Kansas Citys, Missouri and Kansas
Flood Damage Reduction Feasibility Study
(Section 216 – Review of Completed Civil Works Projects)
Engineering Appendix to the Interim Feasibility Report

Chapter A-6

GEOTECHNICAL ANALYSIS EAST BOTTOMS (MISSOURI AND BLUE RIVERS CONFLUENCE AREA)

CHAPTER A-6
GEOTECHNICAL ANALYSIS
EAST BOTTOMS (MISSOURI AND BLUE RIVERS CONFLUENCE AREA)

A-6.1 INTRODUCTION

This chapter presents the results of the geotechnical evaluation for an area in the East Bottoms Unit determined to have a certain probability of failure under the existing level of protection that warranted further study. The information utilized in this determination is from existing borings and soil tests, along with recent subsurface boring and soil test data.

A-6.2 SOURCES OF EXISTING LEVEE DESIGN INFORMATION

The primary sources of information for this geotechnical analysis include the references listed in the References section of this chapter.

A-6.3 DESCRIPTION OF THE LEVEE UNIT

Refer to Section A-4.3.6 for a detailed description of the levee unit. Note that the Blue River has been channelized and modified by the Corps of Engineers as a separate flood protection system and is not included in this analysis, except for the lower reach which is associated with the East Bottoms levee tieback.

A-6.4 LEVEE DESIGN FEATURES

A-6.4.1 Basic Existing Levee and Floodwall Sections

The East Bottoms Unit is an existing federal levee. It was originally constructed as a local levee, but was removed and replaced using Federal standards in 1950.

The basic existing levee sections were constructed with a 10-foot crown width, having 1V on 3H riverside and 1V on 4H landside side slopes. The internal zoning consists of a riverside impervious zone with random fill in the remaining levee section. Stability berms have been constructed in some reaches. The stability berms generally extend 55 feet riverside and 50 feet landside of the primary levee slope toe. The minimum stability berm width is 20 feet. A plan view of the East Bottoms Unit and typical sections are provided as Exhibits A-6.1 through A-6.15 found in the Supplemental Exhibits section of this chapter.

A floodwall section was constructed in areas with limited real estate availability. The floodwall was constructed after excavation of upper sand seams and placement of silt fill to connect with the deeper blanket materials. The wall section is an inverted T-wall section with a riverside key. A toe drain was placed at the landside toe of the base of the wall to capture seepage and relieve foundation pressures below the wall. An extensive buried collector system (23,020 linear feet) was constructed to relieve the pressures at the landside toe of the levee to prevent piping failures. Twenty eight relief wells were constructed to protect the area between Station 297+00 and Station 350+00.

A-6.4.2 Future Flood Protection Concerns

This levee unit is not recommended for a raise based on the hydraulic analysis of the Missouri and Kansas Rivers. As a result of consulting with local industry within the

flood protection areas, Station 365+00 to Station 435+00 was reported to have serious flood fighting activity during the 1993 flood event. The local owners of the property inside of the levee reported multiple sand boils with large areas of excessive seepage. Their flood fight efforts consisted of sand bag ring dikes with temporary sand fill placement inside of the seepage areas. Landside piping was reported in areas 20 feet in diameter. The seepage areas that are documented are shown on the plan view in the supplemental Exhibit A-6.17. The 1993 flood did not reach the top of levee in these problem areas. A full head to the top of the levee may have lead to catastrophic underseepage failure of this area and all other areas inside the East Bottoms Unit. High river stages on the Blue River could most certainly result in full head on the section of the East Bottoms levee that aligns with the Blue River. The Blue River has historically risen as rapidly as 4 feet per hour.

A-6.4.3 Area Site Characterization

Private sector and Corps of Engineers boring information was used to characterize the foundation located between Station 365+00 and Station 435+00. This information is contained in the Supplemental Exhibits section (Exhibits A-6.18 through A-6.24). The Corps borings were located in the as-built drawings listed in the references. Two new borings (D-351 and D-352) were completed in 2001 and supplement the existing borings. A large number of engineering design firm borings were also used - see Reference 18. The vital information obtained from the borings was the thickness of overlying blanket materials. From this information, contour maps showing the variability of the blanket thickness were overlaid on the map of the known underseepage boil activity in 1993. The existing underseepage control features were also identified on this map. The map is provided in the supplemental Exhibit A-6.16. The map shows a highly variable blanket thickness from as low as 1 foot to as high as 20 feet. The concentrated excessive seepage areas coincide with locations of minimum blanket thickness. The area map was zoned to show the limits of the underseepage concern.

