BYU | CIVIL & ENVIRONMENTAL ENGINEERING
IRA A. FULTON COLLEGE

TEMPORARY SLOPE REPAIR FOR HIGHWAY EXPANSION
Project ID: CEEn_2016CPST_006

50% Completion Report

by

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A Capstone project submitted to

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March 5, 2018

Executive Summary

The BYU Capstone Team analyzed a slope failure of the Midtown Express in Texas. Kiewit Engineering requested a temporary slope repair design to aid construction of a temporary road to facilitate construction of a road widening project. The team analyzed the mechanisms causing the temporary slope to fail. Boring logs taken from the site were used to determine possible causes of slope failure. The failure was found using a combination of AutoCAD and UTexas, leading to the slope failure plane. Possible solutions such as mesh with anchors, shotcrete cover and driven piles were analyzed to find the optimal and most cost efficient result.

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Introduction

The purpose of this report is to present the findings for a temporary slope failure repair of the Midtown Express road in Texas. During a road widening project, a slope failed on the construction site. The objective is to find a temporary solution to stabilize the slope in a cost-effective and timely manner while preventing the slope from failing again. The solution must have a design life of at least 2 years. This report consists of the approach to find the slope failure, the failure findings, the scope of possible solutions and appendices.

Site Conditions

The following pictures show the condition of the site after the failure occurred during the road widening.

Figure 1. Site Condition After Failure

Figure 2. Bottom of Slope After Failure

Approach

The team was given boring logs and slope CAD drawings to analyze the failure planes. To investigate the possible causes of failure the team proceeded as follows:

- Researched slope failures and probable causes
- Analyzed boring logs
- Researched soil properties
- Researched Texas Cone Penetrometer and SPT conversions
- Added soil layering to slope CAD drawings via boring logs and interpolation
- Studied UTexas manual
- Entered soil layering into UTexas along with soil properties
- Investigated failure planes by using UTexas
- Iterated all stations to understand how the different variables affected the soil failure plane
- Contacted professors to clarify UTexas concepts and properties
- Researched several slope stability methods as well as most cost effective options
- Created a spreadsheet to compare costs
- Finalized slope stability method option

Failure Findings

The failure plane is on the top clay layer of the slope, it daylights on the interface between the sand and clay layer, in the same area of the water level. Figure 3 below illustrates the failure plane, along with the factor of safety. The lowest factor of safety found was 0.874.

