LETTER OF TRANSMITTAL

CVL
COE & VAN LOO
PLANNING • ENGINEERING
LANDSCAPE ARCHITECTURE
4550 NORTH 12TH STREET
PHOENIX, ARIZONA 85014
TELEPHONE (602) 264-6831

TO: Flood Control Dist. of Maricopa County
3335 West Durango Street
Phoenix, AZ. 85009

ATTN: John Rodriguez, P.E.

RE: NEW RIVER, MIX DESIGN

DATE	CVL JOB NO.
10/13/88	1090-03

GENTLEMEN:

WE ARE SENDING YOU HEREWITH ☒ ORIGINALS ☐ COPIES OF THE FOLLOWING:

☐ AS REQUESTED BY: ______

PLATS:
- ____ SKETCH
- ____ PRELIMINARY PLAT
- ____ PRE-FINAL
- ____ FINAL
- ____ MAP OF DEDICATION

PLANS & DRAWINGS:
- ____ MASTER PLAN
- ____ SITE PLAN
- ____ WATER
- ____ SEWER
- ____ PAVING
- ____ GRADING & DRAINAGE
- ____ BOUNDARY & TOPO SURVEY
- ____ LANDSCAPE PLANS
- ____ IRRIGATION PLANS
- ____ ALTA SURVEY
- ____ IMPROVEMENT PLANS

REPORTS & DESCRIPTIONS:
- ____ SOILS TEST
- ____ LEGAL DESCRIPTION
- ____ COST ESTIMATES
- ____ QUANTITY ESTIMATE
- ____ SPECIFICATIONS
- ____ DRAINAGE STUDY
- x Updated Mix Design

FORMS AND APPLICATIONS
- ____ SUBDIVISION APPLICATION
- ____ APPLICATION FOR APPROVAL TO CONSTRUCT
- ____ WATER SERVICE AGREEMENT
- ____ SEWER SERVICE AGREEMENT
- ____ GARBAGE SERVICE AGREEMENT

FEES IN THE AMOUNT OF $ ______
FOR ______

THESE ARE TRANSMITTED:

☒ FOR REVIEW ☒ FOR APPROVAL ☒ FOR YOUR USE ☐ FOR SIGNATURE

REMARKS: Here is an updated report on soil-cement mix design. It incorporates comments and suggestions from your office in a meeting dated Sept. 22, 1988. Please review and if you have any questions do not hesitate to call me or Dal at WTI.
Thanks,

COPY TO: ✓ Nick Karan, P.E.;
R. W. Shobe, P.E.

SINCERELY,
COE & VAN LOO

Ashok C. Patel, P.E.

RECEIVED BY: ______ DATE: ______

WESTERN TECHNOLOGIES INC.
3737 East Broadway Road
P.O. Box 21387
Phoenix, Arizona 85036
(602) 437-3737

October 10, 1988

Coe and Van Loo
4550 North 12th Street
Phoenix, Arizona 85014-4291

Attn: Mr. Ashok C. Patel
Senior Vice President

Re: Proposed Channelization of the New River Between Olive Avenue and Bethany Home Road
Maricopa County, Arizona
SOIL-CEMENT MIX PROPORTIONS

Job No. 2128J068
(A revision of the report of July 5, 1988)

Dear Mr. Patel:

This report is a revision of our preliminary report dated 7/5/88. This report provides information for estimating the quantities of cement and fly ash necessary to produce soil cement for embankment protection and grade-control structures on the referenced project. Four soil-cement mix designs have been performed, using soils obtained from the geotechnical investigation test pits. The soils used in the mix designs were proportioned and blended in the laboratory on the basis of the gradations and plasticity indices of the channel excavation soils. Soils with a Plasticity Index higher than five (5) were not used in the mix design.

RECOMMENDED SOIL-CEMENT AGGREGATE GRADATIONS

The aggregates for soil-cement mixes were blended from the soil samples obtained from the test pits within the zones of proposed channel bottom excavation.

The following gradation limits and plasticity index limit are recommended to be specified for soil cement aggregate:

Maximum plasticity index of five (5)

Sieve Size	Percent Passing
1 1/2 inch	98 - 100
No. 4	60 - 80
No. 200	5 - 15

The above gradation limits and plasticity index are considered appropriate for the following reasons:

1. Review of Portland Cement Associations publication, Dam Construction and Facing with Soil-Cement, by P.J. Nussbaum and B.E. Colley. This research and development bulletin evaluates cement content of soil-cement versus resistance to abrasion by water-borne particles, permeability, and strength. The paper compares the results of tests on three soils. A granular soil, non-plastic, with ten (10) percent passing the No. 200 sieve was found to provide superior erosion resistance with lower cement content, in comparison to the other soils tested. The other soils contained more material passing the No. 200 sieve and less gravel retained on the No. 4 sieve.

2. The PCA bulletin concludes that, "When soil-cement is used in areas exposed to rapid stream flow carrying sand or gravel or other debris, the cement content should be 2 percentage points greater than the minimum required by standard tests. In addition, the soil selected should have a gravel component exceeding 20 percent."

3. The gradations of the New River samples show that the 1 1/2" sieve is the largest screen size at which any of the channel excavation soils can be scalped to provide aggregate meeting the other gradation requirements. Most of the channel excavation soils would have to be scalped on a smaller screen size to meet these requirements.

4. The PCA bulletin shows that, for a given cement content, soil-cement using granular soils with non-plastic, low fines content has a higher angle of internal friction under triaxial load testing, in comparison to soils with more fines content.

MIX DESIGN AGGREGATE GRADATIONS

Four soil-cement mixes, each with different aggregate gradations, were tested. The aggregate gradations for each of the four soil cement mixes are shown on the attached Table 1. The blends were adjusted to provide the following variations in gradation:

	Screen Size/Percent Passing		
Mix Number	3/4 in.	No. 4	No. 200
1	100	82	6
2	100	83	15
3	100	61	6
4	100	65	16

MIX DESIGN METHOD

The following procedures were used to mold the soil-cement test specimens and to determine their compressive strengths:

1. Type F fly ash was combined with Arizona Type II cement by ratio of 17.5:82.5 (fly ash:cement). This cementitious material was then blended with each of the mix design aggregates. Separate blends were mixed with each aggregate, using 7.0%, 10.0% and 13.0%, respectively of cementious material. Percentage of cementitious material was calculated by:

$$\frac{(\text{Weight of Cem. Mat'l}) \times 100}{(\text{Weight of Cem. Mat'l}) + (\text{Dry Weight of Aggregate})}$$

2. The maximum density and optimum moisture content for each blend of soil-cement was determined in accordance with ASTM D558, Method B. All test compaction was performed between forty and sixty minutes after water was added to the blends.

3. Three compressive strength test cylinders were molded at optimum moisture content from each blend, and all cylinders were tested for compressive strength at the age of seven days. All test cylinders were compacted within forty and sixty minutes after water was mixed into the blend. The specimens were molded, cured and tested for strength in accordance with ASTM D1633, Method A.

4. Strength correction factors, conforming to Section 6.7.2 of ASTM, C42, for ratios of cylinder lengths to diameters (l/d) were applied to the test results. The corrected strengths were used thereafter.

5. The average strength for each soil-cement blend was calculated from the three strengths which had been determined for each blend. These average strengths are shown plotted for the 7-day compressive strength versus cementitious material content graph shown on attached Figure 1.

It may be of interest to note that, except for reporting optimum moisture contents to the nearest 0.1%, all test methods used also conform to the testing procedures required for determining of cement content for soil-cement at the Agua Fria River from Buckeye Road to north of Indian School Road.

TEST RESULTS

Table 1, attached, summarizes each design curve's aggregate gradation, and the maximum density and optimum moisture of the twelve strength specimen batches.

Figure 1, attached, shows the four mix design curves.

CONCLUSIONS AND RECOMMENDATIONS

The mix design curves indicate that variations within the required aggregate gradation bands will produce the following range of demands for cementitious material:

Strength	Percent Cementitious Material by Weight of Total Dry Mix
750 psi	8.5 to 9.4
1000 psi	10.9 to 12.9

The Portland Cement Association's research publications and common practice call for adding two (2) percent cementitious material to the above percentages. Western Technologies' experience on two previous Agua Fria River Projects has been that approximately another one (1) percent is necessary to offset production variations in soil cement moisture content and the differences between field conditions and a laboratory blending process.

Therefore, for estimating purposes, we recommend that 12 percent be used for 750 psi mix and 16 percent be used for 1000 psi mix.

We recommend that 133 pounds per cubic foot be used as the compacted dry weight of soil cement for estimating purposes. The dry weight of soil cement would be 1.7955 tons per cubic yard. Twelve percent cementitious material is 9.9% cement and 2.1% fly ash. Sixteen percent is 13.2% cement and 2.8% fly ash. Therefore:

	Estimated Weight per Cubic Yard	
Mix Strength	Cement	Fly Ash
750 psi	0.1778 ton	0.0377 ton
1000 psi	0.2370 ton	0.0503 ton

Please call if you have any questions.

Sincerely,
WESTERN TECHNOLOGIES INC.

Dal N. Wakefield, P.E.

Reviewed by: M. Kent Hamm, P.E.

cc/2984C

Copies to: Addressee (5)
R. Bergquist (1)
D. Wakefield (1)

