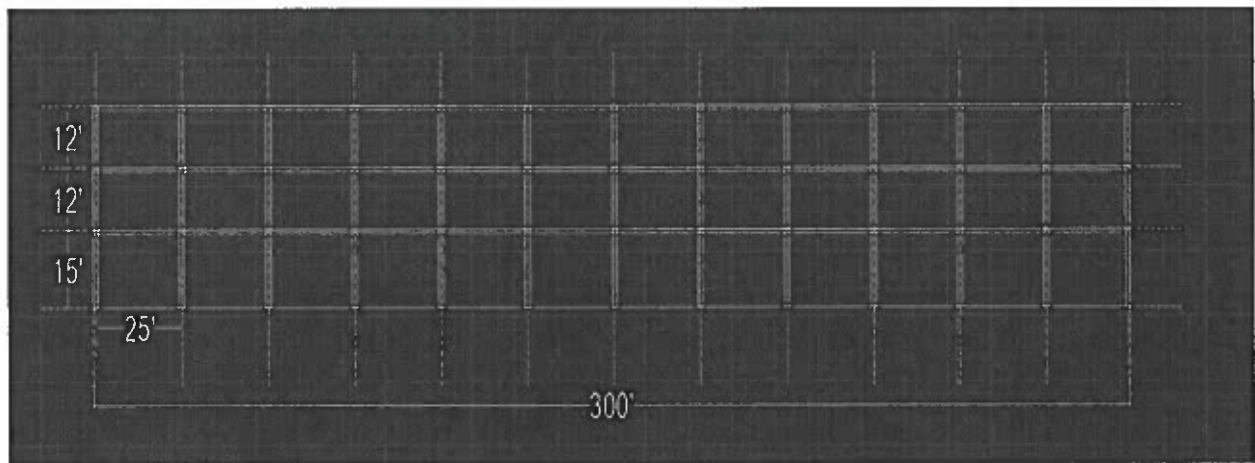


Figure 07: Convention Center front view of the building

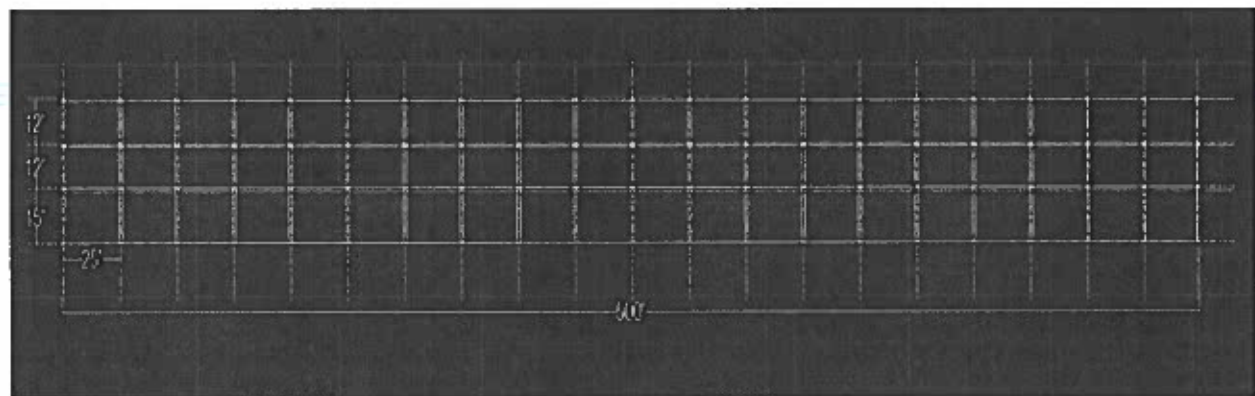


Figure 08: Convention Center side view of building

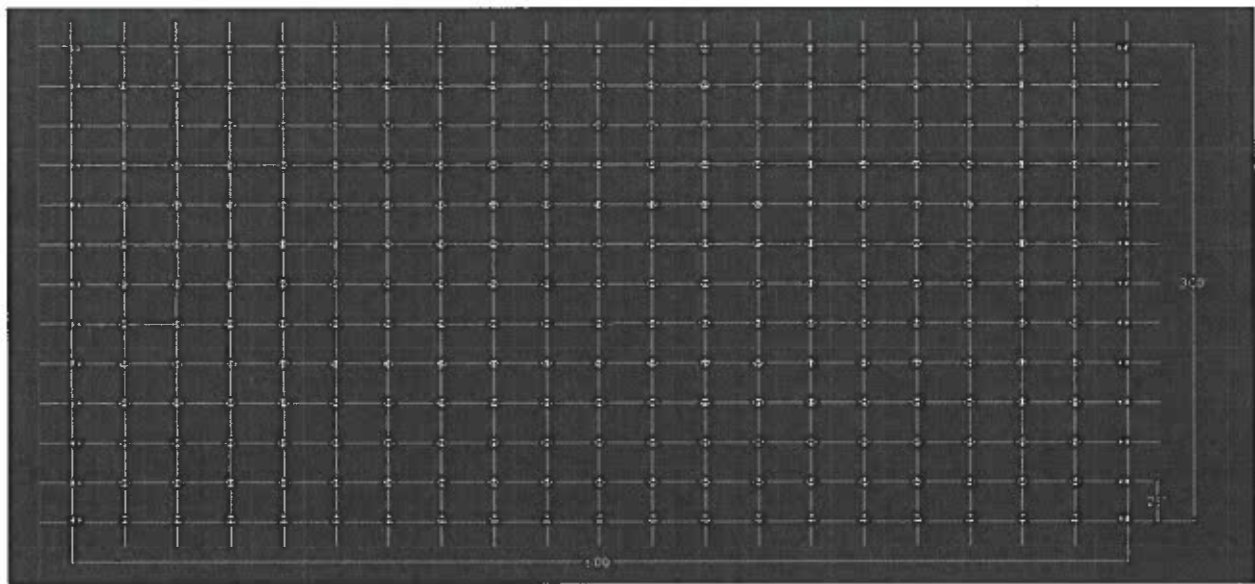


Figure 08: Convention Center top view of a typical floor

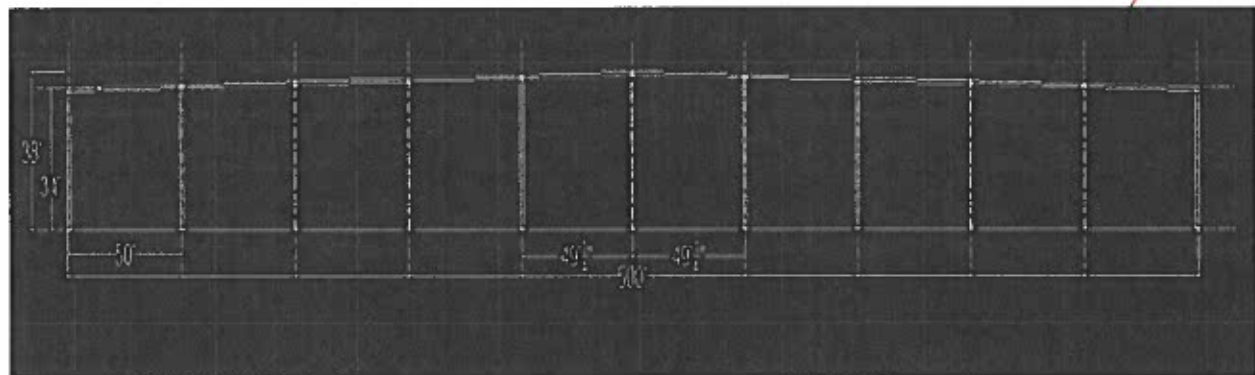


Figure 09: Amazon warehouse front view

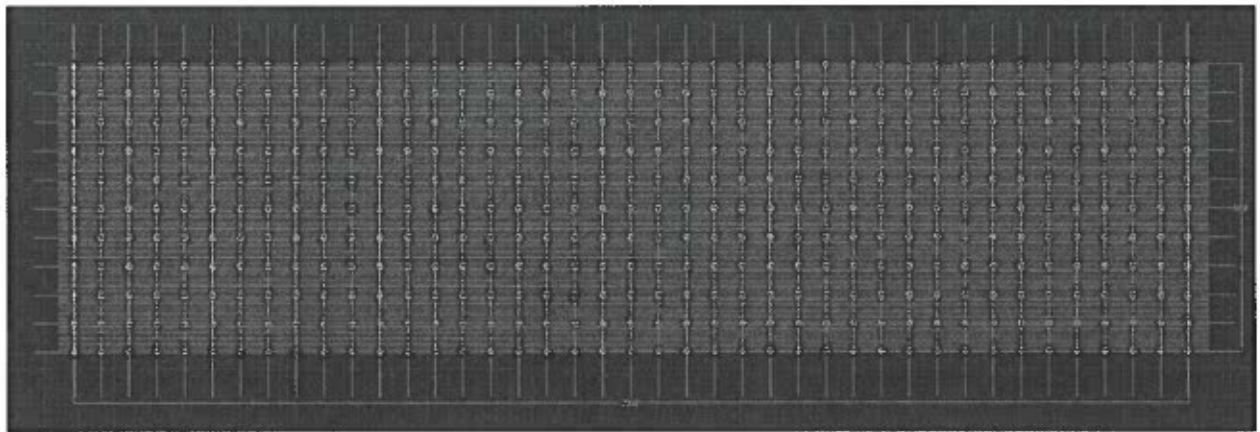


Figure 10: Amazon warehouse top view

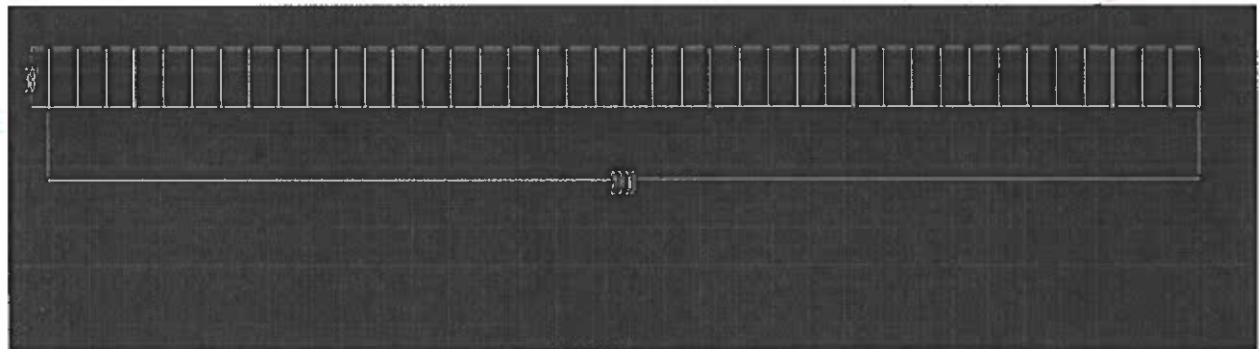


Figure 11: Amazon Warehouse side view of building

Joist Beam

The design of the joist is to provide additional lateral support of the roof load and any additional equipment that will be suspended on the ceiling. The joist will run perpendicular to beams that are spaced 50ft apart. They will run parallel to the long side of the warehouse denoted by Figure 04 joist evenly spaced 5ft from beam to joist center. Using the roof live load given to calculate the beam size to be used. The dead load would be the weight of the beam would be given in lb/ft on Table 1.1 from the Steel Manual on Figure 04 & 05.

When

W = Weight

DL = 15 lb/ft (W8x15)

LL_R = 2000 lbs => (2000 lbs) / (50ft) = 40lbs/ft => (40lbs/ft) / (5ft) = 8psf

$$W = D_L + L_L$$

$$W = 15\text{lbs/ft} + 40\text{ lbs/ft}$$

$$W = 55\text{ lbs/ft}$$

Now we will need to calculate the maximum shear and bending moment to see if the beam chosen would work for this application. Using Table 3-23 from Figure 06 from the steel manual.

When

$$V_{\text{Max}} = WL/2$$

$$V_{\text{Max}} = (55\text{ lbs/ft} * 50\text{ft}) / 2$$

$$V_{\text{Max}} = 1,375\text{ lbs/ft} => 1.38\text{ kip/ft}$$

$$M_{\text{Max}} = WL^2 / 8$$

$$M_{\text{Max}} = (55\text{lb/ft} * 50^2\text{ft}) / 8$$

$$M_{\text{Max}} = 17,187.5\text{ lbs} * \text{ft} => 17.19\text{ kips*ft}$$

Check Answers:

$$V_{\text{Max}} < \phi_V V_{nx}$$

1.38 kips < 59.6 Shear is Okay

$$M_{\text{Max}} < \phi_b M_n$$

17.19 kips*ft < 21.5 kips*ft Bending Moment is Okay

The results of the moment and shear provide that the beam for the joist would work to support the roof structure of the warehouse. All the following calculations will be done through Staad Pro as there is the number of calculations that would be provided through the report.

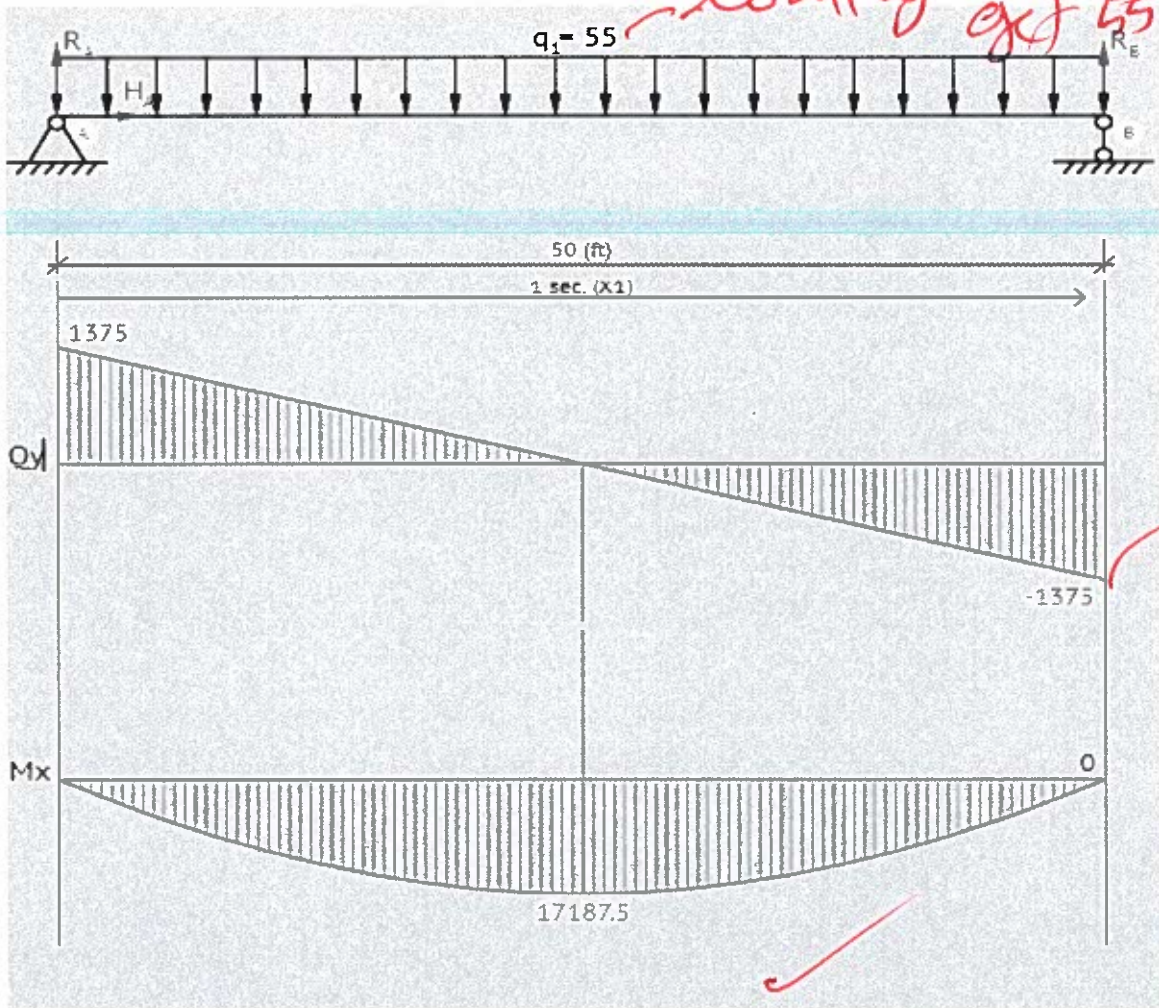


Figure 12: Shear and bending moment of joist

Table 1-1 (continued)
W-Shapes
Dimensions

Shape	Area, A	Depth, d	Web		Flange		Distances					Work- able Gage			
			Thickness, t _w	$\frac{L}{2}$	Width, b _f	Thickness, t _f	k		k ₁	T					
							k _{des}	k _{net}							
	in. ²	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.				
WB-67	19.7	9.00	9	0.570	8 1/4	5/16	8.28	8 1/4	0.935	1 1/8	1.33	1 1/8	15/16	5 3/4	5 1/2
x58	17.1	8.75	8 3/4	0.510	1/2	1/4	8.22	8 1/4	0.810	1 1/8	1.20	1 1/2	7/8	↓	↓
x48	14.1	8.50	8 1/2	0.400	3/8	3/16	8.11	8 1/8	0.685	1 1/8	1.08	1 3/8	13/16	↓	↓
x40	11.7	8.25	8 1/4	0.360	3/8	3/16	8.07	8 1/8	0.590	1 1/8	0.954	1 1/4	13/16	↓	↓
x35	10.3	8.12	8 1/8	0.310	5/16	3/16	8.02	8	0.495	1/2	0.889	1 1/8	13/16	↓	↓
x31 ¹	9.13	8.00	8	0.285	5/16	3/16	8.00	8	0.435	7/16	0.829	1 1/4	1 1/4	↓	↓
WB-28	8.25	8.08	8	0.285	5/16	3/16	6.54	6 1/2	0.465	7/16	0.859	1 5/16	5/8	6 1/4	4
x24	7.08	7.83	7 7/8	0.245	1/2	1/8	6.50	6 1/2	0.400	3/8	0.794	7/8	9/16	6 1/4	4
WB-21	6.16	8.28	8 1/4	0.250	1/4	1/8	5.27	5 1/4	0.400	3/8	0.700	7/8	9/16	6 1/2	2 3/4
x18	5.26	8.14	8 1/8	0.230	1/4	1/8	5.25	5 1/4	0.330	5/16	0.630	1 3/16	9/16	6 1/2	2 3/4
WB-15	4.44	8.11	8 1/8	0.245	1/4	1/8	4.02	4	0.315	5/16	0.615	1 3/16	9/16	6 1/2	2 1/4
x13	3.84	7.89	8	0.230	1/4	1/8	4.00	4	0.255	1/4	0.555	3/4	9/16	↓	↓
x10 ²	2.99	7.89	7 7/8	0.170	3/16	1/8	3.94	4	0.205	3/16	0.505	1 1/16	1/2	↓	↓
WB-25	7.34	8.38	8 3/8	0.320	5/16	3/16	6.08	6 1/8	0.455	7/16	0.705	1 5/16	9/16	4 1/2	3 1/2
x20	5.87	8.20	8 1/4	0.280	1/4	1/8	6.02	6	0.365	3/8	0.615	7/8	9/16	↓	↓
x15 ¹	4.43	5.99	6	0.230	1/4	1/8	5.99	6	0.290	1/4	0.510	3/4	9/16	↓	↓
WB-18	4.74	8.28	8 1/4	0.260	1/4	1/8	4.03	4	0.405	3/8	0.655	7/8	9/16	4 1/2	2 1/4
x12	3.55	8.03	8	0.230	1/4	1/8	4.00	4	0.290	1/4	0.530	3/4	9/16	↓	↓
x9 ¹	2.68	5.90	5 7/8	0.170	3/16	1/8	3.94	4	0.215	3/16	0.485	1 1/16	1/2	↓	↓
x8.5 ¹	2.52	5.83	5 7/8	0.170	3/16	1/8	3.94	4	0.195	3/16	0.445	1 1/16	1/2	↓	↓
WB-10	5.58	5.15	5 1/8	0.270	1/4	1/8	5.03	5	0.430	7/16	0.730	1 3/16	7/8	3 1/2	2 3/4
x18	4.71	5.01	5	0.240	1/4	1/8	5.00	5	0.360	3/8	0.660	3/4	7/8	3 1/2	2 3/4
WB-13	3.83	4.18	4 1/8	0.280	1/4	1/8	4.08	4	0.345	3/8	0.595	3/4	1/2	2 1/4	2 1/4

¹ Shape is slender for compression with $F_y = 50$ ksi.

² Shape exceeds compact limit for flexure with $F_y = 50$ ksi.

³ The actual size, combination and orientation of fastener components should be compared with the geometry of the cross section to ensure compatibility.

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Figure 13: Steel Manual Table 1-1

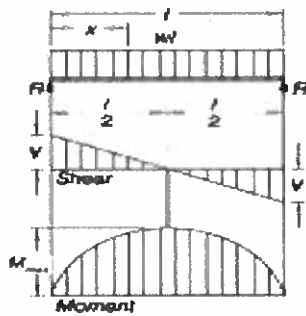
Table 1-1 (continued)														
W-Shapes														
Properties														
														
W8-W4														
Nom- inal Wt.	Compact Section Criteria		Axis X-X				Axis Y-Y				r_x	r_y	Torsional Properties	
			I	S	r	Z	I	S	r	Z			J	C_w
	d_c in.	b_f in.	I_x in. ⁴	S_x in. ³	r_x in.	Z_x in. ³	I_y in. ⁴	S_y in. ³	r_y in.	Z_y in. ³			J in. ⁴	C_w in. ⁶
67	4.43	11.1	272	80.4	3.72	70.1	88.9	21.4	2.12	32.7	2.43	8.07	5.06	1440
58	5.07	12.4	228	52.0	3.65	59.8	75.1	18.3	2.10	27.9	2.39	7.84	3.33	1180
48	5.82	15.9	184	43.2	3.61	49.0	60.9	15.0	2.08	22.9	2.35	7.82	1.98	991
40	7.21	17.8	148	35.5	3.53	38.8	49.1	12.2	2.04	18.5	2.31	7.69	1.12	729
35	8.10	20.5	127	31.2	3.51	34.7	42.6	10.6	2.03	16.1	2.28	7.63	0.769	619
31	9.19	22.3	110	27.5	3.47	30.4	37.1	9.27	2.02	14.1	2.26	7.57	0.536	530
28	7.03	22.3	98.0	24.3	3.45	27.2	21.7	6.83	1.82	10.1	1.84	7.80	0.537	312
24	8.12	25.9	82.7	20.9	3.42	23.1	18.3	5.63	1.81	8.57	1.81	7.53	0.346	259
21	6.59	27.5	75.3	18.2	3.49	20.4	9.77	3.71	1.28	5.89	1.46	7.88	0.282	152
18	7.95	29.9	61.9	15.2	3.43	17.0	7.97	3.04	1.23	4.86	1.43	7.81	0.172	122
15	6.37	28.1	48.0	11.8	3.29	13.6	3.41	1.70	0.878	2.87	1.08	7.80	0.137	51.8
13	7.84	29.9	39.9	9.91	3.21	11.4	2.73	1.37	0.843	2.15	1.03	7.74	0.0871	40.8
10	9.81	40.5	30.8	7.81	3.22	8.87	2.09	1.08	0.841	1.88	1.01	7.69	0.0428	30.9
25	6.88	15.5	53.4	16.7	2.70	18.9	17.1	5.81	1.52	8.68	1.74	5.83	0.481	150
20	8.25	19.1	41.4	13.4	2.69	14.9	13.3	4.41	1.50	6.72	1.70	5.84	0.240	113
15	11.5	21.8	29.1	9.72	2.59	10.8	9.32	3.11	1.45	4.75	1.66	5.73	0.101	79.5
16	4.98	19.1	32.1	10.2	2.60	11.7	4.43	2.20	0.987	3.39	1.13	5.88	0.223	38.2
12	7.14	21.8	22.1	7.31	2.49	8.30	2.99	1.50	0.918	2.32	1.08	5.75	0.0903	24.7
9	9.16	29.2	18.4	5.58	2.47	6.23	2.20	1.11	0.905	1.72	1.08	5.69	0.0405	17.7
8.5	10.1	29.1	14.9	5.10	2.43	5.73	1.98	1.01	0.890	1.58	1.05	5.64	0.0333	15.8
19	5.85	13.7	28.3	10.2	2.17	11.8	9.13	3.83	1.28	5.53	1.45	4.72	0.318	50.9
16	6.94	15.4	21.4	8.55	2.13	9.63	7.51	3.00	1.28	4.58	1.43	4.85	0.192	40.8
13	5.88	10.8	11.3	5.48	1.72	6.28	3.88	1.90	1.00	2.92	1.16	3.82	0.151	14.0

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Figure 14: Steel Manual Table 1-1

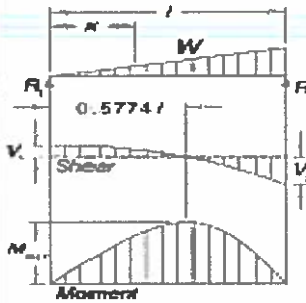
Table 3-23
Shears, Moments and Deflections

1. SIMPLE BEAM — UNIFORMLY DISTRIBUTED LOAD



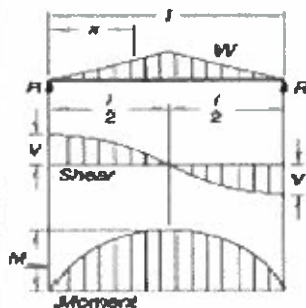
Total Equiv. Uniform Load	$= wl$
$R_1 = V_1$	$= \frac{wl}{2}$
V_2	$= w\left(\frac{l}{2} - x\right)$
M_{max} (at center)	$= \frac{wl^2}{8}$
M_x	$= \frac{wx}{2}(l - x)$
Δ_{max} (at center)	$= \frac{5wl^4}{384EI}$
Δ_x	$= \frac{wx}{24EI}(l^3 - 2lx^2 + x^3)$

2. SIMPLE BEAM — LOAD INCREASING UNIFORMLY TO ONE END



Total Equiv. Uniform Load	$= \frac{16W}{9\sqrt{3}} = 1.03W$
$R_1 = V_1$	$= \frac{W}{3}$
$R_2 = V_2 = V_{max}$	$= -\frac{2W}{3}$
V_x	$= \frac{W}{3} - \frac{Wx^2}{l^2}$
M_{max} (at $x = \frac{l}{\sqrt{3}} = 0.577l$)	$= \frac{2Wl}{9\sqrt{3}} = 0.125Wl$
M_x	$= \frac{Wx}{3l^2}(l^3 - x^3)$
Δ_{max} (at $x = l\sqrt{\frac{8}{15}} = 0.519l$)	$= 0.0130 \frac{Wl^3}{EI}$
Δ_x	$= -\frac{Wx}{180EI^2}(3l^4 - 10l^2x^2 + 7x^4)$

3. SIMPLE BEAM — LOAD INCREASING UNIFORMLY TO CENTER



Total Equiv. Uniform Load	$= \frac{4W}{3}$
$R_1 = V_1$	$= \frac{W}{3}$
V_2 (when $x = \frac{l}{2}$)	$= -\frac{W}{3}$
M_{max} (at center)	$= \frac{Wl}{6}$
M_x (when $x = \frac{l}{2}$)	$= Wx\left(\frac{l}{3} - \frac{2x^2}{3l}\right)$
Δ_{max} (at center)	$= \frac{Wl^3}{80EI}$
Δ_x (when $x = \frac{l}{2}$)	$= \frac{Wx}{480EI^2}(5l^2 - 4x^2)^2$

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Figure 15: Table 3-23 Shear, Moment and Deflections

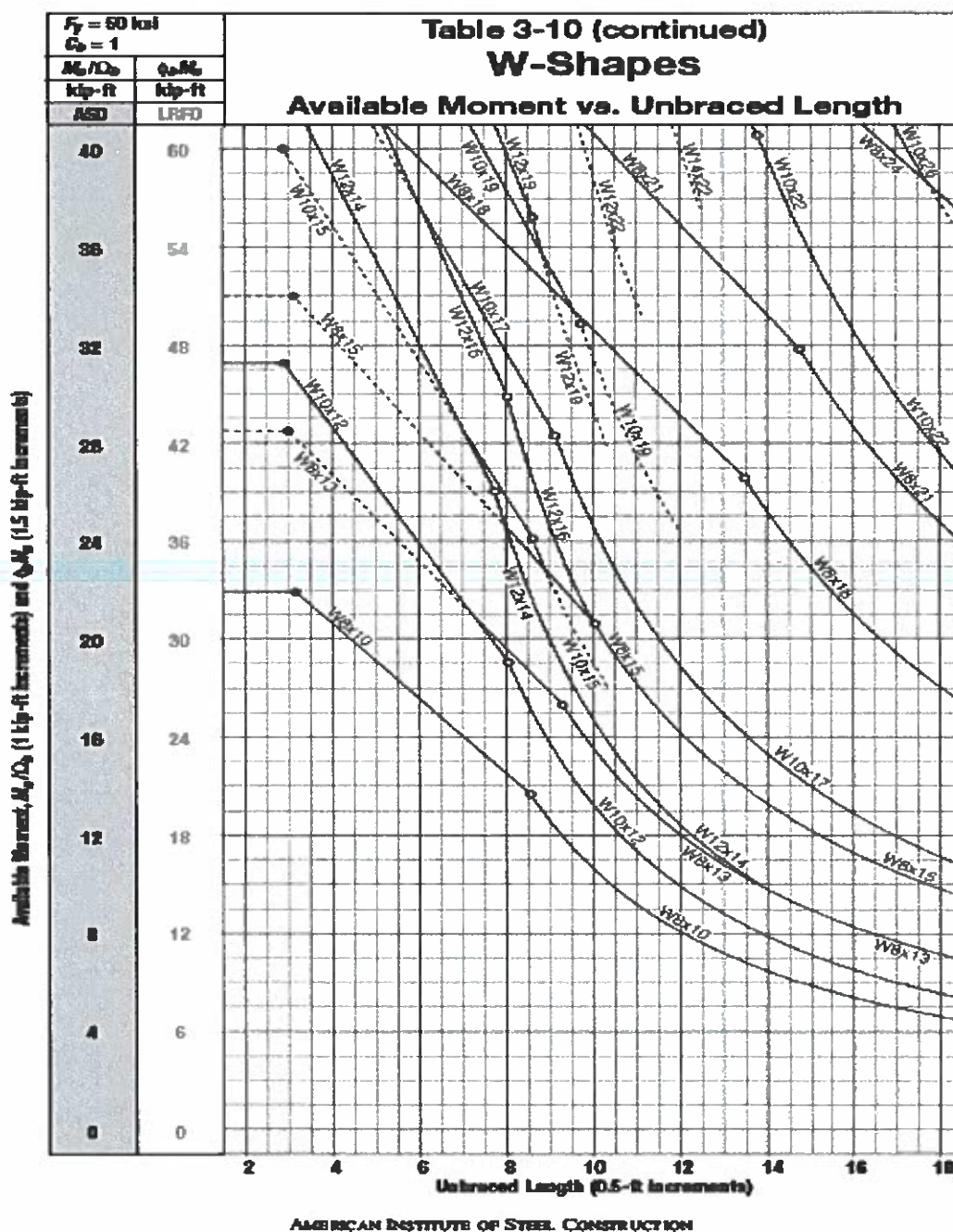


Figure 16: Table 3-10 W-Shapes Available Moment vs Unbraced Length

Table 3-2 (continued)													Z_x	
$F_y = 50 \text{ ksi}$														
W-Shapes														
Selection by Z_x														
Shape	Z_x in. ³	M_{px}/Ω_b		M_{py}/Ω_b		M_{px}/Ω_b		M_{py}/Ω_b		L_p ft	L_r ft	L_c ft	$\phi_b M_{px}$	
		kip-ft	LRFD	kip-ft	LRFD	kip-ft	LRFD	kip-ft	LRFD				kip-ft	LRFD
W12x16	20.1	50.1	75.4	28.9	44.9	3.88	5.73	2.73	8.05	103	81.9	52.8	79.2	
W10x17	18.7	48.7	70.1	28.3	42.5	2.88	4.47	2.88	9.18	81.9	81.9	48.5	72.7	
W12x14 ¹	17.4	43.4	65.3	23.0	39.1	3.43	5.17	2.66	7.73	88.8	88.8	42.8	64.3	
W8x18	17.0	42.4	63.8	29.5	39.9	1.74	2.61	4.34	13.5	81.9	81.9	37.4	56.2	
W10x15	16.0	39.9	60.0	24.1	36.2	2.75	4.14	2.88	8.81	88.8	88.8	48.0	68.9	
W8x15	13.6	33.9	51.0	20.8	31.0	1.00	2.85	3.09	10.1	48.0	48.0	39.7	59.6	
W10x12 ¹	12.6	31.2	46.9	18.0	28.6	2.38	3.53	2.87	8.85	53.8	53.8	37.5	56.3	
W8x13	11.4	28.4	42.8	17.3	26.0	1.78	2.67	2.98	9.27	39.8	39.8	38.8	55.1	
W8x10 ¹	8.87	21.8	32.9	13.6	20.5	1.54	2.30	3.14	8.52	30.8	30.8	26.3	40.2	
ASD	LRFD	* Shape exceeds compact limit for flexure with $F_y = 50 \text{ ksi}$ * Shape does not meet the A/F_y limit for shear in AISC Specification Section G2.1(a) with $F_y = 50 \text{ ksi}$; therefore, $\phi_v = 0.80$ and $\Omega_v = 1.87$.												
$\Omega_b = 1.87$ $\Omega_v = 1.80$	$\phi_b = 0.80$ $\phi_v = 1.00$													

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Figure 17: Table 3-2 W-Shapes Selection by Z_x

Beams design

The beam is to be spread out between columns at 50ft evenly spacing and having joists running perpendicular between the beams. Bracing members must be connected with a minimum of one bolt or its equivalent (Steel Manual).

When

W = Weight

DL = 40 lb/ft (W16x40)

LL = 3,500 lbs/ft

$$W = DL + LL$$

$$W = 40 \text{ lbs/ft} + 10(3,500 \text{ lbs/ft})$$

$$W = 590 \text{ lbs/ft}$$

Now we will need to calculate the maximum shear and bending moment to see if the beam chosen would work for this application. Using Table 3-23 from Figure 06 from the steel manual.