A-6.4.4 Underseepage analyses

The entire reach reported to have sand boils was reconsidered for underseepage analysis. The underseepage analysis was modeled after consideration of the types of soils landward of the levee, the consistency of the thickness of the soil blanket clays or silts, the thickness of the sand deposit below the levee blanket materials, the lateral extent of the blanket landside and riverward of the levee, the effects of the location of the Missouri River or Blue River, and the height of the existing levee. All of these variables were considered during the development of the model to characterize the representative reaches along the alignment of the levee. These reaches were considered separately to determine the landside resistance to upward gradient pressures which could initiate piping of the blanket materials. This could lead to subsequent piping of sand grains toward the river entrance, leading to ultimate collapse of the levee section due to the foundation voids caused by piping. The collapse, or slumping, of the crest of the levee due to loss of foundation materials would allow for overtopping of the levee. This would be followed by an accelerated total collapse of the levee section with uncontrolled flow of water into the East Bottoms interior protected area. Initiation of the movement of the soil from the blanket is represented by a definition of the factor of safety with respect to the downward weight of a soil column to resist the upward change in pressure head

(gradient) acting along the vertical distance of the column of soil in the blanket materials. The intention of underseepage design is to keep the upward gradient from exceeding the weight using a margin of safety.

In urban areas that have personnel on site to perform flood fight operations in a manageable length of protected area, the margin of safety is not as large as would be considered for a longer levee having no activity within to provide for flood fight personnel. The margin of safety with respect to the East Bottoms levee was set at 1.1 for checking the existing materials at the landside toe of the levee. An additional design requirement is to provide underseepage control when the factor of safety with respect to critical gradient is less than 1.5 with the design water surface 3 feet below the top of levee. Usually the 1.5 safety factor controls the required underseepage design. If the 1.1 factor of safety or secondary check of 1.5 is not satisfied, the design meets a requirement of 1.5 for the berm design, the buried collector design, and the relief well design.

Berm design was considered only when the area landside of the levee was available for construction. If unavailable, a buried collector system was considered. In areas that exhibited a blanket thickness of less than 5 feet, relief wells were considered appropriate to provide the underseepage control. The margin of safety between wells was set to a minimum of 1.5. The pressures at the base of the blanket, at the midpoint between wells, will reach a maximum. These will be the first locations for initiation of soil grain movement.

The blanket materials were assigned permeability parameters based on the content of silt, clay or sand. Only areas that contained a blanket thickness of at least ¼ the height of the levee were considered meaningful in the underseepage model. When this happened, the reach was modeled using relief wells for underseepage control. This information was used to evaluate the underseepage control needs.

The existing factor of safety in the underseepage analysis was calculated using water at the top of levee. The relative magnitude of the permeability ratios of the clean foundation sands to the blanket materials was set after the Kansas City District's observation of boil activity from the 1951 flood. The KCD method of estimating the underseepage gradient and the required factors of safety deviate somewhat from the method presented in the EM-1110-2-1913. The KCD traditional empirical approach has been used since the 1960's and has proven effective in providing adequate underseepage control for most reaches within the East Bottoms Unit. It has been accepted for use as the basis of determining the need for underseepage treatment on levee units within the District. This method is based on conclusions of a Corps of Engineers, Missouri River Division Conference, held in Omaha in Nov, 1962. The effectiveness of this procedure has been demonstrated by the excellent historical performance of the District's levees in multiple flood events including the 1993 flood event on the Missouri River. The traditionally assumed permeability ratios for blanket materials are shown in Table A-6.1.

Table A-6.1 - Permeability Ratios for Blanket Materials

Blanket Material	Assigned Permeability Ratio
SM : Silty Sand	100
ML : Silt	200-400
ML-CL : Silt/Clay	400
CL: Lean Clay	400-600
CH: Fat Clay	800-1000

The calculations of the underseepage factors of safety that were used in the underseepage analysis are as follows:

The gradient piping factor of safety is defined as:

$$FS_i = i_c / i_o$$

where i_o = actual gradient and i_c = critical gradient

$i_c = \gamma_b / \gamma_w$ when soils particles movement can begin at the toe

and $\gamma_b = \gamma_{sat} - \gamma_w$ where γsat = saturated unit weight of the soil and

γ_w = unit weight of water

i_o = upward gradient through the blanket = change in head from the base of the blanket to the top of the blanket. The reference datum is set at the top of the blanket because the movement of the soil grain will begin at the top of the blanket.