TABLE NO. 1

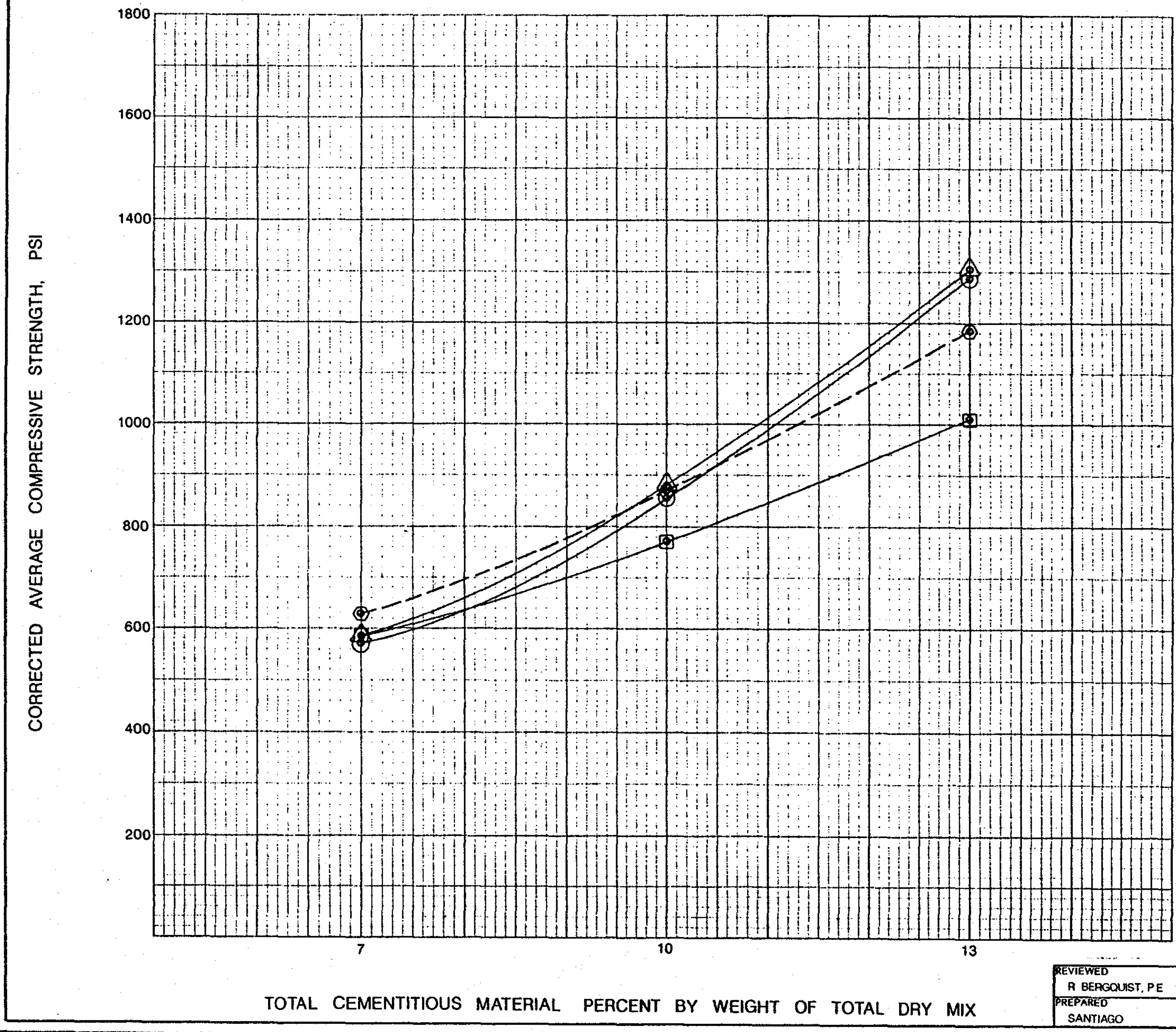
PHYSICAL PROPERTIES OF SOIL-CEMENT COMBINATIONS

Aggregate Gradations (% Passing):

Screen Size	Curve 1	Curve 2	Curve 3	Curve 4
3/4"	100	100	100	100
1/2"	95	95	85	80
No. 4	82	83	61	65
8	72	74	54	58
10	68	70	51	55
16	59	62	43	49
30	37	41	26	33
40	28	32	23	26
50	22	27	17	22
100	14	19	10	17
200	6	16	6	15

Moisture/Density per ASTM D558, Method B:

	Curve 1	Curve 2	Curve 3	Curve 4
With 7% Cementitious Material:				
Maximum Dry Density, pcf	128.0	129.5	131.1	132.0
Optimum Moisture, %	9.3	9.5	8.7	8.5
With 10% Cementitious Material;				
Maximum Dry Density, pcf	128.5	129.7	130.7	132.2
Optimum Moisture, %	9.6	8.7	9.0	8.7
With 13% Cementitious Material:				
Maximum Dry Density, pcf	130.0	130.6	131.6	132.0
Optimum Moisture, %	8.8	9.0	8.2	8.3



New River Channelization

7 Day Compressive Strength vs. Cementitious Content

JOB NO. 2128J068

FIGURE NO. 1

- ◎ Gradation Curve No. 1
- ⬡ Gradation Curve No. 2
- △ Gradation Curve No. 3
- ⊡ Gradation Curve No. 4

NOTE: Specimen cured 6 days in moist cabinet then soaked in water for 24 hours.

REVIEWED R BERGQUIST, P.E	WESTERN TECHNOLOGIES INC. The Quality People
PREPARED SANTIAGO	

WESTERN
TECHNOLOGIES
INC.

3737 East Broadway Road
P.O. Box 21387
Phoenix, Arizona 85036
(602) 437-3737

October 4, 1988

Coe & Van Loo
4550 North 12th Street
Phoenix, Arizona 85014-4291

Attn: Mr. Ash C. Patel, P.E., R.L.S.
Senior Vice-President

Re: Evaluation of Landfills for
The New River Project
Maricopa County Flood Control District
Phoenix, Arizona

Ref. No. 2178A346

I. INTRODUCTION

Per our September 30, 1988, meeting with Maricopa County, Western Technologies Inc. (WTI) is pleased to submit this proposal for providing Coe & Van Loo (CVL) with the landfill environmental engineering services to evaluate suspected landfills identified during the geotechnical phase for the New River Rechannelization Project near west Phoenix, Arizona.

II. PROJECT DESCRIPTION

WTI understands that Coe & Van Loo is designing the rechannelization of the New River waterway. Areas which may have or do contain landfills within the boundaries of the project must be defined and subsequently tested for the presence of hazardous or toxic waste prior to removal.

Depending on the waste characterization of the landfills, based on testing and operational records, evaluations will be made to see if the landfills contain hazardous or non-hazardous waste. The results of this evaluation will establish the criteria for removal and/or closure of the landfills.

III. SCOPE OF SERVICES

In general, the objective of our studies is to evaluate the New River Project for the existence of landfills that contain hazardous or non-hazardous waste. Furthermore, if such landfills are discovered, WTI will evaluate these for the potential or existence of specific contamination. As part of our work scope, WTI will perform initial waste characterization studies on suspect areas to define the areal extent of possible contamination.

More specifically, we propose to perform the work as follows:

Task 1: Records Review

WTI will prepare a historical profile of past and present suspect landfill operations located within the boundaries of the New River rechannelization project. This profile will be based on our analysis of available literature, published reports, documents, and a review of information found during our geotechnical phase.

We will consult with appropriate federal, state, county, municipal and private officials who may have knowledge of the site conditions and landfill operations. Review of available maps, charts, geotechnical reports and records pertaining to geological and hydrological conditions will be made to establish suspect landfill locations not found during the geotechnical phase.

We will also study past aerial photographs of the subject area to further define suspect landfill location areas.

Task 2: On-Site Reconnaissance

WTI will perform an on-site reconnaissance of the defined New River Corridor. The on-site review will consist of walking the site area for visible signs of illegal landfills. We will pay particular attention to: stains; soil discoloration; dead or dying vegetation; waste piles; and other visible signs of environmental concerns relating to landfills. Nuisance orders arising from these landfills will be described. Utilizing the historical profile, WTI will attempt to locate and mark suspect landfill areas. In addition, we will interview selected individuals who are either owners, users and/or live adjacent to the site and record the interviews. We will also prepare a photographic log of site conditions and record our observations.

Task 3: Subsurface Material Sampling

Upon identification of suspect landfill areas, WTI will use a backhoe to obtain near surface and subsurface samples. The suspect landfills will be tested by field methods for the generation of methane and for the off-gassing of volatile organic compounds prior to any backhoe excavation. We propose to use steel pipe driven into the soils of the suspect area and monitor soil gases with Organic Volatile Analyzation (OVA) and HNU meters. Several such measurements will be made at each site visited. Subsurface samples will be obtained and composited for purposes of screening for hazardous or toxic waste. A Resource Conservation and Recovery Act (RCRA) Screen (e.g., GC/MS (Solvent Screen), E.P. Toxicity (metals), Corrosivity (pH), Igniteability (flash point), and Reactivity (sulfides, cyanides)), will be used to confirm or deny the characteristics of hazardous waste. Based on the results of the subsurface material sampling, recommendations will be made to either expand the sampling grid to evaluate the degree and extent of contamination or to sample no further.

WTI will adhere to EPA recommended procedures and protocols. All samples will be accompanied by Chain-of-Custody Records, iced down and transported in a closed container. Based on the results of near surface material sampling, recommendations will be made to sample subsurface materials to specific depths at different locations. This will not be done unless approved by your representative.

Equipment decontamination procedures will be observed and necessary equipment will be cleaned between sampling efforts to prevent cross-contamination.

Task 4: Testing & Analyses

Sample analyses will take place at WTI's own certified laboratory. Specific analytical methods cannot be determined until we have an indication of the type of suspect materials present. It is anticipated that the methods chosen will be in accordance with regulated detection limits in order to characterize a specific suspect contaminant (e.g., RCRA screen, GC/MS solvent screen, pH, flashpoint, E.P. Toxicity and Reactivity).

Task 5: Office Engineering/Report Preparation

Upon completion of Tasks 1 through 4, WTI will review the work done to date, evaluate the data, and perform any necessary office engineering. Following the completion of the office engineering, we will summarize the results of our studies and will include, but not necessarily be limited to, the following:

- An Executive Summary.
- A summary of field observations made at the project site.
- Results of historical records review.
- Results of subsurface material sampling.
- Results of phone conversations and a summary of our record reviews with federal, state, county, utilities and municipalities.

- Results of phone conversations and interviews with selected owners/managers and other parties.
- Photographic evidence of site conditions with accompanying photographic logs, wherever possible.
- WTI's conclusions and recommendations including need for additional services, if deemed necessary.
- Recommendations for services pertaining to closure and/or remediation, if found necessary.

V. ADDITIONAL SERVICES FOR FOLLOW-UP ACTIVITIES

We can, if necessary, provide you with the following services:

- Providing quality control services during closure and/or remediation including geotechnical, material and analytical testing.
- Preparation and implementation of closure and/or remedial action plans.
- Preparation of environmental regulatory compliance documents and programs.
- Advice for negotiations with federal, state and municipal regulatory agencies.
- Conduct negotiations with regulatory agencies on behalf of CVL.
- Expert witness testimony.

VI. ESTIMATED BUDGET

A. **Task 1 - Field Investigations**
(Subsurface sampling, travel, backhoe, Field Engineer, etc.) Estimated 140 hrs. at $60/hr. and expenses (mileage, photographs, etc.) -----$8400.00

Task 2 - Records Research/Data Evaluation
Estimated 30 hrs. at $60/hr. and expenses ----$1,800.00

Task 3 - Testing and Analysis
Estimated 5 Landfills 2 samples/landfill
at $450/ea. and expenses (sampling materials,
steel pipe, etc.) ----------------------------$4,600.00

Task 4 - Office Engineering
(written report, review, clerical, etc.)
Estimated 22.0 hrs. at $60/hr. and expenses
(Report Reproduction, misc.) -----------------$1,700.00

TOTAL $16,500.00

WTI estimates our fee will be on the order of $16,500.00. We will not exceed this fee without your prior approval. Actual billings will be computed on a time and materials basis.

The fee estimate does not include client meetings, additional telephone consultation, or other services not specifically stated in the body of this proposal. These charges would be additional if applicable.