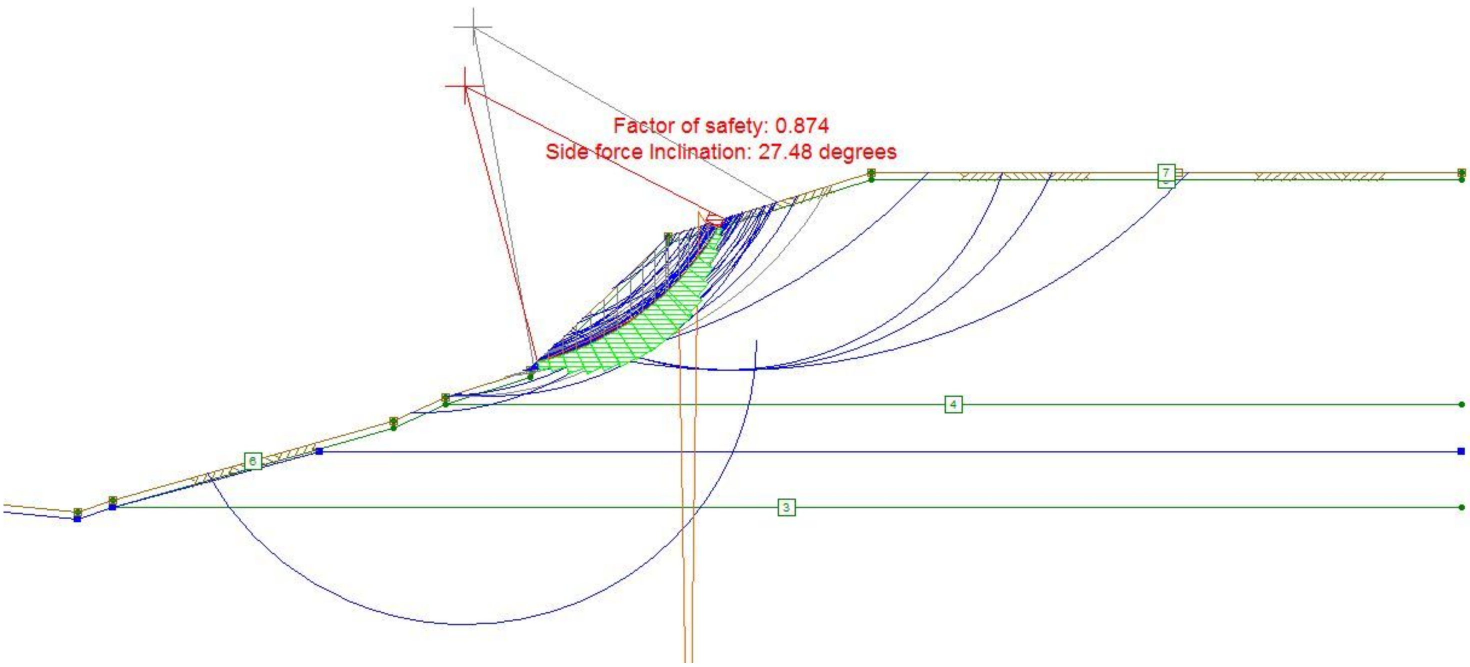


Figure 3. Slope Failure

Scope of Possible Solutions

Three different possible solutions were investigated as part of this project:

1. Soil Nails extending through the problem area to provide stability with a wire mesh cover on the surface of the slope to prevent shallow slides.
2. Soil Nails extending through the problem area to provide stability with a shotcrete facing over the surface of the slope
3. Reinforcing driven piles / drilled shafts into the slope to provide stability.

These possible solutions were briefly analyzed according to several criteria in order to determine their feasibility. This analysis also assisted in determining which solution to move forward with for the stability design. The criteria used in the preliminary comparison are as follows:

1. Cost
2. Ease of Construction / Feasibility / Accessibility
3. Capacity to Carry the Design Load
4. Meets Design Life / Corrosion
5. Aesthetically Pleasing / Environmentally Friendly

Each solution was given a rating based on its performance in the above criteria, with cost being the criteria with the highest weight.

Ratings Table: 1 = lowest (worst), 4 = highest (best)	Drill Shafts	Driven Piles	Shotcrete	Steel Mesh
Cost (weighting = 0.85)	1	2	3	4
Ease of Construction (Weighting = 0.3	1	4	3	2
Capacity Design Load (Weighting = 0.5)	4	2	3	1
Meets Design Life (Weighting = (0.25)	1	2	3	4
Aesthetic/Environment (Weighting = 0.15)	1	3	2	4
Sum of (Rating Times Weighting)	3.55	4.85	6	6.1

Steel Mesh was given the highest overall rating at 6.1 for our design criteria weights. (See explanation and analysis below for more details.)

EXPLANATION OF KEY ITEMS ON THE TABLE:

The cost determination was very simple. We made some brief preliminary cost estimates based on similar job sites total project cost, and experience of our engineering advisors. The most costly received a rating of 1, with the least costly a rating of 4.

Ease of construction was determined considering standard procedures used for each method. Since our failure is on a moderately steep slope accessibility and the feasibility of construction were taken into consideration. Drilled shafts require heavy equipment, a large amount of work, and might be difficult to access on a slope. Wire Mesh also requires a lot of work and more precision and consideration of the terrain than other methods. Shotcrete requires almost the same amount of work, but less precision is needed, as long as the thickness of the concrete slab meets the minimum requirement. Finally driven piles requires minimal effort providing access is easily obtainable on site.