When

$$V_{\text{Max}} = WL/2$$

$$V_{\text{Max}} = (590 \text{ lbs/ft} * 50\text{ft}) / 2$$

$$V_{\text{Max}} = 14.75 \text{ lbs/ft} \Rightarrow 14.8 \text{ kip/ft}$$

$$M_{\text{Max}} = WL^2 / 8$$

$$M_{\text{Max}} = (590 \text{ lb/ft} * 50^2\text{ft}) / 8$$

$$M_{\text{Max}} = 184,375 \text{ lbs} \cdot \text{ft} \Rightarrow 184.4 \text{ kips} \cdot \text{ft}$$

Check Answers:

$$V_{\text{Max}} < \phi_V V_{nx}$$

14.8 kips < 146 kips Shear is Okay

$$M_{\text{Max}} < \phi_b M_n$$

184.4 kips*ft < 200 kips*ft Bending Moment is Okay

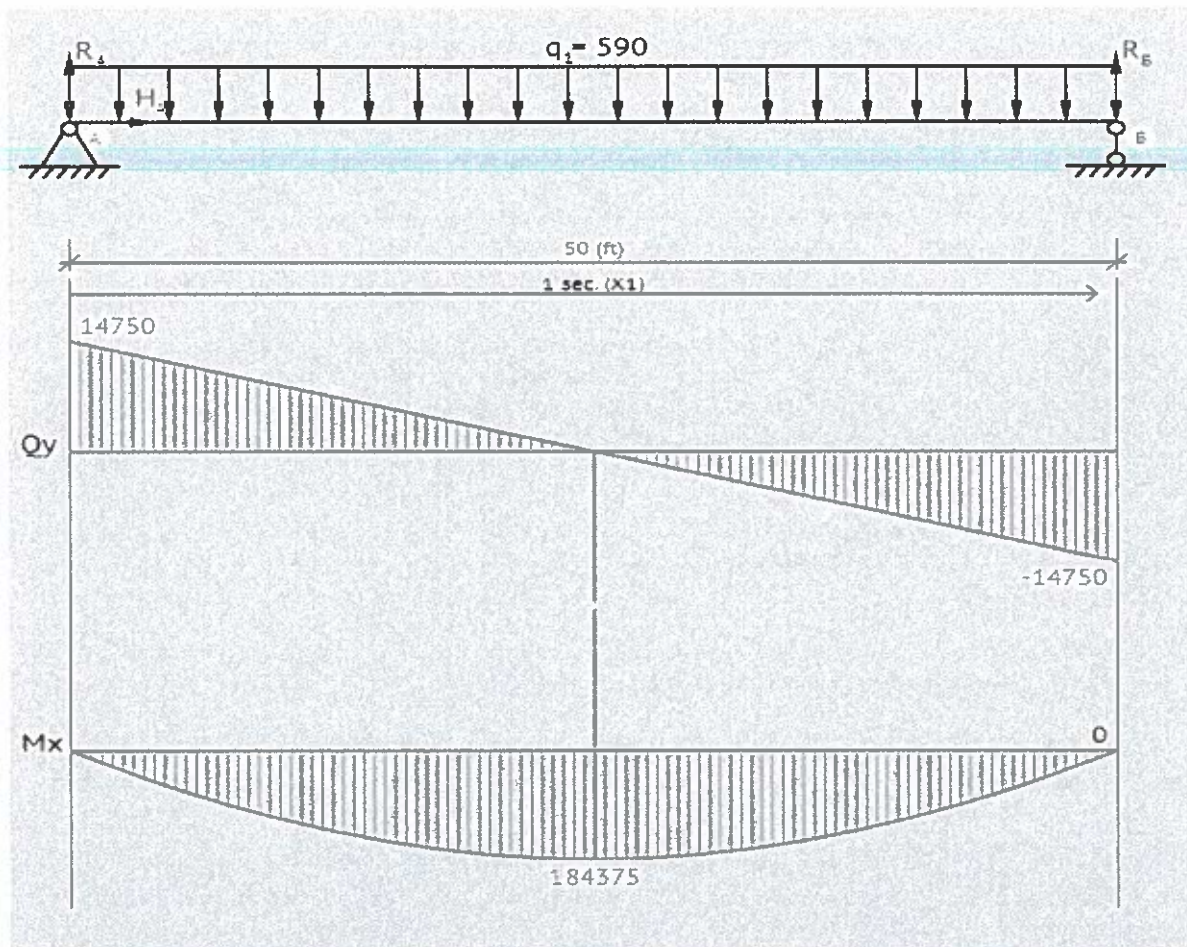


Figure 18: Shear and bending moment of beam

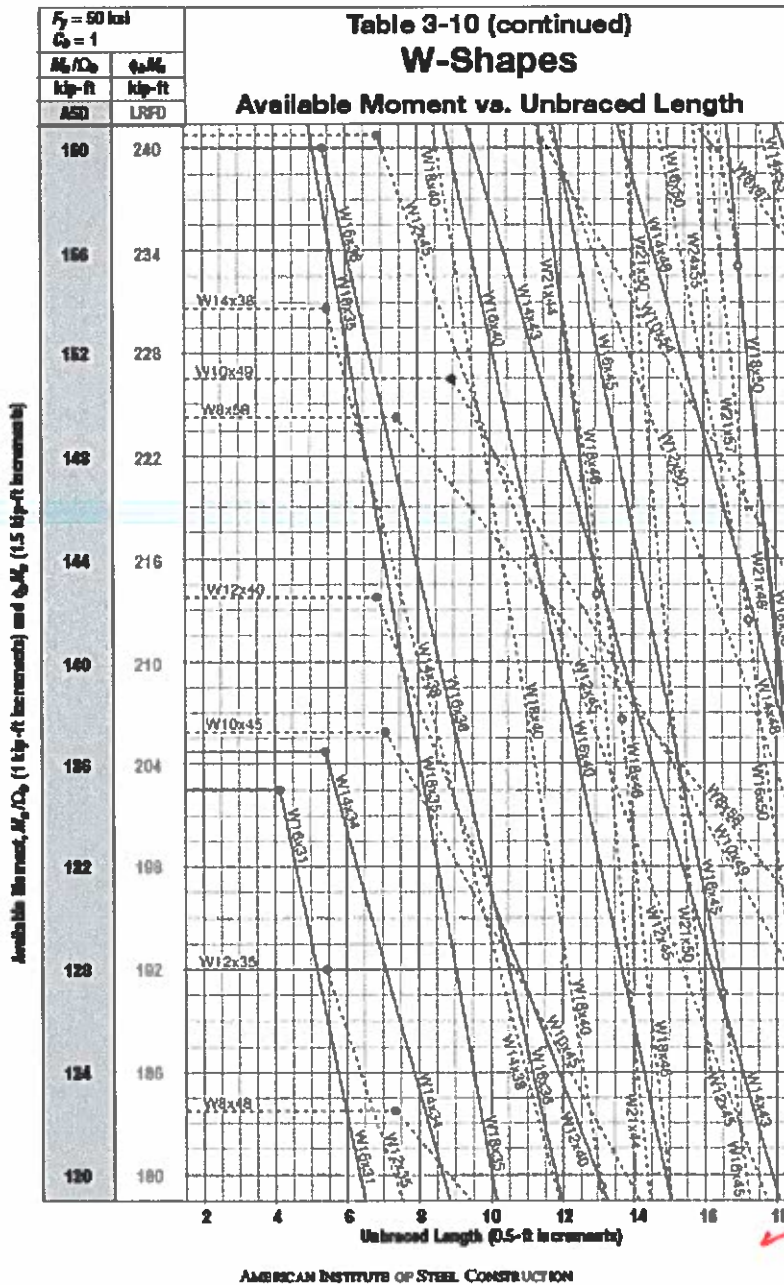


Figure 19: Table 3-10 W-Shapes Available Moment vs Unbraced Length

Table 3-2 (continued)													Z_x							
$F_y = 50$ ksi																				
W-Shapes																				
Selection by Z_x																				
Shape	Z_x in. ³	M_p/Ω_b		ϕM_p		M_r/Ω_b		ϕM_r		B_F/Ω_b		ϕB_F		L_p ft	L_r ft	L_c in. ⁴	M_n/Ω_b		ϕM_n	
		kip-ft		kip-ft		kip-ft		kip-ft		kip-ft		kip-ft					kip-ft		kip-ft	
		ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD				ASD	LRFD	ASD	LRFD
W21x55	126	314	473	182	288	10.8	16.3	6.11	17.4	1140	158	234								
W14x74	128	314	473	186	294	5.31	8.05	8.78	31.0	795	128	192								
W18x60	123	307	461	189	284	9.82	14.4	5.93	18.2	984	151	227								
W12x79	119	297	448	187	281	3.78	5.67	10.8	38.9	682	117	175								
W14x68	115	287	431	180	270	5.19	7.81	8.69	29.3	722	116	174								
W10x88	113	282	424	172	259	2.82	3.94	8.29	51.2	534	131	198								
W18x55	112	279	420	172	258	9.15	13.8	5.90	17.6	890	141	212								
W21x50	110	274	413	165	249	12.1	18.3	4.59	13.6	984	158	237								
W12x72	108	269	405	170	258	3.69	5.56	10.7	37.5	697	108	159								
W21x45	107	265	398	162	244	9.89	14.8	5.86	16.5	959	144	216								
W18x57	105	262	394	161	242	7.98	12.0	5.65	18.3	758	141	212								
W14x61	102	254	383	161	242	4.93	7.48	8.65	27.5	640	104	158								
W18x50	101	252	379	155	233	8.78	13.2	5.83	16.9	800	128	192								
W10x77	97.8	244	368	150	225	2.60	3.90	9.18	45.3	455	112	169								
W12x65	96.8	237	358	154	231	3.58	5.39	10.7	35.1	533	94.4	142								
W21x44	95.4	238	358	143	214	11.1	16.8	4.45	13.0	843	145	217								
W18x50	92.0	230	345	141	213	7.69	11.4	5.62	17.2	859	124	186								
W18x46	90.7	226	340	138	207	9.63	14.6	4.58	13.7	712	130	195								
W14x53	87.1	217	327	138	204	5.22	7.93	6.78	22.3	541	109	154								
W12x58	86.4	216	324	138	205	3.82	5.69	8.87	29.8	475	87.8	132								
W10x68	85.3	213	320	132	199	2.58	3.85	9.15	40.8	394	87.8	147								
W18x45	82.3	205	309	127	191	7.12	10.8	5.55	16.5	586	111	167								
W18x40	78.4	196	294	119	180	3.84	5.82	4.49	13.1	812	113	168								
W14x48	78.4	196	294	123	184	5.09	7.67	6.75	21.1	484	98.8	141								
W12x53	77.9	194	292	123	185	3.65	5.50	8.78	26.2	425	83.5	125								
W10x60	74.8	188	280	118	175	2.54	3.82	9.08	36.8	341	85.7	129								
W18x40	73.0	182	274	118	170	6.87	10.0	5.55	15.9	518	87.8	146								
W12x50	71.9	179	270	112	169	3.97	5.98	6.82	23.8	391	80.3	135								
W8x67	70.1	175	263	105	159	1.75	2.59	7.49	47.6	272	109	154								
W14x43	69.8	174	261	109	164	4.88	7.28	6.68	20.0	428	83.8	125								
W10x54	66.6	168	250	105	158	2.48	3.75	9.04	33.6	303	74.7	112								
ASD	LRFD	Shape exceeds compact limit for flexure with $F_y = 50$ ksi																		
$\Omega_b = 1.67$	$\phi_b = 0.90$																			
$\Omega_y = 1.60$	$\phi_y = 1.00$																			

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Figure 20: Table 3-2 W-Shapes Selection by Z_x

Columns Design

The columns are to provide the support of the structures live and dead loads of the building. These compression members are critical that the correct column size is used for its application to provide the ample support of the structure and the cost of not over building the structure if not needed. We can calculate the load on the column by the following.

$$P_u = 1.2P_D + 1.6P_L$$

With the assumptions of the following values the column requirement can be provided:

$$L_{\text{Column}} = 34\text{ft}$$

$$P_D = 165\text{kips}$$

$$P_L = 535\text{kips}$$

$$P_u = 1.2(165\text{kips}) + 1.6(535\text{kips})$$

$$P_u = 1054\text{kips}$$

Getting our total design load for the particular column with a column length of 34 for feet referencing Table 4-1 from Figure 20. The following W- shape beam values will be utilized to meet load requirements.

W12x252

$$\phi_c P_n = 1120 \text{ kips}$$

$$1054 \text{ kips} < 1120 \text{ kips, Okay beam to use}$$

The beam W12x252 will meet the requirements for the total axial load of that particular beam at 34ft in length.

		Table 4-1 (continued) Available Strength in Axial Compression, kips W-Shapes												 W12	
Shape		W12x													
lb/ft		235*		305*		270*		252*		230*		210			
Design		P_u/ϕ_c ASD		P_u/ϕ_c LRFD		P_u/ϕ_c ASD		P_u/ϕ_c LRFD		P_u/ϕ_c ASD		P_u/ϕ_c LRFD		P_u/ϕ_c ASD	
Effective length, KL (ft), with respect to least radius of gyration, r_y	0	2360	4450	2680	4030	2450	3680	2220	3330	2030	3050	1850	2780		
	6	2870	4310	2580	3800	2370	3570	2140	3220	1890	2940	1760	2680		
	7	2840	4260	2580	3850	2340	3520	2120	3180	1890	2910	1760	2650		
	8	2800	4210	2530	3800	2310	3470	2090	3140	1810	2860	1740	2610		
	9	2760	4150	2480	3740	2280	3420	2060	3090	1880	2820	1710	2570		
	10	2710	4080	2450	3680	2240	3380	2020	3030	1840	2770	1680	2520		
	11	2680	4000	2400	3610	2190	3300	1980	2970	1800	2710	1640	2470		
	12	2610	3920	2350	3540	2150	3230	1940	2910	1760	2650	1610	2420		
	13	2550	3840	2300	3460	2100	3150	1890	2840	1720	2590	1570	2360		
	14	2490	3750	2250	3380	2050	3080	1840	2770	1680	2520	1530	2300		
	15	2430	3660	2190	3290	1990	3000	1790	2700	1630	2450	1480	2230		
	16	2370	3560	2130	3200	1940	2910	1740	2620	1590	2380	1440	2160		
	17	2300	3460	2070	3100	1880	2820	1690	2540	1540	2310	1390	2100		
	18	2230	3350	2000	3010	1820	2730	1630	2460	1480	2230	1350	2030		
	19	2160	3250	1940	2910	1760	2640	1580	2370	1430	2160	1300	1950		
	20	2090	3140	1870	2810	1700	2550	1520	2290	1380	2070	1250	1880		
	22	1940	2910	1730	2610	1570	2360	1410	2110	1270	1910	1150	1730		
	24	1790	2690	1600	2400	1440	2170	1290	1940	1170	1750	1060	1580		
	25	1840	2480	1480	2190	1320	1980	1170	1760	1080	1590	955	1440		
	28	1490	2240	1320	1990	1160	1790	1080	1590	954	1430	859	1290		
	30	1350	2030	1190	1790	1070	1610	949	1430	854	1280	787	1150		
	32	1210	1820	1070	1600	954	1430	843	1270	758	1140	678	1020		
	34	1090	1620	945	1420	845	1270	748	1120	670	1010	600	902		
	36	959	1440	843	1270	754	1130	688	1000	597	898	535	805		
	38	861	1280	757	1140	678	1020	598	898	538	808	481	722		
	40	777	1170	683	1030	610	917	539	811	484	727	434	652		
Properties															
P_n , kips		1050	1580	897	1340	783	1170	665	998	574	881	492	738		
P_n , kips/in.		59.3	89.0	54.3	81.5	51.0	78.5	48.7	70.0	43.0	64.5	38.3	58.0		
P_n , kips		10000	15100	7600	11600	6380	9590	4870	7320	3810	5730	2980	4400		
P_n , kips		1840	2480	1370	2070	1140	1720	947	1420	802	1210	676	1020		
L_p , ft		12.3		12.1		11.9		11.8		11.7		11.6			
L_r , ft		160		137		128		114		105		95.8			
A_g , in. ²		68.9		68.5		61.9		74.1		67.7		61.8			
b_f , in. ⁴		4060		3550		3110		2720		2420		2140			
I_y , in. ⁴		1190		1050		937		828		742		664			
r_y , in.		5.47		3.42		3.36		3.34		3.31		3.28			
$r_{x/y}$		1.85		1.84		1.82		1.81		1.80		1.80			
$P_n/(KL)^2/10^4$, k-in. ²		118000		102000		89000		77900		69300		61300			
$P_n/(KL)^2/10^4$, k-in. ²		34100		30100		26800		23700		21200		19000			
ASD		LRFD		* Flange thickness is greater than 2 in. Special requirements may apply per AISC Specification Section A3.1c.											
$\phi_c = 1.87$		$\phi_c = 0.90$													

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Figure 20: Table 4-1 Axial Compression kips

Joints and connections

The joints and the connection points for the structure will be provided depending on the results provided by STAAD Pro. As to assume all the joints depend on its final design parameters.

Building Slab

The building slab is to be addressed the following year due to time restraints.

Footings Design

The footing design will be coordinated with Geotechnical Technical engineering to provide the adequate footing support for each of the structures. This is dependent on the load bearing capacity of the soil type at each of the locations. From there knowing the on total load from each of the buildings' live and dead loads.

Water Resources

Introduction:

The Water Resources design is part of phase C of the project. In the water resources portion of this design project, the task was to design a trapezoidal storm water drainage ditch based on a 100-year rainfall investigation period all while avoiding flood risks and property damage from the storm water runoff. The trapezoidal ditch is to be designed by using hydrologic and hydraulic methods. The hydrologic methods used was using the Rational Method to obtain the peak runoff outflow and the "Tractive Force based Unlined Channel Design Method" to get the design dimensions for the channel.

Design Methods and Equations (Theory)

Before the design of the channel/ditch could be done, the Rational Method was used to find the peak runoff outflow, which was then recorded and used to find the design of the channel.

$$Q = CiA \quad (1)$$

Where,

Q = Peak Outflow, cfs

C = Runoff Coefficient based on land

i = Rainfall Intensity, in/hr = 3.93 in/hr (determined by Figure 1 below)

A = Drainage Area, acre = 400 acre

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)

Duration	1	2	5	10	25	50	100	200	500	1000
5-min	0.466 (0.353-0.616)	0.535 (0.410-0.703)	0.651 (0.497-0.857)	0.745 (0.559-0.992)	0.871 (0.632-1.19)	0.964 (0.681-1.36)	1.06 (0.729-1.53)	1.15 (0.776-1.72)	1.29 (0.833-1.98)	1.39 (0.879-2.19)
10-min	0.741 (0.561-0.978)	0.852 (0.653-1.18)	1.04 (0.792-1.37)	1.19 (0.833-1.59)	1.39 (1.01-1.91)	1.55 (1.10-2.18)	1.70 (1.17-2.46)	1.84 (1.24-2.74)	2.03 (1.32-3.12)	2.17 (1.37-3.42)
15-min	0.937 (0.709-1.24)	1.07 (0.820-1.4)	1.30 (0.888-1.71)	1.48 (1.11-1.97)	1.73 (1.26-2.38)	1.92 (1.36-2.7)	2.11 (1.46-3.06)	2.30 (1.55-3.42)	2.55 (1.66-3.92)	2.73 (1.73-4.32)
30-min	1.33 (1.00-1.75)	1.51 (1.16-1.99)	1.82 (1.39-2.43)	2.07 (1.56-2.76)	2.41 (1.75-3.30)	2.66 (1.86-3.75)	2.91 (2.01-4.22)	3.18 (2.14-4.74)	3.56 (2.31-5.48)	3.85 (2.44-6.08)
60-min	1.73 (1.31-2.29)	1.99 (1.53-2.62)	2.42 (1.85-3.19)	2.77 (2.00-3.69)	3.24 (2.34-4.42)	3.58 (2.62-5.03)	3.93 (2.71-5.70)	4.33 (2.92-6.48)	4.91 (3.20-7.58)	5.39 (3.41-8.52)
2-hr	2.10 (1.61-2.75)	2.48 (1.91-3.20)	3.09 (2.28-4.02)	3.61 (2.73-4.76)	4.33 (3.15-5.85)	4.87 (3.46-6.79)	5.46 (3.78-7.85)	6.16 (4.17-9.12)	7.22 (4.71-11.1)	8.12 (5.16-12.8)
3-hr	2.31 (1.77-3.00)	2.78 (2.14-3.54)	3.52 (2.71-4.53)	4.16 (3.16-5.45)	5.07 (3.72-6.84)	5.79 (4.13-8.04)	6.59 (4.59-9.43)	7.55 (5.12-11.1)	9.02 (5.90-13.8)	10.3 (6.50-16.1)
6-hr	2.65 (2.05-3.40)	3.30 (2.53-4.09)	4.26 (3.21-5.41)	5.14 (3.94-6.69)	6.44 (4.77-8.62)	7.51 (5.41-10.4)	8.73 (6.12-12.4)	10.2 (6.94-14.9)	12.4 (8.16-18.9)	14.4 (9.16-22.3)
12-hr	2.97 (2.32-3.77)	3.81 (2.91-4.89)	5.00 (3.90-6.28)	6.15 (4.76-7.89)	7.92 (5.94-10.5)	9.47 (6.90-13.0)	11.3 (7.95-15.9)	13.4 (9.15-19.4)	16.6 (10.9-25.0)	19.3 (12.4-29.9)
24-hr	3.31 (2.61-4.18)	4.37 (3.32-5.12)	5.78 (4.56-7.18)	7.23 (5.65-9.18)	9.50 (7.23-12.6)	11.8 (9.53-15.8)	14.0 (9.93-19.5)	16.7 (11.5-24.0)	20.8 (13.7-31.0)	24.1 (15.5-37.0)
2-day	3.71 (2.95-4.61)	4.99 (3.81-6.73)	6.67 (5.30-8.15)	8.42 (6.64-10.6)	11.2 (8.65-14.8)	13.8 (10.3-18.8)	16.8 (12.0-23.3)	19.9 (13.7-28.2)	24.2 (16.0-35.7)	27.6 (17.8-42.0)
3-day	4.03 (3.22-4.98)	5.41 (4.17-6.20)	7.26 (5.80-8.91)	9.14 (7.24-11.4)	12.1 (9.39-15.9)	14.8 (11.1-20.2)	18.0 (12.9-24.6)	21.2 (14.6-29.9)	25.5 (17.0-37.6)	29.0 (19.0-44.0)
4-day	4.31 (3.47-5.30)	5.79 (4.46-6.59)	7.67 (6.16-9.28)	9.80 (7.63-11.9)	12.6 (9.77-16.4)	15.4 (11.5-20.6)	18.4 (13.2-25.3)	21.6 (15.0-30.4)	26.0 (17.1-38.2)	29.6 (19.2-44.8)
7-day	5.00 (4.05-6.09)	6.44 (5.12-7.45)	8.49 (6.89-10.2)	10.4 (8.37-12.9)	13.4 (10.4-17.3)	16.0 (12.0-21.3)	19.0 (13.7-25.8)	22.1 (15.4-31.0)	26.7 (17.9-39.0)	30.4 (19.8-45.5)
10-day	5.8 (4.56-6.75)	7.04 (5.68-8.18)	9.19 (7.49-11.0)	11.2 (8.99-13.7)	14.1 (11.0-18.0)	16.7 (12.5-22.0)	19.5 (14.1-26.4)	22.6 (16.6-31.6)	27.2 (18.3-39.7)	31.0 (20.2-46.6)
25-day	7.34 (6.03-8.79)	8.93 (7.36-10.4)	11.4 (9.43-13.5)	13.6 (11.0-16.4)	16.7 (13.0-21.0)	19.2 (14.4-24.9)	21.9 (15.9-29.4)	24.8 (17.5-34.5)	29.1 (19.7-42.2)	32.7 (21.4-48.7)
30-day	8.82 (7.28-10.6)	10.5 (8.78-12.3)	13.3 (11.0-15.7)	15.6 (12.7-19.8)	18.8 (14.7-23.5)	21.3 (16.1-27.6)	24.0 (17.5-32.0)	26.8 (19.0-37.0)	30.8 (20.6-44.4)	34.0 (22.3-50.5)
45-day	11.0 (9.11-13.0)	12.8 (10.6-15.0)	15.9 (13.4-18.7)	18.5 (15.2-22.1)	21.9 (17.2-27.1)	24.4 (18.5-31.3)	27.0 (19.8-35.9)	29.7 (21.1-40.8)	33.4 (22.7-48.0)	36.4 (23.9-53.6)
60-day	12.9 (10.8-15.2)	14.9 (12.7-17.5)	18.3 (15.5-21.5)	21.0 (17.3-25.0)	24.6 (19.3-30.3)	27.2 (20.6-34.7)	29.7 (21.8-39.3)	32.3 (24.4-43.3)	35.8 (24.4-51.3)	38.5 (25.4-56.8)

¹ Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS). Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound or less than the lower bound is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values. Please refer to NOAA Atlas 14 document for more information.

Figure 1

Upon completion of the Rational Method, The peak outflow was recorded and continued to be represented by 'Q' when it came to using the "Tractive Force based Unlined Channel Design Method" to find the design dimensions of the channel. Those dimensions were the side slope (z), bottom width (b), design depth from water surface (y_0), and velocity of the channel (V). Each of the dimensions were calculated and determined with the following equations:

$$n = .031d_{75}^{1/6} \quad (2)$$

Where,

n = Manning's roughness coefficient based on land

d_{75} = sediment size, ft

d_{75} will then obtained by manipulating Equation (2)

$$d_{75} = \left(\frac{n}{.031}\right)^6 \quad (3)$$

The value of d_{75} will then be determined.

The slope of the land, S , will be obtained by taking the latitude, longitude, and elevation from the site and comparing it to the latitude, longitude, and elevation of another point in Washington County:

$$S = \frac{\Delta z}{\sqrt{\Delta x + \Delta y}} \quad (4)$$

Where,

S = slope of land

Δx = Change in longitude, ft

Δy = Change in latitude, ft

Δz = Change in elevation, ft

Next, the critical shear stress could either be obtained from Figure 8-11 (from water resources book) or from the following equation:

$$\tau_b = k_b \gamma_w y_0 S_0 \quad (5)$$

Where,

τ_b = critical shear stress, psf

$k_b = 1.0$

γ_w = unit weight of water = 62.4 pcf

y_0 = design depth from water surface, ft

$$S_0 = \text{Slope of land} = .00076$$

The τ_b value will be found from Figure 8-11 (from water resources book) using the determined d_{75} converted from feet to millimeters.

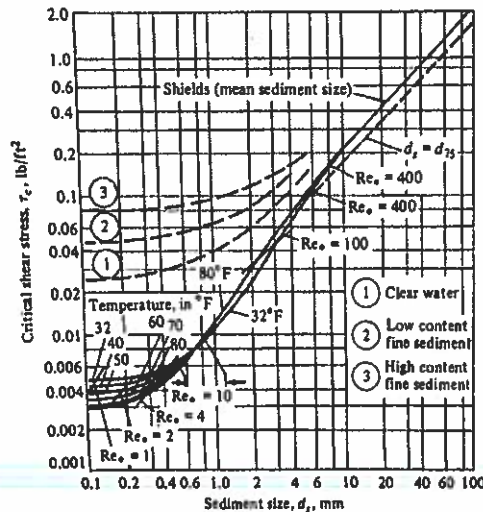


Figure 8-11 Critical shear stress for quartz particles in water (Vanoni, 1975, p. 99)

Scanned with CamScanner

Figure 2

The angle of repose (ϕ) will be determined by using Figure 8-22 (from water resources book) using the obtained d_{75} .



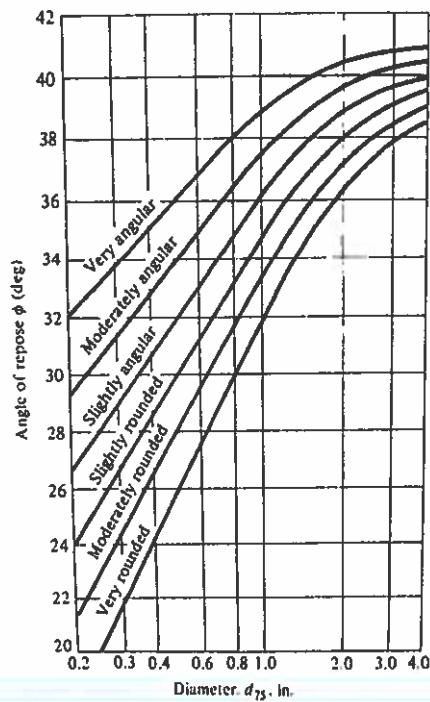


Figure 8-22 Angle of repose (Lane, 1955, p. 1247).

Scanned with CamScanner

Figure 3

The angle from the side slope was determined by:

$$\alpha = z$$

(6)

Where,

z = side slope

For the side slope (z) to be sufficient, it must be greater than $\cot \phi$.

τ_s will be determined with the help from this equation:

$$K = \frac{\tau_s}{\tau_b} = \sqrt{1 - \frac{\alpha}{\phi}}$$

(7)

Where,

τ_b = critical shear stress, psf

τ_s = shear stress, psf

α = angle from side slope

ϕ = angle of repose

τ_s will be determined by manipulating Equation 7:

$$\tau_s = \tau_b \sqrt{1 - \frac{\alpha}{\phi}} \quad (8)$$

τ_s could also be determined by:

$$\tau_s = k_s \gamma_w y_0 S_0 \quad (9)$$

Where,

τ_s = shear stress, psf

$k_s = 0.75$

The design depth (y_0) will be determined by manipulating Equations (5) and (9) and using the equation that produces the smaller value:

$$y_0 = \frac{\tau_b}{k_b \gamma_w S_0} \quad (10)$$

$$y_0 = \frac{\tau_s}{k_s \gamma_w S_0} \quad (11)$$

After conducting proper calculations, the value from the Equation with the lowest value will be used.

Next the bottom width (b) will be determined using the following equation:

$$Q = \frac{1}{n} * \frac{A^{5/3}}{P^{2/3}} * S_0^{1/2} \quad (12)$$

Where,

Q = Outflow

n = Manning's $n = 0.035$

$S_0 = 0.00076$

A = Area of Trapezoidal Channel

P = Perimeter of Trapezoidal Channel

The Area of Trapezoidal Channel was equivalent to:

$$A = by_0 + zy_0^2 \quad (13)$$

The Perimeter of Trapezoidal Channel was equivalent to:

$$P = b + 2y_0\sqrt{1 + z^2} \quad (14)$$

By substituting Equations (13) and (14) into Equation (12):

$$Q = \frac{1}{n} * \frac{(by_0 + zy_0^2)^{5/3}}{(b + 2y_0\sqrt{1 + z^2})^{2/3}} * S_0^{1/2} \quad (15)$$

Equation (15) was then manipulated to solve for b:

$$\frac{Qn}{S_0^{1/2}} = \frac{(by_0 + zy_0^2)^{5/3}}{(b + 2y_0\sqrt{1 + z^2})^{2/3}} \quad (16)$$

b will then be solved by putting Equation (16) into a solver.

The design velocity must be greater than the Kennedy equation velocity. The design velocity will be determined by:

$$V = \frac{Q}{A} \quad (17)$$

Where,

V = design velocity, m/s

The Kennedy equation velocity is given by:

$$V_0 = 0.84y_0^{0.64} \quad (18)$$

Where,

V_0 = Kennedy equation velocity, m/s

After calculations are done for each of the velocities, the design velocity would be sufficient if it is greater than the Kennedy equation velocity.

Results and Discussions

Design Channel Dimensions/Results

Q	235.8 cfs
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~~SE~~ check again

Conclusions

Once all the calculations and procedures are finished, the trapezoidal channel/drainage ditch will be successfully designed. There is currently nothing else that has been completed at this time.

Transportation Engineering

Introduction

The task of the transportation portion of this project was to design the roadway layout for the entire project. This included connecting roads from the site to existing roads and highways, interchange design, traffic study, parking lot layout, pavement design cross-section, and the plan and profile of a typical local road in development.

Site Layout

The **Figure 1** below shows the entire layout of the project site and where each of the buildings, drainage ditch, and water treatment plant will be. The Convention Center was placed at the main entrance of the project site near Farm to Market Road 332 which connects to the major Highway 290. The dimensions of the building were made to be 1600 ft by 300 ft. The two Commercial Offices are located in the middle north side of the project site with dimensions of 500 ft by 250 ft. The Warehouse is located on the furthest south west point of the project site out of the way of the office buildings and visitor convention center. The dimensions of the Warehouse is 2000 ft by 500ft. The Warehouse is located by an existing road Baranowski Rd, which allows easy access for trucks to import and export goods from the ports located on the west most portion of the warehouse. The existing road connects to Farm to Market Road 389 which leads to the major Highway 290. Parking lots are placed near and in between each building allowing for easy access for employees and guests to access the buildings. Interconnecting roads were placed within the project site connecting each parking lot. The Detention basin and Water Treatment plant are located in the southeast most part of the project site. This location of the project site is at the lowest elevation of the land which is also located by a forking creek. This will allow the runoff water and drainage water to travel more efficiently to the basin and water treatment plant.

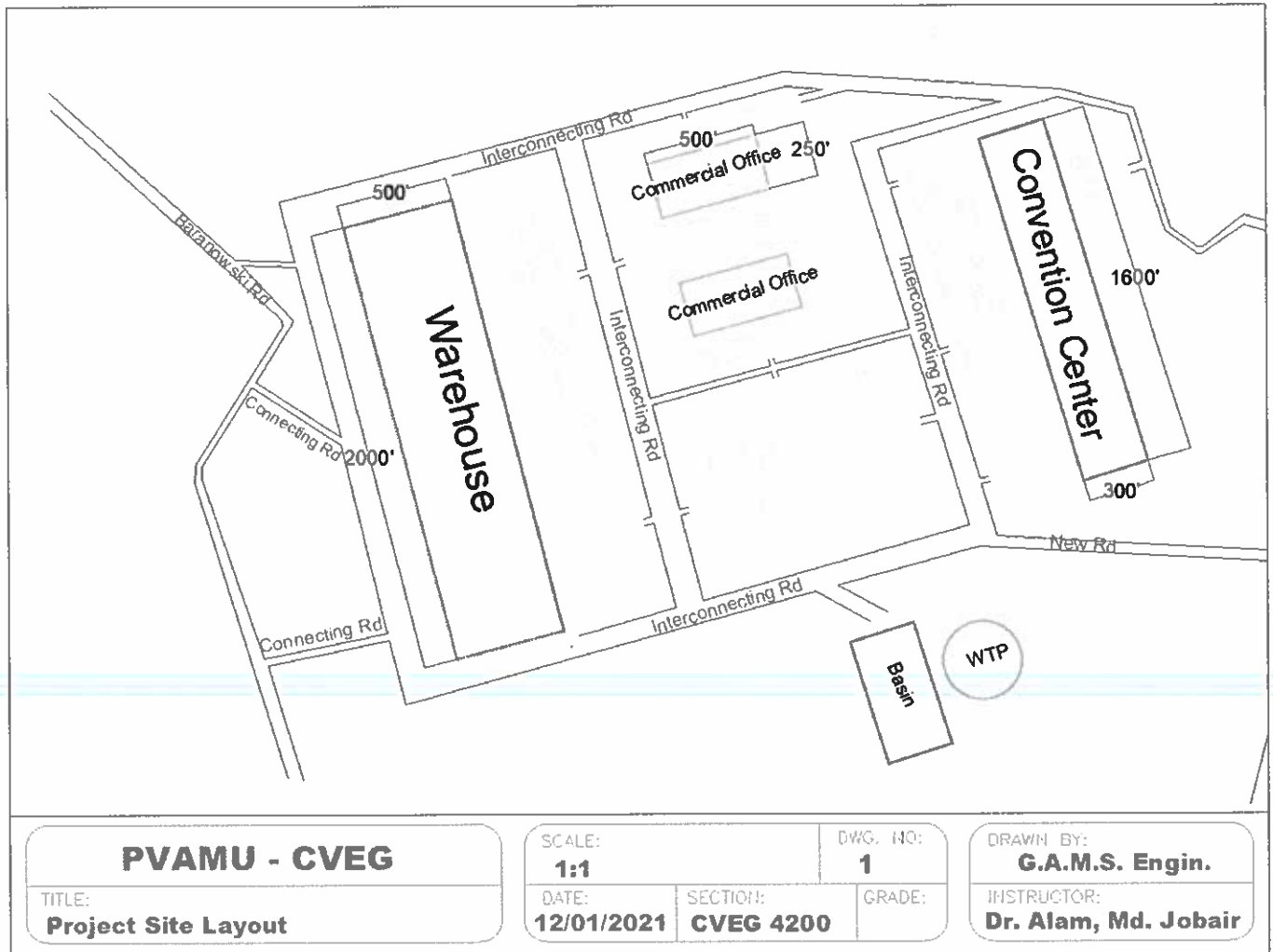


Figure 1: Project layout without geological map

overall layout plan
go at the beginning of the
report.