Western Technologies Inc. appreciates the opportunity to submit this proposal and looks forward to providing continuing services on this project. If this proposal meets with your approval, please have the acceptance block of this proposal signed by an authorized agent of Coe & Van Loo as a basis of mutual understanding on the terms and conditions for this project and return one copy to WTI.

Coe & Van Loo
Ref. No. 2178A346

Please call us at (602) 437-3737 if you have any questions or need additional information. Thank you for allowing Western Technologies Inc. to serve you on this project.

Respectfully submitted,
WESTERN TECHNOLOGIES INC.

Accepted For:
Coe & Van Loo

By: ____________________

Title: ____________________

Date: ____________________

Terry L. White
Project Manager
Environmental Engineering Services

Mohammad A. Latif, P.E.
Managing Director
Environmental Engineering Services

/clp

Attachments: Indemnity Clause
General Conditions Agreement

INDEMNITY

Projects involving environmental hazards, hazardous waste and hazardous materials address an existing problem and possibly an existing liability. Western Technologies has neither created the problem nor contributed to it, and, therefore, it is unreasonable to ask or expect Western Technologies to assume the liability that has been created. For this reason, standard contracts and indemnification clauses are inappropriate. We will agree to be liable for our own acts, but require the following Indemnity Clause as a part of our contract with all hazardous waste and materials project clients.

It is understood and agreed that, by the terms of this Agreement, the Client is engaging the services of Western Technologies Inc. (hereinafter WTI) on matters involving the presence or potential presence of hazardous chemicals, substances, materials, or wastes, and it is further understood and agreed that WTI is not assuming or undertaking any of the Client's obligations or obligations for the Client's benefit. Therefore, Client hereby covenants and agrees to hold harmless, indemnify and defend WTI, its officers, Directors, Stockholders, Employees and Agents, from and against any and all claims, losses, damages, and liability, of whatsoever kind or nature, whether to persons, including death, or property, and costs, including but not limited to attorney's fees and costs of defense, arising out of or in any way connected with the presence, sudden or gradual dispersal, discharge, escape, or release of contaminants of any kind which shall include, but not be limited to, smoke, vapors, soot, fumes, acids, alkalis, toxic chemicals, liquids, or pollutants, into or upon land, the atmosphere, or any water course or body of water, arising out of or any way connected with WTI's performance of services under this Agreement. Provided however the above indemnification shall not operate to indemnify against the negligent or willful acts, errors or omissions of WTI, its Officers, Directors, Stockholders, Employees, or Agents. However, WTI does hereby indemnify and hold client harmless from all liability for damages, of whatsoever kind and nature, occasioned by WTI's negligent acts, errors or omissions in the performance of its work under this agreement.

GENERAL CONDITIONS

Project: Coe & Van Loo
Ref No. 2178A346

1.0 **Workmanship**
Western Technologies Inc (hereinafter called WT) will perform its services in accordance with local generally accepted engineering and testing practices. No other expressed or implied warranty or representation, either written or oral is made, included or intended in our proposals, contracts or reports.

1.1 **Utilities**
When performing its work, WT will take all reasonable precautions to avoid damage or injury to subterranean structures or utilities. Client agrees to hold WT harmless for any damages to such subterranean structures or utilities which are not called to WT's attention and correctly shown on the plans furnished.

1.2 **Safety**
Work will be performed only under safe conditions. Client may be charged for safety or security measures required by hazardous job conditions.

1.3 **Samples**
WT will discard all samples thirty (30) days after submission of our report. Further storage or transfer of samples after that time can be made upon written request and at Client's expense.

1.4 **Manner of Payment**
Invoices are due and payable upon receipt and are delinquent thirty (30) days after date of invoice. Work in progress will be billed monthly for portions completed and upon job completion for final balance. If payments are not made in full prior to delinquency, Client agrees to pay interest on the unpaid amount at the highest allowable rate from delinquency date. All payments received shall first be credited to payment of interest, and then to the principal balance.

1.5 **Ownership of Documents**
WT will consider all reports to be confidential property of Client. Upon payment of its charges WT will distribute reports to those persons, organizations or agencies specifically designated by Client or his authorized representative. All boring logs, field data, field notes, laboratory test data, calculations, estimates and other documents prepared by WT shall remain the property of WT.

1.6 **Insurance**
For your benefit, WT maintains the following insurance and amounts: Workman's Compensation, statutory limits; General Liability Insurance, $100,000/$300,000; Blanket Excess Liability, $10,000,000, Automobile Liability, $300,000; Professional Liability, $1,000,000.

1.7 **Limits of Liability**
WT shall not be liable for loss, damage, injury or harm occasioned by or arising from any acts by the Client, the Client's officers, employees, agents or subcontractors. Client agrees that WT shall not be liable for any of Client's losses, damages, injury, harm of claims, and costs, regardless of origin, and however caused, beyond the limits and amounts of the insurance set forth in 1.6 above.

1.8 **Litigation**
In the event of litigation between the parties to this Agreement, WT shall be entitled to all reasonable costs incurred, including staff time, court costs, attorney fees, and other related expenses, if it is found to be the prevailing party.

1.9 **Subpoenas**
The Client is responsible, after notification, for payment of time and expenses resulting from our required response to subpoenas issued in conjunction with our work. Compensation will be based on schedules in effect at the time the subpoena is served.

1.10 **Assigns**
Neither Client nor WT may delegate, assign or transfer his duties or interest in this Agreement without the written consent of the other party.

The foregoing proposal and the General Conditions have been read and are hereby accepted.

____
COMPANY ORGANIZATION

____
SIGNATURE (OFFICER, PARTNER OR OWNER) *DATE*

CVL
COE & VAN LOO
PLANNING • ENGINEERING
LANDSCAPE ARCHITECTURE

Project NEW RIVER CHANNELIZATION
Project No. FCD 88-5
Sheet No. 1 of
Calculated by GRANILLO Date 12/4/89
Checked by KNICKERBOCKER Date

NEW RIVER CHANNELIZATION
BETHANY HOME ROAD TO OLIVE AVENUE
CONTRACT FCD 88-5

CALCULATION OF:

DROP STRUCTURE STABILITY @ STA 238+69 N. of Olive

FOR:

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

CHECKED BY:

KENNETH L. KNICKERBOCKER, P.E.

DATE:

DECEMBER 4, 1989

4550 NORTH 12TH STREET • PHOENIX, ARIZONA 85014 • PHONE (602) 264-6831

COE & VAN LOO
PLANNING • ENGINEERING
LANDSCAPE ARCHITECTURE

Project NEW RIVER CHANNELIZATION
Project No. FCD 88-5
Sheet No. 3a of
Calculated by GRANILLO Date 12/4/87
Checked by KNICKERBOCKER Date

REVISED 02/05/90

II.) METHOD OF CALCULATIONS, CONT

B.) TYPES OF FORCES

$Wt = \Sigma A_n \gamma_n$ (WT OF STRUCTURE COMPONENTS)

$U = \gamma_w h \times b$ (UPLIFT PRESSURE @ BOTTOM STRUCTURE)

$R_y = \Sigma F_y$ (RESULTANT FORCE IN Y DIRECTION)

$F_f = \Sigma \mu_n R_n$ (FRICTION FORCE @ BOTTOM STRUCTURE)

$\mu_{c/s} = 0.45$; COEFF FRICTION → CONC. / SOIL ? BETWEEN CONC. & SOIL

$\mu_{c/s} = \tan\left(\frac{2\phi}{3}\right) = \tan 20° $, $\mu_{c/s} = 0.36$

~~$\mu_{s/s} = \tan 30° = 0.57$~~ ; " " → SOIL / SOIL

$P_a = C_a \gamma_s H_a^2 / 2$ (ACTIVE EARTH FORCE)　　γ_s = UNIT WT. SOIL

$P_p = C_p \gamma_s H_p^2 / 2$ (PASSIVE EARTH FORCE)

$P_R = C_R \gamma_s H_R^2 / 2$ (AT REST EARTH FORCE)

$C_a = \frac{1 - \sin\phi}{1 + \sin\phi}$; $C_a = 1/C_p$; $C_R = 1 - \sin\phi$

$\gamma_{SUB} = \gamma_{SAT} - \gamma_w$ (UNIT WT SUBMERGED SOIL) ; $\gamma_w = 62.4$ #/ft³

$F_I = \rho V^2 A \cos\alpha$ (HYDROSTATIC IMPULSE FORCE) $\rho = 1.94$ slug/ft³, $g = 32.2$ ft/s²

C.) ASSUMPTIONS:

1. STATIC FORCES CAUSED BY EARTHQUAKE MOVEMENT ARE IGNORED FOR BOTH WATER & THE STRUCTURE ITSELF

CVL
COE & VAN LOO
PLANNING • ENGINEERING
LANDSCAPE ARCHITECTURE

Project NEW RIVER CHANNELIZATION
Project No. FCD 88-5
Sheet No. 3b of
Calculated by TRANILLO Date 12/4/89
Checked by KNICKERBOCKER Date

REVISED 02/05/90

II METHOD OF CALCULATIONS, CON'T

C.) ASSUMPTIONS, CONT:

2. $\gamma_w = 62.4$ #/FT³ , $\gamma_{SOIL/CEMENT} = 125$ #/FT³ ,

3. γ_D ? = 110 #/FT³ (120 #/FT³) , $\phi = 30°$, $G_s = 2.7$, SANDY GRAVEL TO 10.5' DEEP

4. ALLOWABLE WORKING STRESS IN SOIL = 5.0 K/FT² MAX

5. SOIL WEDGE BELOW CONC. IS INERT ; FAILURE @ ITS BASE

6. FORCES ANALYZED WHEN:

CONDITION i. SCOUR UPSTREAM & DOWNSTREAM @ RIVER FLOWING FULL

CONDITION ii. SCOUR DOWNSTREAM ONLY @ SUDDEN DRAWDOWN:
- UPSTREAM @ FULL HYDROSTATIC & EARTH FORCES
- DOWNSTREAM HOLE FULL OF WATER

CONDITION iii SCOUR DOWNSTREAM ONLY @ RIVER FLOWING FULL

7. HYDROSTATIC FORCES ANALYZED (CONDITION i)

III. SUMMARY OF RESULTS

	CONDITION i	CONDITION ii	CONDITION iii
F.S. O.T. =	0.98 1.4	~~2.04~~ 1.9	~~1.09~~ 1.6
F.S. S =	5.5 2.6	11.0 1.5	9.6 [illegible]
MAX STRESS σ_s =	[illegible] 0.014 K/FT²	3.15 0.93 K/FT²	[illegible] K/FT²

FS STRESS σ_s
FS
MAX

COE & VAN LOO
PLANNING • ENGINEERING
LANDSCAPE ARCHITECTURE

Project NEW RIVER CHANNELIZATION
Project No. FCD 88-5
Sheet No. 2 of
Calculated by GRANILLO Date 2/4/89
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I. PROBLEM STATEMENT

DETERMINE THE STABILITY OF THE DROP STRUCTURE FOUND @ STA. 238+69 ON DESIGN PLANS FOR SAID PROJECT PREPARED BY COE & VAN LOO CONSULTING ENGINEERS. FOR PURPOSES OF THIS ANALYSIS, STABILITY IS THE FACTOR OF SAFETY (F.S.) AGAINST OVERTURNING (O.T.) & SLIDING (S.) THESE TWO (2) EVENTS ARE STUDIED INDEPENDENTLY OF ONE ANOTHER WITH THE APPROPRIATE FORCES. THE WORST CASE OF STABILITY IS BELIEVED TO OCCUR WHEN SCOUR HAS ERODED SOIL ABOUT THE STRUCTURE REMOVING THE SUBMERGED SOIL FROM ITS STABILIZING EFFECT.

