Kansas Citys, Missouri and Kansas
Flood Risk Management Feasibility Study

Engineering Appendix to the Final Feasibility Report

Chapter A-4b

GEOTECHNICAL ANALYSIS

CID-MISSOURI

CHAPTER A-4b
GEOTECHNICAL ANALYSIS
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CHAPTER A-4b

GEOTECHNICAL ANALYSIS

A-4b.1 INTRODUCTION

This Appendix presents the results of the geotechnical evaluation performed for the Central Industrial District Levee Unit - Missouri (CID-MO). The evaluation started with a thorough review of existing project documentation, defining existing subsurface conditions along the entire unit based upon existing subsurface information, and estimation of soil parameters for the existing levees, the natural blanket and the aquifer materials. Additional subsurface investigations were performed to better define foundation materials for underseepage and foundation analyses. The estimated soil parameters are based on geotechnical laboratory testing data from adjacent projects since data was not readily available for the CID-MO unit. Data was obtained from the North Kansas City Levee (across MO River), CID-KS Levee (upstream on KS River), East Bottoms Levee (downstream on MO River), and the Fairfax Jersey Creek Levee (upstream on MO River). **All elevations used in the geotechnical portion of the feasibility study are NGVD 29 unless otherwise stated.**

Geotechnical analysis of the unit consisted mainly of underseepage and foundation capacity calculations to support Structural Analysis of the shallow footing and pile founded floodwall for the existing level of flood protection (approximately 500+3).

Underseepage factors of safety were calculated along the entire CID-MO unit. Since all areas met underseepage criteria, no reliability analysis was performed. Shallow footing and pile capacities were provided for Structural Analysis.

A-4b.2 LEVEE BACKGROUND INFORMATION

A-4b.2.1 Levee Description

The CID-MO Unit is located in Jackson County, Missouri and extends along the right bank of the Missouri River from RM 365.7, at the Kansas-Missouri state line and termination of the CID-KS levee unit (Station 83+01.29), downstream to RM 367.2, near the Grand St. viaduct (Station 0+00), where the floodwall terminates into high ground upstream of the East Bottoms levee unit. The CID-MO and CID-KS units are directly connected and there is no hydraulic separation.

The unit consists of a system of mostly floodwall with some levee segments, stoplog gaps, pumping plants, drainage structures, riprap and levee toe protection, and surfaced levee crown and ramps. The greater portion of the area is highly industrialized. These areas are occupied largely by railroads, wholesale houses, water treatment plants, and manufacturing plants. The total length of the unit is 8,301 feet or 1.6 miles.

There are many bridges, structures, and utilities within the critical area of the line of protection. For the purposes of the Geotechnical Analysis, it was assumed that all bridge foundation elements, structures, and utilities within the levee embankment and critical area of the

foundation blanket material meet all pertinent Corps of Engineers criteria. Henceforth, no analysis was completed regarding their integrity.

A-4b.2.2 History

The Kansas Citys Flood Control Project, of which the Central Industrial Unit (Missouri Section) is a part, was authorized by Section 9 of the Flood Control Act approved 22 June 1936, Public Law 738, 74th Congress, 2d Session, as modified and extended by Section 10 of the Flood Control Act approved 22 December 1944, Public Law 634, 78th Congress, 2d Session.

Early flood protection works prior to Federal participation consisted of levees and retaining walls. Federal participation started with the Flood Control Act of 1936, and on 6 March 1946, a contract was awarded for the construction of levees, floodwalls, and appurtenances for the Central Industrial Unit (Missouri Section). Construction began on 21 March 1946 and was completed on 9 September 1947. Since that time, improvements have been made to the unit under other Corps of Engineers' contracts to construct the Broadway and Santa Fe Pumping Plants, restore the flood protection after the 1951 flood (CID-KS overtopping led to an exit overtopping and large scour hole near station 80+00 by the stoplog gap), restore riverside slope protection after the 1951 food, construction of emergency gates and appurtenances, and minor scour repairs after the 1993 flood. The following discussion describes the existing unit in additional detail by major features in a downstream direction.

Station 83+01.29 to 80+54.12. This is a floodwall section that is a continuation of the CID-KS floodwall. This section was constructed on a large pervious fill. There is a buried collector system that extends from station 78+00 and terminates at Station 5+00 CID-KS to collect underseepage through the fill.

Station 80+54.12 to 78+00. This section is a levee section with a stoplog gap at station 80+19.

Station 78+00 to 0+00. This section is floodwall section with a landward toe drain. The floodwall is supported by driven concrete piles with a concrete riverside cut off wall from station 78+00 to the Hannibal Bridge near station 25+25. The floodwall is supported by a shallow footing bearing on bedrock between station 25+75 and 10+00. The floodwall is supported by a shallow footing on soil between station 10+00 and 0+00. There are gap structures at stations 70+71, 68+90, 63+15, 14+80, 8+68, 5+24, and 1+53.

Based upon the record drawings, the existing levee sections are homogeneous embankments constructed of impervious fill.

A-4b.2.3 General Geology of the Region (Missouri River)

The units are near the southern edge of the Dissected Till Plains section of the Central Lowlands Physiographic Province. The southern limit of glaciation in Missouri is generally considered to be just south of the Missouri River. During the Pleistocene, both the Nebraskan and Kansas glaciation crossed Platte County. The topography consists mainly of flat-lying alluvial sediments of the Missouri River floodplain, bounded by rolling hills comprising the valley walls. Maximum relief in the area is about 170 feet. The Missouri River alluvium generally ranges from

approximately 110 to 130 feet in thickness, with the exception of buried stream channels that may extend into the Marmaton Group. All of the Missouri alluvium lies on shales and siltstones in the Pleasanton Group of the late Pennsylvanian System. The valley walls are composed of alternating layer of shales and limestone of the Kansas City Group. Drainage is by means of a maturely developed dendritic pattern except where it has been altered by human activity.

A-4b.2.4 Subsurface Conditions for CID-MO

Assessments of the subsurface conditions for the project were derived from the Record Drawings, Design Memorandums and borings made at selected sites during Phase I and Phase II of the feasibility study. Typical subsurface conditions for the CID-MO unit consist of a "two blanket" system. There is an upper blanket with typical thickness of 3-6 feet, underlain by an upper pervious layer with typical thickness of 8-20 feet, underlain by a lower blanket with typical thickness of 14-20 feet, underlain by the aquifer with typical thickness of 45-55 feet, underlain by bedrock. The upper and lower blankets appear to be connected riverward of the floodwall. **Cross sections are located with the underseepage calculations**. It is hypothesized that lower blanket is the natural blanket, and the upper pervious layer and upper blanket were fill placed to raise the area during commercial development prior to construction of the floodwall. The floodwall does bear directly on bedrock between approximate stations 10+00 and 25+75. Groundwater levels are dependent on seasonal changes and are generally equal to the Missouri River elevation.

A-4b.3 UNDERSEEPAGE ANALYSIS

The Kansas City District method of estimating the hydraulic gradients due to underseepage is slightly different than the method described in the EM 1110-2-1913. It is based on the findings made at the Missouri River Division Conference held by the Corps of Engineers in 1962 in Omaha. The underseepage analysis was based on experience during the flood event in 1952 along the Missouri River. The main differences in the Kansas City District method are:

1. The Kansas City District Method uses permeability ratios (See Table A-4b.1.) related to differing material types of the blanket material instead of using actual horizontal and vertical permeabilities.

2. The Kansas City District Method assumes an infinite landside blanket in the analysis.

3. The Kansas City District Method does not use a transformed thickness for the soil stratum considered as EM 1110-2-1913 allows, instead, a representative permeability ratio is applied to the overall blanket thickness.

For the underseepage analysis, the entire CID-MO Unit was divided into reaches of similar protection height, blanket thickness, blanket composition, aquifier thickness, and seepage entrance conditions. The factor of safety with respect to hydraulic gradient through the natural blanket was calculated for each of these reaches at the landside toe of the levee section or floodwall for a series of alternatives. Five alternative analysis methods were used to analyze the

unique foundation conditions at the CID-MO area due to the upper and lower blankets and buried collector system. The floodwall toe drain was ignored in all analyses.

TABLE A-4b.1
Permeability Ratios for Blanket Material Based on Material Type

Blanket Material	Assumed Permibility Ratio
SM	100
ML	200-400
ML-CL	400
CL	400-600
CH	800-1000

Analysis Alternative 1 assumes the blanket that is resistant to underseepage forces is equal to the thickness of the upper and lower blanket thicknesses added together. This analysis, while the least conservative of all alternatives, is conservative in that it ignores the thickness of the upper pervious layer in between the two blankets. This analysis is thought to be the most realistic of alternatives 1-4.

Analysis Alternative 2 assumes the blanket thickness that is resistant to underseepage forces is equal to only the upper blanket thickness. This analysis is the most conservative analysis and ignores the existence of the lower blanket completely.

Analysis Alternative 3 assumes the blanket thickness that is resistant to underseepage forces is equal to only the upper blanket thickness and used the upper pervious layer as the aquifer. However, the analysis assumed that the upper and lower blankets are connected by the seepage cut off wall and/or the riverside tie in, and the hydraulic pressure head was reduced by 25%. This analysis is a conceptual check on the gradient through the upper blanket.

Analysis Alternative 4 assumes the blanket thickness that is resistant to underseepage forces is equal to only the lower blanket thickness. The upper pervious layer is assumed to have hydrostatic conditions, and the aquifer is assumed to be surcharged by the river. This analysis is a conceptual check on the gradient through the lower blanket.

Analysis Alternative 5 is an analysis that was used where the buried collector system exists where the levee and floodwall was constructed on the large pervious fill. The analysis assumes that the buried collector system maintains hydrostatic conditions in the upper pervious layer, and the lower blanket is the resistance to underseepage forces. This analysis is a check on the gradient through the lower blanket where the buried collector system exists.

Exhibit 1 (Underseepage folder) shows the calculated factor of safety with respect to hydraulic gradient for the entire CID-MO Levee Unit for all analysis alternative methods with water at the top of protection. The analysis shows all input parameters used to calculate the

factor of safety. Supporting documentation consisting of riverside and centerline subsurface profiles and foundation cross sections are also included. For all alternative analysis methods except for Alternative 2 indicate the levee will perform well for a top of wall loading. Calculated factors of safety are generally in excess of 1.6. This is in agreement with observations during the 1993 flood which reported no adverse seepage conditions with water 2-3 feet from the top of protection. Kansas City District Underseepage Criteria is discussed in the NWK Levee Underseepage Guidance attachement.

A-4b.4 SOIL STRENGTH PARAMETERS

The required parameters for soils in the CID-MO unit were estimated mainly from the significant amount of geotechnical laboratory testing data performed for adjacent levee units. Little information regarding strength parameter development for the CID-MO unit could be located for this study. Soil information from CID-KS, East Bottoms, Fairfax Jersey Creek, and North Kansas City levees were used. This information is located in the attached exhibits. A summary of the soil parameters is provided in Table A-4b.2 below and discussed in the following paragraphs.

Table A-4b.2 - Geotechnical Design Parameters

Recommended Parameters for Phase 2 Feasibility Study - CID-MO

	Unit Weight (pcf)		Drained Shear Strength		Undrained Shear Strength*	
Material	Moist	Saturated	ϕ' (degrees)	c' (psf)	ϕ (degrees)	c (psf)
Embankment	115	120	29	0	0	1000
Fill/Debris+	110	115	20	0	N/A	600
Foundation Blanket*	110	115	22	0	0	600
Foundation Sand	115	120	30	0	N/A	N/A

+Assumed parameters based on weakest perceived material likely to be present
*CH material not included

The blanket materials consist mostly of ML and CL materials, with some discontinuous layers of CH, SM, and unclassified fill material. The shear strength for the foundation sands was estimated from standard penetration test data performed in October 2001. The information used is considered adequate, if not conservative, for this study. These strength parameters were used in the Structural Analysis for floodwall stability.

A-4b.5 FOUNDATION CAPACITY

A-4b.4.1 Shallow Foundation Capacity

Shallow foundation bearing capacity was calculated using Vesic's bearing capacity factors for floodwall founded on soil and provided for structural analysis. Bearing capacity for floodwall

founded on limestone was estimated using AASHTO HB-17, Table 4.11.4.1.4-1. Shallow foundation bearing capacity is shown in the attached exhibits. Generally bearing capacity does not control floodwall stability, as sliding stability is usually more critical. Additional discussion is located in the Structural Analysis.

A-4b.4.1 Deep Foundation Capacity

Deep foundation capacity was calculated in general accordance with EM 1110-2-2906 *Design of Pile Foundations*. Capacity was calculated for drained and undrained conditions, however drained conditions usually controlled the analysis. Skin friction resistance and tip resistance were calculated separately and added together to determine total pile axial compression capacity. Tensile capacity was taken as 70% of the compression skin friction resistance as recommended in Table 4-5 of EM 1110-2-2906. Earth pressure coefficients for skin resistance of 1.25 for clay and 2.0 for sand were also obtained from Table 4-5 for a high displacement driven pile. There was no reduction in soil-pile interaction friction angle. Additionally, the concept of a "critical depth" for drained analysis was not used even though it is specified in EM 1110-2-2906. This is because published work and other governmental agencies (FHWA) have determined that the concept of "critical depth" as stated in EM 1110-2-2906 is overly conservative. There is evidence that a limiting value of side and tip resistance is appropriate in some cases, but generally at pile depths greater than what are present at CID-MO.

All the bearing piles at CID-MO are square precast concrete driven piles. However, different lengths and sizes were used. Lengths varied between 21 and 34 feet and sizes varied between 16 and 18 inches. Additionally, the concrete cut off pile was considered for capacity. The concrete cut off pile is typically 16 feet long and 10 inches wide.

A summary of calculated pile capacities is shown below in Table A-4b.3. The calculated capacities are in general agreement with capacity estimates from driving formulas during original floodwall construction. For further information on pile founded floodwall stability, see the Structural Analysis.

Table A-4b.3 – Ultimate Pile Capacity summary

Station Start	Station Stop	Pile Size (inch)	Pile Shape	Pile Length (feet)	Axial Compressive Capacity (lb)	Axial Tensile Capacity (lb)	Axial Compressive Capacity (ton)	Driving Formula Estimate, Construction (ton)	Monolith Range
22+81.46	24+54.76	18	tapered	21	63,184	34,428	32	35	50-53
24+54.76	25+38.76	16	straight	25	94,544	47,066	47	40	54-55
25+38.76	26+22.76	16	straight	29	117,871	60,583	59	35+	56-57
26+22.76	27+90.76	16	straight	30	110,124	56,280	55	35+	58-61
22+81.46	27+90.76	10	cut off pile*	16	22,839	9,174	11	-	-
27+90.76	30+42.75	16	straight	34	165,730	93,113	83	50	62-67
30+42.75	32+52.76	16	straight	21	87,472	44,990	44	50+	68-72
27+90.76	30+42.75	10	cut off pile*	16	34,658	7,421	17	-	-
32+52.76	48+06.76	16	straight	21	118,051	67,168	59	35-50	73-109
32+52.76	48+06.76	10	cut off pile*	16	46,675	15,817	23	-	-
48+06.76	60+24.76	18	tapered	21	76,858	45,490	38	35-50	110-138
48+06.76	60+24.76	10	cut off pile*	16	28,969	14,351	14	-	-
60+24.76	73+20.14	18	straight	34	137,963	73,264	69	40-50+	139-167
73+20.14	78+12.22	16	straight	21	67,405	34,166	34	30	168-179
60+24.76	78+12.22	10	cut off pile*	16	20,730	9,401	10	-	-

*cut off pile capacities are in lb/ft

A-4b.10 REFERENCES

1. Operations and Maintenance Manual, Kansas City Flood Control Project, Missouri and Kansas River, Central Industrial Unit - Missouri Section, Volume I, 1981.

2. Operations and Maintenance Manual, Record Drawings, Kansas City Flood Control Project, Missouri and Kansas River, Central Industrial Unit Missouri Section, Volume I, Appendix I, Dated 1944 - 1957.

3. Corps of Engineers Engineering Manuals, Technical Letters, Etc as referenced within.

A-4b.11 ATTACHMENTS AND EXHIBITS

NWK Levee Underseepage Guidance

Underseepage Exhibits

1. Centerline Subsurface profile
2. Riverside Subsurface profile
3. Underseepage Cross Sections
4. Overall Underseepage

Floodwall Foundation Exhibits

1. Ultimate Pile Capacity Summary
2. Ultimate Pile Capacity Calculations
3. Parameters for Pile Capacity Reliability
4. Strength Parameters Determination
5. Limestone Friction Angle Determination
6. Floodwall Shallow Footing Capacity Calculations
7. Bearing Capacity – Floodwall
    a. Bearing Capacity Coefficient Chart
    b. Bearing Capacity Coefficient Data
    c. Bearing Capacity Floodwall
    d. Blanket Bearing
    e. Sand Bearing
    f. Fill Bearing
8. Shear Strength 2001 SPT Blowcounts

CENWK-ED-GD 28 February 2011

MEMORANDUM for RECORD

SUBJECT: Kansas City District Levee Underseepage Guidelines

1. PURPOSE

This memorandum documents levee underseepage guidelines that Kansas City District (NWK) will use until updated USACE underseepage guidelines are available. When USACE guidelines are revised, NWK guidelines will be reviewed and revised if necessary.

The underseepage guidelines will be applied to NWK projects currently in Pre-Construction, Engineering, and Design (PED) phase. Current PED project details and consequences of failure are listed in Table 1. Project details were obtained from completed feasibility reports for the respective projects. The NWK underseepage guidelines will also be used in other NWK PED and feasibility study projects with similar failure consequences that are not currently planned. If NWK undertakes a future PED or feasibility study project that has lower failure consequences, NWK guidance will be developed for those projects at the beginning of the engineering effort in a Memorandum for Record.

Table 1 Current NWK Projects

Project	Nominal Frequency of Overtopping[3]	Economic Damages of Failure	Population at Risk	Failure Consequences
Topeka Oakland Unit	~300 yr	$578 million	7,600[1]	Very High
North Topeka Unit	~300 yr	$1.47 billion	8,200[1]	Very High
North Kansas City Unit	~750 yr	$3 billion	31,585[2]	Very High
MRLS L-455	~500 yr	$1.43 billion	3,700[1]	Very High
MRLS R-471-460	~200 yr	$571 million	2,000[1]	Very High

1 – Assumes 2.5 persons per residential and non-residential structure
2 – Residential population and employment population,
3 – Nominal frequency of overtopping is equivalent to the 50% confidence level, or expected value.

2. BACKGROUND

U.S. Army Corps of Engineers (USACE) underseepage design guidelines are being revised. Current USACE guidelines are contained in Engineer Manual (EM) 1110-2-1913 *Design and Construction of Levees*, 30 April 2000. New underseepage guidelines superseding many of the recommendations in EM 1110-2-1913 were published in Engineer Technical Letter (ETL) 1110-2-569 *Design Guidance for Levee Underseepage*, 1 May 2005. ETL 1110-2-569 stated that it would be rescinded when EM 1110-2-1913 was revised. EM 1110-2-1913 has not been revised but the ETL officially expired in May 2010. A draft version of revised EM 1110-2-1913, Appendix C - *Design of Seepage Berms* was issued for USACE internal review in October 2006 but has not been finalized. EC 1110-2-6067 *USACE Process for the National Flood Insurance*

Program (NFIP) Levee System Evaluation, 31 August 2010, states expired ETL 1110-2-569 should be used as a guide to evaluate levee structures and is current USACE policy instead of the requirements in the current EM 1110-2-1913.

Some USACE districts have been establishing local underseepage guidelines based on current, expired, and draft USACE underseepage guidelines. For example, the New Orleans Hurricane and Storm Damage Risk Reduction System (HSDRSS) guidelines in use by New Orleans District (MVO) were presented at the Geotechnical and Materials Community of Practice (CoP) Meeting in St. Louis in August 2010. In this memorandum, NWK is establishing underseepage guidelines for district use.

3. COMPARISON OF USACE AND NWK UNDERSEEPAGE GUIDELINES

There have been significant variations between current, recently expired, and draft USACE underseepage guidelines and historical NWK practice. The proposed NWK underseepage guidelines simplify and standardize underseepage guidelines for design and analysis of levees and floodwalls. NWK-proposed underseepage guidelines are based on an adequate subsurface exploration being performed to have a high confidence in the blanket thickness in accordance with standard engineering practice and published USACE guidelines. The general requirement in ETL 1110-2-569 is three borings (landside toe, riverside toe, and levee crest) every 1,000 feet, supplemented where appropriate with geophysical investigation. The subsurface investigation guidance in ETL 1110-2-569 will be considered the absolute minimum investigation required, and will typically be surpassed.

EM 1110-2-1913 states that the net head on a levee for gradient calculations is usually based on the "design water surface" elevation but is sometimes based on the top of levee (p. B-3). The "design water surface" is defined as the design or project flood stage, or the top of levee minus the freeboard allowance (typically 2 to 3 feet). In ETL 1110-2-569 water elevation recommendations for gradient calculations are not given, indicating the guidelines in EM 1110-2-1913 are still applicable. In Draft Appendix C, EM 1110-2-1913 the water elevation for gradient calculations is based on water at the top of levee or at the elevation of 100, 250, or 500–year frequency flood events based on consequences of failure. NWK traditional methodology checked gradient factor of safety (FS_i) with water at the design water surface and at the top of levee. The current proposed NWK underseepage guidelines standardize all calculations to a water elevation equal to the design top of levee elevation, excluding overbuild.

The following tables show the underseepage recommendations in current, expired, and draft USACE publications, traditional NWK guidelines, and proposed NWK guidelines.

A comparison of underseepage guidelines at the levee landside toe is shown in Table 2. One of the largest evolutions in underseepage guidelines has been from an exit gradient check to a FS_i check. This change was made because the critical gradient is variable with blanket unit weight. Having a check based on exit gradient meant that FS_i was variable for different soil types. Other changes have been proposed to change the design water loading and to take into account consequences of failure and flood frequency. The NWK guidelines for FS_i at the levee toe were developed to generally align with ETL 1110-2-569 requirements, which imply a FS_i of 1.6 is desired. The guidelines in Draft EM 1110-2-1913 are not well understood for very high failure consequence levees. It is not clear if levees with a higher frequency of overtopping are intended to be designed to a higher FS_i, or if the intent is to check FS_i at less than extreme loading conditions. Regardless of the interpretation of Draft EM 1110-2-1913, NWK considers the FS_i guidelines recommended in ETL 1110-2-569 appropriate for very high consequence levees for the extreme loading condition. The recommended FS_i of 1.6 in Table 2 will apply to the landside levee toe for all circumstances; whether the natural landside blanket, underseepage berms, relief wells, or other features are providing underseepage protection. When relief wells are used, the recommended FS_i will be met at all points in between relief wells.

Table 2 Underseepage Guidelines at Levee Landside Toe

Document	Current EM 1110-2-1913, April 2000	Expired ETL 1110-2-569, May 2005	Draft EM 1110-2-1913 Appendix C, October 2006			Traditional NWK Guidelines	NWK Guidelines, 2011
			Consequences				
			Low	High	Very High		
Underseepage Guidelines - Levee Landside Toe	Gradient through cohesive blanket < 0.8 evaluation <0.3 new seepage control	Gradient through cohesive blanket < 0.5	FS_i = 1.3	FS_i = 1.6	FS_i = 2.0,100 yr frequency event FS_i = 1.8, 250 yr frequency event FS_i = 1.6, 500 yr frequency event	FS_i = 1.1, water at levee top and FS_i = 1.5, design water surface	FS_i = 1.6, water at levee top

A comparison of underseepage guidelines at underseepage berm toes is shown in Tables 3a through 3c. Again, the largest evolution has been from a gradient check to a FS_i check. Other changes have been proposed to take into account confidence in design parameters and ratio of levee height and berm width. The NWK guidelines were developed to generally align with the guidelines in Draft EM 1110-2-1913. NWK agrees that reducing the minimum FS_i at berm toes as distance from the levee toe increases is a sound approach. This approach considers that failure risk is reduced as the distance from the levee increases. However, the NWK guidelines specify the recommended FS_i at berm toes with distance from the levee toe regardless of levee

height. Specifying FS_i by distance from the levee toe simplifies the design process and removes unique situations of short height levees with high failure consequences having relatively low factors of safety close to the levee toe. The guidelines can be linearly interpolated for intermediate distances. For typical levee heights between 10 and 20 feet, the NWK guidelines generally meet or exceed the recommendations in Draft EM 1110-2-1913.

The recommended FS_i in Table 3c will also apply to other features landward of the levee where underseepage may be a concern. The recommended FS_i will apply to features such as interior drainage ditches, localized depressions, pits, or any other feature landward of the levee toe. The recommended FSi will apply whether the natural landside blanket or underseepage control measures are providing underseepage protection at the feature location.

A comparison of underseepage berm width, thickness, and overbuild guidelines is shown in Table 4. These guidelines have not changed significantly with evolving criteria. The NWK guidelines simplify the guidelines with the intent that FS_i will control designs instead of arbitrary minimum or maximum recommendations.

Table 3a Underseepage Guidelines at Underseepage Berm Toe

Document	Current EM 1110-2-1913, April 2000	Expired ETL 1110-2-569, May 2005	Traditional NWK Guidelines
Underseepage Guidelines - Levee Underseepage Berm Toe	Gradient through cohesive blanket < 0.8	Not addressed, use EM	FS_i = 1.1 for Urban Levees and FS_i = 0.8 for Agricultural Levees, water at design water surface

Table 3b Underseepage Guidelines at Underseepage Berm Toe

Document	Draft EM 1110-2-1913 Appendix C, October 2006 – small uncertainty*, for consequences as shown below											
Underseepage Guidelines - Levee Underseepage Berm Toe	Berm Width/Levee Height ≤ 4			Berm Width/Levee Height < 8			Berm Width/Levee Height < 12			Berm Width/Levee Height < 16		
	Low	High	Very High	Low	High	Very High	Low	High	Very High	Low	High	Very High
	FS_i = 1.05	FS_i = 1.30	FS_i = 1.50	FS_i = 1.10	FS_i = 1.15	FS_i = 1.30	FS_i = 0.95	FS_i = 1.00	FS_i = 1.10	FS_i = 0.90	FS_i = 0.90	FS_i = 0.90

*based on obtaining adequate subsurface information for small uncertainty in design parameters; document also shows recommended FS_i for large uncertainty

Table 3c Underseepage Guidelines at Underseepage Berm Toe

Document	NWK Guidelines, 2011				
Underseepage Guidelines - Levee Underseepage Berm Toe	Distance From Landside levee Toe (ft)				
	100*	200	300	400	500+
	FS_i = 1.5	FS_i = 1.4	FS_i = 1.3	FS_i = 1.2	FS_i = 1.1

*100 feet is the proposed minimum berm width from the landside levee toe

Table 4 Underseepage Berm Width, Thickness, and Overbuild Guidelines

Document	Current EM 1110-2-1913, April 2000	Expired ETL 1110-2-569, May 2005	Draft EM 1110-2-1913 Appendix C, October 2006	Traditional NWK Guidelines	NWK Guidelines, 2011
Minimum Berm Width	150 feet	4 X Levee Height	4 X Levee Height	NA*	100 feet
Maximum Berm Width	400 feet	Use caution when limiting berm width to 300-400 feet	No Limit Specified	NA	No Limit, FS_i guidelines must be met
Minimum Berm Thickness – Levee Toe	5 feet	5 feet	5 feet	NA	5 feet
Minimum Berm Thickness – Berm Toe	2 feet	2 feet	2 feet	NA	2 feet
Berm Thickness Increase for Shrinkage and Consolidation	25%	Calculate based on Consolidation Theory	Calculate based on Consolidation Theory	NA	25% if no consolidation data available, or as calculated

					with consolidation data
Berm Slope for Surface Drainage	Generally 1V on 50H or steeper	NA	Generally 1V on 50H or steeper	Not Specified	Minimum 1 % away from levee for 100 ft, graded away from levee at all distances.

*Not addressed – Same as EM 1110-2-1913, April 2000

4. CONCLUSION

The NWK underseepage guidelines are intended to be realistically conservative, practical, and easy to implement. They were developed to generally satisfy the intent of recent USACE underseepage guidelines and provide standardized guidance for NWK. As always, the use of engineering judgment is recommended for each individual project. The Kansas City District will use these underseepage guidelines until updated general USACE guidance is available. Development of this memorandum was coordinated with NWD (Y. Rhee, S. Fink) through a series of phone calls and emails in January and February 2011. Additionally, limited coordination with HQUSACE (J. Koester) and ERDC (K. Klaus) was performed via email

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Chief, Geotechnical Branch

CENWK ED-GD
SUBJECT: Kansas City District Levee Underseepage Guidelines

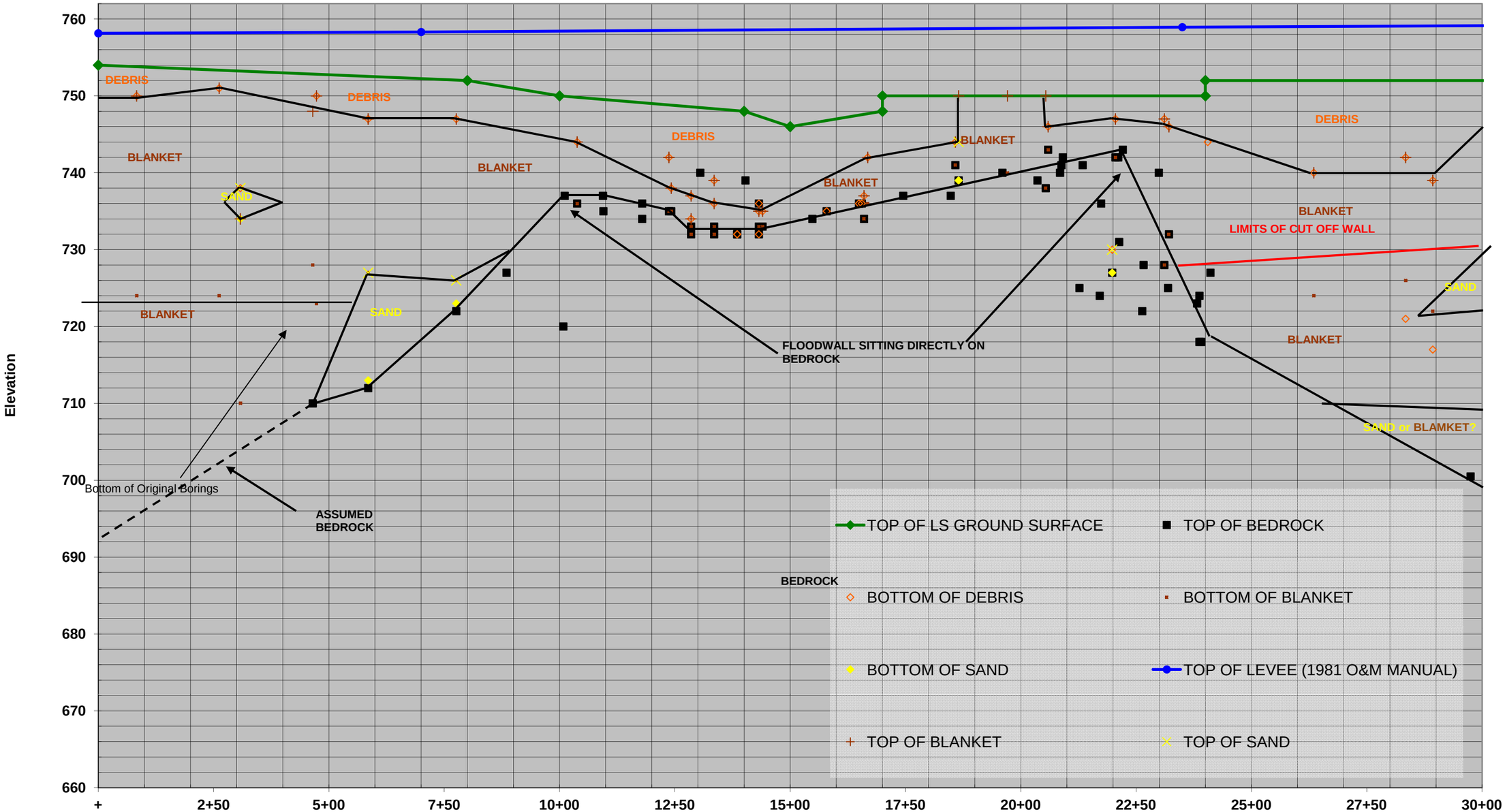
JENSON
ED-GD

BELLEW
ED-GD

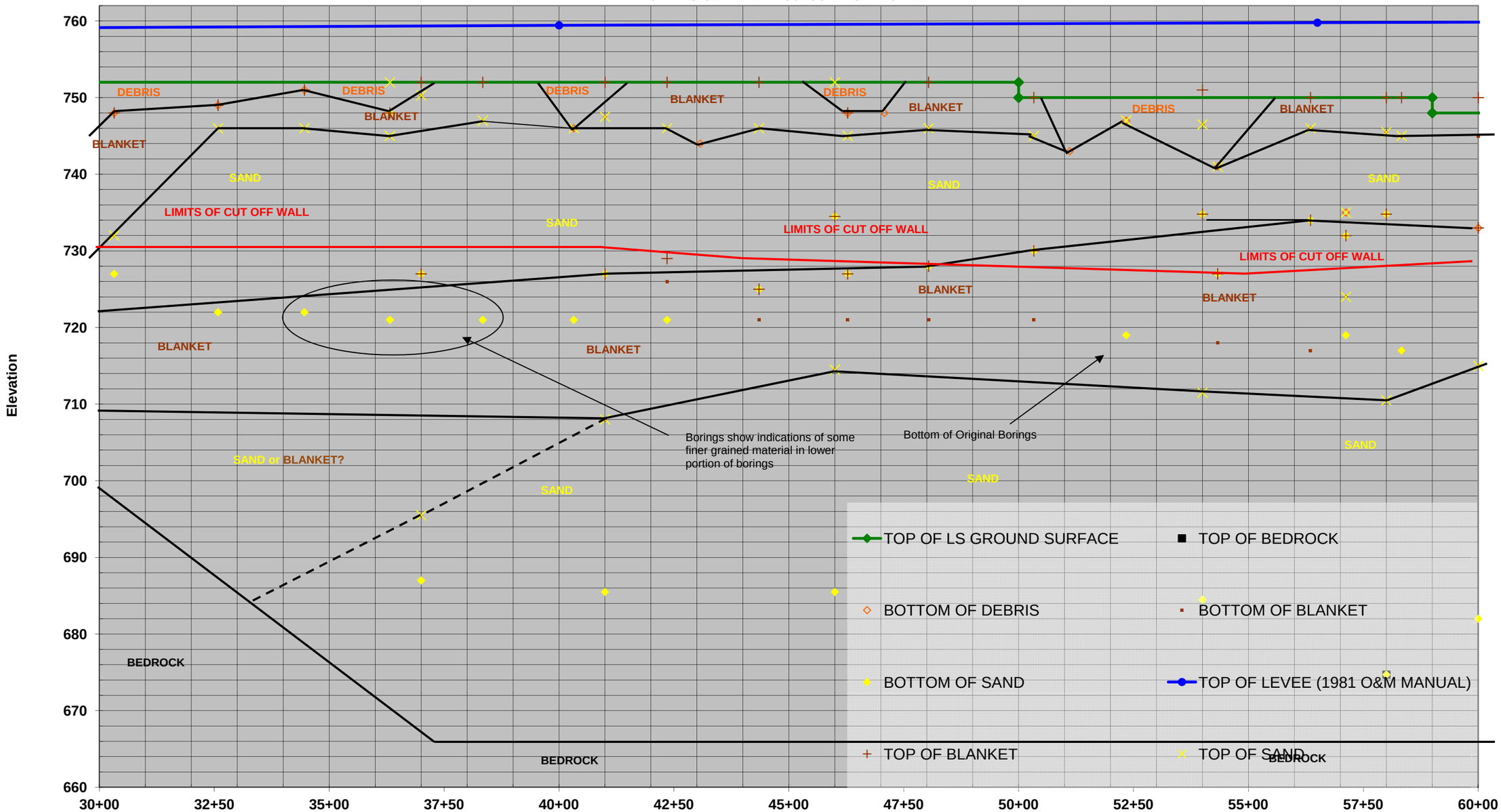
for VOLLINK
ED-GD

JONES
ED-GD

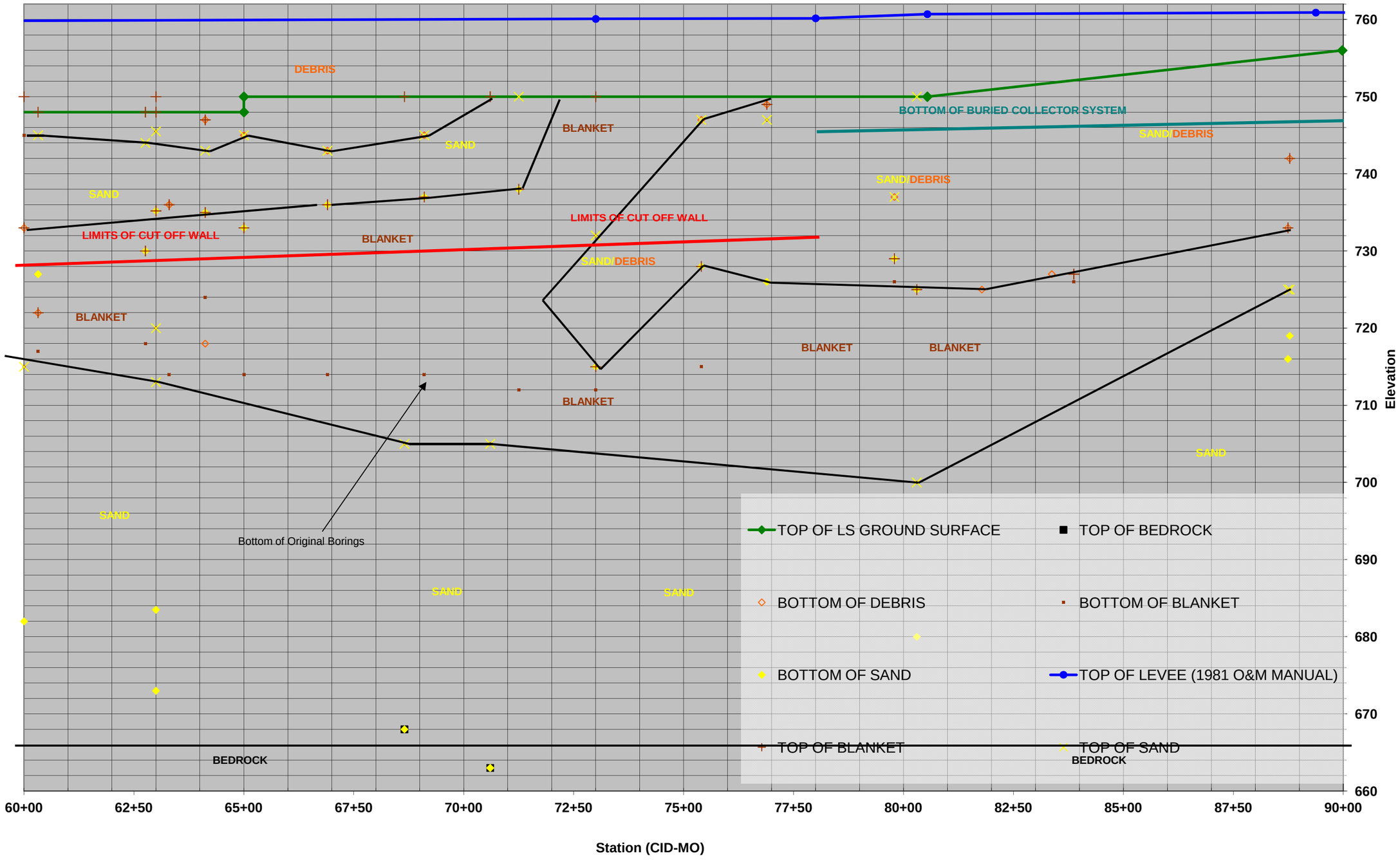
CID-MO CENTERLINE SUBSURFACE PROFILE

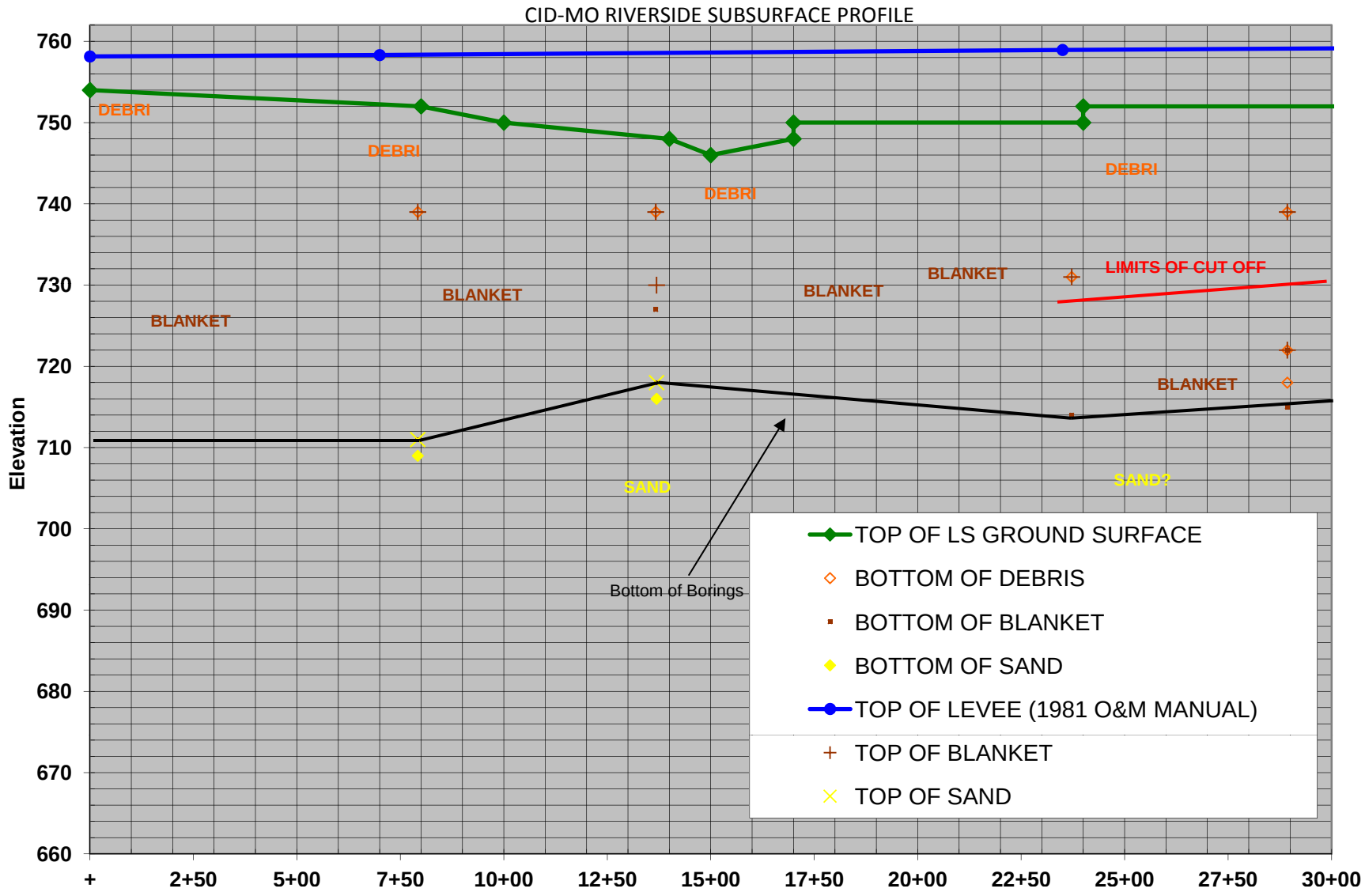


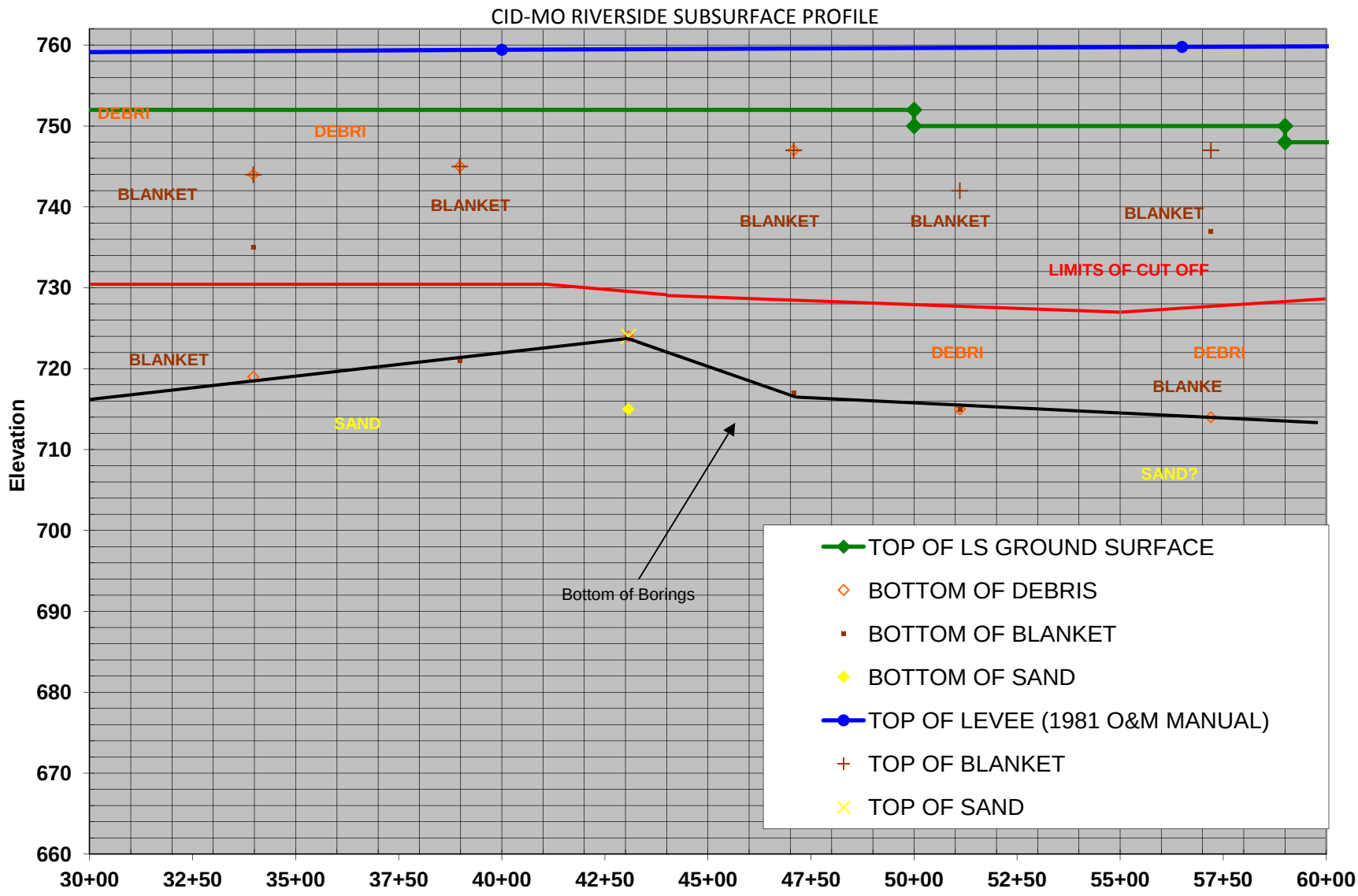
CID-MO CENTERLINE SUBSURFACE PROFILE

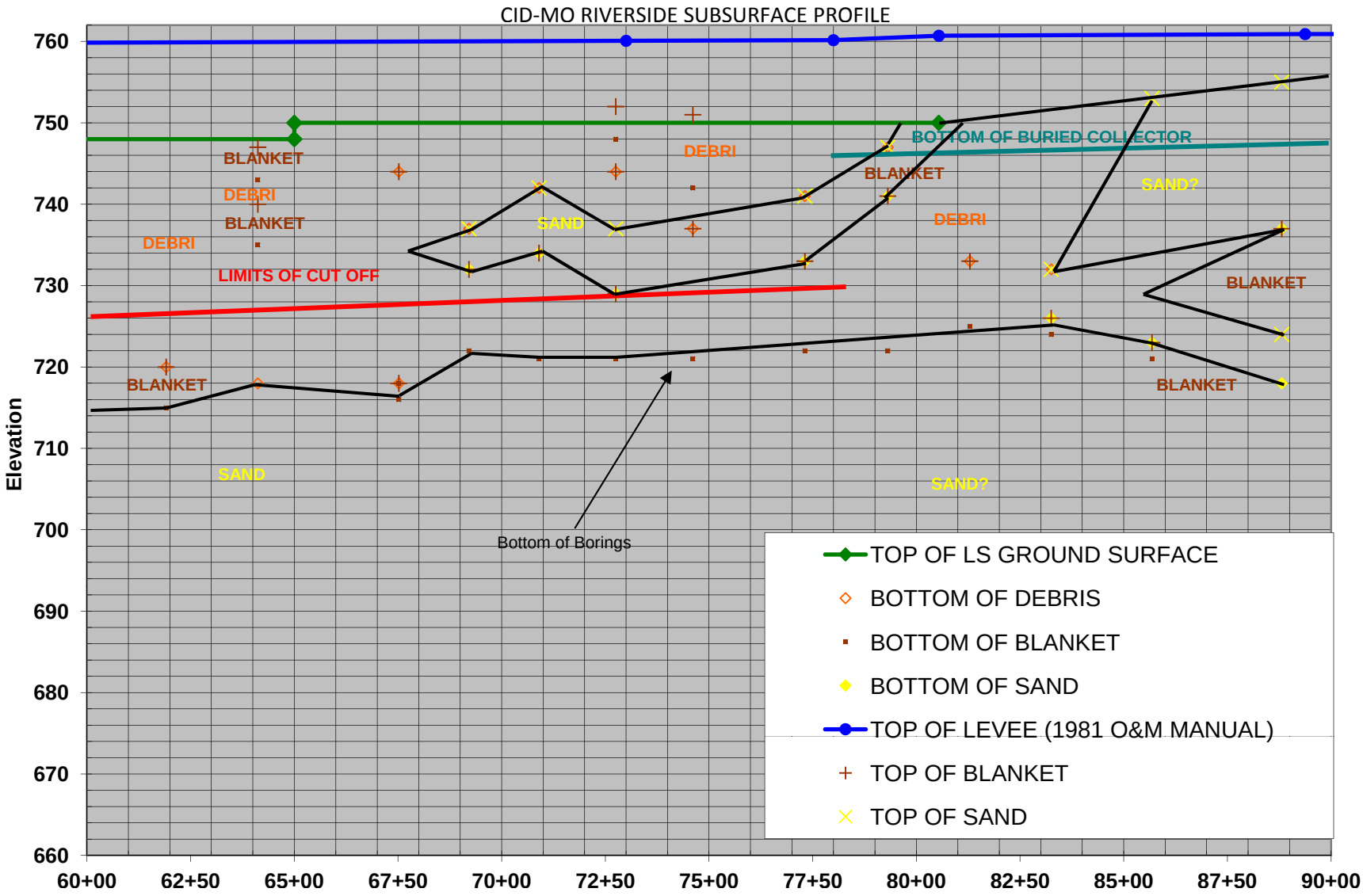


CID-MO CENTERLINE SUBSURFACE PROFILE

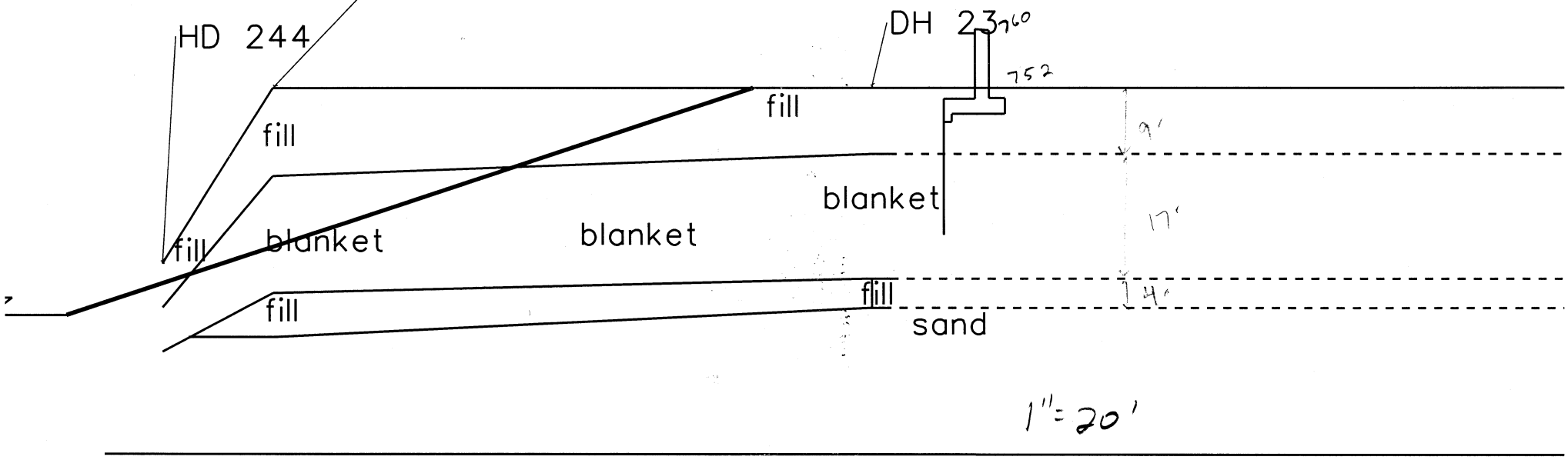



CID-MO RIVERSIDE SUBSURFACE PROFILE
Elevation
760
750
740
730
720
710
700
690
680
670
660
+
2+50
5+00
7+50
10+00
12+50
15+00
17+50
20+00
22+50
25+00
27+50
30+00
DEBRI
DEBRI
DEBRI
DEBRI
BLANKET
BLANKET
BLANKET
BLANKET
BLANKET
LIMITS OF CUT OFF
SAND
SAND?
Bottom of Borings
TOP OF LS GROUND SURFACE
BOTTOM OF DEBRIS
BOTTOM OF BLANKET
BOTTOM OF SAND
TOP OF LEVEE (1981 O&M MANUAL)
TOP OF BLANKET
TOP OF SAND