Capacity to carry Design Loads. This parameter varies with time. Steel Mesh is considered a passive solution and may need extra structural consideration depending on the abnormalities in the site. It may fail at a later date when initially secure thus the lowest rating. Driven piles require very high soil cohesive values. This project has median soil values and would require extra tieing into the slope and other structural considerations. Shotcrete has been proven to perform very well on most types of similar slope projects. Driven Piles are immovable and very structurally sound. The higher the diameter the more force it can resist.

The design life is 2 years. We want our project to exceed this parameter, but not become a burden to remove in the future. Drilled shafts, Driven piles, Shotcrete all meet the requirements, but may be difficult to remove in the future. Methods of corrosion may help speed the process, but ultimately Steel Wire Mesh meets the design life the most efficiently.

Aethstetic / Environmentally Friendly. Drilled shafts disturb the environment the most, by heaving up great amounts of dirt, and permanently adding multiple concrete structures. Shotcrete also adds a more permanent structure and can be aesthetically displeasing unless properly treated for corrosion resistance. Driven Piles are much less visible (if at all) than Drilled Shafts, but still would disturb the surrounding soils. Wire mesh is removable and compatible with surrounding foliage if a corrosive retardant is applied at installment.

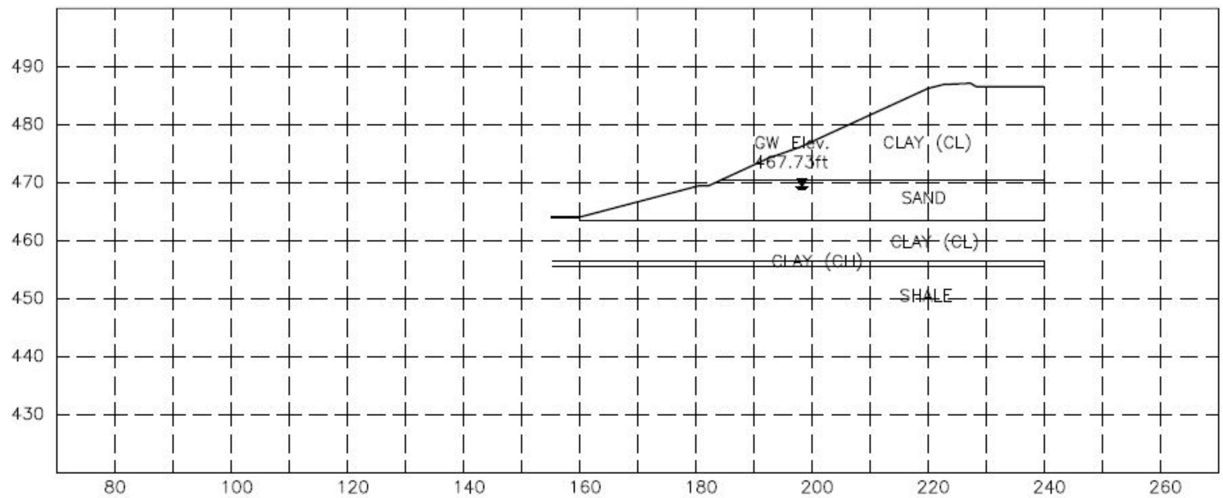
Selected Design

The preferred slope stability design will use soil nails and steel mesh over the slope. This method has the greatest design score based on the criteria above, and is the most viable solution for the problem at hand. It is a cheap, but effective solution to slope failure, and is widely used around the world.

Soil nails are placed into slopes to prevent and remediate slope failure. They are a passive design, meaning that resistance along the nails is developed through movement of the soil around the nail. These nails serve to anchor the slope and prevent deep-seated slides. The mesh is anchored to the surface of the slope by the nails, and provides a retaining force to the surface of the soil, preventing shallow sloughing of the soil at the surface. Often, a layer of shotcrete is also applied over the surface as an aesthetic cover, but there are organic mats which may be placed under the mesh which promote plant growth and may be used as an alternative aesthetic element of design.