Figure 2: Project layout without background of site

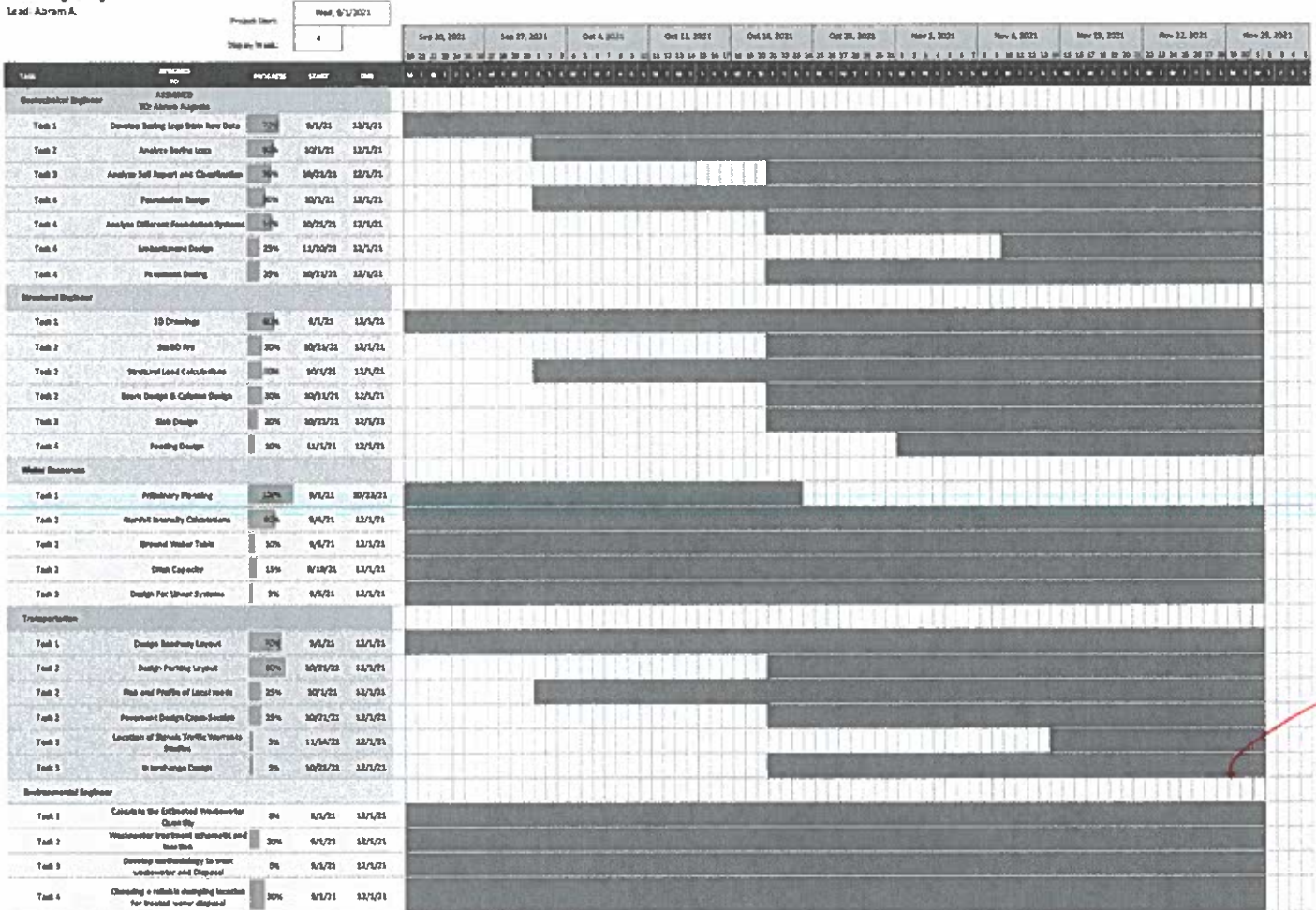
Future Work

In the next phase of the project starting in January, the Transportation Engineering portion of the project will go more in depth showing steps, procedures, and calculations with Interchange Design, Location of signals, Traffic Warrant Studies, Plan and profile as well as pavement design cross-sections for a typical local road in the development.

Gantt Chart

SENIOR DESIGN

G.A.M.S Engineering
Lead: Abram A.



*not visible
make it landscape*

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Prairie View A&M University
Roy G. Perry College of Engineering



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Civil & Environmental Department
CVEG 4200: Senior Design Project

SAPS Engineering

Autumn Carter

Shadaria Lynch

Scott McGary

Perla Zaldivar

Prairie View A&M University
Prairie View, Texas 77446

SAPS Engineering Inc.

Dec 1, 2021

Dear Professor Alam,

The attached report contains the detailed plans for a newly constructed business and distribution center, IT Hub, and office development in Colorado County, Texas. This report includes the scope of work, six disciplines of civil engineering to design the development adequately.

SAPS Engineering Inc. is available to answer any questions you may have concerning this report or the project. You can contact our team lead Scott McGary at (phone number: 901-647-5996 or email: smcgary@pvamu.edu)

Sincerely,

Autumn Carter

Shadaria Lynch

Scott McGary

Perla Zaldivar

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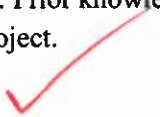
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Acknowledgment

The project was prepared by Scott McGary, Autumn Carter, Shadaria Lynch, and Perla Zaldivar collectively. The completion of the project would not have been possible without the hard work and productivity of each team member. Also, a special thanks to Dr. Alam and the Civil & Environmental Engineering Department for providing resources and guidance throughout the semester. Prior knowledge from each design course allowed us to have an advantage in creating a well-planned project.



Gantt chart goes at the end.

Gantt Timeline

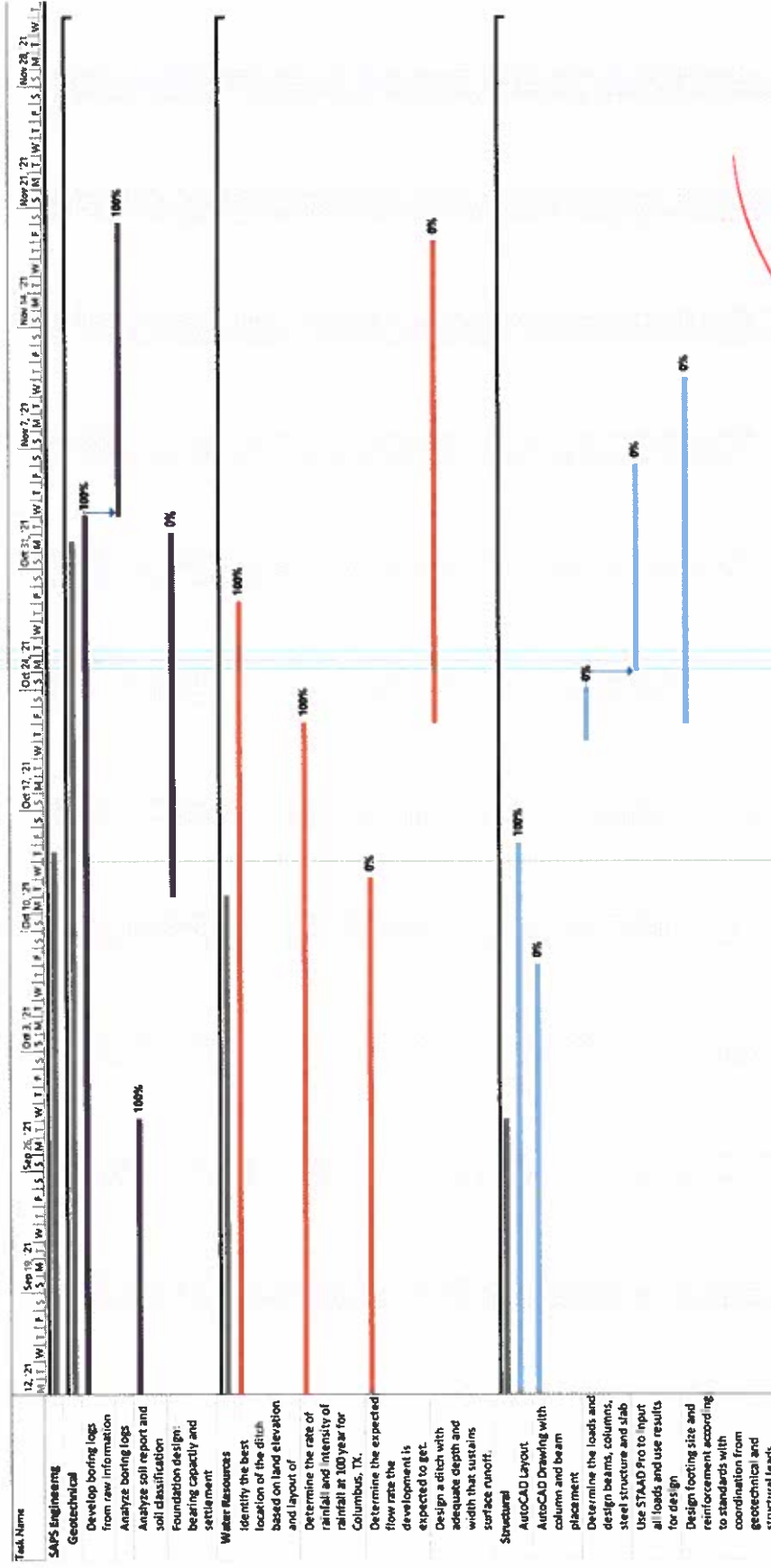
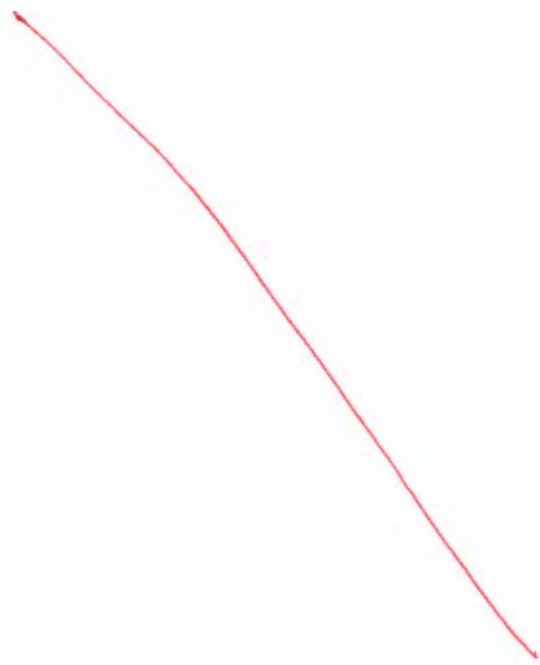


Figure 1. Gantt chart

Introduction

The proposed development is located south of Columbus, TX in Colorado County. The proposed development will be located on 400 acres of land near I-10. The property was designed for 20,000 it will consist of 4 buildings, parking lots that accommodate employees, visitors, and trucks. Within the development, a detention basin and drainage ditch were added to prevent stormwater damage. A wastewater treatment process facility based on the population projection for 15 years. SAPS Engineering designed the roads and parking to effectively and efficiently allow the flow of traffic from I-10 to the Amazon distribution center and other buildings on the property.



Chapter 1: Project Scope

1.1 Problem Statement

Design a two five-story commercial office building, a steel structure warehouse, a three-story convention center, and parking lots for Amazon located in Colorado County, Texas

1.2 Project Goals

The design team was required to perform civil engineering site development and design services and address all aspects outlined in the reporting requirements and deliverable items of this project description. This project aims to provide an AutoCAD geometric design that includes an Amazon distribution headquarters with a roadway layout and a detention pond. Water & Wastewater Treatment plants are needed to serve 20,000 people for the center and surrounding area. In addition, a 2D conceptual layout design of the and office building is needed. Also, in the area, parking facilities will be designed for each building.

Chapter 2: Task Definition and Project Design

2.1 Geotechnical Engineering

To first complete this aspect of the project the task had to be defined first. This task needed to analyze the topography map to develop boring logs from raw information and analyze those boring logs to develop the soil classification. Once this is done the foundation design can begin. To complete this project the foundation design needs to be completed where I will go for both shallow foundation and deep foot foundation and choose which is the most safe at the best cost.

The picture below is a topography map that shows the location of the site. The location of the site is south of I-10, in Colorado County TX. The size of the site is 400 acres. The elevation of the site goes into a downwards slope from 300 to 289 feet above sea level. Therefore the average elevation of the site is 294.5 feet above sea level. The black circles shown on the topography map represent the locations where the borings were taken.

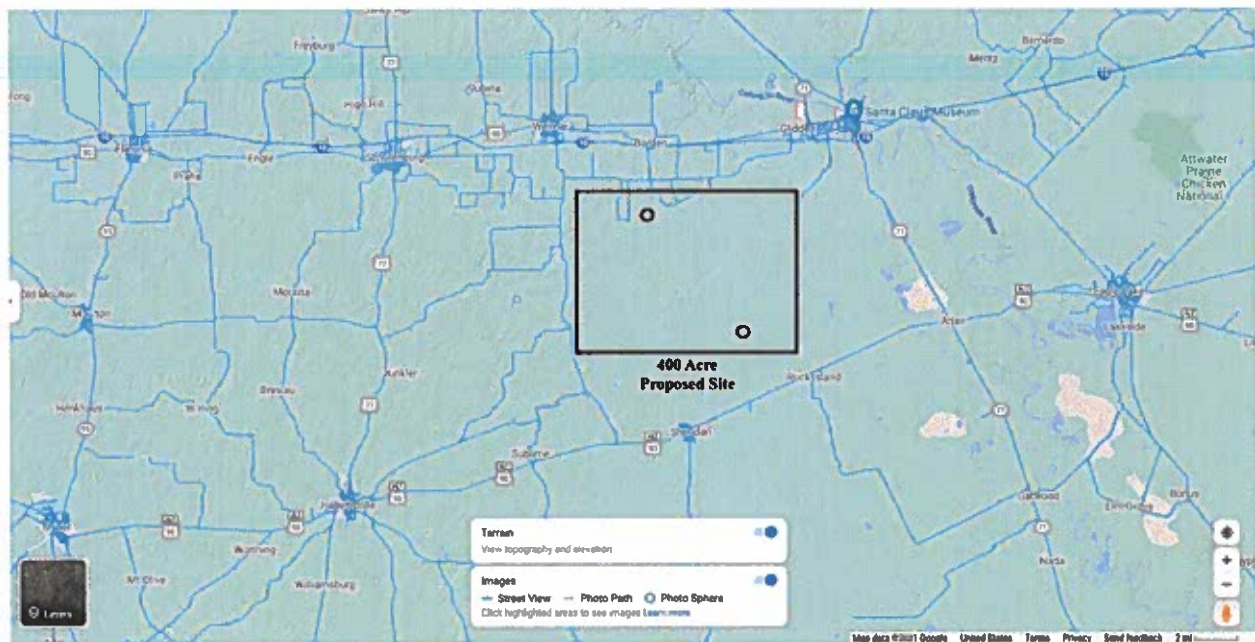


Figure 2.1 Proposed Site

AutoCAD was used in this project to create a preliminary layout of the 400 Acres. In the plan view provided by Google Maps; 2 miles scales to $\frac{1}{2}$ inch. In order to follow the constraints of the project the layout includes two five-story commercial office buildings, a steel structure warehouse, three-story convention center, facility parking lots, new road network development, sidewalks, driveways, and extension of major highways and connecting local road with highway and a storm water ditch connecting a lake. The layout below shows the preliminary layout of the proposed site plan. The layout includes a main entrance for 2-axle cars containing a right-turn lane, traffic signal, and ability to make left turn movements into each entrance. Also in the layout

service truck parking for the warehouse is provided. A wastewater treatment plant with a retention pond provides both stormwater attenuation and water quality treatment by providing additional storage capacity to retain runoff and release at a controlled rate. The design of the pond features includes an emergency spillway for safe overflow when storage capacity is exceeded.

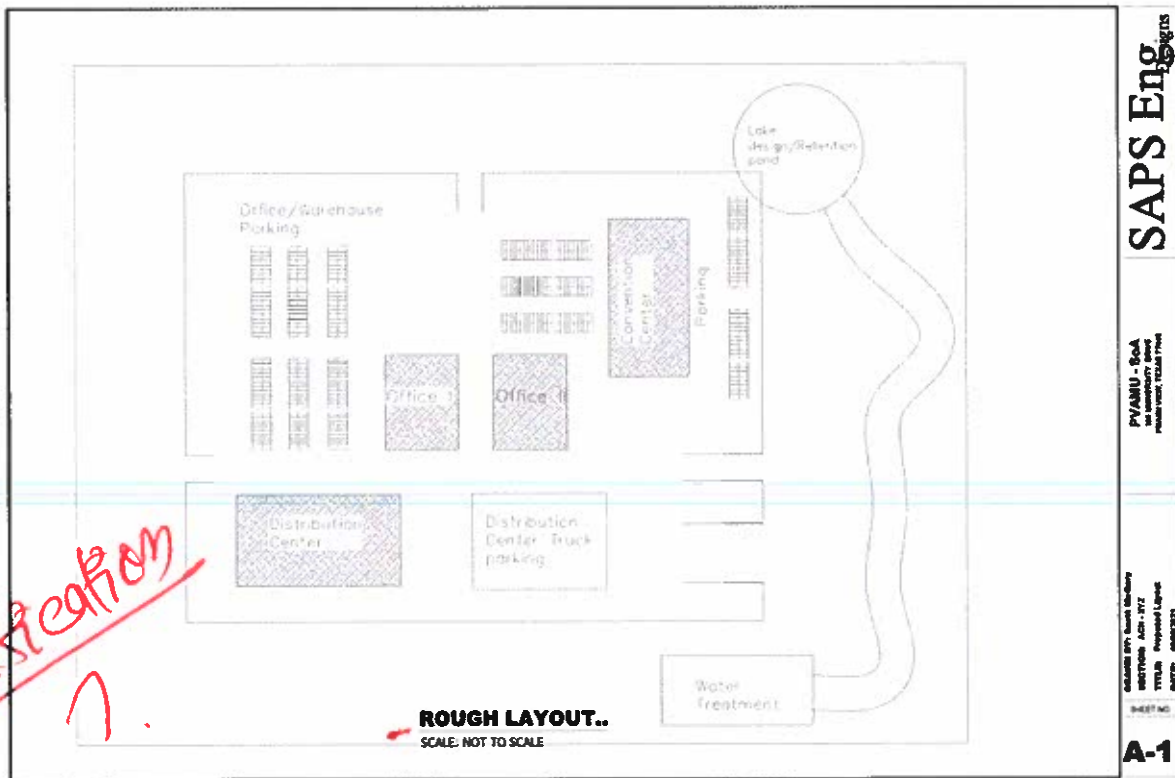
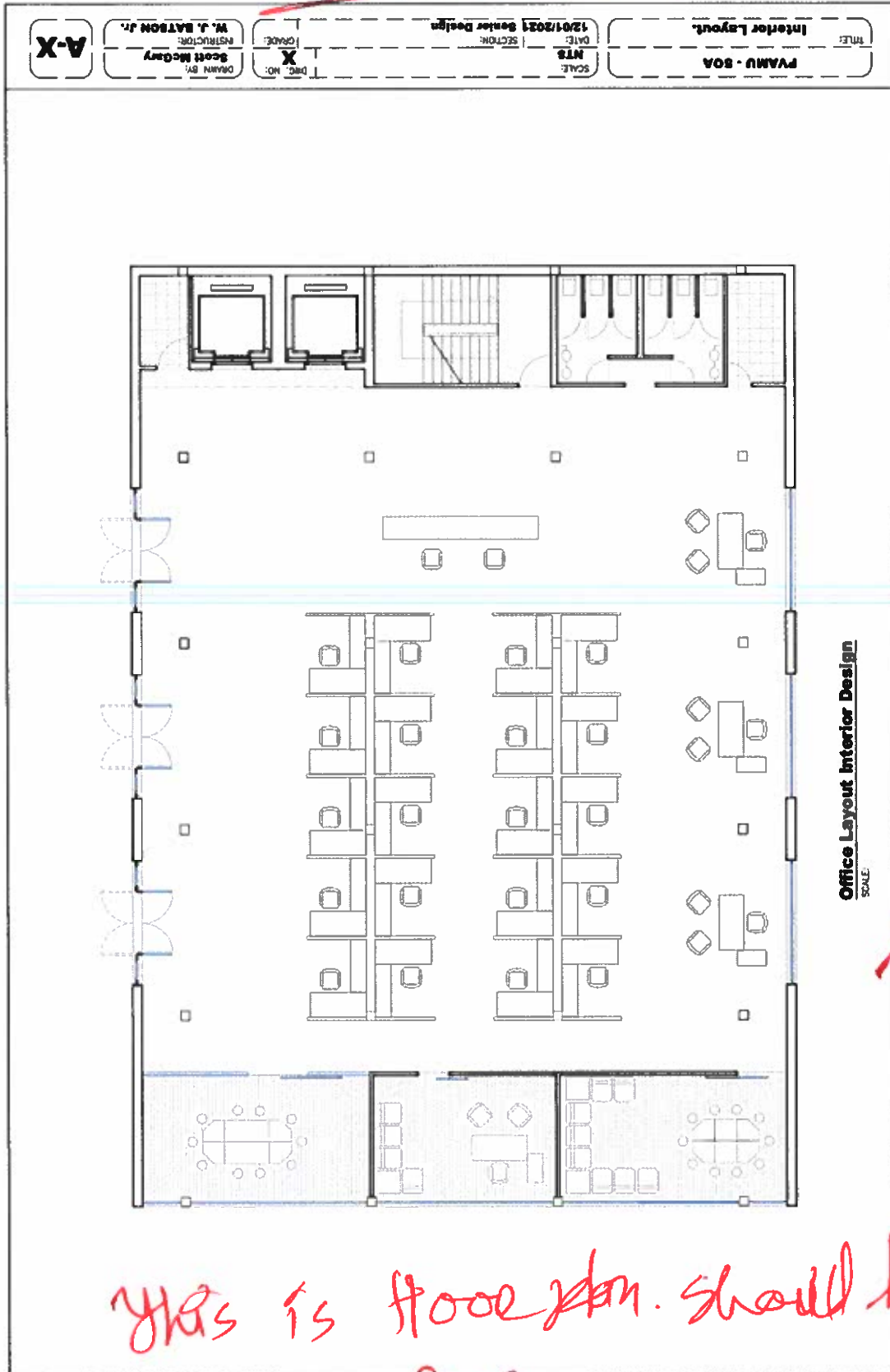


Figure 2.2 Preliminary Layout

Layout plan should be on separate page in landscape.

structures?



Geotechnical - section

2.1.2 Soil Properties

The boring log data for the location of the site is located below. This boring log displays the testing of the soil to classify the type of soil it is, the amount of stress it can take, as well as other properties of the soil that will make a difference when designing a structure on it.

The boring log tells the engineer the results from various tests of the soil within the site location. The log shows the depth of each kind of soil down to 70 feet. Based on the boring log data, the soil is classified as mostly Sandy Elastic Silt from boring 1 and Sandy Fat Clay from boring 2. Excel was utilized in developing a table to analyze this data. This was found by using the Liquid Limit (50), Plastic Limit (30), and Plasticity Index (29) according to the first table and Liquid Limit (60), Plastic Limit (27), and Plasticity Index (32) for the second table. This is shown on the boring log, and the use of the table and chart below to classify the soil of the site.

The bearing capacity of the soil was calculated by using the bearing capacity equation along with the safety factor.

$$q_u = 1.3cN_c' + qN_q' + 0.4\gamma B N_\gamma' \text{ (square foundation)}$$

Where

c = cohesion

B = width of footing

D_f = depth of the footing

The exact calculations of this are provided in the appendix. Using a FS factor of safety, of 3, the allowable bearing capacity, q_{allow} , was found.

$$q_{allow} = \frac{q_u}{FS}$$

Table 2.1 Soil Classification 1

Depth(ft)	Liquid Limit	Plastic Limit	Plastic Index	Sieve Analysis (#200)	Coarse Fraction	Water Content	Group Name	Classification
2.5	48	20		28	54%	46%	13% CL	Sandy Lean Clay
5	51	32		19	69%	31%	14% MH	Sandy Elastic Silt
10 ~	~	~	~	~	~	~	8%	Sand
12.5	46	19		27	74%	26%	18% CL	Sandy Lean Clay
17 ~	~	~	~	~	~	~	10%	Sand
20	32	16		16	59%	41%	13% CL	Sandy Lean Clay
25	60	31		29	81%	19%	21% MH	Sandy Elastic Silt
30	72	31		41	82%	18%	20% CH	Sandy Fat Clay
40	68	39		29	62%	38%	4% MH	Sandy Elastic Silt
50	80	39		41	69%	31%	18% MH	Sandy Elastic Silt
60	68	34		34	84%	16%	20% MH	Sandy Elastic Silt

Table 2.2 Soil Classification 2

Depth(ft)	Liquid Limit	Plastic Limit	Plastic Index	Sieve Analysis (#200)	Coarse Fraction	Water Content	Group Name	Classification
2.5	43	16		27	71%	29%	19% CL	Sandy Lean Clay
7.5	47	19		28	81%	19%	12% CL	Sandy Lean Clay
8.5 ~	~	~	~	~	20%	80%	6% ~	Sand
15	51	24		27	69%	31%	13% CH	Sandy Fat Clay
20 ~	~	~	~	~	16%	84%	8% ~	Sand
25	62	30		32	80%	20%	15% CH	Sandy Fat Clay
30	62	27		35	79%	21%	13% CH	Sandy Fat Clay
40	69	28		41	83%	17%	17% CH	Sandy Fat Clay
50	71	33		38	72%	28%	18% CH	Sandy Fat Clay
60	69	34		35	79%	21%	19% CH	Sandy Fat Clay

The Plasticity chart which is a graph between plasticity index (PI) and liquid limit (LL) in percentage which is used for the classification of fine-grained soils in accordance with the USCS. From the graph the geotechnical engineer can determine that low plasticity has a (LL) = < 35%, Intermediate plasticity (LL) = 35-50%, High plasticity (LL) = 50-70%, Very High plasticity (LL) 70-90%, and Extremely High plasticity (LL) = > 90%

To develop the boring logs AutoCAD needed to be used. The raw data given was tabulated, and the data produced was essential in creating the boring logs used to show the various fine-grained soils. This boring log also shows the elevations from which the raw information was taken.

Table 2.3 Boring 1 Analysis For Square Pile Section

Depth (ft)	SPT	Cu (psf)	Cu/Pa	α	Qp (lb)	Qs (lb)	Qu (lb)	f	f*AL
0	0	0	0	0	0	0	0	0	0
2.5	7	900	0.43	0.72	32400.00	3240.00	35640.00	648	1620
7.5	10	1200	0.57	0.6	43200.00	14040.00	57240.00	720	5400
9	15	0	0.00	0	0.00	14040.00	14040.00	0	0
15	15	2000	0.96	0.49	72000.00	43440.00	115440.00	980	14700
20	20	0	0.00	0	0.00	43440.00	43440.00	0	0
30	25	3400	1.63	0.38	122400.00	120960.00	243360.00	1292	38760
40	39	5300	2.54	0.34	190800.00	265120.00	455920.00	1802	72080
50	53	7100	3.40	0.34	255600.00	506520.00	762120.00	2414	120700
60	60	8000	3.83	0.34	288000.00	832920.00	1120920.00	2720	163200
68	89	9400	4.50	0.34	338400.00	1267576.00	1605976.00	3196	217328
							Sum		633788

Table 2.4 Boring 2 Analysis for Square Pile Section

Depth (ft)	SPT	Cu (psf)	Cu/Pa	α	Qp (lb)	Qs (lb)	Qu (lb)	f	f*AL
0	0	0	0.00	0.00	0.00	0.00	0.00	0	0
2.5	8	1000	0.48	0.67	36000.00	6700.00	42700.00	670	1675
5	10	1200	0.57	0.61	43200.00	21340.00	64540.00	732	3660
10	16	2100	1.01	0.48	75600.00	61660.00	137260.00	1008	10080
12.5	17	2250	1.08	0.47	81000.00	114535.00	195535.00	1057.5	13218.75
15	20	2500	1.20	0.41	90000.00	176035.00	266035.00	1025	15375
20	24	3300	1.58	0.39	118800.00	278995.00	397795.00	1287	25740
30	24	3300	1.58	0.39	118800.00	433435.00	552235.00	1287	38610
40	54	7200	3.45	0.34	259200.00	825115.00	1084315.00	2448	97920
50	44	5600	2.68	0.34	201600.00	1205915.00	1407515.00	1904	95200
60	72	9400	4.50	0.34	338400.00	1972955.00	2311355.00	3196	191760
68	98	9400	4.50	0.34	338400.00	2842267.00	3180667.00	3196	217328
							Sum		69748.75

capacity curve = ??

?

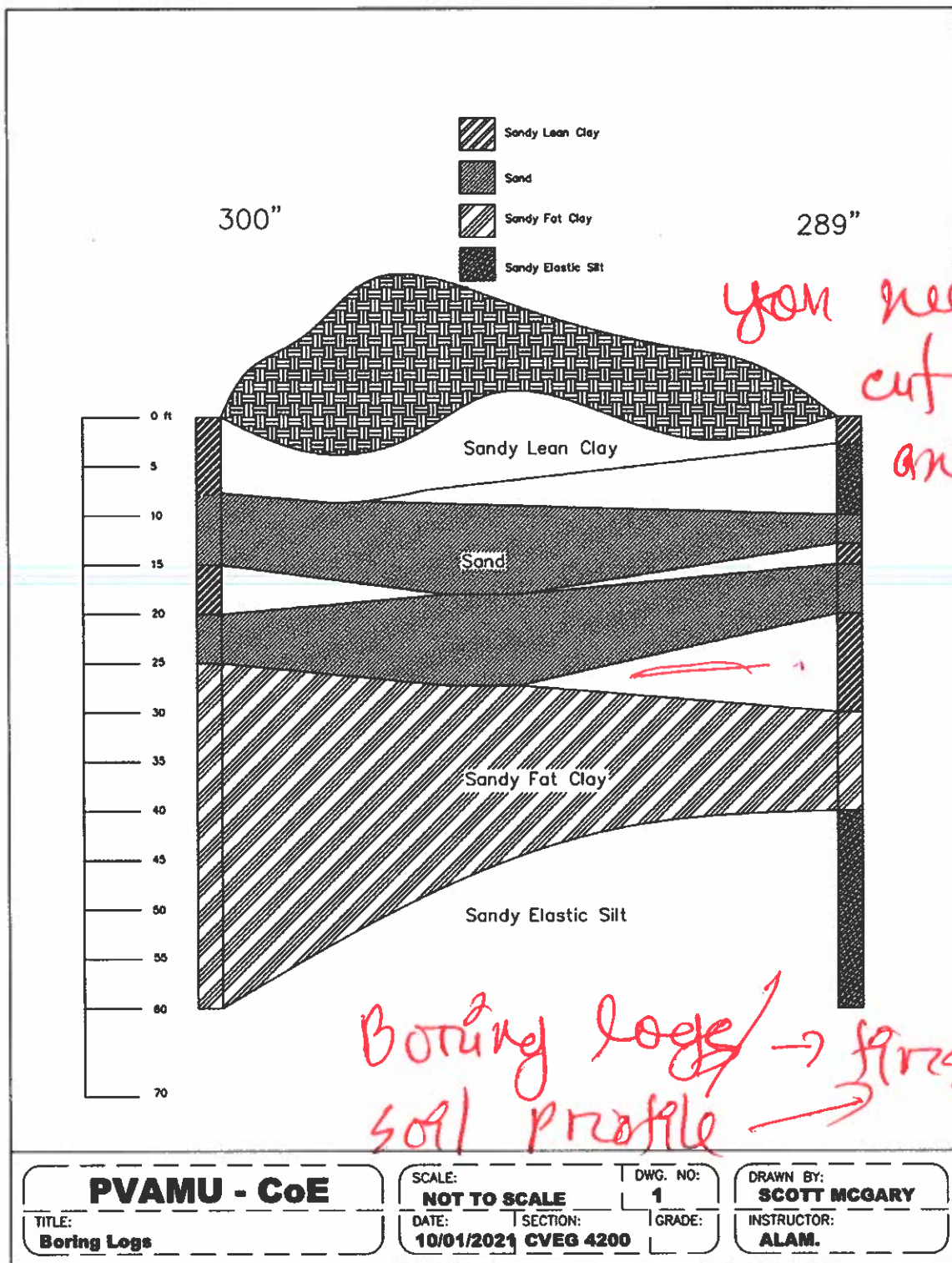


Figure 2.4 Boring Logs

2.2 Water Resources Engineering

2.2.1 Water Resources Objective

The objective of water resources is to design a ditch and a detention basin for the development of 400-acre land. The location of the proposed stormwater ditch was located at the lowest elevation of the proposed site using the local topographic map. The rainfall intensity for 100-year flooding was determined for Colorado County. The quantity of water and stormwater runoff was determined in order to build a ditch that can sustain the flow and detention basin.

2.2.2 Rainfall Intensity

The rainfall intensity was determined by using NOAA's National Weather Service. Using the chart the intensity interval for the 100 year flood period was found to be 0.591 in/hr. Reference Figure A.4 in Appendix that displays the precipitation frequency for Columbus, TX.