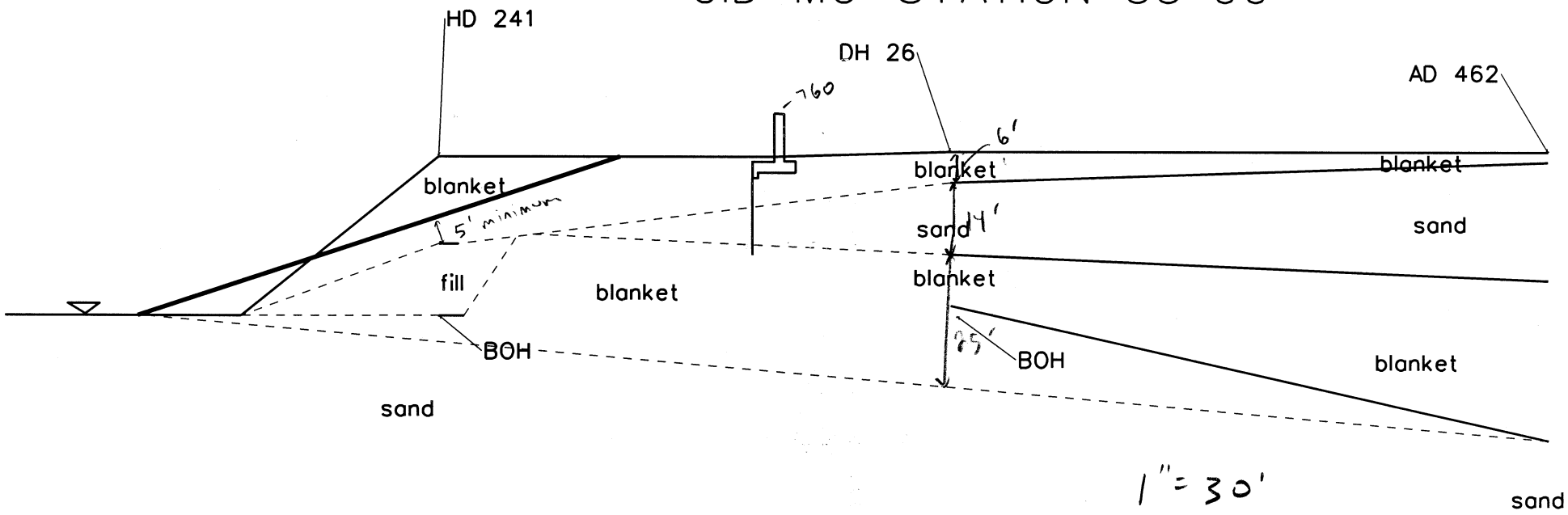

CID-MO RIVERSIDE SUBSURFACE PROFILE
Elevation
760
750
740
730
720
710
700
690
680
670
660
30+00
32+50
35+00
37+50
40+00
42+50
45+00
47+50
50+00
52+50
55+00
57+50
60+00
DEBRI
DEBRI
BLANKET
BLANKET
BLANKET
BLANKET
BLANKET
LIMITS OF CUT OFF
BLANKET
DEBRI
DEBRI
BLANKE
SAND
SAND?
Bottom of Borings
TOP OF LS GROUND SURFACE
BOTTOM OF DEBRIS
BOTTOM OF BLANKET
BOTTOM OF SAND
TOP OF LEVEE (1981 O&M MANUAL)
TOP OF BLANKET
TOP OF SAND


CID-MO RIVERSIDE SUBSURFACE PROFILE
Elevation
760
750
740
730
720
710
700
690
680
670
660
60+00
62+50
65+00
67+50
70+00
72+50
75+00
77+50
80+00
82+50
85+00
87+50
90+00
BLANKET
DEBRI
BLANKET
DEBRI
LIMITS OF CUT OFF
BLANKET
SAND
DEBRI
BLANKET
DEBRI
BOTTOM OF BURIED COLLECTOR
SAND?
BLANKET
BLANKET
SAND
SAND?
Bottom of Borings
TOP OF LS GROUND SURFACE
BOTTOM OF DEBRIS
BOTTOM OF BLANKET
BOTTOM OF SAND
TOP OF LEVEE (1981 O&M MANUAL)
TOP OF BLANKET
TOP OF SAND

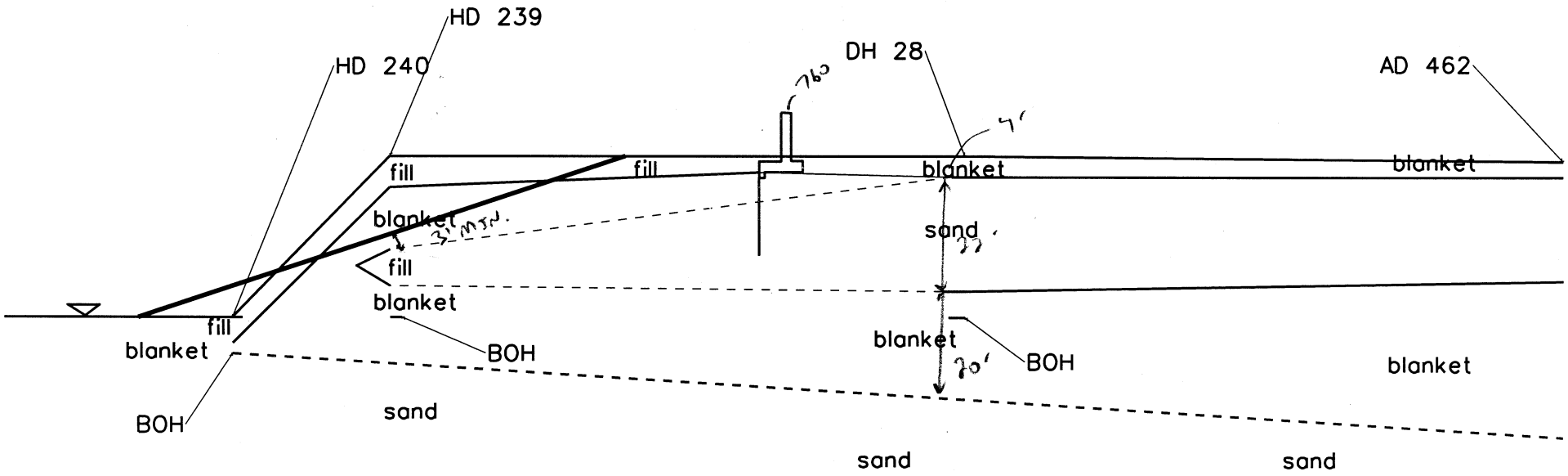
CID MO STATION 29+00



CID MO STATION 35+00

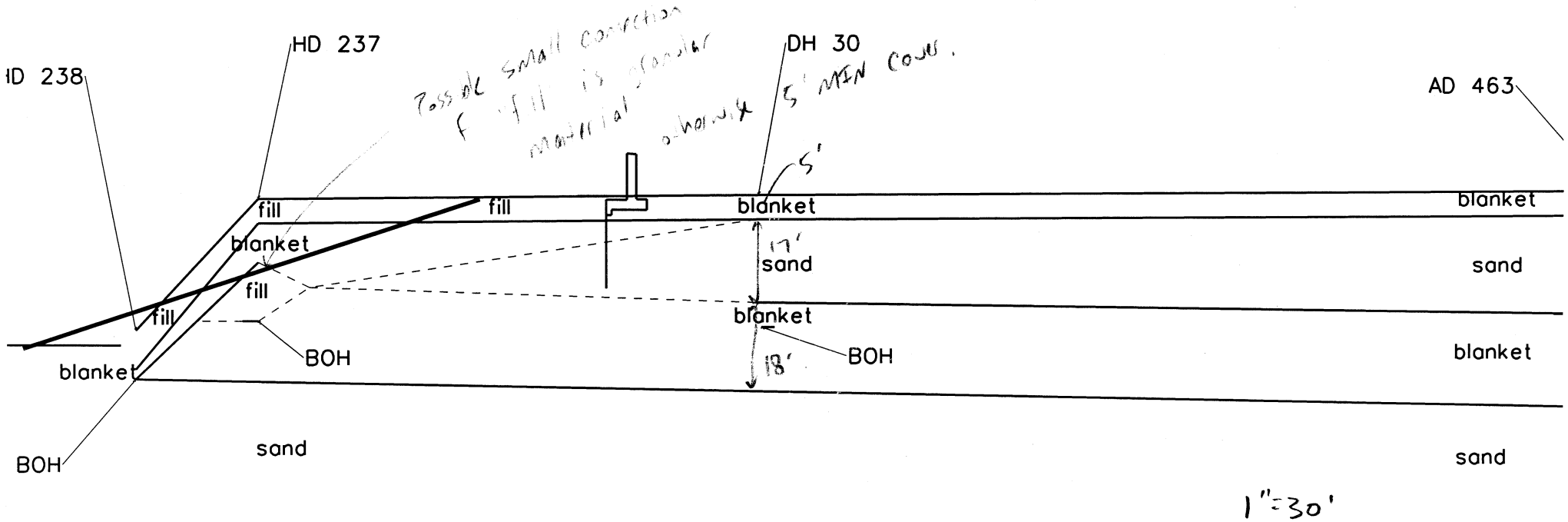


CID MO STATION 39+00



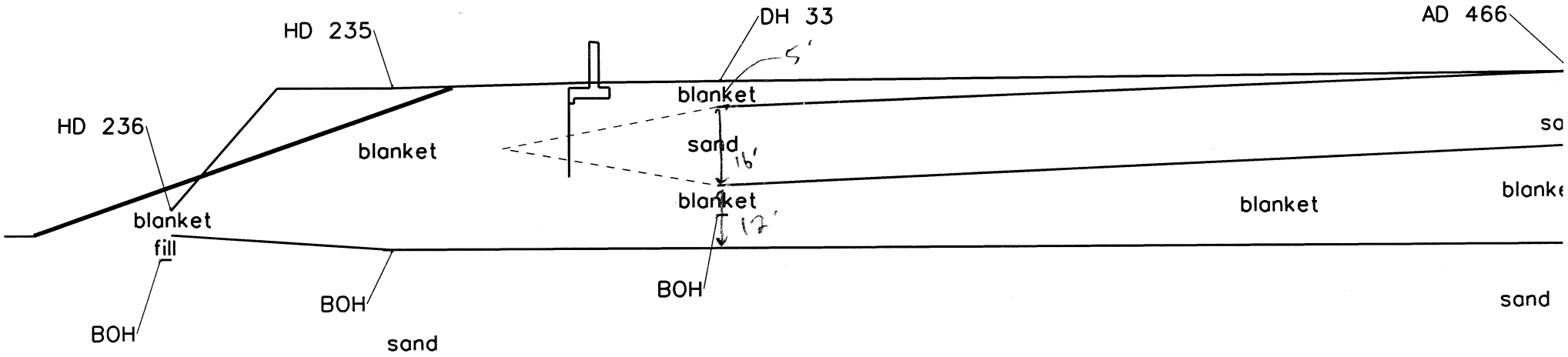
1" = 30'

CID MO STATION 42+00



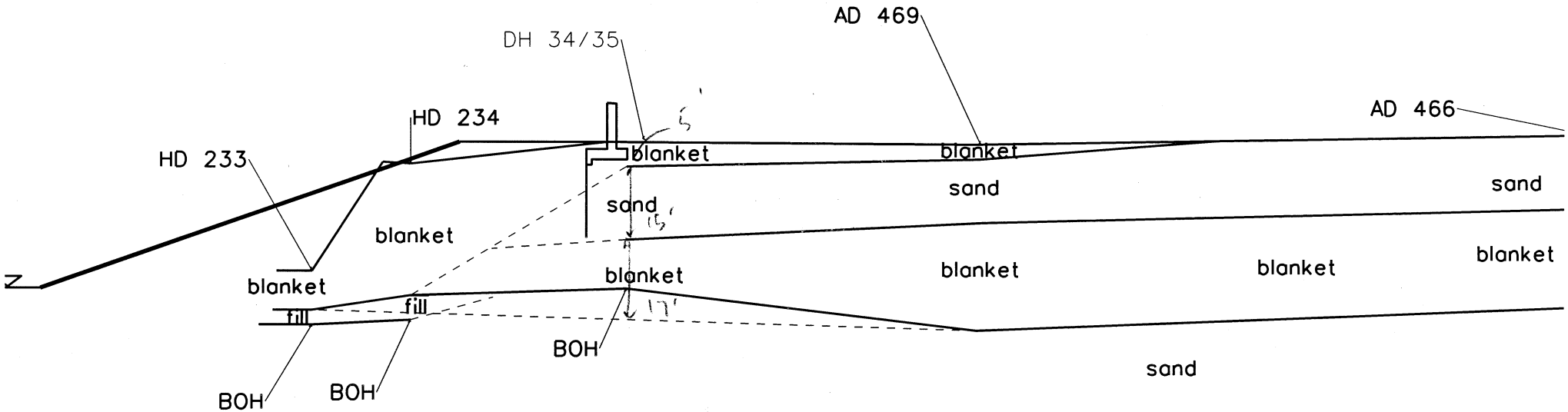
1"=30'

CID MO STATION 47+00



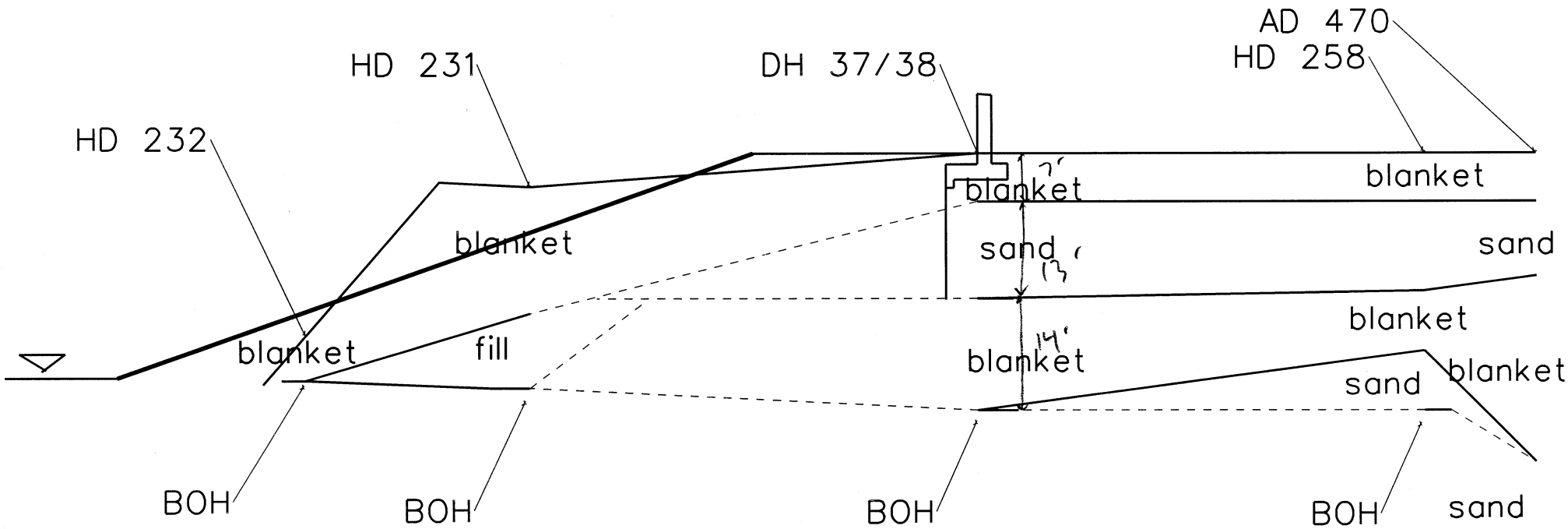
1" = 30'

CID MO STATION 51+00



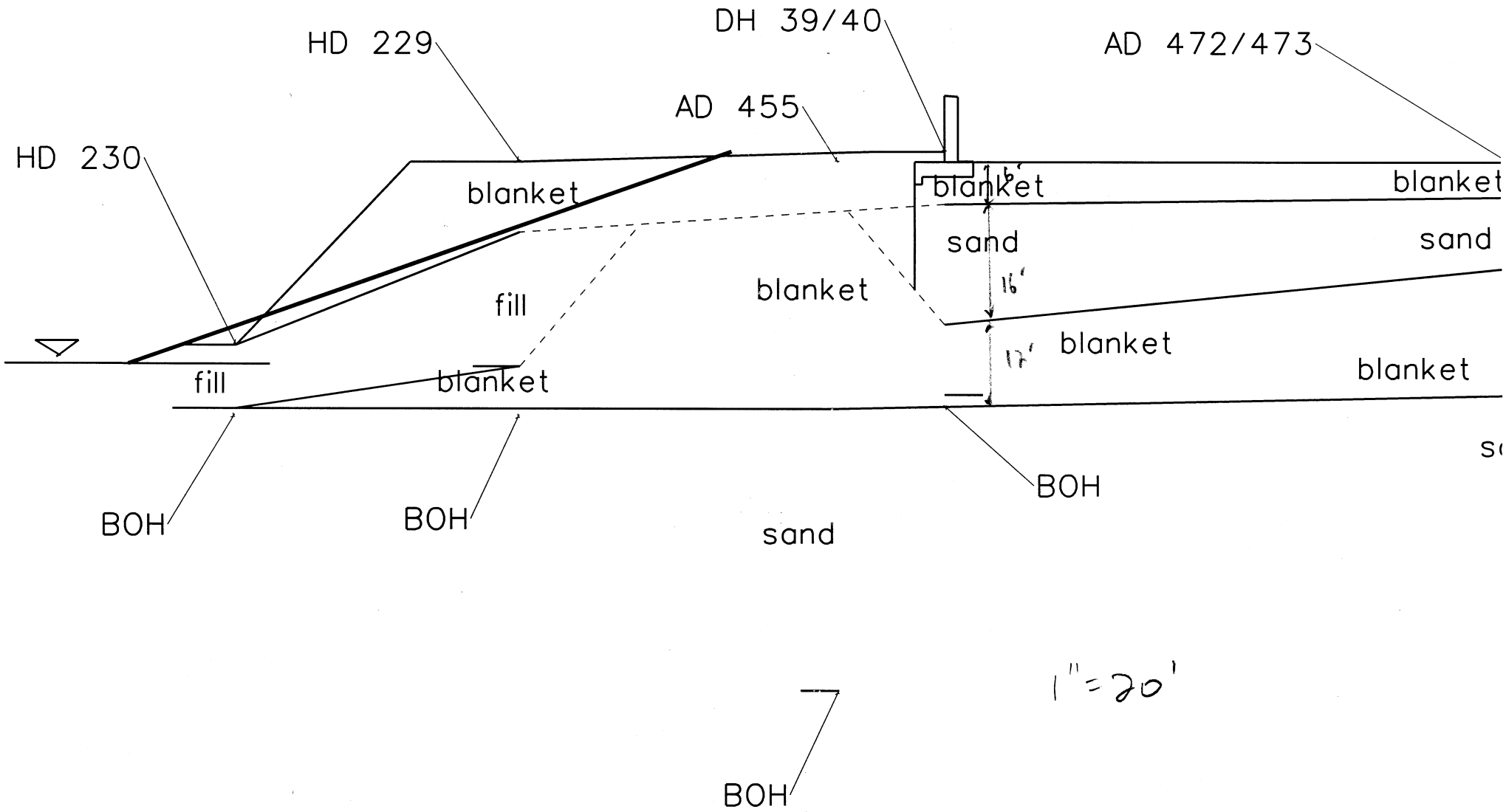
1" = 30'

CID MO STATION 57+00



1" = 20'

CID MO STATION 62+00



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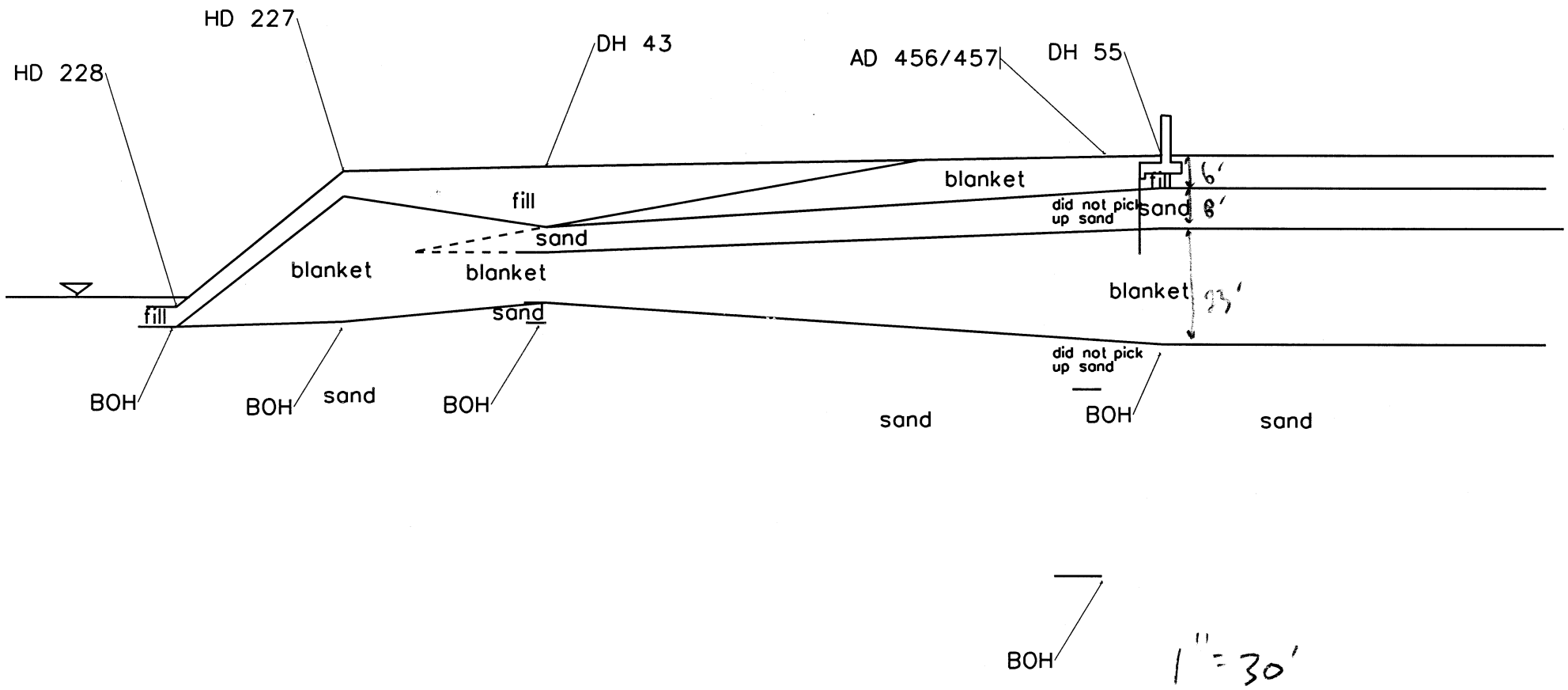

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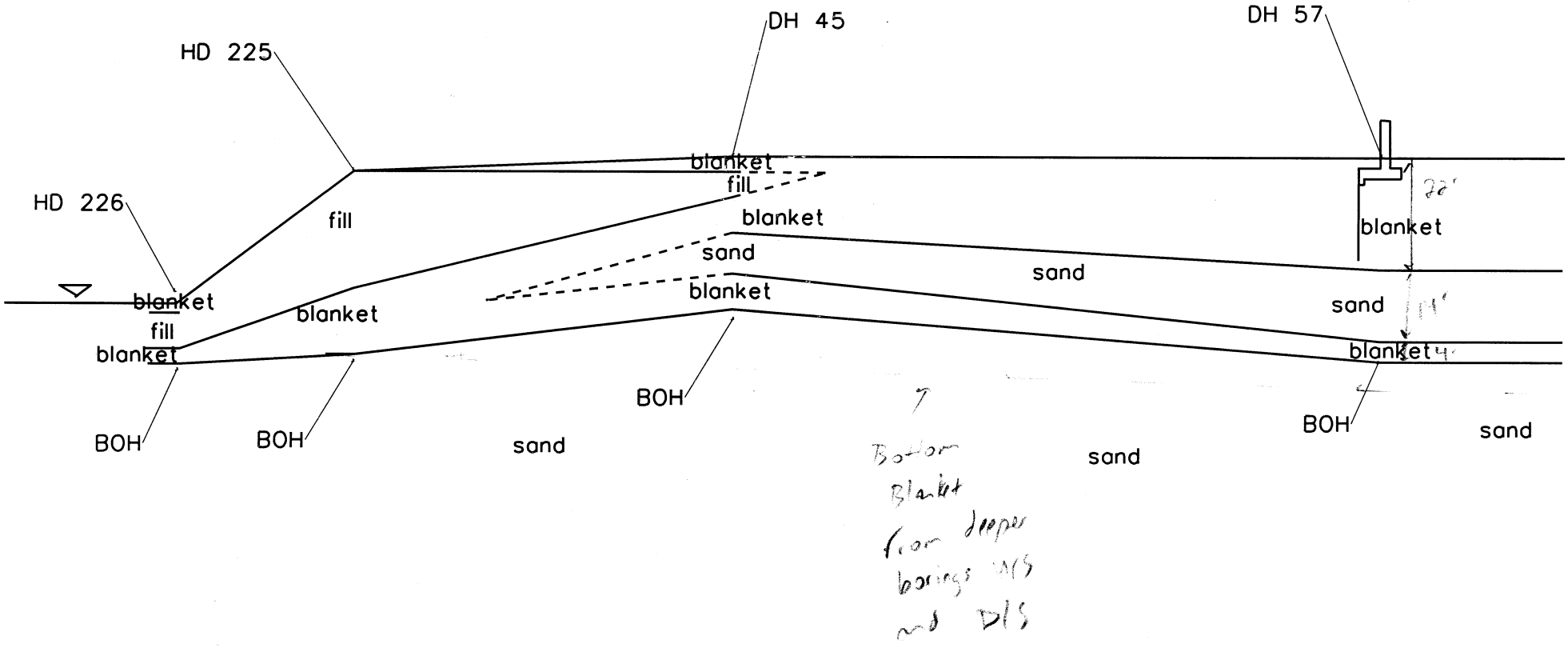
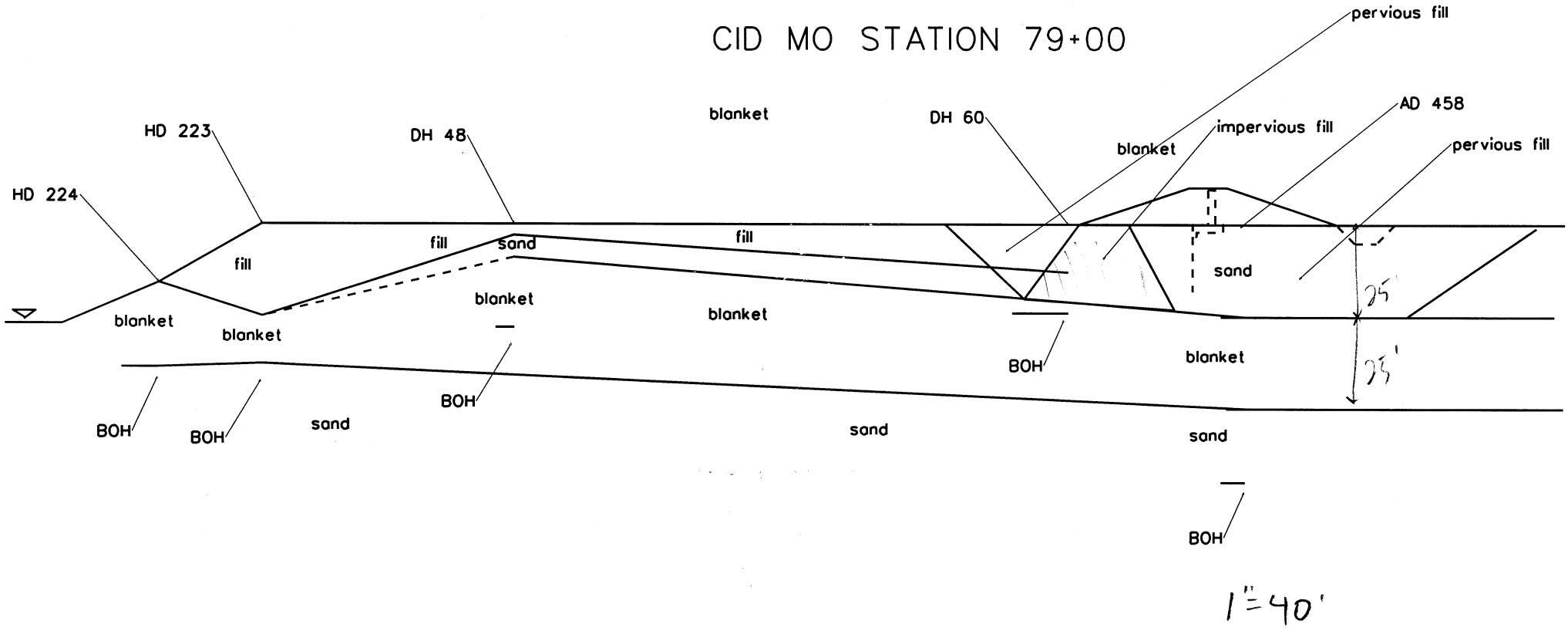
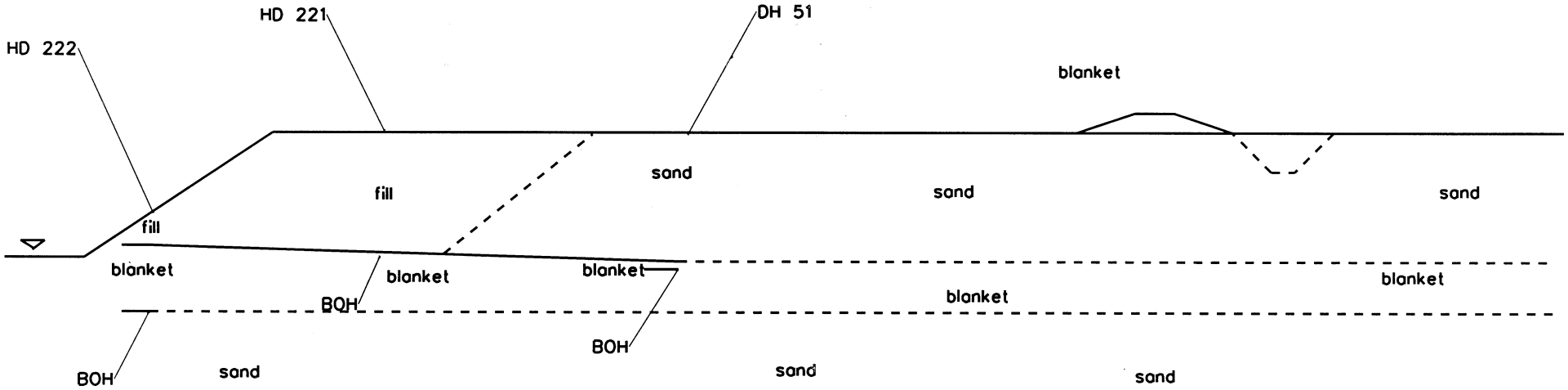


CID MO STATION 79+00



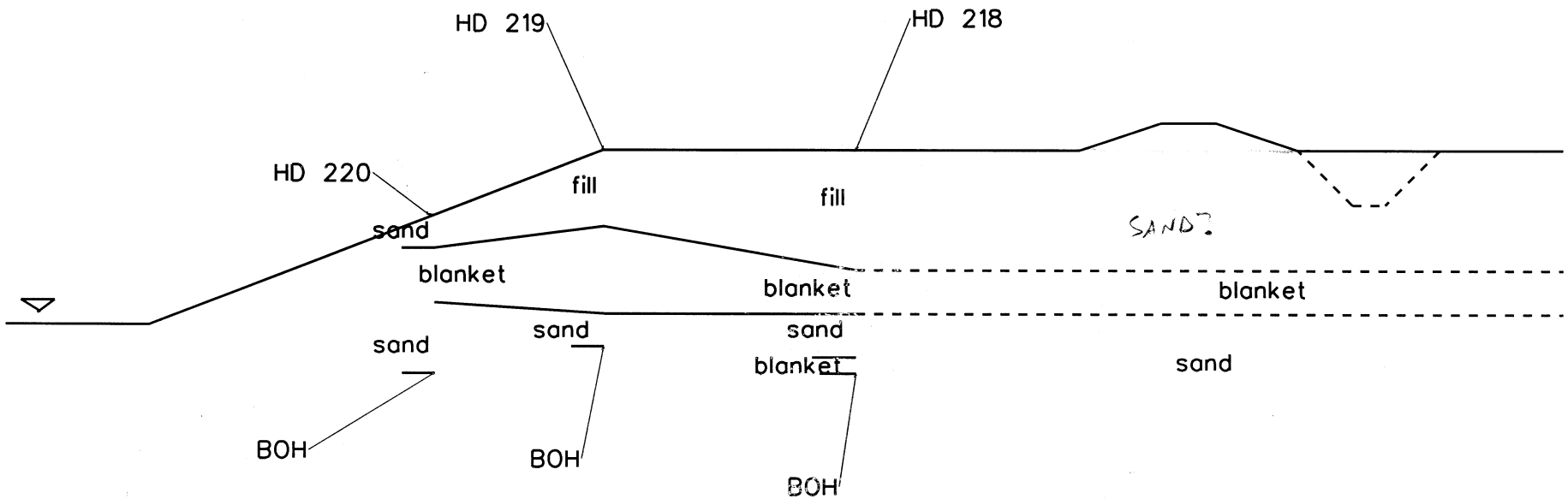
1" = 40'

CID MO STATION 86+00



1"=40'

CID MO STATION 89+00



1" = 30'

Designer	Glen M Bellew, PE(MO)	
Peer Review	Charlie Detrick	5-Jul-09
Evaluation	Glen M Bellew, PE(MO)	
Backcheck	Charlie Detrick	27-Jul-09

Assumptions used for underseepage calculations:

1. Semi-pervious blanket both on the river side and landward side
2. Landward side blanket of infinite extent
3. If an underseepage blanket exists, 1/2 of the width is included in the levee width L_2

Factors used in underseepage calculations:

k_f = horizontal permeability of the pervious foundation
k_{br} = vertical permeability of the blanket, river side
k_{bl} = vertical permeability of the blanket, landward side
z_{br} = thickness of the blanket, river side
z_{bo} = thickness of the blanket under the levee
z_{bl} = thickness of the blanket, landward side
d = thickness of pervious foundation
H = Net head on levee
L_1 = distance to river from riverside levee toe
L_2 = base width of levee and berms
L_3 = length of blanket beyond landside levee toe
c_r = factor used in calculations for river side
c_l = factor used in calculations for landward side
x_1 = distance from effective seepage entry to riverside levee toe
x_3 = distance from landside levee toe to effective seepage exit
h_o = head at base of blanket, landward levee toe, measured above the ground surface, feet
i_o = computed hydraulic gradient at landside levee toe
i_c = critical hydraulic gradient
γ_b = bouyant unit weight of blanket soils
γ_w = unit weight of water
h_x = pressure head at base of blanket measured above the ground surface
x = distance from levee toe, positive indicates landward

Equations:

$c_r = (k_{br}/k_f z_{br} d)^{1/2}$

$c_l = (k_{bl}/k_f z_{bl} d)^{1/2}$

$x_1 = \tanh(c_r L_1)/c_r$

$x_3 = 1/c_l$

$i_o = h_o/z_{bl}$

$i_c = \gamma_b/\gamma_w$

$h_o = H((x_3/(x_1+L_2+x_3))$

$h_x = h_o e^{-cx}$

for calculations with bluff as seepage block:

$x_3 = 1/ (c_l \tanh (c_l L3)$

for calculations with a seepage block at entrance

$c_r = (k_{br}/k_f z_{br} d)^{1/2}$

zbr = block thickness
d = upper aquifer thickness

$x_1 = 1/(c_r \tanh (cL_1))$

L1= distance to seepage block

CID-MO Levee Kansas City Phase 2 Feasibility
Saturday, August 08, 2009 Revised:
Levee Foundation Information - EXISTING CONDITIONS, Water to Top of Levee

DRAFT

Blanket Unit Weight = 115.0 pcf (saturated)
Rubble Fill Unit Weight = 115.0 pcf (saturated)

Station	Top of Levee Elevation (msl)	River Side Ground Elevation (msl)	Land Side Ground Elevation (msl)	River Blanket Bottom Elevation (msl)	Land Blanket Bottom Elevation	Top of Blanket Elevation (msl)	Top of Bedrock Elevation (msl)	Driving Head (ft) H	Permeability Ratio River Side k_f/k_{br}	Permeability Ratio Land Side k_f/k_{bl}	Impervious Blanket Thickness (ft) River Side z_{br}	Impervious Blanket Thickness (ft) Levee z_{bo}	Impervious Blanket Thickness (ft) Land Side z_{bl}	Pervious Blanket Thickness (ft) d	Seepage Length (ft) River Side L_1	Seepage Length (ft) Levee L_2	Seepage Length (ft) Land Side L_3	Factor c_r	Factor c_l	Effective Seepage Length (ft) River Side x_1	Effective Seepage Length (ft) Land Side x_3	Head at Toe (ft) h_o	Computed Hydraulic Gradient i_o	Critical Hydraulic Gradient i_c	Factor of Safety for Piping (i_c/i_o)	Remarks
0+00 to 10+00	758.0	750	752	711	725	749	710	6.0	300	300	39	31.5	24	15	100	15	1000	0.002387	0.003043	98	329	4.46	0.19	0.84	4.53	
10+00 to 22+50	758.5	750	750	715	floodwall sitting on bedrock	750	735	8.5	300	300	35	#VALUE!	#VALUE!	#VALUE!	100	15	1000	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	0.84	#VALUE!	floodwall is bearing directly on bedrock and there is a toe drain at the landward edge of the floodwall. A line of creep analysis, or similar, will have to be performed if the uplift along the floodwall is needed.
22+50 to 27+50	759.0	750	752	716	710	742	700	7.0	300	300	34	33	32	10	100	15	1000	0.003131	0.003227	97	310	5.14	0.16	0.84	5.24	
27+50 to 32+50 - Assumption 1	759.3	750	752	716	710	735	690	7.3	300	300	34	29.5	25	20	100	15	1000	0.002214	0.002582	98	387	5.61	0.22	0.84	3.76	Lower and upper blanket thickness added together to compute Zbl and FSi. This assumes that the riverside has an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This is the LEAST conservative approach
27+50 to 32+50 - Assumption 2	759.3	750	752	716	740	748	690	7.3	300	300	5	6.5	8	50	50	15	1000	0.003651	0.002887	49	346	6.11	0.76	0.84	1.10	Only the upper blanket thickness was used to compute Zbl and FSi. This assumes that the riverside does not have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall does not provide a cut off between the river and the middle sand. This is the MOST conservative approach
27+50 to 32+50 - Assumption 3	759.3	750	752	716	740	748	690	5.4	300	300	5	6.5	8	14	50	15	1000	0.006901	0.005455	437	183	1.57	0.20	0.84	4.30	Only the upper blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand that is used to calculate x1. the concrete sheetpile cutoff wall reduces the head by 25% in the upper sand. This calculation checks the gradient through the upper blanket.
27+50 to 32+50 - Assumption 4	759.3	750	752	716	710	722	690	7.3	300	300	34	23	12	20	100	15	1000	0.002214	0.003727	98	268	5.10	0.42	0.84	1.98	Only the lower blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This calculation checks the gradient through the lower blanket. Assumes hydrostatic conditions in the upper sand.
32+50 to 37+50 - Assumption 1	759.4	750	752	720	710	730	665	7.4	300	300	30	25	20	45	100	15	1000	0.001571	0.001925	99	520	6.07	0.30	0.84	2.78	Lower and upper blanket thickness added together to compute Zbl and FSi. This assumes that the riverside has an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This is the LEAST conservative approach
32+50 to 37+50 - Assumption 2	759.4	750	752	720	745	752	665	7.4	300	300	30	18.5	7	80	50	15	1000	0.001179	0.002440	50	410	6.39	0.91	0.84	0.92	Only the upper blanket thickness was used to compute Zbl and FSi. This assumes that the riverside does not have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall does not provide a cut off between the river and the middle sand. This is the MOST conservative approach
32+50 to 37+50 - Assumption 3	759.4	750	752	720	745	752	665	5.5	300	300	5	6	7	22	50	15	1000	0.005505	0.004652	677	215	1.32	0.19	0.84	4.48	Only the upper blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand that is used to calculate x1. the concrete sheetpile cutoff wall reduces the head by 25% in the upper sand. This calculation checks the gradient through the upper blanket.
32+50 to 37+50 - Assumption 4	759.4	750	752	720	710	724	665	7.4	300	300	30	22	14	45	100	15	1000	0.001571	0.002300	99	435	5.86	0.42	0.84	2.01	Only the lower blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This calculation checks the gradient through the lower blanket. Assumes hydrostatic conditions in the upper sand.
37+50 to 41+00 - Assumption 1	759.4	750	752	721	709	733	665	7.4	300	300	29	26.5	24	44	100	15	1000	0.001616	0.001777	99	563	6.19	0.26	0.84	3.27	Lower and upper blanket thickness added together to compute Zbl and FSi. This assumes that the riverside has an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This is the LEAST conservative approach
37+50 to 41+00 - Assumption 2	759.4	750	752	721	746	752	665	7.4	300	300	29	17.5	6	81	50	15	1000	0.001191	0.002619	50	382	6.36	1.06	0.84	0.80	Only the upper blanket thickness was used to compute Zbl and FSi. This assumes that the riverside does not have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall does not provide a cut off between the river and the middle sand. This is the MOST conservative approach
37+50 to 41+00 - Assumption 3	759.4	750	752	721	746	752	665	5.6	300	300	3	4.5	6	20	50	15	1000	0.007454	0.005270	377	190	1.82	0.30	0.84	2.78	Only the upper blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand that is used to calculate x1. the concrete sheetpile cutoff wall reduces the head by 25% in the upper sand. This calculation checks the gradient through the upper blanket.
37+50 to 41+00 - Assumption 4	759.4	750	752	721	709	727	665	7.4	300	300	29	23.5	18	44	100	15	1000	0.001616	0.002052	99	487	6.03	0.33	0.84	2.52	Only the lower blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This calculation checks the gradient through the lower blanket. Assumes hydrostatic conditions in the upper sand.

Station	Top of Levee Elevation (msl)	River Side Ground Elevation (msl)	Land Side Ground Elevation (msl)	River Blanket Bottom Elevation (msl)	Land Blanket Bottom Elevation	Top of Blanket Elevation (msl)	Top of Bedrock Elevation (msl)	Driving Head (ft) H	Permeability Ratio River Side k_f/k_{br}	Permeability Ratio Land Side k_f/k_{bl}	Impervious Blanket Thickness (ft) River Side z_{br}	Impervious Blanket Thickness (ft) Levee z_{bo}	Impervious Blanket Thickness (ft) Land Side z_{bl}	Pervious Blanket Thickness (ft) d	Seepage Length (ft) River Side L_1	Seepage Length (ft) Levee L_2	Seepage Length (ft) Land Side L_3	Factor c_r	Factor c_l	Effective Seepage Length (ft) River Side x_1	Effective Seepage Length (ft) Land Side x_3	Head at Toe (ft) h_o	Computed Hydraulic Gradient i_o	Critical Hydraulic Gradient i_c	Factor of Safety for Piping (i_c/i_o)	Remarks
41+00 to 46+00 - Assumption 1	759.5	750	752	722	712	734	665	7.5	300	300	28	25	22	47	100	15	1000	0.001592	0.001795	99	557	6.22	0.28	0.84	2.98	Lower and upper blanket thickness added together to compute Zbl and FSi. This assumes that the riverside has an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This is the LEAST conservative approach
41+00 to 46+00 - Assumption 2	759.5	750	752	722	746	752	665	7.5	300	300	28	17	6	81	50	15	1000	0.001212	0.002619	50	382	6.41	1.07	0.84	0.79	Only the upper blanket thickness was used to compute Zbl and FSi. This assumes that the riverside does not have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall does not provide a cut off between the river and the middle sand. This is the MOST conservative approach
41+00 to 46+00 - Assumption 3	759.5	750	752	722	746	752	665	5.6	300	300	5	5.5	6	16	50	15	1000	0.006455	0.005893	497	170	1.40	0.23	0.84	3.61	Only the upper blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand that is used to calculate x1. the concrete sheetpile cutoff wall reduces the head by 25% in the upper sand. This calculation checks the gradient through the upper blanket.
41+00 to 46+00 - Assumption 4	759.5	750	752	722	709	725	665	7.5	300	300	28	22	16	44	100	15	1000	0.001645	0.002176	99	460	6.01	0.38	0.84	2.24	Only the lower blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This calculation checks the gradient through the lower blanket. Assumes hydrostatic conditions in the upper sand.
46+00 to 50+00 - Assumption 1	759.6	750	752	718	713	733	665	7.6	300	300	32	26	20	48	100	15	1000	0.001473	0.001863	99	537	6.27	0.31	0.84	2.69	Lower and upper blanket thickness added together to compute Zbl and FSi. This assumes that the riverside has an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This is the LEAST conservative approach
46+00 to 50+00 - Assumption 2	759.6	750	752	718	746	752	665	7.6	300	300	32	19	6	81	50	15	1000	0.001134	0.002619	50	382	6.50	1.08	0.84	0.78	Only the upper blanket thickness was used to compute Zbl and FSi. This assumes that the riverside does not have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall does not provide a cut off between the river and the middle sand. This is the MOST conservative approach
46+00 to 50+00 - Assumption 3	759.6	750	752	718	746	752	665	5.7	300	300	5	5.5	6	18	50	15	1000	0.006086	0.005556	557	180	1.37	0.23	0.84	3.70	Only the upper blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand that is used to calculate x1. the concrete sheetpile cutoff wall reduces the head by 25% in the upper sand. This calculation checks the gradient through the upper blanket.
46+00 to 50+00 - Assumption 4	759.6	750	752	718	713	729	665	7.6	300	300	32	24	16	48	100	15	1000	0.001473	0.002083	99	480	6.14	0.38	0.84	2.20	Only the lower blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This calculation checks the gradient through the lower blanket. Assumes hydrostatic conditions in the upper sand.
50+00 to 52+50 - Assumption 1	759.7	750	750	715	712	736	665	9.6	300	300	35	29.5	24	47	100	15	1000	0.001423	0.001719	99	582	8.06	0.34	0.84	2.51	Lower and upper blanket thickness added together to compute Zbl and FSi. This assumes that the riverside has an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This is the LEAST conservative approach
50+00 to 52+50 - Assumption 2	759.7	750	750	715	745	750	665	9.6	300	300	35	20	5	80	50	15	1000	0.001091	0.002887	50	346	8.13	1.63	0.84	0.52	Only the upper blanket thickness was used to compute Zbl and FSi. This assumes that the riverside does not have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall does not provide a cut off between the river and the middle sand. This is the MOST conservative approach
50+00 to 52+50 - Assumption 3	759.7	750	750	715	745	750	665	4.8	300	300	5	5	5	14	50	15	1000	0.006901	0.006901	437	145	1.17	0.23	0.84	3.60	Only the upper blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand that is used to calculate x1. the concrete sheetpile cutoff wall reduces the head by 50% in the upper sand since it is a full cut off. This calculation checks the gradient through the upper blanket.
50+00 to 52+50 - Assumption 4	759.7	750	750	715	712	731	665	9.6	300	300	35	27	19	47	100	15	1000	0.001423	0.001932	99	518	7.90	0.42	0.84	2.03	Only the lower blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This calculation checks the gradient through the lower blanket. Assumes hydrostatic conditions in the upper sand.
52+50 to 55+00 - Assumption 1	759.7	750	750	715	711.5	738.5	665	9.7	300	300	35	31	27	46.5	100	15	1000	0.001431	0.001629	99	614	8.18	0.30	0.84	2.78	Lower and upper blanket thickness added together to compute Zbl and FSi. This assumes that the riverside has an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This is the LEAST conservative approach
52+50 to 55+00 - Assumption 2	759.7	750	750	715	744	750	665	9.7	300	300	35	20.5	6	79	50	15	1000	0.001098	0.002652	50	377	8.27	1.38	0.84	0.61	Only the upper blanket thickness was used to compute Zbl and FSi. This assumes that the riverside does not have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall does not provide a cut off between the river and the middle sand. This is the MOST conservative approach
52+50 to 55+00 - Assumption 3	759.7	750	750	715	744	750	665	4.9	300	300	5	5.5	6	10	50	15	1000	0.008165	0.007454	316	134	1.40	0.23	0.84	3.62	Only the upper blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand that is used to calculate x1. the concrete sheetpile cutoff wall reduces the head by 50% in the upper sand since it is a full cut off. This calculation checks the gradient through the upper blanket.
52+50 to 55+00 - Assumption 4	759.7	750	750	715	711.5	732.5	665	9.7	300	300	35	28	21	46.5	100	15	1000	0.001431	0.001848	99	541	8.01	0.38	0.84	2.21	Only the lower blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This calculation checks the gradient through the lower blanket. Assumes hydrostatic conditions in the upper sand.