Δh = gradient head calculated at the base of the blanket measure from the reference datum, the top of the blanket. This gradient calculation procedure is provided in Appendix IV with defined equations and illustrative nomenclature.

z_{bl} = the thickness of the blanket

$i_o = \Delta h / z_{bl}$

then $FS_i = i_c / i_o = (\gamma_b / \gamma_w) / (\Delta h / z_{bl}) = (\gamma_b * z_{bl}) / (\Delta h * \gamma_w)$

The characterization of the thickness of the blanket from Station 366+00 to Station 454+00 provides the focus for the area of concern. An underseepage analysis is provided in the supplemental Exhibits A-6.25 through A-6.28 to demonstrate the integrity of the reaches identified with the factor of safety with respect to gradient. The spreadsheet provided is relevant for blanket thicknesses greater than ¼ of the height of

the levee. Although data is shown for all reaches, the integrity of a very thin blanket to provide a confining layer is questionable.

The original designers developed a design for a buried collector system inside of the area being considered. The equations appear to have a built-in factor of safety of two. The buried collector has been constructed in the reach in question. It appears that the highest concentration of uncontrolled flow does occur near the opening between two separate lengths of buried collector. One could suggest providing an additional length of buried collector system to connect between the two systems. This would assuredly be the most economical solution.

It should be recognized that the original design assumptions for this reach considered a blanket thickness of 4 feet minimum. The site characterization map shows that this assumption is invalid based on all of the boring information obtained after the original design.

Kansas City District underseepage design history indicates that, in areas where very thin to no thickness in blanket materials are present, relief wells were the system chosen to control underseepage. The thin zones in the East Bottoms reach from Station 403+00 to Station 420+00 are recommended to be protected using relief wells. The recommended spacing is based on calculations contained in the supplemental Exhibits A-6.29 through A-6.34.

Other alternatives to wells have been considered. The other alternatives considered include: 1) flood fighting, 2) construction of driven steel sheet piling to bedrock from Station 396+00 to Station 427+00, and 3) excavation of a slurry trench from Station 396+00 to Station 427+00. Relocation of the levee riverside of the existing alignment was considered, but dismissed due to encroachment on the river foreshore and opposite bank flooding impacts.

A-6.5 REFERENCES

1. East Bottoms Levee Unit, Definite Project Report, July 1948.

2. East Bottoms Levee Unit, Design Analysis for Levee, Floodwall, September 1945.

3. East Bottoms Levee Unit, Analysis of Design Gillis Street, Lydia Avenue and Prospect Pump Plant, September 1948.

4. East Bottoms Levee Unit, Milwaukee Bridge, Truman Bridge and Hawthorn Pump Plant, October 1949

5. East Bottoms Levee Unit, Toes and Bank Protection, Design Memorandum No. 1.

6. East Bottoms Levee Unit, Left Bank Raise Big Blue River, November 1958.

7. East Bottoms Levee Unit, Construction Drawings for Levee Floodwall and Appurtenances, January 1948.

8. East Bottoms Levee Unit, Construction Drawings for Pump Plants Gillis, Lydia, Prospect, April 1949.

9. East Bottoms Levee Unit, Record Drawings for Levee, Floodwall and Appurtenances, December 1950.

10. East Bottoms Levee Unit, Record Drawings, Appendix I, Structures, May 1953 (RD April 1954).

11. East Bottoms Levee Unit, Construction Plans for Emergency Gates – Part I, April 1956.

12. East Bottoms Levee Unit, Construction Plans for Emergency Gates – Part II, May 1957.

13. East Bottoms Levee Unit, Periodic General Inspection No. 1, July 1970.

14. East Bottoms Levee Unit, Periodic General Inspection No. 1, March 1976.

15. East Bottoms Levee Unit, Operations and Maintenance Manual Volume I, January 1978.

16. Bayer Crop Science, Geotechnical Investigation Site III, V, VII, IX, prepared by URS Greiner Woodward Clyde, September 2000.