2.2.3 Stormwater Runoff

The water runoff depends upon the precipitation that infiltrates the ground. Once the infiltration capacity of the soil exceeds, the water begins to runoff. Development typically increases runoff and decreases absorption of water. Therefore, it is essential to determine the expected stormwater runoff to prevent damage to the property. To manage the stormwater, the pre-development runoff was determined. The runoff can be calculated with the rational equation,

$$Q = ciA$$

Q = peak runoff rate (cfs)

c = runoff coefficient

i = storm intensity (in/hr)

A = area (acres)

The area taken into account for pre-development was 400 acres since the land has no existing buildings. The runoff coefficient was determined to be 0.3 for farmland, the runoff for the pre-development was determined to be 47.28 cfs.

2.2.4 Drainage Ditch

An open channel is an integral part of a stormwater ditch design. In order to design an open trapezoidal channel, the manning equation was utilized.

$$Q = \frac{1.49}{n} AR^{2/3} S_o^{1/2}$$

Q = discharge, ft^3/s

n = roughness coefficient

A = flow area, ft^2

R = hydraulic radius

S_o = channel slope

The hydraulic radius can be expressed as,

$$R = \frac{A}{P}$$

P = perimeter, ft

The area and perimeter can be defined as,

$$A = by_o + zy_o^2$$
$$P = b + 2y_o\sqrt{1 + z^2}$$

z = side slope of the bank

y_o = channel depth, ft

b = bottom width, ft

The manning equation can be written as,

$$Q = \frac{1.49 A^{5/3}}{n P^{2/3}} S_o^{1/2}$$

The continuity equation can be written to find the design velocity,

$$Q = VA$$
$$V_{design} = \frac{Q}{A}$$

V_{design} = velocity, ft/s

2.2.5 Drainage Ditch Design

The Manning's equation and continuity equation were used to find the ditch dimensions.

Manning's roughness coefficient for a grass lined channel is 0.03 with a max permissible channel velocity of 3 to 6 ft/s. The slope of the channel is based on the elevation on the property, which was determined to be 0.7177. The slope of the drainage ditch will be 1:3. Excel was used to determine the channel depth and bottom width. The channel depth came out to be 0.494 ft and width of 3 ft.

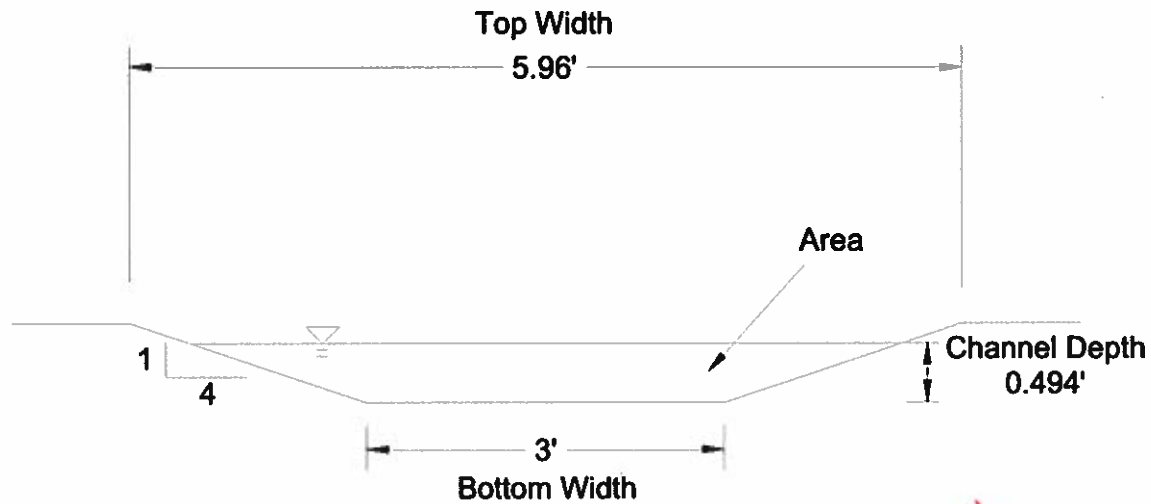


Figure 2.5 Section View of Trapezoid Ditch

The dimensions of the trapezoidal channel will support the discharge for the 100-year flood. Figure 2.6 displays the ditch in and flow of water on for a section of the development.

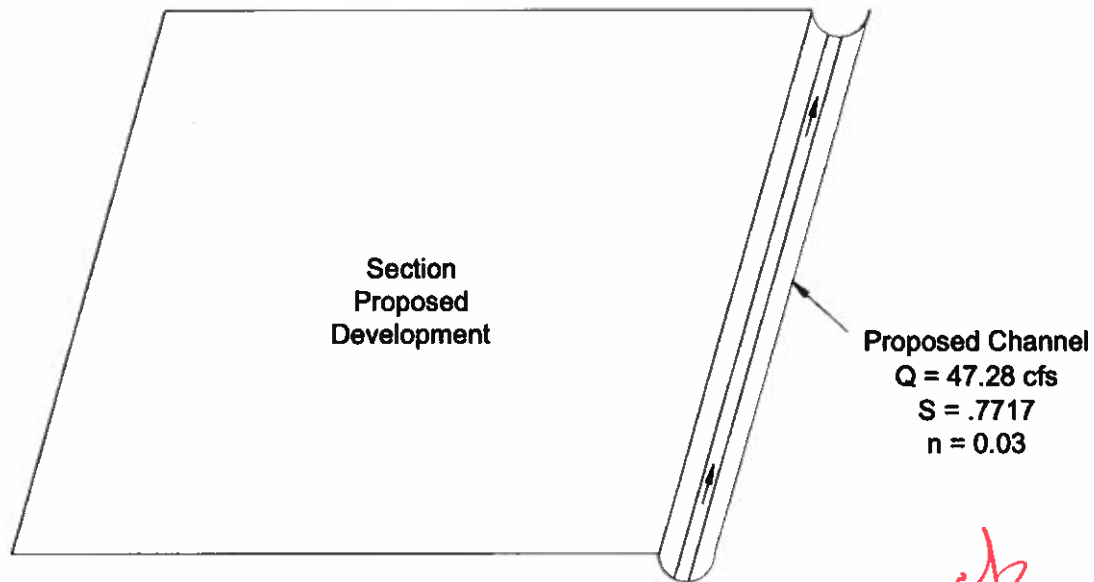


Figure 2.6 Profile View of Trapezoid Ditch

2.2.6 Stormwater Basin

The development requires a stormwater basin that allows the storage of runoff water in order to prevent flooding. With the data found on USGS the inflow of the ditch can be determined. A routing table can be developed to determine peak outflow, as shown in Table 2.2.6.

Table 2.5 Routing Table

Index	Time	Inflow, I	$(2s/\Delta t) - O$	$(2s/\Delta t) + O$	Outflow, O
(i)	(days)	(cfs)	(cfs)	(cfs)	(cfs)
1	0	517	21,600		500
2	1	519	22000	22,636	510
3	2	532	23000	23,051	550
4	3	741	24100	24,273	610
5	4	937	24200	25,778	690
6	5	645	25500	25,782	700
6	6	600	24000	26,745	690
7	7	590	23900	25,190	620
8	8	570	23800	25,060	610
9	9	565	23000	24,935	590

Figure 2.7 illustrates the inflow and outflow of the routing table. The peak discharge taken into account for the detention basin is 700 cfs.

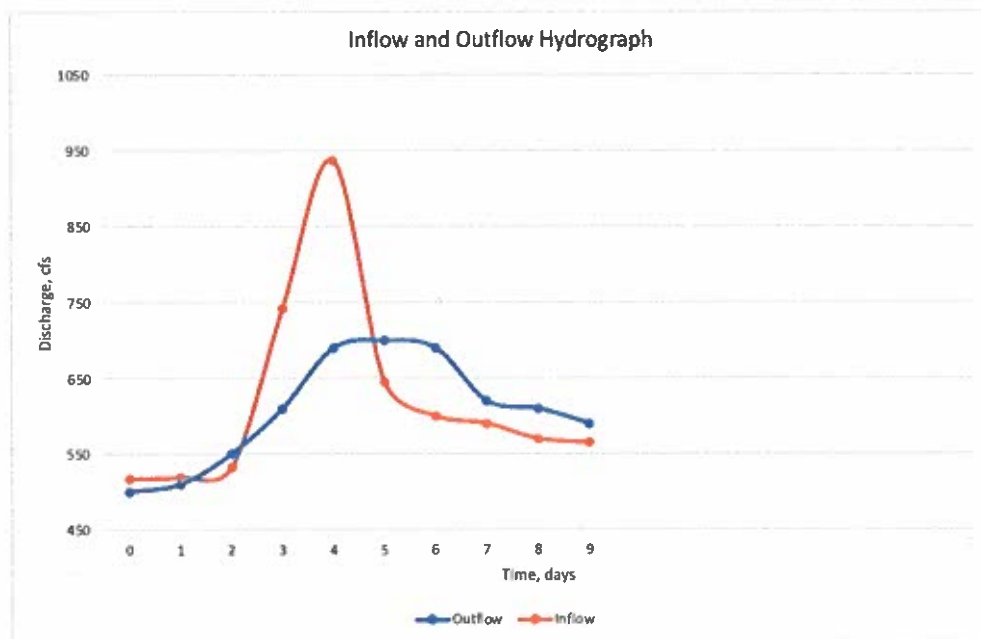


Figure 2.7 Inflow Hydrograph

The basin is suggested to have dimensions of 64ft by 64ft with a depth of 3.2ft. Figure 2.8 and 2.9 shows the section and profile view respectively.

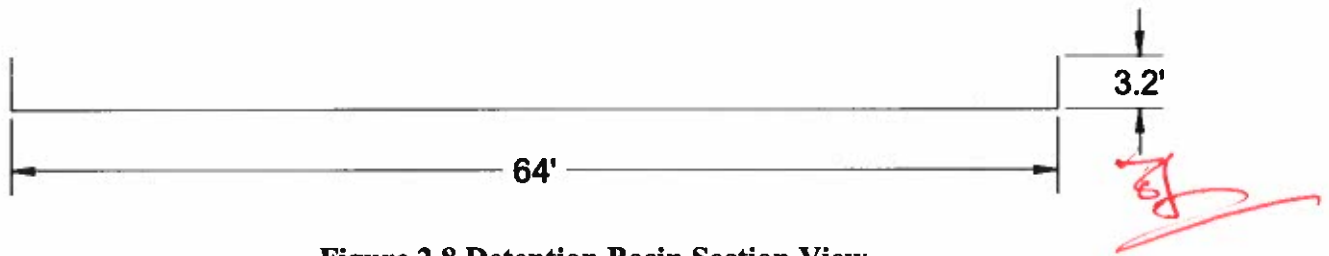


Figure 2.8 Detention Basin Section View

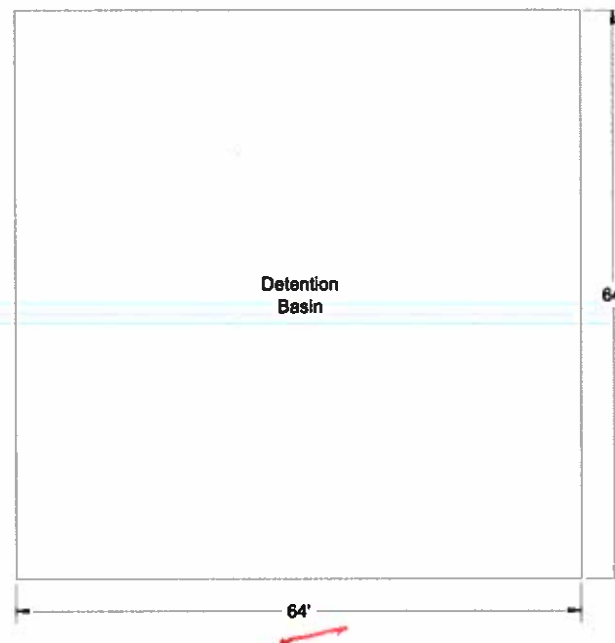


Figure 2.9 Detention Basin Profile View

*cross section
required.*

2.3 Structural Engineering

Structural requires a 2D drawing of the office buildings, warehouse, and convention center. To determine structural load calculations, wind, dead, and live load will be taken for each structure. The load calculations will then be put into STAAD Pro, to provide maximum values of BM, shear, and axial load. Moreover, the structural design will include slab design, beam, and column design, the steel structure design of the warehouse, and reinforcement bars, and reinforced concrete design for foundations, including footing size, reinforcement.

2.4 Transportation Engineering

The goal for transportation is to provide a roadway layout for the project site and to have a connecting road with the highway (I-10). When designing the road interchange designs will be implemented. Plan and profile view and pavement-design cross-section of a typical road will be

included as well. When designing the roads, there will be a minimum of two entrances, left turn movements will be at each entrance, a right-turn lane will be at the main entrance, and at least one entrance will be regulated by traffic signals. Also, there will be parking lots within the project site, service truck parking for the warehouse will be separated from cars to accommodate visitors coming to the office building for Amazon. Additionally, the site will also include sidewalks throughout the business center and subdivision including residential areas, landscaping, and streetlights.

To get started on transportation, the roadway layout will be the first step. The engineer will determine how many roads are needed by taking into consideration existing roads nearby and the type of interchange that will best fit and meet Texas Department of Transportation (TxDOT) and US DOT requirements and specifications. The design for the roadway layout will begin in the next few weeks. Then, next semester the other sections for transportation will be completed.

2.5 Environmental Engineering

The beneficial purpose of environmental designing in the vicinity of Amazon's Distribution Center and IT Hub is to provide an efficient amount of water used for primary purposes that are useful to human life. The importance of water is to control and eliminate diseases, quality of life, carry out waste, and commercial and industrial activities. The municipal water use for this project will be categorized into domestic, and commercial/industrial usage; initializing the quality and quantity of water that will be useful on this site.

As the environmental engineer on this project, we will estimate the inflow water demand for the facility population of twenty thousand with a project projection for 15 years. We will also calculate the water demand for expansion for an additional 10-15 years for possible expansion of the center and surrounding area and communities. With the inflow of water throughout the quarters of the premises we'll have to follow EPA (Environmental Protection Agency) regulations regarding the Maximum Contaminant Level (MCL) that is legally enforced for human consumption and usage; National Primary Drinking Water Regulation. The placement of our wastewater treatment plant (WWTP) is located in the lower southeast region of our 400-acre lot, as of now, we are still working on the methodology for cleaning the wastewater before the disposal of effluent into a source of surface water. The disposal source for the facilities will be Griffin Lake following the Texas Administrative Code (TAC).

The first portion of the design process will start with calculating the population in Columbus, Texas from the past five years, then calculate the population projection with the addition of twenty-thousands employees for future population. We will obtain the current estimated per capita raw water demand to determine our Q values. This process will begin over the span of Christmas Break up until the start of spring semester. The remaining tasks such as developing a wastewater schematic design, developing a disposal site, and articulating the proper disposal of

treated effluent contaminant level causing no harm to the environment and ecosystem will be completed throughout the upcoming semester.

82

Chapter 3: References

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Appendix 1 Images

Geotechnical Data Collected

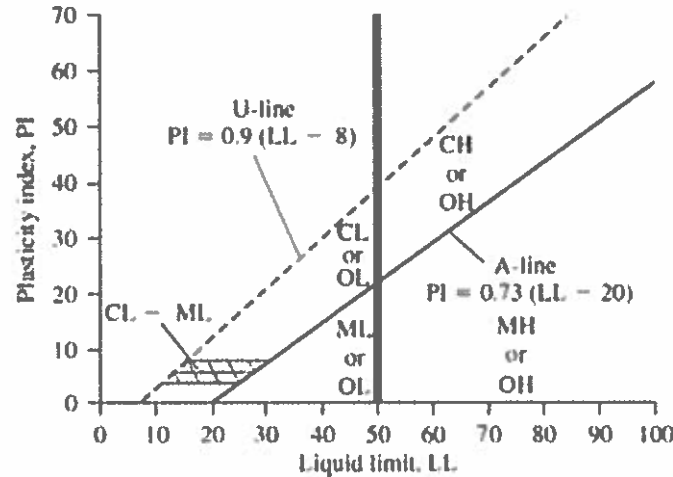


Figure A.1 Plasticity Chart

3.3 Terzaghi's Bearing Capacity Theory 139

Table B.1 Terzaghi's Bearing Capacity Factors—Eqs. (3.4), (3.5), and (3.6) a From Kumbhojkar (1993)

ϕ°	N_c	N_q	N_γ^a	ϕ°	N_c	N_q	N_γ^a
0	5.70	1.00	0.00	26	27.09	14.21	9.84
1	6.00	1.10	0.01	27	29.24	15.90	11.60
2	6.30	1.22	0.04	28	31.61	17.81	13.70
3	6.62	1.35	0.06	29	34.24	19.98	16.18
4	6.97	1.49	0.10	30	37.16	22.46	19.13
5	7.34	1.64	0.14	31	40.41	25.28	22.63
6	7.73	1.81	0.20	32	44.04	28.52	26.87
7	8.15	2.00	0.27	33	48.09	32.23	31.94
8	8.60	2.21	0.35	34	52.64	36.50	38.04
9	9.09	2.44	0.44	35	57.75	41.44	45.41
10	9.61	2.69	0.56	36	63.53	47.16	54.36
11	10.16	2.98	0.69	37	70.01	53.80	65.27
12	10.76	3.29	0.85	38	77.50	61.55	78.61
13	11.41	3.63	1.04	39	85.97	70.61	95.03
14	12.11	4.02	1.26	40	95.66	81.27	115.31
15	12.86	4.45	1.52	41	106.81	93.85	140.51
16	13.68	4.92	1.82	42	119.67	108.75	171.99
17	14.60	5.45	2.18	43	134.58	126.50	211.56
18	15.12	6.04	2.59	44	151.95	147.74	261.60
19	16.56	6.70	3.07	45	172.28	173.28	325.34
20	17.69	7.44	3.64	46	196.22	204.19	407.11
21	18.92	8.26	4.31	47	224.55	241.80	512.84
22	20.27	9.19	5.09	48	258.28	287.85	650.67
23	21.75	10.23	6.00	49	298.71	344.63	831.99
24	23.36	11.40	7.08	50	347.50	415.14	1072.80
25	25.13	12.72	8.34				

^aFrom Kumbhojkar (1993)

Figure A.2: Terzaghi Bearing Capacity Factors

Table 24. Approximate values of undrained shear strength for cohesive soils based on SPT blow count N-values (from Terzaghi and Peck, 1967)

Soil Consistency	SPT N (See Note)	S _u (psf)
Very Soft	< 2	< 250
Soft	2 - 4	250 - 500
Medium	4 - 8	500 - 1000
Stiff	8 - 15	1000 - 2000
Very Stiff	15 - 30	2000 - 4000
Hard	> 30	> 4000

Figure A.3: Approximate Value of Cu, SPT and soil consistency

Water Resources Engineering

Duration	PDS-based precipitation frequency estimates with 90% confidence intervals (in inches/hour) ¹									
	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	5.72 (4.33-7.57)	6.61 (5.08-8.66)	8.08 (6.19-10.6)	9.28 (6.96-12.3)	10.9 (7.92-15.0)	12.1 (8.59-17.1)	13.4 (9.23-19.4)	14.6 (9.84-21.8)	16.3 (10.8-25.2)	17.6 (11.2-27.8)
10-min	4.55 (3.44-6.01)	5.26 (4.02-6.89)	6.43 (4.90-8.46)	7.40 (5.55-9.86)	8.72 (6.35-12.0)	9.73 (6.90-13.7)	10.7 (7.39-15.6)	11.7 (7.84-17.4)	12.9 (8.37-19.8)	13.8 (8.71-21.8)
15-min	3.84 (2.91-5.08)	4.42 (3.38-5.80)	5.38 (4.10-7.08)	6.17 (4.63-8.22)	7.24 (5.28-9.92)	8.04 (5.89-11.3)	8.84 (6.10-12.8)	9.66 (6.50-14.4)	10.8 (6.90-16.6)	11.6 (7.34-18.3)
30-min	2.74 (2.07-3.61)	3.13 (2.40-4.11)	3.79 (2.89-4.99)	4.33 (3.25-5.77)	5.06 (3.67-6.82)	5.59 (3.95-7.88)	6.14 (4.23-8.90)	6.73 (4.53-10.0)	7.54 (4.90-11.6)	8.19 (5.18-12.9)
60-min	1.78 (1.35-2.38)	2.06 (1.58-2.70)	2.51 (1.92-3.31)	2.88 (2.17-3.85)	3.40 (2.46-4.84)	3.77 (2.66-5.31)	4.17 (2.87-6.04)	4.60 (3.10-6.88)	5.23 (3.40-8.07)	5.74 (3.63-8.77)
2-hr	1.07 (0.816-1.41)	1.28 (0.973-1.64)	1.60 (1.22-2.08)	1.87 (1.41-2.48)	2.26 (1.65-3.08)	2.57 (1.82-3.60)	2.90 (2.01-4.18)	3.26 (2.23-4.85)	3.84 (2.50-5.89)	4.31 (2.74-6.76)
3-hr	0.779 (0.584-1.02)	0.947 (0.720-1.21)	1.20 (0.921-1.56)	1.43 (1.08-1.89)	1.77 (1.28-2.40)	2.03 (1.45-2.84)	2.33 (1.62-3.34)	2.68 (1.81-3.94)	3.18 (2.08-4.86)	3.51 (2.30-5.65)
6-hr	0.447 (0.342-0.579)	0.541 (0.424-0.700)	0.728 (0.559-0.934)	0.894 (0.671-1.18)	1.12 (0.826-1.51)	1.31 (0.943-1.83)	1.54 (1.07-2.19)	1.79 (1.22-2.62)	2.17 (1.42-3.29)	2.48 (1.58-3.88)
12-hr	0.259 (0.183-0.323)	0.323 (0.243-0.385)	0.428 (0.327-0.538)	0.534 (0.399-0.800)	0.675 (0.502-0.910)	0.809 (0.584-1.12)	0.982 (0.673-1.36)	1.13 (0.771-1.64)	1.38 (0.912-2.09)	1.58 (1.03-2.47)
24-hr	0.141 (0.109-0.181)	0.186 (0.136-0.224)	0.248 (0.181-0.312)	0.309 (0.237-0.399)	0.405 (0.303-0.544)	0.491 (0.358-0.679)	0.581 (0.445-0.809)	0.686 (0.478-1.00)	0.854 (0.583-1.27)	0.961 (0.632-1.50)
2-day	0.090 (0.062-0.101)	0.107 (0.080-0.127)	0.144 (0.112-0.180)	0.182 (0.140-0.233)	0.241 (0.183-0.324)	0.297 (0.218-0.409)	0.358 (0.253-0.499)	0.419 (0.287-0.597)	0.509 (0.330-0.738)	0.582 (0.383-0.854)
3-day	0.068 (0.045-0.073)	0.078 (0.059-0.092)	0.105 (0.082-0.130)	0.132 (0.102-0.169)	0.174 (0.133-0.234)	0.214 (0.158-0.294)	0.257 (0.182-0.387)	0.299 (0.205-0.424)	0.354 (0.236-0.521)	0.396 (0.266-0.590)
4-day	0.047 (0.036-0.059)	0.062 (0.047-0.073)	0.083 (0.065-0.103)	0.104 (0.080-0.132)	0.136 (0.104-0.181)	0.168 (0.122-0.226)	0.198 (0.148-0.274)	0.230 (0.158-0.325)	0.272 (0.181-0.389)	0.306 (0.197-0.459)
7-day	0.031 (0.024-0.039)	0.040 (0.031-0.048)	0.053 (0.041-0.065)	0.065 (0.050-0.082)	0.083 (0.063-0.108)	0.099 (0.073-0.134)	0.117 (0.083-0.161)	0.135 (0.093-0.191)	0.161 (0.107-0.234)	0.181 (0.117-0.271)
10-day	0.024 (0.019-0.030)	0.030 (0.024-0.037)	0.040 (0.031-0.049)	0.048 (0.038-0.061)	0.061 (0.046-0.080)	0.072 (0.053-0.097)	0.084 (0.060-0.116)	0.097 (0.067-0.138)	0.115 (0.077-0.165)	0.130 (0.085-0.194)
20-day	0.016 (0.012-0.019)	0.019 (0.015-0.023)	0.025 (0.019-0.030)	0.032 (0.023-0.037)	0.038 (0.027-0.048)	0.041 (0.030-0.055)	0.047 (0.034-0.064)	0.053 (0.037-0.074)	0.062 (0.042-0.090)	0.069 (0.045-0.103)
30-day	0.012 (0.010-0.015)	0.015 (0.012-0.018)	0.019 (0.015-0.023)	0.022 (0.017-0.028)	0.027 (0.020-0.035)	0.031 (0.022-0.040)	0.034 (0.025-0.046)	0.038 (0.027-0.053)	0.044 (0.030-0.063)	0.048 (0.032-0.072)
45-day	0.010 (0.008-0.013)	0.012 (0.010-0.015)	0.015 (0.012-0.019)	0.018 (0.014-0.022)	0.021 (0.015-0.027)	0.023 (0.017-0.031)	0.026 (0.019-0.036)	0.029 (0.020-0.040)	0.032 (0.022-0.046)	0.035 (0.022-0.051)
60-day	0.009 (0.007-0.011)	0.011 (0.009-0.013)	0.013 (0.010-0.018)	0.015 (0.012-0.019)	0.018 (0.013-0.023)	0.020 (0.015-0.026)	0.022 (0.016-0.029)	0.024 (0.017-0.033)	0.026 (0.018-0.037)	0.028 (0.018-0.041)

Figure A.4 Precipitation Point Frequency

Channel Description	Manning's n	Maximum Permissible Channel Velocity (ft/s)
MINOR NATURAL STREAMS		
Fairly regular section		
1. Some grass and weeds; little or no brush	0.030	3 to 6
2. Dense growth of weeds, depth of flow materially greater than weed height	0.035	3 to 6
3. Some weeds, light brush on banks	0.035	3 to 6
4. Some weeds, heavy brush on banks	0.050	3 to 6
5. Some weeds, dense willows on banks	0.060	3 to 6
For trees within channels with branches submerged at high stage, increase above values by	0.010	
Irregular section with pools, slight channel meander, increase above values by	0.010	
Floodplain – Pasture		
1. Short grass	0.030	3 to 6
2. Tall grass	0.035	3 to 6
Floodplain – Cultivated Areas		
1. No crop	0.030	3 to 6
2. Mature row crops	0.035	3 to 6
3. Mature field crops	0.040	3 to 6
Floodplain – Uncleared		
1. Heavy weeds scattered brush	0.050	3 to 6
2. Wooded	0.120	3 to 6
MAJOR NATURAL STREAMS		
Roughness coefficient is usually less than for minor streams of similar description on account of less effective resistance offered by irregular banks or	Range from 0.028 to 0.060	3 to 6

Figure A.5 Roughness Coefficient

Appendix 2 Calculations

Water Resources

Stormwater Runoff

$$Q = ciA$$

$$Q = (0.3)(0.91 \text{ in/hr})(400 \text{ acres})$$

$$Q = 47.28 \text{ cfs}$$

Drainage Ditch

$$Q = 47.28 \text{ cfs}$$

$$Z = 3 \quad (1:3)$$

$$S_0 = 0.7177 \text{ ft/ft}$$

$$\text{assume } b = 3$$

• Flow area

$$A = by + zy^2$$

$$A = (3 \text{ ft})(0.494 \text{ ft}) + (3)(0.494 \text{ ft})^2$$

$$A = 2.214 \text{ ft}^2$$

• Top width

$$T = b + 2zy$$

$$T = (3 \text{ ft}) + 2(3)(0.494 \text{ ft})$$

$$T = 5.904 \text{ ft}$$

• Wetted Perimeter

$$P = b + 2\sqrt{y^2 + Z^2y^2}$$

$$P = 3 \text{ ft} + 2\sqrt{(0.494 \text{ ft})^2 + (3)^2(0.494 \text{ ft})^2}$$

$$P = 6.124 \text{ ft}$$

• Hydraulic Radius

$$R = A/P$$

$$R = (2.214 \text{ ft}^2) / 6.124 \text{ ft}$$

$$R = 0.3615 \text{ ft}$$

hand calculation - ?

• Hydraulic Depth

$$D = A / T$$

$$D = (2.214 \text{ ft}^2) / 5.964$$

$$D = 0.3712 \text{ ft}$$

• Flowrate

$$Q = \frac{1.49}{n} A R^{2/3} S_o^{1/2}$$

$$Q = \frac{1.49}{0.03} (2.214 \text{ ft}^2) (0.3015 \text{ ft})^{2/3} (0.7177)^{1/2}$$

$$Q = 47.28 \text{ cfs}$$

• Channel Velocity

$$V = Q / A$$

$$V = \frac{47.28 \text{ cfs}}{2.214 \text{ ft}^2}$$

$$V = 21.35 \text{ ft/s}$$

75

Prairie View A&M University
Roy G Perry College of Engineering
Civil & Environmental Engineering Department



CVEG 4200-P01 – Senior Design

Fall 2021

**Project Report 1- Development of Business and
Distribution Center, and IT Hub for Amazon**

Submitted to:

Dr. Jobair Bin Alam

Submitted by: JJMPS Consulting

Sydney Jones, Paige Hines, Jerral Walker, Michael Leblanc,

Johnathon Chevalier

Date Due: December 1st, 2021

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Introduction

PVAMU Civil Engineering Students are to develop and design the business and distribution center, IT Hub, and office development on a 400-acre site located in Waller, Washington and Colorado Counties located south of major Highways (US 290 and I-10) for Amazon. The specific scope of the project will include Civil Engineering Development and Design services for the entire site which will include two five-story commercial office buildings, a steel structure warehouse, a three-story convention center, and parking lots. The students will also perform new road network development, engineering design of pavement and pavement subgrade, intersections, sidewalks, driveways, and extension of major highways/service road and connecting local road with highway, a storm water ditch connecting a major lake, a municipal solid waste and a temporary recyclables disposal facility, and wastewater treatment process and facility. The facilities will be designed for 20,000 people or based on population projection for 15 years. A map showing site locations is included at the end of this document.

Project Scope

The project team is required to perform Civil Engineering Site Development and Design services and address all aspects outlined in the project description:

Employee Count – 20,000 employees

- o 40% of employees in the warehouse
- o 35% of employees in the warehouse

- o 15% of employees in the IT Hub
- o 10% of employees in the warehouse

Location – Waller County



Figure 1.1: Waller County Project Location

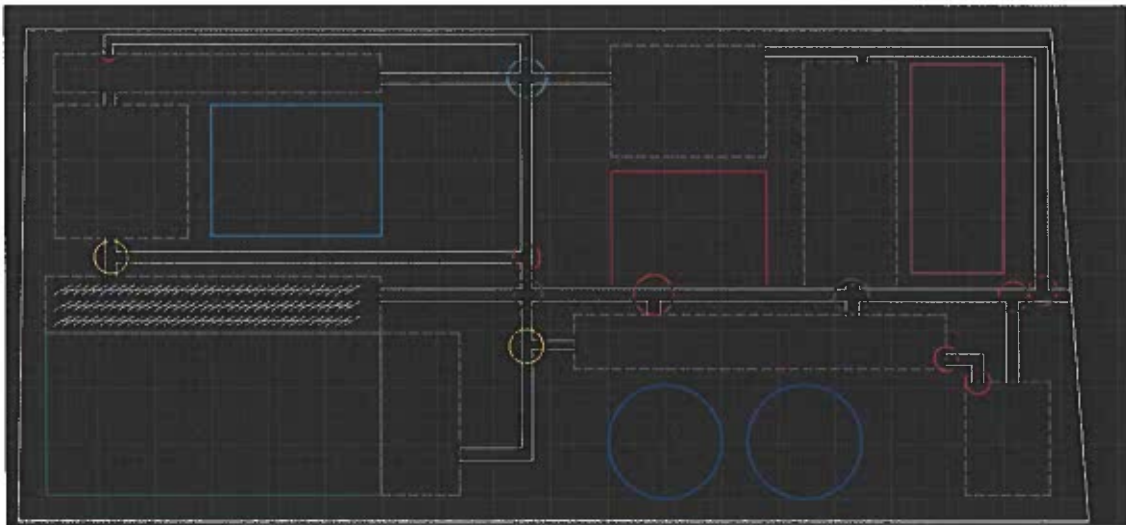


Figure 1.2: Project Plan View

Labels?
Layout plan on any CAD drawing in white background is recommended.