Station	Top of Levee Elevation (msl)	River Side Ground Elevation (msl)	Land Side Ground Elevation (msl)	River Blanket Bottom Elevation (msl)	Land Blanket Bottom Elevation	Top of Blanket Elevation (msl)	Top of Bedrock Elevation (msl)	Driving Head (ft) H	Permeability Ratio River Side k_f/k_{br}	Permeability Ratio Land Side k_f/k_{bl}	Impervious Blanket Thickness (ft) River Side z_{br}	Impervious Blanket Thickness (ft) Levee z_{bo}	Impervious Blanket Thickness (ft) Land Side z_{bl}	Pervious Blanket Thickness (ft) d	Seepage Length (ft) River Side L_1	Seepage Length (ft) Levee L_2	Seepage Length (ft) Land Side L_3	Factor c_r	Factor c_l	Effective Seepage Length (ft) River Side x_1	Effective Seepage Length (ft) Land Side x_3	Head at Toe (ft) h_o	Computed Hydraulic Gradient i_o	Critical Hydraulic Gradient i_c	Factor of Safety for Piping (i_c/i_o)	Remarks
55+00 to 57+50 - Assumption 1	759.8	750	750	714.5	711	737.5	665	9.8	300	300	35.5	31	26.5	46	100	15	1000	0.001429	0.001654	99	605	8.24	0.31	0.84	2.71	Lower and upper blanket thickness added together to compute Zbl and FSi. This assumes that the riverside has an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This is the LEAST conservative approach
55+00 to 57+50 - Assumption 2	759.8	750	750	714.5	745	750	665	9.8	300	300	35.5	20.25	5	80	50	15	1000	0.001083	0.002887	50	346	8.25	1.65	0.84	0.51	Only the upper blanket thickness was used to compute Zbl and FSi. This assumes that the riverside does not have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall does not provide a cut off between the river and the middle sand. This is the MOST conservative approach
55+00 to 57+50 - Assumption 3	759.8	750	750	714.5	745	750	665	4.9	300	300	5	5	5	12	50	15	1000	0.007454	0.007454	377	134	1.25	0.25	0.84	3.37	Only the upper blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand that is used to calculate x1. the concrete sheetpile cutoff wall reduces the head by 50% in the upper sand since it is a full cut off. This calculation checks the gradient through the upper blanket.
55+00 to 57+50 - Assumption 4	759.8	750	750	714.5	711	732.5	665	9.8	300	300	35.5	28.5	21.5	46	100	15	1000	0.001429	0.001836	99	545	8.10	0.38	0.84	2.24	Only the lower blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This calculation checks the gradient through the lower blanket. Assumes hydrostatic conditions in the upper sand.
57+50 to 62+50 - Assumption 1	760.0	750	748	715	714	736	665	12.0	300	300	35	28.5	22	49	100	15	1000	0.001394	0.001758	99	569	9.99	0.45	0.84	1.86	Lower and upper blanket thickness added together to compute Zbl and FSi. This assumes that the riverside has an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This is the LEAST conservative approach
57+50 to 62+50 - Assumption 2	760.0	750	748	715	745	748	665	12.0	300	300	35	19	3	80	50	15	1000	0.001091	0.003727	50	268	9.66	3.22	0.84	0.26	Only the upper blanket thickness was used to compute Zbl and FSi. This assumes that the riverside does not have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall does not provide a cut off between the river and the middle sand. This is the MOST conservative approach
57+50 to 62+50 - Assumption 3	760.0	750	748	715	745	748	665	6.0	300	300	5	4	3	12	50	15	1000	0.007454	0.009623	377	104	1.26	0.42	0.84	2.01	Only the upper blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand that is used to calculate x1. the concrete sheetpile cutoff wall reduces the head by 50% in the upper sand since it is a full cut off. This calculation checks the gradient through the upper blanket.
57+50 to 62+50 - Assumption 4	760.0	750	748	715	714	733	665	12.0	300	300	35	27	19	49	100	15	1000	0.001394	0.001892	99	528	9.87	0.52	0.84	1.62	Only the lower blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This calculation checks the gradient through the lower blanket. Assumes hydrostatic conditions in the upper sand.
62+50 to 65+00 - Assumption 1	760.0	750	748	717	712	738	665	12.0	300	300	33	29.5	26	47	100	15	1000	0.001466	0.001652	99	605	10.09	0.39	0.84	2.17	Lower and upper blanket thickness added together to compute Zbl and FSi. This assumes that the riverside has an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This is the LEAST conservative approach
62+50 to 65+00 - Assumption 2	760.0	750	748	717	744	748	665	12.0	300	300	33	18.5	4	79	50	15	1000	0.001131	0.003248	50	308	9.91	2.48	0.84	0.34	Only the upper blanket thickness was used to compute Zbl and FSi. This assumes that the riverside does not have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall does not provide a cut off between the river and the middle sand. This is the MOST conservative approach
62+50 to 65+00 - Assumption 3	760.0	750	748	717	744	748	665	6.0	300	300	5	4.5	4	8	50	15	1000	0.009129	0.010206	256	98	1.59	0.40	0.84	2.12	Only the upper blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand that is used to calculate x1. the concrete sheetpile cutoff wall reduces the head by 50% in the upper sand since it is a full cut off. This calculation checks the gradient through the upper blanket.
62+50 to 65+00 - Assumption 4	760.0	750	748	717	712	734	665	12.0	300	300	33	27.5	22	47	100	15	1000	0.001466	0.001795	99	557	9.96	0.45	0.84	1.86	Only the lower blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This calculation checks the gradient through the lower blanket. Assumes hydrostatic conditions in the upper sand.
65+00 to 67+50 - Assumption 1	760.0	750	750	715	709	742	665	10.0	300	300	35	34	33	44	140	15	1000	0.001471	0.001515	138	660	8.12	0.25	0.84	3.43	Lower and upper blanket thickness added together to compute Zbl and FSi. This assumes that the riverside has an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This is the LEAST conservative approach
65+00 to 67+50 - Assumption 2	760.0	750	750	715	744	750	665	10.0	300	300	35	20.5	6	79	100	15	1000	0.001098	0.002652	100	377	7.67	1.28	0.84	0.66	Only the upper blanket thickness was used to compute Zbl and FSi. This assumes that the riverside does not have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall does not provide a cut off between the river and the middle sand. This is the MOST conservative approach
65+00 to 67+50 - Assumption 3	760.0	750	750	715	744	750	665	5.0	300	300	5	5.5	6	7	100	15	1000	0.009759	0.008909	136	112	2.13	0.35	0.84	2.38	Only the upper blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand that is used to calculate x1. the concrete sheetpile cutoff wall reduces the head by 50% in the upper sand since it is a full cut off. This calculation checks the gradient through the upper blanket.
65+00 to 67+50 - Assumption 4	760.0	750	750	715	709	736	665	10.0	300	300	35	31	27	44	140	15	1000	0.001471	0.001675	138	597	7.96	0.29	0.84	2.86	Only the lower blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This calculation checks the gradient through the lower blanket. Assumes hydrostatic conditions in the upper sand.

Station	Top of Levee Elevation (msl)	River Side Ground Elevation (msl)	Land Side Ground Elevation (msl)	River Blanket Bottom Elevation (msl)	Land Blanket Bottom Elevation	Top of Blanket Elevation (msl)	Top of Bedrock Elevation (msl)	Driving Head (ft) H	Permeability Ratio River Side k_f/k_{br}	Permeability Ratio Land Side k_f/k_{bl}	Impervious Blanket Thickness (ft) River Side z_{br}	Impervious Blanket Thickness (ft) Levee z_{bo}	Impervious Blanket Thickness (ft) Land Side z_{bl}	Pervious Blanket Thickness (ft) d	Seepage Length (ft) River Side L_1	Seepage Length (ft) Levee L_2	Seepage Length (ft) Land Side L_3	Factor c_r	Factor c_l	Effective Seepage Length (ft) River Side x_1	Effective Seepage Length (ft) Land Side x_3	Head at Toe (ft) h_o	Computed Hydraulic Gradient i_o	Critical Hydraulic Gradient i_c	Factor of Safety for Piping (i_c/i_o)	Remarks
67+50 to 71+00 - Assumption 1	760.0	750	750	719	706	743	665	10.0	300	300	31	34	37	41	140	15	1000	0.001619	0.001482	138	675	8.15	0.22	0.84	3.82	Lower and upper blanket thickness added together to compute Zbl and FSi. This assumes that the riverside has an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This is the LEAST conservative approach
67+50 to 71+00 - Assumption 2	760.0	750	750	719	744	750	665	10.0	300	300	31	18.5	6	79	100	15	1000	0.001167	0.002652	100	377	7.67	1.28	0.84	0.66	Only the upper blanket thickness was used to compute Zbl and FSi. This assumes that the riverside does not have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall does not provide a cut off between the river and the middle sand. This is the MOST conservative approach
67+50 to 71+00 - Assumption 3	760.0	750	750	719	744	750	665	5.0	300	300	5	5.5	6	10	100	15	1000	0.008165	0.007454	182	134	2.03	0.34	0.84	2.50	Only the upper blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand that is used to calculate x1. the concrete sheetpile cutoff wall reduces the head by 50% in the upper sand since it is a full cut off. This calculation checks the gradient through the upper blanket.
67+50 to 71+00 - Assumption 4	760.0	750	750	719	706	737	665	10.0	300	300	31	31	31	41	140	15	1000	0.001619	0.001619	138	617	8.02	0.26	0.84	3.26	Only the lower blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This calculation checks the gradient through the lower blanket. Assumes hydrostatic conditions in the upper sand.
71+00 to 75+00 - Assumption 1	760.0	750	750	738	704	729	665	10.0	300	300	12	18.5	25	39	140	15	1000	0.002669	0.001849	134	541	7.84	0.31	0.84	2.69	Lower and upper blanket thickness added together to compute Zbl and FSi. This assumes that the riverside has an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This is the LEAST conservative approach
71+00 to 75+00 - Assumption 2	760.0	750	750	738	740	750	665	10.0	300	300	12	11	10	75	100	15	1000	0.001925	0.002108	99	474	8.07	0.81	0.84	1.05	Only the upper blanket thickness was used to compute Zbl and FSi. This assumes that the riverside does not have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall does not provide a cut off between the river and the middle sand. This is the MOST conservative approach
71+00 to 75+00 - Assumption 3	760.0	750	750	738	740	750	665	7.5	300	300	5	7.5	10	20	100	15	1000	0.005774	0.004082	333	245	3.10	0.31	0.84	2.72	Only the upper blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand that is used to calculate x1. the concrete sheetpile cutoff wall reduces the head by 50% in the upper sand since it is a full cut off. This calculation checks the gradient through the upper blanket.
71+00 to 75+00 - Assumption 4	760.0	750	750	719	704	718	665	10.0	300	300	31	22.5	14	39	140	15	1000	0.001660	0.002471	138	405	7.26	0.52	0.84	1.62	Only the lower blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This calculation checks the gradient through the lower blanket. Assumes hydrostatic conditions in the upper sand.
75+00 to 78+00 - Assumption 5	760.0	750	750	749	704	720	665	10.0	300	300	1	8.5	16	39	0	75	1000	0.009245	0.002311	0	433	8.52	0.53	0.84	1.58	Only the lower blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand to make pressures in the upper sand hydrostatic. This calculation checks the gradient through the lower blanket. Assumes hydrostatic conditions in the upper sand.
78+00 to 80+00 - Assumption 5	760.0	750	750	749	701	726	665	10.0	300	300	1	13	25	36	0	75	1000	0.009623	0.001925	0	520	8.74	0.35	0.84	2.41	Only the lower blanket thickness was used to compute Zbl and FSi. A large impervious section cuts off the middle sand. Also, the buried collector system maintains the pressure in the sand landward at hydrostatic. This is the likely scenario for this section.
80+00 to 82+50 - Assumption 5	760.0	750	750	749	703	726	665	10.0	300	300	1	12	23	38	0	75	1000	0.009366	0.001953	0	512	8.72	0.38	0.84	2.22	Only the lower blanket thickness was used to compute Zbl and FSi. A large impervious section cuts off the middle sand. Also, the buried collector system maintains the pressure in the sand landward at hydrostatic. This is the likely scenario for this section.
82+50 to 85+00 - Assumption 5	761.0	750	750	749	711	728	665	11.0	300	300	1	9	17	46	0	75	1000	0.008513	0.002065	0	484	9.53	0.56	0.84	1.50	Only the lower blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does not have an impervious layer over the middle sand but the buried collector system maintains the pressure in the sand landward at hydrostatic. This is the likely scenario for this section.
85+00 to 87+50 - Assumption 5	761.0	750	753	749	717	730	665	8.0	300	300	1	7	13	52	0	75	1000	0.008006	0.002221	0	450	6.86	0.53	0.84	1.60	Only the lower blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does not have an impervious layer over the middle sand but the buried collector system maintains the pressure in the sand landward at hydrostatic. This is the likely scenario for this section.
87+50 to 89+00 - Assumption 5	761.0	750	754	749	725	733	665	7.0	300	300	1	4.5	8	60	0	75	1000	0.007454	0.002635	0	379	5.84	0.73	0.84	1.15	Only the lower blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does not have an impervious layer over the middle sand but the buried collector system maintains the pressure in the sand landward at hydrostatic. This is the likely scenario for this section.

Summary of Calculated **Drained Ultimate Design Pile Capacities**, CID-MO Unit

Station Start	Station Stop	Pile Size, inches	Pile Shape	Pile Length, feet	Axial Compressive Capacity, lbs	Axial Tensile Capacity, lbs
22+81.46	24+54.76	18	tapered	21	**63,184**	34,428
24+54.76	25+38.76	16	straight	25	**94,544**	47,066
25+38.76	26+22.76	16	straight	29	**117,871**	60,583
26+22.76	27+90.76	16	straight	30	**110,124**	56,280
22+81.46	27+90.76	10	cut off pile*	16	22,839	**9,174**
27+90.76	30+42.75	16	straight	34	**165,730**	93,113
30+42.75	32+52.76	16	straight	21	**87,472**	44,990
27+90.76	30+42.75	10	cut off pile*	16	34,658	**7,421**
32+52.76	48+06.76	16	straight	21	**118,051**	67,168
32+52.76	48+06.76	10	cut off pile*	16	46,675	**15,817**
48+06.76	60+24.76	18	tapered	21	**76,858**	45,490
48+06.76	60+24.76	10	cut off pile*	16	28,969	**14,351**
60+24.76	73+20.14	18	straight	34	**137,963**	73,264
73+20.14	78+12.22	16	straight	21	**67,405**	34,166
60+24.76	78+12.22	10	cut off pile*	16	20,730	**9,401**

*cut off pile capacities are in lb/ft

CALCULATED BY GLEN BELLEW
PEER REVIEWED BY SCOTT LOEHR ON AUGUST 25, 2009 and SEPTEMBER 01, 2011

CAPACITIES BEFORE 09/01/11 REVISIONS WHERE "K" AND FRICTION FACTORS INCREASED TO REMOVE EXCESS CONSEF

Axial Compressive Capacity, lbs	Axial Tensile Capacity, lbs		
49,062	24,543	29%	40%
75,328	33,552	26%	40%
93,021	43,188	27%	40%
87,040	40,121	27%	40%
19,076	**6,540**	20%	40%
111,013	54,811	49%	70%
59,247	25,233	48%	78%
29,896	**5,291**	16%	40%
64,439	29,639	83%	127%
32,322	**6,973**	44%	127%
46,000	24,080	67%	89%
18,316	**6,894**	58%	108%
101,867	47,997	35%	53%
48,018	20,609	40%	66%
14,860	**5,292**	40%	78%
		41%	69%

RVATISM

08/27/09

CID-MO "DESIGN"

ULTIMATE PILE CAPACITIES

CALC: GLEN M BELLEW PE

PEER: SCOTT A LOEHR, PE

SCAN to file the CALCS

Peer Review
Documentation

Subject: Peer Review of Central Industrial District – MO, Geotechnical Pile Capacities
Date: August 25, 2009

Responses by Glen M Bellew (GMB), 08/26/09

1. The subject project information provided included as built drawings, soils characterization along the floodwall profile, underseepage calculations, and hand calculations for determining the ultimate capacities of the existing floodwall pile and concrete cutoff wall.

GMB – Noted.

2. The data presented did not provide any boring information. It is assumed that all available data was reviewed including the 2001 boring taken to obtain SPT blow counts for some reaches of the floodwall, at eh pump plants and at the floodwall gaps. The technical documentation should include a discussion of the available data used for the assessment.

GMB – Boring information was obtained from the "as-built" drawings, the 2001 borings, and some additional 2009 borings. This information will be provided and discussed in the technical documentation for the analysis.

3. The profiles provided did not shown the depth to which the piles were founded for the general reaches identified in the analyses. The spread footing versus pile foundation would be helpful for future reviews. Even of the piles are at a constant depth future documentation illustrations should assure that a note or a market is shown on the profiles.

GMB – the profiles were developed for an underseepage analysis and were subsequently used for the pile capacity analysis. The length of each driven pile for the entire CID-MO floodwall was provided on the "as-built" drawings. The elevation of the pile cap was also provided on the "as-built" drawings. From the information provided, the elevations of the pile top and bottom can be obtained. In light of the information available, the pile depths will not be shown on the profile.

4. During review of the calculations provided, the reviewer assumes this package is to support the development of the existing conditions (EC) assessment. The following comments are related to this assumption:

a. For an EC assessment, the soil parameters appear to be on the conservative side of the expected mean values. If using for design use – the parameters appear acceptable. If for an EC condition, the use of a low phi angle yields a very low value for the Nq values used for end bearing. Minor variations in phi will yield considerable increases in the Nq and end bearing resistance capacity. No calculations are shown to consider the variations in the expected soils parameters and resultant variations in the Qult.

GMB – The analysis provided was for a "design" ultimate capacity of the existing condition. These "design" values will be used by ED-DS to calculate a factor of safety for the piles. If any areas have low factors of safety under "design" conditions, a reliability analysis will be performed for those areas. For a reliability analysis of the existing conditions, an "expected" or "mean" ultimate pile capacity will be provided (considering a slightly higher strength as Reviewer stated) in the weak areas, and that ultimate pile capacity will be varied in accordance with the values provided in ETL 1110-2-561.

b. If for an EC assessment, the use of the EM and the limiting critical depth that truncated the effective overburden has been questioned by the District in the past during the development of Qult for Fairfax. I believe the critical depth was implemented in the FHWA design critical by Dr. O'Neil after a directive by the FHWA and the Corps also adopted it for DESIGN purposes. If the EC truly utilizes all available resistance with depth, the total effective overburden pressure should be utilized. The reality of a critical depth has been questioned by Dr. Kulhawy of Cornell, Dr. Duncan of Virginia Tech and other at ER-DC. ITR reviewer may question NWK on the use of the D_c.

GMB – You are correct that the limiting critical depth does not appear to be very highly regarded by most people anymore. The FHWA manual from 1998 actually specifies to use no limiting values of side friction or bearing resistance for effective stress analysis. Other literature specifies to use a limiting value (but not related to only pile diameter), but it only comes into play at depths greater than what we have here. The calculations were revised to include no limits on side friction or bearing resistance for the effective stress analysis. This increased the pile capacities slightly in those reaches where the pile was longer than the previously calculated critical depth.

c. The use of one of 4 sets of underseepage pressures assumptions needs to be documented. If the rationale is conservative for design reasons, that is easy to understand. But using one or the other for EC does not incorporate the variability of the potential changes in the foundations pressures due to the presence of highly variable layering. The assessment should address the selection of assumption 3 for the upper sands and assumption 4 for the lower sands.

GMB – Assumptions 1 and 2 represent an absolute best case and an absolute worst case with respect to underseepage. Assumption 1 is fairly realistic, but is probably overconservative. Assumption 2 is not really feasible, but is just a lower bound solution.. Assumptions 3 and 4 are considered to best represent the underseepage characteristics of the foundation at CID-MO and were therefore used in the pile capacity calculations.

5. The final documentation of the capacities should identify the meaning of the values in terms of a representation of a conservative design value or for use as an expected mean values for EC report. If the intent of this assessment is for providing conservation design values for structural use in assessing the future condition need for the Central Industrial District - MO, the calculations appear to have adequately used the EM guidance requirements to provide a geotechnical recommendation that is reasonable.

GMB – the capacities will be documented as" design ultimate capacities" when they are provided to ED-DS. However, they do not represent "conservative design" values, but simply "design" values. There is always some inherent conservatism in "design" values, and certainly there is some inherent conservatism in the calculated pile capacities. But I do not believe there is evidence of excess conservatism that it is deemed noteworthy to call the capacities "conservative" design values.

6. If you have any question please contact Scott Loehr at 816-389-3601.

Scott A. Loehr

Scott Loehr, P.E.
Geotechnical Engineer

7. Reviewed revision made to hand calculations to represent the expected value soil mechanic parameters. Some math corrections noted and comments provided. Scott Loehr 9/1/2011

Pile Capacity Calculations

Revised.

Drained Round

Undrained N/A

Is a value of 22° representative of an expected value for blanket - could be raised somewhat? it could be a little low but not unreasonable so.

CID-MO Pile FNDN Axial Cap. 08/20/09 BELLEW 1/

EM 1110-2-2906 Design of Pile Foundations, Method.

Revised 08/26/09

Drained Revised 09/01/11

Pile Capacity, $Q_{ult} = Q_s + Q_t$

side friction capacity, $Q_s = f_s A_s$

tip capacity, $Q_t = q A_t$

* EM suggests limiting f_s and q to a critical depth related to pile diameter for effective stress analysis. However, FHWA and others say that the critical depth concept is ill advised. the general consensus is to use a limiting f_s and q based on material type and pile type, but it only comes into play at great depths therefore, no limiting factors will be used here in the Revised Analysis

Undrained Analysis

$$Q_s = \overbrace{\alpha C}^{f_s} A_s$$

$$Q_t = \underbrace{9C}_{q} A_t$$

C = cohesion or undrained shear strength

A_s = Area in contact with soil

α = Adhesion factor = 0.9 from Fig 4-5a

Drained Analysis

$$Q_s = \underbrace{\bar{\sigma}_v K \tan \delta}_{f_s} A_s$$

$\bar{\sigma}_v$ limited to $\bar{\sigma}_{v_{D_c}}$

$$Q_t = \bar{\sigma}_{v_t} N_q A_t$$

$\bar{\sigma}_{v_t}$ limited to $\bar{\sigma}_{v_{D_c}}$

$\bar{\sigma}_v$ = vertical effective stress

K = earth pressure coefficient

$K_{compression} = \cancel{1.0}\ 1.25$ clay

$K_{tension} = 0.7 \rightarrow 2.0$ SAND

table ~~4-4~~ 4-5

$\delta = \cancel{.9\bar{\phi}}\ 1.0\bar{\phi}$

table 4-3

A_s = side Area

For $\bar{\phi} = 20° \rightarrow N_{q_{Blanket}} = 10$

figure 4-4

For $\bar{\phi} = 30° \rightarrow N_{q_{SAND}} = \cancel{25}\ 28$

figure 4-4

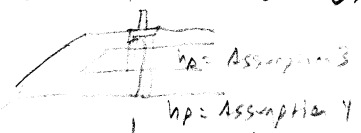
Soil Properties

	c_u	$\bar{c}$	$\bar{\phi}$	γ
Blanket/fill	600psf	0psf	22°	115 pcf
SAND	0psf	0psf	30°	115 pcf

Unit weights assumed same to simplify calcs

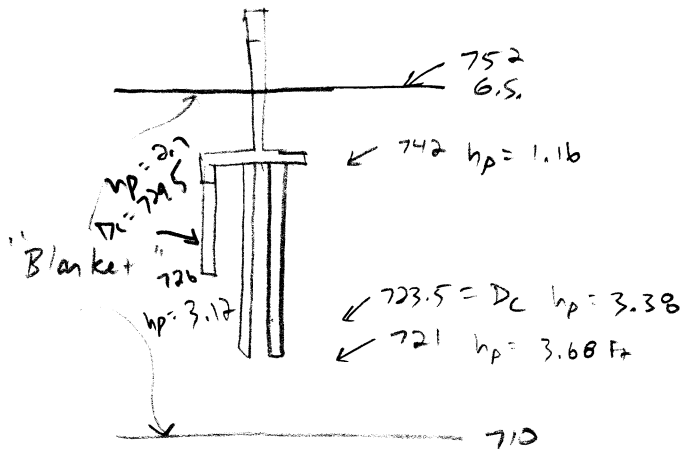
Assumptions:

- 16" × 16" square piles shown on typical sections in RD for type "N", "P" and "Q" walls are ~~not shown on Pile details and are assumed to be tapered to 12" × 12" at their tip~~ NOT TAPERED PER ED-DS DRAWING
- Excess heads are computed in the underseepage analysis



- ALL calculations are for ultimate capacity of a single pile in compression
- Excess head acting at base of blankets are dissipated linearly through the blanket
- Pile and Wall details obtained from O+M Record Drawings
- Tensile capacities = 0.7 * Q_s for all piles.

Station 22+81.46 to 24+54.76



Type "R" Wall
21' Long Piles

□ 18" × 18", tapered to 12" × 12"

AVG = 15" × 15"

6' o.c.

SAND HGL in SAND = 757

Undrained Analysis:

$Q_t = 9CA_t$

$= (9)(600\,psf)(1' \times 1')$

$Q_t = 5400$ lb

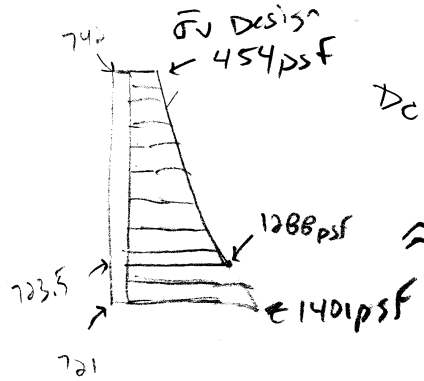
$Q_s = \alpha C A_s$

$= (.9)(600\,psf)(4 \times \frac{15''}{12''} \times 21')$

$Q_s = 56{,}700$ lb

$Q_{ult} = 62{,}100$ lb

Drained Analysis:



$Q_t = \bar{\sigma}_v N_q A_t$

$= (1400\,psf)(10)(1' \times 1')$

$Q_t = 14{,}000$ lb

$D_c = \cancel{15'/1.5 = 15}$

$\cancel{= 18.75\ Ft}$

$\cancel{\approx el\ 723.5}$

GMB

$Q_s = \bar{\sigma}_v K \tan\delta A_s$

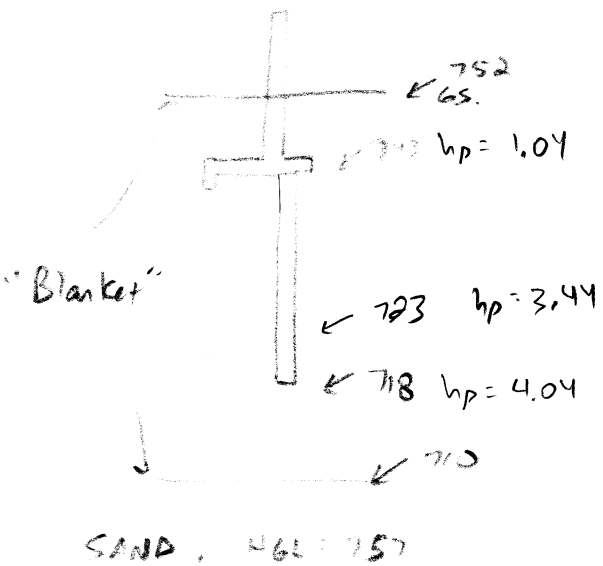
$= (\cancel{1.0}\ 1.25)(\tan \cancel{.9 \times 22°}\ 1.0)\left[\left(\frac{454 + 1401}{2} \times 4 \times \frac{15''}{12''} \times 21'\ Ft\right) \cancel{+ \left(1288 \times 4 \times \frac{15}{12} \times 2.5'\right)}\right]$

$Q_s = \cancel{35{,}062}\ 49{,}183$ lb

$Q_{ult} = \cancel{49{,}062}\ 63{,}184$ lb

DRAINED = .79 UNDRAINED

Station 24+54.76 to 25+38.76



Type "Q" wall, 25' long piles
□ 16" × 16" concrete pile
4' o.c.

Undrained Analysis:

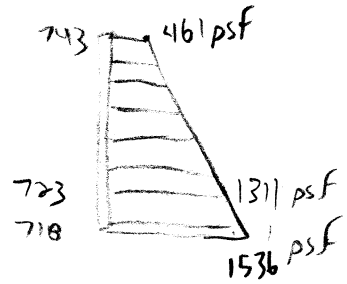
$Q_t = 9 C A_t$
$= (9)(600\ psf)(\frac{16}{12} \times \frac{16}{12})$
$Q_t = 9600\ lb$

$Q_s = \alpha C A_s$
$= (.9)(600\ psf)(4 \times \frac{15}{12} \times 25')$
$Q_s = 67{,}500\ lb$

$\boxed{Q_{ult} = 77{,}100\ lb}$

Drained Analysis:

$\bar{\sigma}_v$ Design



$\cancel{D_c = \frac{16}{12} \times 15}$
$\cancel{= 20'}$
$\cancel{= el\ 723}$

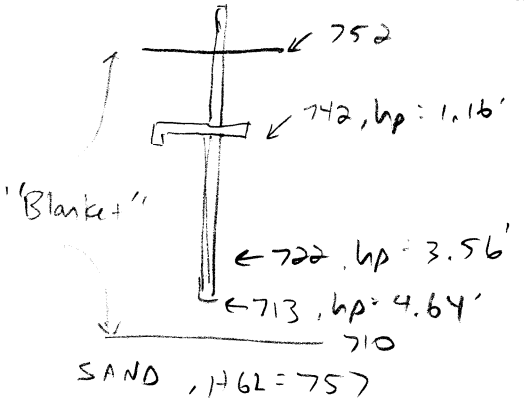
$Q_t = \bar{\sigma}_v N_q A_t$
$= (1536\ psf)(10)(\frac{16}{12} \times \frac{16}{12})$
$Q_t = 27{,}307\ lb$

$Q_s = \bar{\sigma}_v K \tan\delta A_s$
$= (\cancel{1.0}\ 1.25)(\tan \cancel{.94}\ 1.0\ 22)(4)(\frac{16}{12}) * \left[\frac{461 + \cancel{1311}\ 1536}{2} \cdot \cancel{20}\ 25 + \cancel{1311 * 5}\right]$
$Q_s = \cancel{47{,}237}\ \cancel{41{,}431}\ lb$

$\boxed{Q_{ult} = \cancel{75{,}238}\ 94{,}544\ lb}$

DRAINED = .98 UNDRAINED

Station 25+38.76 to 26+22.76



Type "P" Wall, 29' piles
□ 16"×16" concrete piles
5' O.C.

Undrained Analysis:

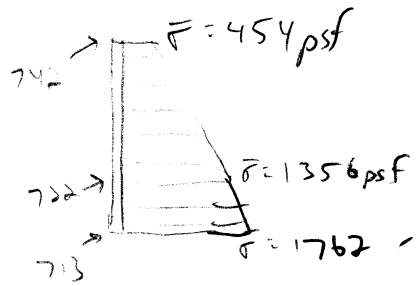
$Q_t = 9CA_t$
$= (9)(600\,psf)(\frac{16}{12} \times \frac{16}{12})$
$Q_t = 9600$ lb

$Q_s = \alpha C A_s$
$= (0.9)(600\,psf)(4)(29)(\frac{16}{12})$
$Q_s = 83{,}520$ lb

$$\boxed{Q_{ult} = 93{,}120 \text{ lb}}$$

Drained Analysis:

$Q_t = \bar{\sigma}_v N_q A_t$
$= (\cancel{1356}\ 1762\,psf)(10)(\frac{16}{12} \times \frac{16}{12})$
$Q_t = 31324$ lb



~~$D_L = \frac{16}{12} \times 15 = 20'$ @ el 722~~

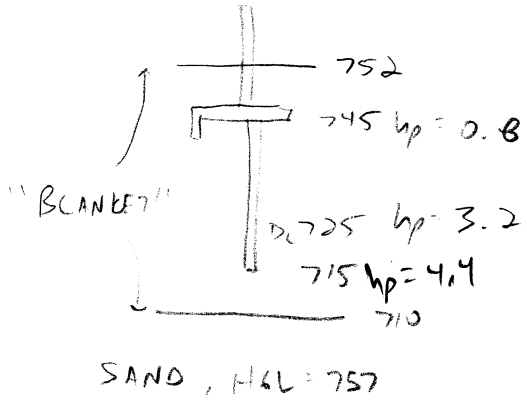
$Q_s = \bar{\sigma}_v K \tan\delta\, A_s$
$= (\frac{1.75}{1.0})(\tan \frac{1.3}{\cancel{0.9}} \times 22°)(4)(\frac{16}{12})\left[\left(\frac{454 + \cancel{1356}\ 1762}{2} \times \cancel{20}\ 29\right) + \cancel{(1356 \times 9)}\right]$

$Q_s = \cancel{61{,}697}\ 86{,}547$ lb

$$\boxed{Q_{ult} = \cancel{93{,}021}\ 117{,}871 \text{ lb}}$$

DRAINED = UNDRAINED

Station 26+22.76 to 27+90.76



Type "N" WALL, 30' piles
□ 16" × 16" piles
6' O.C.

Undrained Analysis:

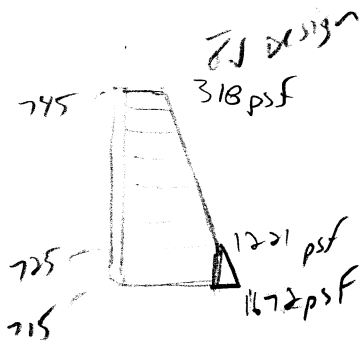
$Q_t = 9 C A_t$
$= (9)(600 psf)(\frac{16}{12} \times \frac{16}{12})$
$Q_t = 9600$ psf

$Q_s = \alpha C A_s$
$= (0.9)(600 psf)(\frac{16}{12})(4)(30)$
$Q_s = 86,400$ lb

$$\boxed{Q_{ult} = 96,000 \text{ lb}}$$

Drained Analysis:

$Q_t = \bar{\sigma}_v N_q A_t$
$= (\cancel{1672}\ 1672 psf)(10)(\frac{16}{12} \times \frac{16}{12})$
$Q_t = \cancel{21,707}\ 29,724$ lb



$\cancel{D_c = \frac{16}{12} \times 15 = 20' = el\ 725}$

$Q_s = \bar{\sigma}_v K \tan\delta A_s$
$= (\cancel{1.0}\ 1.25)(\tan \cancel{29°}\ 1.2 \cdot 22°)(4)(\frac{16}{12})\left[\frac{318 + 1672}{2} \times \cancel{20}\ 30\right]$
$Q_s = \cancel{57,315}\ 80,420$ lb

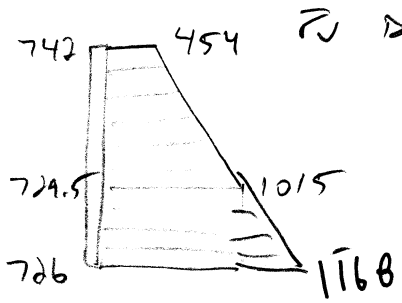
$$\boxed{Q_{ult} = \cancel{137,040}\ \cancel{111,024}\ 110,124 \text{ lb}}$$

DRAINED = .91 UNDRAINED

Cut-off pile Station 22+81.46 to 27+90.76

DRAINED SINCE IT CONTROLS

10" Wide Reinforced Concrete, 16' Long



~~$D_c = \frac{10''}{12} \times 15 = 12.5'$~~

$Q_t/ft = \bar{\sigma}_v N_q A_t$

$= (\cancel{1015}\ 1168)(10)\left(\frac{12}{12}\right)$

$Q_t/ft = \cancel{9458}\ 9733\ lb/ft$

$Q_s/ft = \bar{\sigma}_v K \tan\delta A_s$

$= \left[\left[\left(\frac{454 + \cancel{1015}\ 1168}{2}\right)\left(\frac{\cancel{12.4}}{16}\right)\right] \cancel{+(1015 * 3.5)}\right] *$

$\cancel{1.0}\ 1.25 * 2 * 1\ ft * \tan(\cancel{.9}\ 1.0(22))$

sides

$Q_s/ft = \cancel{9345}\ \cancel{9116}\ lb/ft$

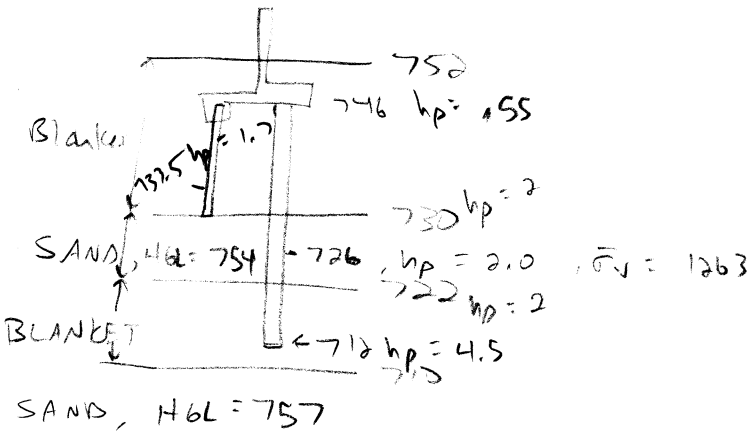
13,106.

$Q_{tot} = \cancel{17,574}\ \cancel{19,076}\ 22,839\ lb/ft$

see page 3 for Drawing

Station 27+90.76 to 30+42.75

Type "N" WALL, 34' piles
□ 16" × 16" piles
6' O.C.



Undrained Analysis:

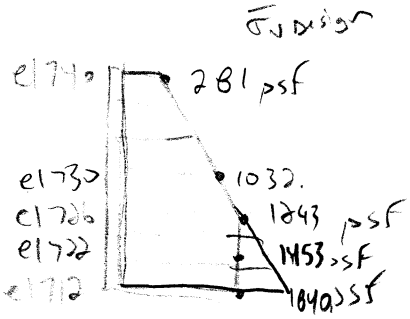
$Q_t = (9)(C)(A_t)$
$= (9)(600\ psf)(\frac{16}{12} \times \frac{16}{12})$
$Q_t = 9600\ lb$

$Q_s = f_s A_s = \Sigma \alpha C A_s + \Sigma \bar{\sigma}_v K \tan\delta A_s$
$= [(0.9)(600\ psf)(16') + (0.9)(600\ psf)(10')$
$+ (1263\ psf)(1.0)(\tan .9 \times 22°)(8')] 4 \times \frac{16}{12}$
$= [8640 + 5400 + 3638] 4 \times \frac{16}{12}$
$Q_s = 94,283\ lb$

$\boxed{Q_{ult} = 103,883\ lb}$

Drained Analysis:

$Q_t = \bar{\sigma}_v N_q A_t$
$= (\cancel{1243}\ 1840\ psf)(10)(\frac{16}{12} \times \frac{16}{12})$
$Q_t = 32,717\ lb$



~~$D_c = \frac{16}{12} \times 15$~~
~~$= 20'$~~
~~$= el\ 726$~~

$Q_s = \Sigma \bar{\sigma}_v K \tan\delta A_s$
$= (1.0)(4)(\frac{16}{12})[(\frac{\cancel{1032}\ 281}{2} \times 16' \times \tan(\cancel{.9} \times 22°))$
$+ (\frac{1840 + 1453}{2} \times 10 \times \tan(\cancel{.9} \times 22))$
$+ (\cancel{1243 \times 10' \times \tan(.9 \times 22°)})]$
$\cancel{= 5.3(3782 + 5064 + 6928)}$
$\cancel{= 5.3(3782 + 5066 + 4173)}$
$Q_s = \cancel{69,234}\ \cancel{78,302}\ lb$ 133,019

$(2.0 \times \frac{1453 + 1032}{2} \times 8 + \tan(\cancel{.9} \times 30))$
$\cancel{+ (1243 \times 8' \times \tan(.9 \times 30°))}$

$5.3(5305 + 11,476 + 8,315)$

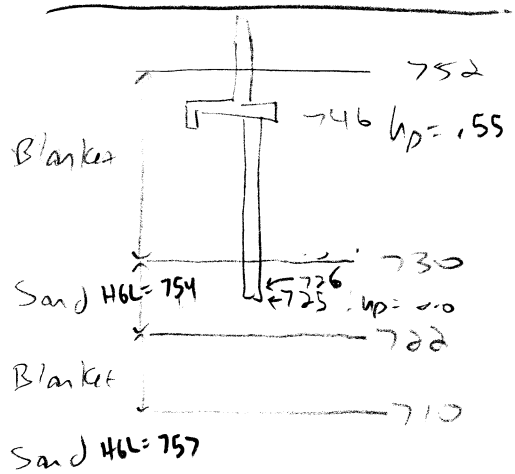
165,730

$\boxed{Q_{ult} = \cancel{111,013}\ \cancel{101,945}\ lb}$

DRAINED > Undrained

Station 30+42.75 to 32+52.76, worst case @ 30+42.75

Type "N" Wall, 21' piles
□ 16"x16"
6' O.C.



Undrained Analysis:

Use Blanket since only separated by 3xB.

$Q_t = (9)(C)(A_t)$
$= (9)(600psf)(\frac{16}{12} \cdot \frac{16}{12})$
$Q_t = 9600$ lb

$Q_s = \alpha C A_s + \bar{\sigma}_v K \tan\delta A_s$
$= (0.9)(600psf)(4)(\frac{16}{12})(16)$
$+ (1.0)(\tan .9 \cdot 22)(4)(\frac{16}{12})\left[\frac{1032+1263}{2} \cdot 4 + 1263 + 1\right.$

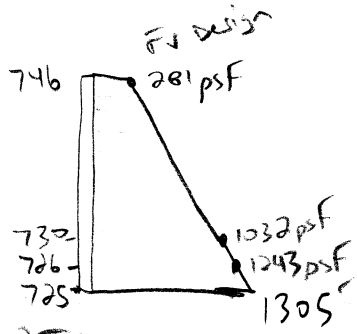
$Q_s = 46080 + 11238$
$Q_s = 57,318$ lb

$$\boxed{Q_{ult} = 66,918 \text{ lb}}$$

Drained Analysis:

Use Blanket since only separated by 3xB

$Q_t = \bar{\sigma}_v N_q A_t$
$= (\cancel{1243}\ 1305 psf)(10)(\frac{16}{12} \cdot \frac{16}{12})$
$Q_t = 23,200$ lb



~~$D_c = \frac{16}{12} + 15$~~
~~$= 20'$~~
~~$= el\ 726$~~

$Q_s = \Sigma \bar{\sigma}_v K \tan\delta A_s$ 1.25x
$= \cancel{(1.0)}(4)(\frac{16}{12})\left[\left(\frac{281+1032}{2} \cdot \tan(\cancel{.9} \cdot 22) + 16\right) + \left(\frac{1305+1032}{2} \cdot \tan(\cancel{.9} \cdot 30) \cancel{+ 44}\right)\right.$ 1.0 2.0x

$\cancel{+ (\ \ \tan(.9 \cdot 30)\ \ )}$

$= (1)(4)(\frac{16}{12})\ \cancel{5182}\ 5305 = \cancel{2301 + 633}\ \cancel{2916}\ 6746$

$Q_s = \cancel{35,861}$ lb $\cancel{36,040}$ lb 64,272

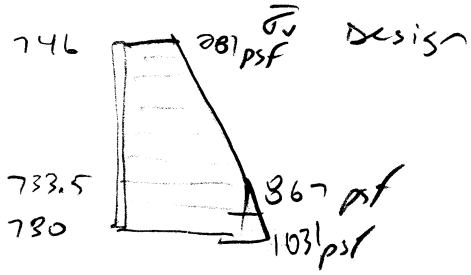
$$\boxed{Q_{ult} = \cancel{59,247}\ 87,472 \text{ lb}}$$

DRAINED = .88 UNDRAINED

Cut-off pile station 27+90.76 to 30+40.75

10" wide Reinforced concrete pile, 16' Long

Drained capacity only.