Existing

CHECK FOR UPLIFT PROBLM!

II. METHOD OF CALCULATIONS

A. EQUATIONS OF STABILITY

$F.S._{O.T.} = \Sigma M_R / \Sigma M_{O.T.}$ (FACTOR OF SAFETY AGAINST OVERTURNING)

$F.S._{S.} = \Sigma F_R / \Sigma F_{O.T}$ (FACTOR OF SAFETY AGAINST SLIDING)

ΣM_R = SUMMATION OF MOMENTS RESTORING
ΣM_{OT} = " " " OVERTURNING

B. TYPES OF FORCES

$H_H = \gamma_W H^2/2$ (HYDROSTATIC HORIZ)

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$$\frac{12.4 \times 18^2/2 + 5 \times 13^2/2 + 5^2/2\,(13+5/3)}{(12.4 \times 18) + (5 \times 13) + 5^2/2} = 8.?$$

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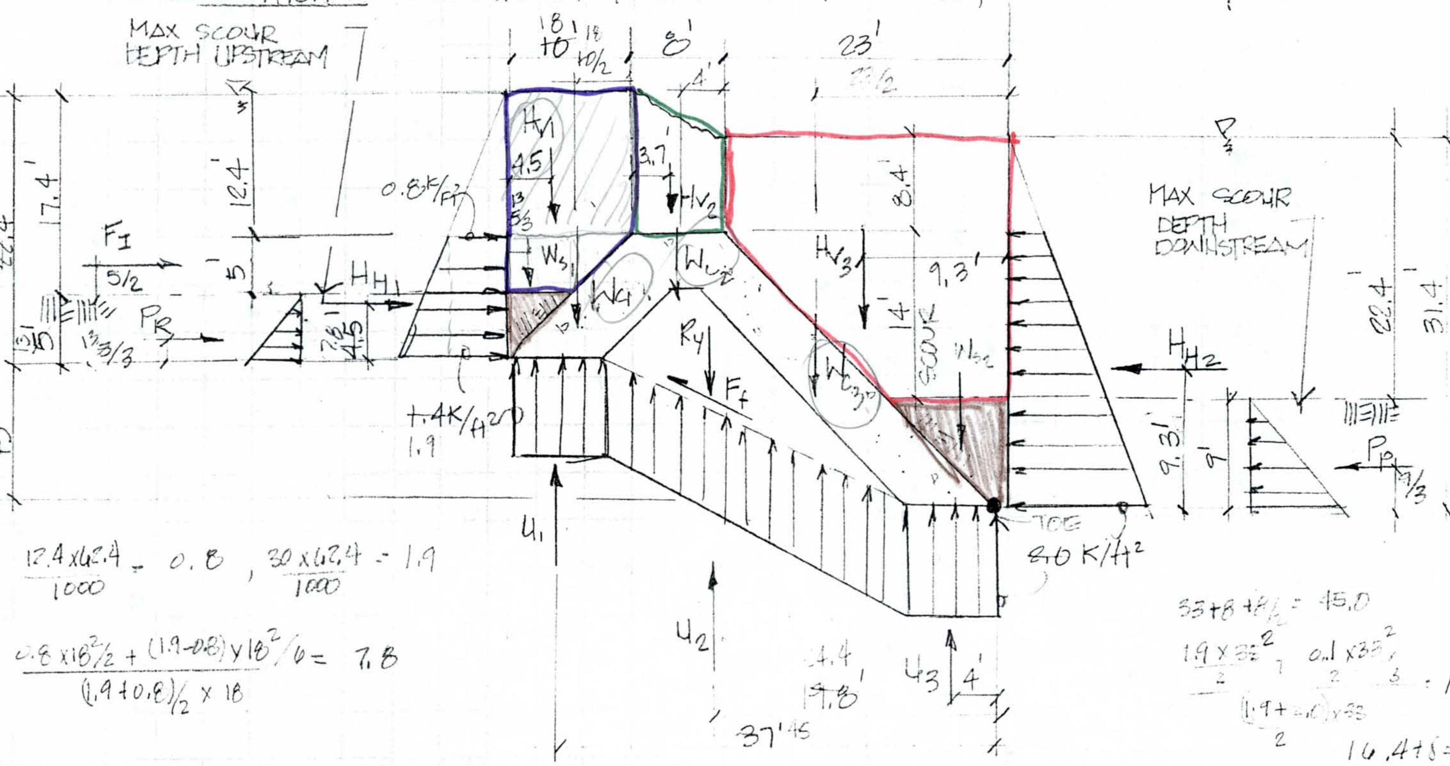
IV. CALCULATIONS, CONT'

5. FREE BODY DIAGRAMS

CONDITION i UPSTREAM & DOWNSTREAM SCOUR; RIVER FLOWING FULL



$\frac{12.4 \times 62.4}{1000} = 0.8$, $\frac{30 \times 62.4}{1000} = 1.9$

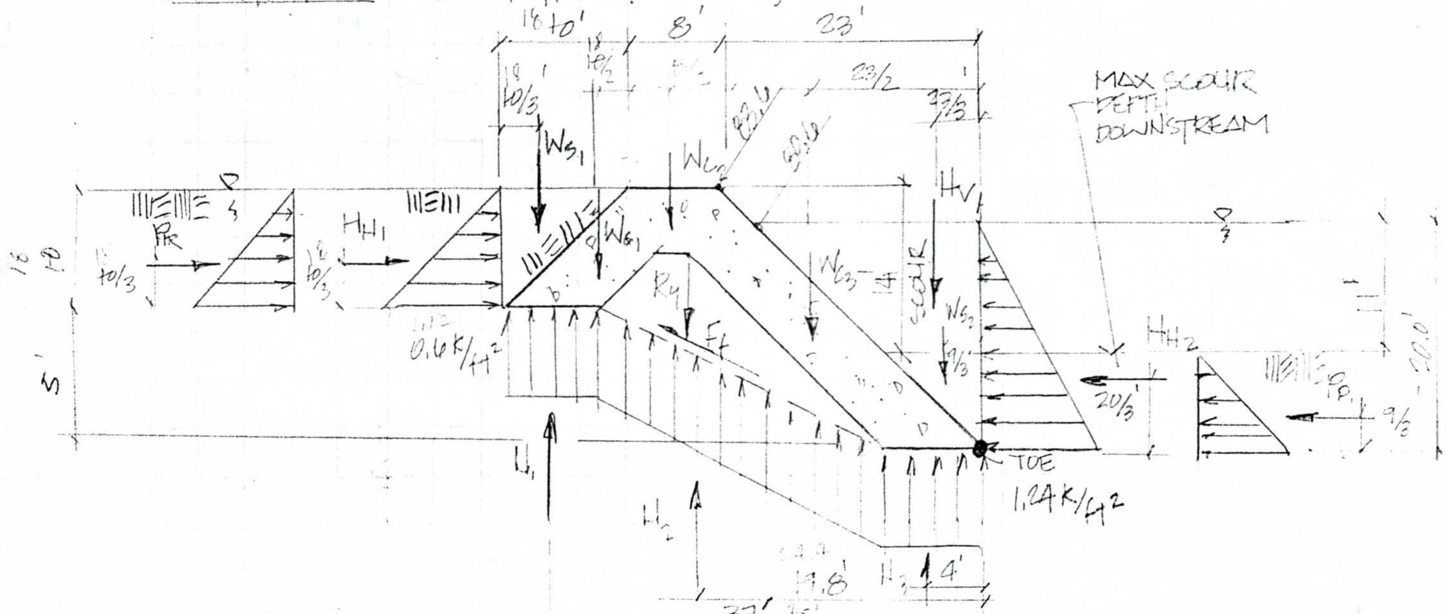
$$\frac{0.8 \times 18^2/2 + (1.9-0.8) \times 18^2/6}{(1.9+0.8)/2 \times 18} = 7.8$$

$33+8+8/2 = 45.0$

$$\frac{1.9 \times 33^2/2 + 0.1 \times 33^2/2 \cdot /3}{(1.9+0.0) \times 33/2} = 16.4$$

$16.4 + 8 = 24.4$

CONDITION ii DOWNSTREAM SCOUR; SUDDEN DRAWDOWN



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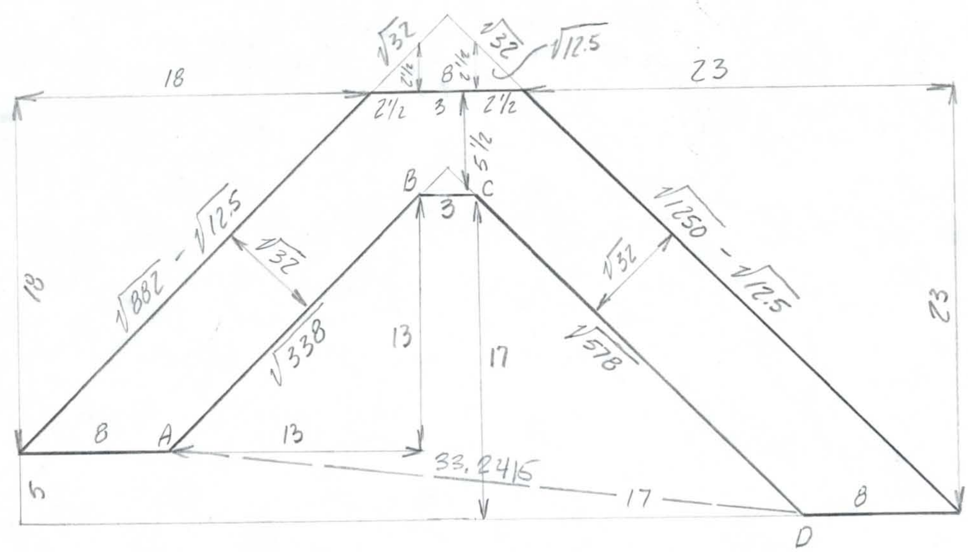