Progression Timeline

Structural Engineering:

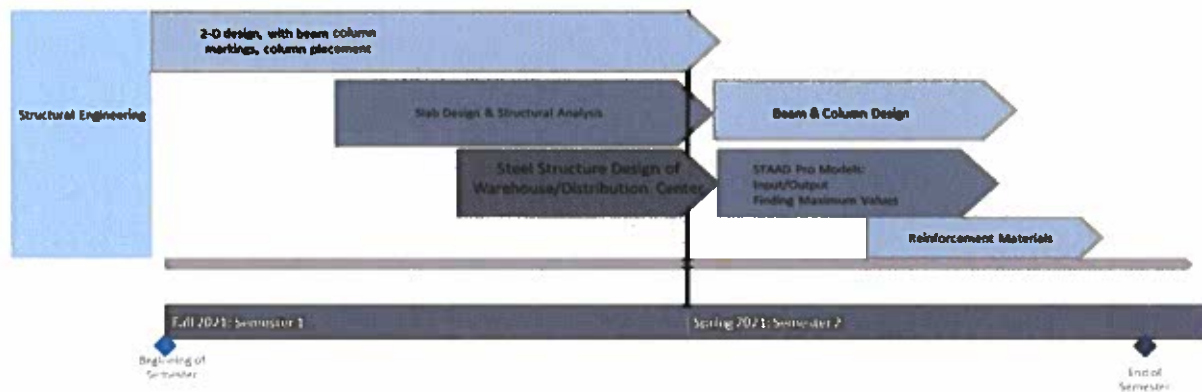


Figure 2.1: Structural Engineering Progression Timeline

Geotechnical Engineering:

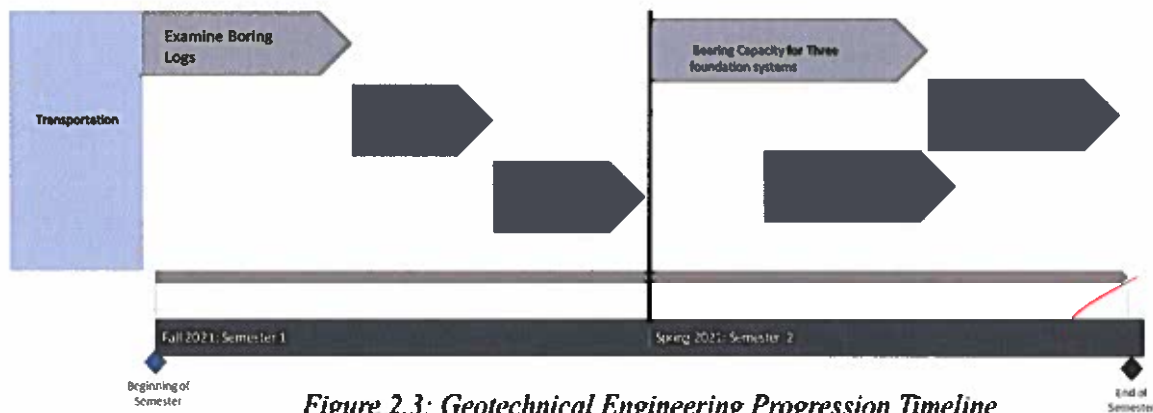


Figure 2.3: Geotechnical Engineering Progression Timeline

Water Resources Engineering:

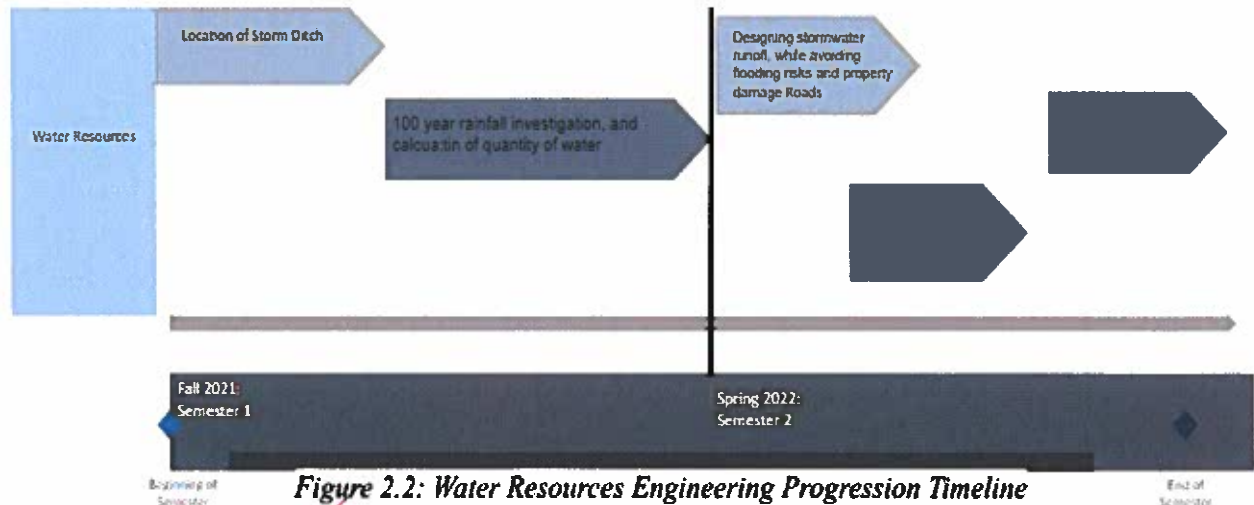


Figure 2.2: Water Resources Engineering Progression Timeline

Transportation Engineering:

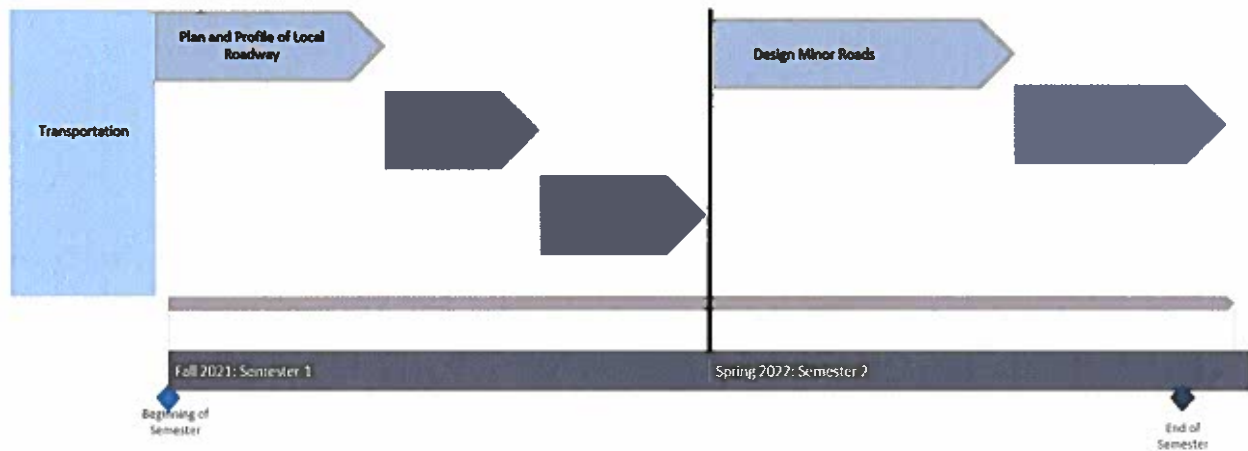


Figure 2.4: Transportation Engineering Progression Timeline

Environmental Engineering:

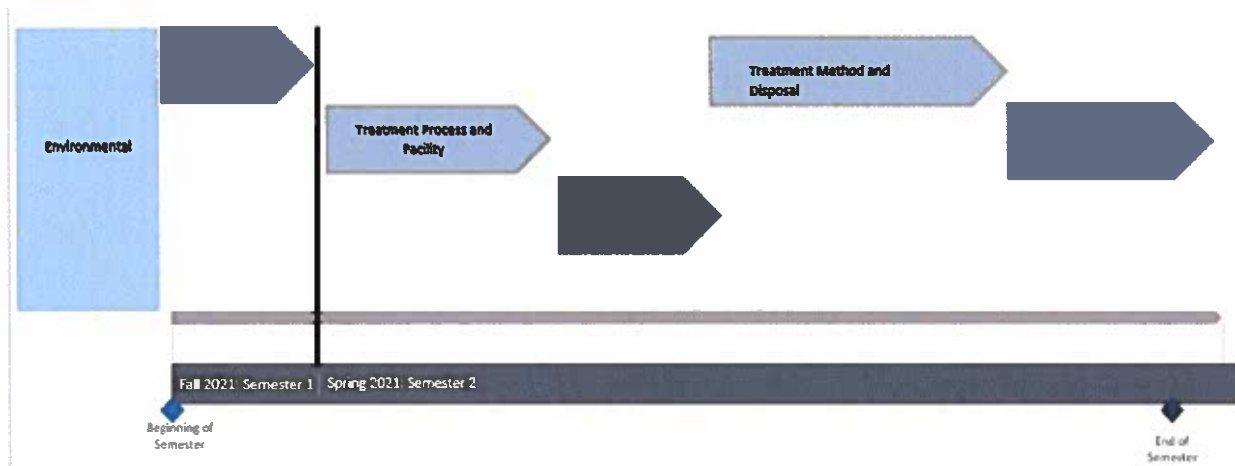


Figure 2.4: Environmental Engineering Progression Timeline

OK

OK! now
more detail breakdown
of the tasks is required.

Water Resources

For the water resources part, the location of the storm water ditch was discussed and placed with the help of the environmental and geotechnical authorities so that all aspects balance out. Engineers studied the site using google maps to understand the elevation of the construction site. Obtaining that information, the storm drainage ditches could be designed by the use of gravity to create flow from the highest elevation. Below is a demonstration of where the storm ditch will be placed as well as the detention basin:



The quantity of water was calculated by using the rational method. This equation represents the relationship between rainfall intensity and catchment area as independent variables and the investigation of the 100 year peak flood discharge as a dependent variable. This will help with determining Q, the storm water runoff to avoid risk of flooding and property damage.

Rational Method:

$$Q = C * I * A$$

Where

Q = Runoff Flow

C = Runoff Coefficient

I = Rainfall Intensity

A = Acres

$$127.05cfs = .3 \times 1.05 \frac{in}{hr} \times 400acres \times \frac{43560 ft}{1in} \times \frac{1ft}{12in} \times \frac{1hr}{3600s}$$

All water will be carried from the pre/post construction area at its highest elevation, in a designed trapezoid channel based on the peak rainfall in Waller county. The elevation information has been obtained from my geotechnical engineer. To complete the design a profile and crosssection will be provided.

~ why trapezoidal? you may decide your channel geometry after design?

Structural Engineering

Requirements and Designs

- i. 2D Drawing- For the purpose of understanding, the IT Hub will be fully disclosed with figures and an explanation as a guide to how the other buildings were designed and accurately accounted for. Refer to appendix for *Excel file 1* to account for the other buildings.

1. It Hub

a. AREA:

- i. 100,000 square feet
- ii. 400'x 250'

b. 4 – story building

- c. This building is to be able to employ 10% of the projected 20,000 employees that are to be hired by Amazon.

2. Office Buildings

a. AREA:

- i. 540,225 square feet (Combined)
- ii. 12.5 acres roughly

b. 5 – story building each

- c. These buildings are to be able to employ of 30% of the projected 20,000 employees that is to be hired by Amazon.

3. Convention Center

a. AREA:

- i. 2.5 million square feet
- ii. 57 acres (largest structure)

b. 3 – story building

- c. This building is to be able to employ at least 15% of the projected 20,000 employees that is to be hired by Amazon.

4. Warehouse

a. AREA:

- i. 350,000 square feet
- ii. 1000'x 350'

b. 1 – story building

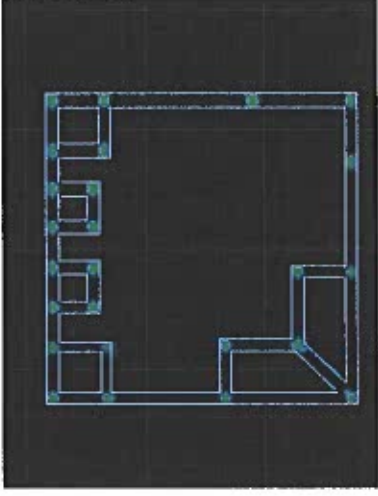
- c. This building is to be able to employ at least 45% of the projected 20,000 employees that are to be hired by Amazon.

2. Structural load calculation/ Slab Design

- i. As an update, the determination of load for each structure is being calculated and appraised with regards to references from multiple manuals and from similar buildings of the same structure in the nearby area.
- 3. Beam Column Design
- 4. Completion of Steel Structure
- 5. STAAD Pro
- 6. Reinforcement Materials

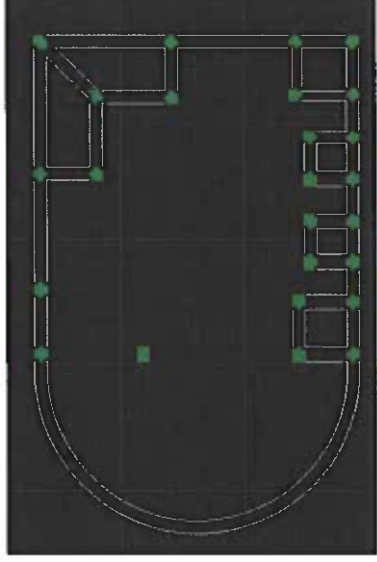
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 label?

Figure 3.1: First Floor of IT Hub



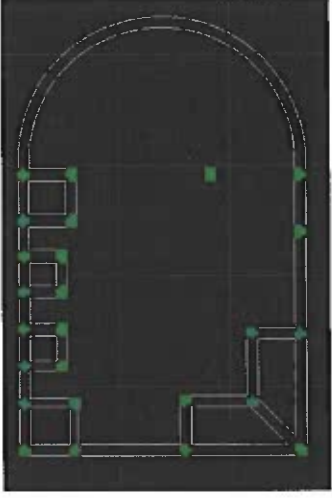
This figure includes an autocad version of the 2-D drawing of the first floor of the IT Hub designs with beam & column placement.

Figure 3.2: Second Floor of IT Hub



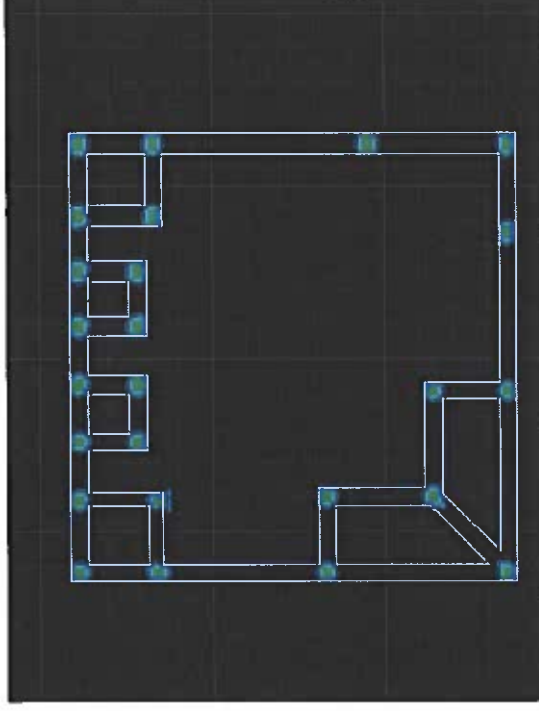
This figure includes an autocad version of the 2-D drawing of the second floor of the IT Hub designs with beam & column placement.

Figure 3.3: Third Floor of IT Hub



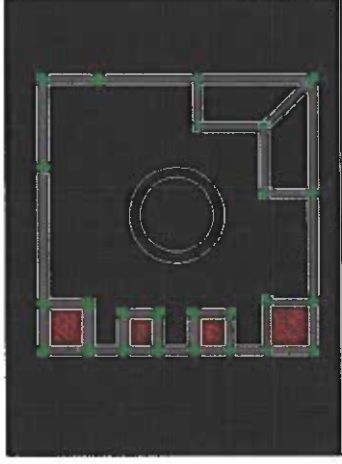
This figure includes an autocad version of the 2-D drawing of the third floor of the IT Hub designs with beam & column placement.

Figure 3.4: Fourth Floor of IT Hub



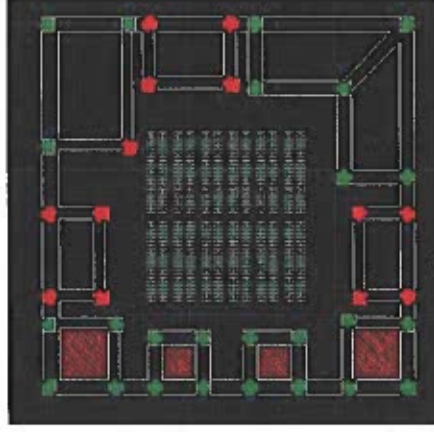
This figure includes an autocad version of the 2-D drawing of the fourth floor of the IT Hub designs with beam & column placement.

Figure 3.5: First Floor of Office Buildings



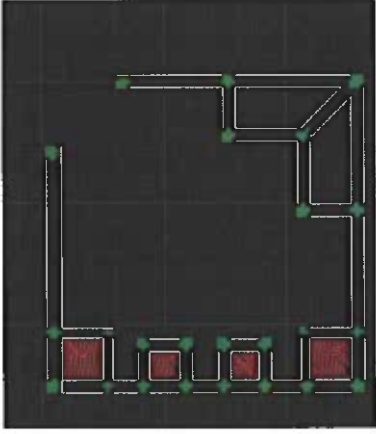
This figure includes an autocad version of the 2-D drawing of the first floor of the office building designs with beam & column placement.

Figure 3.6: Second Floor of Office Buildings



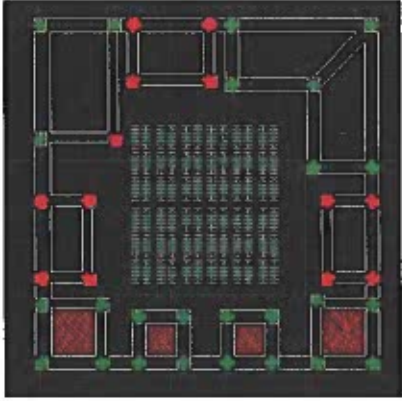
This figure includes an autocad version of the 2-D drawing of the first floor of the office building designs with beam & column placement.

Figure 3.7: Third Floor of Office Buildings



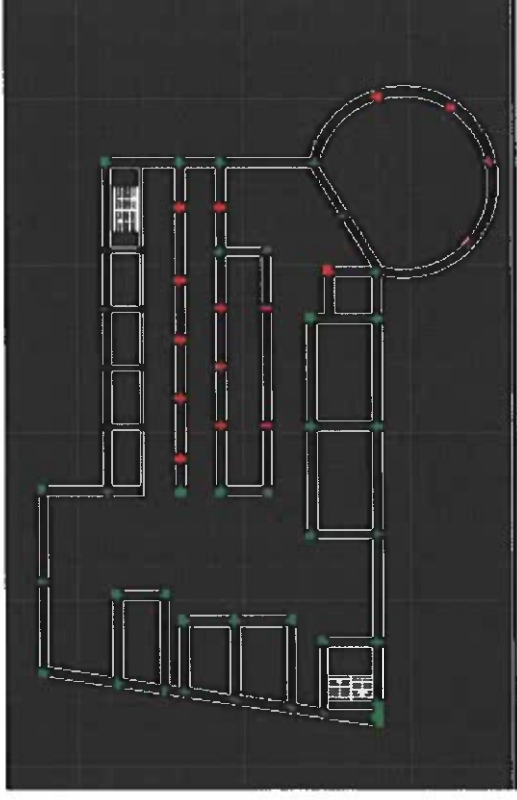
This figure includes an autocad version of the 2-D drawing of the third floor of the office building designs with beam & column placement.

Figure 3.8: Fourth/Fifth Floor of Office Buildings



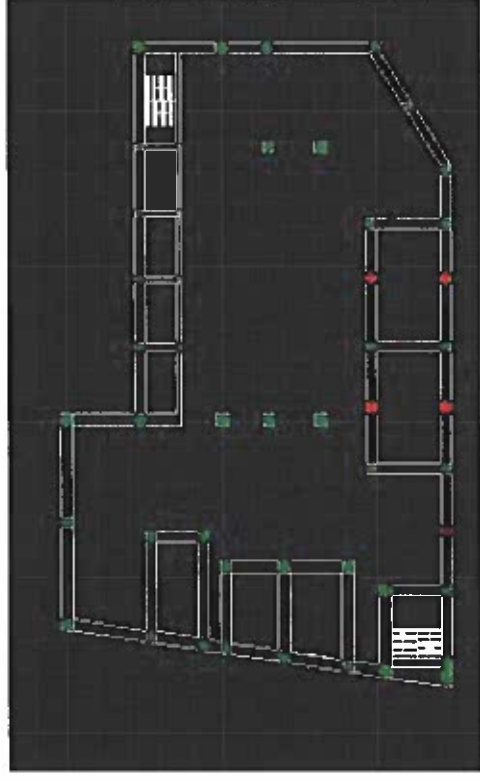
This figure includes an autocad version of the 2-D drawing of the fourth and fifth floor of the office building designs with beam & column placement.

Figure 3.9: First Floor of Convention Center



This figure includes an autocad version of the 2-D drawing of the first floor of the convention center designs with beam & column placement

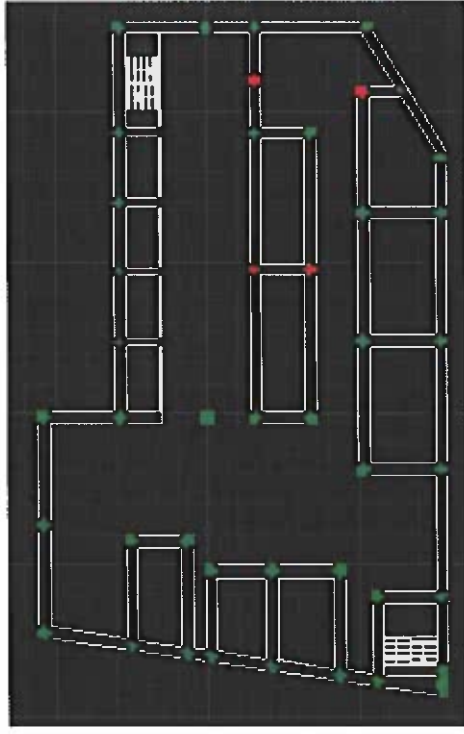
Figure 3.10: Second Floor of Convention Center



This figure includes an autocad version of the 2-D drawing of the second floor of the convention center designs with beam & column placement

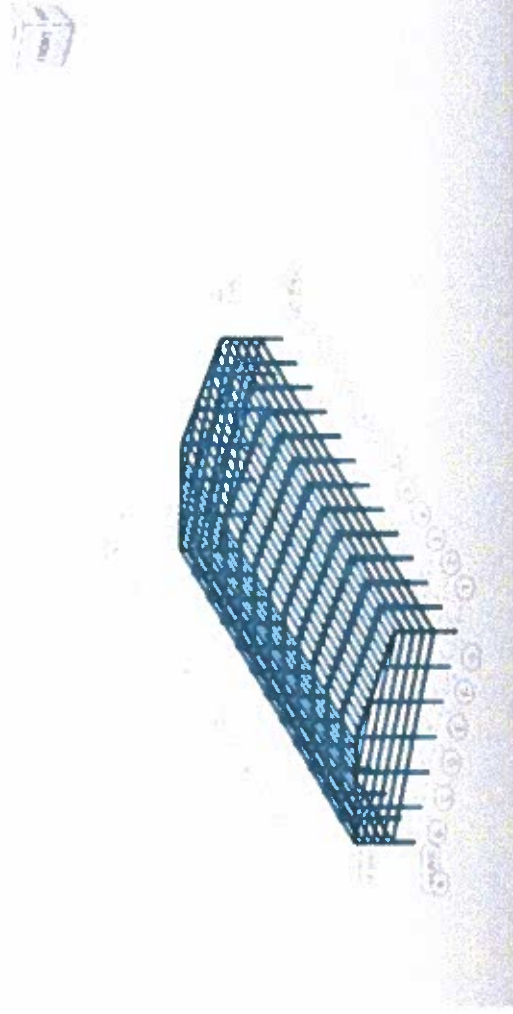
you need to
provide proper
labelling!

Figure 3.11: Third Floor of Convention Center



This figure includes an autocad version of the 2-D drawing of the third floor of the convention center designs with beam & column placement

Figure 3.12: Ground Floor of Steel Distribution Center ?



This figure includes an autocad version of the 3-D drawing of the Ground floor of the Steel Structure
Distribution center designs with beam & column placement

Geotechnical

Introduction:

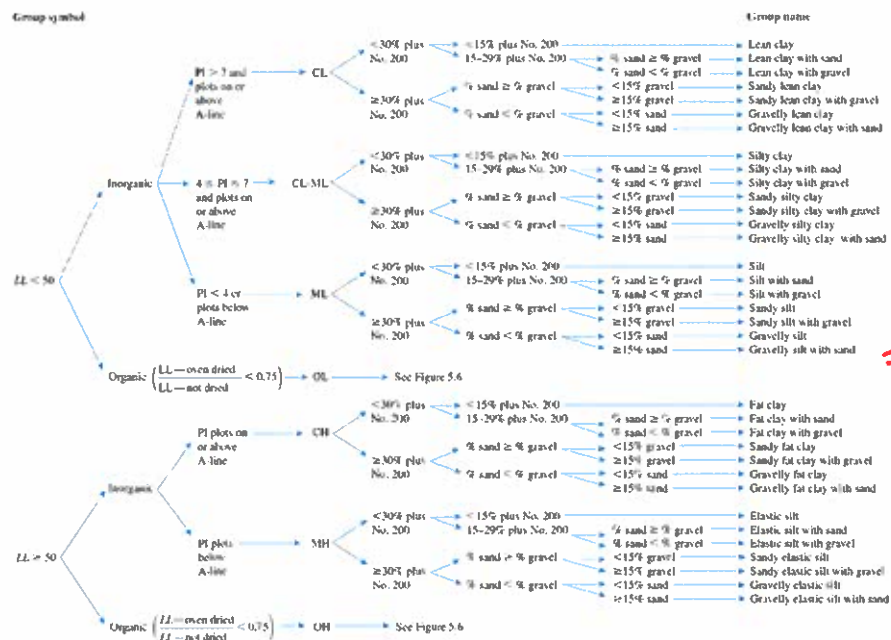
This section of the report is the progress for the geotechnical engineering portion of the Amazon Business building and Distribution center. Our Company was contacted by Dr. Alam to perform the appropriate task to make this project successful. The starting point for this project was the SPT test. The Standard Penetration Test (SPT) is a method of determining the geotechnical parameters of subsurface soil. This test is inexpensive and can accurately estimate the density and shear strength of soil. To conduct this test, a standard, thick-walled sample tube is driven into the earth at the bottom of a borehole. Strikes from a slide hammer mechanism with a set weight and fall distance accomplish this.

Scope Of work:

The investigation's goal was to undertake subsurface exploration and establish subsurface conditions at the project site so that geotechnical recommendations for the Amazon parking lots, distribution facility, and company buildings could be developed. Testing and classifying subsurface soils for strength, allowed bearing capacities, and foundation options, as well as foundation soil expansive properties for construction of the above-mentioned institutions based on laboratory tests and best engineering practices, are also included. The soil research began with the drilling of two holes to a depth of 70 feet in the project site's center and the northwest corner of the 400-acre property.

Drilling, Sampling, and Soil Classification:

The CME 75 Drilling Rig was used for the drilling. The subgrade soils were investigated with a continuous flight auger that was used to advance the hole's dryness. Soil samples were collected using thin-walled tubes in accordance with ASTM D 1587 during the drilling operation, and split spoon sampler testing (STP) was performed in accordance with ASTM D 1586. Because bedrock was encountered, continuous push tube samples were taken for the ground surface to a depth of 70 feet, and the borings were spaced 80 feet apart. The changes in soil strata noticed during drilling operations were meticulously calculated and recorded on the boring logs. The procedures outlined in ASTM D 2487, based on the Unified Soil Classification System, were used to classify all soil samples (shown in Figure 1). Furthermore, using the methods provided in the Plasticity Chart, the soils are documented in the boring logs (Shown in figure two). The Boring logs' soil Classification were placed in Table 1 and Table 2 shown below.



⇒ This is appendix

Figure 4.1: Unified Soil Classification System

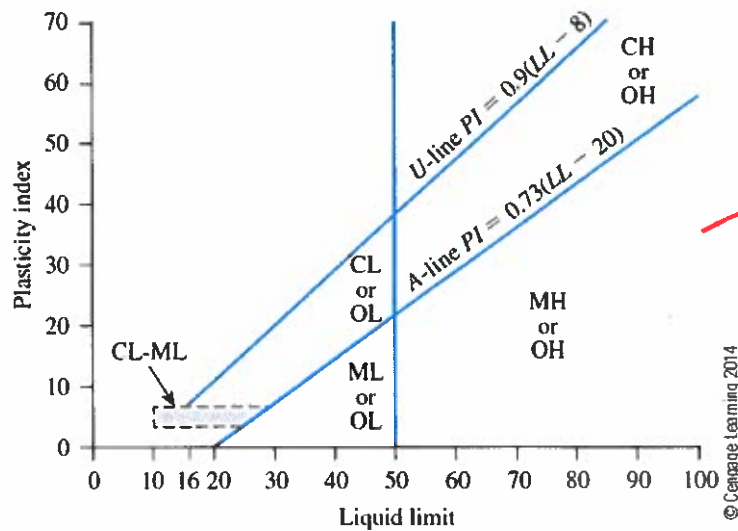


Figure 4.2: Plasticity Chart

Depth (ft)	Liquid Limit	Plastic Limit	Plastic Index	Sieve Analysis (#200)	Coarse Fraction	Water Content	Group Name	Classification
2.5	43	16	27	71%	29%	19%	CL	Sandy lean Clay
7.5	47	19	28	81%	19%	12%	CL	Sandy lean Clay
8.7	-	-	0	20%	80%	6%	-	Sand
15	51	24	27	69%	31%	13%	CH	Sandy Fat Clay
20	-	-	0	16%	84%	8%	-	Sand
25	62	30	32	80%	20%	15%	CH	Sandy Fat Clay
30	62	27	35	79%	21%	13%	CH	Sandy Fat Clay
40	69	28	41	83%	17%	17%	CH	Sandy Fat Clay
50	71	33	38	72%	28%	18%	CH	Sandy Fat Clay
60	69	34	35	79%	21%	19%	CH	Sandy Fat Clay

Table 4.1: Soil Classification for Test hole #1

Depth (ft)	Liquid Limit	Plastic Limit	Plastic Index	Sieve Analysis (#200)	Coarse Fraction	Water Content	Group Name	Classification
2.5	48	20	28	54%	46%	13%	CL	Sandy lean Clay
5	51	32	19	69%	31%	14%	MH	Sandy Elastic Silt
10	-	-	-	-	-	8%	-	Sand
12.5	46	19	27	74%	26%	18%	CL	Sandy lean Clay
17	-	-	-	-	-	10%	-	Sand
20	32	16	16	54%	46%	13%	CL	Sandy lean Clay
25	60	31	29	81%	19%	21%	MH	Sandy Elastic Silt
30	72	31	41	82%	18%	20%	CH	Sandy Fat Clay
40	68	39	29	62%	38%	4%	MH	Sandy Elastic Silt
50	80	39	41	69%	31%	18%	MH	Sandy Elastic Silt
60	68	34	34	84%	16%	20%	MH	Sandy Elastic Silt

Table 4.2: Soil Classification for Test hole #2

The next step is to gather the unit weight of each soil layer and after recently receiving the Unconsolidated Undrained test we can now calculate the settlement conditions, allowable

bearing capacity, and develop a foundation recommendation. The foundation will not only be safe for loading but will also be very cost efficient.

Transportation

For the Transportation aspect of this project, the parking lot design, plan and profile of the local road, and the roadway intersections have been completed. For the parking lot design, the amount of employees in each building was calculated based on the percentage of employees working in each building. For the warehouse, 40% of employees work in the building so the parking lot's capacity was 8000 parking spots. For the office development, 35% of employees worked in the buildings so 7000 parking spots were designed. The convention center holds 15% of the total number of employees so the parking lot will consist of 3000 parking spots and finally the IT Hub will hold 10% of the total employees and will require 2000 parking spots. The parking lot angle selected to ensure enough parking spots will fit in the provided area will be 30 degrees. This allows the space between one aisle to another to be the smallest at 14 feet. The MUTCD was utilized to ensure the number of spots and the dimensions of the parking spots and rows met the code.

For the plan and profile of the local road, the elevation for Warren Road, the road we plan on connecting to, was determined and a 2% grade was calculated and drawn in autocad to create an accurate profile curve. Below in figure 5.2 and 5.3 the plan and profile drawing completed in autocad can be found. We designed each road within the property that will connect one building to the next and allow simple access to each designated parking lot. Between each lot where there is an intersection, the type was selected based on the maximum flow during peak hours. There is a minimum of two entrances/exits for each parking lot to prevent congestion and allow a smooth

flow of traffic on the property. The roadway intersections were designed based on the maximum number of employees that will be expected to travel through that area and estimate the peak hours of traffic and the minimum for accurate timing on the signals. Next it was determined what risks were found at each intersection and designed necessary barriers and and other protective structures to protect all commuters that met the MUTCD code. Finally, utilizing autocad, a plan drawing of each intersection was created so the layout and proximity to each parking lot is clear. Below are the autocad drawings of each type of intersection as well as a sample parking lot plan view to show the dimensions of each bay as well as the distance each row is from the next.

Figure 5.1 : 4-way intersection with stop sign

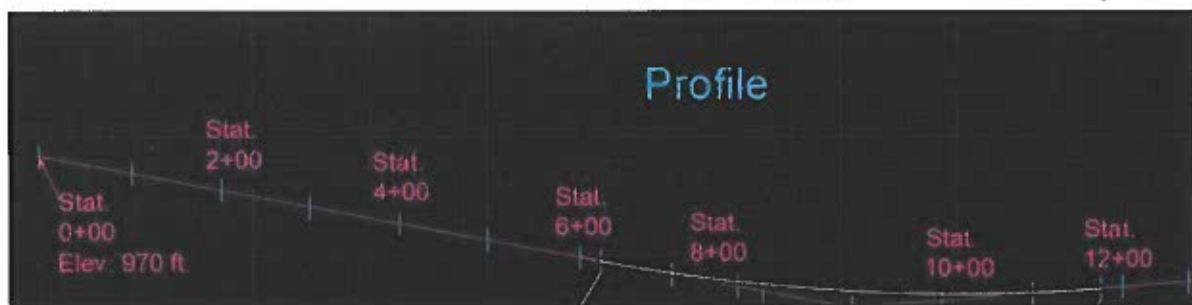
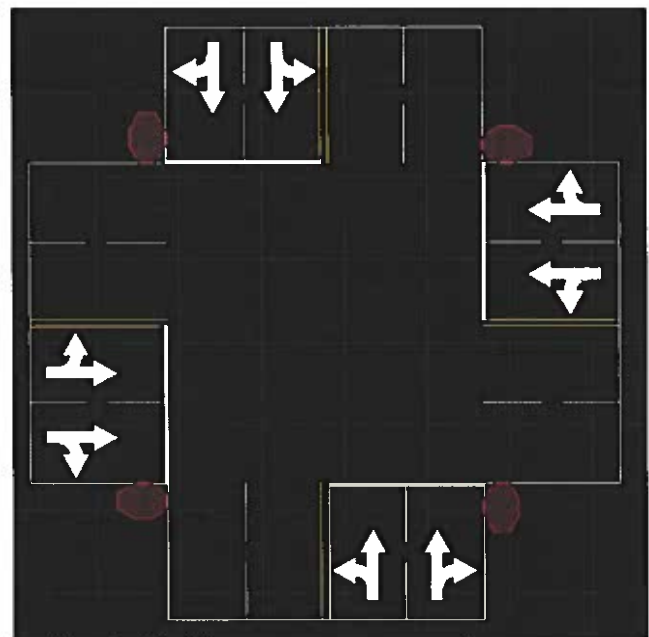


Figure 5.2: Profile View of Local Roadway

white background of the CAD drawing is recommended.