$D_c = \frac{10}{12} \times 15$
$= 12.5'$
$= el\ 733.5$

$Q_t = \bar{\sigma}_v N_q A_t$ 28

$= (\cancel{867}\ 1031\ psf)(\cancel{26}\ 16)(\frac{10''}{12''})$

Use N_q SAND B/C Tip at sand and Blanket 28B Down

$Q_t/ft = \cancel{18,785}\ \cancel{22338}$ lb/ft

24056

$Q_s = \bar{\sigma}_v K L \tan\delta A_s$

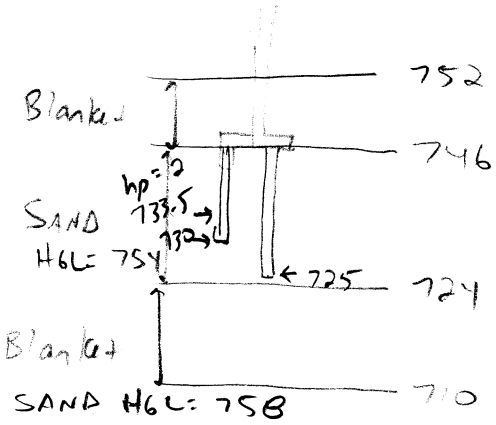
$= \left[\left(\frac{\cancel{867}\ 1031 + 281}{2}\right)\cancel{12.5}\ 16 + (\cancel{867 \times 3.5})\right] \times \cancel{1.0}\ 1.25 \times \tan(\cancel{A}\ 1.0 \times 22) \times 2\ sides \times 1ft$

$Q_s/ft = \cancel{2351}\ \cancel{7558}$ lb/ft 10602

$Q_{tot} = \cancel{26,136}\ \cancel{29,896}\ 34,658$ lb/ft

See page 8 for Drawing

Station 32+52.76 to 48+06.76



Type "N" Wall, 21' piles
□ 16" × 16" 6' O.C
32+52.76 → 42+18.76

Type "P" wall, 21' piles
□ 16" × 16" 5' O.C
42+18.76 → 43+86.76

Type "Q" wall, 21' piles
□ 16" × 16" 4' O.C
43+86.76 → 48+06.76

Undrained Analysis:

Use Blanket
Use 10' separation

$Q_t = 9cA_t$

$= (9)(600\,psf)\left(\frac{16}{12} \times \frac{16}{12}\right)$

$Q_t = 9600\ psf$

$Q_s = \bar{\sigma}_v K \tan\delta A_s$

$= \left(\frac{190.8 + 1243}{2}\right)(20) + (1243 \times) \times 20 \times$

$Q_s = \cancel{12,511}\ 95,954$ $[\tan(\cancel{42}\ 30)] \times 4 \times \frac{16}{12}$

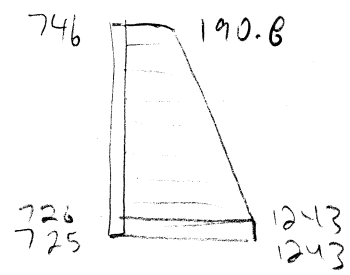
$\bar{\sigma}_v$ design

$D_c = \frac{16}{12} \times 15$

$= 20'$

$= el\ 726$

$Q_{ult} = 5,941\ lb$



DRAINED Analysis:

$Q_t = \bar{\sigma}_v N_q A_t$

$= (1243)(10)\left(\frac{16}{12} \times \frac{16}{12}\right)$

$Q_t = 22097\ lb$

$Q_s = Q_s$ from above

$Q_s = \cancel{12,511}\ 95,954$

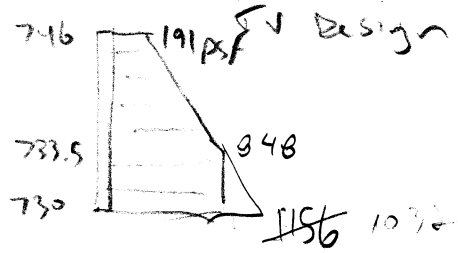
$Q_{ult} = \cancel{64,459}\ 118,051$

$D_c \approx$ end of pile, No Revision

<u>Cut-off pile</u> station 32+52.76 to 48+06.76

10" wide concrete pile 16' Long

IN SAND SO DRAINED = UNDRAINED



USE SAND END BEARING

CAUSE Blanket ≈ 8B AWAY

$Q_t/ft = \bar{\sigma}_v N_q A_t$

$= (\cancel{848}\ 1156\ 1032\ DSF)(\cancel{26}\ 28)(\frac{10''}{12''})$

$Q_t/ft = \cancel{18,373}\ \cancel{25,054}\ \cancel{21,560}\ 24,080\ lb/ft$

$Q_s/ft = \bar{\sigma}_v K \tan\delta A_s$

$= \left[\left(\frac{191 + \cancel{848}\ 1156\ 1032}{2}\right)(\cancel{2.5}\ 16) + \cancel{(848)(3.5)}\right] * \cancel{1.0}\ 2.0 * (\tan \cancel{\phi}\ 30) * 1' \times 2 \text{ sides}$

$Q_s/ft = \cancel{9647}\ \cancel{10981}\ \cancel{2302}\ 22,595\ lb/ft$

46,675

$\cancel{32,322}$

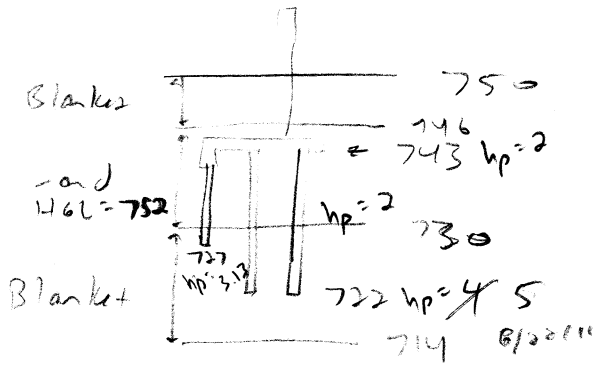
$\cancel{36,035}$

$$\boxed{Q_{total} = \cancel{28,015}\ lb/ft}$$

Station 48+06.76 to 60+24.76

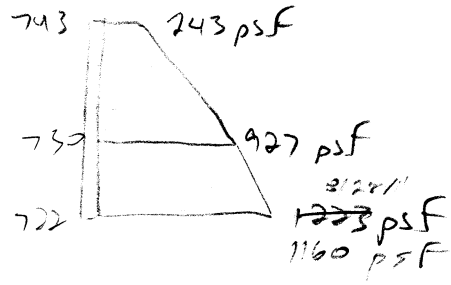
Type "S" wall, 21' piles
□ 18"×18", tapered 4' o.c. 2 Rows

Type "R" wall, 21' piles
□ 18"×18", tapered to 12"×12"
6' O.C., 2 rows Avg = 15"×15"



Sand
HGL= ~~756~~ 758
8/22/11

$\bar{\sigma}_v$ Design



$D_c = \frac{15}{12} \times 15$
$= 19$
$D_c \approx$ Pile length

Undrained Analysis

$Q_t = qCA_t$
$= (9 \cdot 1600\ psf)(\frac{12}{12} \cdot \frac{12}{12})$
$Q_t = 5400\ lb$

$Q_s = \bar{\sigma}_v K \tan\delta A_s$
$= \left[\left(\frac{927+243}{2}\right)(13)\tan(\cancel{\phi}\ 1.0 \times 30°)\right] + \left[\left(\frac{\cancel{1223}\ 1160 + 927}{2}\right)(6)\tan(\cancel{\phi}\ 1.0 \times 22°)\right] \times 1.25$
$+ (\cancel{15}\ 8761 + 4 \times 4216 \times \frac{15}{12})$
$= (\cancel{3875}\ 3875 + \cancel{3096}\ 3225)\ \cancel{5}$

$Q_s = \cancel{34,855}\ lb$
$\cancel{34,100}\ lb$
64,765

$Q_{tot} = \cancel{40,255}\ lb$
46,660

Drained Analysis

$Q_t = \bar{\sigma}_v N_q A_t$
$= (\cancel{1223}\ 1160\ psf)(10)(\frac{12}{12} \cdot \frac{12}{12})$
$Q_t = \cancel{12,230}\ 11,600\ lb$

Q_s = Same as above

76,565

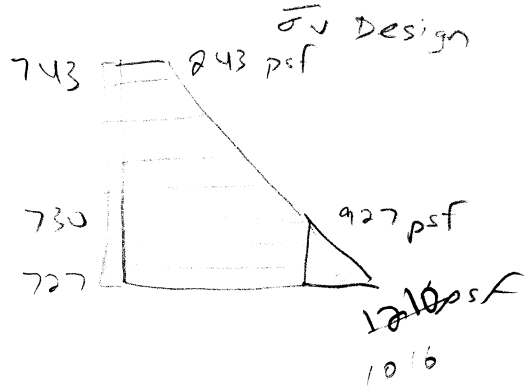
$Q_{tot} = \cancel{47,085}\ lb$
$\cancel{46,000}$

$D_c \approx$ pile length
No Revision.

Cut-off pile 48+06.76 to 60+24.76

10" wide concrete pile, 16' Long

Undrained Analysis



$Q_t/ft = \alpha C A_t$

$= (.9)(600 psf)(.10/12 \, ft)$

$Q_t/ft = 4508 \, lb/ft$

$Q_s = f_s A_s = \alpha C A_s + \bar{\sigma}_v K \tan\delta A_s$ (Clay: $\alpha C A_s$; SAND: $\bar{\sigma}_v K \tan\delta A_s$)

$Q_s/ft = (.9)(600 psf)(2 sides)(3') + \left(\frac{927+243}{2}\right)\left(\frac{2.2}{1.0}\right)(\tan 1.0 \times 30)(2 sides)(13')$

$Q_s/ft = 3240 + \cancel{7750}\ 17{,}563$

$Q_s/ft = 10{,}990 \, lb/ft$

$$\boxed{Q_{tot} = 15{,}498 \, lb/ft}$$

Drained Analysis

$Q_t = \bar{\sigma}_v N_q A_t$

$= (\cancel{927}\ 1210\ 10'6\ psf)(1.0)(10/12)$

$Q_t/ft = \cancel{1{,}125}\ \cancel{10{,}083}\ 8{,}4167 \, lb/ft$

Same as above

$Q_s = \Sigma \bar{\sigma}_v K \tan\delta A_s$ = CLAY DRAINED + SAND DRAINED

$= \left(\frac{1210+927}{2}\right)\left(\frac{1.25}{1.0}\right)(\tan 1.0 \times 22)(3') \times 2 sides + \cancel{7750}\ 17{,}563$

2939

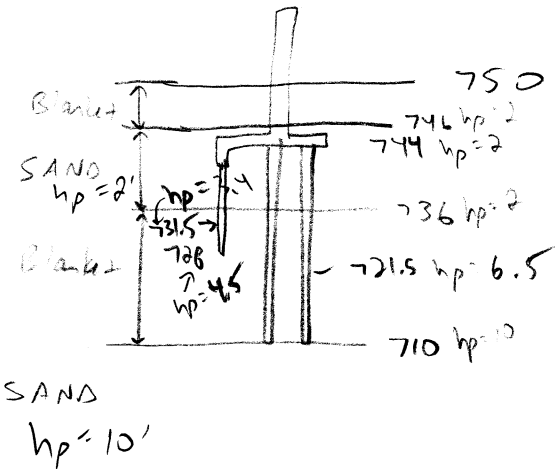
$= \cancel{9308} + \cancel{7750}\ 17{,}563$

$Q_s/ft = \cancel{10058}\ \cancel{20{,}141}\ 20{,}502 \, lb/ft$

$$\boxed{Q_{tot} = \cancel{17{,}477}\ 20141 \, lb/ft}$$

$\cancel{8{,}776}\ 28{,}967$

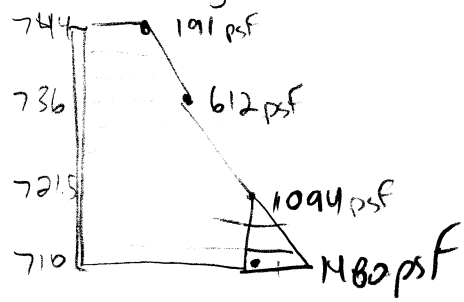
Station 60+24.76 to 73+20.14



Type "R" Wall
Avg Piles = 34'
IJ 18"x18" straight
6' O.C. 2 Rows

$D_c = \frac{18}{12} \times 15$
$= 22.5$
$= 721.5$

$\bar{\sigma}_v$ Design



Undrained Analysis:

Use tip in Blanket B/C clay.

$Q_t = 9CA_t$
$= (9)(600psf)(\frac{18 \times 18}{144})$
$Q_t = 12150$ lb

Clay + SAND

$Q_s = \alpha C A_s + \bar{\sigma}_v K \tan\delta A_s$
$= (.9)(600psf)(4)(\frac{18}{12})(26) +$
$(\frac{612+191}{2})(\cancel{1})(\tan \cancel{.9}\,1.2)(22)(4)(\frac{18}{12})(6)$

$Q_s = 84,240 + \cancel{9820}\ 22,254$
$Q_s = 94060$ lb

$Q_{tot} = 106,210$ lb

Drained Analysis:

$Q_t = \bar{\sigma}_v N_q A_t$
$= (\cancel{1094}\ 1480 psf)(10)(\frac{18 \times 18}{144})$
$Q_t = \cancel{24615\ lb}\ 33,300$ lb

$Q_s = \Sigma \bar{\sigma}_v K \tan\delta A_s$ (split out clay and sand)
sand same as above

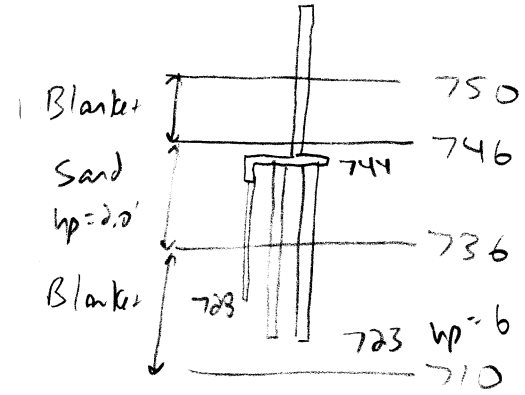
$Q_s = \cancel{9820}\ 22,254$ lb $+ \left[\frac{\cancel{1094}\ 1480 + 612}{2}(\cancel{14.5}\ 26) + (\cancel{1094}\ \cancel{11.5})\right](\cancel{1.0})(\tan \cancel{.9}\,1.2)(22)(4)(\frac{18}{12})$ 1.25

$= \cancel{9820} + \cancel{53994}\ 22254\ \cancel{58247}\ 82409$

$Q_s = \cancel{63,714}$ lb 104,663

$Q_{total} = \cancel{101,867}\ \cancel{88,329}$ lb 137,963

Station 73+20.14 to 78+12.22

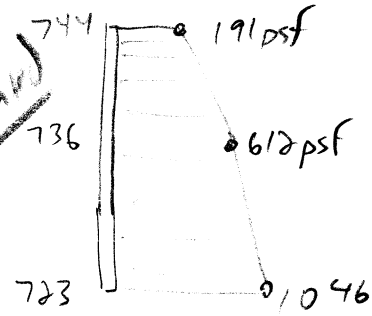


SAND
hp = 10'

Type "R" Wall, 21" Piles
□ 18"×18" TAPERED
6' o.c.

Type "Q" WALL, 21" Piles
□ 16"×16" Square
4' o.c.

$\bar{\sigma}_v$ Design use Type "Q" WALL in CALCS.



$D_L = \frac{16}{12} + 15$
$= 20'$
≈ Pile length

Undrained Analysis

NOT USED

$Q_t = 9cA_t$
$= (9)(600psf)(\frac{16}{12} \times \frac{16}{12})$

$Q_t = 9600\ lb$

$Q_s = \bar{\sigma}_v k \tan\delta A_s + \alpha C A_s$ (SAND, CLAY)
$= (\frac{612+191}{2})(1.0)(\tan 1.0 \times 30)(4)(\frac{16}{12})(8') +$
$(.9)(600psf)(4)(\frac{16}{12})(13')$
$= \cancel{8129\ lb}\ 19,781 + 37440\ lb$

$Q_s = 46169\ lb$

$Q_{tot} = 55,769\ lb$

Drained Analysis

$Q_t = \bar{\sigma}_v N_q A_t$
$= (1046psf)(10)(\frac{16}{12} \times \frac{16}{12})$

$Q_t = 18,596\ lb$

$Q_s = \Sigma \bar{\sigma}_v k \tan\delta A_s$ (split clay/sand, sand as above)
$= \cancel{8129}\ 19,781 + (\frac{612+1046}{2})(1.25)(\tan 1.0 \times 22)(4)(\frac{16}{12})(13')$
$= \cancel{8129}\ 19,781 + \cancel{20,069}\ 28,628$

$Q_s = \cancel{29,422}\ lb$
48,809

$Q_{total} = \cancel{48,018\ lb}$ 67,425

D_L = Pile length, No Revision.

Cut-off wall Station 60+24.76 → 78+12.22

10' wide concrete pile, 16' LONG

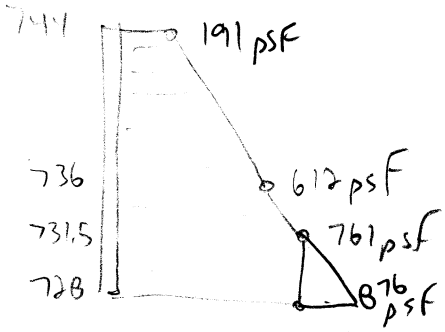
$\bar{\sigma}_v$ Design

$D_c = \frac{10}{12} \times 15$

$= 12.5$

$el = 731.5$

see page 15 for diagram



Drained Analysis since it controls other piles

$Q_t = \bar{\sigma}_v N_q A_t$

$= (\cancel{761}\ 876\ psf)(10)(10'/12) \times 1 ft$

$Q_t/ft = \cancel{6342}\ 7300\ lb/ft$

$Q_s = \Sigma \bar{\sigma}_v K \tan\delta A_s$ $\times 2.0$ $\times 1.25$

$= \left[\left(\frac{191+612}{2}\right)(\tan \cancel{.9}\ 1.0 \times 30)(8) + \left[\left(\frac{612+\cancel{761}\ 876}{2}\right)(\cancel{4.5}\ 8) + \cancel{(761+5.5)}\right] \tan(\cancel{.9}\ 1.0 \times 22)\right] \times 2\ sides$

$= (\cancel{1637}\ 3709 + \cancel{2113}\ 3006) \times 2\ sides$

2103

$Q_s/ft = \cancel{6043}\ \cancel{7560}\ lb/ft$

13,430

$$\boxed{Q_{total}/ft = \cancel{12,385}\ \cancel{14,060}\ lb/ft}$$

20,730

8/26/11 Drawn: G. Brison

CID-MO Pile Capacities For FD-05 Reliability Work:

18

FD-05 needs pile capacities for [illegible] for reliability analysis for the following sections:

Sta 48+06.76 - 60+84.76, 13" tapered pile, 21' long

Sta 48+06.76 - 60+84.76 10" cut off pile, 16' long

Sta 60+84.76 - 73+80.11 16" straight pile, 34' long

Sta 73+80.11 - 78+[illegible] 16" straight pile, [illegible]' long

Sta 60+[illegible] - 78+[illegible] 10" cut off pile, 16' long

Assumptions:

- Parameters and assumptions the same as TOS pile calculations
- Only drained analysis to be performed

$Q_s = \bar{\sigma}_v K L \alpha \delta A_s$, $K = 1.0$ compression, $K = 0.7$ tension, $\delta = 0.75$

$Q_t = \bar{\sigma}_{vo} N_q A_t$ $N_q = 10$ silt, $N_q = 25$ sand

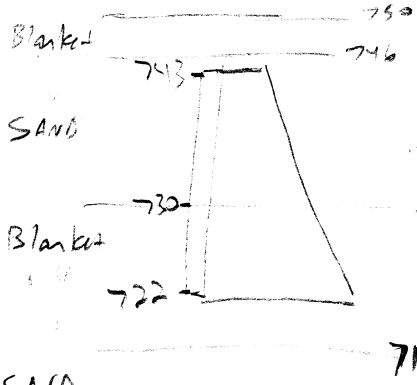
Note: conservation removed in revised calcs. Reliability Not revised b/c not used.

After doing 1st section, there is very little increase in capacity as the water level decreases.

Do Not increase capacities for reliability. Note as best candidate

Station 48+06.76 to 60+24.76 21' long piles

continued from page 38



Water elevation		$h_{p\,743}$	$h_{p\,730}$	$h_{p\,722}$	$\bar{\sigma}_{743}$	$\bar{\sigma}_{730}$	$\bar{\sigma}_{722}$
759.6	TOL	2	2	[illegible]	[illegible]	[illegible]	1160
759.6	TOL-1	2	2	4.7	[illegible]	[illegible]	1180
758.6	TOL-2	2	2	4.3	[illegible]	[illegible]	1204
756.6	TOL-3	2	2	3.8	[illegible]	[illegible]	1236

[illegible] SAND FROM
[illegible] 758
[illegible] 757.3
[illegible] 756.5
[illegible] 755.6

[illegible] middle sand held @ $h_p = 2'$

Tip: $Q_t = \bar{\sigma} N_q A_t$

$= (\bar{\sigma}_{722})(10)(\frac{15}{12})(\frac{15}{12})$

$= \bar{\sigma}_{722} \times 10$

Side: $Q_s = \sum \bar{\sigma}_v K \tan\delta A_s$

$= \left[\frac{\bar{\sigma}_{722} + 927}{2}(2)\pm 2 \times 1.2 \times 30' + \frac{\bar{\sigma}_{722} + 927}{2}(6)\tan(1.7 \times 20')\right]$

$\times 1.0 \times 4.0 \times \frac{15}{12}$

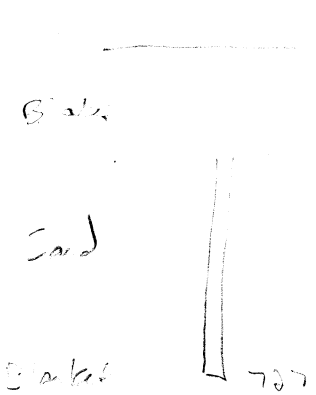
$= 19375 + (\bar{\sigma}_{722} + 927) \times 7.2$

Water	Tip (lb)	Side (lb)	Total Comp (lb)	Tension (lb)
TOL	11,600	34,401	46,001	24081
TOL-1	11,800	34,545	46,345	24182
TOL-2	12,040	34,718	46,758	24,303
TOL-3	12,360	34,949	47,309	24,464

Station [illegible] to [illegible]

10" concrete cut off pile

Continued from page [illegible]



Water	$h_{p\,743}$	$h_{p\,732}$	$h_{p\,727}$	$\bar{\sigma}_{743}$	$\bar{\sigma}_{732}$	$\bar{\sigma}_{727}$
TOL	2	2	3.1	743	997	1016
TOL-1	2	2	3.0	↓	↓	1023
TOL-2	2	2	2.8			1035
TOL-3	2	2	2.7			1041

Tip: $Q_t = \bar{\sigma} N_q A_t$

$= (\bar{\sigma}_{727})(10)(\frac{10}{12})$

$= \bar{\sigma}_{727} \times 8.\bar{3}$ lb/ft

Side: $Q_s = \Sigma \bar{\sigma}_i K \tan\delta A_s$

$= \left(\frac{\bar{\sigma}_{727} + \bar{\sigma}_{743}}{2}\right)(1)(\tan 19.4°)(3)(2\pi b) + \left(\frac{\bar{\sigma}_{727} + \bar{\sigma}_{732}}{2}\right)(1)(\tan 19.4°)(10 \times 12)(13')$

$= \bar{\sigma}_{727} \times 1.08 + 7750$

Water	Tip lb/ft	Side lb/ft	Handicap lb/ft	Tasio lb/ft
TOL	8467	9849	18,316	6874
TOL-1	8525	9856	18,381	6899
TOL-2	8625	9869	18,494	6908
TOL-3	8667	9875	18,542	6913

Underseepage Calculations

for h_p.

Assumption 3 is h_p for

"upper" SAND

Assumption 4 is h_p for "lower" sand

Underseepage Calculations

for hp.

Assumption 3 is hp for

"upper" SAND

Assumption 4 is hp for "lower" sand

CID-MO Levee Kansas City Phase 2 Feasibility
Saturday, August 08, 2009 Revised:
Levee Foundation Information - EXISTING CONDITIONS, Water to Top of Levee

DRAFT

Blanket Unit Weight = 115.0 pcf (saturated)
Rubble Fill Unit Weight = 115.0 pcf (saturated)

Station	Top of Levee Elevation (msl)	River Side Ground Elevation (msl)	Land Side Ground Elevation (msl)	River Blanket Bottom Elevation (msl)	Land Blanket Bottom Elevation	Top of Blanket Elevation (msl)	Top of Bedrock Elevation (msl)	Driving Head (ft) H	Permeability Ratio River Side k_f/k_{br}	Permeability Ratio Land Side k_f/k_{bl}	Impervious Blanket Thickness (ft) River Side z_{br}	Impervious Blanket Thickness (ft) Levee z_{bo}	Impervious Blanket Thickness (ft) Land Side z_{bl}	Pervious Blanket Thickness (ft) d	Seepage Length (ft) River Side L_1	Seepage Length (ft) Levee L_2	Seepage Length (ft) Land Side L_3	Factor c_r	Factor c_i	Effective Seepage Length (ft) River Side x_1	Effective Seepage Length (ft) Land Side x_3	Head at Toe (ft) h_o	Computed Hydraulic Gradient i_o	Critical Hydraulic Gradient i_c	Factor of Safety for Piping (i_c/i_o)	Remarks
0+00 to 10+00	758.0	750	752	711	725	749	710	6.0	300	300	39	31.5	24	15	100	15	1000	0.002387	0.003043	98	329	4.46	0.19	0.84	4.53	
10+00 to 22+50	758.5	750	750	715	floodwall sitting on bedrock	750	735	8.5	300	300	35	#VALUE!	#VALUE!	#VALUE!	100	15	1000	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	0.84	#VALUE!	floodwall is bearing directly on bedrock and there is a toe drain at the landward edge of the floodwall. A line of creep analysis, or similar, will have to be performed if the uplift along the floodwall is needed.
22+50 to 27+50	759.0	750	752	716	710	742	700	7.0	300	300	34	33	32	10	100	15	1000	0.003131	0.003227	97	310	5.14	0.16	0.84	5.24	
27+50 to 32+50 - Assumption 1	759.3	750	752	716	710	735	690	7.3	300	300	34	29.5	25	20	100	15	1000	0.002214	0.002582	98	387	5.61	0.22	0.84	3.76	Lower and upper blanket thickness added together to compute Zbl and FSi. This assumes that the riverside has an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This is the LEAST conservative approach
27+50 to 32+50 - Assumption 2	759.3	750	752	716	740	748	690	7.3	300	300	5	6.5	8	50	50	15	1000	0.003651	0.002887	49	346	6.11	0.76	0.84	1.10	Only the upper blanket thickness was used to compute Zbl and FSi. This assumes that the riverside does not have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall does not provide a cut off between the river and the middle sand. This is the MOST conservative approach
27+50 to 32+50 - Assumption 3	759.3	750	752	716	740	748	690	5.4	300	300	5	6.5	8	14	50	15	1000	0.006901	0.005455	437	183	1.57	0.20	0.84	4.30	Only the upper blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand that is used to calculate x1. the concrete sheetpile cutoff wall reduces the head by 25% in the upper sand. This calculation checks the gradient through the upper blanket.
27+50 to 32+50 - Assumption 4	759.3	750	752	716	710	722	690	7.3	300	300	34	23	12	20	100	15	1000	0.002214	0.003727	98	268	5.10	0.42	0.84	1.98	Only the lower blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This calculation checks the gradient through the lower blanket. Assumes hydrostatic conditions in the upper sand.
32+50 to 37+50 - Assumption 1	759.4	750	752	720	710	730	665	7.4	300	300	30	25	20	45	100	15	1000	0.001571	0.001925	99	520	6.07	0.30	0.84	2.78	Lower and upper blanket thickness added together to compute Zbl and FSi. This assumes that the riverside has an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This is the LEAST conservative approach
32+50 to 37+50 - Assumption 2	759.4	750	752	720	745	752	665	7.4	300	300	30	18.5	7	80	50	15	1000	0.001179	0.002440	50	410	6.39	0.91	0.84	0.92	Only the upper blanket thickness was used to compute Zbl and FSi. This assumes that the riverside does not have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall does not provide a cut off between the river and the middle sand. This is the MOST conservative approach
32+50 to 37+50 - Assumption 3	759.4	750	752	720	745	752	665	5.5	300	300	5	6	7	22	50	15	1000	0.005505	0.004652	677	215	1.32	0.19	0.84	4.48	Only the upper blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand that is used to calculate x1. the concrete sheetpile cutoff wall reduces the head by 25% in the upper sand. This calculation checks the gradient through the upper blanket.
32+50 to 37+50 - Assumption 4	759.4	750	752	720	710	724	665	7.4	300	300	30	22	14	45	100	15	1000	0.001571	0.002300	99	435	5.86	0.42	0.84	2.01	Only the lower blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This calculation checks the gradient through the lower blanket. Assumes hydrostatic conditions in the upper sand.
37+50 to 41+00 - Assumption 1	759.4	750	752	721	709	733	665	7.4	300	300	29	26.5	24	44	100	15	1000	0.001616	0.001777	99	563	6.19	0.26	0.84	3.27	Lower and upper blanket thickness added together to compute Zbl and FSi. This assumes that the riverside has an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This is the LEAST conservative approach
37+50 to 41+00 - Assumption 2	759.4	750	752	721	746	752	665	7.4	300	300	29	17.5	6	81	50	15	1000	0.001191	0.002619	50	382	6.36	1.06	0.84	0.80	Only the upper blanket thickness was used to compute Zbl and FSi. This assumes that the riverside does not have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall does not provide a cut off between the river and the middle sand. This is the MOST conservative approach
37+50 to 41+00 - Assumption 3	759.4	750	752	721	746	752	665	5.6	300	300	3	4.5	6	20	50	15	1000	0.007454	0.005270	377	190	1.82	0.30	0.84	2.78	Only the upper blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand that is used to calculate x1. the concrete sheetpile cutoff wall reduces the head by 25% in the upper sand. This calculation checks the gradient through the upper blanket.
37+50 to 41+00 - Assumption 4	759.4	750	752	721	709	727	665	7.4	300	300	29	23.5	18	44	100	15	1000	0.001616	0.002052	99	487	6.03	0.33	0.84	2.52	Only the lower blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This calculation checks the gradient through the lower blanket. Assumes hydrostatic conditions in the upper sand.
41+00 to 46+00 - Assumption 1	759.5	750	752	722	712	734	665	7.5	300	300	28	25	22	47	100	15	1000	0.001592	0.001795	99	557	6.22	0.28	0.84	2.98	Lower and upper blanket thickness added together to compute Zbl and FSi. This assumes that the riverside has an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This is the LEAST conservative approach

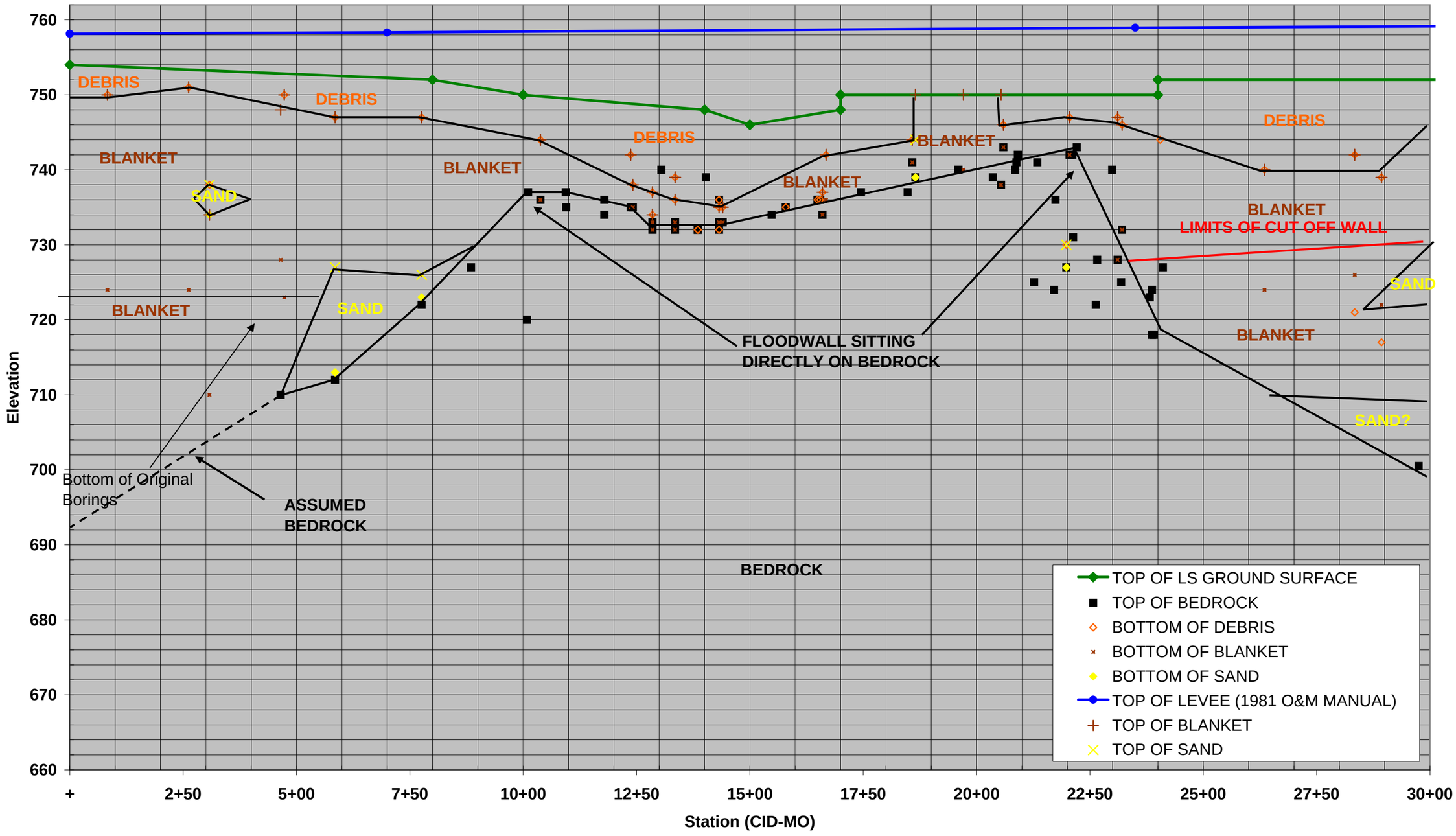
41+00 to 46+00 - Assumption 2	759.5	750	752	722	746	752	665	7.5	300	300	28	17	6	81	50	15	1000	0.001212	0.002619	50	382	6.41	1.07	0.84	0.79	Only the upper blanket thickness was used to compute Zbl and FSi. This assumes that the riverside does not have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall does not provide a cut off between the river and the middle sand. This is the MOST conservative approach
41+00 to 46+00 - Assumption 3	759.5	750	752	722	746	752	665	5.6	300	300	5	5.5	6	16	50	15	1000	0.006455	0.005893	497	170	1.40	0.23	0.84	3.61	Only the upper blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand that is used to calculate x1. the concrete sheetpile cutoff wall reduces the head by 25% in the upper sand. This calculation checks the gradient through the upper blanket.
41+00 to 46+00 - Assumption 4	759.5	750	752	722	709	725	665	7.5	300	300	28	22	16	44	100	15	1000	0.001645	0.002176	99	460	6.01	0.38	0.84	2.24	Only the lower blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This calculation checks the gradient through the lower blanket. Assumes hydrostatic conditions in the upper sand.
46+00 to 50+00 - Assumption 1	759.6	750	752	718	713	733	665	7.6	300	300	32	26	20	48	100	15	1000	0.001473	0.001863	99	537	6.27	0.31	0.84	2.69	Lower and upper blanket thickness added together to compute Zbl and FSi. This assumes that the riverside has an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This is the LEAST conservative approach
46+00 to 50+00 - Assumption 2	759.6	750	752	718	746	752	665	7.6	300	300	32	19	6	81	50	15	1000	0.001134	0.002619	50	382	6.50	1.08	0.84	0.78	Only the upper blanket thickness was used to compute Zbl and FSi. This assumes that the riverside does not have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall does not provide a cut off between the river and the middle sand. This is the MOST conservative approach
46+00 to 50+00 - Assumption 3	759.6	750	752	718	746	752	665	5.7	300	300	5	5.5	6	18	50	15	1000	0.006086	0.005556	557	180	1.37	0.23	0.84	3.70	Only the upper blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand that is used to calculate x1. the concrete sheetpile cutoff wall reduces the head by 25% in the upper sand. This calculation checks the gradient through the upper blanket.
46+00 to 50+00 - Assumption 4	759.6	750	752	718	713	729	665	7.6	300	300	32	24	16	48	100	15	1000	0.001473	0.002083	99	480	6.14	0.38	0.84	2.20	Only the lower blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This calculation checks the gradient through the lower blanket. Assumes hydrostatic conditions in the upper sand.
50+00 to 52+50 - Assumption 1	759.7	750	750	715	712	736	665	9.6	300	300	35	29.5	24	47	100	15	1000	0.001423	0.001719	99	582	8.06	0.34	0.84	2.51	Lower and upper blanket thickness added together to compute Zbl and FSi. This assumes that the riverside has an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This is the LEAST conservative approach
50+00 to 52+50 - Assumption 2	759.7	750	750	715	745	750	665	9.6	300	300	35	20	5	80	50	15	1000	0.001091	0.002887	50	346	8.13	1.63	0.84	0.52	Only the upper blanket thickness was used to compute Zbl and FSi. This assumes that the riverside does not have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall does not provide a cut off between the river and the middle sand. This is the MOST conservative approach
50+00 to 52+50 - Assumption 3	759.7	750	750	715	745	750	665	4.8	300	300	5	5	5	14	50	15	1000	0.006901	0.006901	437	145	1.17	0.23	0.84	3.60	Only the upper blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand that is used to calculate x1. the concrete sheetpile cutoff wall reduces the head by 50% in the upper sand since it is a full cut off. This calculation checks the gradient through the upper blanket.
50+00 to 52+50 - Assumption 4	759.7	750	750	715	712	731	665	9.6	300	300	35	27	19	47	100	15	1000	0.001423	0.001932	99	518	7.90	0.42	0.84	2.03	Only the lower blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This calculation checks the gradient through the lower blanket. Assumes hydrostatic conditions in the upper sand.
52+50 to 55+00 - Assumption 1	759.7	750	750	715	711.5	738.5	665	9.7	300	300	35	31	27	46.5	100	15	1000	0.001431	0.001629	99	614	8.18	0.30	0.84	2.78	Lower and upper blanket thickness added together to compute Zbl and FSi. This assumes that the riverside has an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This is the LEAST conservative approach
52+50 to 55+00 - Assumption 2	759.7	750	750	715	744	750	665	9.7	300	300	35	20.5	6	79	50	15	1000	0.001098	0.002652	50	377	8.27	1.38	0.84	0.61	Only the upper blanket thickness was used to compute Zbl and FSi. This assumes that the riverside does not have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall does not provide a cut off between the river and the middle sand. This is the MOST conservative approach
52+50 to 55+00 - Assumption 3	759.7	750	750	715	744	750	665	4.9	300	300	5	5.5	6	10	50	15	1000	0.008165	0.007454	316	134	1.40	0.23	0.84	3.62	Only the upper blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand that is used to calculate x1. the concrete sheetpile cutoff wall reduces the head by 50% in the upper sand since it is a full cut off. This calculation checks the gradient through the upper blanket.
52+50 to 55+00 - Assumption 4	759.7	750	750	715	711.5	732.5	665	9.7	300	300	35	28	21	46.5	100	15	1000	0.001431	0.001848	99	541	8.01	0.38	0.84	2.21	Only the lower blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This calculation checks the gradient through the lower blanket. Assumes hydrostatic conditions in the upper sand.
55+00 to 57+50 - Assumption 1	759.8	750	750	714.5	711	737.5	665	9.8	300	300	35.5	31	26.5	46	100	15	1000	0.001429	0.001654	99	605	8.24	0.31	0.84	2.71	Lower and upper blanket thickness added together to compute Zbl and FSi. This assumes that the riverside has an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This is the LEAST conservative approach

55+00 to 57+50 - Assumption 2	759.8	750	750	714.5	745	750	665	9.8	300	300	35.5	20.25	5	80	50	15	1000	0.001083	0.002887	50	346	8.25	1.65	0.84	0.51	Only the upper blanket thickness was used to compute Zbl and FSi. This assumes that the riverside does not have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall does not provide a cut off between the river and the middle sand. This is the MOST conservative approach
55+00 to 57+50 - Assumption 3	759.8	750	750	714.5	745	750	665	4.9	300	300	5	5	5	12	50	15	1000	0.007454	0.007454	377	134	1.25	0.25	0.84	3.37	Only the upper blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand that is used to calculate x1. the concrete sheetpile cutoff wall reduces the head by 50% in the upper sand since it is a full cut off. This calculation checks the gradient through the upper blanket.
55+00 to 57+50 - Assumption 4	759.8	750	750	714.5	711	732.5	665	9.8	300	300	35.5	28.5	21.5	46	100	15	1000	0.001429	0.001836	99	545	8.10	0.38	0.84	2.24	Only the lower blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This calculation checks the gradient through the lower blanket. Assumes hydrostatic conditions in the upper sand.
57+50 to 62+50 - Assumption 1	760.0	750	748	715	714	736	665	12.0	300	300	35	28.5	22	49	100	15	1000	0.001394	0.001758	99	569	9.99	0.45	0.84	1.86	Lower and upper blanket thickness added together to compute Zbl and FSi. This assumes that the riverside has an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This is the LEAST conservative approach
57+50 to 62+50 - Assumption 2	760.0	750	748	715	745	748	665	12.0	300	300	35	19	3	80	50	15	1000	0.001091	0.003727	50	268	9.66	3.22	0.84	0.26	Only the upper blanket thickness was used to compute Zbl and FSi. This assumes that the riverside does not have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall does not provide a cut off between the river and the middle sand. This is the MOST conservative approach
57+50 to 62+50 - Assumption 3	760.0	750	748	715	745	748	665	6.0	300	300	5	4	3	12	50	15	1000	0.007454	0.009623	377	104	1.26	0.42	0.84	2.01	Only the upper blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand that is used to calculate x1. the concrete sheetpile cutoff wall reduces the head by 50% in the upper sand since it is a full cut off. This calculation checks the gradient through the upper blanket.
57+50 to 62+50 - Assumption 4	760.0	750	748	715	714	733	665	12.0	300	300	35	27	19	49	100	15	1000	0.001394	0.001892	99	528	9.87	0.52	0.84	1.62	Only the lower blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This calculation checks the gradient through the lower blanket. Assumes hydrostatic conditions in the upper sand.
62+50 to 65+00 - Assumption 1	760.0	750	748	717	712	738	665	12.0	300	300	33	29.5	26	47	100	15	1000	0.001466	0.001652	99	605	10.09	0.39	0.84	2.17	Lower and upper blanket thickness added together to compute Zbl and FSi. This assumes that the riverside has an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This is the LEAST conservative approach
62+50 to 65+00 - Assumption 2	760.0	750	748	717	744	748	665	12.0	300	300	33	18.5	4	79	50	15	1000	0.001131	0.003248	50	308	9.91	2.48	0.84	0.34	Only the upper blanket thickness was used to compute Zbl and FSi. This assumes that the riverside does not have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall does not provide a cut off between the river and the middle sand. This is the MOST conservative approach
62+50 to 65+00 - Assumption 3	760.0	750	748	717	744	748	665	6.0	300	300	5	4.5	4	8	50	15	1000	0.009129	0.010206	256	98	1.59	0.40	0.84	2.12	Only the upper blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand that is used to calculate x1. the concrete sheetpile cutoff wall reduces the head by 50% in the upper sand since it is a full cut off. This calculation checks the gradient through the upper blanket.
62+50 to 65+00 - Assumption 4	760.0	750	748	717	712	734	665	12.0	300	300	33	27.5	22	47	100	15	1000	0.001466	0.001795	99	557	9.96	0.45	0.84	1.86	Only the lower blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This calculation checks the gradient through the lower blanket. Assumes hydrostatic conditions in the upper sand.
65+00 to 67+50 - Assumption 1	760.0	750	750	715	709	742	665	10.0	300	300	35	34	33	44	140	15	1000	0.001471	0.001515	138	660	8.12	0.25	0.84	3.43	Lower and upper blanket thickness added together to compute Zbl and FSi. This assumes that the riverside has an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This is the LEAST conservative approach
65+00 to 67+50 - Assumption 2	760.0	750	750	715	744	750	665	10.0	300	300	35	20.5	6	79	100	15	1000	0.001098	0.002652	100	377	7.67	1.28	0.84	0.66	Only the upper blanket thickness was used to compute Zbl and FSi. This assumes that the riverside does not have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall does not provide a cut off between the river and the middle sand. This is the MOST conservative approach
65+00 to 67+50 - Assumption 3	760.0	750	750	715	744	750	665	5.0	300	300	5	5.5	6	7	100	15	1000	0.009759	0.008909	136	112	2.13	0.35	0.84	2.38	Only the upper blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand that is used to calculate x1. the concrete sheetpile cutoff wall reduces the head by 50% in the upper sand since it is a full cut off. This calculation checks the gradient through the upper blanket.
65+00 to 67+50 - Assumption 4	760.0	750	750	715	709	736	665	10.0	300	300	35	31	27	44	140	15	1000	0.001471	0.001675	138	597	7.96	0.29	0.84	2.86	Only the lower blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This calculation checks the gradient through the lower blanket. Assumes hydrostatic conditions in the upper sand.
67+50 to 71+00 - Assumption 1	760.0	750	750	719	706	743	665	10.0	300	300	31	34	37	41	140	15	1000	0.001619	0.001482	138	675	8.15	0.22	0.84	3.82	Lower and upper blanket thickness added together to compute Zbl and FSi. This assumes that the riverside has an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This is the LEAST conservative approach

67+50 to 71+00 - Assumption 2	760.0	750	750	719	744	750	665	10.0	300	300	31	18.5	6	79	100	15	1000	0.001167	0.002652	100	377	7.67	1.28	0.84	0.66	Only the upper blanket thickness was used to compute Zbl and FSi. This assumes that the riverside does not have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall does not provide a cut off between the river and the middle sand. This is the MOST conservative approach
67+50 to 71+00 - Assumption 3	760.0	750	750	719	744	750	665	5.0	300	300	5	5.5	6	10	100	15	1000	0.008165	0.007454	182	134	2.03	0.34	0.84	2.50	Only the upper blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand that is used to calculate x1. the concrete sheetpile cutoff wall reduces the head by 50% in the upper sand since it is a full cut off. This calculation checks the gradient through the upper blanket.
67+50 to 71+00 - Assumption 4	760.0	750	750	719	706	737	665	10.0	300	300	31	31	31	41	140	15	1000	0.001619	0.001619	138	617	8.02	0.26	0.84	3.26	Only the lower blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This calculation checks the gradient through the lower blanket. Assumes hydrostatic conditions in the upper sand.
71+00 to 75+00 - Assumption 1	760.0	750	750	738	704	729	665	10.0	300	300	12	18.5	25	39	140	15	1000	0.002669	0.001849	134	541	7.84	0.31	0.84	2.69	Lower and upper blanket thickness added together to compute Zbl and FSi. This assumes that the riverside has an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This is the LEAST conservative approach
71+00 to 75+00 - Assumption 2	760.0	750	750	738	740	750	665	10.0	300	300	12	11	10	75	100	15	1000	0.001925	0.002108	99	474	8.07	0.81	0.84	1.05	Only the upper blanket thickness was used to compute Zbl and FSi. This assumes that the riverside does not have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall does not provide a cut off between the river and the middle sand. This is the MOST conservative approach
71+00 to 75+00 - Assumption 3	760.0	750	750	738	740	750	665	7.5	300	300	5	7.5	10	20	100	15	1000	0.005774	0.004082	333	245	3.10	0.31	0.84	2.72	Only the upper blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand that is used to calculate x1. the concrete sheetpile cutoff wall reduces the head by 50% in the upper sand since it is a full cut off. This calculation checks the gradient through the upper blanket.
71+00 to 75+00 - Assumption 4	760.0	750	750	719	704	718	665	10.0	300	300	31	22.5	14	39	140	15	1000	0.001660	0.002471	138	405	7.26	0.52	0.84	1.62	Only the lower blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand. This calculation checks the gradient through the lower blanket. Assumes hydrostatic conditions in the upper sand.
75+00 to 78+00 - Assumption 5	760.0	750	750	749	704	720	665	10.0	300	300	1	8.5	16	39	0	75	1000	0.009245	0.002311	0	433	8.52	0.53	0.84	1.58	Only the lower blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does have an impervious layer over the middle sand and/or the concrete sheetpile cutoff wall provides a satisfactory cut off between the river and the middle sand to make pressures in the upper sand hydrostatic. This calculation checks the gradient through the lower blanket. Assumes hydrostatic conditions in the upper sand.
78+00 to 80+00 - Assumption 5	760.0	750	750	749	701	726	665	10.0	300	300	1	13	25	36	0	75	1000	0.009623	0.001925	0	520	8.74	0.35	0.84	2.41	Only the lower blanket thickness was used to compute Zbl and FSi. A large impervious section cuts off the middle sand. Also, the buried collector system maintains the pressure in the sand landward at hydrostatic. This is the likely scenario for this section.
80+00 to 82+50 - Assumption 5	760.0	750	750	749	703	726	665	10.0	300	300	1	12	23	38	0	75	1000	0.009366	0.001953	0	512	8.72	0.38	0.84	2.22	Only the lower blanket thickness was used to compute Zbl and FSi. A large impervious section cuts off the middle sand. Also, the buried collector system maintains the pressure in the sand landward at hydrostatic. This is the likely scenario for this section.
82+50 to 85+00 - Assumption 5	761.0	750	750	749	711	728	665	11.0	300	300	1	9	17	46	0	75	1000	0.008513	0.002065	0	484	9.53	0.56	0.84	1.50	Only the lower blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does not have an impervious layer over the middle sand but the buried collector system maintains the pressure in the sand landward at hydrostatic. This is the likely scenario for this section.
85+00 to 87+50 - Assumption 5	761.0	750	753	749	717	730	665	8.0	300	300	1	7	13	52	0	75	1000	0.008006	0.002221	0	450	6.86	0.53	0.84	1.60	Only the lower blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does not have an impervious layer over the middle sand but the buried collector system maintains the pressure in the sand landward at hydrostatic. This is the likely scenario for this section.
87+50 to 89+00 - Assumption 5	761.0	750	754	749	725	733	665	7.0	300	300	1	4.5	8	60	0	75	1000	0.007454	0.002635	0	379	5.84	0.73	0.84	1.15	Only the lower blanket thickness was used to compute Zbl and FSi. It was assumed that the riverside does not have an impervious layer over the middle sand but the buried collector system maintains the pressure in the sand landward at hydrostatic. This is the likely scenario for this section.

CID-MO Subsurface

Profiles along ℄.