Appendix A

CAD Soil Profiles



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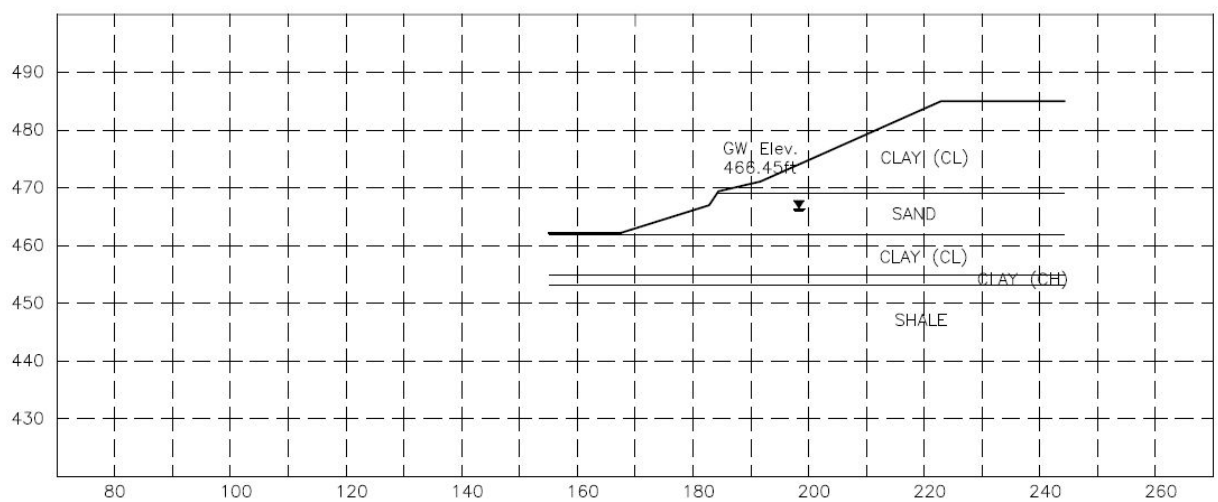

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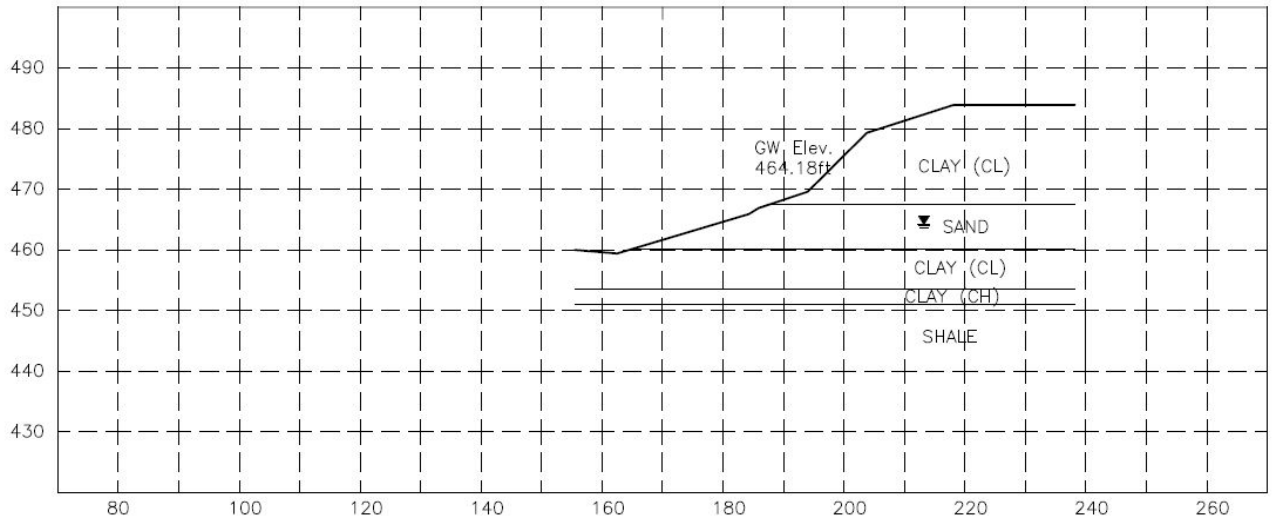
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SHALE