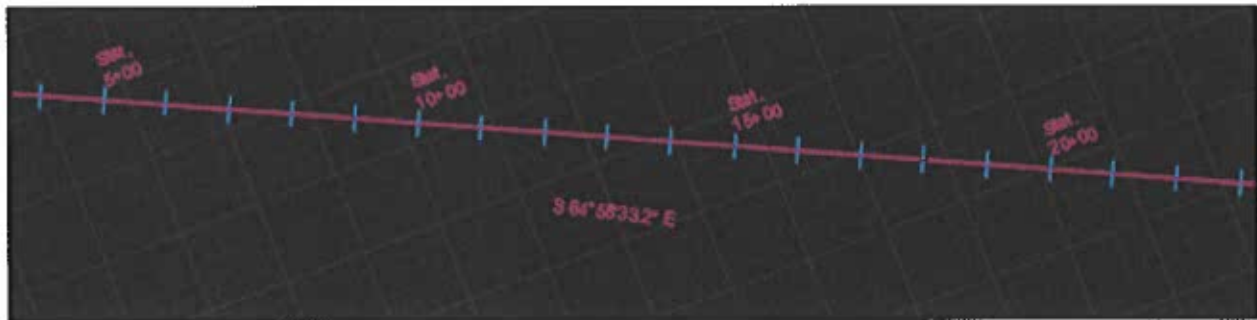


Figure 5.3: Plan View of Local Roadway

- Cyan:** 4-Way intersection with stop signs
- Green:** 4-Way intersection with stop light
- Yellow:** 3-Way intersection with stop signs
- Red:** Continuous traffic with singular stop sign

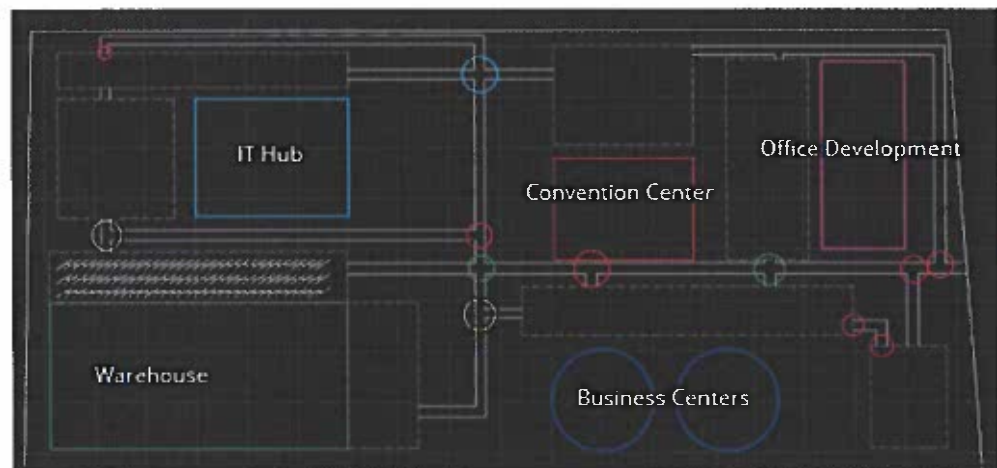


Figure 5.4: Intersection plan view of Project

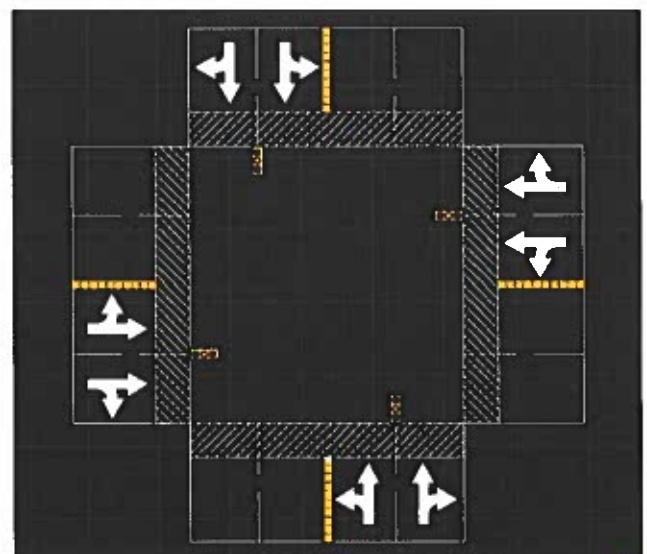


Figure 5.5: 4-way intersection with stop light

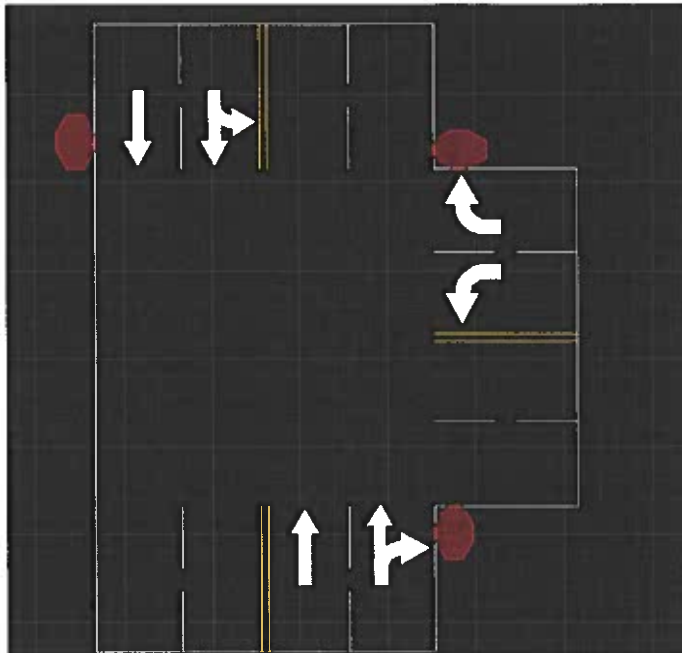


Figure 5.6: 3-way intersection with stop signs

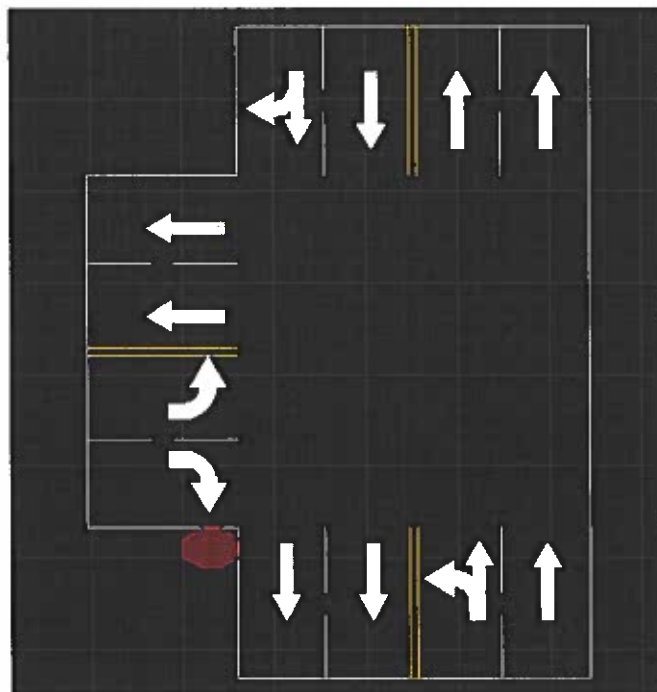


Figure 5.7: Continuous Traffic Intersection

Environmental

Wastewater treatment is the process of removing impurities from wastewater (water that is no longer needed or appropriate for use) and converting it into effluent that can be returned to the environment. The Texas Commission on Environmental Quality (TCEQ) and the Texas Administrative Code (TAC) Chapter 30 will be used to design the Wastewater Treatment Plant.

Table : Wastewater Characteristics

→ Table number - ??

Constituent	Concentration, mg/l
-------------	---------------------

	Strong	Medium	Weak
Total solids	1200	700	350
Dissolved solids (TDS) ¹	850	500	250
Suspended solids	350	200	100
Nitrogen (as N)	85	40	20
Phosphorus (as P)	20	10	6
Chloride ¹	100	50	30
Alkalinity (as CaCO ₃)	200	100	50
Grease	150	100	50
BOD ₅ ²	300	200	100

In accordance with the Texas Commission of Environmental Quality (TCEQ) Design Organic Loadings and Flows for a New Wastewater Treatment Facility, for an office building or factory, designed for the largest shift, will produce a daily wastewater flow of 20 gallons/person.

Table : Design Organic Loadings and Flows for a New Wastewater Treatment Facility

Source	Remarks	Daily Wastewater Flow (gallons/person)	Wastewater Strength (mg/l BOD ₅)	Wastewater Strength (mg/l NH ₃ -N)
Municipality	Residential	75-100	250-400	15-75
Subdivision	Residential	75-100	250-400	15-75
Trailer Park (Transient)	2½ Individuals per Trailer	50-60	250-350	15-75
Mobile Home Park	3 Individuals per Trailer	50-75	300	15-75
School	Cafeteria & Showers	20	300	15-75
	Cafeteria/No Showers	15	300	15-75
Recreational Parks	Overnight User	30	200	15-75
	Day User	5	100	15-75
Office Building or Factory	A facility must be designed for the largest shift	20	300	15-75
Hotel/Motel	Per Bed	50-75	300	15-75
Restaurant	Per Meal	7-10	1000*	15-75
Restaurant with bar or cocktail lounge	Per Meal	9-12	1000*	15-75
Hospital	Per Bed	200	300	15-75
Nursing Home	Per Bed	75-100	300	15-75
Alternative Collection Systems (Subchapter D of this chapter)	Per Capita	75	N/A	N/A
*Based on a restaurant with a grease trap				

With this data, the expected wastewater flow may be calculated by multiplying the flow per person by the population, and then converting the units to meters cubed per day using the conversion factor.

calculation:

$$AADF = \text{Population} \times \text{Average Daily Flow per Capita}$$

$$AADF = 20000 \text{ ppl} \times 20 \frac{\text{gal}}{\text{capita} - \text{day}} = 400000 \frac{\text{gal}}{\text{day}}$$

$$Q = 400000 \frac{\text{gal}}{\text{day}} \times 0.003785 \frac{\text{m}^3}{\text{gal}} = 1514 \frac{\text{m}^3}{\text{day}}$$

caption?

what quantity
is that?

Executive Summary

Structural Problem Statement for Structural

In a recent request, Amazon has proposed a problem of expansion of distribution centers for the Texas region. Only been provided with 400 acres of land and being asked to construct five different structures along with wastewater management systems and a flood prevention technique, there seems to be issues with proper location access within certain sub-disciplines. To best accomplish, from a structural standpoint, or what Amazon is asking to do we must take in a considerable design and make them simplistic yet intricate to the point where they will function but in an Amazon style without disturbing existing surroundings.

Proposed Solutions for Structural

JPMS Consulting creates solutions to fit what is being asked for. The structural design components have been set in place by the firm. With these designs, we will be able to actively maximize the size of the buildings while still reducing cost of buildings by doing the following:

1. Allowing column beams to share the same footings would reduce cost.
2. By building identical office buildings it will help us determine cost and when it comes to planning exactly how the building should be built.
3. Due to the small staff and the number of employees in the IT department, we can reduce the size of the IT department and add office space to the office buildings.
4. And to incorporate an Amazon style building, with all of these are cost-efficient solutions and we can add a skywalk between the identical office buildings.

JPMS Consulting creates solutions to fit what is being asked for. The structural design components have been set in place by the firm. With these designs, we will be able to actively maximize the size of the buildings while still reducing cost of buildings by doing such in the following: Note that our solutions are only apply to four of the five buildings being asked to be built this is only because for our steel structure warehouse it has a more open floor design which is automatically going to cost less the materials may cost more by finding the proper material is the only effective problem at hand.

Value for Structural

With the inclusions of this land and the construction of these buildings, add personal belief that the highest value of Amazon's net worth will increase. The location may not have a high demand population but is in high demand with high traffic volume. The structural design components will not only as be mentioned before reducing costs play be an area where there is easier access to any building maintenance that needs to occur. So, the value that is being 6 portrayed is more song a long-term value in the sense of being one of the first to build on a new area, and he when he comes to needing to get heavy equipment for maintenance equipment there's not as much in-tune section of regular traffic.

Final Thoughts and Next Steps for Structural

My recommendation for the enhancements of things is by increasing the dimensions of the workplace buildings by permitting another story within the building to accommodate the remaining worker overflow from the IT Hub or produce a second building of a smaller nature to accommodate the remaining share of staff. As for the opposite buildings, the steel structure of the warehouse was designed from innovation except for easier calculations, the warehouse can mimic that of the FedEx warehouse off ninety-nine grand drive south. As for the workplace buildings, mimicking the thought of the dual towers, however, not knowing the precise load can produce these difficulties, so finding the foremost stable foundation within the profile for a minimum of one, 600 sq. footage. The convention center was originally placed and is unambiguously designed however the sole recommendation that's being thought of is to relocate the building to accommodate alternative subdisciplines of the project

Proposed Solution for Water Resources

The first solution to the problem is to find where the location of the drainage ditch will be placed. We will use gravity to create the flow of the water to the nearest existing lake water source which is East of our construction site. The drainage ditch will start at its highest elevation of 456.9 coming from the topography map. Next the calculation of the rainfall intensity and collection for 100 years should be computed. This is to keep the area from flooding. I will do so by using the typical rainfall intensity -duration -recurrence interval curves. This graph shows the rainfall inserted in in/h proportional with time min and hours.

1. A design and location of a storm water ditch that avoids flooding hazards and damage to valuable property.
2. Rainfall intensity and rainfall collection for 100-year flooding

Note that the project is still in progress and on route to be completed in 2022.

Value for Water Resources

The storm water drainage ditch has been stamped to its location with the help of my geotechnical and environmental engineer. This was decided by locating the start of the ditch at its highest elevation to help with gravitating the water to its correct location.

Final Thoughts and Steps for Water Resources

Final steps for this project pertaining to water resources would be to calculate the quantity of water, design the storm water ditch based on a rainfall study, and show a profile and cross section of the drainage ditch.

Problem Statement for Transportation

For the JJMPS consulting firm, the transportation engineer will be in charge of the entire roadway layout of the project, interchange design, a parking lot proposal, and a plan and profile of each local road.

Proposed Solution for Transportation

The dimensions for each major roadway will be determined and the speed for the minor and major roads will be chosen based on the overall layout and utilizing the MUTCD (Manual on

Uniform Traffic Control Devices). The size of each parking lot will be selected to accommodate each employee in the vicinity as well as overflow and guests and the dimensions of each parking spot and the angle of each spot will be chosen utilizing the MUTCD. Interchanges will be 4 designed based on the flow of traffic in the area at peak times. The type of interchange will be selected based on the peak flow and location of the area. The roadway layout of the entire project will be designed to meet the peak amount of traffic and to ensure that no congestion will occur at peak hours of traffic flow. The dimensions of the lanes will be chosen to match the local roads surrounding the project. This will allow a simple transition between one local road and a minor road on the project site. A plan and profile will be drafted using the local existing road's elevation and using that to continue a seamless transition from one roadway to another.

Value for Transportation

The value of this project is to provide necessary insight and experience for each member of the JJMPS Consulting company. The design portion of this project allows the transportation group to utilize skills learned in previous courses and allows the application of those skills towards real world issues and will force the transportation group to learn to adapt and apply them as necessary.

Problem Statement for Geotechnical

The scope of work is to execute a geotechnical analysis for Amazon's proposed 400-acre commercial and distribution center, IT hub, and office development in Waller County, which is located south of major highways (US 290 and I-10). The report includes the findings of the site inspection as well as project recommendations.

Solution for Geotechnical

For the drilling, a CME 75 Drilling Rig was employed. A continuous flight auger was employed to progress the holes dry as the subgrade soils were explored. During the drilling operation, soil samples were obtained using thin-walled tubes according to ASTM D 1587, and split spoon sampler testing (STP) was done according to ASTM D 1586. Due to the presence of bedrock, continuous push tube samples were taken from the ground surface to a depth of 70 feet, with the borings spaced 80 feet apart. Soil samples were sent to a lab to be examined for soil characteristics. The findings were incorporated into the final report. During soil testing, a 7m depth of water was detected. In addition, the study discusses the many types of retaining structures and how to choose them based on the data provided. To help grasp the design and focus on the details, a visual layout has been provided. In addition, calculations for footings and settlements were performed to see whether they met the necessary requirement, and if appropriate, helpful recommendations were made.

Geotechnical Value & Recommendations

The report includes a broad description of the soils found, their qualities, expected behavior during construction, and measured groundwater levels. The final report includes geotechnical advice for shallow foundations, pavement design, pile foundations, and embankment design. The foundation design parameters were calculated using calculations from Braja M. Das Nagaratnam Sivakugan's "Principles of Foundation Engineering, 9th Edition, SI Edition" and an engineering textbook.

Problem Statement for Environmental

For our project, the environmental engineer will be calculating the estimated wastewater quantity for the project area. The location of the wastewater treatment facility should be near the lowest elevation. After analyzing the wastewater quality, a method to treat said water can be determined, as well as picking a suitable dumping location.

The Solution for Environmental

The environmental engineer will be utilizing the instruction given in the environmental design course to determine the wastewater quantity. It is known that the wastewater treatment facility should be placed at the lowest elevation to allow gravity to maneuver the wastewater to its proper location. The wastewater will be disposed of in a local stream or, if treated properly, could be used as irrigation for the project area.

Value for Environmental

The purpose of this project is to give students a chance to apply the knowledge that they have been acquiring over their last 4-5 years at university. The project is expected to be completed by May 2022.

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**OUTCOME “7” SPECIFIC ASSIGNMENTS
USED TO ASSESS THE OUTCOME IN**

**CVEG 4093
SYSTEMS ENGINEERING**

DEPARTMENT OF

CIVIL & ENVIRONMENTAL ENGINEERING

OUTCOME SPECIFIC ASSIGNMENT

COVER SHEET

CVEG 4093

Systems Engineering

Fall 2020

Instructor: Dr. Emmanuel U. Nzewi, PE

Title of Assignment

- 1) Taskstream – Homework 07-
- 2) Final Exam - Problem 6

Outcome Measured Using this Assignment

Outcome 7

Ability to acquire and apply new knowledge as needed, using appropriate learning strategies

Brief Description of the suitability of this assignment for the outcome

- Homework 07 [Solution of LPs via LINGO] score use of new tools.
- Final Exam – Critical thinking related to risk analysis

Homework 07

(TaskStream)

Solving Mixed Integer Linear Programming (MILP) Problems

SUBMIT THIS as cover sheet with your work

Name [PRINT] _____

Instructions:

In all the problems you must provide enough details and description of the solution method to demonstrate your knowledge of the solution method. A substantial portion of the grade will be based on your methods.

You may obtain free online-printed graph paper at: <http://www.printfreegraphpaper.com/>

GRADE ⇒

800

Problem 1 [100]

Solve the following discrete-valued linear program **graphically**. Show all the feasible points and plot the objective function through the optimal point as a broken line (=====). X2 should be the ordinate.

$$\text{Minimize } Z = 6.0 X_1 - 6.0 X_2$$

s. t.

$$2 X_1 + 2 X_2 \leq 24 \quad (1)$$

$$X_1 - X_2 \leq 6 \quad (2)$$

$$2X_1 \geq 3 \quad (3)$$

$$X_1 \in (1,2,3,4,6,5,8); \quad X_2 \in (0,2,4,6,7,5,8,11)$$

Problem 2 [250]

Consider the following discrete-valued problem:

$$\text{Minimize } Z = 4 X_1 + 2 X_2 + 5 X_3$$

$$\text{s.t. } X_1 + X_2 + X_3 \leq 36 \quad (1)$$

$$X_1 - X_2 + X_3 \leq 16 \quad (2)$$

$$4X_1 + 4X_3 \geq 42 \quad (3)$$

$$X_1 \in (1,2,3,4,6,3,8); \quad X_2 \in (0,2,4,6,7.5,8,11); \quad X_3 \in (0,1,2,3,4,5,6,7,8,9,10,11,12)$$

Solve this problem by the **Branch-And-Bound algorithm** described in the class notes.

SHOW EACH STEP CLEARLY!

If you have more than one candidate LP to be solved, always select the continuous linear program LP-**k** with the smallest number (**k** is the number of the candidate LP). For example, suppose you have candidate LPs: LP-3 and LP-5, by this rule, you would choose to solve LP-3 first. Furthermore, always branch on the variable with the smallest subscript; that is, if both X1 and X2 have unacceptable values, branch on X1. When you branch, the LP to which the ≤ constraint is added should be numbered lower (i+1) and the LP to which the ≥ constraint is added should be number higher (i+2).

ALL continuous LPs must be solved using LINDO-LP as a separate PURE LP model.

For each continuous LP, identify the PURE LP Model corresponding to each LP-**k** and its optimal point(s) and the corresponding objective function (**Z**) value.

Provide the corresponding **Branch-And-Bound tree** to summarize your results. Whenever a "tree branch" is **fathomed**, state the reason for the fathom.

Problem 3 [150]

(a) [80] Solve the discrete-valued LP given in **problem 2** using LINDO-MIP. Add the necessary constraints to allow solution by the LINDO-MIP solver. **ONLY one** MIP must be solved to provide the solution. Write out the LINDO-MIP program first (and include any "comment" statements which explain your model). Recall from the class notes that you should introduce and use additional integer (0,1) variables to setup the program in LINDO-MIP format. An additional consideration is that you must use the smallest number of integer (0,1) variables. [Hint: Use Binary Expansion for variable X_3 and show all work.]

(b) [70] Solve the discrete-valued LP given in **problem 2** again, using LINDO-MIP. Add the necessary constraints to allow solution by the LINDO-MIP solver. **ONLY one** MIP must be solved to provide the solution. Write out the LINDO-MIP program first (and include any "comment" statements which explain your model). Recall from the class notes that you should introduce and use additional integer (0,1) variables to setup the program in LINDO-MIP format. **In this situation you are required to use (add) GIN variable(s) where appropriate.** However you must still add the smallest number of additional binary (0,1) variables where necessary.

Problem 4 [300]

You have, as the owner and operator of a new trucking company, *WeHaul and Drop, LLC*, contracted to make 5 deliveries each week to customers denoted as A through E (see the table below). You plan to capitalize on your knowledge of Systems Engineering to optimize your operations. You have 4 different delivery trucks, each having different operational costs depending on assignment and weight capacities as follows:

TRUCK	CAPACITY [lb]	FIXED COST [\$]	COST [\$/LB] FOR CUSTOMER				
			A	B	C	D	E
1	3,500	550	0.55	0.65	0.50	0.58	0.41
2	7,500	900	0.45	0.48	0.55	0.50	0.45
3	8,000	450	0.38	0.43	0.38	0.68	0.60
4	12,000	980	0.35	0.35	0.27	0.46	0.65

Each week, you must make a 2,000 lb. delivery to Customer A, a 3,000 lb. delivery to Customer B, a 2,500 lb. delivery to Customer C, a 4,800 lb. delivery to Customer D, and a 7,500 lb delivery to Customer E.

Because of location, a single vehicle **cannot** deliver to both Customers A and B.

Formulate and solve a mixed integer linear program (MILP) to determine the optimal shipping strategy that minimizes the overall transportation cost of your company's delivery operation.

[50] Clearly describe how you handled the requirement that the same truck cannot deliver to both Customers A and C in your LP.

[50] Present the LINDO model and solution and describe the solution fully.

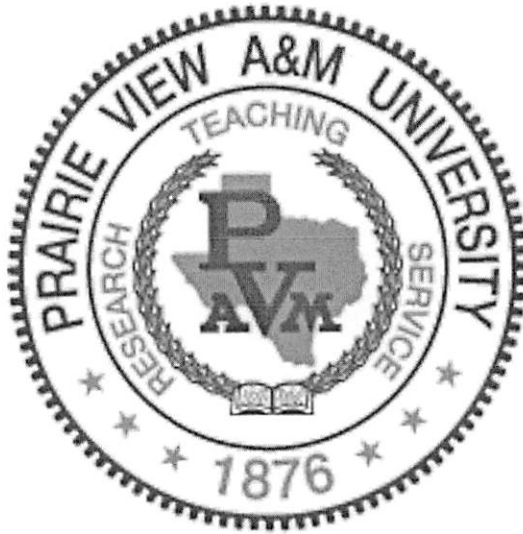
[50] On a network diagram, present the results of your model solution.

HINT:

You will probably need to define some continuous variables and some binary variables.

STUDENT #1 - High

**CIVIL ENGINEERING DEPARTMENT
PRAIRIE VIEW A&M UNIVERSITY**



CVEG 4093 SYSTEMS ENGINEERING

FALL 2020

Homework #7

Submitted by

Milton Cruz

On

November 6, 2020

Dr. Nzewi

Cruz, Milton

Problem # 1)

710/800

Minimize $z = 6.0 X_1 - 6.0 X_2$

s.t.

$$2X_1 + 2X_2 \leq 24 \quad (1)$$

$$X_1 - X_2 \leq 6 \quad (2)$$

$$2X_1 \geq 3 \quad (3)$$

$$X_1 \in (1, 2, 3, 4, 6.5, 9); \quad X_2 \in (0, 2, 4, 6, 7.5, 8, 11)$$

$$\textcircled{1} \quad 2X_1 + 2X_2 \leq 24$$

$$X_1 = 0; \quad X_2 = 12$$

$$X_2 = 0; \quad X_1 = 12$$

$$\textcircled{2} \quad X_1 - X_2 \leq 6$$

$$X_1 = 7; \quad X_2 = 1$$

$$X_2 = 0; \quad X_1 = 6$$

$$\textcircled{3} \quad 2X_1 \geq 3$$

$$X_1 = 1.5$$

$$6X_1 - 6X_2 = 24$$

$$X_1 = 5; \quad X_2 = 1$$

$$X_2 = 4; \quad X_1 = 8$$

Feasible Points

$$A(1.5, 0)$$

$$B(1.5, 10.5)$$

$$C(9, 3)$$

$$D(6, 0)$$

Z-values

$$A) \quad 6(1.5) - 6() = 9$$

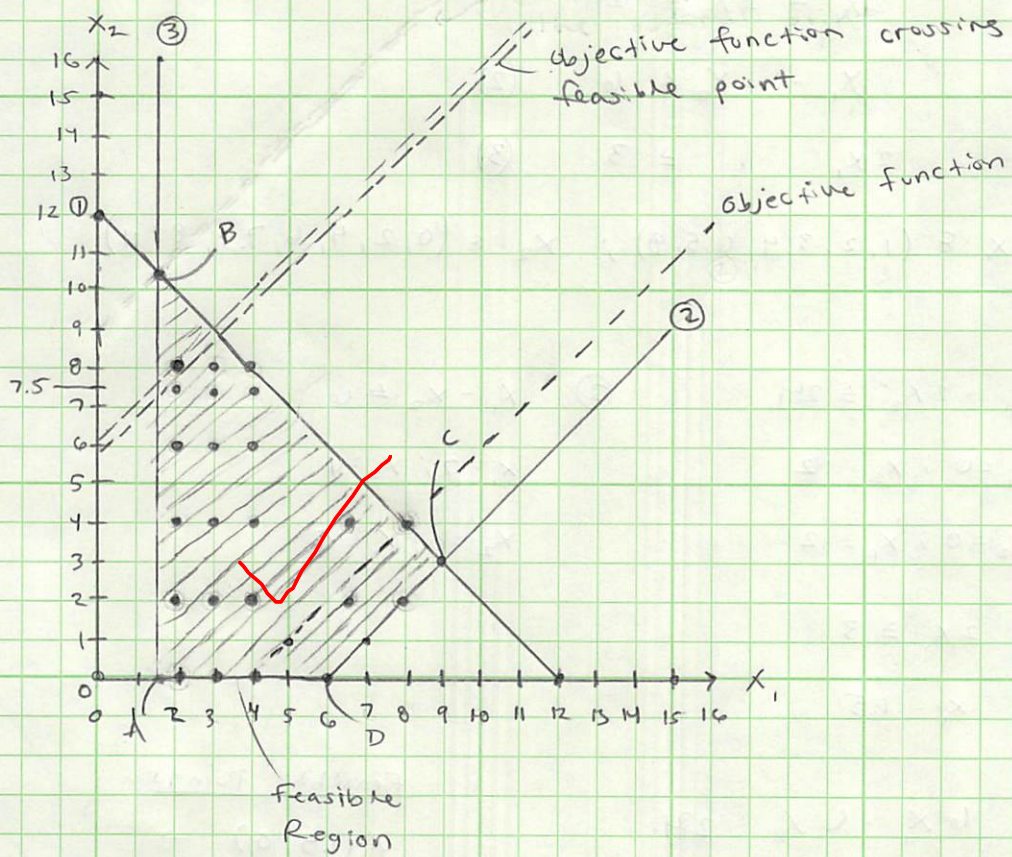
$$B) \quad 6(1.5) - 6(10.5) = -54$$

$$C) \quad 6(9) - 6(3) = 36$$

$$D) \quad 6(6) - 6(0) = 36$$

$$\underline{6(2) - 6(8) = -36}$$

* optimal point $\rightarrow (2, 8)$



Problem #2)

Minimize $Z = 4x_1 + 2x_2 + 5x_3$

s.t.

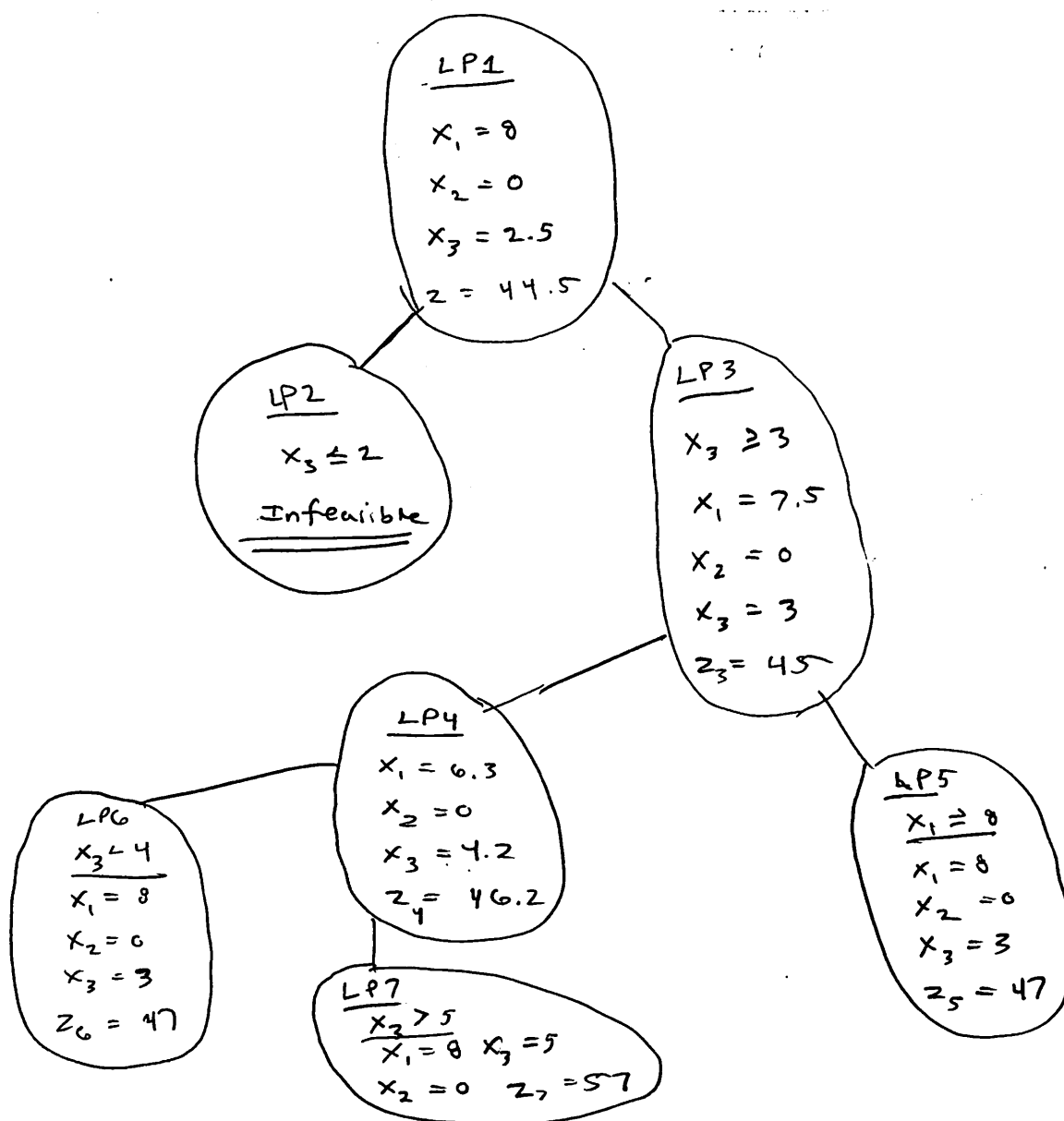
$$x_1 + x_2 + x_3 \leq 36 \quad (1)$$

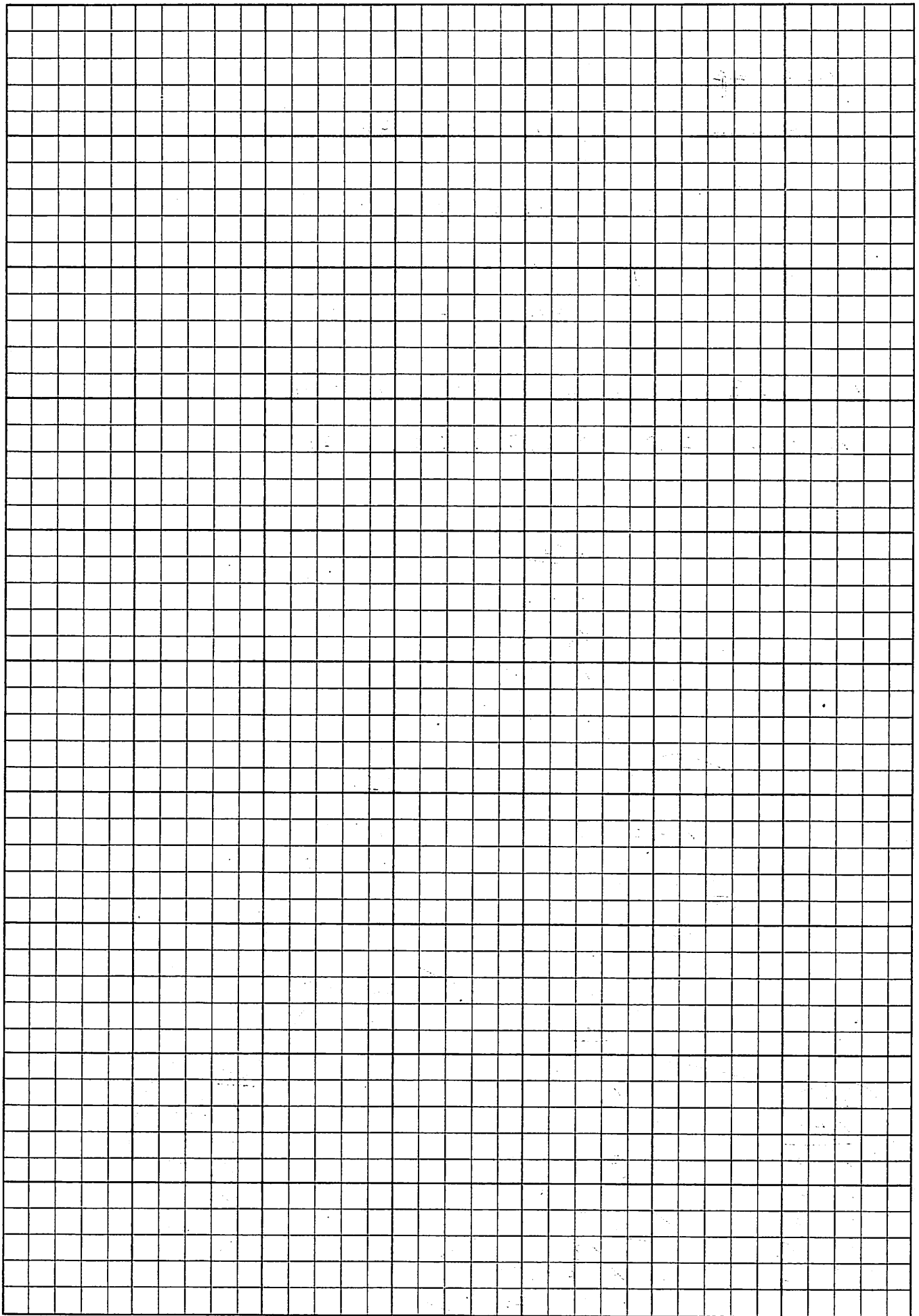
$$x_1 - x_2 + x_3 \leq 16 \quad (2)$$

$$4x_1 \quad 4x_3 \leq 42 \quad (3)$$

$$x_1 \in (1, 2, 3, 4, 6.3, 8); \quad x_2 \in (0, 2, 4, 6, 7.5, 8, 11)$$

$$x_3 \in (0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12)$$





Problem 2

! LP1

Min Z) $4X_1 + 2X_2 + 5X_3$

ST

$X_1 + X_2 + X_3 < 36$

$X_1 - X_2 + X_3 < 16$

$4X_1 + 4X_3 > 42$

$X_1 < 8$

$X_2 < 11$

$X_3 < 12$

END

Solution:

Global optimal solution found.