760
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Elevation
+
2+50
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17+50
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Station (CID-MO)
DEBRIS
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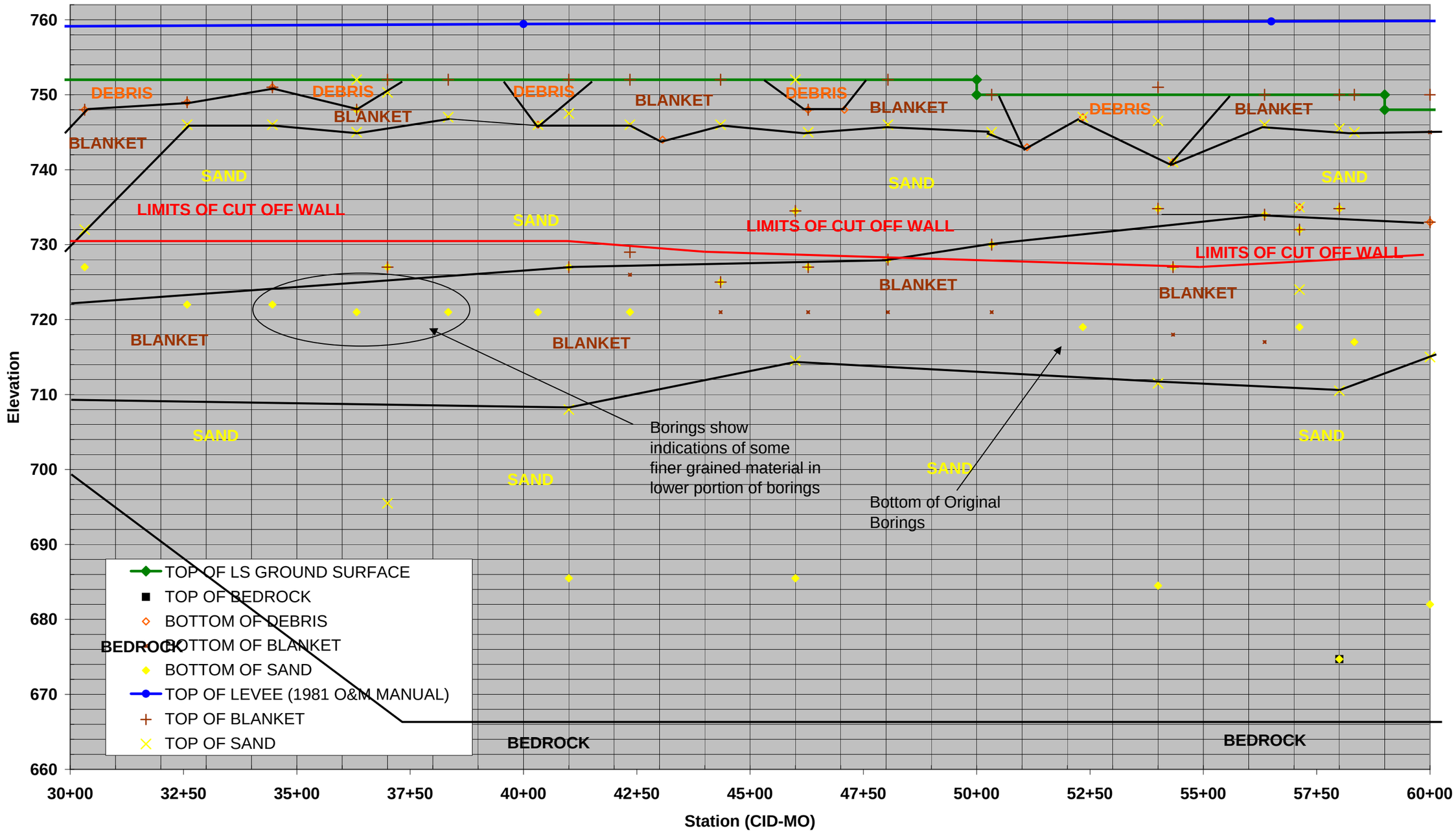
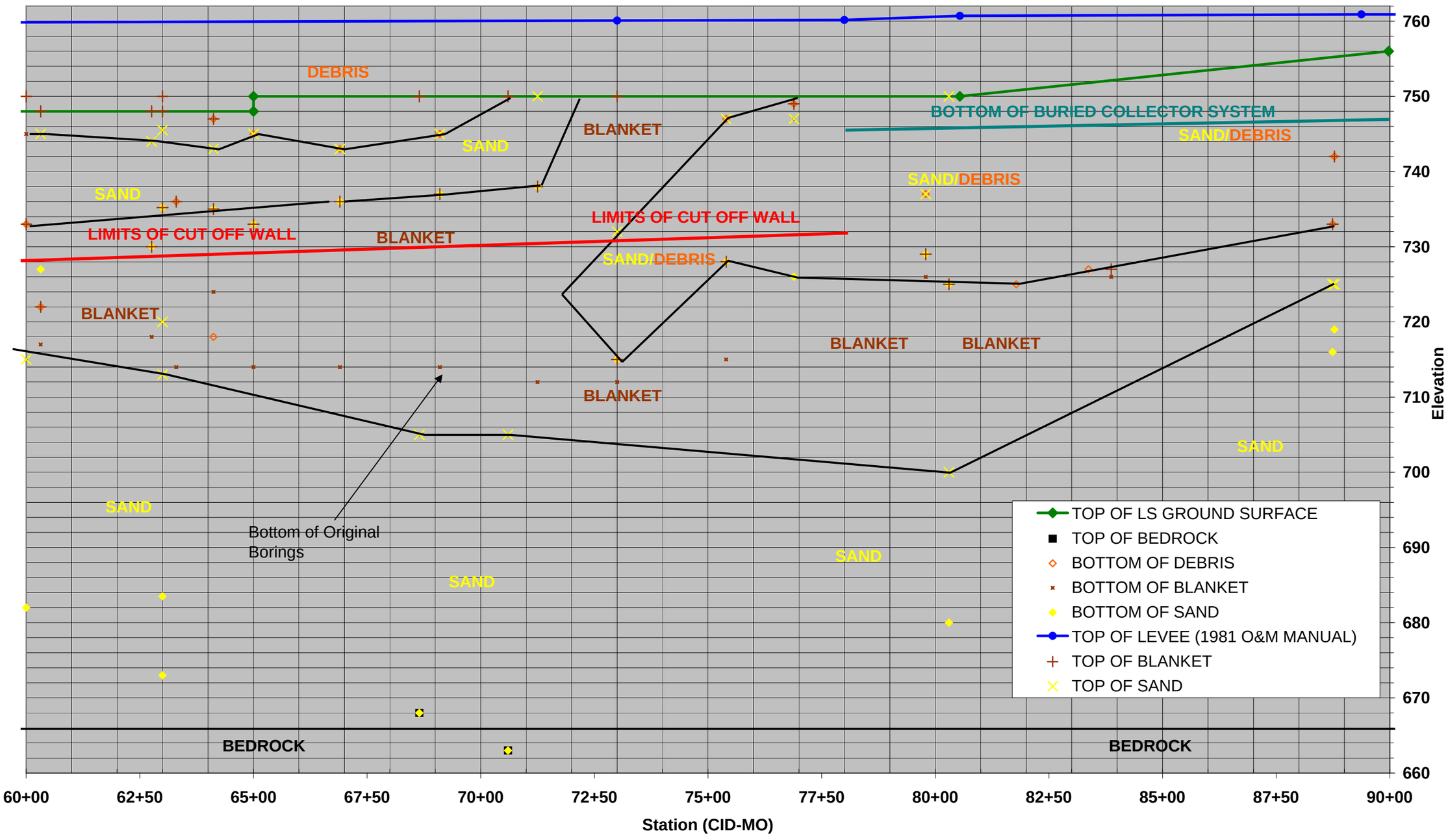
SAND
SAND
SAND
SAND?
LIMITS OF CUT OFF WALL
FLOODWALL SITTING
DIRECTLY ON BEDROCK
Bottom of Original
Borings
ASSUMED
BEDROCK
BEDROCK
TOP OF LS GROUND SURFACE
TOP OF BEDROCK
BOTTOM OF DEBRIS
BOTTOM OF BLANKET
BOTTOM OF SAND
TOP OF LEVEE (1981 O&M MANUAL)
TOP OF BLANKET
TOP OF SAND


760
750
740
730
720
710
700
690
680
670
660
Elevation
30+00
32+50
35+00
37+50
40+00
42+50
45+00
47+50
50+00
52+50
55+00
57+50
60+00
Station (CID-MO)
DEBRIS
BLANKET
SAND
LIMITS OF CUT OFF WALL
BEDROCK
Borings show indications of some finer grained material in lower portion of borings
Bottom of Original Borings
TOP OF LS GROUND SURFACE
TOP OF BEDROCK
BOTTOM OF DEBRIS
BOTTOM OF BLANKET
BOTTOM OF SAND
TOP OF LEVEE (1981 O&M MANUAL)
TOP OF BLANKET
TOP OF SAND


DEBRIS
BLANKET
SAND
BOTTOM OF BURIED COLLECTOR SYSTEM
SAND/DEBRIS
SAND
SAND/DEBRIS
LIMITS OF CUT OFF WALL
LIMITS OF CUT OFF WALL
BLANKET
SAND/DEBRIS
BLANKET
BLANKET
BLANKET
BLANKET
SAND
SAND
Bottom of Original Borings
SAND
SAND
BEDROCK
BEDROCK
TOP OF LS GROUND SURFACE
TOP OF BEDROCK
BOTTOM OF DEBRIS
BOTTOM OF BLANKET
BOTTOM OF SAND
TOP OF LEVEE (1981 O&M MANUAL)
TOP OF BLANKET
TOP OF SAND
760
750
740
730
720
710
700
690
680
670
660
Elevation
60+00
62+50
65+00
67+50
70+00
72+50
75+00
77+50
80+00
82+50
85+00
87+50
90+00
Station (CID-MO)

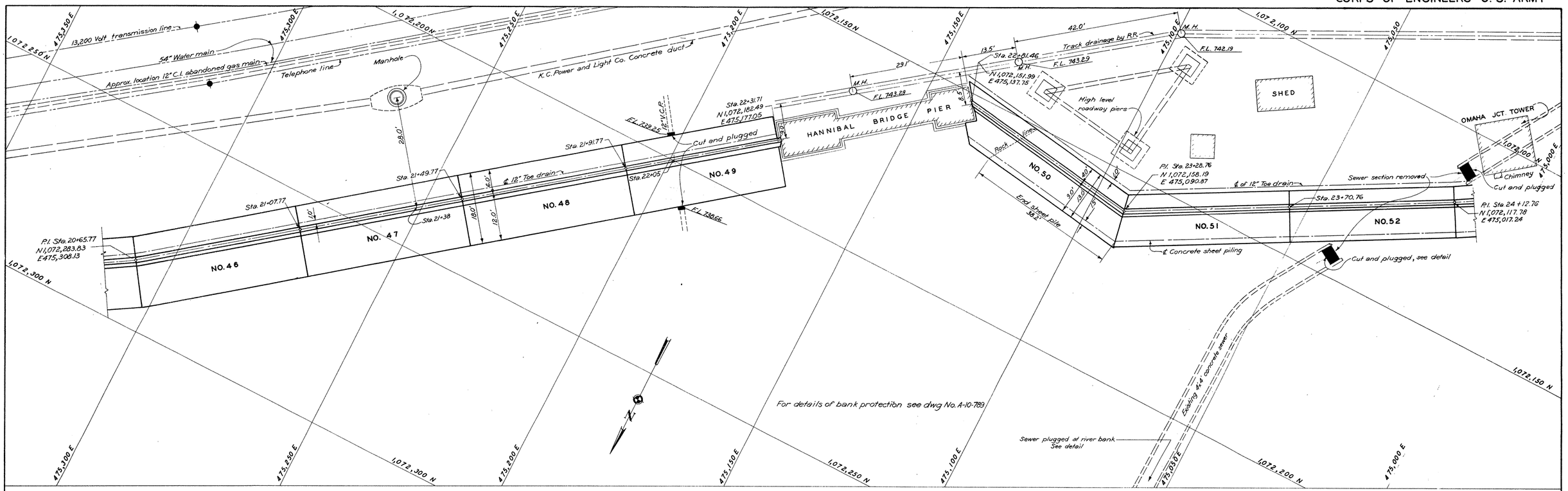
Record Drawings Used

Floodwall Plan

Pile Driving Records

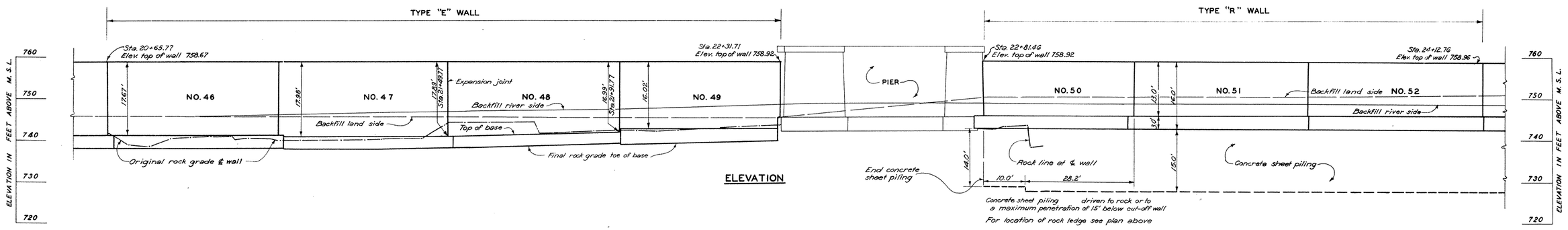
Floodwall Typical Sections

Pile Details

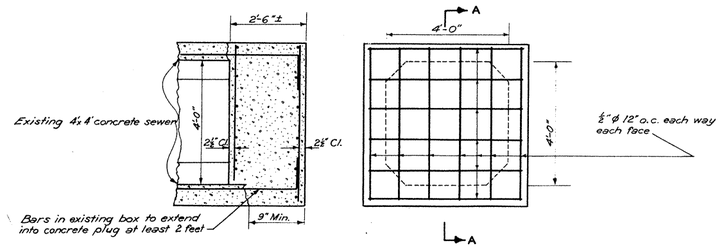


PLAN

SCALE: 1"=10'-0"



ELEVATION



SECTION A-A

ELEVATION

DETAIL OF PLUG

Scale: ½" = 1'-0"

NOTE-

For typical sections showing excavation and backfill payment lines see dwg No. A-10-784

For proper details on rock bearing wall refer to cross sections and dwg A-10-1186

RECORD DRAWING

NO.	DATE	BY	REVISION	APP'D.
2	6-23-47	G.C.B.	For as built conditions	
1	10-10-44	R.L.G.	Toe drain removed-Minor Revisions	

KANSAS CITY FLOOD CONTROL PROJECT

CENTRAL INDUSTRIAL DISTRICT

(MISSOURI SECTION)

FLOOD WALL

PLAN AND ELEVATION

SECTIONS-46 TO 52 INC.

In 23 Sheets. Sheet No. 7 Scale as shown

U. S. ENGINEER OFFICE
KANSAS CITY DISTRICT

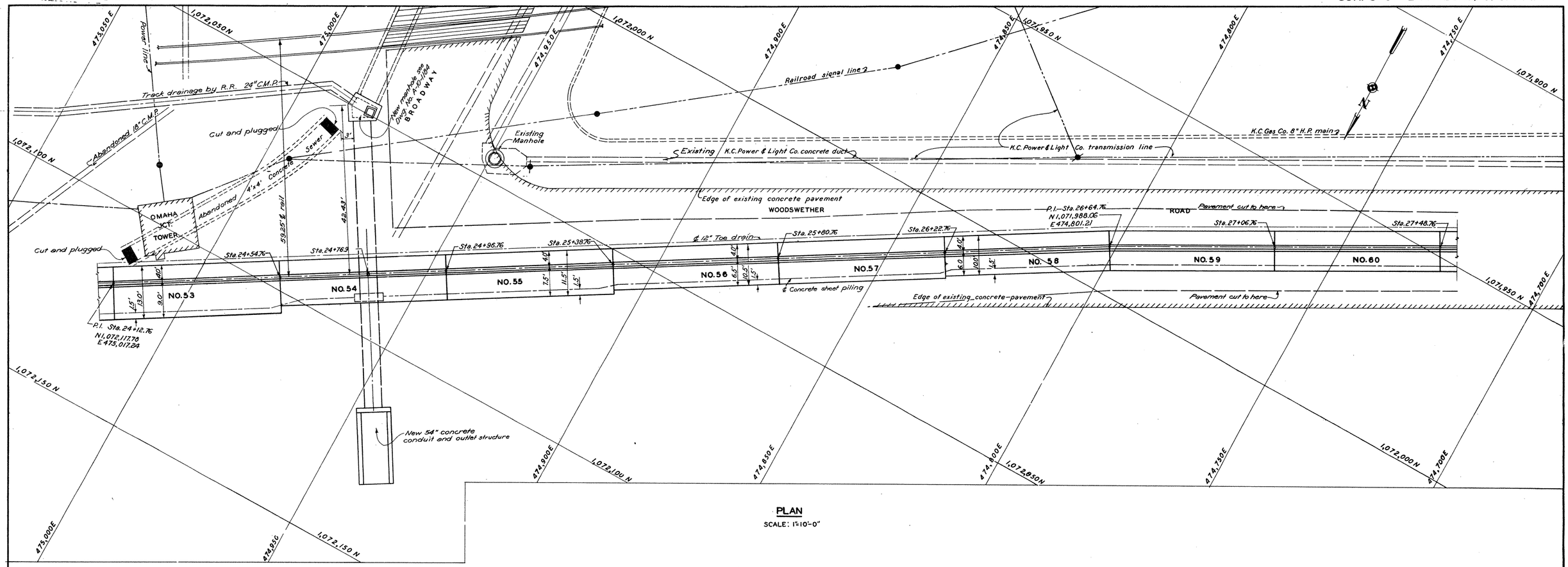
KANSAS CITY MO.
JUNE 1944

Submitted: Louis G. Faile — Senior Engineer

Recommended: [illegible] — Principal Engineer

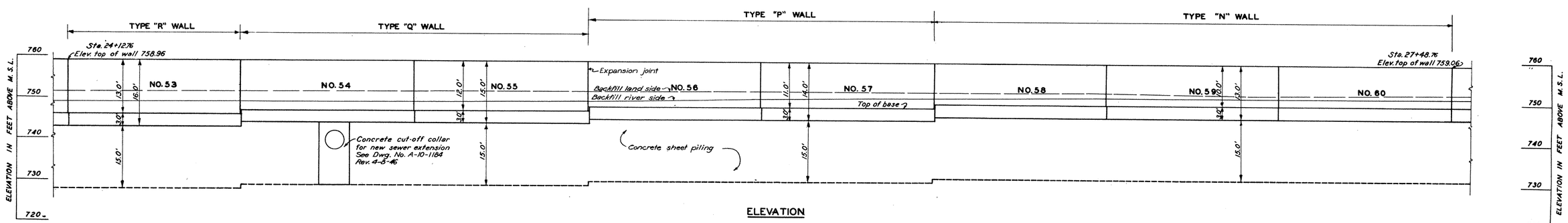
Approved: [illegible] — Lt. Colonel, Corps of Engrs.

Drawn By:	Traced By	Checked By:	To Accompany Specifications	File No.
C.B.O.	J.R.M.-W.M.B.	R.L.G.	Dated JANUARY 1946	A-10-719

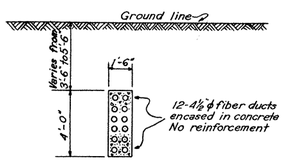


PLAN

SCALE: 1"=10'-0"



ELEVATION



TYPICAL SECTION THRU CONCRETE POWER DUCT

NOTE—
For typical section showing excavation and backfill payment lines see dwg. A-10-784, revised 2-1-45.
For wall details see dwg. A-10-824, revised 4-8-46.
For bank protection details see dwg. A-10-789, revised 6-23-47.

RECORD DRAWING

NO.	DATE	BY	REVISION	APPD.
2	6-23-47	S.C.B.	For as built conditions	
1	10-10-44	R.L.G.	Typical section concrete power duct added Toe drain removed-Minor revisions	

KANSAS CITY FLOOD CONTROL PROJECT

CENTRAL INDUSTRIAL DISTRICT
(MISSOURI SECTION)

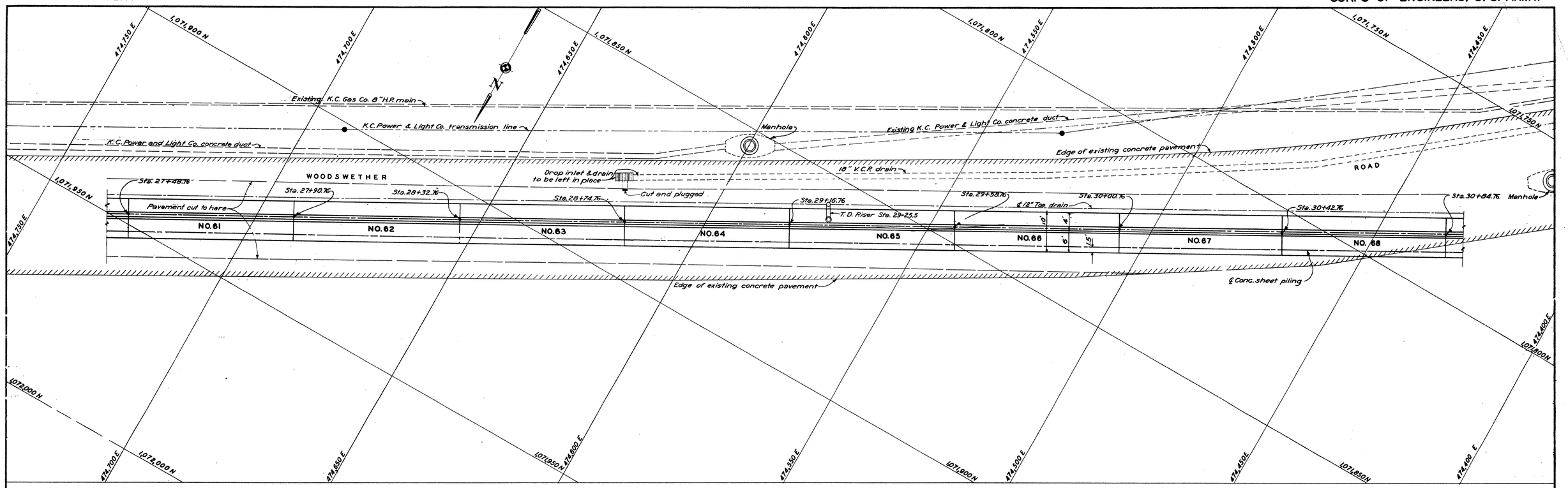
FLOOD WALL
PLAN AND ELEVATION
SECTIONS-53 TO 60 INC.

In 23 Sheets — Sheet No. 8 — Scale: as shown

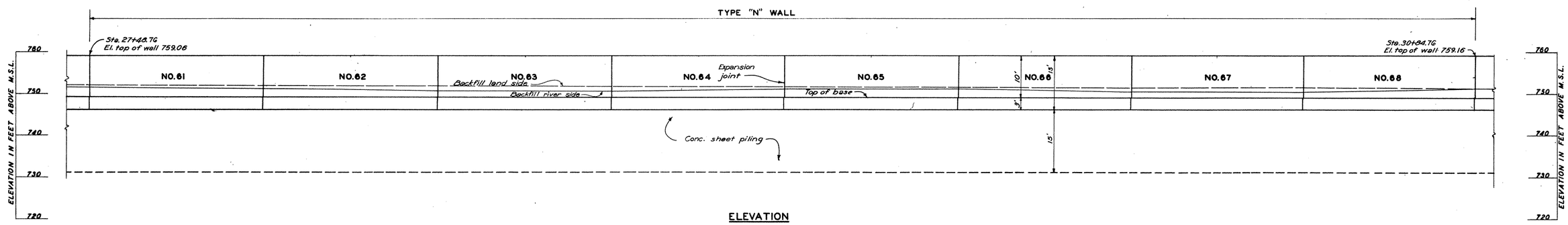
U. S. ENGINEER OFFICE
KANSAS CITY DISTRICT
KANSAS CITY, MO.
JUNE 1944

Submitted: Senior Engineer — Recommended: Principal Engineer — Approved: Lt. Colonel, Corps of Engrs.

Drawn By:	Traced By:	Checked By:	To Accompany Specifications	File No.
C.B.O.	J.R.M.-W.M.B.	R.L.G.	Dated JANUARY 1944	A-10-780



PLAN
SCALE: 1"=10'-0"



ELEVATION

RECORD DRAWING

NOTE–
For typical section showing excavation and backfill payment lines see dwg. No. A-10-784, revised 2-1-45.
For wall details see dwg. No. A-10-824, revised 4-8-46.

NO.	DATE	BY	REVISION	APP'D.
2	6-23-47	C.C.B.	For as built conditions.	
1	10-10-44	R.L.G.	Tee drain removed - Minor revisions.	

KANSAS CITY FLOOD CONTROL PROJECT

CENTRAL INDUSTRIAL DISTRICT
(MISSOURI SECTION)
FLOOD WALL
PLAN AND ELEVATION
SECTIONS - 61 TO 68 INC.

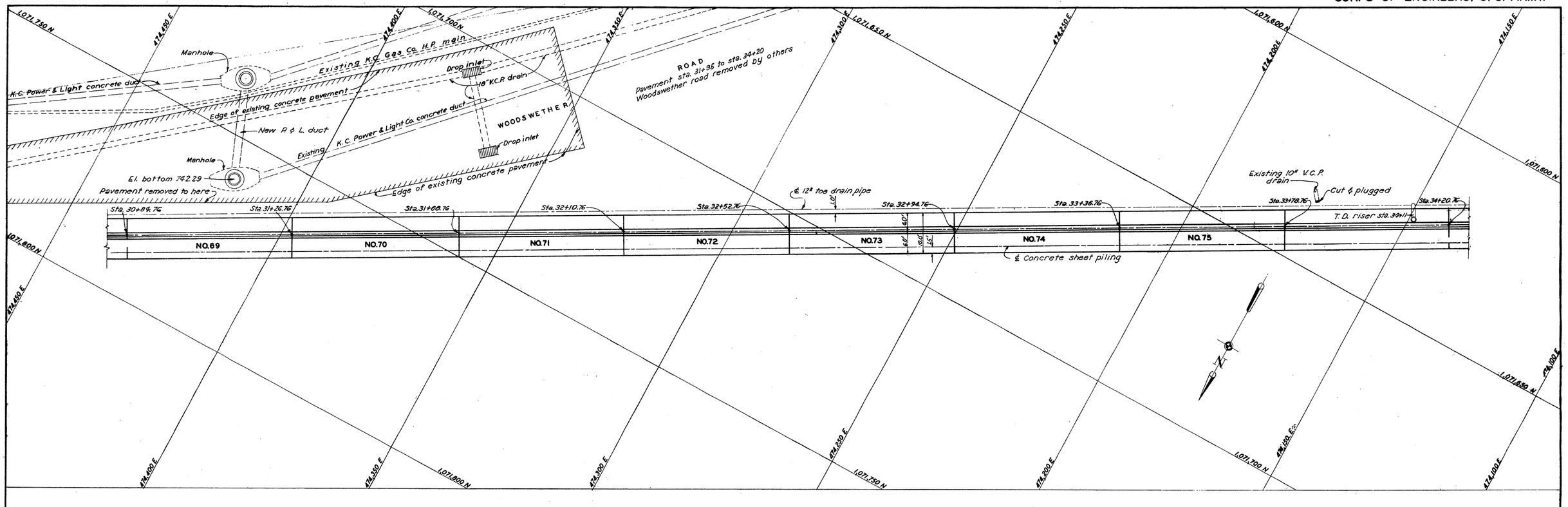
In 23 Sheets — Sheet No. 9 — Scale: as shown

U. S. ENGINEER OFFICE
KANSAS CITY DISTRICT

KANSAS CITY, MO.
JUNE 1944

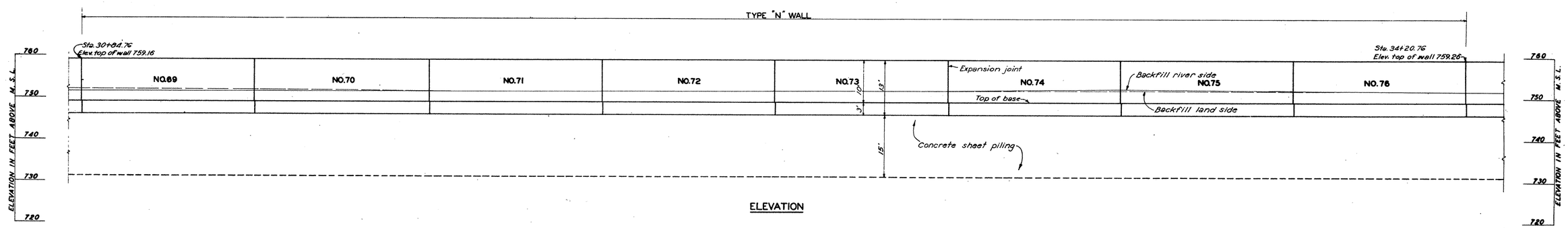
Submitted:	Recommended:	Approved:
Senior Engineer	Principal Engineer	Lt. Colonel, Corps of Engrs.

Drawn By:	Traced By:	Checked By:	To Accompany Specifications	File No.
C.B.O.	J.R.M.	R.L.G.	Dated JANUARY 1946	A-10-721



PLAN

SCALE: 1" = 10'-0"



ELEVATION

NOTE:
For typical section showing excavation and backfill payment lines see dwg. No. A-10-784, revised 2-1-45.
For wall details see dwg. No. A-10-824, revised 4-8-46.

RECORD DRAWING

NO.	DATE	BY	REVISIONS	APP'D
2	6-23-47	G.C.B.	For as built conditions	
1	10-10-44	R.L.G.	Toe Drain Removed.	

KANSAS CITY FLOOD CONTROL PROJECT

CENTRAL INDUSTRIAL DISTRICT
(MISSOURI SECTION)

FLOOD WALL
PLAN AND ELEVATION
SECTIONS-69 TO 76 INC.

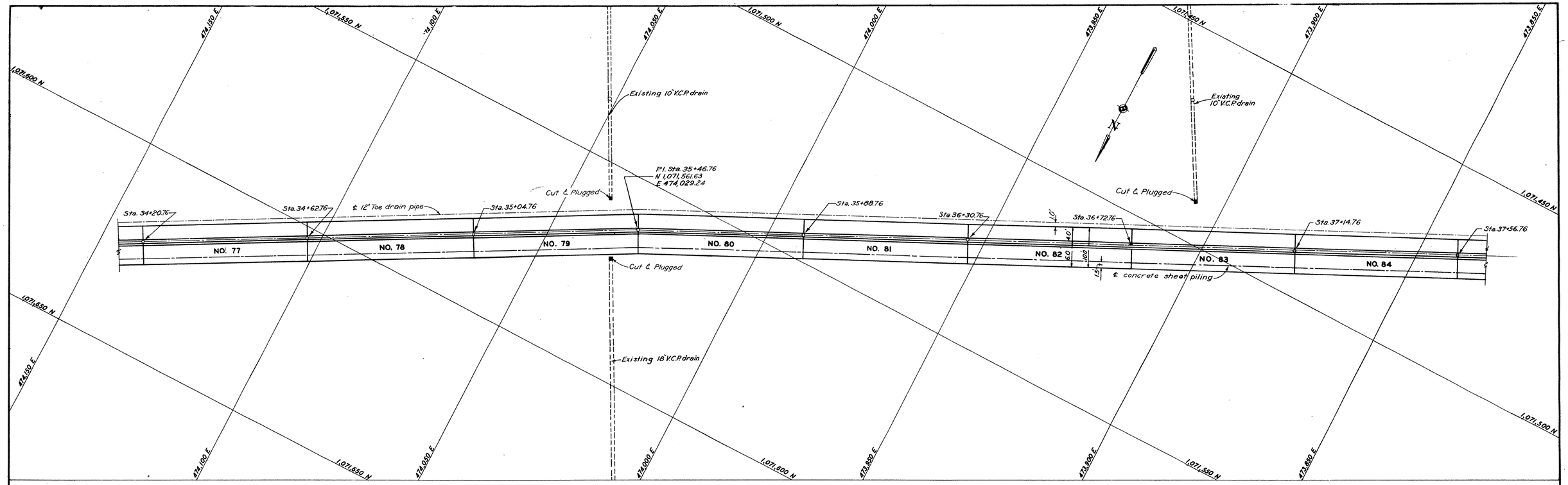
In 23 Sheets — Sheet No. 10 — Scale: as shown

U. S. ENGINEER OFFICE
KANSAS CITY DISTRICT

KANSAS CITY, MO.
JUNE 1944

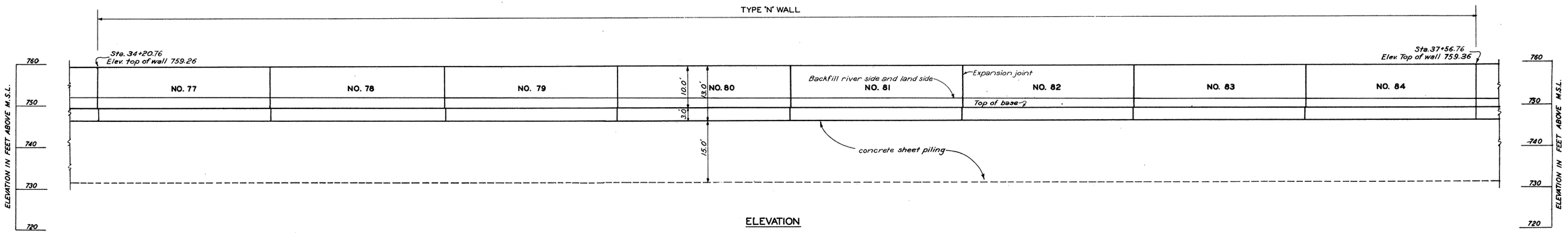
Submitted: Senior Engineer — Recommended: Principal Engineer — Approved: Lt. Colonel, Corps of Engrs.

Drawn By:	Traced By:	Checked By:	To Accompany Specifications	File No.
C. B. O.	J. R. M.	R. L. G.	Dated JANUARY 1946	A-10-722



PLAN

SCALE: 1"=10'-0"



ELEVATION

RECORD DRAWING

NOTE-
For typical section showing excavation and backfill payment lines see drawing No. A-10-784, rev. 2-1-45.
For wall details see drawing No. A-10-824, rev. 4-8-46.

NO.	DATE	BY	REVISIONS	APP'D
2	6-23-47	G.C.B.	For as built conditions.	
1	10-10-44	R.L.G.	Toe Drain Removed. Minor Revisions.	

KANSAS CITY FLOOD CONTROL PROJECT

CENTRAL INDUSTRIAL DISTRICT

(MISSOURI SECTION)

FLOOD WALL

PLAN AND ELEVATION

SECTIONS-77 TO 84 INC.

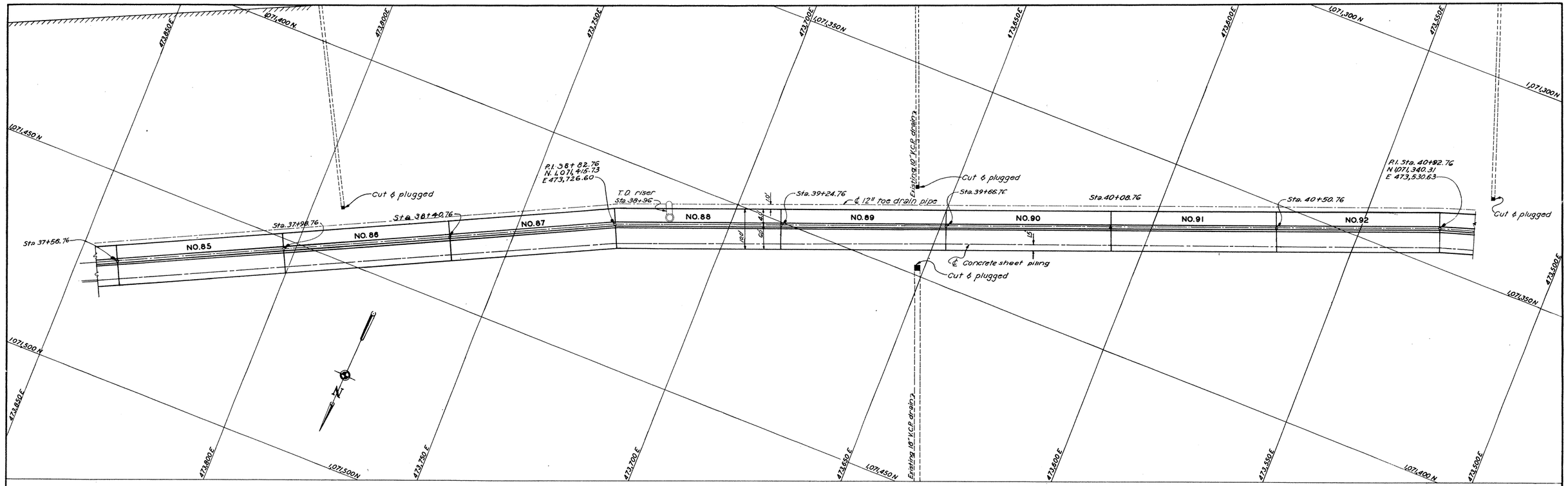
In 23 Sheets | Sheet No. 11 | Scale: as shown

U. S. ENGINEER OFFICE
KANSAS CITY DISTRICT

KANSAS CITY, MO.
JUNE 1944

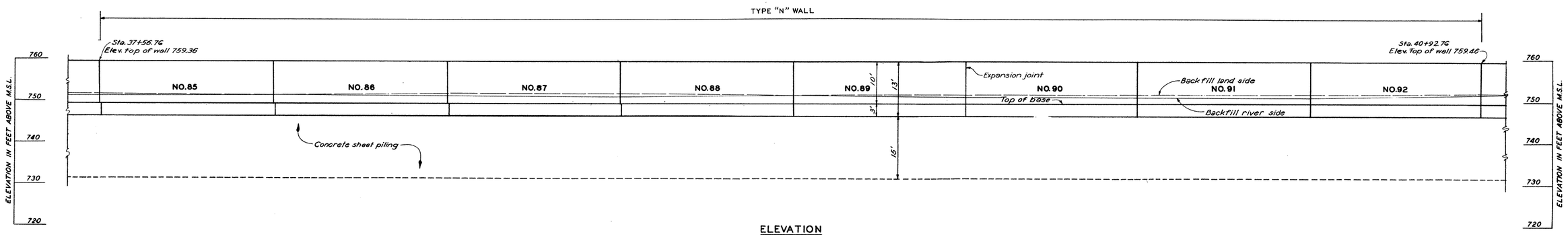
Submitted:	Recommended:	Approved:
Senior Engineer	Principal Engineer	Lt. Colonel, Corps of Engrs.

Drawn By:	Traced By:	Checked By:	To Accompany Specifications	File No.
C. B. O.	B.R.T.-J.F.K.	R. L. G.	Dated JANUARY 1944	A-10-723



PLAN

SCALE: 1" = 10'-0"



ELEVATION

NOTE:
For typical section showing excavation and backfill payment lines see dwg. No. A-10-784, revised 2-1-45.
For wall details see dwg. No. A-10-824, revised 4-8-46.

RECORD DRAWING

NO.	DATE	BY	REVISIONS	APP'D.
2	6-23-47	G.C.B.	For as built conditions	
1	10-10-44	R.L.G.	Toe Drain Removed - Minor Revisions	

KANSAS CITY FLOOD CONTROL PROJECT

CENTRAL INDUSTRIAL DISTRICT
(MISSOURI SECTION)

FLOOD WALL
PLAN AND ELEVATION
SECTIONS-85 TO 92 INC.

In 23 Sheets — Sheet No. 12 — Scale: as shown

U. S. ENGINEER OFFICE
KANSAS CITY DISTRICT

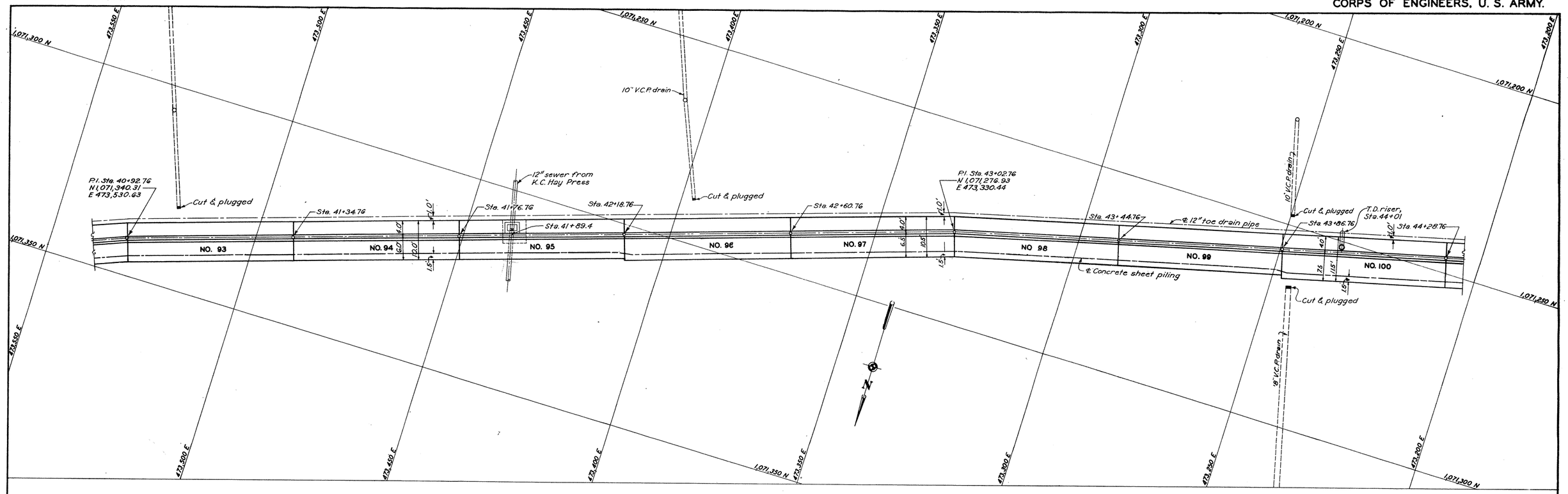
KANSAS CITY, MO.
JUNE, 1944

Submitted:	Recommended:	Approved:
Senior Engineer	Principal Engineer	Lt. Colonel, Corps of Engineers

Drawn By:	Traced By:	Checked By:	To Accompany Specifications	File No.
C.B.O.	B.E.T.-L.E.P.	R.L.G.	Dated JANUARY 1946	A-10-724

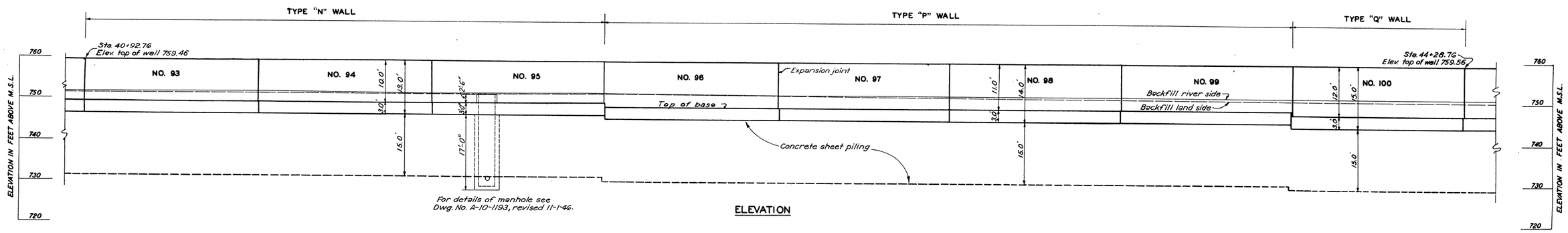
WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY.



PLAN

SCALE: 1"=10'-0"



ELEVATION

NOTE–
For typical section showing excavation and backfill payment lines see Dwg. No. A-10-784, revised 2-1-45.
For wall details for sections Nos. 93, 94, 96, 97, 98, 99 and 100 see Dwg. No. A-10-824, revised 4-8-46. For section No. 95 see Dwg. No. A-10-1193, revised 11-1-46.

RECORD DRAWING

NO.	DATE	BY	REVISION	APP'D.
2	6-23-47	G.C.B.	For as built conditions.	
1	10-10-44	R.L.G.	Toe drain removed-Minor revisions.	

KANSAS CITY FLOOD CONTROL PROJECT

CENTRAL INDUSTRIAL DISTRICT

(MISSOURI SECTION)

FLOOD WALL

PLAN AND ELEVATION

SECTIONS-93 TO 100 INC.

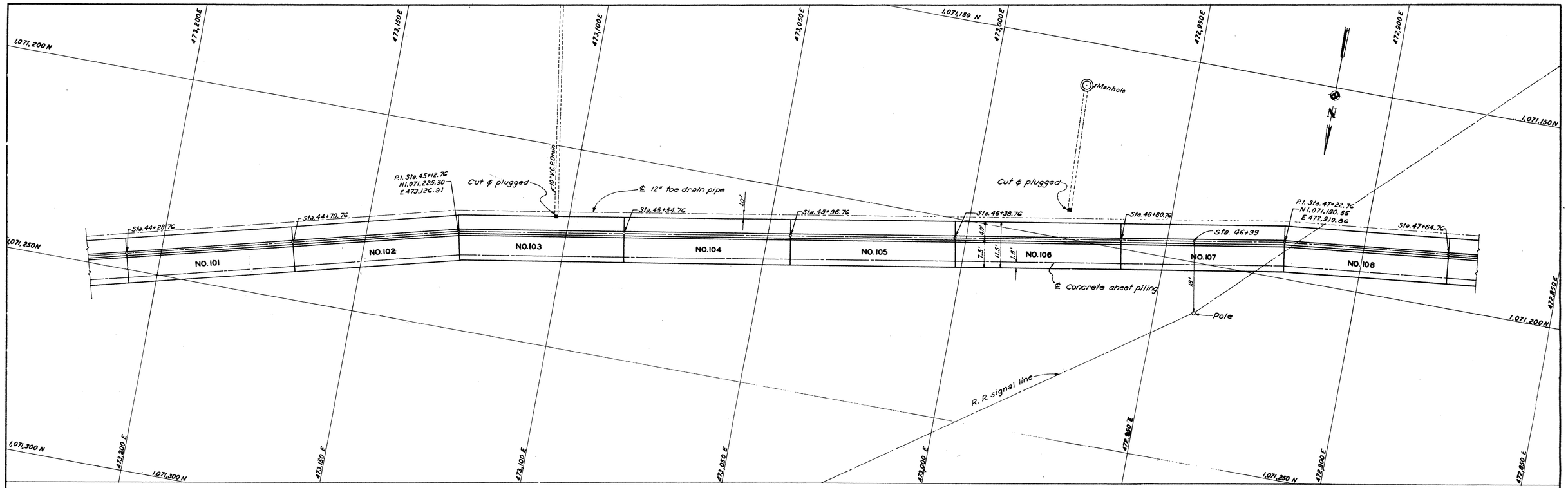
In 23 Sheets | Sheet No. 13 | Scale: as shown

U. S. ENGINEER OFFICE
KANSAS CITY DISTRICT

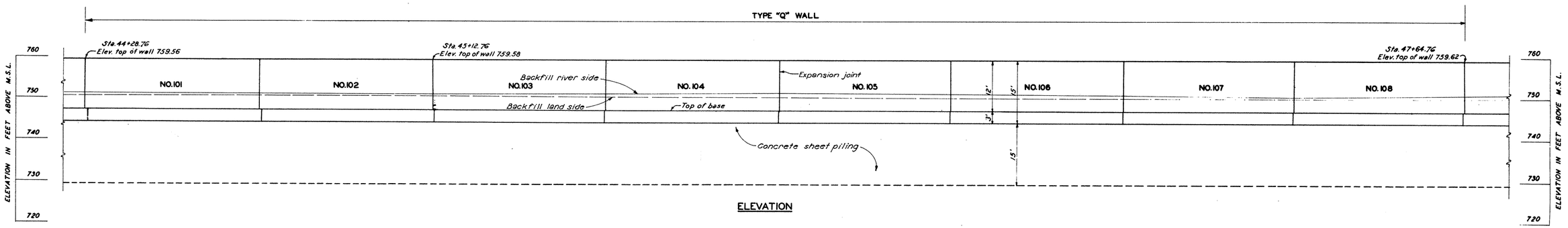
KANSAS CITY, MO.
JUNE 1944

Submitted:	Recommended:	Approved:
Senior Engineer	Principal Engineer	Lt. Colonel, Corps of Engrs.

Drawn By:	Traced By:	Checked By:	To Accompany Specifications	File No.
C. B. Q.	B.R.T.-J.F.K.	R. L. G.	Dated JANUARY 1949	A-10-725



PLAN
SCALE: 1"=10'-0"



ELEVATION

RECORD DRAWING

NOTE:
For typical section showing excavation and backfill payment lines see dwg. No. A-10-784, revised 2-1-45.
For well details see dwg. No. A-10-824, revised 4-8-46.

NO.	DATE	BY	REVISIONS	APP'D
2	6-23-47	G.C.B.	For as built conditions	
1	10-10-44	R.L.G.	Toe Drain Removed. Minor Revisions.	

KANSAS CITY FLOOD CONTROL PROJECT

CENTRAL INDUSTRIAL DISTRICT

(MISSOURI SECTION)

FLOOD WALL

PLAN AND ELEVATION
SECTIONS-101 TO 108 INC.

In 23 Sheets | Sheet No. 14 | Scale: as shown

U. S. ENGINEER OFFICE
KANSAS CITY DISTRICT

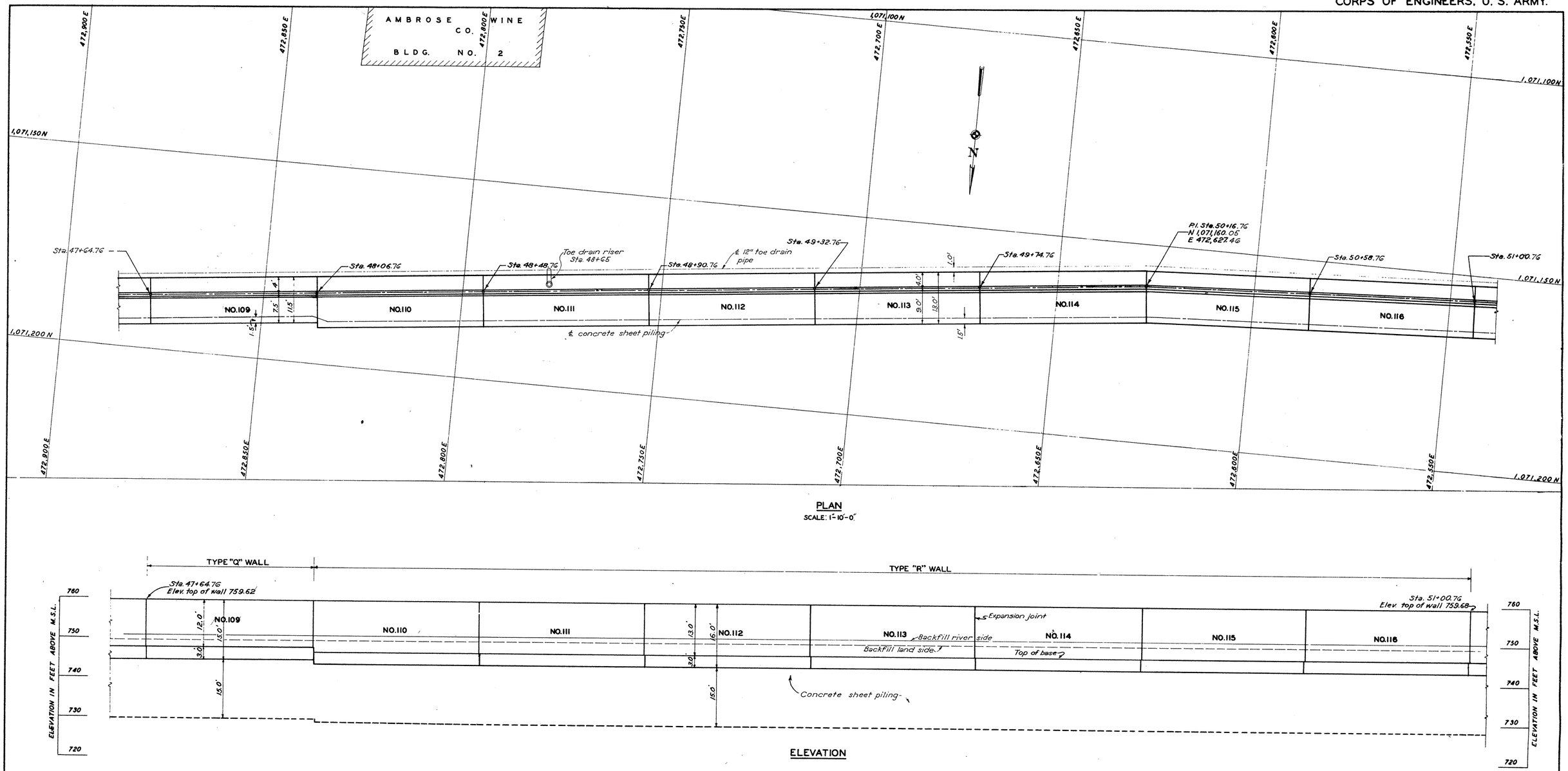
KANSAS CITY, MO.
JUNE 1944

Submitted: Louis B. Ford, Senior Engineer
Recommended: J. R. McDonald, Principal Engineer
Approved: J. G. Neff, Lt. Colonel, Corps of Engrs.