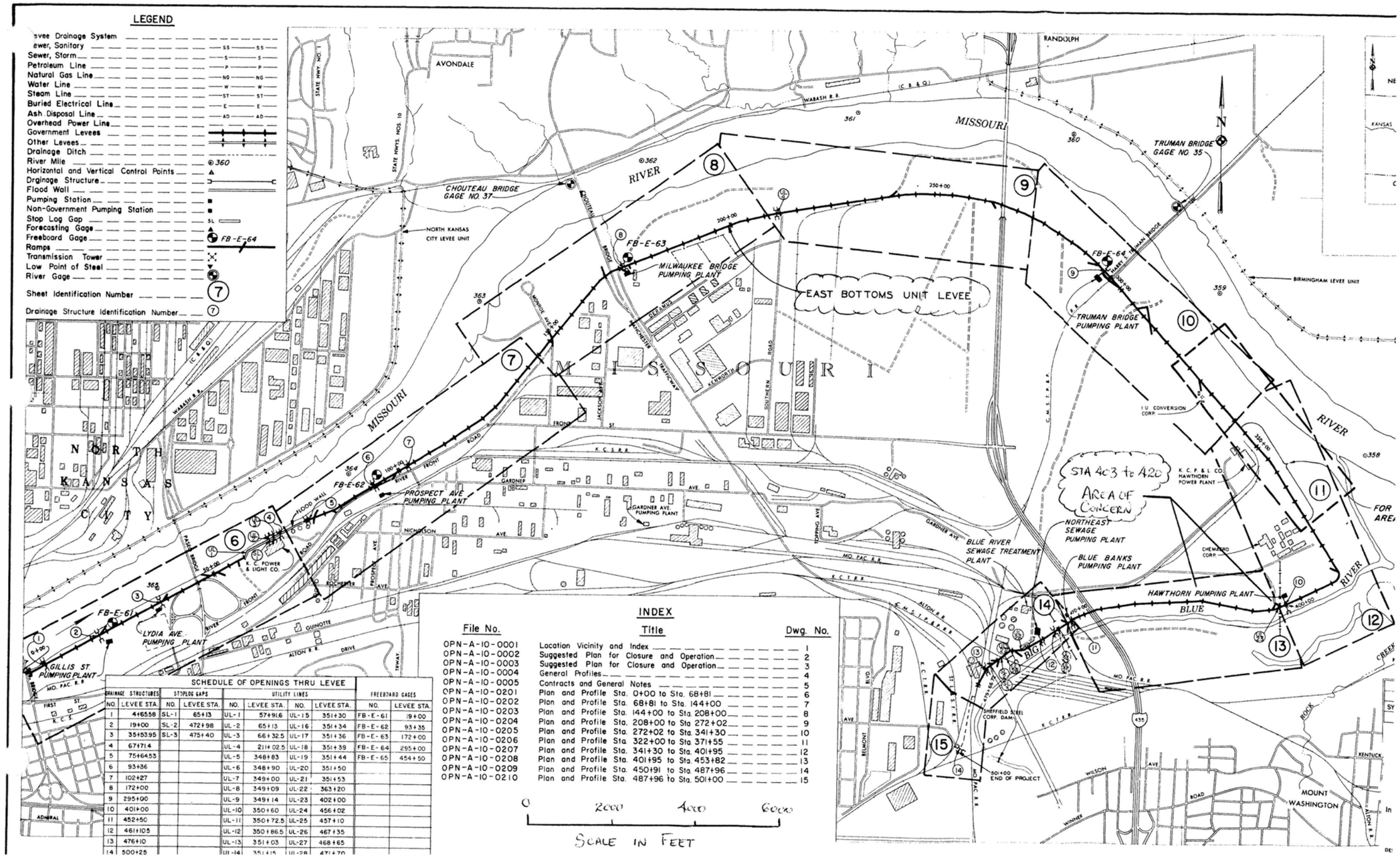
17. Bayer Crop Science, Site Drainage Studies, April 28, 2000.

18. Mobay Plant Site, Characterization and Evaluation of Site Subsurface Conditions, Woodward-Clyde Consultants, April 1981.