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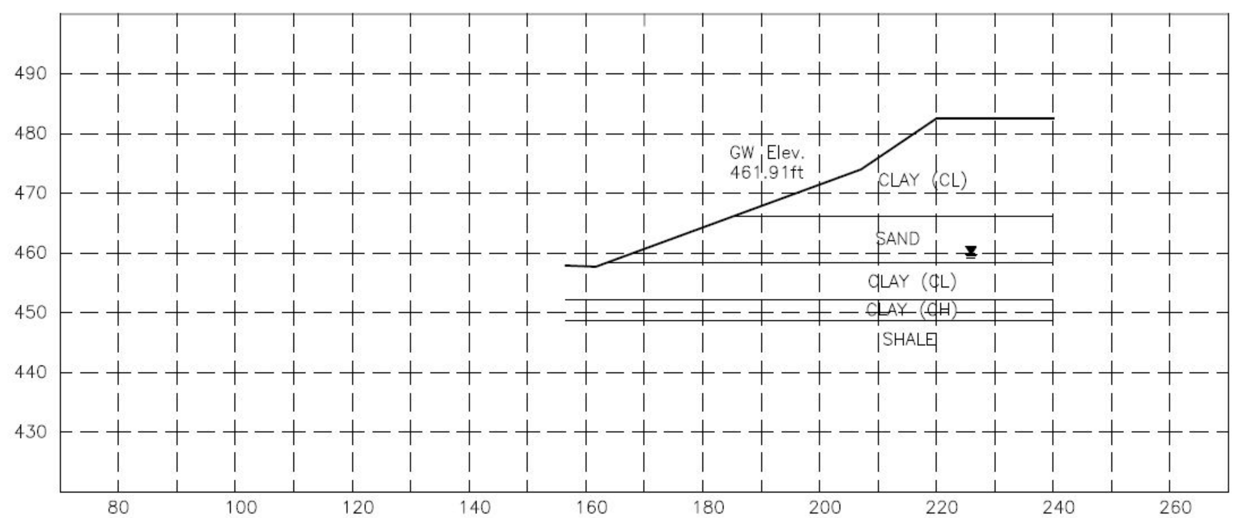
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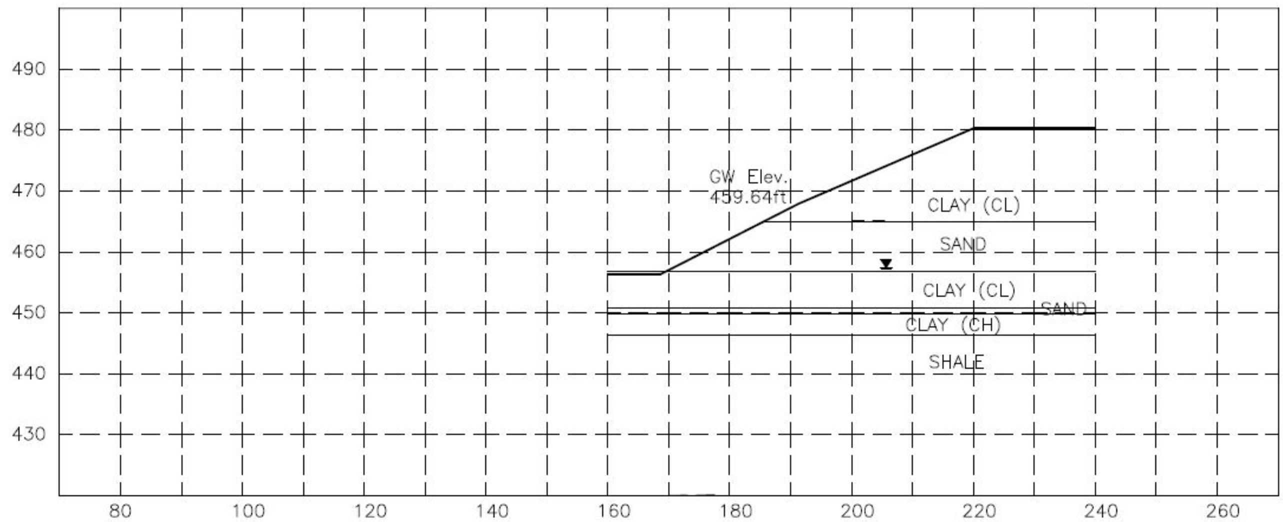