Drawn By: C.B.O.	Traced By: J. R. M.	Checked By: R.L.G.	To Accompany Specifications Dated JANUARY 1945	File No. A-10-726

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY.



RECORD DRAWING

NOTE:
For typical section showing excavation and backfill payment lines see dwg. No. A-10-784, revised 2-1-45.
For wall details see dwg. No. A-10-824, revised 4-8-46.

NO.	DATE	BY	REVISIONS	APP'D
3	6-3-47	G.C.B.	For as built conditions.	
2	2-1-45	R.L.G.	Minor Revisions	
1	10-10-44	R.L.G.	Toe Drain Removed.	

KANSAS CITY FLOOD CONTROL PROJECT

CENTRAL INDUSTRIAL DISTRICT
(MISSOURI SECTION)

FLOOD WALL
PLAN AND ELEVATION
SECTIONS-109 TO 116 INC.

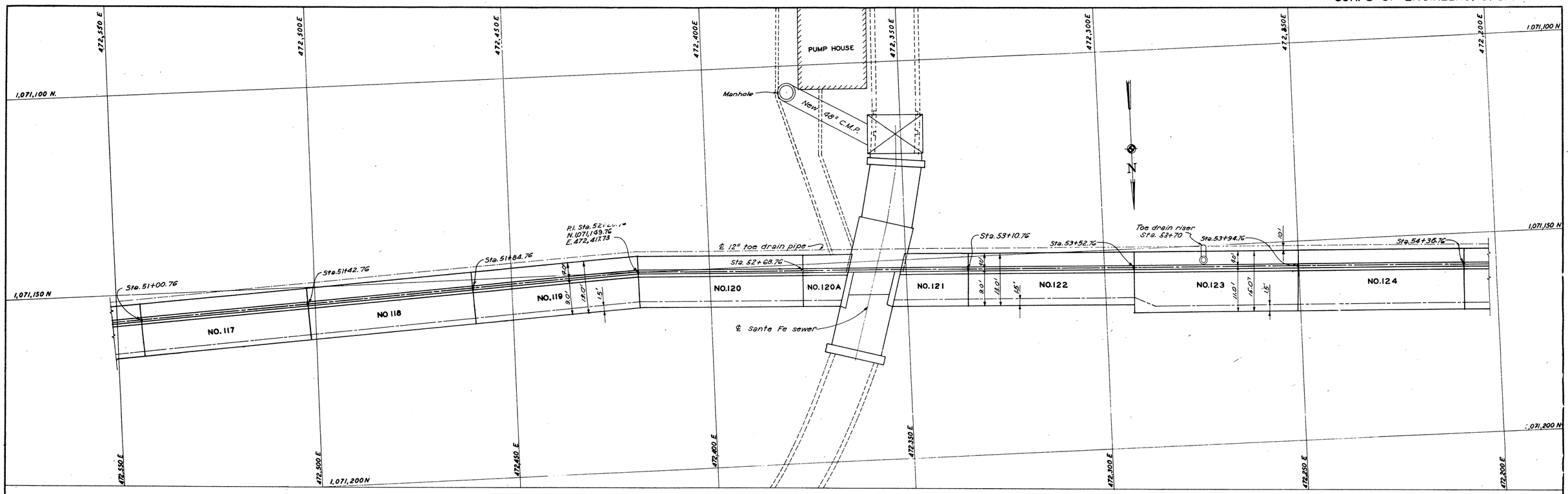
In 23 Sheets — Sheet No. 15 — Scale: as shown

U. S. ENGINEER OFFICE
KANSAS CITY DISTRICT

KANSAS CITY, MO.
JUNE 1944.

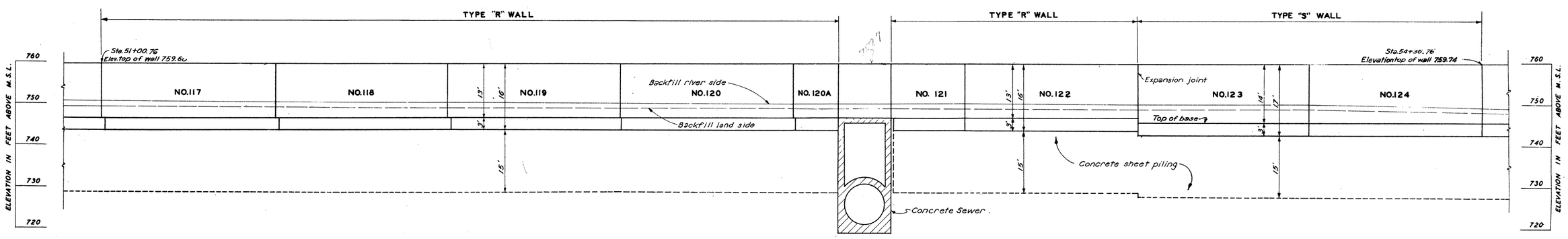
Submitted:	Recommended:	Approved:
Senior Engineer	Principal Engineer	Lt. Colonel, Corps of Engrs.

Drawn By:	Traced By:	Checked By:	To Accompany Specifications	File No.
C.B.O.	J.R.M.	R.L.G.	Dated JANUARY 1948	A-10-727



PLAN

SCALE: 1"=10'-0"



ELEVATION

RECORD DRAWING

NOTE:
For typical section showing excavation and backfill payment lines see dwg. No. A-10-784, revised 2-1-45.
For Sante Fe sewer details see dwg. No. A-10-1194, revised 10-23-46.
For wall details see dwg. No. A-10-824, revised 4-8-46.

NO.	DATE	BY	REVISION	APP'D
3	6-23-47	G.C.B.	For as built conditions	
2	2-1-45		Type "a-1" Wall deleted. Santa Fe St. Sewer gate house moved	
1	10-10-44	R.L.G.	Toe drain Removed-Sewer Revised	

KANSAS CITY FLOOD CONTROL PROJECT

CENTRAL INDUSTRIAL DISTRICT

(MISSOURI SECTION)

FLOOD WALL

PLAN AND ELEVATION

SECTIONS-117 TO 124 INC.

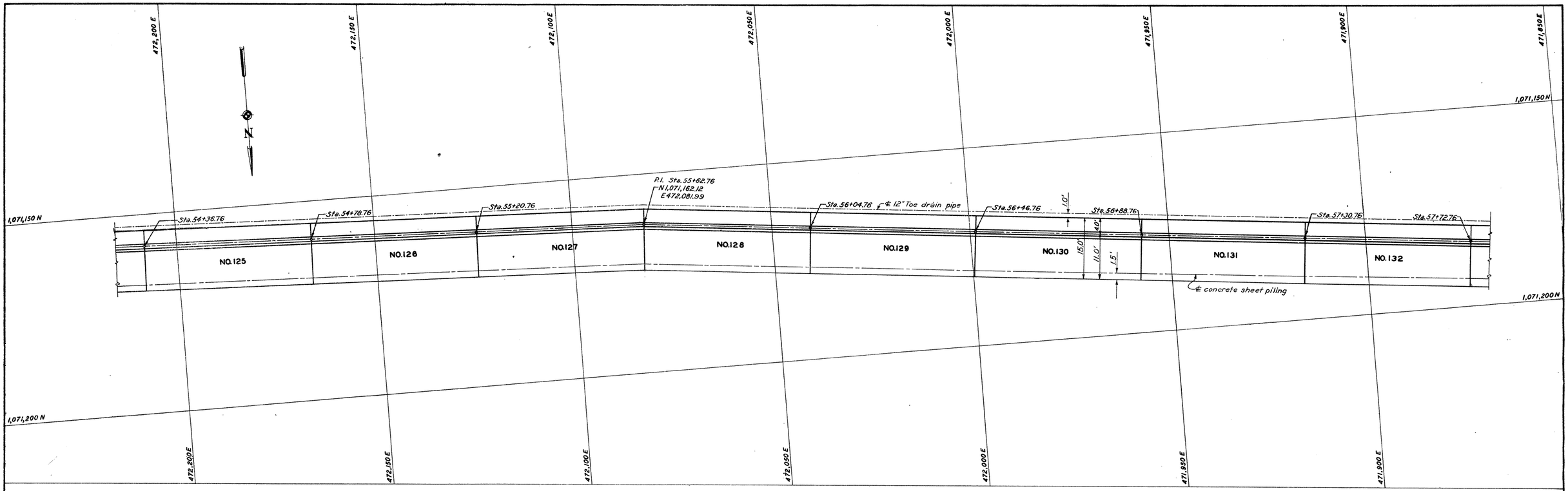
In 23 Sheets — Sheet No. 16 — Scale: as shown

U. S. ENGINEER OFFICE
KANSAS CITY DISTRICT

KANSAS CITY, MO.
JUNE 1944

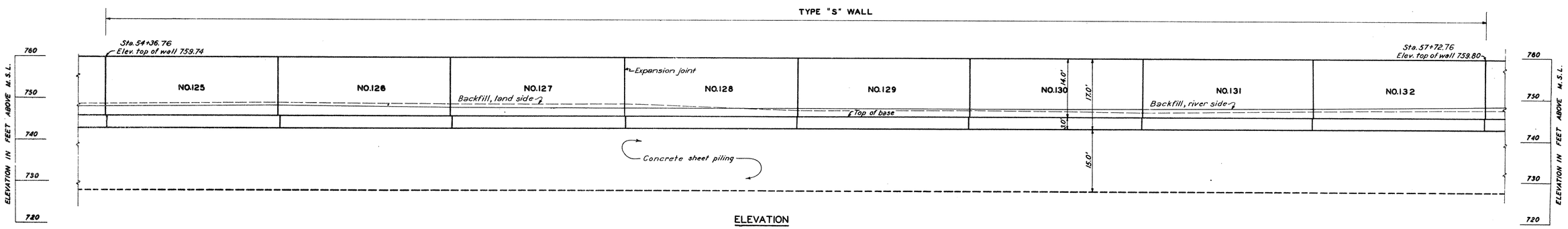
Submitted:	Recommended:	Approved:
Louis B. Feil, Senior Engineer	R. M. McDonald, Principal Engineer	L. N. Neff, Lt. Colonel, Corps of Engrs.

Drawn By:	Traced By:	Checked By:	To Accompany Specifications	File No.
C.B.O.	J.R.M.-L.E.P.	R.L.G.	Dated JANUARY 1946	A-10-728



PLAN

SCALE: 1"=10'-0"



ELEVATION

RECORD DRAWING

NOTES:-
For typical section showing excavation and backfill payment lines see dwg. No. A-10-784, revised 2-1-45
For wall details see Dwg. No. A-10-824, revised 4-8-46

NO.	DATE	BY	REVISIONS	APPD.
2	6-23-47	G.C.B.	For as built conditions	
1	10-10-44	R.L.G.	Toe drain removed	

KANSAS CITY FLOOD CONTROL PROJECT

CENTRAL INDUSTRIAL DISTRICT

(MISSOURI SECTION)

FLOOD WALL

PLAN AND ELEVATION

SECTIONS-125 TO 132 INC.

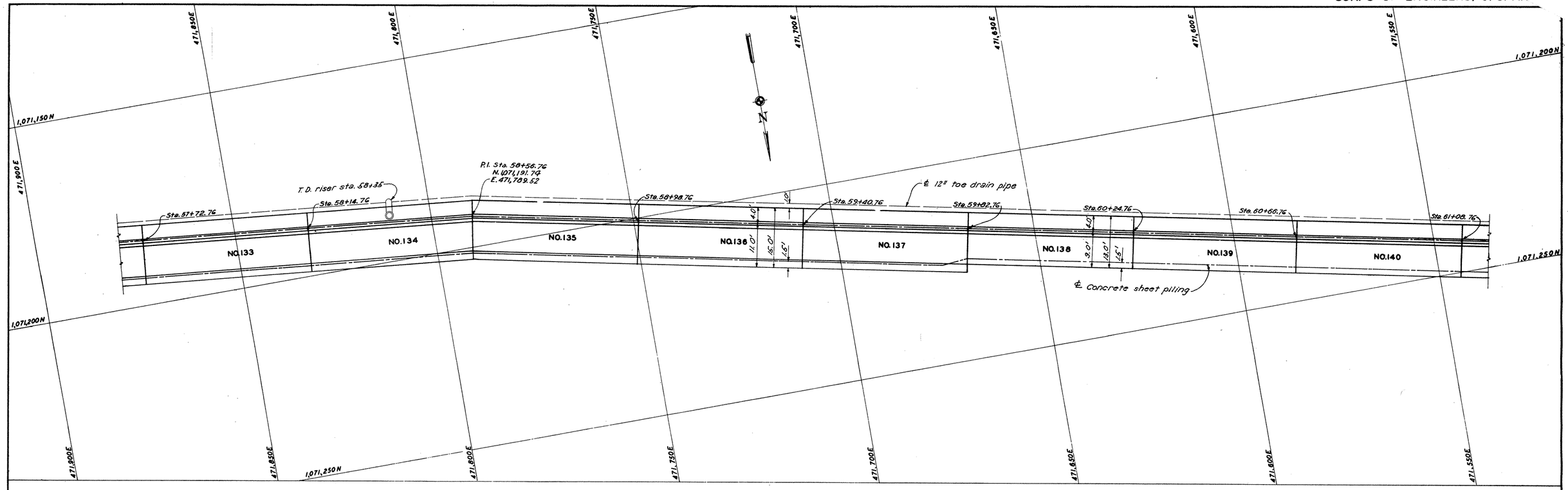
In 23 Sheets. Sheet No. 17 Scale: as shown

U. S. ENGINEER OFFICE
KANSAS CITY DISTRICT

KANSAS CITY, MO.
JUNE 1944

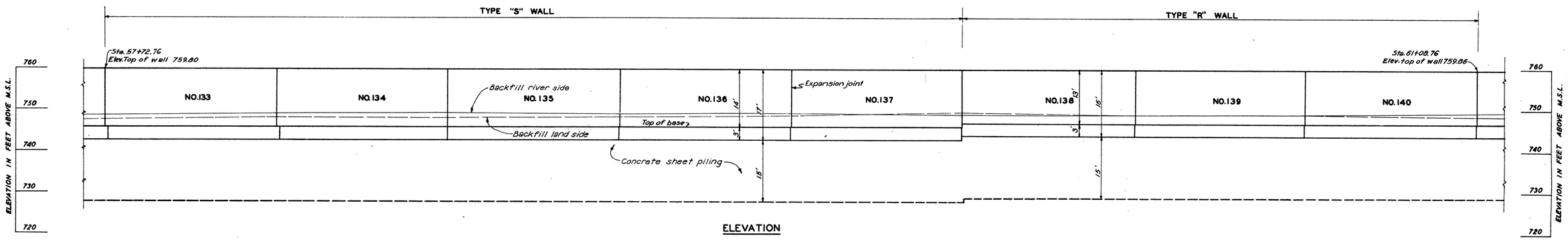
Submitted:	Recommended:	Approved:
Senior Engineer	Principal Engineer	Lt. Colonel, Corps of Engrs.

Drawn By:	Traced By:	Checked By:	To Accompany Specifications	File No.
C.B.O.	J.R.M.-W.M.B.	R.L.G.	Dated JANUARY 1946	A-10-729



PLAN

SCALE: 1"=10'-0"



ELEVATION

RECORD DRAWING

NOTE:
For typical section showing excavation and backfill payment lines see dwg. No. A-10-784, revised 2-1-45.
For wall details see dwg. No. A-10-829, revised 4-8-46.

NO	DATE	BY	REVISION	APRD
2	6-23-47	G.C.B.	For as built conditions	
1	10-10-44	R.L.G.	Toe drain removed	

KANSAS CITY FLOOD CONTROL PROJECT

CENTRAL INDUSTRIAL DISTRICT

(MISSOURI SECTION)

FLOOD WALL

PLAN AND ELEVATION

SECTIONS-133 TO 140 INC.

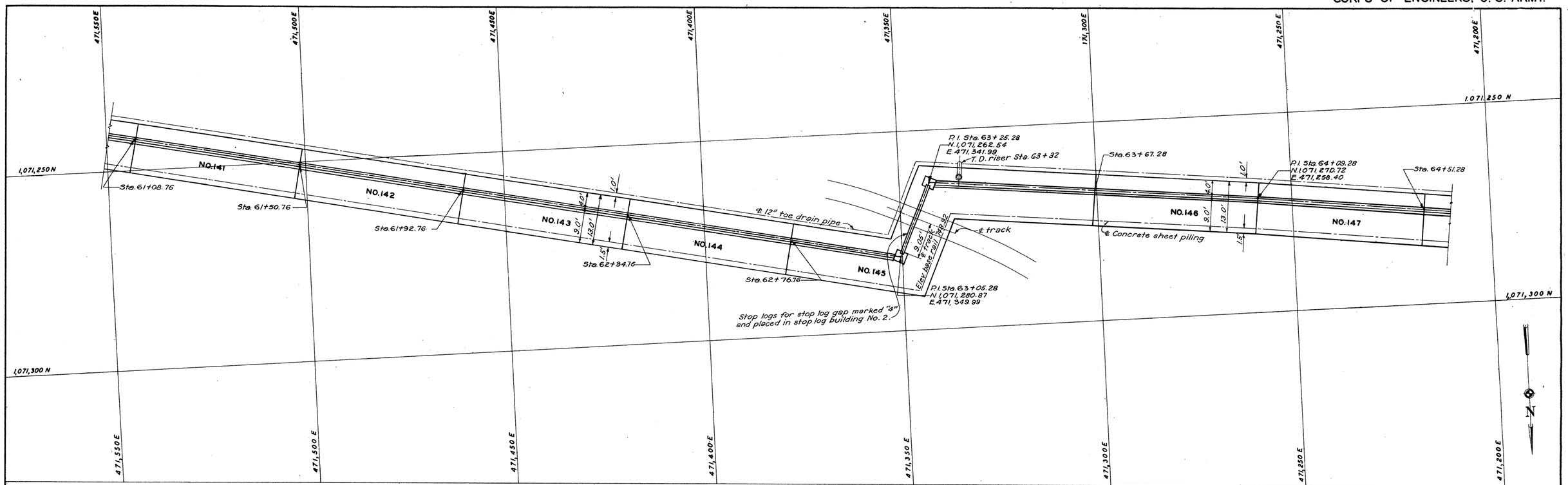
In 23 Sheets. Sheet No. 18 Scale: as shown

U. S. ENGINEER OFFICE
KANSAS CITY DISTRICT

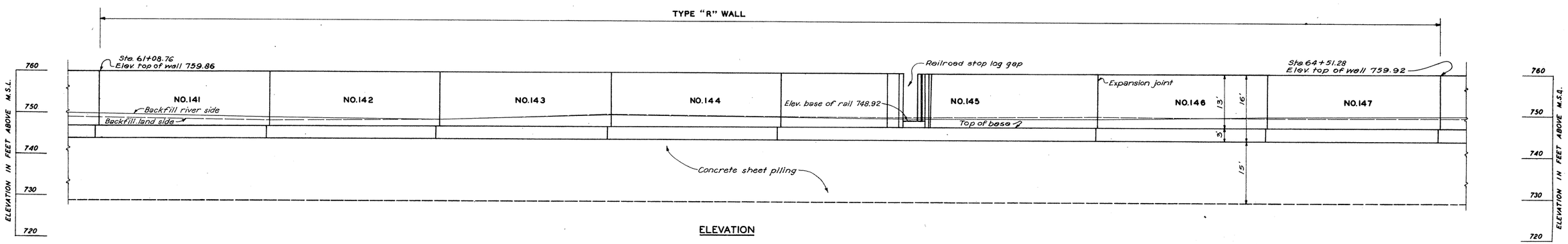
KANSAS CITY, MO.
JUNE 1944

Submitted: Senior Engineer — Recommended: Principal Engineer — Approved: Lt. Colonel, Corps of Engrs.

Drawn By:	Traced By:	Checked By:	To Accompany Specifications Dated JANUARY 1946	File No.
C.B.O.	J.R.M.	R.L.G.		A-10-730



PLAN
SCALE: 1"=10'-0"



ELEVATION

RECORD DRAWING

NO.	DATE	BY	REVISION	APPD.
3	6-23-47	G.C.B.	For as built conditions	
2	2-1-45	R.L.G.	Type "R-3" changed to "R-5"	
1	10-10-44	R.L.G.	Toe drain removed-Minor revisions	

NOTE:
For typical section showing excavation and backfill payment lines see dwg. No. A-10-784, revised 2-7-45.
For wall section details see dwg. No. A-10-824, revised 4-8-46.
For details of section No. 145 see dwg No. A-10-1180, revised 4-8-46.

KANSAS CITY FLOOD CONTROL PROJECT

CENTRAL INDUSTRIAL DISTRICT
(MISSOURI SECTION)

FLOOD WALL

PLAN AND ELEVATION
SECTIONS -141 TO 147 INC.

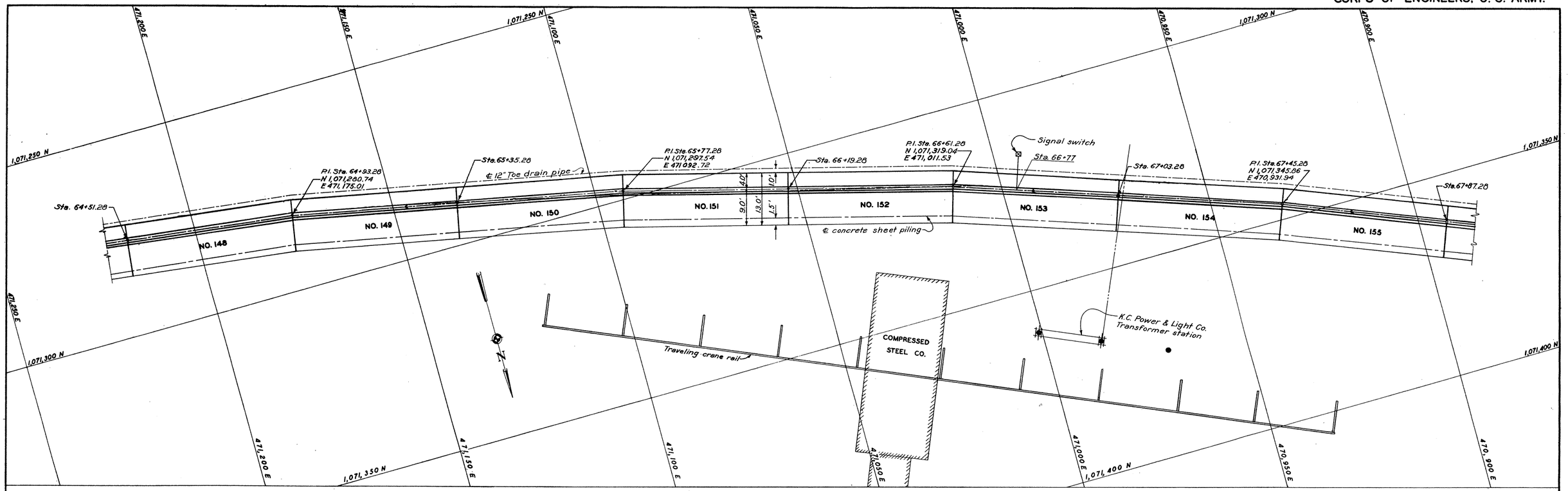
In 23 Sheets — Sheet No. 19 — Scale: as shown

U. S. ENGINEER OFFICE
KANSAS CITY DISTRICT

KANSAS CITY, MO.
JUNE, 1944

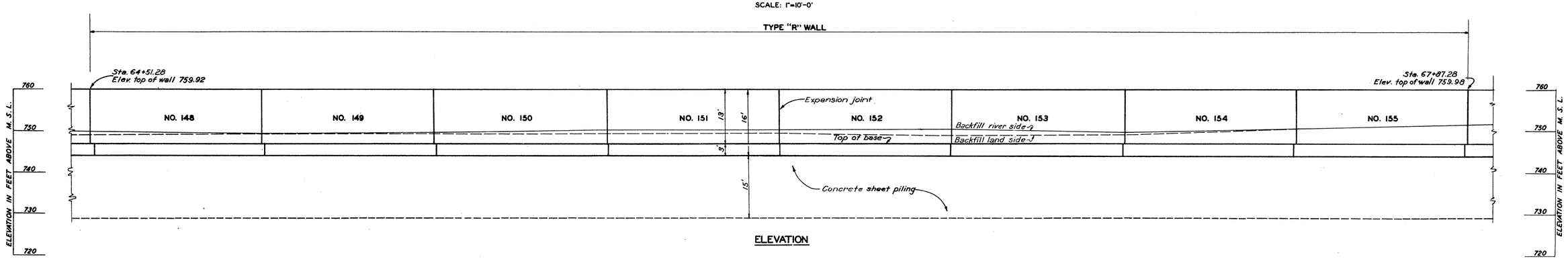
Submitted: Senior Engineer — Recommended: Principal Engineer — Approved: Lt. Colonel, Corps of Engrs.

Drawn By:	Traced By:	Checked By:	To Accompany Specifications	File No.
C.B.O.	J.R.M.	R.L.G.	Dated JANUARY 1948	A-10-731



PLAN

SCALE: 1"=10'-0"



ELEVATION

RECORD DRAWING

NOTES:-
For typical section showing excavation and backfill payment lines see dwg No. A-10-784, revised 2-1-45
For wall details see Dwg. A-10-824, revised 4-8-46

NO.	DATE	BY	REVISION	APPD.
2	6-23-47	G.C.B.	For as built conditions	
1	10-10-44	R.L.G.	Toe drain removed	

KANSAS CITY FLOOD CONTROL PROJECT

CENTRAL INDUSTRIAL DISTRICT
(MISSOURI SECTION)

FLOOD WALL

PLAN AND ELEVATION
SECTIONS - 148 TO 155 INC.

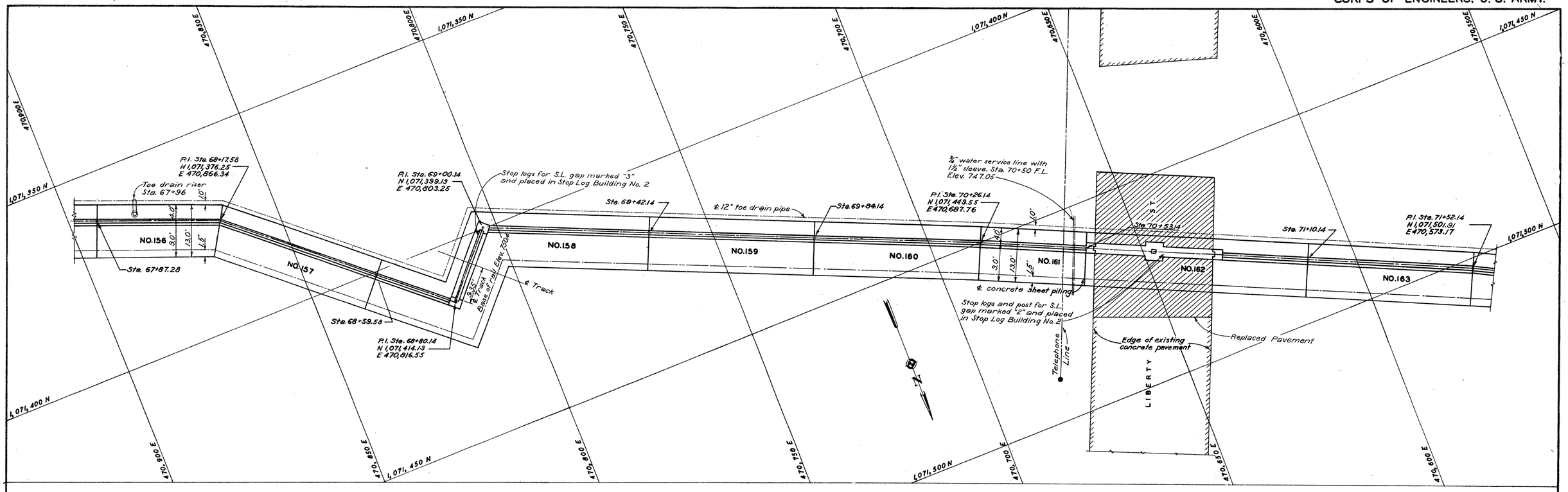
In 23 Sheets | Sheet No. 20 | Scale: as shown

U. S. ENGINEER OFFICE
KANSAS CITY DISTRICT

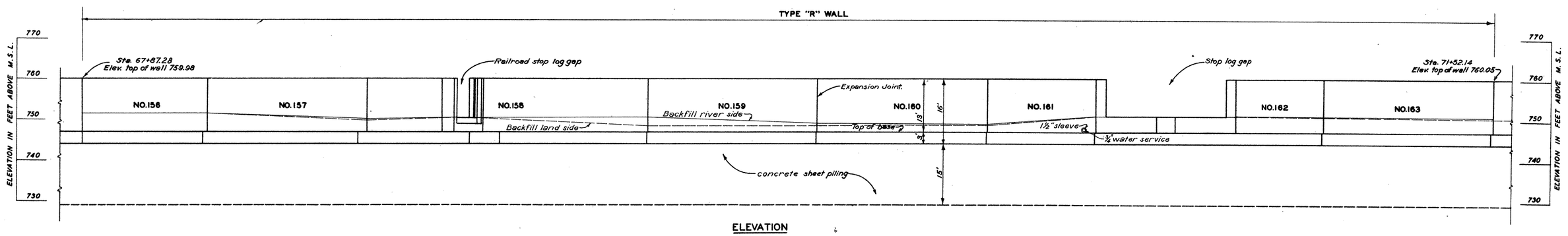
KANSAS CITY, MO.
JUNE 1944

Submitted:	Recommended:	Approved:
Senior Engineer	Principal Engineer	Lt. Colonel, Corps of Engrs.

Drawn By:	Traced By:	Checked By:	To Accompany Specifications	File No.
C.B.O.	B.R.T.-J.F.K.	R.L.G.	Dated JANUARY 1945	A-10-732



PLAN
SCALE: 1"=10'-0"



ELEVATION

RECORD DRAWING

NOTE:
For typical section showing excavation and backfill payment lines see dwg. No. A-10-784, rev. 2-1-45
For wall details for sections 156-157-159-160-161-163 see Dwg. A-10-824, revised 4-8-46.
For section 158 see Dwg. A-10-1181, revised 4-8-46.
For section 162 see Dwg. A-10-1182, revised 4-8-46.

NO.	DATE	BY	REVISIONS	APP'D.
3	6-23-47	G.C.B.	For as built conditions	
2	2-1-45	R.L.G.	Types R-4, 5, 6, and 7 changed to R-6, 7, 8 and 9 respectively	
1	10-10-44	R.L.G.	Toe drain removed-Stop Log Gap revised	

KANSAS CITY FLOOD CONTROL PROJECT

CENTRAL INDUSTRIAL DISTRICT
(MISSOURI SECTION)
FLOOD WALL
PLAN AND ELEVATION
SECTIONS-156 TO 163 INC.

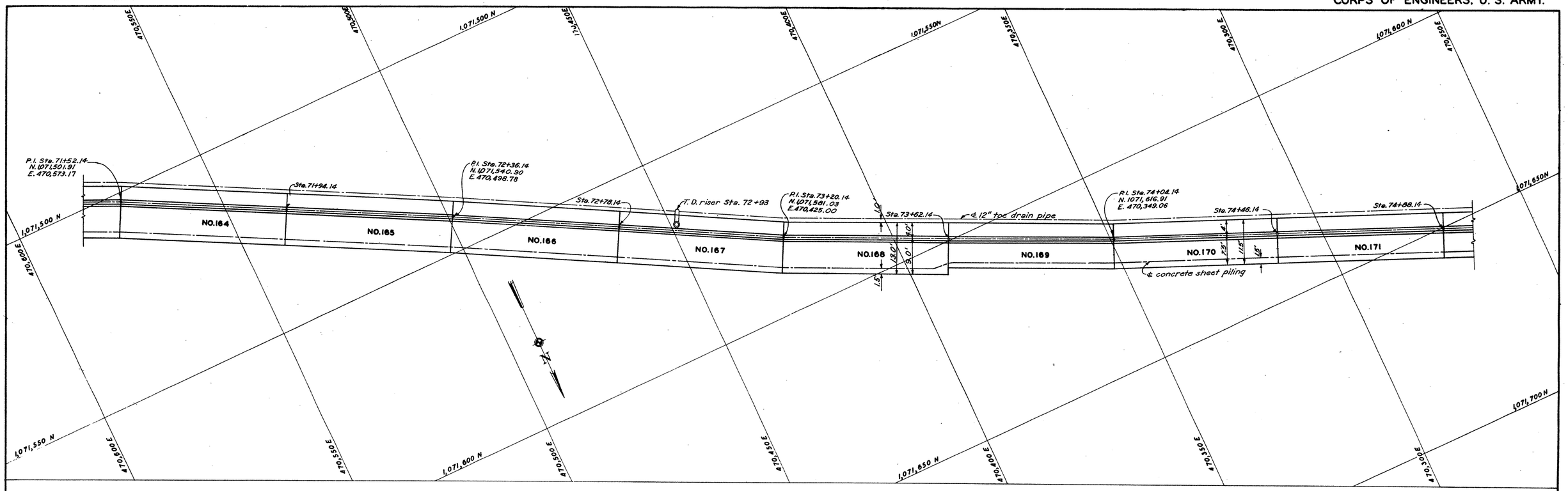
In 23 Sheets — Sheet No. 21 — Scale: as shown

U. S. ENGINEER OFFICE
KANSAS CITY DISTRICT

KANSAS CITY, MO.
JUNE 1944

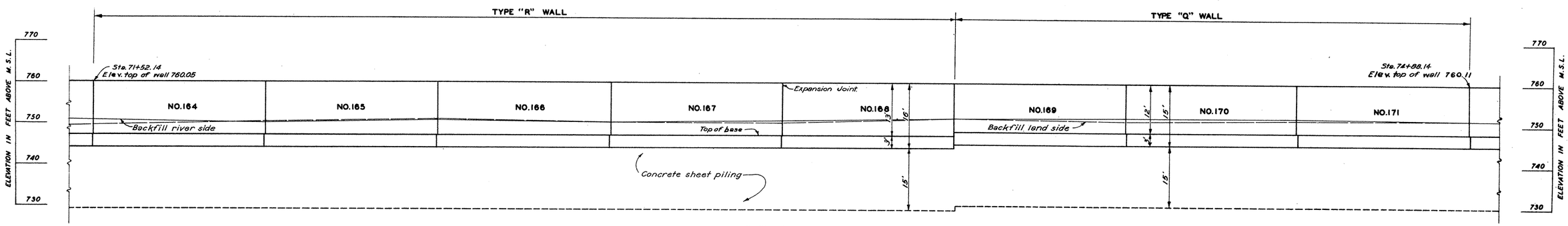
Submitted:	Recommended:	Approved:
Senior Engineer	Principal Engineer	Lt. Colonel, Corps of Engrs.

Drawn By:	Traced By:	Checked By:	To Accompany Specifications	File No.
C. B. O.	J. R. M.	R. L. G.	Dated JANUARY 1946	A-10-733



PLAN

SCALE: 1"=10'-0"



ELEVATION

NOTE-
For typical section showing excavation and backfill payment lines see dwg. No. A-10-784, revised 2-1-45.
For wall details see dwg. No. A-10-824, revised 4-8-46.

RECORD DRAWING

NO.	DATE	BY	REVISIONS	APP'D.
2	6-23-47	G.C.B.	For as built conditions	
1	10-10-44	R.L.G.	Toe drain removed	

KANSAS CITY FLOOD CONTROL PROJECT

CENTRAL INDUSTRIAL DISTRICT
(MISSOURI SECTION)

FLOOD WALL
PLAN AND ELEVATION
SECTIONS-164 TO 171 INC.

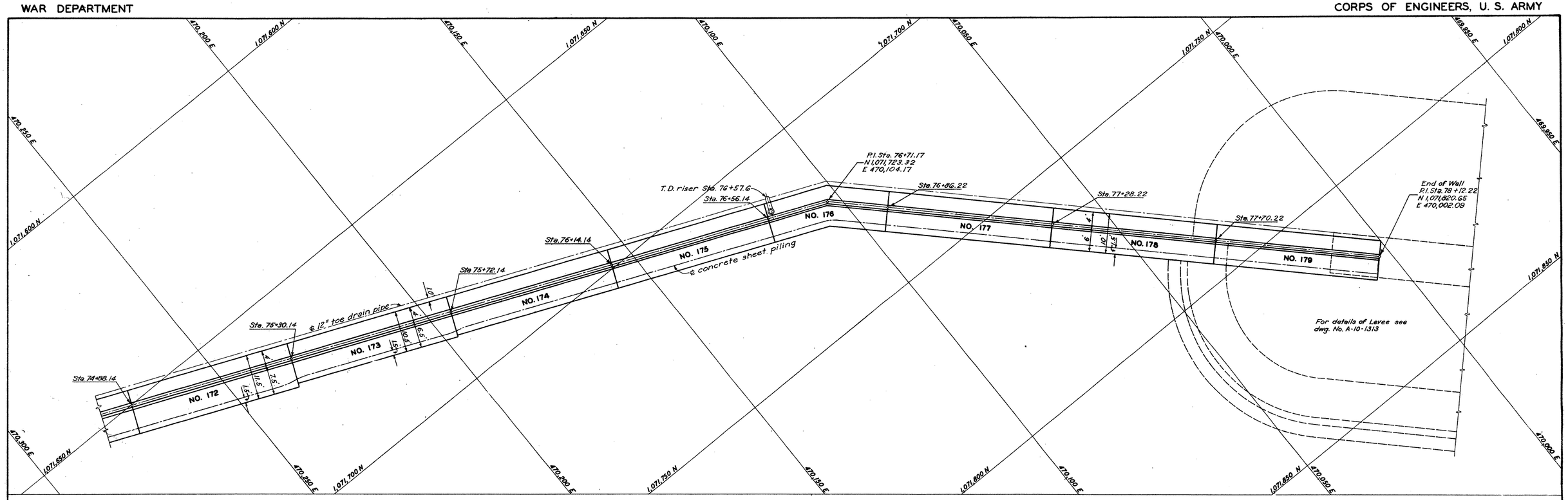
In 23 Sheets. Sheet No. 22 Scale: as shown

U. S. ENGINEER OFFICE
KANSAS CITY DISTRICT

KANSAS CITY, MO.
JUNE 1944

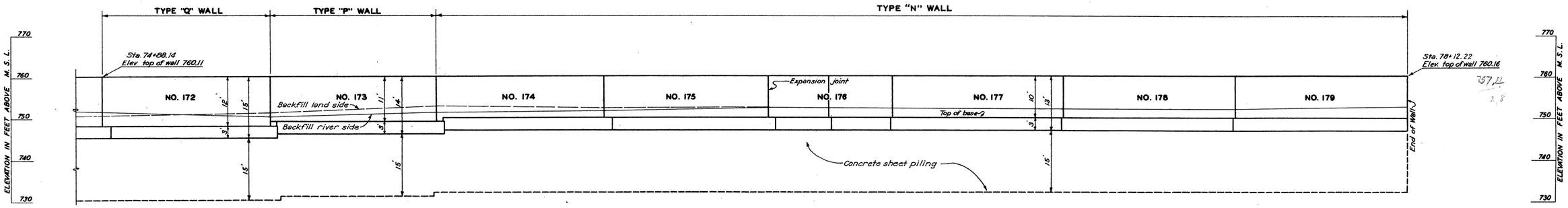
Submitted: Senior Engineer
Recommended: Principal Engineer
Approved: Lt. Colonel, Corps of Engrs.

Drawn By:	Traced By:	Checked By:	To Accompany Specifications	File No.
C.B.O.	J.R.M.	R.L.G.	Dated JANUARY 1946	A-10-734



PLAN

SCALE: 1"=10'-0"



ELEVATION

RECORD DRAWING

NOTE:
For typical section showing excavation and backfill payment lines see dwg. No. A-10-784, revised 2-1-45.
For wall details see dwg. No. A-10-824, revised 4-8-46.

NO.	DATE	BY	REVISIONS	APPROVED
2	6-23-47	G.C.B.	For as built conditions.	
1	11-15-44	R.L.G.	Supersedes dwg. No. A-10-735 Redrawn-Wall relocated & shortened-levee added	

KANSAS CITY FLOOD CONTROL PROJECT

CENTRAL INDUSTRIAL DISTRICT
(MISSOURI SECTION)

FLOOD WALL
PLAN AND ELEVATION
SECTIONS-172 TO 179 INCL.

In 23 Sheets — Sheet No. 23 — Scale: as shown

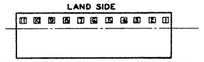
U. S. ENGINEER OFFICE
KANSAS CITY DISTRICT

KANSAS CITY, MO.
NOVEMBER 1944

Submitted:	Recommended:	Approved:
Louis S. Teil, Senior Engineer	R. L. McDonald, Principal Engineer	L. G. Neff, Lt. Col., Corps of Engineers

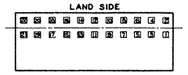
Drawn By:	Traced By:	Checked By:	To Accompany Specifications Dated:	File No.
C. B. O.	J. F. K.	R. L. G.	JANUARY 1946	A-10-790

TYPE "Q"



SECTIONS NOS. 55, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 169, 170, 171, & 172.

TYPE "S"

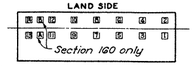


SECTIONS NOS. 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, & 137.

TYPE "N"

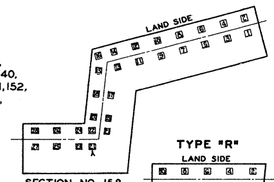
SECTIONS NOS. 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 174, 175, 177, 178 & 179.

TYPE "R"



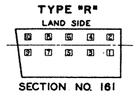
SECTIONS NOS. 51, 52, 53, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 122, 138, 139, 140, 141, 142, 143, 144, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 157, 159, 160, 163, 164, 165, 166, 167 & 168.

TYPE "R"



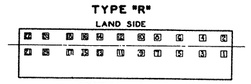
SECTION NO. 158

TYPE "R"



SECTION NO. 161

TYPE "R"

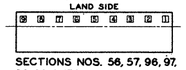


SECTION NO. 162

TYPE "N"

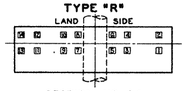
STOP LOG GAP AT STATION 80+18.62

TYPE "P"



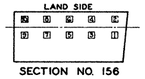
SECTIONS NOS. 56, 57, 96, 97, 98, 99 & 173.

TYPE "R"



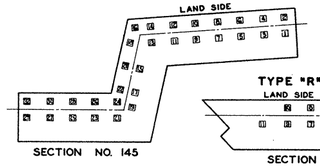
SECTION NO. 54

TYPE "R"



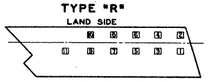
SECTION NO. 156

TYPE "R"



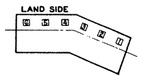
SECTION NO. 145

TYPE "R"

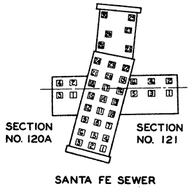


SECTION NO. 50

TYPE "N"



SECTION NO. 176



SANTA FE SEWER

LINEAL FEET DRIVEN

16" X 16"	12,916.5'
18" X 18"	28,629.5'
TOTAL	41,546.5'

CUT-OFF LENGTH

16" X 16"	116.0'
18" X 18"	590.0'
TOTAL	706.0'

TOTAL DOES NOT INCLUDE LINEAL FEET OF BEARING PILE DRIVEN FOR SANTA FE SEWER.