Σ = 78.67
A = 266

Coordinates	N	E
A	100	100
B	113	113
C	113	116
D	96	133

$$\text{Area } ABCDA = \frac{1}{2}\begin{pmatrix} A & B & C & D & A \\ 100 & 113 & 113 & 96 & 100 \\ 100 & 113 & 116 & 133 & 100 \end{pmatrix} = \frac{1}{2}(49{,}037 - 48{,}505)$$

$$\frac{1}{2}(532) = 266 \text{ ft}^2 \checkmark$$

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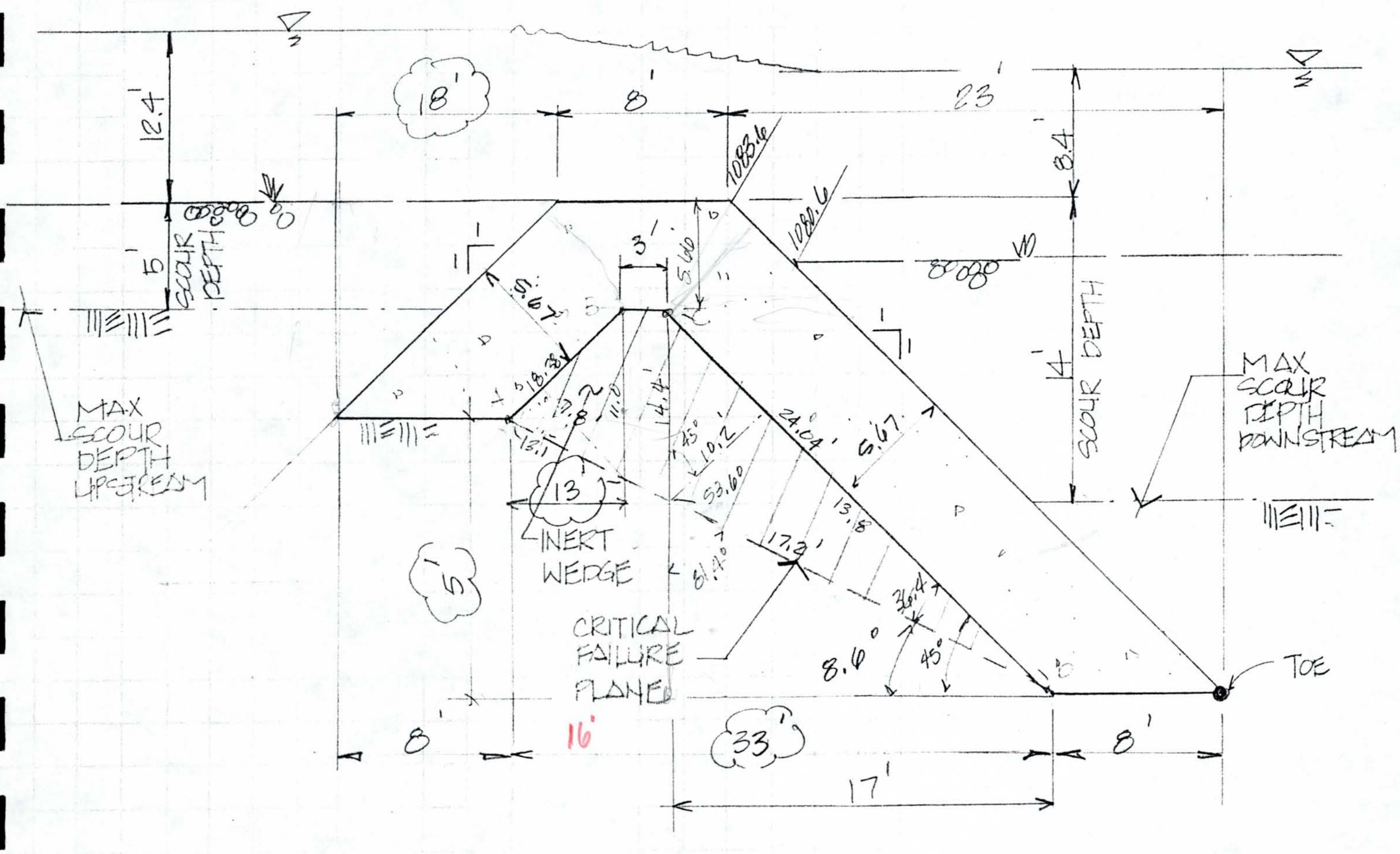
IV CALCULATIONS

A. SKETCH



DROP STRUCTURE @ STA 238+69

AREA ABCD =

$\tan^{-1}(5/33) = 8.6°$ ✓

$(17^2+17^2)^{1/2} = 24.04$ ✓

$(13^2+13^2)^{1/2} = 18.38$

$17/\cos 8.6° = 17.2$

$3/\cos 8.6 = 3.0$

$13/\cos 8.6 = 13.1$

$17.2(\sin 36.4) = 10.2$

$17.2(\cos 36.4) = 13.8$

$10.2/\cos 45° = 14.4$

$13.1 \cos 53.6° = 7.8$

$7.8/\cos 45° = 11.0$

$(18.4)(7.8)/2 + \frac{(11.0+14.4)}{2}(3) + (24.0)(10.2)/2 =$

$71.76 + 38.1 + 122.4 = 232.3$#

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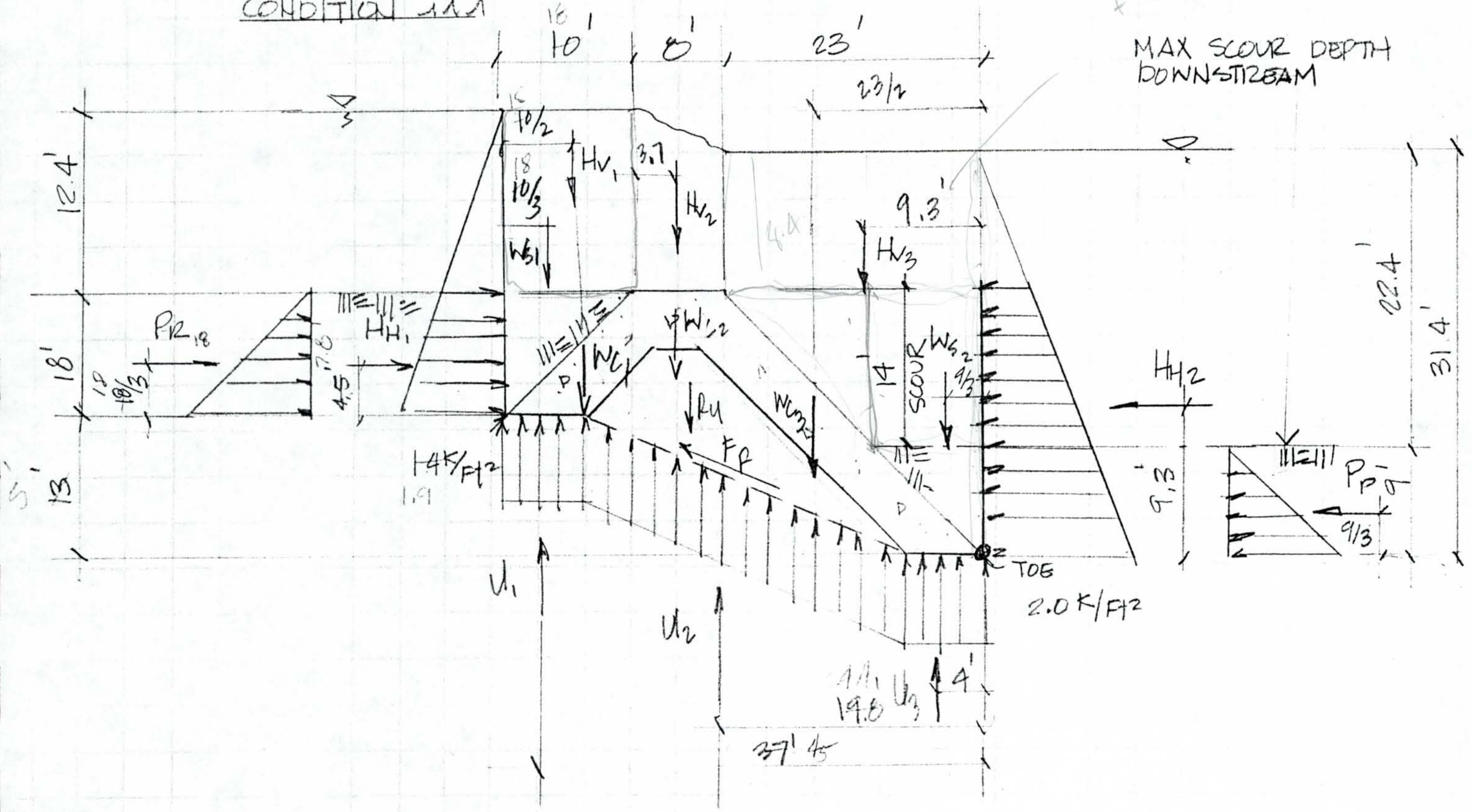
IV CALCULATIONS, CONT

B. FREE BODY DIAGRAMS

CONDITION iii



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IV. CALCULATIONS CONT'

C. FORCES

CONDITION 1

1. HYDROSTATIC

$H_{VT} = 49.91\ K$

VERT:

$H_{V_1} = [(12.4 \times 18) + (13^2) + (5^2/2)] \times 62.4 / 1000 = 18.76\ K/'$ (13×5) ~~10.08~~

$H_{V_1} = [(12.4 \times 18') + (13^2) + (5^2/2)] \cdot .0624 = 25.3\ K/ft$

$H_{V_2} = \left(\frac{12.4 + 8.4}{2}\right) \times 8 \times 62.4/1000 = 5.12\ K/'$

$H_{V_2} = \left(\frac{12.4 + 8.4}{2}\right) * 8 * .0624 = 5.2\ K/ft$

$H_{V_3} = \left(\frac{8.4 + 31.4}{2}\right) \times 14 \times 62.4 / 1000 = 26.03\ K/'$ ~~17.38~~

$(8.4 \times 23 + 14^2/2 + 9 \times 14) * 62.4$

$H_{V_3} = [(8.4 * 23) + 0.5 \times 14^2 + 14 * 9] * .0624 = 26.0$

47.7 ~~32.57~~ $K/F = H_{VT}$

$H_{VT} = 56.5\ K/F$

HORIZ:

$H_{H_1} = \left[\frac{(12.4 \times 62.4) + (30 \times 62.4)}{2 \times 1000}\right] \times 18 = 23.8\ K/'$ ~~1.09~~

$H_{H_1} = \left[\left(\frac{12.4 * 62.4}{2}\right) + \left(\frac{30 * 62.4}{2}\right)\right] * 18 = 23.8\ K/F$

$H_{H_2} = \left[\frac{(8.4 \times 62.4) + (31.4 \times 62.4)}{2 \times 1000}\right] \times 23 = 28.52\ K/'$ ~~1.24~~

$H_{H_2} = \left[\left(\frac{0.52 + 1.96}{2}\right) * 23\right] = 28.52\ K/FT$

UPLIFT:

$U_1 = \frac{(30 \times 62.4) \times 8}{1000'} = 1.9^K \times 8' = 15.2\ K/'$ ~~11.18~~

$U_1 = 15.2\ K/FT$ OK.