Objective value: 44.50000

Infeasibilities: 0.000000

Total solver iterations: 1

Elapsed runtime seconds: 0.06

Model Class: LP

Total variables: 3

Nonlinear variables: 0

Integer variables: 0

Total constraints: 7

Nonlinear constraints: 0

Total nonzeros: 14

Nonlinear nonzeros: 0

Variable	Value	Reduced Cost
X1	8.000000	0.000000
X2	0.000000	2.000000
X3	2.500000	0.000000

Row	Slack or Surplus	Dual Price
Z	44.50000	-1.000000
2	25.50000	0.000000
3	5.500000	0.000000
4	0.000000	-1.250000
5	0.000000	1.000000
6	11.00000	0.000000
7	9.500000	0.000000

! LP2

Min Z) $4X_1 + 2X_2 + 5X_3$

ST

$X_1 + X_2 + X_3 < 36$

$X_1 - X_2 + X_3 < 16$

$4X_1 + 4X_3 > 42$

$X_1 < 8$

$X_2 < 11$

$X_3 < 12$

$X_3 < 2$

END

Solution:

No feasible solution found.

Infeasibilities:

Total solver iterations:

Elapsed runtime seconds:

0.5000000

2

112.17

Model Class:

LP

Total variables: 3

Nonlinear variables: 0

Integer variables: 0

Total constraints: 8

Nonlinear constraints: 0

Total nonzeros: 15

Nonlinear nonzeros: 0

Variable	Value	Reduced Cost
X1	8.000000	0.000000
X2	0.000000	2.000000
X3	2.500000	0.000000

Row	Slack or Surplus	Dual Price
Z	0.500000	-1.000000
2	25.50000	0.000000
3	5.500000	0.000000
4	0.000000	-1.250000
5	0.000000	1.000000
6	11.00000	0.000000
7	9.500000	0.000000
8	-0.500000	0.000000

! LP3

Min Z) $4X_1 + 2X_2 + 5X_3$

ST

$X_1 + X_2 + X_3 < 36$

$X_1 - X_2 + X_3 < 16$

$4X_1 + 4X_3 > 42$

$X_1 < 8$

$X_2 < 11$

$X_3 < 12$

$X_3 > 3$

END

Solution:

Global optimal solution found.

Objective value:

45.00000

Infeasibilities:

0.000000

Total solver iterations:

1

Elapsed runtime seconds:

0.03

Model Class:

LP

Total variables: 3

Nonlinear variables: 0

Integer variables: 0

Total constraints: 8

Nonlinear constraints: 0

Total nonzeros: 15

Nonlinear nonzeros: 0

Variable	Value	Reduced Cost
X1	7.500000	0.000000
X2	0.000000	2.000000
X3	3.000000	0.000000

Row	Slack or Surplus	Dual Price
Z	45.00000	-1.000000
2	25.50000	0.000000
3	5.500000	0.000000
4	0.000000	-1.000000
5	0.500000	0.000000
6	11.00000	0.000000
7	9.000000	0.000000
8	0.000000	-1.000000

! LP4

Min Z) $4X_1 + 2X_2 + 5X_3$

ST

$X_1 + X_2 + X_3 < 36$

$X_1 - X_2 + X_3 < 16$

$4X_1 + 4X_3 > 42$

$X_1 < 8$

$X_2 < 11$

$X_3 < 12$

$X_3 > 3$

$x_1 < 6.3$

END

Solution:

Global optimal solution found.

Objective value: 46.20000
Infeasibilities: 0.000000
Total solver iterations: 1
Elapsed runtime seconds: 0.03

Model Class: LP

Total variables: 3
Nonlinear variables: 0
Integer variables: 0

Total constraints: 9
Nonlinear constraints: 0

Total nonzeros: 16
Nonlinear nonzeros: 0

Variable	Value	Reduced Cost
X1	6.300000	0.000000
X2	0.000000	2.000000
X3	4.200000	0.000000

Row	Slack or Surplus	Dual Price
Z	46.20000	-1.000000
2	25.50000	0.000000
3	5.500000	0.000000
4	0.000000	-1.250000
5	1.700000	0.000000
6	11.00000	0.000000
7	7.800000	0.000000
8	1.200000	0.000000
9	0.000000	1.000000

! LP 5

Min Z) $4X_1 + 2X_2 + 5X_3$

ST

$X_1 + X_2 + X_3 < 36$

$X_1 - X_2 + X_3 < 16$

$4X_1 + 4X_3 > 42$

$X_1 < 8$

$X_2 < 11$

$X_3 < 12$

$X_3 > 3$

$x_1 > 8$

END

Solution:

Global optimal solution found.

Objective value:

Infeasibilities:

Total solver iterations:

Elapsed runtime seconds:

47.000000

0.000000

0

0.05

Model Class:

LP

Total variables: 3

Nonlinear variables: 0

Integer variables: 0

Total constraints: 9

Nonlinear constraints: 0

Total nonzeros: 16

Nonlinear nonzeros: 0

Variable	Value	Reduced Cost
X1	8.000000	0.000000
X2	0.000000	2.000000
X3	3.000000	0.000000

Row	Slack or Surplus	Dual Price
Z	47.00000	-1.000000
2	25.00000	0.000000
3	5.000000	0.000000
4	2.000000	0.000000
5	0.000000	0.000000
6	11.00000	0.000000
7	9.000000	0.000000
8	0.000000	-5.000000
9	0.000000	-4.000000

! LP 6

Min Z) $4X_1 + 2X_2 + 5X_3$

ST

$X_1 + X_2 + X_3 < 36$

$X_1 - X_2 + X_3 < 16$

$4X_1 + 4X_3 > 42$

$X_1 < 8$

$X_2 < 11$

$X_3 < 12$

$X_3 > 3$

$x_1 > 8$

$x_3 < 4$

END

Solution:

Global optimal solution found.

Objective value:

47.00000

Infeasibilities:

0.000000

Total solver iterations:

0

Elapsed runtime seconds:

0.04

Model Class:

LP

Total variables: 3

Nonlinear variables: 0

Integer variables: 0

Total constraints: 10

Nonlinear constraints: 0

Total nonzeros: 17

Nonlinear nonzeros: 0

-35
Incorrect

Variable	Value	Reduced Cost
X1	8.000000	0.000000
X2	0.000000	2.000000
X3	3.000000	0.000000

Row	Slack or Surplus	Dual Price
Z	47.00000	-1.000000
2	25.00000	0.000000
3	5.000000	0.000000
4	2.000000	0.000000
5	0.000000	0.000000
6	11.00000	0.000000
7	9.000000	0.000000
8	0.000000	-5.000000
9	0.000000	-4.000000
10	1.000000	0.000000

! LP 7

Min Z) $4X_1 + 2X_2 + 5X_3$

ST

$X_1 + X_2 + X_3 < 36$

$X_1 - X_2 + X_3 < 16$

$4X_1 + 4X_3 > 42$

$X_1 < 8$

$X_2 < 11$

$X_3 < 12$

$X_3 > 3$

$x_1 > 8$

$x_3 > 5$

END

Solution:

Global optimal solution found.

Objective value:

Infeasibilities:

Total solver iterations:

Elapsed runtime seconds:

57.00000

0.000000

0

0.04

Model Class:

LP

Total variables: 3

Nonlinear variables: 0

Integer variables: 0

Total constraints: 10

Nonlinear constraints: 0

Total nonzeros: 17

Nonlinear nonzeros: 0

-35

Incorrect

Variable	Value	Reduced Cost
X1	8.000000	0.000000
X2	0.000000	2.000000
X3	5.000000	0.000000

Row	Slack or Surplus	Dual Price
Z	57.00000	-1.000000
2	23.00000	0.000000
3	3.000000	0.000000
4	10.00000	0.000000
5	0.000000	0.000000
6	11.00000	0.000000
7	7.000000	0.000000
8	2.000000	0.000000
9	0.000000	-4.000000
10	0.000000	-5.000000

!Problem 3A
Min Z) $4X1+2X2+5X3$

st

- 1) $X1+X2+X3 < 36$
- 2) $X1-X2+X3 < 16$
- 3) $4X1 + 4X3 > 42$

SwX1) $X1-Y11-Y12-3Y13-4Y14-6.3Y15-8Y16 = 0$
SwX2) $X2-2Y21-4Y22-6Y23-7.5Y24-8Y25-11Y26 = 0$
SwX3) $X3-Y31-2Y32-3Y33-4Y34-5Y35-6Y36-7Y37-8Y38-9Y39-10Y310-11Y311-12Y312 = 0$
Swx1Y) $Y11+Y12+Y13+Y14+Y15+Y16 = 1$
Swx2Y) $Y21+Y22+Y23+Y24+Y25+Y26 < 1$
Swx3Y) $Y31+Y32+Y33+Y34+Y35+Y36+Y37+Y38+Y39+Y310+Y311+Y312 > 1$
End

int Y11
int Y12
int Y13
int Y14
int Y15
int Y16
int Y21
int Y22
int Y23
int Y24
int Y25
int Y26
int Y31
int Y32
int Y33
int Y34
int Y35
int Y36
int Y37
int Y38
int Y39
int Y310
int Y311
int Y312

Solution:

Global optimal solution found.

Objective value:

Objective bound:

Infeasibilities:

Extended solver steps:

Total solver iterations:

Elapsed runtime seconds:

47.00000

47.00000

0.000000

1

64

1.59

Model Class:

MILP

Total variables:

27

Nonlinear variables:

0

Integer variables:

24

Total constraints:	10
Nonlinear constraints:	0
Total nonzeros:	62
Nonlinear nonzeros:	0

Variable	Value	Reduced Cost
X1	8.000000	0.000000
X2	0.000000	0.000000
X3	3.000000	0.000000
Y11	0.000000	4.000000
Y12	0.000000	4.000000
Y13	0.000000	12.000000
Y14	0.000000	16.000000
Y15	0.000000	25.200000
Y16	1.000000	32.000000
Y21	0.000000	4.000000
Y22	0.000000	8.000000
Y23	0.000000	12.000000
Y24	0.000000	15.000000
Y25	0.000000	16.000000
Y26	0.000000	22.000000
Y31	1.000000	5.000000
Y32	1.000000	10.000000
Y33	0.000000	15.000000
Y34	0.000000	20.000000
Y35	0.000000	25.000000
Y36	0.000000	30.000000
Y37	0.000000	35.000000
Y38	0.000000	40.000000
Y39	0.000000	45.000000
Y310	0.000000	50.000000
Y311	0.000000	55.000000
Y312	0.000000	60.000000

Row	Slack or Surplus	Dual Price
Z	47.000000	-1.000000
2	25.000000	0.000000
3	5.000000	0.000000
4	2.000000	0.000000
SWX1	0.000000	-4.000000
SWX2	0.000000	-2.000000
SWX3	0.000000	-5.000000
SWX1Y	0.000000	0.000000
SWX2Y	1.000000	0.000000
SWX3Y	1.000000	0.000000

!Problem 3B
Min Z) $4X_1 + 2X_2 + 5X_3$

st

- 1) $X_1 + X_2 + X_3 < 36$
- 2) $X_1 - X_2 + X_3 < 16$
- 3) $4X_1 + 4X_3 > 42$

SwX1) $X_1 - Y_{11} - Y_{12} - 3Y_{13} - 4Y_{14} - 6.3Y_{15} - 8Y_{16} = 0$
SwX2) $X_2 - 2Y_{21} - 4Y_{22} - 6Y_{23} - 7.5Y_{24} - 8Y_{25} - 11Y_{26} = 0$
SwX3) $X_3 - Y_{31} - 2Y_{32} - 3Y_{33} - 4Y_{34} - 5Y_{35} - 6Y_{36} - 7Y_{37} - 8Y_{38} - 9Y_{39} - 10Y_{310} - 11Y_{311} - 12Y_{312} = 0$
Swx1Y) $Y_{11} + Y_{12} + Y_{13} + Y_{14} + Y_{15} + Y_{16} = 1$
Swx2Y) $Y_{21} + Y_{22} + Y_{23} + Y_{24} + Y_{25} + Y_{26} < 1$
Swx3Y) $Y_{31} + Y_{32} + Y_{33} + Y_{34} + Y_{35} + Y_{36} + Y_{37} + Y_{38} + Y_{39} + Y_{310} + Y_{311} + Y_{312} > 1$
End

int Y11
int Y12
int Y13
int Y14
int Y15
int Y16
int Y21
int Y22
int Y23
int Y24
int Y25
int Y26
GIn X3

Solution:

Global optimal solution found.
Objective value: 47.00000
Objective bound: 47.00000
Infeasibilities: 0.000000
Extended solver steps: 0
Total solver iterations: 27
Elapsed runtime seconds: 0.05

Model Class: MILP

Total variables: 27
Nonlinear variables: 0
Integer variables: 13

Total constraints: 10
Nonlinear constraints: 0

Total nonzeros: 62
Nonlinear nonzeros: 0

Variable	Value	Reduced Cost
X1	8.000000	0.000000

X2	0.000000	0.000000
X3	3.000000	5.000000
Y11	0.000000	4.000000
Y12	0.000000	4.000000
Y13	0.000000	12.000000
Y14	0.000000	16.000000
Y15	0.000000	25.200000
Y16	1.000000	32.000000
Y21	0.000000	4.000000
Y22	0.000000	8.000000
Y23	0.000000	12.000000
Y24	0.000000	15.000000
Y25	0.000000	16.000000
Y26	0.000000	22.000000
Y31	0.800000	0.000000
Y32	0.000000	0.000000
Y33	0.000000	0.000000
Y34	0.000000	0.000000
Y35	0.000000	0.000000
Y36	0.000000	0.000000
Y37	0.000000	0.000000
Y38	0.000000	0.000000
Y39	0.000000	0.000000
Y310	0.000000	0.000000
Y311	0.200000	0.000000
Y312	0.000000	0.000000

Row	Slack or Surplus	Dual Price
Z	47.000000	-1.000000
2	25.000000	0.000000
3	5.000000	0.000000
4	2.000000	0.000000
SWX1	0.000000	-4.000000
SWX2	0.000000	-2.000000
SWX3	0.000000	0.000000
SWX1Y	0.000000	0.000000
SWX2Y	1.000000	0.000000
SWX3Y	0.000000	0.000000

!Porblem 4

Min 550T1+900T2+450T3+980T4
+0.55X1A+0.65X1B+0.50X1C+0.58X1D+0.41X1E
+0.45X2A+0.48X2B+0.55X2C+0.50X2D+0.45X2E
+0.38X3A+0.43X3B+0.38X3C+0.68X3D+0.60X3E
+0.35X4A+0.35X4B+0.27X4C+0.46X4D+0.65X4E

S.T.

3500T1-X1A-X1B-X1C-X1D-X1E $\geq$ 0
7500T2-X2A-X2B-X2C-X2D-X2E $\geq$ 0
8000T3-X3A-X3B-X3C-X3D-X3E $\geq$ 0
12000T4-X4A-X4B-X4C-X4D-X4E $\geq$ 0
X1A+X2A+X3A+X4A = 2000
X1B+X2B+X3B+X4B = 3000
X1C+X2C+X3C+X4C = 2500
X1D+X2D+X3D+X4D = 4800
X1E+X2E+X3E+X4E = 7500
3500TA1-X1A $\geq$ 0
3500TB1-X1B $\geq$ 0
TA1+TB1 $\leq$ 1
7500TA2-X2A $\geq$ 0
7500TB2-X2B $\geq$ 0
TA2+TB2 $\leq$ 1
8000TA3-X3A $\geq$ 0
8000TB3-X3B $\geq$ 0
TA3+TB3 $\leq$ 1
12000TA4-X4A $\geq$ 0
12000TB4-X4B $\geq$ 0
TA4+TB4 $\leq$ 1

END

INT T1
INT T2
INT T3
INT T4
INT TA1
INT TA2
INT TA3
INT TA4
INT TB1
INT TB2
INT TB3
INT TB4

-20

Solution:

Global optimal solution found.

Objective value: 10398.00
Objective bound: 10398.00
Infeasibilities: 0.000000
Extended solver steps: 0
Total solver iterations: 189
Elapsed runtime seconds: 0.09

Model Class: MILP

Total variables: 32
Nonlinear variables: 0
Integer variables: 12

Total constraints: 22
Nonlinear constraints: 0

Total nonzeros: 92
Nonlinear nonzeros: 0

	Variable	Value	Reduced Cost
	T1	0.000000	410.0000
	T2	1.000000	900.0000
	T3	1.000000	450.0000
	T4	1.000000	980.0000
	X1A	0.000000	0.2100000
	X1B	0.000000	0.3400000
	X1C	0.000000	0.2700000
	X1D	0.000000	0.1600000
	X1E	0.000000	0.000000
0.7000000E-01	X2A	0.000000	
	X2B	0.000000	0.1300000
	X2C	0.000000	0.2800000
	X2D	0.000000	
0.4000000E-01	X2E	7500.000	0.000000
	X3A	2000.000	0.000000
	X3B	0.000000	
0.8000000E-01	X3C	0.000000	0.1100000
	X3D	0.000000	0.2200000
	X3E	0.000000	0.1500000
	X4A	0.000000	0.000000
	X4B	3000.000	0.000000
	X4C	2500.000	0.000000
	X4D	4800.000	0.000000
	X4E	0.000000	0.2000000
	TA1	1.000000	0.000000
	TB1	0.000000	0.000000
	TA2	1.000000	0.000000
	TB2	0.000000	0.000000
	TA3	1.000000	0.000000

TB3	0.000000	0.000000
TA4	0.000000	-360.0000
TB4	1.000000	0.000000

	Row	Slack or Surplus	Dual Price
	1	10398.00	-1.000000
0.4000000E-01	2	0.000000	-
	3	0.000000	0.000000
	4	6000.000	0.000000
	5	1700.000	0.000000
	6	0.000000	-0.3800000
	7	0.000000	-0.3500000
	8	0.000000	-0.2700000
	9	0.000000	-0.4600000
	10	0.000000	-0.4500000
	11	3500.000	0.000000
	12	0.000000	0.000000
	13	0.000000	0.000000
	14	7500.000	0.000000
	15	0.000000	0.000000
	16	0.000000	0.000000
	17	6000.000	0.000000
	18	0.000000	0.000000
	19	0.000000	0.000000
	20	0.000000	-
0.3000000E-01	21	9000.000	0.000000
	22	0.000000	0.000000

STUDENT #2 - Mid



Department of Civil & Environmental Engineering

CVEG 4093Z01

Systems Engineering

Fall 2020

Dr. Vaziri

Homework 07

Assigned: 10/29/2020

Due: Friday, Nov 06, 2020 at 10:00 PM (Canvas)

Solving Mixed Integer Linear Programming (MILP) Problems

SUBMIT THIS as cover sheet with your work
Instructions:

Name [PRINT] Perly Zaldivar

In all the problems you must provide enough details and description of the solution method to demonstrate your knowledge of the solution method. A substantial portion of the grade will be based on your methods.

You may obtain free online-printed graph paper at: <http://www.printfreegraphpaper.com/>

GRADE ⇒

420

800

Problem 1 [100]

Solve the following discrete-valued linear program **graphically**. Show all the feasible points and plot the objective function through the optimal point as a broken line (=====). X_2 should be the ordinate.

Minimize $Z = 6.0 X_1 - 6.0 X_2$

s. t.

$$2 X_1 + 2 X_2 \leq 24 \quad (1)$$

$$X_1 - X_2 \leq 6 \quad (2)$$

$$2X_1 \geq 3 \quad (3)$$

$X_1 \in (1, 2, 3, 4, 6.5, 8); X_2 \in (0, 2, 4, 6, 7.5, 8, 11)$

Problem 2 [250]

Consider the following discrete-valued problem:

Minimize $Z = 4 X_1 + 2 X_2 + 5 X_3$

$$\text{s.t.} \quad X_1 + X_2 + X_3 \leq 36 \quad (1)$$

$$X_1 - X_2 + X_3 \leq 16 \quad (2)$$

$$4X_1 + 4X_3 \leq 42 \quad (3)$$

$X_1 \in (1, 2, 3, 4, 6.3, 8); X_2 \in (0, 2, 4, 6, 7.5, 8, 11); X_3 \in (0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12)$

Solve this problem by the **Branch-And-Bound algorithm** described in the class notes.

SHOW EACH STEP CLEARLY!

If you have more than one candidate LP to be solved, always select the continuous linear program LP- k with the smallest number (k is the number of the candidate LP). For example, suppose you have candidate LPs: LP-3 and LP-5, by this rule, you would choose to solve LP-3 first. Furthermore, always branch on the variable with the smallest subscript; that is, if both X_1 and X_2 have unacceptable values, branch on X_1 . When you branch, the LP to which the $\leq$ constraint is added should be numbered lower ($i+1$) and the LP to which the $\geq$ constraint is added should be number higher ($i+2$).

ALL continuous LPs must be solved using LINDO-LP as a separate PURE LP model.

For each continuous LP, identify the PURE LP Model corresponding to each LP- k and its optimal point(s) and the corresponding objective function (Z) value.

Provide the corresponding **Branch-And-Bound tree** to summarize your results. Whenever a "tree branch" is **fathomed**, state the reason for the fathom.

Problem 3 [150]

(a) [80] Solve the discrete-valued LP given in **problem 2** using LINDO-MIP. Add the necessary constraints to allow solution by the LINDO-MIP solver. **ONLY one** MIP must be solved to provide the solution. Write out the LINDO-MIP program first (and include any "comment" statements which explain your model). Recall from the class notes that you should introduce and use additional integer (0,1) variables to setup the program in LINDO-MIP format. An additional consideration is that you must use the smallest number of integer (0,1) variables. [Hint: Use Binary Expansion for variable X_3 and show all work.]

(b) [70] Solve the discrete-valued LP given in **problem 2** again, using LINDO-MIP. Add the necessary constraints to allow solution by the LINDO-MIP solver. **ONLY one** MIP must be solved to provide the solution. Write out the LINDO-MIP program first (and include any "comment" statements which explain your model). Recall from the class notes that you should introduce and use additional integer (0,1) variables to setup the program in LINDO-MIP format. In this situation you are required to use (add) **GIN** variable(s) **where appropriate**. However you must still add the smallest number of additional binary (0,1) variables where necessary.

Problem 4 [300]

You have, as the owner and operator of a new trucking company, *WeHaul and Drop, LLC*, contracted to make 5 deliveries each week to customers denoted as A through E (see the table below). You plan to capitalize on your knowledge of Systems Engineering to optimize your operations. You have 4 different delivery trucks, each having different operational costs depending on assignment and weight capacities as follows:

TRUCK	CAPACITY [lb]	FIXED COST [\$]	COST [\$/LB] FOR CUSTOMER				
			A	B	C	D	E
1	3,500	550	0.55	0.65	0.50	0.58	0.41
2	7,500	900	0.45	0.48	0.55	0.50	0.45
3	8,000	450	0.38	0.43	0.38	0.68	0.60
4	12,000	980	0.35	0.35	0.27	0.46	0.65

Each week, you must make a 2,000 lb. delivery to Customer A, a 3,000 lb. delivery to Customer B, a 2,500 lb. delivery to Customer C, a 4,800 lb. delivery to Customer D, and a 7,500 lb delivery to Customer E. Because of location, a single vehicle **cannot** deliver to both Customers A and B.

Formulate and solve a mixed integer linear program (MILP) to determine the optimal shipping strategy that minimizes the overall transportation cost of your company's delivery operation.

[50] Clearly describe how you handled the requirement that the same truck cannot deliver to both Customers A and C in your LP.

[50] Present the LINDO model and solution and describe the solution fully.

[50] On a network diagram, present the results of your model solution.

HINT:

You will probably need to define some continuous variables and some binary variables.

PROBLEM 1

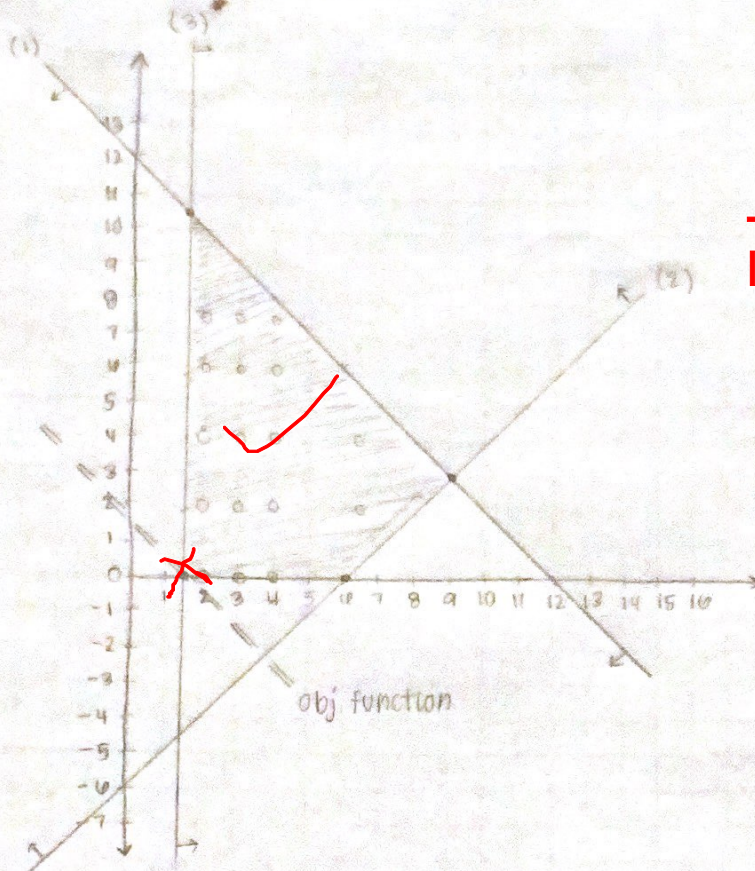
Min $Z = 0X_1 - 0X_2$
 St.

$2X_1 + 2X_2 \leq 24$ (1)
 $X_1 - X_2 \leq 0$ (2)
 $2X_1 \geq 3$ (3)

(1) $X_1 = 0$ $X_2 = 12$
 $X_2 = 0$ $X_1 = 12$

(2) $X_1 = 0$ $X_2 = -0$
 $X_2 = 0$ $X_1 = 0$

(3) $X_1 = 3/2$



-30
 Incorrect Z

$Q = 0X_1 - 0X_2$
 $X_1 = 0$ $X_2 = -1.5$
 $X_2 = 0$ $X_1 = 1.5$

$X_1 \in \{1, 2, 3, 4, 0.5, 0\}$
 $X_2 \in \{0, 2, 4, 0, 1.5, 11\}$

Problem 2

Minimize $Z = 4x_1 + 2x_2 + 5x_3$

st.

$$x_1 + x_2 + x_3 \leq 30 \quad (1)$$

$$x_1 - x_2 + x_3 \leq 10 \quad (2)$$

$$4x_1 + 4x_3 \geq 42 \quad (3)$$

$$x_1 \in \{1, 2, 3, 4, 6, 8, 9\}$$

$$x_2 \in \{0, 2, 4, 6, 7, 8, 11\}$$

$$x_3 \in \{0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12\}$$

Min Z) $4X_1 + 2X_2 + 5X_3$

ST

ONE) $X_1 + X_2 + X_3 \leq 36$

TWO) $X_1 - X_2 + X_3 \leq 16$

THREE) $4X_1 + 4X_3 \geq 42$

FOUR) $X_1 < 8$

FIVE) $X_2 < 11$

SIX) $X_3 < 12$

! X_1 TAKES 1, 2, 3, 4, 6.3, 8

! X_2 TAKES 0, 2, 4, 6, 7.5, 8, 11

! X_3 TAKES 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12

SWITCH1) $X_1 - Y_{11} - 2Y_{12} - 3Y_{13} - 4Y_{14} - 6.3Y_{15} - 8Y_{16} = 0$

LIMIT1) $Y_{11} + Y_{12} + Y_{13} + Y_{14} + Y_{15} + Y_{16} < 1$

SWITCH2) $X_2 - 2Y_{21} - 4Y_{22} - 6Y_{23} - 7.5Y_{24} - 8Y_{25} - 11Y_{26} = 0$

LIMIT2) $Y_{21} + Y_{22} + Y_{23} + Y_{24} + Y_{25} + Y_{26} < 1$

SWITCH3) $X_3 - Y_{31} - 2Y_{32} - 3Y_{33} - 4Y_{34} - 5Y_{35} - 6Y_{36} - 7Y_{37} - 8Y_{38} - 9$

LIMIT3) $Y_{31} + Y_{32} + Y_{33} + Y_{34} + Y_{35} + Y_{36} + Y_{37} + Y_{38} + Y_{39} + Y_{310} +$
END

-215
Incomplete

Problem 3a

Global optimal solution found.

Objective value:

Infeasibilities:

Total solver iterations:

Elapsed runtime seconds:

Model Class:

Total variables:

Nonlinear variables:

Integer variables:

Total constraints:

Nonlinear constraints:

Total nonzeros:

Nonlinear nonzeros:

44.50000

0.000000

3

0.11

LP

27

0

0

13

0

65

0

Variable

X1

X2

X3

Y11

Y12

Y13

Y14

Y15

Y16

Y21

Value

8.000000

0.000000

2.500000

0.000000

0.000000

0.000000

0.000000

0.000000

1.000000

0.000000

Reduced Cost

0.000000

2.000000

0.000000

0.000000

0.000000

0.000000

0.000000

0.000000

0.000000

0.000000

Y22	0.000000	0.000000
Y23	0.000000	0.000000
Y24	0.000000	0.000000
Y25	0.000000	0.000000
Y26	0.000000	0.000000
Y31	0.000000	0.000000
Y32	0.000000	0.000000
Y33	0.000000	0.000000
Y34	0.000000	0.000000
Y35	0.000000	0.000000
Y36	0.000000	0.000000
Y37	0.000000	0.000000
Y38	0.312500	0.000000
Y39	0.000000	0.000000
Y310	0.000000	0.000000
Y311	0.000000	0.000000
Y312	0.000000	0.000000

Row	Slack or Surplus	Dual Price
Z	44.50000	-1.000000
ONE	25.50000	0.000000
TWO	5.500000	0.000000
THREE	0.000000	-1.250000
FOUR	0.000000	1.000000
FIVE	11.00000	0.000000
SIX	9.500000	0.000000
SWITCH1	0.000000	0.000000
LIMIT1	0.000000	0.000000
SWITCH2	0.000000	0.000000
LIMIT2	1.000000	0.000000
SWITCH3	0.000000	0.000000

LIMIT3

0.6875000

0.000000

Min Z) $4X_1 + 2X_2 + 5X_3$

ST

ONE) $X_1 + X_2 + X_3 \leq 36$

TWO) $X_1 - X_2 + X_3 \leq 16$

THREE) $4X_1 + 4X_3 \geq 42$

FOUR) $X_1 < 8$

FIVE) $X_2 < 11$

SIX) $X_3 < 12$

! X_1 TAKES 1, 2, 3, 4, 6.3, 8

! X_2 TAKES 0, 2, 4, 6, 7.5, 8, 11

! X_3 TAKES 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12

SWITCH1) $X_1 - Y_{11} - 2Y_{12} - 3Y_{13} - 4Y_{14} - 6.3Y_{15} - 8Y_{16} = 0$

LIMIT1) $Y_{11} + Y_{12} + Y_{13} + Y_{14} + Y_{15} + Y_{16} < 1$

SWITCH2) $X_2 - 2Y_{21} - 4Y_{22} - 6Y_{23} - 7.5Y_{24} - 8Y_{25} - 11Y_{26} = 0$

LIMIT2) $Y_{21} + Y_{22} + Y_{23} + Y_{24} + Y_{25} + Y_{26} < 1$

SWITCH3) $X_3 - Y_{31} - 2Y_{32} - 3Y_{33} - 4Y_{34} - 5Y_{35} - 6Y_{36} - 7Y_{37} - 8Y_{38} - 9$

LIMIT3) $Y_{31} + Y_{32} + Y_{33} + Y_{34} + Y_{35} + Y_{36} + Y_{37} + Y_{38} + Y_{39} + Y_{310} +$

END

INT Y_{11}

INT Y_{12}

INT Y_{13}

INT Y_{14}

INT Y_{15}

INT Y_{16}

INT Y_{21}

INT Y_{22}

INT Y_{23}

INT Y_{24}

INT Y_{25}

INT Y_{26}

INT Y_{31}

INT Y_{32}

INT Y_{33}

INT Y_{34}

INT Y_{35}

INT Y_{36}

INT Y_{37}

INT Y_{38}

INT Y_{39}

INT Y_{310}

INT Y_{311}

INT Y_{312}

Problem 3b

Global optimal solution found.