Position	Wall Type	Feet Pile	Tons Bearing
50-1	Spec	21	34.4
2		21	40.7
3		21	42.7
4		21	R
5		21	R
6		19	R
7		21	R
8		15	R
9		16	R
10		13	R
11		12	R
51-1	R	21	36.7
2		21	38.5
3		21	32.9
4		21	36.5
5		21	33.7
6		21	38.5
7		21	39
8		21	38.2
9		22	R
10		21	37.4
11		21	32.4
12		21	35
13		21	34.1
14		21	45
52-1	R	22	R
2		22	R
3		22	R
4		25	32.7
5		22	R
6		22	R
7		21	36.5
8		22	R
9		21	27.5
10		22.5	R
11		22.5	R
12		21	39.6
13		21	38.2
14		21	35.9
53-1	R	22	R
2		21	R
3		25	R
4		22.5	R
5		23.5	R
6		22.5	R
7		26.5	R
8		21.5	R
9		21.5	R
10		21.5	R
11		21.5	R
12		21.5	R
13		22	R
14		22	R
54-1	Spec	31	R
2		33	R
3		31	R
4		23	R
5		24	R
6		21	R
7		25	R
8		22	R
9		23	R
10		21	R
11		25	R
12		21	R
13		22	R
14		21	R
55-1	Q	29	43
2		25	37.5
3		24	35/
4		23	35/
5		23	35/
6		25	40/
7		25	35
8		25	39
9		29	39
10		27	39
11		29	39
56-1	P	25	35
2		23	35
3		29	46
4		29	49
5		29	46
6		29	35/
7		29.5	33/
8		25	27.2
9		29	46

Position	Wall Type	Feet Pile	Tons Bearing
57-1	P	29	36
2		29	35/
3		27	35/
4		27	35/
5		29	35/
6		29	35/
7		29	35/
8		27	35/
9		25	35/
58-1	N	32	35/
2		30	35/
3		30	35/
4		29	35/
5		29	35/
6		29	35/
7		29	35/
59-1	N	32	35/
2		29	25
3		33	35/
4		32	35/
5		32	35/
6		32	35/
7		32	35/
60-1	N	29	32
2		29	30
3		20	30
4		20	30
5		34	35/
6		29	30/
7		29	30/
61-1	N	29	30/
2		27	29/
3		32	35/
4		34	35/
5		32	35/
6		32	35/
7		32	35/
62-1	N	25	28
2		29	26
3		34	34
4		34	34
5		34	34
6		34	32.2
7		34	R
63-1	N	39	50/
2		34	30
3		37	50/
4		38	50/
5		37	50/
6		37	50/
7		35	43
64-1	N	40	34.5
2		43	35
3		25	24.5
4		40	38
5		40	38
6		37	35.7
7		28	34.5
65-1	N	34	48
2		34	43
3		34	43
4		34	37
5		36	50/
6		34	43
7		34	41.5
66-1	N	38	41
2		40	42.5
3		38	45
4		34	38
5		34	38
6		34	42.5
7		34	38
67-1	N	25	27
2		34	39
3		40	44.5
4		40	44.5
5		40	44.5
6		38	33.7
7		40	41

Position	Wall Type	Feet Pile	Tons Bearing
68-1	N	29	36
2		21	39
3		21	39
4		21	41
5		21	39
6		21	36
7		21	30
69-1	N	21	44
2		21	44
3		21	48
4		21	48
5		21	44
6		21	44
7		21	50/
70-1	N	20.5	50/
2		21	50/
3		21	50/
4		21	50/
5		21	50/
6		21	44
7		21	44
71-1	N	21	50/
2		21	50/
3		21	50/
4		21	50/
5		21	50/
6		21	50/
7		21	50/
72-1	N	21	50/
2		21	50/
3		21	50/
4		21	50/
5		21	50/
6		21	50/
7		21	50/
73-1	N	21	49
2		21	50
3		21	50
4		21	50
5		21	50
6		21	50
7		21	50
74-1	N	21	39
2		21	38
3		21	38
4		21	41
5		21	38
6		21	44
7		21	44/
75-1	N	21	44/
2		21	44/
3		21	34
4		21	37
5		21	38
6		21	39
7		21	34
76-1	N	21	44
2		21	39
3		21	41
4		21	39
5		21	44/
6		21	44
7		21	44
77-1	N	21	39
2		21	38
3		21	41
4		21	39
5		21	36
6		21	44
7		21	38
78-1	N	21	38
2		21	37
3		21	39
4		21	37
5		21	35
6		21	37
7		21	39

Position	Wall Type	Feet Pile	Tons Bearing
79-1	N	25	38.7
2		21	43.5
3		21	39
4		21	38
5		21	41
6		21	39
7		21	38
80-1	N	21	38
2		21	34
3		21	37
4		21	38
5		21	38
6		21	44/
7		21	44
81-1	N	21	37
2		21	38
3		21	34
4		21	34
5		21	38
6		21	38
7		21	37
82-1	N	21	44
2		21	36
3		21	39
4		21	38
5		21	41
6		21	38
7		21	38
83-1	N	21	44
2		21	39
3		21	39
4		21	37
5		21	32
6		21	44
7		21	39
84-1	N	21	36
2		21	38
3		21	36
4		21	38
5		21	44
6		21	38
7		21	39
85-1	N	21	39
2		21	31
3		21	44
4		21	38
5		21	36
6		21	34
7		21	31
86-1	N	21	44
2		21	38
3		21	38
4		21	44/
5		21	41
6		21	39
7		21	44
87-1	N	21	39
2		21	44/
3		21	44
4		21	41
5		21	37
6		21	44/
7		21	39
88-1	N	21	39
2		21	41
3		21	41
4		21	44/
5		21	44
6		21	37
7		21	37
89-1	N	25	44
2		21	41
3		21	44/
4		21	44/
5		21	39
6		21	44/
7		21	38

Position	Wall Type	Feet Pile	Tons Bearing
90-1	N	21	44/
2		21	44
3		21	44
4		21	39
5		21	28.2
6		21	36
7		21	39
91-1	N	21	39
2		21	41
3		21	38
4		21	34
5		21	38
6		21	41
7		21	39
92-1	N	21	44/
2		21	44/
3		21	44/
4		21	44/
5		21	44/
6		21	34
7		21	39
93-1	N	21	44/
2		21	44/
3		21	44/
4		21	44/
5		21	44/
6		21	44/
7		21	44/
94-1	N	21	42.2
2		21	44
3		21	44/
4		21	44/
5		21	44/
6		21	44/
7		21	44/
95-1	N	21	50/
2		21	48
3		40	44
4		40	41
5		40	40
6		40	36
7		26	42
96-1	P	21	44
2		21	44
3		21	44
4		21	44/
5		21	44/
6		20	44
7		21	44
8		21	44
9		21	44
97-1	P	25	38.5
2		25	43.5
3		21	38.7
4		21	38.5
5		21	44
6		21	38
7		21	38
8		21	38
9		21	44
98-1	P	21	41
2		21	41
3		21	44
4		21	44/
5		21	44/
6		21	44
7		21	38.5
8		21	38.5
9		21	38.5
99-1	P	21	37
2		21	37
3		21	37
4		21	41
5		21	37
6		21	41
7		21	44
8		20	41
9		21	41

Position	Wall Type	Feet Pile	Tons Bearing
100-1	Q	21	39
2		21	44
3		21	34
4		21	36
5		21	41
6		21	39
7		21	36
8		21	38
9		21	37
10		21	37
11		21	37
101-1	Q	21	44/
2		21	37
3		21	41
4		21	41
5		21	41
6		21	44/
7		21	41
8		21	44
9		21	41
10		21	41
11		21	44
102-1	Q	21	44/
2		21	38
3		21	44
4		21	38
5		21	37
6		21	37
7		21	38
8		21	37
9		21	38
10		21	41
11		21	37
103-1	Q	21	38
2		21	37
3		21	37
4		21	38
5		21	37
6		21	38
7		21	37
8		21	37
9		21	38
10		21	41
11		21	44
104-1	Q	21	44
2		21	39
3		21	44/
4		21	44/
5		21	44
6		21	44
7		21	38
8		21	38
9		21	44/
10		21	41
11		20.5	44/
105-1	Q	21	44
2		21	44/
3		21	44/
4		21	44
5		21	44
6		21	44/
7		21	44/
8		21	44/
9		21	44/
10		21	44
11		21	42.5
106-1	Q	21	44/
2		21	44/
3		21	44/
4		21	44/
5		21	44/
6		21	44/
7		21	44/
8		21	44/
9		21	41
10		21	44
11		21	44/

Position	Wall Type	Feet Pile	Tons Bearing
107-1	Q	25	33.2
2		25	41.2
3		21	38.2
4		21	38.2
5		21	44
6		21	44/
7		21	44/
8		21	44/
9		21	44/
10		21	44/
11		21	44/
108-1	Q	21	44
2		21	41
3		21	39
4		21	37
5		21	37
6		21	39
7		21	37
8		21	37
9		19.5	34.2
10		21	38
11		21	44/
109-1	Q	21	44
2		21	44/
3		21	44/
4		21	44/
5		21	44
6		21	44
7		21	44
8		21	44/
9		21	44
10		21	44
11		21	44
110-1	R	21	44
2		20	39
3		21	39
4		21	44/
5		21	44/
6		21	44/
7		21	44
8		21	44/
9		21	43
10		21	39
11		21	44
12		21	44
13		21	41
14		21	41
111-1	R	21	37
2		21	38
3		21	37
4		21	39
5		21	38
6		21	38
7		21	38
8		21	38
9		21	37
10		21	39
11		21	37
12		21	41
13		21	39
14		21	41
112-1	R	21	44
2		21	39
3		21	38
4		21	38
5		21	34
6		21	38
7		21	37
8		21	37
9		21	38
10		21	37
11		21	37
12		21	39
13		20	39
14		21	37

Position	Wall Type	Feet Pile	Tons Bearing
113-1	R	21	34
2		21	38
3		21	38
4		21	38
5		21	38
6		21	38
7		21	38
8		21	38
9		21	38
10		21	41
11		21	41
12		21	38
13		21	41
14		21	41
114-1	R	21	38
2		21	38
3		21	38
4		21	38
5		25	31.7
6		25	35.7
7		21	31.7
8		25	31.7
9		21	34
10		21	38
11		21	41
12		21	38
13		21	39
14		21	41
115-1	R	21	41
2		21	44
3		21	45
4		21	41
5		21	39
6		21	41
7		21	39
8		21	39
9		21	39
10		21	41
11		21	34
12		21	37
13		21	34
14		21	37
116-1	R	21	44/
2		21	44
3		21	41
4		21	44
5		21	39
6		21	44/
7		21	44
8		21	44
9		21	41
10		21	41
11		21	40
12		21	40
13		21	41
14		21	44
117-1	R	21	41
2		21	41
3		21	44
4		21	41
5		21	41
6		21	41
7		21	38
8		21	41
9		21	41
10		21	41
11		21	41
12		21	41
13		21	41
14		21	41
118-1	R	21	44
2		21	44/
3		21	44/
4		21	44
5		21	44
6		21	44
7		21	44/
8		21	44
9		21	44
10		21	44
11		21	44
12		21	43
13		21	44
14		21	42

Position	Wall Type	Feet Pile	Tons Bearing
119-1	R	21	44
2		21	44
3		21	39
4		18	41
5		21	42
6		21	44
7		21	41
8		21	44
9		21	42
10		21	44/
11		21	42
12		21	44/
13		21	39
14		21	44
120-1	R	21	31
2		21	30
3		21	44
4		21	43
5		21	44
6		21	44/
7		21	44
8		21	44/
9		21	44
10		21	44/
11		21	44/
12		21	44
13		21	41
14		21	39
120A-1		37	37.2
2		36	44.9
3		40	39.1
4		38	41.5
Santa Fe Sewer-1	Spec	25	50
2		25	50
3		25	50
4		25	42
5		25	41
6		29	44
7		21	28
8		25	50
9		25	42
10		25	46
11		25	41
12		25	42
13		25	50
14		25	47
15		25	44
16		25	50
17		25	50
18		25	46
19		25	41
20		25	42
21		25	38
22		25	45
23		25	46
24		25	50
25		25	41
26		25	37
27		25	50
28		25	48
29		25	38
30		21	36
121-1	Spec	45	41.1
2		45	42.7
3		40	33.7
4		45	43.5
5		45	38.2
6		45	42.8
122-1	R	21	34.5
2		21	38
3		21	41
4		21	45
5		21	43.4
6		21	44.5
7		21	42.5
8		21	43
9		21	38.5
10		21	50/
11		21	49
12		21	38.5
13		21	41
14		21	42.5

R = Refusal

RECORD DRAWING

NO.	DATE	BY	REVISION	APP'D
1	6-23-47	G.C.B.	For as built conditions.	

KANSAS CITY FLOOD CONTROL PROJECT

CENTRAL INDUSTRIAL DISTRICT

(MISSOURI SECTION)

FOUNDATION PILING
BEARING CAPACITY

In 2 Sheets — Sheet No. 1 — Scale as shown

CORPS OF ENGINEERS, KANSAS CITY DISTRICT — KANSAS CITY, MO. APRIL 1948

Submitted:	Recommended:	Approved:
Chief, Design Branch	Chief, Engineering Division	Col, C.of E., District Engineer

Drawn By:	Traced By:	Checked By:	To Accompany Specifications	File No.
C.A.P.	O.C.T.	R.L.G.	Dated: JANUARY 1948	A-10-1178

Position	Wall Type	Feet Pile	Tons Bearing
123-1	S	21	37
2		21	38.7
3		21	38.5
4		21	39
5		21	41
6		21	42
7		21	42
8		21	44/
9		21	40
10		21	43.5
11		21	40
12		21	44/
13		21	38.5
14		21	41
15		21	41
16		21	45
17		21	43.5
18		21	45/
19		21	46
20		21	45
21		21	45/
22		21	45/
124-1	S	21	37.5
2		21	37.6
3		21	35.6
4		21	30
5		21	35.5
6		21	35.5
7		21	33
8		21	36.6
9		21	41
10		21	43
11		21	38.5
12		21	38
13		21	38
14		21	38
15		21	38.8
16		21	38.6
17		21	37
18		21	39
19		21	31.5
20		21	38.5
21		21	38.6
22		21	37.5
125-1	S	21	37.5
2		21	39
3		21	38.5
4		21	41
5		21	37.5
6		21	37.5
7		21	37.6
8		21	37.6
9		21	37.6
10		21	37.5
11		21	37.6
12		21	38.4
13		21	35.5
14		21	37.6
15		21	38.5
16		21	38.5
17		21	38.6
18		21	37.5
19		21	38.2
20		21	38
21		21	38
22		21	36
126-1	S	21	37
2		21	41
3		21	37
4		21	41
5		21	37
6		21	37
7		21	41
8		21	42
9		21	41
10		21	38
11		21	41/
12		21	38
13		21	37
14		21	44/
15		21	38
16		21	44
17		21	37
18		21	37
19		21	37
20		21	37
21		21	36
22		21	38
127-1	S	21	34
2		21	42
3		21	34
4		21	36
5		21	34
6		21	34
7		21	36
8		21	44
9		21	39
10		21	36
11		21	38
12		21	38
13		21	34
14		21	38
15		21	34
16		21	38
17		21	36
18		21	39
19		21	36
20		21	38
21		21	36
22		21	36

Position	Wall Type	Feet Pile	Tons Bearing
128-1	S	21	34
2		21	34
3		21	33
4		21	32
5		21	28
6		21	34
7		21	30
8		21	31
9		21	34
10		21	37
11		21	38
12		21	38
13		21	37
14		21	38
15		21	39
16		21	38
17		21	37
18		21	38
19		21	37
20		21	38
21		21	37
22		21	37
129-1	S	21	30
2		21.5	44/
3		21	31
4		21	31
5		21	31
6		21	30
7		21	30
8		21	30
9		21	28
10		21	28
11		21	30
12		21	30
13		21	31
14		21	30
15		21	34
16		21	29
17		21	30
18		21	34
19		21	37
20		21	32
21		21	34
22		21	34
130-1	S	25	24
2		21	27.5
3		25	25
4		21	33
5		25	26
6		21	34
7		25	28.5
8		21	31.5
9		25	25
10		21	27
11		25	22.5
12		25	26
13		21	22
14		49	37.5
15		21	26.5
16		25	26.5
17		21	28
18		21	28
19		21	25
20		21	33
21		21	30
22		21	30
131-1	S	21	32.5
2		25	38
3		21	31.8
4		21	37.5
5		21	21.5
6		25	26
7		21	24.5
8		25	34.5
9		21	21.5
10		25	31.5
11		21	25.5
12		25	31.4
13		21	21.5
14		46	37
15		21	30
16		21	30
17		21	23.5
18		46	42.5
19		41	23.5
20		45	42.5
21		40	30.5
22		49	41.5
132-1	S	21	32
2		21	34.5
3		21	37
4		21	35
5		21	39
6		21	37
7		21	37
8		21	37.5
9		21	35
10		21	33
11		21	37.5
12		21	37
13		21	35
14		21	37.5
15		21	31
16		21	33
17		21	32.5
18		21	35
19		21	34.5
20		21	34.5
21		21	29.7
22		21	31

Position	Wall Type	Feet Pile	Tons Bearing
133-1	S	21	41
2		21	46.5
3		21	39
4		21	43
5		21	46.5
6		21	51
7		21	41.2
8		21	48
9		21	48
10		21	49
11		21	40.5
12		25	50.7
13		21	44
14		21	47/
15		21	44
16		21	45
17		21	37.5
18		21	44
19		21	44
20		21	41.7
21		21	37.5
22		21	37.5
134-1	S	21	44.5
2		21	38
3		21	44
4		21	43.5
5		21	47
6		21	33.5
7		21	46.4
8		21	45
9		21	45.1
10		21	32
11		21	45.1
12		21	44
13		21	46
14		21	44
15		21	45
16		26	28.5
17		21	46.5
18		21	44
19		21	40.4
20		21	31
21		21	44
22		21	43
135-1	S	21	43
2		21	42
3		21	37.5
4		21	36
5		21	50/
6		21	50/
7		21	50/
8		21	49
9		21	50/
10		21	50/
11		21	45.5
12		21	42
13		21	46.7
14		21	44
15		21	46
16		21	49
17		21	45
18		21	44.2
19		21	44
20		21	42
21		21	44
22		21	43.2
136-1	S	21	43
2		21	41
3		21	39.5
4		21	43
5		21	38
6		21	44
7		21	42.5
8		21	46
9		21	50/
10		21	39.5
11		21	32.8
12		21	42.2
13		21	33.6
14		21	43
15		21	43
16		21	43
17		21	50/
18		21	41.6
19		21	50/
20		21	42.1
21		21	40.9
22		21	50/
137-1	S	21	41.7
2		21	40.8
3		21	39.5
4		21	44.5
5		21	44
6		21	43.5
7		21	46.1
8		21	50/
9		21	46
10		21	50/
11		21	46.6
12		21	50/
13		21	44.5
14		21	40.1
15		21	37.5
16		21	50/
17		21	34.5
18		21	46.1
19		21	43.5
20		21	44.5
21		21	41.7
22		21	44

Position	Wall Type	Feet Pile	Tons Bearing
138-1	R	21	32
2		25	44
3		21	50/
4		25	47.2
5		21	46
6		21	41.7
7		21	48.9
8		21	50/
9		21	43
10		21	40.1
11		21	44
12		21	45.6
13		21	44.5
14		21	40.1
139-1	R	25	38.9
2		40	40.2
3		25	36.9
4		40	41.5
5		25	36.1
6		40	43.5
7		25	42
8		34	36.1
9		25	50/
10		25	43.1
11		21	40.9
12		25	48.1
13		21	37.5
14		21	38
140-1	R	25	41.5
2		40	43
3		25	32.2
4		29	36.9
5		25	33
6		37	41
7		21	31
8		40	43.2
9		40	45
10		40	46
11		25	30.4
12		34	37.9
13		25	30
14		40	40.1
141-1	R	25	32.2
2		29	26
3		25	30
4		40	41
5		25	31.4
6		40	37
7		25	36.9
8		40	40.2
9		25	35.5
10		40	45.5
11		25	35.2
12		40	41
13		25	43
14		40	44.5
142-1	R	29	42.1
2		34	41.9
3		25	36.9
4		30	36
5		25	33.9
6		34	35.7
7		25	31.4
8		34	43.2
9		25	32.2
10		34	36.2
11		25	36.2
12		29	30.6
13		25	38.2
14		29	32.6
143-1	R	32	39.1
2		34	48.7
3		34	44.7
4		34	44.1
5		29	32.7
6		31	42.5
7		29	32.7
8		34	37.4
9		29	40.2
10		34	38.7
11		29	41.6
12		34	28
13		25	30.4
14		25	24.5
144-1	R	37	42.4
2		32	37.5
3		45	45.2
4		36	46
5		36	46/
6		34	40
7		40	43.5
8		33	47.7
9		34	40.5
10		22	32.8
11		32	34.9
12		34	46.2
13		34	41.2
14		34	47.9

Position	Wall Type	Feet Pile	Tons Bearing
145-1	Spec	34	46.2
2		32	50
3		34	50
4		34	50
5		25	38.9
6		34	50
7		25	31.4
8		34	50
9		34	50
10		34	50
11		34	50
12		30	46.4
13		25	30.4
14		34	50/
15		34	49.5
16		34	50/
17		34	49
18		34	49
19		25	30.4
20		34	50
21		34	47.5
22		34	48.5
23		34	46.4
24		34	48
25		34	44.8
26		34	49.8
27		34	34.9
28		34	50/
29		34	48.5
30		35	46
31		36	46
146-1	R	33	37
2		45	46/
3		34	46
4		31	36.2
5		34	50/
6		45	46/
7		34	50/
8		45	46/
9		25	50/
10		34	48.1
11		25	31.4
12		36	34.5
13		25	30.4
14		34	49.5
147-1	R	25	32.2
2		34	47.2
3		25	33
4		25	39.9
5		25	31.4
6		34	46.5
7		25	31.4
8		34	43.2
9		45	49
10		34	36.9
11		45	46/
12		45	46/
13		34	33.4
14		45	46/
148-1	R	34	49
2		34	50/
3		34	48.5
4		34	49
5		34	48
6		34	50/
7		34	47.7
8		34	45.1
9		34	47.4
10		34	45.1
11		25	38.9
12		31	46.5
13		25	38.9
14		34	50/
149-1	R	34	43.5
2		45	39
3		34	44.2
4		38	45.1
5		34	38.5
6		45	46/
7		34	33.4
8		34	38.5
9		34	43.2
10		45	43.5
11		34	41.5
12		45	46/
13		34	39
14		34	43.2
150-1	R	45	46/
2		40	38.4
3		40	40.2
4		45	46/
5		45	45.7
6		34	40.1
7		28	32.9
8		34	35.7
9		34	43
10		34	35.4
11		32	31.2
12		41	38.6
13		34	37.4
14		39	35.2

Position	Wall Type	Feet Pile	Tons Bearing
151-1	R	29	33.4
2		32	37.5
3		42	43
4		31	36.7
5		45	44.9
6		45	46/
7		31	37
8		45	46/
9		45	44.2
10		45	46/
11		25	30.4
12		45	46/
13		31	39
14		45	46/
152-1	R	45	46/
2		45	46/
3		45	44
4		45	45.7
5		45	43
6		45	44.7
7		29	38.2
8		29	50/
9		45	45.2
10		45	45.9
11		45	46/
12		45	46/
13		45	46/
14		41	46
153-1	R	45	46/
2		45	41.2
3		45	44.4
4		34	26.7
5		45	40.7
6		45	38
7		45	39.2
8		45	36.4
9		45	37
10		45	41
11		45	37.5
12		45	46/
13		45	42.4
14		42	43.5
154-1	R	30	35.1
2		35	47
3		40	50/
4		40	50/
5		40	50/
6		40	50/
7		31	33/
8		40	47
9		40	44.5
10		40	41
11		45	38.9
12		38	38.6
13		45	41.5
14		45	40
155-1	R	25	28.8
2		40	49
3		25	49
4		40	51
5		25	29.7
6		40	47
7		25	30
8		40	47
9		25	28.6
10		40	47
11		40	50/
12		40	50/
13		40	50/
14		40	50/
156-1	Spec	25	35.2
2		27	50/
3		25	30
4		34	50/
5		25	29.8
6		34	50/
7		25	30
8		29	31.2
9		25	30
10		29	32
157-1	R	34	50/
2		30	50/
3		25	43
4		25	34.5
5		25	31.5
6		34	35.2
7		34	25
8		25	32.2
9		25	28.6
10		34	50/
11		25	28.7
12		34	50/
13		25	31.5
14		25	50/

Position	Wall Type	Feet Pile	Tons Bearing
158-1	Spec	34	37
2		34	37
3		34	33.3
4		34	37
5		34	33.3
6		34	42.6
7		34	48
8		34	47.5
9		34	45
10		34	44.7
11		34	47.3
12		34	31.3
13		34	39.7
14		34	41.5
15		34	39.7
16		34	41.6
17		34	38.5
18		34	41.5
19		34	35.3
20		34	32.3
21		34	27.5
21A		34	32.7
22		34	32.7
23		34	35.3
24		34	31.7
25		34	37
26		34	35.3
27		34	44.2
28		31	50/
14		34	29.3
159-1	R	34	36.5
2		34	43.2
3		34	35.7
4		34	43.2
5		34	35.7
6		34	43.2
7		34	43.2
8		34	43.2
9		34	39.7
10		34	43.2
11		34	45
12		34	47.7
13		34	46
14		34	46
160-1	R	40	38
2		40	44.5
3		40	41
4		40	41
5		40	41
6		40	43
7		31	25
8		40	43.1
9		40	41
10		40	47
11		40	46.1
12		34	38
A		21	24.7
B		25	23.5
13		40	44.5
14		34	47
161-1	Spec	29	37.5
2		34	46
3		21	35.5
4		21	28.2
5		25	26.7
6		40	37
7		26	24.5
8		34	37
9		34	29.5
10		40	38.2
162-1	Spec	46	29
2		45	30
3		46	26.5
4		45	30
5		45	27
6		45	30
7		45	31
8		49	33
9		40	32.5
10		45	31
11		38	41
12		31	31.8
13		40	32.7
14		34	47.5
15		29	32.4
16		32	40.4
17		25	25.7
18		23	31.5
19		25	25.7
20		34	36
21		29	36/
22		34	50
163-1	R	45	37.8
2		45	46
3		45	30
4		45	33.2
5		45	33.5
6		45	31.7
7		45	28.7
8		45	31.4
9		45	24.5
10		45	30.7
11		46	25
12		46	29.5
13		46	27.7
14		46	29.5

Position	Wall Type	Feet Pile	Tons Bearing
164-1	R	34	43
2		35	50/
3		34	25
4		34	35
5		34	25
6		34	28
7		40	50/
8		40	50/
9		40	50/
10		40	50/
11		40	50/
12		40	38
13		40	25
14		40	29.3
165-1	R	40	24.4
2		40	31.5
3		40	30.5
4		40	46
5		40	44.4
6		40	44.4
7		40	44.4
8		40	44.4
9		39	50/
10		39	50/
11		37	50/
12		36	50/
13		37	50/
14		34	29.3
166-1	R	34	25
2		38	46
3		40	50/
4		38	50/
5		40	44.5
6		40	45.2
7		40	38.6
8		40	44.6
9		40	50/
10		41.5	50/
11		40	26
12		41	50/
13		40	25
14		40	35.4
167-1	R	32	50/
2		38	50/
3		34	50/
4		31	50/
5		34	50/
6		32	50/
7		34	50/
8		32	50/
9		34	50/
10		32	50/
11		34	50/
12		34	50/
13		21	22.7
14		34	47
168-1	R	21	28.5
2		21	30
3		21	25.1
4		21	30
5		21	25.1
6		21	30
7		21	25.1
8		21	30.1
9		21	25.1
10		21	30
11		21	25.1
12		34	45
13		46	45
14		45	50/
169-1	Q	21	31
2		21	30
3		25	35
4		25	37.5
5		21	30.2
6		21	16.5
7		21	29.9
8		21	30
9		21	29.9
10		21	29.9
11		21	29.9
170-1	Q	21	30.5
2		21	30
3		21	30.5
4		21	30
5		21	32.4
6		21	30.5
7		21	30.2
8		21	30.5
9		21	30.2
10		21	30.0
11		21	29.8
171-1	Q	21	30
2		21	30
3		21	30
4		21	30
5		21	30.5
6		21	30
7		21	30.2
8		21	29.8
9		21	30
10		21	30
11		21	29.8

Position	Wall Type	Feet Pile	Tons Bearing
172-1	Q	21	30.4
2		21	31.5
3		21	32
4		21	33.5
5		21	32.5
6		21	30.5
7		21	32.5
8		21	31.5
9		21	32
10		21	30.4
11		21	32.7
175-1	P	21	31.7
2		21	45
3		21	38.5
4		21	35.5
5		21	32
6		21	32
7		21	34.2
8		21	33
9		21	32.9
174-1	N	21	30
2		21	31.5
3		21	31.6
4		21	30.5
5		21	30.6
6		21	30.6
7		21	31.6
175-1	N	21	38.5
2		21	41.5
3		21	38.5
4		21	35
5		21	35
6		21	34
7		21	35
176-1	Spec	21	36.2
2		21	37.7
3		21	37.8
4		21	38.7
5		21	36.2
6		21	36.7
177-1	N	21	37.7
2		21	41.8
3		21	41.2
4		21	41.5
5		21	34
6		21	26.7
7		21	35
178-1	N	21	37
2		21	35
3		25	38
4		25	30
5		25	22
R		21	30.6
6		21	26.7
7		21	38.6
179-1	N	21	19.5
A		21	29.5
2		21	23.7
3		25	31
4		21	33
5		21	31
6		21	37
7		21	36
180-1			
Stop Log 80/18.6			
1	Spec	21	15
A		21	30.5
2		21	27.5
B		21	31.5
3		21	26.7
C		21	31.5
4		21	24.5
D		21	30.8
5		21	26.3
6		21	27
E		21	32.5
7		21	27
8		21	30.8
9		21	27.5
10		21	30.2
11		21	29.7
12		21	30.2
F		21	27.5
13		21	26.3
G		21	27
14		21	22.6
H		21	26.3
15		21	26

RECORD DRAWING

NO.	DATE	BY	REVISION	APP'D
1	6-23-47	G.C.B.	For as built conditions.	

KANSAS CITY FLOOD CONTROL PROJECT

CENTRAL INDUSTRIAL DISTRICT

(MISSOURI SECTION)

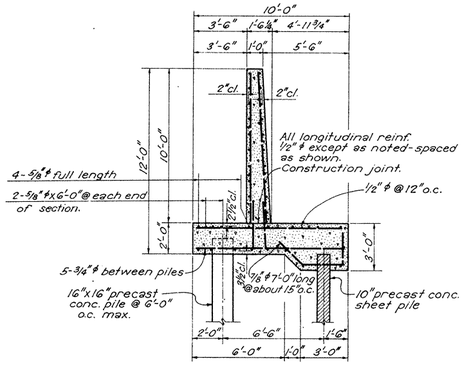
FOUNDATION PILING BEARING CAPACITY

In 2 Sheets — Sheet No. 2 — Scale: as shown

CORPS OF ENGINEERS, KANSAS CITY DISTRICT — KANSAS CITY, MO. APRIL 1948

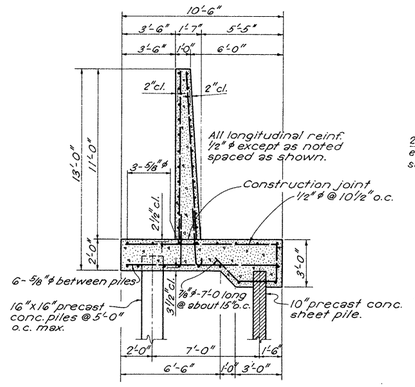
Submitted: Chief, Design Branch — Recommended: Chief, Engineering Division — Approved: Col, Corps of Engineers, District Engineer

Drawn By:	Traced By:	Checked By:	To Accompany Specifications	File No.
C.A.P.	O.C.T.	R.L.G.	Date JANUARY 1946	A-10-1179



TYPICAL SECTION

Scale: 1/4" = 1'-0"



TYPICAL SECTION

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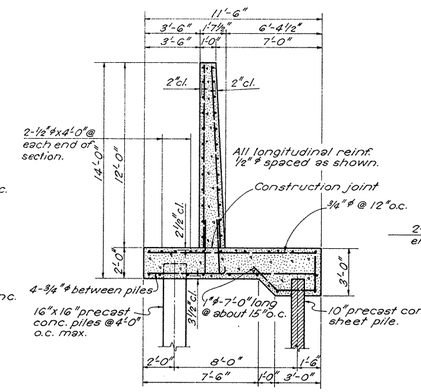
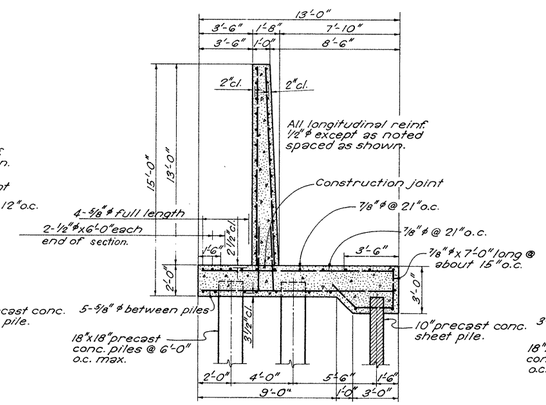


TYPICAL SECTION

Scale: 1/4" = 1'-0"



TYPICAL SECTION

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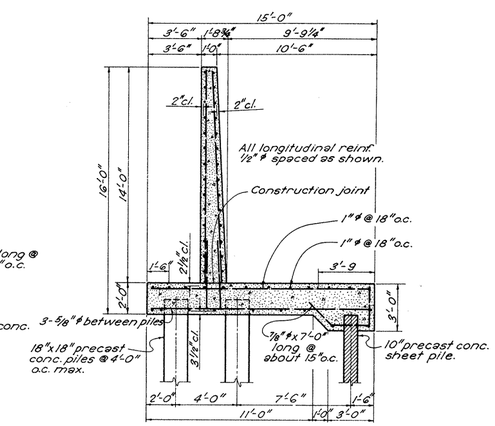
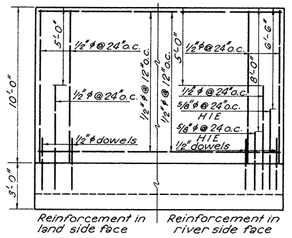


TYPICAL SECTION

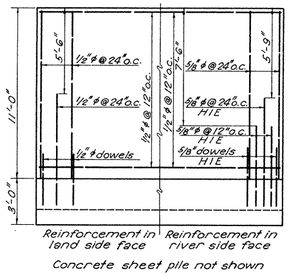
Scale: 1/4" = 1'-0"



RIVER SIDE ELEVATION

Scale: 1/4" = 1'-0"

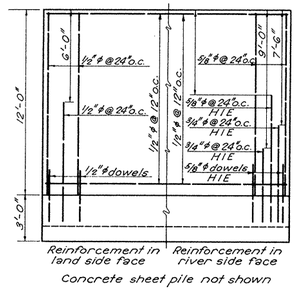
TYPE 'N' WALL



RIVER SIDE ELEVATION

Scale: 1/4" = 1'-0"

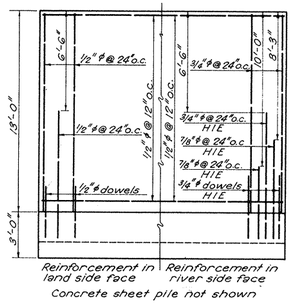
TYPE 'P' WALL



RIVER SIDE ELEVATION

Scale: 1/4" = 1'-0"

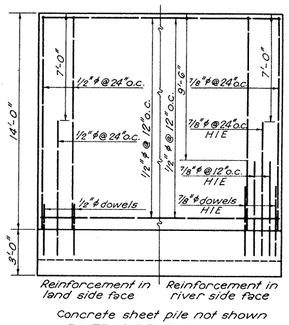
TYPE 'Q' WALL



RIVER SIDE ELEVATION

Scale: 1/4" = 1'-0"

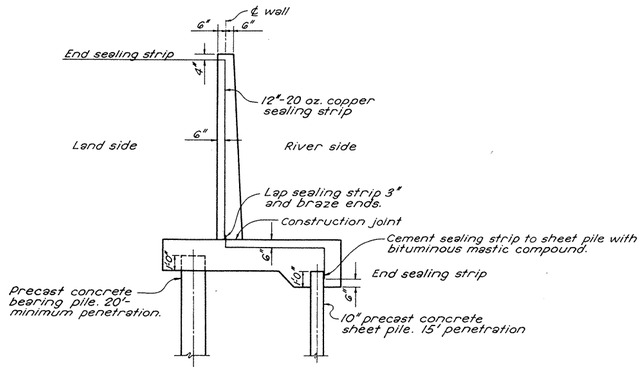
TYPE 'R' WALL



RIVER SIDE ELEVATION

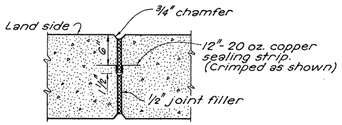
Scale: 1/4" = 1'-0"

TYPE 'S' WALL

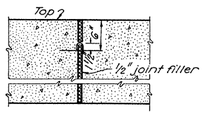


TYPICAL END VIEW

Scale: 1/4" = 1'-0"



VERTICAL WALL



BASE SLAB

TYPICAL SECTION THRU EXPANSION JOINT

No Scale

NOTE

All exposed corners shall be chamfered 3/4 inch.
All reinforcement shall be lapped 40 diameters.
For precast concrete pile details see dwg. No. A-10-825.

RECORD DRAWING

NO.	DATE	BY	REVISION	APP'D
2	6-23-47	G.C.B.	As built	
1	4-8-46	R.L.G.	Pile spacing in type 'O' and 'S' walls and reinforcement in all walls revised	

KANSAS CITY FLOOD CONTROL PROJECT

CENTRAL INDUSTRIAL DISTRICT

(MISSOURI SECTION)

CONCRETE DETAILS

FLOOD WALLS TYPES 'N', 'P', 'Q', 'R' & 'S'

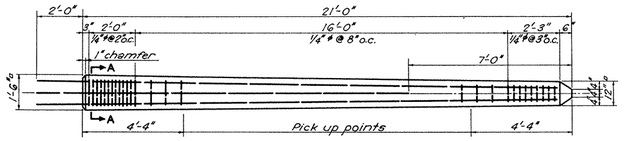
In 1 Sheet — Sheet No. 1 — Scale as shown

U.S. ENGINEER OFFICE
KANSAS CITY DISTRICT

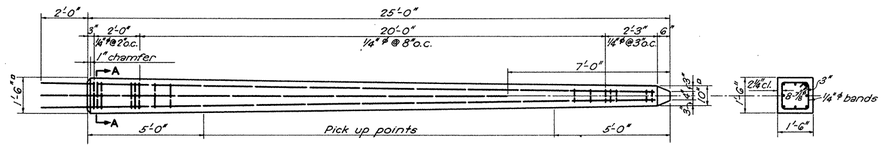
KANSAS CITY, MO.
OCTOBER 1945

Submitted:	Recommended:	Approved:
Principal Engineer	Lt. Colonel, Corps of Engrs.	Colonel, Corps of Engrs.

Drawn By:	Traced By:	Checked By:	To accompany specifications	File No.
L.B.D.	B.U.T.	R.L.G.	Dated: JANUARY 1946	A-10-824

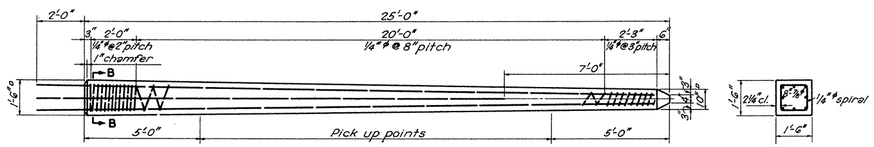


21'-0" BEARING PILES



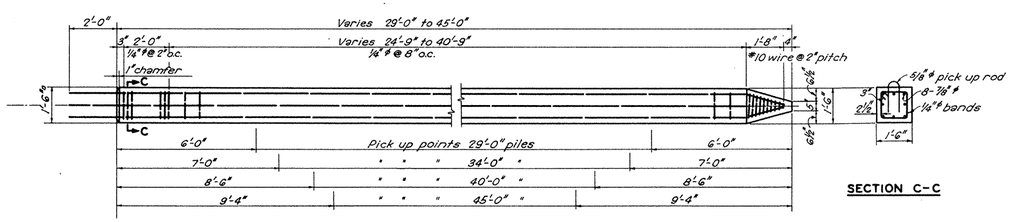
± 75%-25'-0" BEARING PILES

SECTION A-A



± 25%-25'-0" BEARING PILES

SECTION B-B

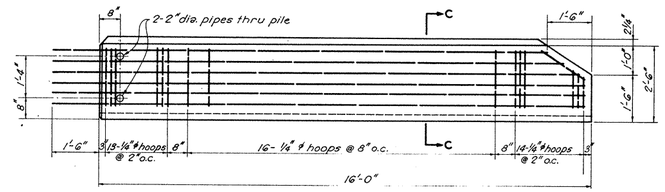


SECTION C-C

29'-0", 34'-0", 40'-0" & 45'-0" BEARING PILES

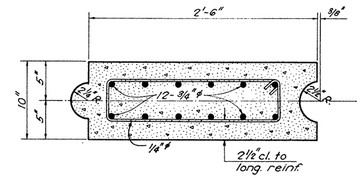
BEARING PILE DETAILS

Scale: 3/8" = 1'-0"



PLAN

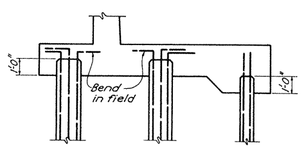
Scale: 1/2" = 1'-0"



SECTION C-C

Scale: 1 1/2" = 1'-0"

PRECAST CONCRETE SHEET PILE



DETAIL OF CONNECTION BETWEEN PILES AND WALL BASE

No scale

RECORD DRAWING

NO.	DATE	BY	REVISIONS	APP'D.
2	6-23-47	G.C.B.	Revised for as built conditions.	
1	4-8-46	R.L.G.	Sheet pile reinf. revised in accordance with addendum No. 3, 3-6-46	

KANSAS CITY FLOOD CONTROL PROJECT

CENTRAL INDUSTRIAL DISTRICT

(MISSOURI SECTION)

PRECAST CONCRETE BEARING AND SHEET PILE DETAILS

In 1 Sheet | Sheet No. 1 | Scale: as shown

U.S. ENGINEER OFFICE
KANSAS CITY DISTRICT

KANSAS CITY, MO.
OCTOBER 1945

Submitted:	Recommended:	Approved:
Principal Engineer	Lt. Col., Corps of Engineers	Colonel, Corps of Engineers

Drawn by	Traced by	Checked by	To accompany specifications	File No.
C.B.O.	B.U.T.	R.L.G.	Dated: January 1946	A-10-825

BELLEW
03/31/08

ϕ_{BL}

Expected value of $\bar{\phi}_{BLANKET}$ = 26°

Source: NKC Analysis of Design ... MAY 1945 it is stated that it most represents "actual" conditions.

COV $\bar{\phi}_{BLANKET}$ = 10%

SOURCE: ETL 1110-2-556

γ_{BL}

Expected value of γ_{BL} = 115 pcf

COV γ_{BL} = 5%

Source: ETL 1110-2-561 and ETL-2-556

Pile capacity

COV pile capacity = 25 comp.
18 tens.

Source: ETL 1110-2-561

Note: there are other parameters in the reference material which may be used as desired.

22-141 50 SHEETS
22-142 100 SHEETS
22-144 200 SHEETS
AMPAD

GMB

CID-MO UNIT

FROM 2001 SPT'S (SEE ATTACHED TABLE)

SAND $\bar{c} = 0$ $\bar{\phi} = 30°$

BLANKET $C_u = 600$ psf $\phi_u = 0$

$\bar{c} = ?$ $\bar{\phi} = ?$

CID-MO UNIT ADOPTED VALUES FOR FEASIBILITY

	γ_{moist} (pcf)	γ_{SAT} (pcf)	C_u (psf)	$\bar{c}$ (psf)	$\bar{\phi}$ (Deg)
EMBANKMENT :	115	120	1000	0	29°
BLANKET* :	110	115	600	0	22°
SAND :	115	120	N/A	0	30°
FILL/DEBRIS+ :	110	115	600	0	20°

* CH MATERIAL NOT INCLUDED.

+ Assumed parameters based on weakest perceived material likely to be present.

ABOVE VALUES CHOSEN BASED ON AVAILABLE SITE SPECIFIC INFORMATION AND AVAILABLE ADJACENT INFORMORATION INCLUDED HERE.

NORTH KANSAS CITY UNIT (ACROSS MO RIVER)

ANALYSIS OF DESIGN ... (MAY 1945)

BLANKET — NO MATERIALS GIVEN

1)	$\bar{c}$ = 0 psf	$\bar{\phi}$ = 27°	ML/SM	ASSUMED MATERIAL
2)	$\bar{c}$ = 500 psf	$\bar{\phi}$ = 14°	CH	
3)	$\bar{c}$ = 200 psf	$\bar{\phi}$ = 22°	CL	
4)	$\bar{c}$ = 0 psf	$\bar{\phi}$ = 22°	CL/ML	

FAIRFAX JERSEY CREEK (J/S on MO RIVER)

FOUNDATION NKC DEFINITE PROJECT REPORT (DEC, 1943)

STABILITY ANALYSIS PLATE

SAND	$\bar{c}$ = 0	$\bar{\phi}$ = 31°
SANDY LOAM	$\bar{c}$ = 0	$\bar{\phi}$ = 31°
SILTY LOAM	$\bar{c}$ = 0	$\bar{\phi}$ = 29°
SILTY CLAY LOAM	$\bar{c}$ = 0	$\bar{\phi}$ = 22°
CLAY LOAM	$\bar{c}$ = 0	$\bar{\phi}$ = 24°
LEAN CLAY	$\bar{c}$ = 0	$\bar{\phi}$ = 17°
MEDIUM CLAY	$\bar{c}$ = 0	$\bar{\phi}$ = 17°

22-141 50 SHEETS
22-142 100 SHEETS
22-144 200 SHEETS
AMPAD

EAST BOTTOMS UNIT (D/S on MO RIVER)

ANALYSIS OF DESIGN TO ACCOMPANY CONSTRUCTION PLANS FOR LEVEE, FLOODWALL AND APPURTENANCES

SEPTEMBER 1945

DESIGN DRAINED STRENGTHS on MO RIVER REACH

		psf		Degrees
FAT CLAY	τ =	100	ϕ =	12°
MEDIUM CLAY	τ =	0	ϕ =	15°
LEAN CLAY	τ =	360	ϕ =	16°
SILTY CLAY	τ =	0	ϕ =	26°
SILT	τ =	0	ϕ =	30°

BEARING CAPACITY : 2000 psf

CID-KS UNIT (U/S on KS RIVER)

1962 MODIFICATION DM (Apr 1973)

FAT CLAY	τ =	400 psf	ϕ =	17°
LEAN CLAY	τ =	0	ϕ =	26°
SILT	τ =	0	ϕ =	24°

ANALYSIS OF DESIGN ... (Feb 1946)

LEAN CLAY	τ =	100	ϕ =	24°

2007 FEASIBILITY STUDY

BLANKET	τ =	0	ϕ =	24°
FILL	τ =	0	ϕ =	21°
FINAN SAND	τ =	0	ϕ =	31°

Kansas City Levees - CID MO
SPT Blowcounts in the aquifer - Drilling performed in October 2001
Data used to estimate shear strength of the foundation materials

Moist Unit Weight = 115 pcf
Saturated Unit Weight = 120 pcf

Boring	Station	Location	Depth (ft)	Material (FC)	Location of Water Table (interpreted) (ft)	Overburden Pressure (tsf)	Overburden Correction C_n	Uncorrected Blowcount	Corrected Blowcount	Friction Angle ϕ' (degrees)	Undrained Shear Strength, Cu (psf)
D-454	29+75	12' RS	2.0	Fill (cinders, gravel)	11	0.12	1.79	22	39		
D-454	29+75	12' RS	4.5	Clayey Sand	11	0.26	1.59	14	22	33	
D-454	29+75	12' RS	7.0	CH	11	0.40	1.43	12	17		2000
D-454	29+75	12' RS	9.5	CH	11	0.55	1.29	6	8		750
D-454	29+75	12' RS	12.0	CH	11	0.66	1.20	7	8		750
D-454	29+75	12' RS	14.5	CH	11	0.73	1.15	6	7		750
D-454	29+75	12' RS	19.5	CH	11	0.88	1.07	4	4		500
D-454	29+75	12' RS	24.5	CH	11	1.02	0.99	5	5		600
D-454	29+75	12' RS	29.5	CH	11	1.17	0.92	5	5		600
D-454	29+75	12' RS	34.5	ML	11	1.31	0.87	28	24		3000
D-454	29+75	12' RS	39.5	ML	11	1.45	0.82	25	20		3000
D-454	29+75	12' RS	44.5	ML	11	1.60	0.77	3	2		350
D-454	29+75	12' RS	49.5	Sand	11	1.74	0.73	70	51	40	
			51.5	Rock							
AD-453	4+65	10' LS	2.0	Clayey Gravel w/sand	100	0.12	1.79	12	22	33	
AD-453	4+65	10' LS	4.5	CL w/sand	100	0.26	1.59	4	6		600
AD-453	4+65	10' LS	7.0	CL w/sand	100	0.40	1.43	9	13		1250
AD-453	4+65	10' LS	9.5	CH w/sand	100	0.55	1.29	12	16		1500
AD-453	4+65	10' LS	12.0	CH	100	0.69	1.18	8	9		1000
AD-453	4+65	10' LS	14.5	CH w/silt,sand	100	0.83	1.09	5	5		600
AD-453	4+65	10' LS	19.5	CH w/silt,sand	100	1.12	0.94	6	6		750
AD-453	4+65	10' LS	24.5	CH w/silt	100	1.41	0.83	4	3		400
AD-453	4+65	10' LS	29.5	Clayey Sand	100	1.70	0.74	8	6	29	
AD-453	4+65	10' LS	34.5	Clayey Sand	100	1.98	0.67	11	7	30	
AD-453	4+65	10' LS	39.5	Clayey Sand	100	2.27	0.61	4	2	28	
			43.7	Rock							
AD-455	63+00	15' RS	2.0	CL (sand, fill?)	24	0.12	1.79	12	22		
AD-455	63+00	15' RS	4.5	Sand w/silt	24	0.26	1.59	14	22	32	
AD-455	63+00	15' RS	7.0	Sand w/silt	24	0.40	1.43	11	16	31	
AD-455	63+00	15' RS	9.5	CH	24	0.55	1.29	4	5		550
AD-455	63+00	15' RS	12.0	OL? (CH/CL)	24	0.69	1.18	7	8		750
AD-455	63+00	15' RS	14.5	CH w/ sand	24	0.83	1.09	6	7		750
AD-455	63+00	15' RS	19.5	Sandy CH	24	1.12	0.94	7	7		750
AD-455	63+00	15' RS	24.5	Sandy CH	24	1.39	0.84	9	8		1000
AD-455	63+00	15' RS	29.5	Sand	24	1.54	0.79	8	6	29	
AD-455	63+00	15' RS	34.5	Sand	24	1.68	0.75	8	6	29	
AD-455	63+00	15' RS	39.5	Sand	24	1.83	0.71	25	18	33	
AD-455	63+00	15' RS	44.5	Sand	24	1.97	0.67	34	23	35	
AD-455	63+00	15' RS	49.5	Sand	24	2.11	0.64	17	11	32	
AD-455	63+00	15' RS	54.5	Sand	24	2.26	0.61	30	18	35	
AD-455	63+00	15' RS	59.5	Sand	24	2.40	0.59	29	17	33	
AD-455	63+00	15' RS	64.5	Sand	24	2.55	0.56	34	19	36	
AD-455	63+00	15' RS	69.5	Sand	24	2.69	0.54	41	22	36	
AD-455	63+00	15' RS	74.5	Sand	24	2.83	0.52	70	37	40	
D-456	68+65	12' RS	4.5	Sandy Clay	34	0.26	1.59	18	29		
D-456	68+65	12' RS	7.0	Ashpalt/Gravel (fill)	34	0.40	1.43	10	14		
D-456	68+65	12' RS	9.5	Cement/Brick (fill)	34	0.55	1.29	7	9		
D-456	68+65	12' RS	12.0	Clay w/ cind, brick	34	0.69	1.18	6	7		
D-456	68+65	12' RS	14.5	Sandy Silt	34	0.83	1.09	11	12		1200
D-456	68+65	12' RS	19.5	Clayey Silt	34	1.12	0.94	6	6		750
D-456	68+65	12' RS	24.5	Clayey Silt	34	1.41	0.83	12	10		1200
D-456	68+65	12' RS	29.5	Clayey Silt	34	1.70	0.74	6	4		600
D-456	68+65	12' RS	34.5	Clayey Silt	34	1.97	0.67	12	8		1100
D-456	68+65	12' RS	39.5	Silty Clay	34	2.11	0.64	9	6		800
D-456	68+65	12' RS	44.5	Sandy Silt	34	2.26	0.61	12	7		1000
D-456	68+65	12' RS	49.5	Silty Sand	34	2.40	0.59	36	21	35	
D-456	68+65	12' RS	54.5	Sand	34	2.55	0.56	28	16	34	
D-456	68+65	12' RS	59.5	Sand	34	2.69	0.54	12	7	30	
D-456	68+65	12' RS	64.5	Sand	34	2.83	0.52	100	52	40	
D-456	68+65	12' RS	69.5	Sand	34	2.98	0.50	37	19	34	
D-456	68+65	12' RS	74.5	Sand	34	3.12	0.49	28	14	34	
D-456	68+65	12' RS	79.5	Sand	34	3.27	0.47	23	11	34	
			82.5	Rock							
D-457	70+60	12' RS	2.0	CL	13.5	0.12	1.79	9	16		1350
D-457	70+60	12' RS	4.5	CH	13.5	0.26	1.59	4	6		600
D-457	70+60	12' RS	7.0	Sandy CH	13.5	0.40	1.43	4	6		600
D-457	70+60	12' RS	9.5	Sand	13.5	0.55	1.29	12	16	33	
D-457	70+60	12' RS	12.0	Sand	13.5	0.69	1.18	11	13	33	
D-457	70+60	12' RS	14.5	CH	13.5	0.81	1.11	6	7		750
D-457	70+60	12' RS	19.5	Clayey Silt	13.5	0.95	1.03	6	6		750
D-457	70+60	12' RS	24.5	Sand	13.5	1.09	0.96	10	10		1200
D-457	70+60	12' RS	29.5	CH	13.5	1.24	0.89	3	3		350
D-457	70+60	12' RS	34.5	Silt	13.5	1.38	0.84	0	0		250
D-457	70+60	12' RS	39.5	Silt	13.5	1.53	0.79	1	1		250
D-457	70+60	12' RS	44.5	Sand	13.5	1.67	0.75	24	18	34	
D-457	70+60	12' RS	49.5	Sand	13.5	1.81	0.71	20	14	32	
D-457	70+60	12' RS	54.5	Sand	13.5	1.96	0.68	14	9	31	
D-457	70+60	12' RS	59.5	Sand	13.5	2.10	0.64	9	6	29	
D-457	70+60	12' RS	64.5	Sand	13.5	2.25	0.62	66	41	40	
D-457	70+60	12' RS	69.5	Sand	13.5	2.39	0.59	58	34	40	
D-457	70+60	12' RS	74.5	Gravel/Sand	13.5	2.53	0.57	11	6	29	
D-457	70+60	12' RS	79.5	Gravel/Sand	13.5	2.68	0.54	23	13	33	
D-457	70+60	12' RS	85.5	Gravel/Sand	13.5	2.85	0.52	27	14	33	
			87.0	Rock							
D-458	80+30	10' LS	2.0	Sand	11	0.12	1.79	12	22	32	
D-458	80+30	10' LS	4.5	Sand	11	0.26	1.59	7	11	29	
D-458	80+30	10' LS	7.0	Gravel	11	0.40	1.43	9	13	30	
D-458	80+30	10' LS	9.5	Sand	11	0.55	1.29	17	22	31	
D-458	80+30	10' LS	12.0	Sand	11	0.66	1.20	13	16	32	
D-458	80+30	10' LS	14.5	Sand	11	0.73	1.15	10	12	30	
D-458	80+30	10' LS	19.5	Sand	11	0.88	1.07	15	16	32	
D-458	80+30	10' LS	24.5	Sandy CH	11	1.02	0.99	2	2		250
D-458	80+30	10' LS	29.5	CH	11	1.17	0.92	4	4		500
D-458	80+30	10' LS	34.5	CH	11	1.31	0.87	0	0		250
D-458	80+30	10' LS	39.5	CH	11	1.45	0.82	4	3		500
D-458	80+30	10' LS	44.5	CH	11	1.60	0.77	3	2		400
D-458	80+30	10' LS	49.5	Clayey Sand	11	1.74	0.73	15	11	31	
D-458	80+30	10' LS	54.5	Sand	11	1.89	0.69	31	21	34	
D-458	80+30	10' LS	59.5	Sand	11	2.03	0.66	18	12	32	
D-458	80+30	10' LS	64.5	Sand	11	2.17	0.63	12	8	29	
D-458	80+30	10' LS	69.5	Sandy CH	11	2.32	0.60	19	11	30	

Notes:
1. Overburden correction to blowcount: $C_n = 2/(1 + \sigma')$, with σ' in tsf
2. Corrected blowcount = $N_{uncorrected} * C_n$
3. C_n from EM 1110-1-1804 Table G-1 and EM 1110-2-2504 Table 3-4
4. ϕ from EM 1110-1-1905 Table 3-1 and EM 1110-2-2504 Table 3-1

	ϕ' (degrees) AVG	ϕ' (degrees) STDEV	C_u (psf) AVG	C_u (psf) STDEV
Sand	32.8	3		
CL			933	292
CH			700	370
Silt			1308	1340

Material	Strength		Source
C_u blanket =	600	psf	SPT
ϕ blanket =	N/A	degrees	SPT
ϕ sand =	30	degrees	SPT
ϕ fill =	N/A	degrees	SPT

FROM: GENERAL DESIGN MEMORANDUM
BRUSH CREEK ENHANCED CHANNEL MODIFICATIONS
MAY 1990

measurements) tests were performed on representative undisturbed samples under confining chamber pressures ranging from 0.25 to 2.0 tsf. The general procedure involved tests on three specimens trimmed from the same horizon. Specimens were trimmed in a humidity controlled room to the dimensions of 1.4 inches in diameter by 3 inches in height. The test specimens were saturated with back pressures ranging from 3.46 to 5.54 tsf. Once saturated, the specimens were consolidated under the assigned confining pressure until the volume change versus log time plot indicated primary consolidation was complete. To reduce consolidation time, peripheral filter paper strips were placed on the specimen to accelerate drainage. The triaxial "R" tests were strain controlled at a rate of 0.012 percent per minute. Failure time ranged from 360 to 1,272 minutes. Overburden test results are shown on plates C-2 thru C-8.

b. Foundation Shales. Both unconfined compression and direct shear testing was performed on representative samples of the foundation shales. Classification and consistency limit tests were also performed on these samples. Direct shear tests were performed on the following shales: Wea, Fontana, Stark, and Galesburg. These tests consisted of shearing three intact specimens under normal loads ranging from 1 to 5 tsf. The specimens were sheared at a constant deformation rate of 0.0003 in/min. Foundation shale test results are shown on plates C-10 thru C-13.

c. Concrete/Rock Contact. Direct shear tests were performed to determine the strength of the concrete/rock contact for retaining walls and dams founded on limestone. These tests were performed on 3" x 3" specimens using standard soil testing equipment. A normal stress of 1.0 tsf was selected for all tests. This pressure roughly corresponds with the average pressure anticipated in the field. A total of four tests were performed, each representing a different potential field condition. Two tests represented the concrete/rock contact without bonding. These specimens were prepared by casting concrete against a natural bedding plane surface covered with plastic wrap. After the concrete set, the plastic wrap was removed and the pieces fit back together. One test was performed to quantify the bond strength. This was achieved by casting concrete directly against a sawcut rock surface. The final test was run on a pre-existing bedding plane break to determine the strength of the bedding planes within the upper Winterset limestone. Concrete/Rock contact test results are shown on plate C-14.