$U_2 = \left[\frac{(1.9^K + 2.0^K) \times 33}{2}\right] *$ = 32.2 ~~42.5~~ $K/'$

$U_2 = 64.35\ K/FT$

$U_3 = \frac{(31.4 \times 62.4) \times 8'}{1000'} = 2.0^K \times 8' = 15.67\ K/'$

$U_3 = 15.68$ OK

63.1 ~~69.35~~ $K/' = U_T$

$U_T = 95.23\ K/FT$

2. SOIL CEMENT STRUCTURE

$W_{C_1} = \left[\frac{(18^2 + 18^2)^{1/2} + (13^2 + 13^2)^{1/2}}{2}\right] \times (8^2 \times 1/2)^{1/2} \times \frac{125\#/ft^3}{1000}$ = OK ~~11.6~~ 15.5 K

5.66'

$W_{C_2} = \frac{(8+3)}{2} \times 5.66 \times \frac{125}{1000} =$ OK 3.9^K ✓ 3.9 K

$W_{C_3} = \left[\frac{(23^2 + 23^2)^{1/2} + (17^2 + 17^2)^{1/2}}{2}\right] \times 5.66' \times \frac{125}{1000} =$ OK 20.0^K ✓ 20.01

24.04

35.6 ~~31.4~~ $K = W_{CT} = 39.4\ K$

W_C

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IV CALCULATIONS, CONT

C. FORCES, CONT

CONDITION 2, CONT

3. SOIL WEIGHT

"MISC. CALCS"

$C_a = \frac{1-\sin\phi}{1+\sin\phi} = \frac{1-\sin 30°}{1+\sin 30°} = 0.5/1.5 = \underline{0.33}$ (active resist)

$C_p = 1/C_a = 1/0.33 = \underline{3.0}$ (passive resistance)

$C_r = 1-\sin 30° = 1-0.5 = \underline{0.5}$ (at rest resistance)

$G_s = 2.7 = \frac{\gamma_s}{\gamma_w}$; $\frac{\rho_s}{\rho_w} = \frac{W_s}{W_w} = \frac{\text{Wt soil}}{\text{Wt water}}$; $\gamma_s = \frac{W_s}{V_s}$

$2.7 = \frac{W_s}{V_s \gamma_w}$ ($W_s = 110^{\#}$ → 1 FT³ DRY SAMPLE ASSUMED)

$V_s = \frac{110\ ^{\#}/FT^3}{(2.7) \times 62.4\ ^{\#}/FT^3} = 0.65$ ~~FT³~~ dimensionless - percentage of solids

$V_T = V_s + V_v$

$V_v = (1.0 - 0.65) = 0.35$

$\rho_{SAT} = \frac{M_s + M_w}{V_t}$; $\gamma_{SAT} = \frac{W_s + W_w}{V_t} = \frac{W_s}{V_t} + \frac{W_w}{V_t}$ $(W_w = V_v \gamma_w)$

$\gamma_{SAT} = \frac{W_s}{V_t} + \frac{V_v}{V_t}\gamma_w = \frac{110^{\#}}{1\ FT^3} + (0.35)(62.4\ ^{\#}/FT^3) = 110 + 21.8 = \underline{\underline{132\ ^{\#}/FT^3}}$

ok

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IV CALCULATIONS, CON'T
C. FORCES, CONDITION i

3. SOIL WEIGHT, CON'T

"MISC. CALCS"

$\gamma_{SUB} = \gamma_{SAT} - \gamma_W = 132\ \#/Ft^3 - 62.4\ \#/Ft^3 = \underline{69.6\ \#/Ft^3}$

$W_{S_1} = \dfrac{132\ \#/Ft^3 \times \cancel{5}\,13^2}{2 \times 1000} = \cancel{1.65}\ 11.2^K$

$W_{S_2} = \dfrac{132\ \#/Ft^3 \times 9^2}{2 \times 1000} = \underline{5.35^K}$

16.6 ~~7.0 K~~ $= W_{ST}$

$W_{INEFT\ WEDGE} = \left(\dfrac{132\ \#/Ft^3}{1000}\right) \times (\cancel{112}\ 232.3)\ Ft^2 = \underline{\cancel{14.78}\ 30.7^K}$

why only γ_{sub}. use γ_{dry} & γ_{sat}

4. SOIL PRESSURE, LATERAL

Active: $P_a = \dfrac{C_a\,\gamma_{SUB}\,H_a^2}{2 \times 1000}$; Passive: $P_p = \dfrac{C_p\,\gamma_{SUB}\,H_p^2}{2 \times 1000}$; At Rest: $P_r = \dfrac{C_r\,\gamma_{SUB}\,H_R^2}{2 \times 1000}$

$\gamma_{SUB} = 69.4\ \#/Ft^3$

$C_a = 0.33$; $C_p = 3.0$; $C_r = 0.5$

H_a [Ft]	P_a [K]
0	0
5	0.29
10	1.15
13	1.94
18	3.72

H_p [Ft]	P_p [K]
0	0
9	8.46

H_r [Ft]	P_r [K]
0	0
5	0.44
10	1.74
13	2.94
18	5.64

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IV CALCULATIONS, Cont.

5. IMPULSE MOMENTUM FORCE CONDITION 1

$F_I = \rho V^2 A \cos\alpha$

where: $\gamma_w = \rho g = 62.4\ \#/ft^3$; $g = 32.2\ ft/s^2$

$\rho = \frac{62.4}{32.2} = 1.94\ slug/ft^3$

($1\#/ft/s^2 = 1\ slug$)

$\alpha = 45°$; $\cos\alpha = 0.707$

$A = \sqrt{5^2+5^2} = 7.1\ ft$

$V_{upstream} = 19\ '/sec$

$\therefore F_I = (1.94\ slug/ft^3) \times (19\ '/sec)^2 \times (7.1\ ft) \cdot (0.707)$

$= \underline{3.52^K}$ ok

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IV CALCULATIONS, CONT

D. CHECK OVERTURNING, CONDITION 1

$\Sigma M_{R_{TOE}} = (W_{C_1} \times 36.0) + (W_{C_2} \times 7) + (W_{C_3} \times \ldots) + (H_{V_1} \times (41 - \ldots)) + (H_{V_2} \times 27)$
$+ (H_{V_3} \times 9/3) + (W_{S_1} \times (41 - 13/3)) + (W_{S_2} \times 9/3) + (H_{H_2} \times 9.3)$
$+ (P_P \times 9/3)$ 1,390.6 K-FT/FT. (3006)

$\Sigma M_{O.T._{TOE}} = (P_R \times (5/3 + 15/3)) + (H_{H_1} \times (5/3 + 4.5)) + (F_I \times (15 + 5 + 5.5))$
$+ (U_1 \times 31) + (U_2 \times 11.6) + (U_3 \times 7) =$ 1,415.7 K-FT/FT (2658)

F.S.O.T. = 1390.6 (3006) / 1,415.7 (2658) = ~~0.98~~ (1.13) > 1.5 O.K.

~~2203.4 K-ft.~~

E. FRICTION FORCE @ CRITICAL FAILURE PLANE, CONDITION 1

1. RESULTANT FORCE

$R_Y = H_{VT} + W_{CT} + W_{ST} - U_T$
$= 33.35^{K/FT} + 31.4^{K/FT} + 7.0^{K/FT} - 69.35^{K/FT} = 3.4^{K/FT}$
(47.7, 37.4, 16.4, 63.1, 38.8)

2. LOCATING THE RESULTANT FORCE

$\bar{X} = \frac{\Sigma M_R - \Sigma M_{O.T}}{R_Y} = \frac{(1390.6 - 1380.4)^{K-FT/FT}}{2.4^{K/FT}} = 14.35'$ (3006, 1872, 38.8, 29.2)

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IV CALCULATIONS, CONT

3. DETERMINE THE GEOMETRY OF THE SOILS REACTION PRESS. PRISM.

• MIDDLE 1/3 OF STRUCTURE BASE?

$41/3 = 13.7 \times 2 = 27.3$ (49; 16.3; 32.7)

$13.7 < 16.3 < 27.3$ (16.3; 32.7)

∴ YES! → WE GET TRAPEZOIDAL PRESSURE PRISM

(1) $(Pry_1 \times 41) + \frac{1}{2}(Pry_2) \times 41 = 2.4^K$ (49; 49; 38.8)

(2) $(Pry_1) \times \frac{41^2}{2} + (Pry_2) \times \frac{41^2}{3} = 39.0$ K-FT/FT (49; 49; 1133)

$Pry_1 = 0.34$

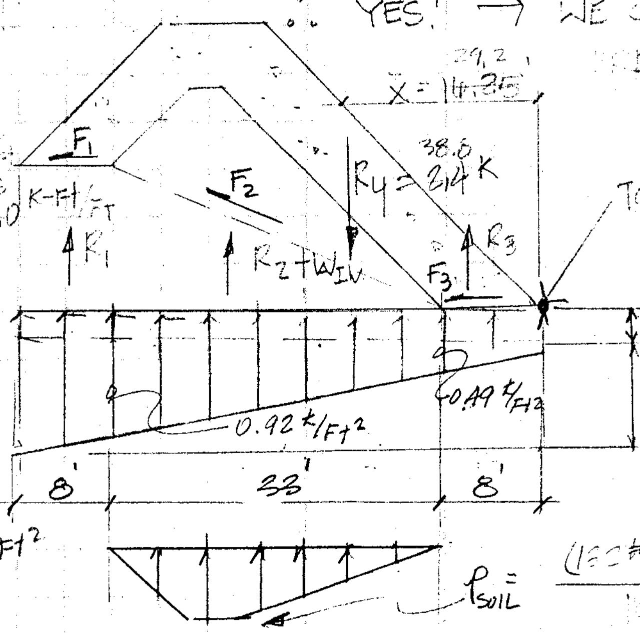
$Pry_2 = 0.91$

0.074 k/ft²

Check

$1.06 + 0.07 = 1.13$ k/ft² < 5.0 k/ft² (1.90 + 1.25 = 3.15)

OK



$38.8 \times 29.2 = 1133$ k-ft/ft

$Pry_1 = 0.032$ k/ft² (0.34)

$Pry_2 = 0.042$ k/ft² (0.91)

$\frac{(150\#/ft^3) \times (8)}{1000} = 1.06^k$ (14; 1.90)

NOTE: MAX SOIL PRESSURE = 5.0 K/FT² = 2.5 TSF
ASSUMES 1" SETTLEMENT IN MEDIUM TO LOOSE SANDS WITH N = 25 [BPF].