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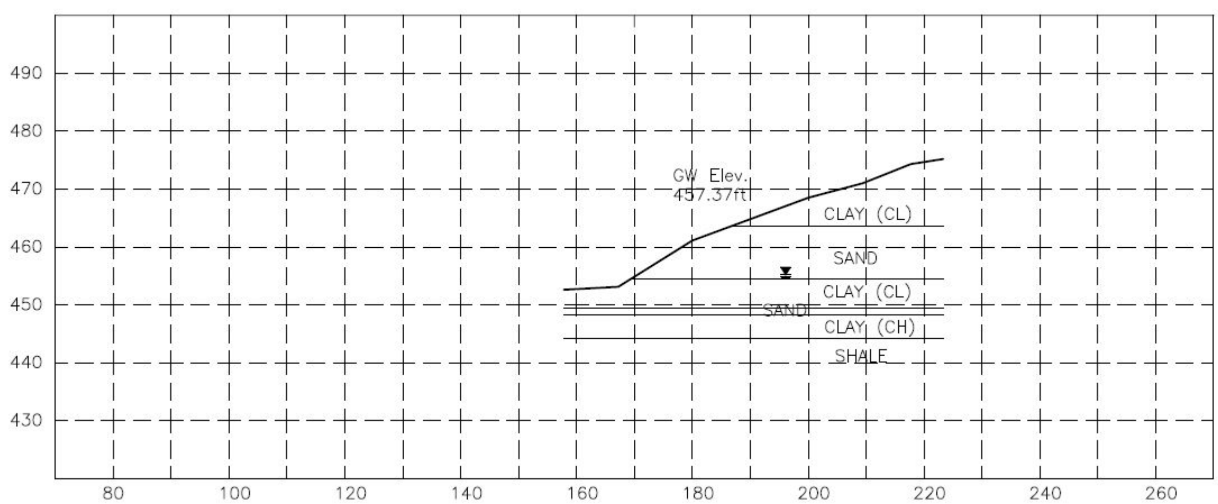
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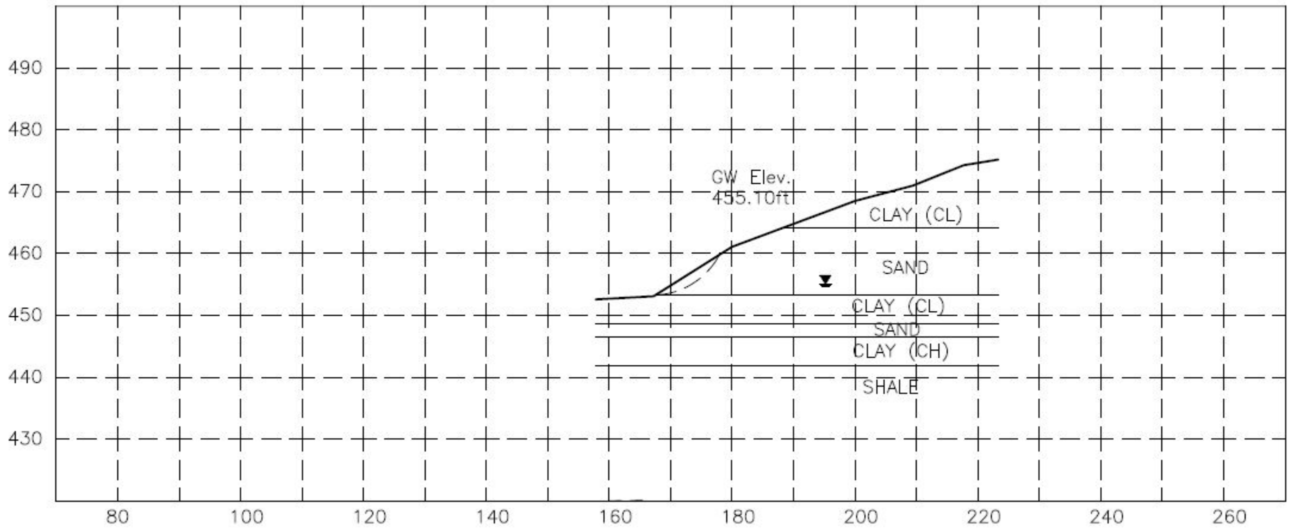