4. DESIGN VALUES. Items considered in the selection of design values include the number of tests, the nature of the material, and the location of the material with respect to potential failure surfaces.

a. Overburden. The foundation overburden varies from natural alluvium to fills. The majority of testing was performed on the fills since they are located in critical areas which could affect stability of the slopes or walls. Initial review of lab results seemed to indicate that material behind Troost wall had different strength parameters than the overburden in the remainder of the channel. Therefore, lab results were plotted separately to differentiate between overburden behind Troost wall (tests 4,5,6,7) and overburden in the remainder of the channel (tests 1,2,3). Test numbers 1,2, and 3 (UC-55, UC-57, and UC-59) indicate rather high cohesion values for both "R" and "S" envelopes. Further evaluation of data

for these tests discovered irregularities in lab results and inconsistencies with torvane values and field description. Due to their suspect nature, these tests were not used in selection of overburden design parameters. The total stress strength parameters represent versus . The failure criteria was maximum deviator stress. This is different from the criteria used in Appendix D (Troost Wall Stability). The total stress failure criteria used for Troost Wall stability calculations was the maximum principle effective stress ratio. Effective stress strength parameters represent versus at the maximum principle effective stress ratio. Overburden test results are summarized on plate C-1.

(1) Total Stress ("R" strength): For overburden material in the Troost wall section a design strength of c=0.20 tsf, tan Ø=0.31 (Ø=17°) was selected.

(2) Effective Stress ("S" strength): For overburden material in the Troost wall section a design strength of c=0.05 tsf, tan Ø=0.42 (Ø=23°) was selected.

b. Foundation Shales. There were a total of ten direct shear tests run on the various shale members. A summary table for the shale testing is shown on plate C-9. The weakest shale members appear to be the Wea shale and the Galesburg shale. Peak shear strength parameters selected for these members are c=0.3 tsf and tan Ø=0.38 (Ø=21°). The most significant shale member for retaining wall design is the Fontana shale. The test performed on the Fontana shale (see plate C-11) indicates a peak shear strength of c=0.6 tsf, tan Ø=0.51 (Ø=27°) and a large strain shear strength of c=0, tan Ø=0.38 (Ø=21°). The unconfined compression test results are presented in Table C-1.

TABLE C-1

Unconfined Compression Tests

Wea Shale (Boring No. UC-96)

Depth El.	35.2-35.4	35.4-36.0
Dry Density (lbs/ft.^{3})	132.0	130.2
Moisture Content (%)	8.9	9.9
Unconfined Compressive Strength (TSF)	13.69	39.35

Fontant Shale (Boring No. UC-47A)

Depth El.	8.7-9.7
Dry Density (lbs./ft.^{3})	129.6
Moisture Content (%)	10.4
Unconfined Compressive Strength (TSF)	31.72

c. Concrete/Rock Contact. Listed below is a summary of test results on the concrete/rock contact tests. Laboratory test results can be found on plate C-14.

RVD 1/17/08
RSK

HOLE NO.	SAMPLE NO.	TEST TYPE	PEAK	LARGE STRAIN
C-100	1	Conc/Rock w/o bonding	54°	40°
C-100	2	Rock/Rock natural break	48°	39°
C-100	3	Conc/Shale w/ bonding	30° (c 2.5 tsf)	27°
C-100	8	Conc/Rock w/o bonding	42°	32°

Sample No.'s 1 & 8 tested concrete cast against a pre-existing bedding plane break with plastic wrap separating the two during casting. Sample No. 1 had larger asperities which resulted in a higher strength. Sample No. 2 tested a pre-existing bedding plane break pieced back together to investigate sliding resistance of the bedding planes within the upper Winterset limestone. Sample No. 3 tested a sawcut rock surface with concrete cast directly against the rock. This test was performed to quantify the bond strength and to determine the magnitude of sliding resistance derived from the asperities found on a normal rock surface. (Note: Common KCD practice is to ignore any bond strength for analysis purposes). Of the four tests performed, sample Nos. 1 & 2 are considered most representative of expected field conditions. Even so, they are believed to be a lower bound of what is possible in the field due to the following: (1) Samples selected for testing were those with the smallest asperities; (2) The plastic wrap used to prevent bonding between the concrete and rock specimens caused some bridging of the rock asperities which resulted in rounded rather than angular asperities in the concrete; (3) One would expect that both the number and size of bedding plane surface irregularities would be much greater over the area of a footing than found in a six-inch diameter core. Design strengths selected for both the Concrete/Rock contact and bedding planes in the upper Winterset are as follows:

Peak w/bonding	c=2.5 tsf
Peak w/o bonding	c=0.0 tsf, Ø = 45°
Large Strain	c=0.0 tsf, Ø = 35°

THESE VALUES ARE FOR THE WINTERSET LIMESTONE.

HOWEVER, the BETHANY FALLS @ CID-MO IS ≥ WINTERSET.

USE ϕ = ~~35°~~ 45 degrees FOR CID-MO

GMB 01/17/08

12/05/11

RVD RSK

1/88

GMB

STA 0+00 → 7+00

SHALLOW FOOTING @ el 745 GROUND @ el 752.

BEARING IN BLANKET MATERIAL. @ DF = 6 ft

q_{ult} = 3400 psf ✓

STA 7+00 → 7+50

SHALLOW FOOTING @ el 740 GROUND @ el 750

BEARING IN BLANKET MATERIAL @ DF = 10 ft

q_{ult} = 3610 psf

STA 7+50 → 10+25

SHALLOW FOOTING @ el 736 GROUND @ el 747

BEARING IN BLANKET MATERIAL @ DF = 11

q_{ult} = 3663 psf ✓

STA 10+25 → 22+31.46

SHALLOW FOOTING BEARING ON ROCK. (LIMESTONE)

q_{all} = 20,000 psf

13 JULY 1999 MFR (Geology)
Geological Report for Design of Brush Creek-Paseo Extension Contract Modification, Kansas City, MO
(ATTACHED)

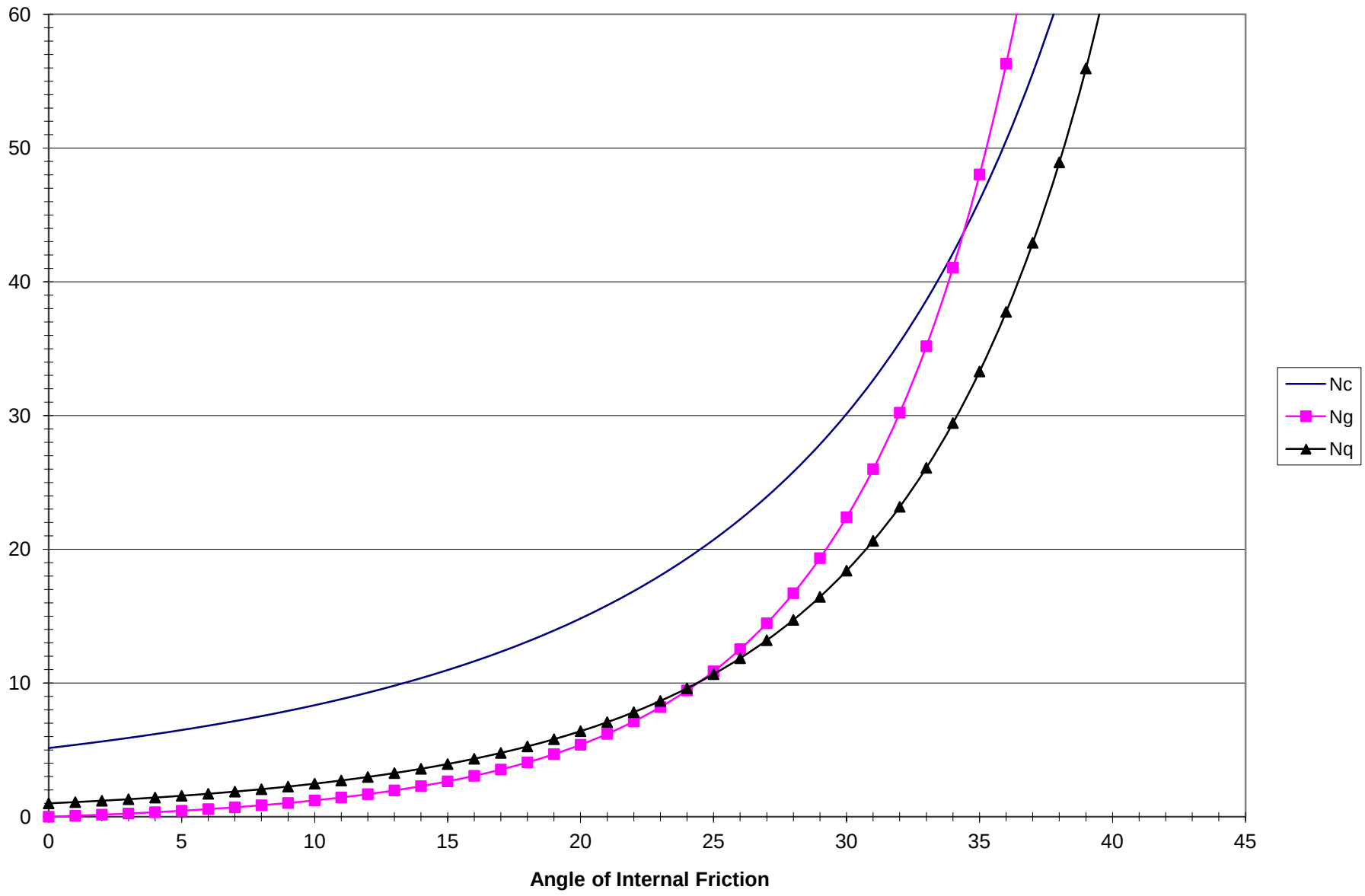
Assume $q_{ult} = q_{all} * 2$ (F.S.)

q_{ult} = 40,000 psf

AASHTO HB-17
TABLE 4.11.4.1.4-1

22-141 50 SHEETS
22-142 100 SHEETS
22-144 200 SHEETS
AMPAD

Chart Bearing Cap Coeff



Data Bearing Cap Coeff

Phi (degrees)	Phi (rads)	Nc	Nγ	Nq
0	0	5.14	0.0	1.0
1	0.017453293	5.4	0.1	1.1
2	0.034906585	5.6	0.2	1.2
3	0.052359878	5.9	0.2	1.3
4	0.06981317	6.2	0.3	1.4
5	0.087266463	6.5	0.4	1.6
6	0.104719755	6.8	0.6	1.7
7	0.122173048	7.2	0.7	1.9
8	0.13962634	7.5	0.9	2.1
9	0.157079633	7.9	1.0	2.3
10	0.174532925	8.3	1.2	2.5
11	0.191986218	8.8	1.4	2.7
12	0.20943951	9.3	1.7	3.0
13	0.226892803	9.8	2.0	3.3
14	0.244346095	10.4	2.3	3.6
15	0.261799388	11.0	2.6	3.9
16	0.27925268	11.6	3.1	4.3
17	0.296705973	12.3	3.5	4.8
18	0.314159265	13.1	4.1	5.3
19	0.331612558	13.9	4.7	5.8
20	0.34906585	14.8	5.4	6.4
21	0.366519143	15.8	6.2	7.1
22	0.383972435	16.9	7.1	7.8
23	0.401425728	18.0	8.2	8.7
24	0.41887902	19.3	9.4	9.6
25	0.436332313	20.7	10.9	10.7
26	0.453785606	22.3	12.5	11.9
27	0.471238898	23.9	14.5	13.2
28	0.488692191	25.8	16.7	14.7
29	0.506145483	27.9	19.3	16.4
30	0.523598776	30.1	22.4	18.4
31	0.541052068	32.7	26.0	20.6
32	0.558505361	35.5	30.2	23.2
33	0.575958653	38.6	35.2	26.1
34	0.593411946	42.2	41.1	29.4
35	0.610865238	46.1	48.0	33.3
36	0.628318531	50.6	56.3	37.8
37	0.645771823	55.6	66.2	42.9
38	0.663225116	61.4	78.0	48.9
39	0.680678408	67.9	92.2	56.0
40	0.698131701	75.3	109.4	64.2
41	0.715584993	83.9	130.2	73.9
42	0.733038286	93.7	155.5	85.4
43	0.750491578	105.1	186.5	99.0
44	0.767944871	118.4	224.6	115.3
45	0.785398163	133.9	271.7	134.9

Bearing Cap FW

Bearing Capacity Floodwalls

Material	
Cohesion psf	600
Phi Angle	0
Strip Foundation Footing Width B (ft)	10
Depth of Footing Df (ft)	5
Factor of Safety	1
Total Unit Weight pcf	115
Boyant Unit Weight pcf	52.6

Nc	5.1
Nγ	0.0
Nq	1.0

qult = c*Nc+.5*B*g'*Nγ+γt*Df+Nq

qult = 3659.00

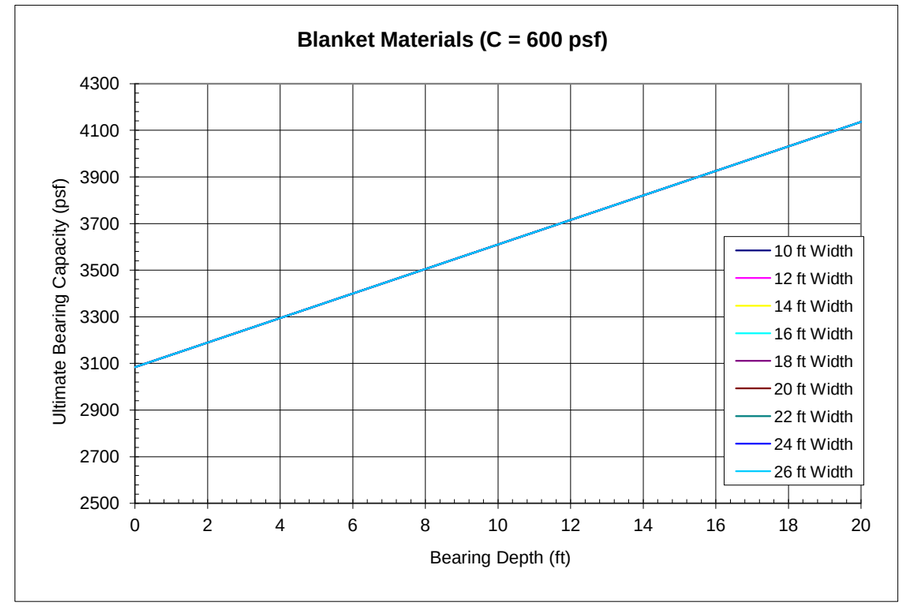
qall = 3659

Bearing Capacity CID-MO Floodwalls

Material	Blanket
Cohesion psf	600
Phi Angle	0
Total Unit Weight pcf	115
Boyant Unit Weight pcf	52.6

Nc	5.1
Nγ	0.0
Nq	1.0

qult = c*Nc+.5*B*g'*Nγ+γt*Df+Nq



Footing Width (ft)	Bearing Depth (ft)	Ultimate Bearing Capacity (psf)	Footing Width (ft)	Bearing Depth (ft)	Ultimate Bearing Capacity (psf)
10	0	3084	12	0	3084
10	2	3189	12	2	3189
10	3	3242	12	3	3242
10	4	3294	12	4	3294
10	5	3347	12	5	3347
10	6	3400	12	6	3400
10	7	3452	12	7	3452
10	8	3505	12	8	3505
10	9	3557	12	9	3557
10	10	3610	12	10	3610
10	11	3663	12	11	3663
10	12	3715	12	12	3715
10	13	3768	12	13	3768
10	14	3820	12	14	3820
10	15	3873	12	15	3873
10	16	3926	12	16	3926
10	17	3978	12	17	3978
10	18	4031	12	18	4031
10	19	4083	12	19	4083
10	20	4136	12	20	4136

Footing Width (ft)	Bearing Depth (ft)	Ultimate Bearing Capacity (psf)	Footing Width (ft)	Bearing Depth (ft)	Ultimate Bearing Capacity (psf)
14	0	3084	16	0	3084
14	2	3189	16	2	3189
14	3	3242	16	3	3242
14	4	3294	16	4	3294
14	5	3347	16	5	3347
14	6	3400	16	6	3400
14	7	3452	16	7	3452
14	8	3505	16	8	3505
14	9	3557	16	9	3557
14	10	3610	16	10	3610
14	11	3663	16	11	3663
14	12	3715	16	12	3715
14	13	3768	16	13	3768
14	14	3820	16	14	3820
14	15	3873	16	15	3873
14	16	3926	16	16	3926
14	17	3978	16	17	3978
14	18	4031	16	18	4031
14	19	4083	16	19	4083
14	20	4136	16	20	4136

Footing Width (ft)	Bearing Depth (ft)	Ultimate Bearing Capacity (psf)	Footing Width (ft)	Bearing Depth (ft)	Ultimate Bearing Capacity (psf)
18	0	3084	20	0	3084
18	2	3189	20	2	3189
18	3	3242	20	3	3242
18	4	3294	20	4	3294
18	5	3347	20	5	3347

18	6	3400	20	6	3400
18	7	3452	20	7	3452
18	8	3505	20	8	3505
18	9	3557	20	9	3557
18	10	3610	20	10	3610
18	11	3663	20	11	3663
18	12	3715	20	12	3715
18	13	3768	20	13	3768
18	14	3820	20	14	3820
18	15	3873	20	15	3873
18	16	3926	20	16	3926
18	17	3978	20	17	3978
18	18	4031	20	18	4031
18	19	4083	20	19	4083
18	20	4136	20	20	4136

Footing Width (ft)	Bearing Depth (ft)	Ultimate Bearing Capacity (psf)	Footing Width (ft)	Bearing Depth (ft)	Ultimate Bearing Capacity (psf)
22	0	3084	24	0	3084
22	2	3189	24	2	3189
22	3	3242	24	3	3242
22	4	3294	24	4	3294
22	5	3347	24	5	3347
22	6	3400	24	6	3400
22	7	3452	24	7	3452
22	8	3505	24	8	3505
22	9	3557	24	9	3557
22	10	3610	24	10	3610
22	11	3663	24	11	3663
22	12	3715	24	12	3715
22	13	3768	24	13	3768
22	14	3820	24	14	3820
22	15	3873	24	15	3873
22	16	3926	24	16	3926
22	17	3978	24	17	3978
22	18	4031	24	18	4031
22	19	4083	24	19	4083
22	20	4136	24	20	4136

Footing Width (ft)	Bearing Depth (ft)	Ultimate Bearing Capacity (psf)
26	0	3084
26	2	3189
26	3	3242
26	4	3294
26	5	3347
26	6	3400
26	7	3452
26	8	3505
26	9	3557
26	10	3610
26	11	3663
26	12	3715
26	13	3768
26	14	3820
26	15	3873
26	16	3926
26	17	3978
26	18	4031
26	19	4083
26	20	4136

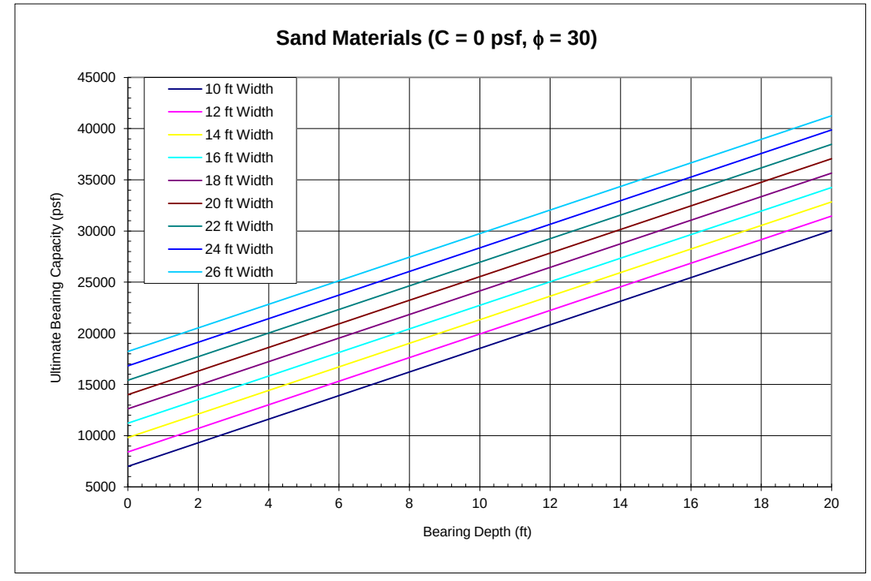
Sand Bearing

Bearing Capacity CID-MO Floodwalls

Material	Sand
Cohesion psf	0
Phi Angle	30
Total Unit Weight pcf	125
Boyant Unit Weight pcf	62.6

Nc	30.1
Nγ	22.4
Nq	18.4

qult = c*Nc+.5*B*g'*Nγ+γt*Df+Nq



Footing Width (ft)	Bearing Depth (ft)	Ultimate Bearing Capacity (psf)	Footing Width (ft)	Bearing Depth (ft)	Ultimate Bearing Capacity (psf)
10	0	7012	12	0	8414
10	2	9316	12	2	10718
10	3	10468	12	3	11870
10	4	11620	12	4	13022
10	5	12772	12	5	14174
10	6	13923	12	6	15326
10	7	15075	12	7	16478
10	8	16227	12	8	17630
10	9	17379	12	9	18782
10	10	18531	12	10	19933
10	11	19683	12	11	21085
10	12	20835	12	12	22237
10	13	21987	12	13	23389
10	14	23139	12	14	24541
10	15	24291	12	15	25693
10	16	25443	12	16	26845
10	17	26594	12	17	27997
10	18	27746	12	18	29149
10	19	28898	12	19	30301
10	20	30050	12	20	31453

Footing Width (ft)	Bearing Depth (ft)	Ultimate Bearing Capacity (psf)	Footing Width (ft)	Bearing Depth (ft)	Ultimate Bearing Capacity (psf)
14	0	9817	16	0	11219
14	2	12121	16	2	13523
14	3	13273	16	3	14675
14	4	14424	16	4	15827
14	5	15576	16	5	16979
14	6	16728	16	6	18131
14	7	17880	16	7	19283
14	8	19032	16	8	20434
14	9	20184	16	9	21586
14	10	21336	16	10	22738
14	11	22488	16	11	23890
14	12	23640	16	12	25042
14	13	24792	16	13	26194
14	14	25944	16	14	27346
14	15	27095	16	15	28498
14	16	28247	16	16	29650
14	17	29399	16	17	30802
14	18	30551	16	18	31954
14	19	31703	16	19	33105
14	20	32855	16	20	34257

Footing Width (ft)	Bearing Depth (ft)	Ultimate Bearing Capacity (psf)	Footing Width (ft)	Bearing Depth (ft)	Ultimate Bearing Capacity (psf)
18	0	12622	20	0	14024
18	2	14925	20	2	16328
18	3	16077	20	3	17480
18	4	17229	20	4	18632
18	5	18381	20	5	19784
18	6	19533	20	6	20935
18	7	20685	20	7	22087
18	8	21837	20	8	23239

18	9	22989	20	9	24391
18	10	24141	20	10	25543
18	11	25293	20	11	26695
18	12	26444	20	12	27847
18	13	27596	20	13	28999
18	14	28748	20	14	30151
18	15	29900	20	15	31303
18	16	31052	20	16	32455
18	17	32204	20	17	33606
18	18	33356	20	18	34758
18	19	34508	20	19	35910
18	20	35660	20	20	37062

Footing Width (ft)	Bearing Depth (ft)	Ultimate Bearing Capacity (psf)	Footing Width (ft)	Bearing Depth (ft)	Ultimate Bearing Capacity (psf)
22	0	15426	24	0	16829
22	2	17730	24	2	19133
22	3	18882	24	3	20284
22	4	20034	24	4	21436
22	5	21186	24	5	22588
22	6	22338	24	6	23740
22	7	23490	24	7	24892
22	8	24642	24	8	26044
22	9	25794	24	9	27196
22	10	26945	24	10	28348
22	11	28097	24	11	29500
22	12	29249	24	12	30652
22	13	30401	24	13	31804
22	14	31553	24	14	32955
22	15	32705	24	15	34107
22	16	33857	24	16	35259
22	17	35009	24	17	36411
22	18	36161	24	18	37563
22	19	37313	24	19	38715
22	20	38465	24	20	39867

Footing Width (ft)	Bearing Depth (ft)	Ultimate Bearing Capacity (psf)
26	0	18231
26	2	20535
26	3	21687
26	4	22839
26	5	23991
26	6	25143
26	7	26295
26	8	27446
26	9	28598
26	10	29750
26	11	30902
26	12	32054
26	13	33206
26	14	34358
26	15	35510
26	16	36662
26	17	37814
26	18	38966
26	19	40117
26	20	41269

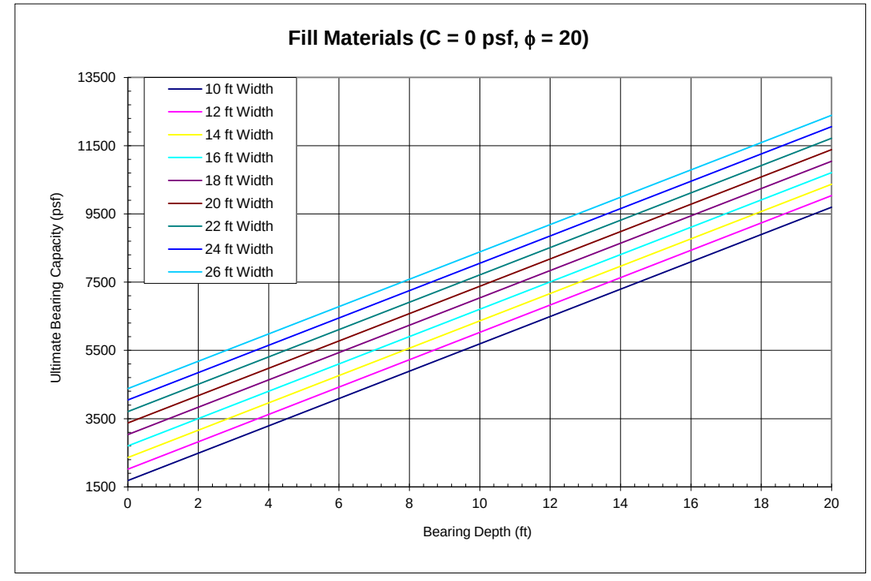
Fill Bearing

Bearing Capacity CID-MO Floodwalls

Material	Fill
Cohesion psf	0
Phi Angle	20
Total Unit Weight pcf	125
Boyant Unit Weight pcf	62.6

Nc	14.8
Nγ	5.4
Nq	6.4

qult = c*Nc+.5*B*g'*Nγ+γt*Df+Nq



Footing Width (ft)	Bearing Depth (ft)	Ultimate Bearing Capacity (psf)	Footing Width (ft)	Bearing Depth (ft)	Ultimate Bearing Capacity (psf)
10	0	1686	12	0	2023
10	2	2487	12	2	2824
10	3	2888	12	3	3225
10	4	3288	12	4	3626
10	5	3689	12	5	4026
10	6	4090	12	6	4427
10	7	4490	12	7	4827
10	8	4891	12	8	5228
10	9	5291	12	9	5629
10	10	5692	12	10	6029
10	11	6093	12	11	6430
10	12	6493	12	12	6830
10	13	6894	12	13	7231
10	14	7294	12	14	7632
10	15	7695	12	15	8032
10	16	8096	12	16	8433
10	17	8496	12	17	8833
10	18	8897	12	18	9234
10	19	9297	12	19	9635
10	20	9698	12	20	10035

Footing Width (ft)	Bearing Depth (ft)	Ultimate Bearing Capacity (psf)	Footing Width (ft)	Bearing Depth (ft)	Ultimate Bearing Capacity (psf)
14	0	2360	16	0	2697
14	2	3161	16	2	3499
14	3	3562	16	3	3899
14	4	3963	16	4	4300
14	5	4363	16	5	4700
14	6	4764	16	6	5101
14	7	5164	16	7	5502
14	8	5565	16	8	5902
14	9	5966	16	9	6303
14	10	6366	16	10	6703
14	11	6767	16	11	7104
14	12	7168	16	12	7505
14	13	7568	16	13	7905
14	14	7969	16	14	8306
14	15	8369	16	15	8706
14	16	8770	16	16	9107
14	17	9171	16	17	9508
14	18	9571	16	18	9908
14	19	9972	16	19	10309
14	20	10372	16	20	10710

Footing Width (ft)	Bearing Depth (ft)	Ultimate Bearing Capacity (psf)	Footing Width (ft)	Bearing Depth (ft)	Ultimate Bearing Capacity (psf)
18	0	3035	20	0	3372
18	2	3836	20	2	4173
18	3	4236	20	3	4574
18	4	4637	20	4	4974
18	5	5038	20	5	5375
18	6	5438	20	6	5775
18	7	5839	20	7	6176
18	8	6239	20	8	6577

18	9	6640	20	9	6977
18	10	7041	20	10	7378
18	11	7441	20	11	7778
18	12	7842	20	12	8179
18	13	8242	20	13	8580
18	14	8643	20	14	8980
18	15	9044	20	15	9381
18	16	9444	20	16	9781
18	17	9845	20	17	10182
18	18	10245	20	18	10583
18	19	10646	20	19	10983
18	20	11047	20	20	11384

Footing Width (ft)	Bearing Depth (ft)	Ultimate Bearing Capacity (psf)	Footing Width (ft)	Bearing Depth (ft)	Ultimate Bearing Capacity (psf)
22	0	3709	24	0	4046
22	2	4510	24	2	4847
22	3	4911	24	3	5248
22	4	5311	24	4	5649
22	5	5712	24	5	6049
22	6	6113	24	6	6450
22	7	6513	24	7	6850
22	8	6914	24	8	7251
22	9	7314	24	9	7652
22	10	7715	24	10	8052
22	11	8116	24	11	8453
22	12	8516	24	12	8853
22	13	8917	24	13	9254
22	14	9317	24	14	9655
22	15	9718	24	15	10055
22	16	10119	24	16	10456
22	17	10519	24	17	10856
22	18	10920	24	18	11257
22	19	11320	24	19	11658
22	20	11721	24	20	12058

Footing Width (ft)	Bearing Depth (ft)	Ultimate Bearing Capacity (psf)
26	0	4383
26	2	5185
26	3	5585
26	4	5986
26	5	6386
26	6	6787
26	7	7188
26	8	7588
26	9	7989
26	10	8389
26	11	8790
26	12	9191
26	13	9591
26	14	9992
26	15	10392
26	16	10793
26	17	11194
26	18	11594
26	19	11995
26	20	12395

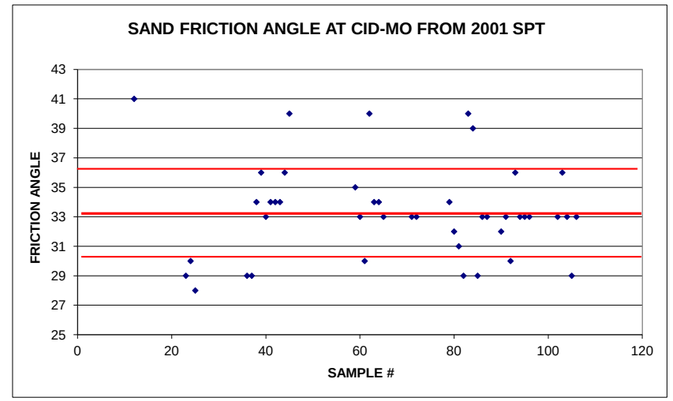
Kansas City Levees - CID MO
SPT Blowcounts in the aquifer - Drilling performed in October 2001
Data used to estimate shear strength of the foundation materials 2428.5 1214.25

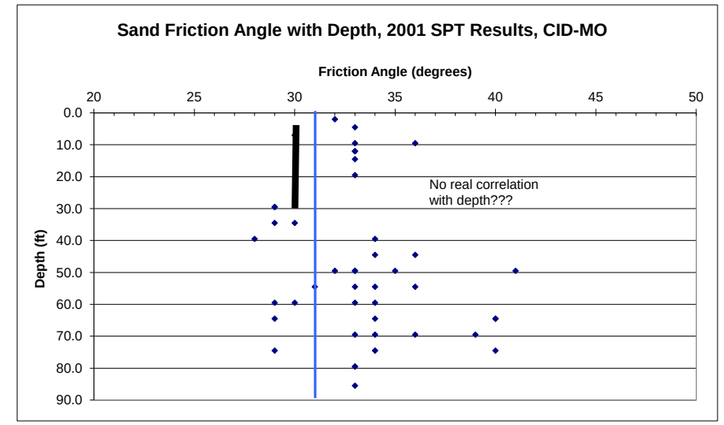
Moist Unit Weight = 115 pcf
Saturated Unit Weight = 120 pcf

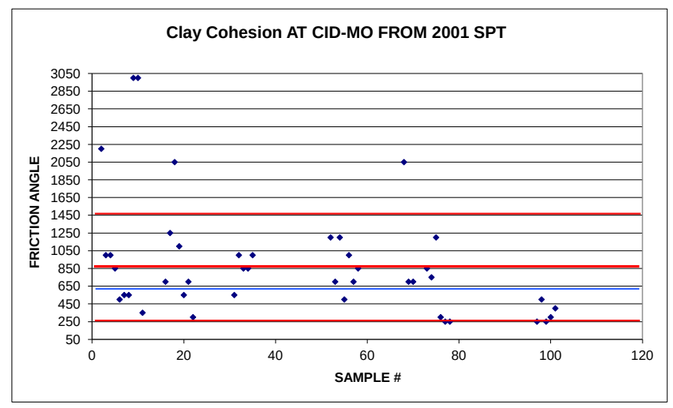
Boring	Station	Location	Depth (ft)	Material (FC)	Location of Water Table (interpreted) (ft)	Overburden Pressure (tsf)	Overburden Correction C_n	Uncorrected Blowcount	Corrected Blowcount	Friction Angle φ' (degrees)	Undrained Shear Strength, Cu (psf)
D-454	29+75	12' RS	2.0	Fill (cinders, gravel)	11	0.12	1.79	22	39		
D-454	29+75	12' RS	4.5	Clayey Sand	11	0.26	1.59	14	22		
D-454	29+75	12' RS	7.0	CH	11	0.40	1.43	12	17		2200
D-454	29+75	12' RS	9.5	CH	11	0.55	1.29	6	8		1000
D-454	29+75	12' RS	12.0	CH	11	0.66	1.20	7	8		1000
D-454	29+75	12' RS	14.5	CH	11	0.73	1.15	6	7		850
D-454	29+75	12' RS	19.5	CH	11	0.88	1.07	4	4		500
D-454	29+75	12' RS	24.5	CH	11	1.02	0.99	5	5		550
D-454	29+75	12' RS	29.5	CH	11	1.17	0.92	5	5		550
D-454	29+75	12' RS	34.5	ML	11	1.31	0.87	28	24		3000
D-454	29+75	12' RS	39.5	ML	11	1.45	0.82	25	20		3000
D-454	29+75	12' RS	44.5	ML	11	1.60	0.77	3	2		350
D-454	29+75	12' RS	49.5	Sand	11	1.74	0.73	70	51	41	
			51.5	Rock							
AD-453	4+65	10' LS	2.0	Clayey Gravel w/sand	100	0.12	1.79	12	22		
AD-453	4+65	10' LS	4.5	CL w/sand	100	0.26	1.59	4	6		700
AD-453	4+65	10' LS	7.0	CL w/sand	100	0.40	1.43	9	13		1250
AD-453	4+65	10' LS	9.5	CH w/sand	100	0.55	1.29	12	16		2050
AD-453	4+65	10' LS	12.0	CH	100	0.69	1.18	8	9		1100
AD-453	4+65	10' LS	14.5	CH w/silt,sand	100	0.83	1.09	5	5		550
AD-453	4+65	10' LS	19.5	CH w/silt,sand	100	1.12	0.94	6	6		700
AD-453	4+65	10' LS	24.5	CH w/silt	100	1.41	0.83	4	3		300
AD-453	4+65	10' LS	29.5	Clayey Sand	100	1.70	0.74	8	6	29	
AD-453	4+65	10' LS	34.5	Clayey Sand	100	1.98	0.67	11	7	30	
AD-453	4+65	10' LS	39.5	Clayey Sand	100	2.27	0.61	4	2	28	
			43.7	Rock							
AD-455	63+00	15' RS	2.0	CL (sand, fill?)	24	0.12	1.79	12	22		
AD-455	63+00	15' RS	4.5	Sand w/silt	24	0.26	1.59	14	22		
AD-455	63+00	15' RS	7.0	Sand w/silt	24	0.40	1.43	11	16		
AD-455	63+00	15' RS	9.5	CH	24	0.55	1.29	4	5		550
AD-455	63+00	15' RS	12.0	OL? (CH/CL)	24	0.69	1.18	7	8		1000
AD-455	63+00	15' RS	14.5	CH w/ sand	24	0.83	1.09	6	7		850
AD-455	63+00	15' RS	19.5	Sandy CH	24	1.12	0.94	7	7		850
AD-455	63+00	15' RS	24.5	Sandy CH	24	1.39	0.84	9	8		1000
AD-455	63+00	15' RS	29.5	Sand	24	1.54	0.79	8	6	29	
AD-455	63+00	15' RS	34.5	Sand	24	1.68	0.75	8	6	29	
AD-455	63+00	15' RS	39.5	Sand	24	1.83	0.71	25	18	34	
AD-455	63+00	15' RS	44.5	Sand	24	1.97	0.67	34	23	36	
AD-455	63+00	15' RS	49.5	Sand	24	2.11	0.64	17	11	33	
AD-455	63+00	15' RS	54.5	Sand	24	2.26	0.61	30	18	34	
AD-455	63+00	15' RS	59.5	Sand	24	2.40	0.59	29	17	34	
AD-455	63+00	15' RS	64.5	Sand	24	2.55	0.56	34	19	34	
AD-455	63+00	15' RS	69.5	Sand	24	2.69	0.54	41	22	36	
AD-455	63+00	15' RS	74.5	Sand	24	2.83	0.52	70	37	40	

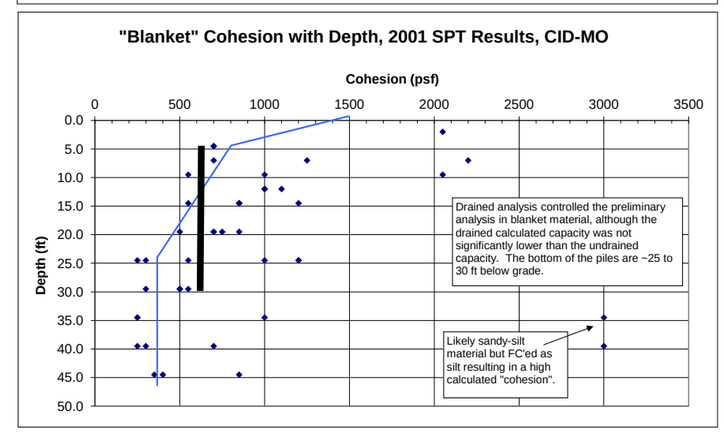
D-456	68+65	12' RS	4.5	Sandy Clay	34	0.26	1.59	18	29		
D-456	68+65	12' RS	7.0	Ashpalt/Gravel (fill)	34	0.40	1.43	10	14		
D-456	68+65	12' RS	9.5	Cement/Brick (fill)	34	0.55	1.29	7	9		
D-456	68+65	12' RS	12.0	Clay w/ cind, brick	34	0.69	1.18	6	7		
D-456	68+65	12' RS	14.5	Sandy Silt	34	0.83	1.09	11	12		1200
D-456	68+65	12' RS	19.5	Clayey Silt	34	1.12	0.94	6	6		700
D-456	68+65	12' RS	24.5	Clayey Silt	34	1.41	0.83	12	10		1200
D-456	68+65	12' RS	29.5	Clayey Silt	34	1.70	0.74	6	4		500
D-456	68+65	12' RS	34.5	Clayey Silt	34	1.97	0.67	12	8		1000
D-456	68+65	12' RS	39.5	Silty Clay	34	2.11	0.64	9	6		700
D-456	68+65	12' RS	44.5	Sandy Silt	34	2.26	0.61	12	7		850
D-456	68+65	12' RS	49.5	Silty Sand	34	2.40	0.59	36	21	35	
D-456	68+65	12' RS	54.5	Sand	34	2.55	0.56	28	16	33	
D-456	68+65	12' RS	59.5	Sand	34	2.69	0.54	12	7	30	
D-456	68+65	12' RS	64.5	Sand	34	2.83	0.52	100	52	40	
D-456	68+65	12' RS	69.5	Sand	34	2.98	0.50	37	19	34	
D-456	68+65	12' RS	74.5	Sand	34	3.12	0.49	28	14	34	
D-456	68+65	12' RS	79.5	Sand	34	3.27	0.47	23	11	33	
			82.5	Rock							

D-457	70+60	12' RS	2.0	CL	13.5	0.12	1.79	9	16		2050
D-457	70+60	12' RS	4.5	CH	13.5	0.26	1.59	4	6		700
D-457	70+60	12' RS	7.0	Sandy CH	13.5	0.40	1.43	4	6		700
D-457	70+60	12' RS	9.5	Sand	13.5	0.55	1.29	12	16	33	
D-457	70+60	12' RS	12.0	Sand	13.5	0.69	1.18	11	13	33	
D-457	70+60	12' RS	14.5	CH	13.5	0.81	1.11	6	7		850
D-457	70+60	12' RS	19.5	Clayey Silt	13.5	0.95	1.03	6	6		750
D-457	70+60	12' RS	24.5	Sand	13.5	1.09	0.96	10	10		1200
D-457	70+60	12' RS	29.5	CH	13.5	1.24	0.89	3	3		300
D-457	70+60	12' RS	34.5	Silt	13.5	1.38	0.84	0	0		250
D-457	70+60	12' RS	39.5	Silt	13.5	1.53	0.79	1	1		250
D-457	70+60	12' RS	44.5	Sand	13.5	1.67	0.75	24	18	34	
D-457	70+60	12' RS	49.5	Sand	13.5	1.81	0.71	20	14	32	
D-457	70+60	12' RS	54.5	Sand	13.5	1.96	0.68	14	9	31	
D-457	70+60	12' RS	59.5	Sand	13.5	2.10	0.64	9	6	29	
D-457	70+60	12' RS	64.5	Sand	13.5	2.25	0.62	66	41	40	
D-457	70+60	12' RS	69.5	Sand	13.5	2.39	0.59	58	34	39	
D-457	70+60	12' RS	74.5	Gravel/Sand	13.5	2.53	0.57	11	6	29	









D-457	70+60	12' RS	79.5	Gravel/Sand	13.5	2.68	0.54	23	13	33	
D-457	70+60	12' RS	85.5	Gravel/Sand	13.5	2.85	0.52	27	14	33	
			87.0	Rock							

D-458	80+30	10' LS	2.0	Sand	11	0.12	1.79	12	22	32	
D-458	80+30	10' LS	4.5	Sand	11	0.26	1.59	7	11	33	
D-458	80+30	10' LS	7.0	Gravel	11	0.40	1.43	9	13	30	
D-458	80+30	10' LS	9.5	Sand	11	0.55	1.29	17	22	36	
D-458	80+30	10' LS	12.0	Sand	11	0.66	1.20	13	16	33	
D-458	80+30	10' LS	14.5	Sand	11	0.73	1.15	10	12	33	
D-458	80+30	10' LS	19.5	Sand	11	0.88	1.07	15	16	33	
D-458	80+30	10' LS	24.5	Sandy CH	11	1.02	0.99	2	2		250
D-458	80+30	10' LS	29.5	CH	11	1.17	0.92	4	4		500
D-458	80+30	10' LS	34.5	CH	11	1.31	0.87	0	0		250
D-458	80+30	10' LS	39.5	CH	11	1.45	0.82	4	3		300
D-458	80+30	10' LS	44.5	CH	11	1.60	0.77	3	2		400
D-458	80+30	10' LS	49.5	Clayey Sand	11	1.74	0.73	15	11	33	
D-458	80+30	10' LS	54.5	Sand	11	1.89	0.69	31	21	36	
D-458	80+30	10' LS	59.5	Sand	11	2.03	0.66	18	12	33	
D-458	80+30	10' LS	64.5	Sand	11	2.17	0.63	12	8	29	
D-458	80+30	10' LS	69.5	Sandy CH	11	2.32	0.60	19	11	33	

Notes:

1. Overburden correction to blowcount: $C_n = 2/(1 + \sigma')$, with σ' in tsf
2. Corrected blowcount = $N_{(uncorrected)}*C_n$, safety hammer on cat head rig, so no other correction per EM
3. C_u from EM 1110-1-1804 Table G-1 and EM 1110-2-2504 Table 3-4
4. ϕ from EM 1110-1-1905 Table 3-1 and EM 1110-2-2504 Table 3-1

	ϕ' (degrees)		C_u (psf)	
	AVG	STDEV	AVG	STDEV
Sand	33.3	3		
CL			983	472
CH			763.4615385	478
Silt			1283	1348
blanket			902	658

Material	Strength		Source
C_u blanket =	600	psf	SPT
ϕ blanket =	N/A	degrees	SPT
ϕ sand =	30	degrees	SPT
ϕ fill =	N/A	degrees	SPT