4. DETERMINE PRESSURE PRISM RESULTANTS.

$\left(\frac{0.91}{49}\right)(8) + 0.34 = 0.49$

$\left(\frac{0.91}{49}\right)(8 + 33) + 0.34 = 0.92$

$R_1 = \frac{(0.032 + 0.040)}{2} \times 8 = 0.29$ K/FT (1.35; 0.6; 5.7)

$R_2 = \frac{(0.0402 + 0.0658)}{2} \times 25 = 1.33$ K/FT (0.92; 0.49; 33; 23.3)

$R_3 = \frac{(0.0658 + 0.0740)}{2} \times 8 = 0.56$ K/FT (0.49; 0.34; 3.3)

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IV CALCULATIONS, CONT

5. DETERMINE THE FORCE OF FRICTION,

$F_1 = R_1 \times \mu_{c/s} = ~~0.31~~\ 8.7 \times 0.45 = \underline{~~0.13~~\ 3.9\ ^k/FT}$

$F_2 = (R_2 + W_{IW}) \times \mu_{s/s} \times \cos ~~27.5°~~\ 8.60° = (~~1.33~~\ 23.3 + ~~14.78~~\ 30.7)\ 0.57\ ~~0.89~~\ 0.99 = ~~8.17~~\ 30.5\ ^k/FT$

$F_3 = R_3 \times \mu_{c/s} = ~~0.56~~\ 3.3 \times 0.45 = \underline{~~0.25~~\ 1.5\ ^k/FT}$

$~~8.55~~\ 35.9\ ^k/FT = F_T$

F. CHECK SLIDING, CONDITION 1

1.) $\Sigma F_O \rightarrow = F_I + P_{R_{13}} + H_{H_1} = (1.5' + ~~0.44~~\ 2.9 + ~~1.09~~\ 23.8)^k = \underline{~~3.33~~\ 28.5\ ^k/FT}$ ✓

2.) $\Sigma F_R \leftarrow = F_T + H_{H_2} + P_P = (~~8.55~~\ 35.9 + ~~1.24~~\ 28.5 + 8.46)^k = \underline{~~18.25~~\ 72.9\ ^k/FT}$ ✓

$F.S._S = \frac{~~18.25~~\ 72.9}{~~3.33~~\ 28.5} = \underline{~~5.5~~\ 2.6}$ ✓ > 1.5 OK!

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IV CALCULATIONS, CONT

C. FORCES, CONDITION ii

1. HYDROSTATIC

VERT:

$H_{V_1} = \left(\frac{20^2}{2}\right) \times 62.4/1000 = 12.48$ K/ft $= H_{VT}$

HORIZ:

$H_{H_1} = \overset{18^2}{\cancel{10}} \times 62.4/2 \times 1000 = 10.1$ K/ft

$H_{H_2} = 20^2 \times 62.4/2 \times 1000 = 12.5$ K/ft

22.6 K/ft $= H_{VT}$

UPLIFT (BOUYANCY):

$U_1 = \frac{(\overset{18}{\cancel{10}} \times 62.4) \times 8'}{1000} = 1.12 \times 8 = \overset{9.0}{4.99}$ K/1

$U_2 = \frac{(\overset{1.12}{\cancel{0.62}} + 1.24) \times 25}{2} = \overset{29.5}{\cancel{11.63}}$ K/1

$U_3 = \frac{(20 \times 62.4) \times 8'}{1000} = 1.24 \times 8 = 9.9$ K/1

48.4 ~~26.60~~ K/1 $= U_T$

2. WEIGHT OF SOIL CEMENT STRUCTURE
(SEE CONDITION i FOR CALCS)

$W_{C_1} =$ 7.5 K/1

$W_{C_2} =$ 3.9 K/1

$W_{C_3} =$ 20.0 K/1

31.4 K/1 $= W_{CT}$

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IV CALCULATIONS, CON'T

C. FORCES, CONDITION ii

3. SOIL WEIGHT
(SEE CONDITION i FOR CALCS)

$\gamma_{SUB} = 69.6\ \#/FT^3$, $\gamma_{SAT} = 132\ \#/FT^3$

$W_{S_1} = (132) \times \frac{10^2}{2} / 1000 = 6.60\ K/FT$ (18; 21.4)

$W_{S_2} = (132) \times \frac{9^2}{2} / 1000 = 5.35\ K/FT$ (✓)

11.95 K/FT = W_{ST} (26.6)

$W_{IW} = 14.78\ K$ (30.7)

4. LATERAL SOIL PRESSURE
(SEE CONDITION i FOR CALCS)

$P_{R_{18}} = 1.74\ K/1$ (5.6)

$P_{P_9} = 8.46\ K/1$ (5 ✓)

5 IMPULSE MOMENTUM FORCE

"NOT APPLICABLE"

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IV CALCULATIONS, CON'T

D. CHECK OVERTURNING, CONDITION ii

$$\Sigma M_{R.TOE} = (W_{C_1} \times 36') + (W_{C_2} \times 27) + (W_{C_3} \times 23/2) + (H_{V_1} \times 23/3)$$
$$+ (W_{S_1} \times (41 - 10/3)) + (W_{S_2} \times 9/3) + (H_{H_2} \times 20/3) + (P_P \times 9/3)$$

(annotations: 7.5K, 40, 3.9K, 20.0K, 11.5, 12.48K, 16.60K, 5.35K, 12.5, 0.64K, 8.44)

$$= \underline{995.3}^{K\text{-}FT/FT}$$ (revised: 2573.2)

$$\Sigma M_{O.T.TOE} = (P_{R_{18}} \times (13 + 10/3)) + (H_{H_1} \times (13 + 10/3)) + (U_1 \times 37) + (U_2 \times 19.8) + (U_3 \times 4')$$

(annotations: 1.74K, 16.3, 0.32K, 13.33, 4.99K, 14.63K, 9.98K)

$$= \underline{487.5}^{K\text{-}FT/FT}$$ (revised: 1357.4)

$$F.S._{OT} = \frac{995.3}{487.5} = \underline{2.04} > 1.5 \text{ OK!}$$ (revised: 2573.2 / 1357.4 = 1.9)

E. FRICTION FORCE @ CRITICAL FAILURE PLANE, CONDITION ii

1. RESULTANT FORCE

1) $R_y = H_{V_T} + W_{C_T} + W_{S_T} - U_T$

$$= 12.48^{K/1} + 31.4^{K/1} + 11.95^{K/1} - 26.60^{K/1} = \underline{29.23}^{K/1}$$ (revised: 33.6, 37.6, 24.8, 18.4, 38.6)

2. LOCATING THE RESULTANT FORCE

$$\bar{X} = \frac{\Sigma M_{R.TOE} - \Sigma M_{O.T.TOE}}{R_y} = \frac{(995.3 - 487.5)^{K\text{-}FT/FT}}{29.23^{K/1}} = \underline{17.37}'$$ (revised: 2573.2 − 1357.4 / 38.6 = 32.2)

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IV CALCULATIONS, CONT

3. DETERMINE THE GEOMETRY OF THE SOILS REACTION PRESS. PRISM.

• MIDDLE 1/3 OF STRUCTURE BASE? 41.0/3 = 13.7 x 2 = 27.3 (49; 16.3; 33.1)

13.7 < 17.4 < 27.3 (16.3 32.0 32.7)

∴ YES! → WE GET TRAPEZOIDAL PRESSURE PRISM

(1) $(-pry_1) \times 20.5 + (-pry_2) \times 41 = 29.23$ K/1 (49; 49; 38.6)

(2) $(-pry_1) \times \frac{41^2}{2} + (-pry_2) \times \frac{41^2}{6\,3} = 507.13$ K-FT/FT (49; 49; 1235.2)

$pry_1 = 0.43$ K/FT² (0.06)

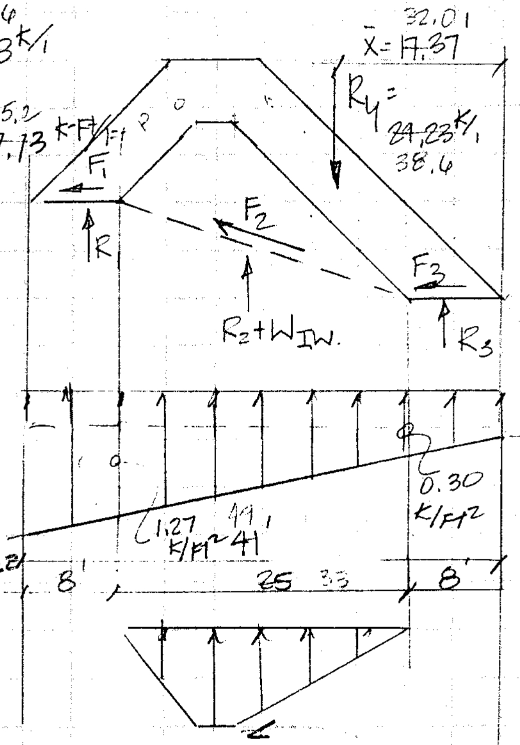
$pry_2 = +0.50$ K/FT² (1.45)

0.13 K/FT² (1.51)

check

$0.43 + 1.06 = 1.99$ K/FT² < 6.0 K/FT² (1.51 1.90 3.41)

OK!



29.23 K/1 (38.6)
x 17.37 (32.0)
507.73 K-FT/FT (1235.2)

$pry_1 = 0.43$ K/FT² (0.06)

$pry_2 = 0.50$ K/FT² (1.45)

$\frac{0.50}{41} \times 8 + .43 = 0.53$ (1.45; 49; 0.06; 0.30)

$\frac{0.50}{41} \times (8+25) + .43 = 0.83$ (1.45; 49; 33; 0.06; 1.2)

4. DETERMINE PRESSURE PRISM RESULTANTS

$P_{SOIL} = \frac{132\ \#/FT^3 \times 8}{1000} = 1.06$ K/FT (144; 1.90)

$R_1 = \frac{(0.43 + 0.53)}{2} \times 8' = 3.84$ K/FT (1.51; 1.27; 11.1)

$R_2 = \frac{(0.53 + 0.83)}{2} \times 25 = 17.0$ K/FT (1.27; 0.30; 33; 46.2)

$R_3 = \frac{(0.83 + 0.93)}{2} \times 8' = 7.04$ K/FT (0.30; 9.06; 1.44)

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IV CALCULATIONS, CON'T

5. DETERMINE THE FORCE OF FRICTION

$F_1 = R_1 \times \mu_{c/s} = \quad$ ~~3.84~~ 11.1 $\times$ 0.45 $=$ ~~1.73~~ 5.0 K/FT

$F_2 = (R_2 + W_{IW}) \times \mu_{s/s}$ ~~0.55~~ $=$ (46.8 + 30.7) × 0.57 × 0.99 $=$ 43.2 K/FT

$F_3 = R_3 \times \mu_{c/s} = \quad$ ~~7.04~~ 1.44 $\times$ 0.45 $=$ ~~3.17~~ 0.6 K/FT

~~13.52~~ 49.3 K/FT $= F_T$

F. CHECK SLIDING, CONDITION ii

1. $\Sigma F_R = P_{R_{18}} + H_{H_1} = ($ ~~1.74~~ 5.6 $+$ ~~0.32~~ 10.1 $)$ K/1 $=$ ~~2.06~~ 15.7 K/1

2. $\Sigma F_R = F_T + H_{H_2} + P_{P_1} = ($ ~~13.52~~ 49.3 $+$ ~~0.64~~ 12.5 $+$ 8.46 $)$ K/1 $=$ ~~22.62~~ 70.3 K/1

$F.S._S = \frac{22.62 \; (70.3)}{2.06 \; (15.7)} =$ ~~11.0~~ 4.5 > 1.0 O.K.!