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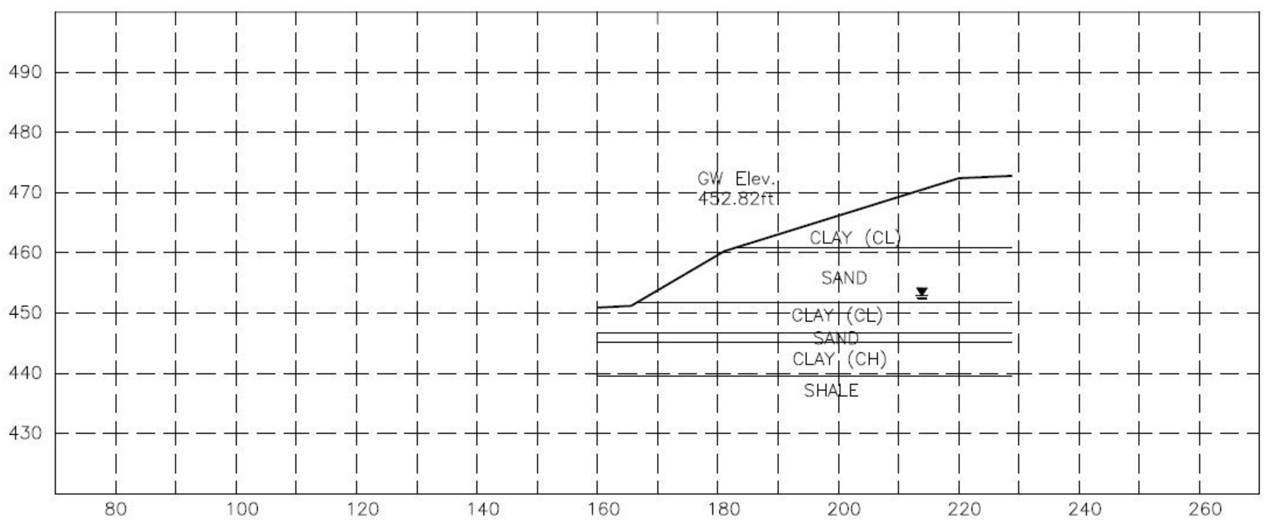
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