Objective value:

Objective bound:

Infeasibilities:

Extended solver steps:

Total solver iterations:

Elapsed runtime seconds:

Model Class:

Total variables:

Nonlinear variables:

Integer variables:

Total constraints:

Nonlinear constraints:

Total nonzeros:

Nonlinear nonzeros:

47.000000
47.000000
0.000000
0.000000
0.000000
97
0.12
MILP

27
0
24
13
0
65
0

Variable

X1
X2
X3
Y11
Y12
Y13
Y14
Y15

Value
8.000000
0.000000
3.000000
0.000000
0.000000
0.000000
0.000000
0.000000

Reduced Cost
0.000000
0.000000
0.000000
4.000000
8.000000
12.000000
16.000000
25.200000

Y16	1.000000	32.000000
Y21	0.000000	4.000000
Y22	0.000000	8.000000
Y23	0.000000	12.000000
Y24	0.000000	15.000000
Y25	0.000000	16.000000
Y26	0.000000	22.000000
Y31	0.000000	5.000000
Y32	0.000000	10.000000
Y33	1.000000	15.000000
Y34	0.000000	20.000000
Y35	0.000000	25.000000
Y36	0.000000	30.000000
Y37	0.000000	35.000000
Y38	0.000000	40.000000
Y39	0.000000	45.000000
Y310	0.000000	50.000000
Y311	0.000000	55.000000
Y312	0.000000	60.000000

Row	Slack or Surplus	Dual Price
Z	47.000000	-1.000000
ONE	25.000000	0.000000
TWO	5.000000	0.000000
THREE	2.000000	0.000000
FOUR	0.000000	0.000000
FIVE	11.000000	0.000000
SIX	9.000000	0.000000
SWITCH1	0.000000	-4.000000
LIMIT1	0.000000	0.000000
SWITCH2	0.000000	-2.000000

LIMIT2
SWITCH3
LIMIT3

1.000000
0.000000
0.000000

0.000000
-5.000000
0.000000

PROBLEM 4

Zaldivar Hofis

```
! Problem 4 CVEG 4093 Fall 2020 PZ
! Variables Definition
! Yi = 0,1, binary for truck i ( 1, 2, 3, 4) Yi = 1 (if truck is used)
! Xij = quantity in pounds (lb) supplied to truck i, j (customer)
! YAi = 1, quantity supplied using truck i to customer A
! YBi = 1, quantity supplied using truck i to customer B
!
! Objective function
!
Min Z) 550Y1 + 900 Y2 + 450Y3 + 980Y4
      + 0.55X1A + 0.65X1B + 0.50X1C + 0.58X1D + 0.41X1E
      + 0.45X2A + 0.48X2B + 0.55X2C + 0.50X2D + 0.45X2E
      + 0.38X3A + 0.43X3B + 0.38X3C + 0.68X3D + 0.60X3E
      + 0.35X4A + 0.35X4B + 0.27X4C + 0.46X4D + 0.65X4E

st
3500Y1 - X1A - X1B - X1C - X1D - X1E >= 0
7500Y2 - X2A - X2B - X2C - X2D - X2E >= 0
8000Y3 - X3A - X3B - X3C - X3D - X3E >= 0
12000Y4 - X4A - X4B - X4C - X4D - X4E >= 0
X1A + X2A + X3A + X4A = 2000
X1B + X2B + X3B + X4B = 3000
X1C + X2C + X3C + X4C = 2500
X1D + X2D + X3D + X4D = 4800
X1E + X2E + X3E + X4E = 7500
3500Y1A - X1A >= 0
3500Y1B - X1B >= 0
YA1 + YB1 <= 1
7500Y2A - X2A >= 0
7500Y2B - X2B >= 0
YA2 + YB2 <= 1
8000Y3A - X3A >= 0
8000Y3B - X3B >= 0
YA3 + YB3 <= 1
12000Y4A - X4A >= 0
12000Y4B - X4B >= 0
YA4 + YB4 <= 1
END
INT Y1
INT Y2
INT Y3
INT Y4
INT YA1
INT YA2
```


INT YA3
INT YA4
INT YB1
INT YB2
INT YB3
INT YB4

Zaidur 13 of 15

-100
Incorrect

Global optimal solution found.
 Objective value:
 Objective bound:
 Infeasibilities:
 Extended solver steps:
 Total solver iterations:
 Elapsed runtime seconds:

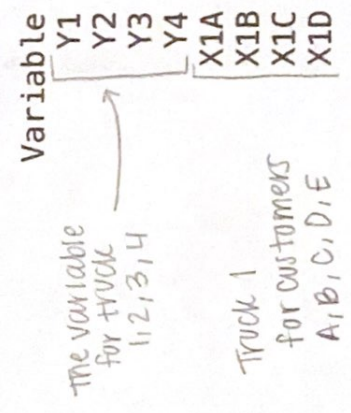
10310.00
 10310.00
 0.000000
 11
 44
 0.13

the value to minimize company cost of operational cost.

MILP

Model Class:

Total variables: 40
 Nonlinear variables: 0
 Integer variables: 12
 Total constraints: 22
 Nonlinear constraints: 0
 Total nonzeros: 92
 Nonlinear nonzeros: 0



Value	Reduced Cost
1.000000	410.0000
1.000000	900.0000
0.000000	370.0000
1.000000	500.0000
0.000000	0.200000
0.000000	0.300000
0.000000	0.230000
0.000000	0.120000

X1E	3500.000	0.000000
X2A	0.000000	0.600000E-01
X2B	0.000000	0.900000E-01
X2C	0.000000	0.2400000
X2D	300.0000	0.000000
X2E	4000.000	0.000000
X3A	0.000000	0.000000
X3B	0.000000	0.500000E-01
X3C	0.000000	0.800000E-01
X3D	0.000000	0.1900000
X3E	0.000000	0.1600000
X4A	2000.000	0.000000
X4B	3000.000	0.000000
X4C	2500.000	0.000000
X4D	4500.000	0.000000
X4E	0.000000	0.2400000
Y1A	0.000000	0.000000
Y1B	0.000000	0.000000
Y1A	1.000000	0.000000
YB1	0.000000	0.000000
Y2A	0.000000	0.000000
Y2B	0.000000	0.000000
YA2	1.000000	0.000000
YB2	0.000000	0.000000
Y3A	0.000000	0.000000
Y3B	0.000000	0.000000
YA3	1.000000	0.000000
YB3	0.000000	0.000000
Y4A	0.1666667	0.000000
Y4B	0.2500000	0.000000
YA4	1.000000	0.000000

TRUCK 2
for customer
A, B, C, D, E

TRUCK 3
for customer
A, B, C, D, E

TRUCK 4
for customer
A, B, C, D, E

obj function value	YB4	Slack or Surplus	Dual Price	reduction on price
	Row			
	Z	10310.00	-1.000000	
	2	0.000000	-0.400000E-01	
	3	3200.000	0.000000	
	4	0.000000	-0.100000E-01	
	5	0.000000	-0.400000E-01	
	6	0.000000	-0.39000000	
	7	0.000000	-0.39000000	
	8	0.000000	-0.31000000	
	9	0.000000	-0.50000000	
	10	0.000000	-0.45000000	
	11	0.000000	0.000000	
	12	0.000000	0.000000	
	13	0.000000	0.000000	
	14	0.000000	0.000000	
	15	0.000000	0.000000	
	16	0.000000	0.000000	
	17	0.000000	0.000000	
	18	0.000000	0.000000	
	19	0.000000	0.000000	
	20	0.000000	0.000000	
	21	0.000000	0.000000	
	22	0.000000	0.000000	

(1) Given $z = 6.0x_1 - 6.0x_2$

300/800

Subject to $2x_1 + 2x_2 \leq 24$ (1)

$x_1 - x_2 \leq 6$ (2)

$2x_1 \geq 3$ (3)

Graphical method

(1) $2x_1 + 2x_2 = 24$

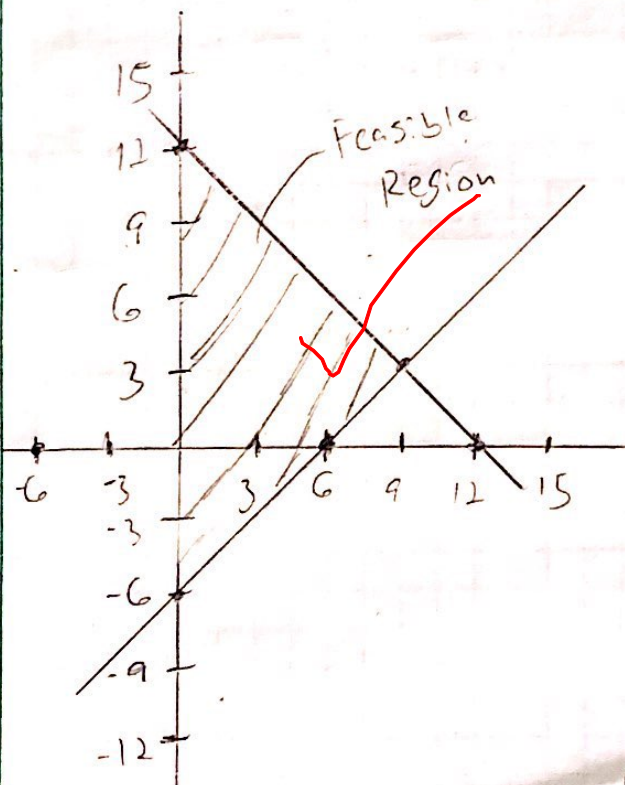
x_1	0	12
x_2	12	0

(2) $x_1 - x_2 = 6$

x_1	0	6
x_2	-6	0

$2x_1 = 3 \Rightarrow x_1 = \frac{3}{2}$

Take $x_1 = x$
 $x_2 = y$



$x_1 \Rightarrow (1)$

$2x_2 = 21$

$x_2 = \frac{21}{2}$

$x_2 = -\frac{9}{2}$

Substitute x_1, x_2 in Objective

$6 + \frac{3}{2} - 6 + \left(-\frac{24}{2}\right) \Rightarrow \frac{18 + 54}{2}$

$= \frac{72}{2}$

JAMAL BAKER

② Min $z \quad 4x_1 + 2x_2 + 5x_3$

ST

ONE) $x_1 + x_2 + x_3 \leq 36$

TWO) $x_1 - x_2 + x_3 \leq 16$

THREE) $4x_1 + 4x_3 \geq 42$

FOUR) $x_1 \leq 8$

FIVE) $x_2 \leq 11$

SIX) $x_3 \leq 12$

! (COMMENT

! x_1 TAKES ON 1, 2, 3, 4, 6, 7, 8

! x_2 TAKES ON 0, 2, 4, 6, 7, 8, 11

! x_3 TAKES ON 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12

SWITCH- x_1) $x_1 - 11 - 2412 - 3413 - 4414 - 6-3415 - 8416 = 0$

LIMIT- x_1) $11 + 12 + 13 + 14 + 15 + 16 < 1$

!

SWITCH- x_2) $x_2 - 2421 - 4422 - 6423 - 7.5424 - 8425 - 11426 = 0$

LIMIT- x_2) $21 + 22 + 23 + 24 + 25 + 26 < 1$

!

SWITCH- x_3) $x_3 - 131 - 2432 - 3433 - 4434 - 5435 - 6436 - 7437 - 8438 - 9439 - 104310 - 114311 - 124312 = 0$

LIMIT- x_3) $131 + 132 + 133 + 134 + 135 + 136 + 137 + 138 + 139 + 1310 + 1311 + 1312 < 1$

-200

END Solve using Branch & Bound Method

JAMAL BAKER

③ Min z) $4x_1 + 2x_2 + 5x_3$

st

ONE) $x_1 + x_2 + x_3 < 36$

TWO) $x_1 - x_2 + x_3 < 16$

THREE) $4x_1 + 4x_3 > 42$

FOUR) $x_1 < 8$

FIVE) $x_2 < 11$

SIX) $x_3 < 12$

! COMMENT

! x_1 TAKES ON 1, 2, 3, 4, 6, 8

! x_2 TAKES ON 0, 2, 4, 6, 7, 5, 8, 11

! x_3 TAKES ON 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12

SWITCH- x_1) $x_1 - y_{11} - 2y_{12} - 3y_{13} - 4y_{14} - 6y_{15} - 8y_{16} = 0$

LIMIT- x_1) $y_{11} + y_{12} + y_{13} + y_{14} + y_{15} + y_{16} < 1$

!

SWITCH- x_2) $x_2 - 2y_{21} - 4y_{22} - 6y_{23} - 7.5y_{24} - 8y_{25} - 11y_{26} = 0$

LIMIT- x_2) $y_{21} + y_{22} + y_{23} + y_{24} + y_{25} + y_{26} < 1$

!

SWITCH- x_3) $x_3 - y_{31} - 2y_{32} - 3y_{33} - 4y_{34} - 5y_{35} - 6y_{36} -$

$7y_{37} - 8y_{38} - 9y_{39} - 10y_{310} - 11y_{311} - 12y_{312} = 0$

LIMIT- x_3) $y_{31} + y_{32} + y_{33} + y_{34} + y_{35} + y_{36} +$

$y_{37} + y_{38} + y_{39} + y_{310} + y_{311} + y_{312} < 1$

JAMAL BAKER

3 COWT

END

INT 411

INT 412

INT 413

INT 414

INT 415

INT 416

INT 421

INT 422

INT 423

INT 424

INT 425

INT 426

INT 431

INT 432

INT 433

INT 434

INT 435

INT 436

-100

Solve using LINDO

JAMIL BAKER

(4)

Model is formulated

$T_i = 1$, if one truck is used

x_{ij} = quantity (lb) to customer j

$TA_i = 1$, quantity supplied using truck i to customer A

$TB_i = 1$, quantity supplied using truck i to customer B

$$\text{Min } 550T_1 + 900T_2 + 450T_3 + 980T_4$$

$$\begin{aligned} &+ 0.35x_{1A} + 0.63x_{1B} + 0.50x_{1C} + 0.5x_{1D} + 0.41x_{1E} \\ &+ 0.45x_{2A} + 0.48x_{2B} + 0.55x_{2C} + 0.50x_{2D} + 0.45x_{2E} \\ &+ 0.38x_{3A} + 0.43x_{3B} + 0.38x_{3C} + 0.68x_{3D} + 0.60x_{3E} \\ &+ 0.35x_{4A} + 0.35x_{4B} + 0.27x_{4C} + 0.46x_{4D} + 0.65x_{4E} \end{aligned}$$

ST

$$3500T_1 - x_{1A} - x_{1B} - x_{1C} - x_{1D} - x_{1E} = 0$$

$$7500T_2 - x_{2A} - x_{2B} - x_{2C} - x_{2D} - x_{2E} = 0$$

$$8000T_3 - x_{3A} - x_{3B} - x_{3C} - x_{3D} - x_{3E} = 0$$

$$12000T_4 - x_{4A} - x_{4B} - x_{4C} - x_{4D} - x_{4E} = 0$$

$$x_{1A} + x_{2A} + x_{3A} + x_{4A} = 2000$$

$$x_{1B} + x_{2B} + x_{3B} + x_{4B} = 3000$$

$$x_{1C} + x_{2C} + x_{3C} + x_{4C} = 2500$$

$$x_{1D} + x_{2D} + x_{3D} + x_{4D} = 4800$$

$$x_{1E} + x_{2E} + x_{3E} + x_{4E} = 7500$$

$$3500T_1 - x_{1A} = 0$$

$$3500T_1 - x_{1B} = 0$$

$$TA_1 + TB_1 = 1$$

$$7500T_2 - x_{2A} = 0$$

$$7500T_2 - x_{2B} = 0$$

$$TA_2 + TB_2 = 1$$

JAMAL BAKER

(4) CONT

$$8000 T3A - x3A \geq 0$$

$$8000 T3B - x3B \geq 0$$

$$TA3 + TB3 \leq 1$$

$$1200 T4A - x4A \geq 0$$

$$1200 T4B - x4B \geq 0$$

$$TA4 + TB4 \leq 1$$

END

INT T1

INT T2

INT T3

INT T4

INT TA1

INT TA2

INT TA3

INT TA4

INT TB1

INT TB2

INT TB3

INT TB4

-200
Solve using LINDO

Final Exam

(Problem 06)

6 [75]

6(a) [15]

What is resiliency. Give and describe 3 factors used to determine resiliency

Factor 1

Factor 2

Factor 3

6(b) [15]

What is the relationship between **risk** and **uncertainty** in engineering design?

6(c) [15]

How is risk addressed/managed in the design of drainage systems?

6(d) [15]

Civil engineers must work with three key players in the project delivery process. List and describe each one

Player 1

Player 2

Player 3

6(e) [15]

A typical project moves through several phases as its developed and implemented

List and any three

Phase 1

Phase 2

Phase 3

STUDENT #1 - High

6 [75]

6(a) [15]

What is resiliency. Give and describe 3 factors used to determine resiliency.

Resilience is a means of assessing the ability to withstand severe conditions.

Factor 1

Robustness - ability to withstand

Factor 2

Redundancy - ability to which system and other elements

Factor 3

Resourcefulness - ability to diagnose and prioritize

satisfy and sustain functional require

6(b) [15]

What is the relationship between risk and uncertainty in engineering design?

Risk refers to decision making situations under which potential outcomes and likelihood of occurrences are known to the decision maker. Uncertainty refers to situations in which the outcomes and/or probabilities of occurrences are unknown to the decision maker.

6(c) [15]

How is risk addressed/managed in the design of drainage systems?

6(d) [15]

Civil engineers must work with three key players in the project delivery process. List and describe each one.

Player 1

owner or client

Player 2

designer (engineer or architect)

Player 3

builder or contractor

6(e) [15]

A typical project moves through several phases as its developed and implemented

List and any three

Phase 1

schematic design

Phase 2

design development

Phase 3

construction documents

STUDENT #2 - Mid

6 [75]

6(a) [15]

What is resiliency. Give and describe 3 factors used to determine resiliency

Factor 1

Factor 2

Factor 3

~~Design capacity
Design limit on material
Analysis of Design~~

-12

6(b) [15]

What is the relationship between risk and uncertainty in engineering design?

The higher uncertainty the bigger the risk

6(c) [15]

How is risk addressed/managed in the design of drainage systems?

~~Drainage system risk management, knowing the type of pipe will lower risk~~

-12

6(d) [15]

Civil engineers must work with three key players in the project delivery process. List and describe each one

Player 1

Player 2

Player 3

~~Client - person paying
Designer - the person designing
general contractor - the person building~~

6(e) [15]

A typical project moves through several phases as its developed and implemented

List and any three

Phase 1

Phase 2

Phase 3

~~Schematic Design
Design Development
construction Documents~~

-24

STUDENT #3 - Low

6 [75]

6(a) [15]

What is resiliency. Give and describe 3 factors used to determine resiliency

Resiliency is the ability to absorb or avoid damage without design completely failing

- Factor 1 Realistic Planning - carry out realistic plans
Factor 2
Factor 3

6(b) [15]

What is the relationship between risk and uncertainty in engineering design?

When it comes to risk, you can predict the possibility of a future outcome but cannot when it comes to uncertainty. A risk is manageable and uncertainty is not.

6(c) [15]

How is risk addressed/managed in the design of drainage systems?

Determining the probability of flooding using hydraulic modeling and risk estimation of probability parameters

6(d) [15]

Civil engineers must work with three key players in the project delivery process. List and describe each one

- Player 1 Client - Determines how they want the project to set done
Player 2 Contractor - Places Bid on project and executes
Player 3 Local / State / Federal Government - Provides regulations and codes you must abide by

6(e) [15]

A typical project moves through several phases as its developed and implemented

List and any three

- Phase 1 Schematic Design ✓
Phase 2 Design Development
Phase 3 Construction Documents OK

ASSIGNMENTS FOR ABET OUTCOME 7

*Ability to acquire and apply new knowledge as needed,
using appropriate learning strategies*

**DEPARTMENT OF
CIVIL & ENVIRONMENTAL ENGINEERING
OUTCOME SPECIFIC ASSIGNMENT
COVER SHEET**

**CVEG 4303
Water Resources Engineering
Spring 2022**

Instructor: Dr. Emmanuel U. Nzewi, PE

Title of Assignment

- 1] Homework 04 – Solution of LPs using LP software and interpretation of results.**
- 2] Homework 06 – Solution of MILPs using LP software for discrete math models**

Outcome Measured Using this Assignment

Outcome 7

Ability to acquire and apply new knowledge as needed, using appropriate learning strategies

Brief Description of the suitability of this assignment for the outcome

In these homework exercises, the student is required to solve both pure LPs and Mixed Integer Linear Program (MILPs) using LINGO software

HOMEWORK

04



Department of Civil & Environmental Engineering

CVEG 4304 P01

Systems Engineering

Spring 2022

Dr. Nzewi

Homework 04 Updated

Assigned: 03/28/2022

SOLUTION OF LINEAR PROGRAMS (LPS) VIA LINDO

Due: Wed., March 30, 2022 at 10:30 AM (in Class)

Due: Tue., March 29, 2022 at 11:00 PM (CANVAS)

SUBMIT THIS as cover sheet with your work

Name [PRINT] **MAAWIKA AGGARWAL**

Instructions:

In all the problems you must provide enough details and description of the solution method to demonstrate your knowledge of the solution method. A substantial portion of the grade will be based on your methods.

GRADE ⇒

600 580
600

In the solution of the following problems you must provide the following to support your solution:

- Provide and describe your LP including at least 1 sentence that describes each constraint and the objective function in the Standard form. (This description should be imbedded in your LINDO LP model.)
- Provide the LINDO/LINGO formatted model. Include a LINGO label for the Objective function and each Constraint.
- Provide the LINDO/LINGO solution.
- Interpret the LINDO/LINGO solution results.
- Provide your LINDO model and the LINDO solution in the format described in class (using a FIXED width font; for example, Courier or Monaco).

1. [300] from Homework 02

Blending Problems: This is another large class of problems in which linear programming is applied heavily. Blending is concerned with mixing different materials called the **constituents** of the mixture (these may be chemicals, gasoline, fuels, solids, colors, foods, etc.) so that the mixture conforms to specifications on several properties or characteristics. To model a blending problem as an LP, the linearity assumptions must hold. This implies that the value for a characteristic for the constituents in the mixtures are the weighted average of the values of that characteristic for the constituents in the mixture; the weights being the proportions of the constituents. As an example, consider a mixture consisting of 4 barrels of fuel 1 and 6 barrels of fuel 2, and suppose the characteristic of interest is the octane rating (Oc.R). If linearity assumptions hold, the Oc.R of the mixture must be equal to $(4 \text{ times the Oc.R of fuel 1} + 6 \text{ times the Oc.R of fuel 2}) / (4 + 6)$. These linearity assumptions hold to a reasonable degree of precision for many important characteristics of blends of gasolines, of crude oils, of paints, of foods, etc. That's why linear programming is used extensively in optimizing gasoline blending, in the manufacture of paints, cattle feeds, beverages, etc. The decision variables in a blending problem are usually either the quantities or the proportions of the constituents.

Problem:

Three liquid mixtures are to be designed as provided in the table below to contain a special chemical called "Optim."

Material	Optim [%]	Availability [gallons]	Cost [\$ / gallon]
1	45	800	20
2	35	1000	15
3	65	700	30
4	30	1500	25

Mixture	Minimum Optim [%]	Maximum Optim [%]	Required Amount [gallons]	Selling Price (\$ / gallon)
X	25	45	600	70
Y	30	50	1200	105
Z	40	65	900	140

Formulate an LP model to determine the production plan that maximizes profit.

2 [300] from Homework 02

Job Scheduling or Project Management Problems [Look up information about PERT or Critical Path Method (CPM)]

You are the project manager for a construction project (maybe capstone design) and you must schedule the various jobs which must be completed before the project is finished. Some of the jobs can begin immediately but other jobs can only begin after others are completed. For example, grading can begin immediately but laying a foundation must be delayed until the grading is completed. The data below are for a project which includes ten jobs; the time it takes to complete each job is known and the set of jobs which must be completed before each job can begin is known. Your objective is to find a schedule (i.e. beginning times and ending times) for all of the jobs such that no jobs begins before any of its predecessors are completed and the time when all jobs are finished is minimized. Formulate a linear programming model to solve the problem.

For the following problem, formulate the Linear program or LP as follows:

- 1) Define the decision variables and briefly explain the significance of each one or group of variables.
- 2) Describe each constraint and the objective function adequately in one or two sentences.
- 3) After developing your model, provide the entire Linear program (LP) on one page.
- 4) Provide the activity network diagram

Be sure to include the non-negativity constraints as necessary.

Job	Time to Complete Job	Preceding Jobs
1	8 days	none
2	6 days	1
3	7 days	none
4	12 days	3
5	4 days	1,3
6	8 days	2,3
7	7 days	1,2, 5
8	14 days	4,5
9	7 days	5,6
10	9 days	1,4

Let B_i be the day on which activity i may start; for example B_1 is the day job 1 may begin.

Let E_F be the earliest time (days) when all jobs have been completed.

PROBLEM 1

LP MODEL:

TITLE MATERIAL PROBLEM

$$\text{!Revenue in mixture X} = 70(X_1 + X_2 + X_3 + X_4)$$

$$\text{!Revenue in mixture Y} = 105(Y_1 + Y_2 + Y_3 + Y_4)$$

$$\text{!Revenue in mixture Z} = 140(Z_1 + Z_2 + Z_3 + Z_4)$$

$$\text{!Total Revenue} = 70(X_1 + X_2 + X_3 + X_4) + 105(Y_1 + Y_2 + Y_3 + Y_4) + 140(Z_1 + Z_2 + Z_3 + Z_4)$$

$$\text{!Cost for Material 1} = 20(X_1 + Y_1 + Z_1)$$

$$\text{!Cost for Material 2} = 15(X_2 + Y_2 + Z_2)$$

$$\text{!Cost for Material 3} = 30(X_3 + Y_3 + Z_3)$$

$$\text{!Cost for Material 4} = 25(X_4 + Y_4 + Z_4)$$

$$\text{!Total Cost} = 20(X_1 + Y_1 + Z_1) + 15(X_2 + Y_2 + Z_2) + 30(X_3 + Y_3 + Z_3) + 25(X_4 + Y_4 + Z_4)$$

$$\text{!Total Profit} = \text{Total Revenue} - \text{Total Cost}$$

$$\text{!Total Profit} = 50 X_1 + 55 X_2 + 40 X_3 + 45 X_4 + 85 Y_1 + 90 Y_2 + 75 Y_3 + 80 Y_4 + 120 Z_1 + 125 Z_2 + 110 Z_3 + 115 Z_4$$

!LP is

$$\text{MAX PROFIT) } 50 X_1 + 55 X_2 + 40 X_3 + 45 X_4 + 85 Y_1 + 90 Y_2 + 75 Y_3 + 80 Y_4 + 120 Z_1 + 125 Z_2 + 110 Z_3 + 115 Z_4$$

! Let X_1, X_2, X_3, X_4 be the materials 1, 2, 3, and 4 respectively, in gallons, required for mixture X for Optim

! Let Y_1, Y_2, Y_3, Y_4 be the materials 1, 2, 3, and 4 respectively, in gallons, required for mixture Y for Optim

! Let Z_1, Z_2, Z_3, Z_4 be the materials 1, 2, 3, and 4 respectively, in gallons, required for mixture Z for Optim

SUBJECT TO

$X_1 + X_2 + X_3 + X_4 \geq 600$! Demand constraint for mixture X, must be greater than equal to the required amount

$Y_1 + Y_2 + Y_3 + Y_4 \geq 1200$! Demand constraint for mixture Y, must be greater than equal to the required amount

$Z_1 + Z_2 + Z_3 + Z_4 \geq 900$! Demand constraint for mixture Z, must be greater than equal to the required amount

$X_1 + Y_1 + Z_1 \leq 800$! Availability constraint for material 1, must be less than equal to the availability in gallons

$X_2 + Y_2 + Z_2 \leq 1000$! Availability constraint for material 2, must be less than equal to the availability in gallons

$X_3 + Y_3 + Z_3 \leq 700$! Availability constraint for material 3, must be less than equal to the availability in gallons

$X_4 + Y_4 + Z_4 \leq 1500$! Availability constraint for material 4, must be less than equal to the availability in gallons

$20 X_1 + 10 X_2 + 40 X_3 + 5 X_4 \geq 0$! Minimum Optim constraint for material X

$15 Y_1 + 5 Y_2 + 35 Y_3 + 0 Y_4 \geq 0$! Minimum Optim constraint for material Y

$5 Z_1 - 5 Z_2 + 20 Z_3 - 10 Z_4 \geq 0$! Minimum Optim constraint for material Z

$0 X_1 - 10 X_2 + 20 X_3 - 15 X_4 \leq 0$! Maximum Optim constraint for material X

$-5 Y_1 - 15 Y_2 + 15 Y_3 - 20 Y_4 \leq 0$! Maximum Optim constraint for material Y

(d) $-20 Z_1 - 30 Z_2 + 0 Z_3 - 35 Z_4 \leq 0$! Maximum Optim constraint for material Z

(h) $X_1 \geq 0$!No negativity constraint

$X_2 \geq 0$

$X_3 \geq 0$

$X_4 \geq 0$

$Y_1 \geq 0$

$Y_2 \geq 0$

$Y_3 \geq 0$

$Y_4 \geq 0$

$Z_1 \geq 0$

$Z_2 \geq 0$

$Z_3 \geq 0$

$Z_4 \geq 0$

END

SOLUTION:

LINGO/WIN64 19.0.53 (17 Feb 2022), LINDO API 13.0.4099.331

Licensee info: Term license, EuNzewi@PVAMU.edu

License expires: 2 OCT 2022

Global optimal solution found.

Objective value: 386500.0

Infeasibilities: 0.000000

Total solver iterations: 9

Elapsed runtime seconds: 0.21

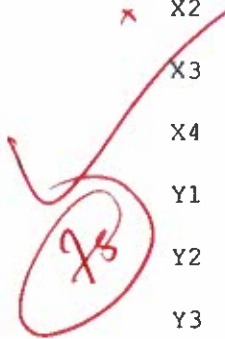
Model Class:

LP

Total variables:	12
Nonlinear variables:	0
Integer variables:	0
Total constraints:	26
Nonlinear constraints:	0
Total nonzeros:	69
Nonlinear nonzeros:	0

Model Title: MATERIAL PROBLEM

Variable	Value	Reduced Cost
X1	0.000000	0.000000
X2	400.0000	0.000000
X3	0.000000	0.000000
X4	200.0000	0.000000
Y1	800.0000	0.000000
Y2	400.0000	0.000000
Y3	0.000000	0.000000
Y4	0.000000	0.000000
Z1	0.000000	0.000000
Z2	200.0000	0.000000
Z3	700.0000	0.000000
Z4	1300.000	0.000000



Row	Slack or Surplus	Dual Price
PROFIT	386500.0	1.000000
2	0.000000	-70.00000
3	0.000000	-35.00000
4	1300.000	0.000000
5	0.000000	120.0000
6	0.000000	125.0000
7	0.000000	110.0000
8	0.000000	115.0000
9	5000.000	0.000000
10	14000.00	0.000000
11	0.000000	0.000000
12	7000.000	0.000000
13	10000.00	0.000000
14	51500.00	0.000000
15	0.000000	0.000000
16	400.0000	0.000000
17	0.000000	0.000000
18	200.0000	0.000000
19	800.0000	0.000000
20	400.0000	0.000000
21	0.000000	0.000000
22	0.000000	0.000000
23	0.000000	0.000000
24	200.0000	0.000000
25	700.0000	0.000000
26	1300.000	0.000000

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PROBLEM 2

LP MODEL:

TITLE PRECEDING JOBS PROBLEM

!Let E_f be the earliest time, in days, to complete all jobs

!Let B_i be the day on which activity i may start for $i = 1, 2, 3, 4, 5, 6, 7, 8, 9$, and 10

MIN E_f !Objective function (Objective function is to minimize the time it takes to finish all jobs)

SUBJECT TO

$B_2 - B_1 \geq 8$!It takes 8 days to finish job B1, Job B1 must start before job B2

$B_5 - B_1 \geq 8$!It takes 8 days to finish job B1, Job B1 must start before job B5

$B_7 - B_1 \geq 8$!It takes 8 days to finish job B1, Job B1 must start before job B7

$B_{10} - B_1 \geq 8$!It takes 8 days to finish job B1, Job B1 must start before job B10

$B_6 - B_2 \geq 6$!It takes 6 days to finish job B2, Job B2 must start before job B6

$B_7 - B_2 \geq 6$!It takes 6 days to finish job B2, Job B2 must start before job B7

$B_4 - B_3 \geq 7$!It takes 7 days to finish job B3, Job B3 must start before job B4

$B_5 - B_3 \geq 7$!It takes 7 days to finish job B3, Job B3 must start before job B5

$B_6 - B_3 \geq 7$!It takes 7 days to finish job B3, Job B3 must start before job B6

75

B8 - B4 $\geq$ 12
before job B8

!It takes 12 days to finish job B4, Job B4 must start

B10 - B4 $\geq$ 12
before job B10

!It takes 12 days to finish job B4, Job B4 must start

B7 - B5 $\geq$ 4
before job B7

!It takes 4 days to finish job B5, Job B5 must start

B8 - B5 $\geq$ 4
before job B8

!It takes 4 days to finish job B5, Job B5 must start

B9 - B5 $\geq$ 4
before job B9

!It takes 4 days to finish job B5, Job B5 must start

B9 - B6 $\geq$ 8
before job B9

!It takes 8 days to finish job B6, Job B6 must start

Ef - B1 $\geq$ 8 !Finishing Job Limit Constraints (The time taken for
respective jobs must be less than equal to Ef)

Ef - B2 $\geq$ 6

Ef - B3 $\geq$ 7

Ef - B4 $\geq$ 12

Ef - B5 $\geq$ 4

Ef - B6 $\geq$ 8

Ef - B7 $\geq$ 7

Ef - B8 $\geq$ 14

Ef - B9 $\geq$ 7

Ef - B10 $\geq$ 9

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B1 $\geq$ 0 !Non-negativity constraint

B2 $\geq$ 0

B3 $\geq$ 0

B4 $\geq$ 0

B5 $\geq$ 0

B6 $\geq$ 0

B7 $\geq$ 0

B8 $\geq$ 0

B9 $\geq$ 0

B10 $\geq$ 0

EF $\geq$ 0

END

Subsonic

SOLUTION:

LINGO/WIN64 19.0.53 (17 Feb 2022), LINDO API 13.0.4099.331

Licensee info: Term license, EuNzewi@PVAMU.edu

License expires: 2 OCT 2022

Global optimal solution found.

Objective value: 33.00000

Infeasibilities: 0.000000

Total solver iterations: 0

Elapsed runtime seconds: 0.37

Model Class: LP

Total variables: 11

Nonlinear variables: 0

Integer variables: 0

Total constraints: 37 ^{1.}
Nonlinear constraints: 0

Total nonzeros: 62 ^{1.}
Nonlinear nonzeros: 0

Model Title: PRECEDING JOBS PROBLEM

*All constraints
must have
labels*

(-14)

Variable	Value	Reduced Cost
EF	33.00000	0.000000
B2	8.000000	0.000000
B1	0.000000	0.000000
B5	8.000000	0.000000
B7	14.00000	0.000000
B10	19.00000	0.000000
B6	14.00000	0.000000
B4	7.000000	0.000000
B3	0.000000	1.000000
B8	19.00000	0.000000
B9	22.00000	0.000000

75

Row	Slack or Surplus	Dual Price
1	33.00000	-1.000000
2	0.000000	0.000000
3	0.000000	0.000000
4	6.000000	0.000000

5	11.00000	0.000000
6	0.000000	0.000000
7	0.000000	0.000000
8	0.000000	-1.000000
9	1.000000	0.000000
10	7.000000	0.000000
11	0.000000	-1.000000
12	0.000000	0.000000
13	2.000000	0.000000
14	7.000000	0.000000
15	10.00000	0.000000
16	0.000000	0.000000
17	25.00000	0.000000
18	19.00000	0.000000
19	26.00000	0.000000
20	14.00000	0.000000
21	21.00000	0.000000
22	11.00000	0.000000
23	12.00000	0.000000
24	0.000000	-1.000000
25	4.000000	0.000000
26	5.000000	0.000000
27	0.000000	0.000000
28	8.000000	0.000000
29	0.000000	0.000000
30	7.000000	0.000000
31	8.000000	0.000000
32	14.00000	0.000000

✓ 78

33	14.00000	0.000000
34	19.00000	0.000000
35	22.00000	0.000000
36	19.00000	0.000000
37	33.00000	0.000000