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IV CALCULATIONS, CONT

C. FORCES, CONDITION iii

1. HYDROSTATIC

VERT.:

$H_{V_1} = [(~~10~~\ 18 \times 12.4) \times 62.4]/1000 = ~~7.74~~\ 13.9$ K/FT

H_{V_2} = (SEE CONDITION i) = 5.1 K/FT ✓

H_{V_3} = (" " ") = 17.4 K/FT ✓

~~30.24~~ 36.4 K/FT = H_{VT}

HORIZ:

H_{H_1} = (SEE CONDITION i) = ~~1.09~~ 23.8 K/FT

H_{H_2} = (" " ") = ~~1.24~~ 28.5 K/FT

UPLIFT:

U_1 = (SEE CONDITION i) = ~~11.18~~ 15.2 K/FT

U_2 = (" " ") = ~~42.5~~ 35.2 K/FT

U_3 = (" " ") = 15.07 K/FT ✓

~~69.35~~ 65.1 K/FT = H_{VT}

2 WEIGHT OF SOIL CEMENT STRUCTURE

W_{C1} = (SEE CONDITION i) = ~~7.5~~ 13.7 K/FT

W_{C2} = (" " ") = 3.9 K/FT ✓

W_{C3} = (" " ") = 20.0 K/FT ✓

.6 31.4 K/FT = W_{CT}

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IV CALCULATIONS, CON'T

C. FORCES, CONDITION iii

3. SOIL WEIGHT
(SEE CONDITION i FOR CALCS)

$\gamma_{SUB} = 69.6\ \#/FT^3$, $\gamma_{SAT} = 132\ \#/FT^3$

W_{S_1} = (SEE CONDITION ii) = ~~6.60~~ 21.4 K/FT

W_{S_2} = (SEE CONDITION ii) = ~~5.35~~ 5.4 K/FT

~~11.95~~ 26.8 K/FT = W_{ST}

W_{IW} = ~~14.78~~ 30.7 K/FT

4. LATERAL SOIL PRESSURE

$P_{R_{18}}$ = (SEE CONDITION ii) = ~~1.74~~ 5.6 K/FT

P_{P_7} = (" " ") = 8.46 K/FT

5. IMPULSE MOMENTUM FORCE

"NOT APPLICABLE"

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IV CALCULATIONS, CONT

D. CHECK OVERTURNING, CONDITION iii

(values above terms: 13.7 7.5 K/Ft, 36 43; 3.9 K/Ft, 27.3; 20.0 K/Ft, 11.5; 13.9 7.74 K/Ft, 36 34)

$$\Sigma M_{R\ TOE} = (W_{C1} \times (41 - 10/2)) + (W_{C2} \times (31 - 3.7)) + (W_{C3} \times 23/2) + (H_{V1} \times (41 - 10/2))$$

(values above terms: 21.4 6.60 K/Ft, 37.7; 51 5.12 K/Ft, 27.3; 17.38 K/Ft, 9.3; 5.35 K/Ft, 3.33)

$$(W_{S1} \times (41 - 10/3)) + (H_{V2} \times (31 - 3.7)) + (H_{V3} \times 9.3) + (W_{S2} \times 9/3)$$

(values above terms: 35.5 1.24 K/Ft; 8.46 K/Ft 3.33)

$$(H_{H2} \times 9.3) + (P_{P1} \times 9/3)$$

$$= 1492.8\ ^{K\text{-}Ft}/_{Ft}$$ (revised: 3014.2)

(values above terms: 44 1.74 K/Ft, 11.0 16.33; 33.3 1.09 K/Ft, 13.8 17.5; 13.2 1.18 K/Ft; 32.2 42.5 K/Ft; 15.07 K/Ft)

$$\Sigma M_{O.T\ TOE} = (P_{P2} \times (13 + 10/3)) + (H_{H1} \times (13 + 4.5)) + (U_1 \times 37) + (U_2 \times 19.8) + (U_3 \times 4')$$

(revised values below: 18 5 15; 5 .8; 45; 21.4)

$$= 1{,}365.4\ ^{K\text{-}Ft}/_{Ft}$$ (revised: 1898.7)

$$FS_{OT} = \frac{1492.8}{1{,}365.4} = 1.09 \geq 1.5\ \text{O.K!}$$

(revised: 3014.2 / 1898.7 = 1.6)

E. FRICTION FORCE @ CRITICAL FAILURE PLANE, CONDITION iii

1. RESULTANT FORCES

$$R_y = H_{VT} + W_{CT} + W_{ST} - U_T$$

$$30.24 + 31.4 + 11.95 - 69.35 = 4.24\ K$$

(revised: 30.4 + 37.6 + 36.8 − 68.1 = 37.7)

2. LOCATING THE RESULTANT FORCE

$$\bar{X} = \frac{\Sigma M_R - \Sigma M_{OT}}{R_y} = \frac{(1492.8 - 1365.4)}{4.24K} = 30.1\ Ft$$

(revised: (3014.2 − 1898.7) / 37.7 = 29.6)

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IV CALCULATIONS, CONT'T

3. DETERMINE THE GEOMETRY OF THE SOILS REACTION PRESS PRISM

- MIDDLE 1/3 OF STRUCTURE BASE?

$\frac{41}{3}$ = 13.7 x 2 = 27.3 (revised: 49/3 = 16.3, 32.7)

13.7 < 30 < 27.3 (revised: 16.3 < 29.6 < 32.7)   YES! → WE GET TRAPEZOIDAL PRESSURE PRISM.

(1) $(Pry_1 \times 49') + (Pry_2 \times 49/2) = 37.7$ K/FT

(2) $(Pry_1 \times 49^2/2) + (Pry_2 \times 49^2/3) = 1115.9$ K-FT/FT

$Pry_1 = 0.29$ K/FT²

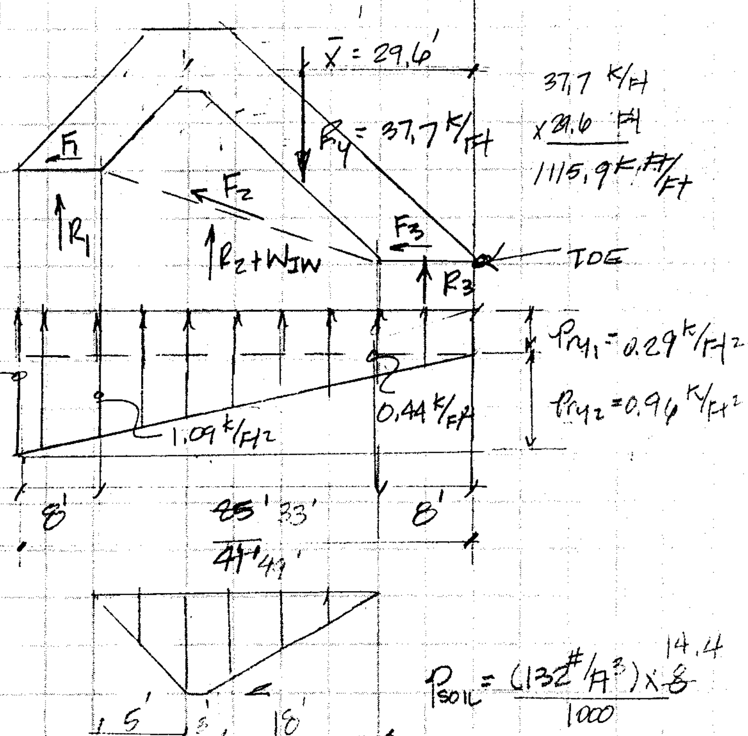
$Pry_2 = 0.96$ K/FT²

1.25 K/FT²

Check:

~~1.06~~ + ~~0.28~~ = ~~1.34~~ K/FT² < 5.0 K/FT²
1.90 1.25 3.15 OK.

37.7 K/FT
x 29.6 FT
1115.9 K-FT/FT



$P_{SOIL} = \frac{(132 \#/FT^3) \times 14.4}{1000}$ = ~~1.06~~ K/FT² 1.90

4. DETERMINE PRESS. PRISM RESULTANTS

$R_1 = \frac{(1.25 + 1.09)}{2} \times 8' = 9.4$ K/FT

$\frac{0.96}{49} \times 8 + 0.29 = 0.44$ ~~0.87~~ K/FT²

$R_2 = \frac{(1.09 + 0.44)}{2} \times 33' = 25.2$ ~~23.1~~ K/FT

$\frac{0.96}{49} \times (8 + 33) + 0.29 = 1.09$ ~~1.12~~ K/FT²

$R_3 = \frac{(0.44 + 0.29)}{2} \times 8' = 3.3$ K/FT

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IV CALCULATIONS, CON'T

5. DETERMINE THE FORCE OF FRICTION

$F_1 = R_1 \times \mu_{c/s_L} = \overset{9.4}{\not{2}} \times 0.15 = \overset{4.1}{\not{4.1}}$ K/FT

$F_2 = (\overset{25.2}{\not{2.31}}^k_2 + \overset{20.7}{\not{14.78}} W_{JW}) \times \overset{0.57}{\mu_{s/s}} \times \cos \overset{8.6°}{\not{27.5}}° = \overset{31.5}{\not{16.4}}$ K/FT

$F_3 = R_3 \times \mu_{cs} = \overset{}{\not{0}} \times 0.45 = \overset{1.5}{\not{0}}$ K/FT

37.2 ~~17.5~~ K/FT = F_T

F. CHECK SLIDING, CONDITION iii

1. $\underrightarrow{\Sigma F}_0 = P_{R_{18}} + H_{H_1} = (\overset{5.6}{\not{1.74}} + \overset{23.8}{\not{1.09}}) = \overset{29.4}{\not{2.83}}$ K/FT

2. $\underleftarrow{\Sigma F}_R = F_T + H_{H2} + P_{P_1} = (\overset{37.2}{\not{17.5}} + \overset{28.5}{\not{1.24}} + \overset{8.6}{\not{8.46}}) = \overset{74.3}{\not{27.3}}$ K/FT

$FS_S = \dfrac{\overset{74.3}{\not{27.3}}}{\underset{29.4}{\not{2.83}}} = \overset{2.5}{\not{9.6}} > 1.0$ OK!