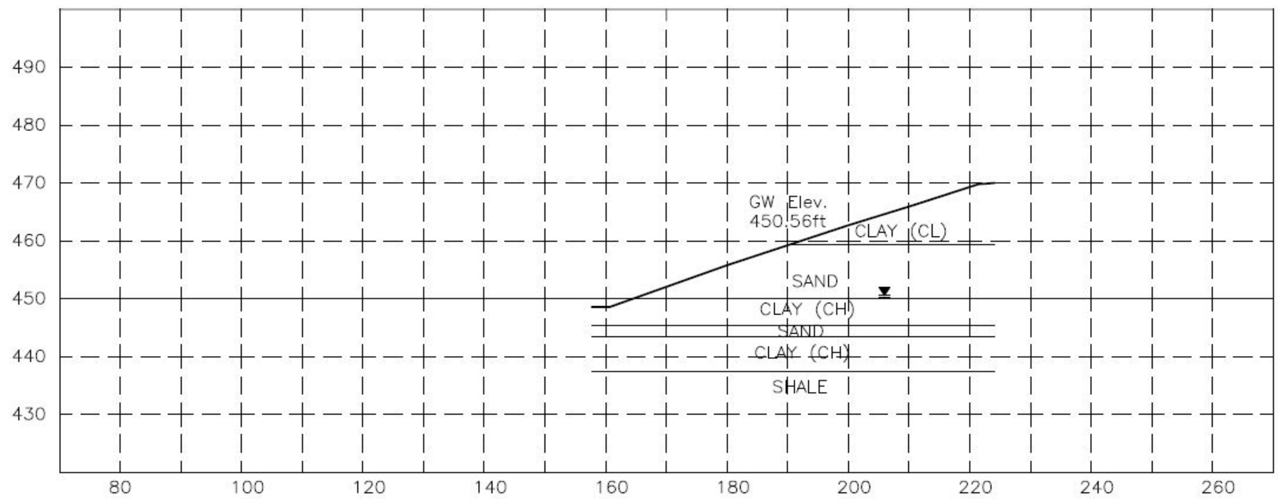
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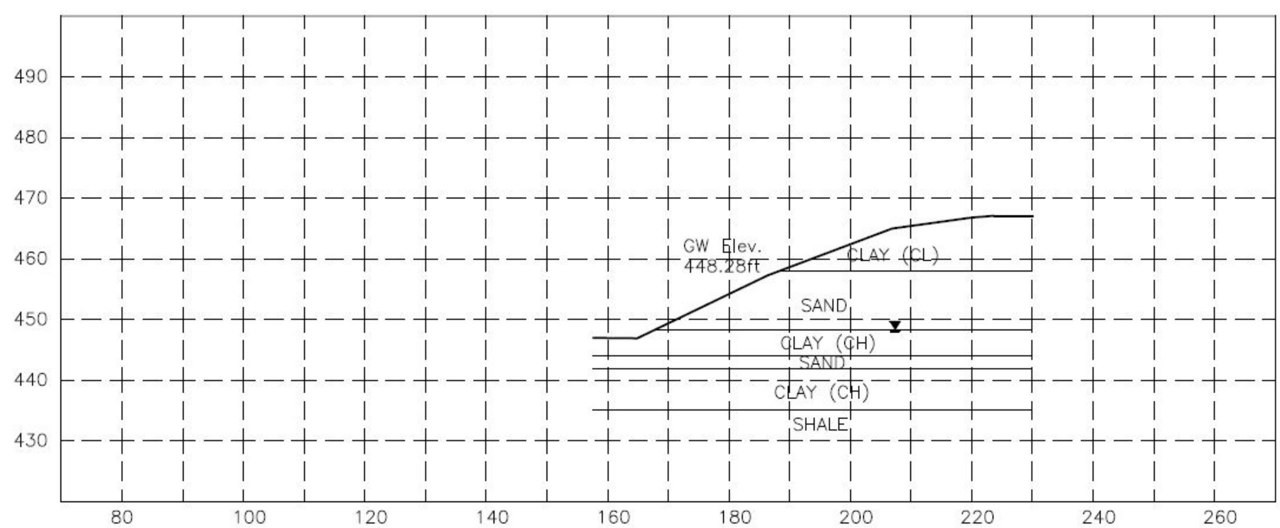
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