A-6.6 SUPPLEMENTAL EXHIBITS

Plan View and Typical Sections

EXHIBIT A-6.1



SCHEDULE OF OPENINGS THRU LEVEE

DRAINAGE STRUCTURES		STOPLOG GAPS		UTILITY LINES				FREEBOARD GAGES	
NO.	LEVEE STA.	NO.	LEVEE STA.	NO.	LEVEE STA.	NO.	LEVEE STA.	NO.	LEVEE STA.
1	4+6558	SL-1	65+13	UL-1	57+91.6	UL-15	351+30	FB-E-61	19+00
2	19+00	SL-2	472+98	UL-2	65+13	UL-16	351+34	FB-E-62	93+35
3	35+53.95	SL-3	475+40	UL-3	66+32.5	UL-17	351+36	FB-E-63	172+00
4	67+71.4			UL-4	211+02.5	UL-18	351+39	FB-E-64	295+00
5	75+64.53			UL-5	348+83	UL-19	351+44	FB-E-65	454+50
6	93+36			UL-6	348+90	UL-20	351+50		
7	102+27			UL-7	349+00	UL-21	351+53		
8	172+00			UL-8	349+09	UL-22	363+20		
9	295+00			UL-9	349+14	UL-23	402+00		
10	401+00			UL-10	350+60	UL-24	456+02		
11	452+50			UL-11	350+72.5	UL-25	457+10		
12	461+103			UL-12	350+86.5	UL-26	467+35		
13	476+10			UL-13	351+03	UL-27	468+65		
14	500+25			UL-14	351+15	UL-28	471+70		

EXHIBIT A-6.2

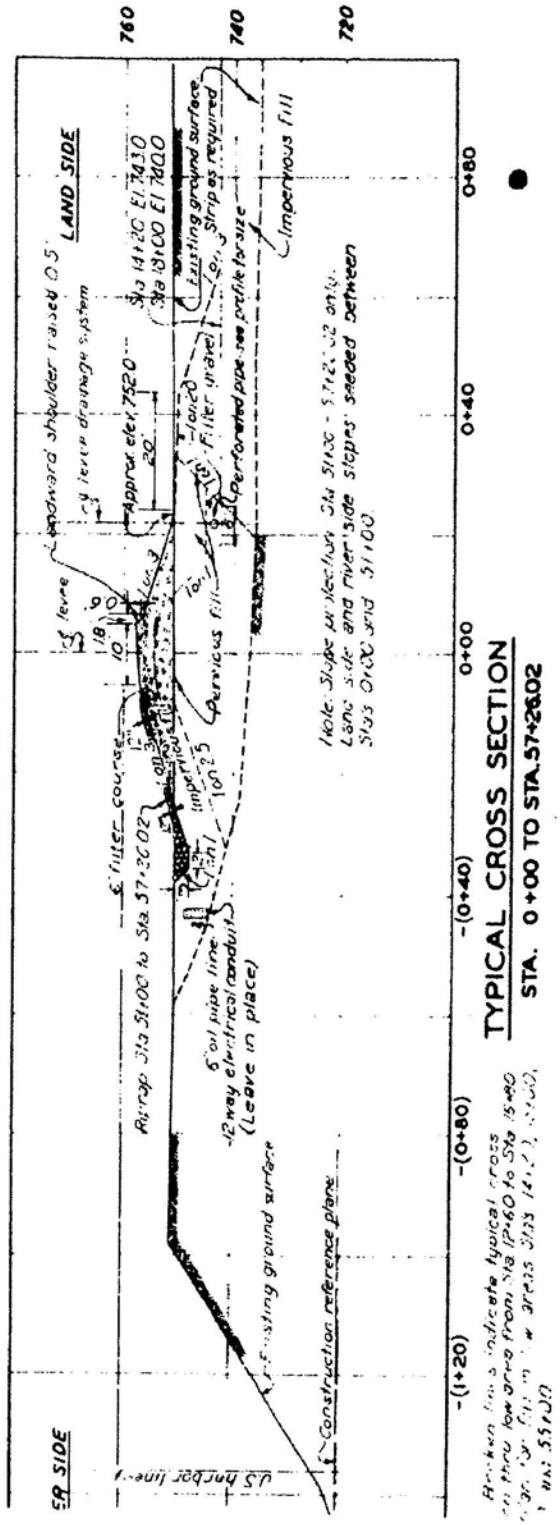
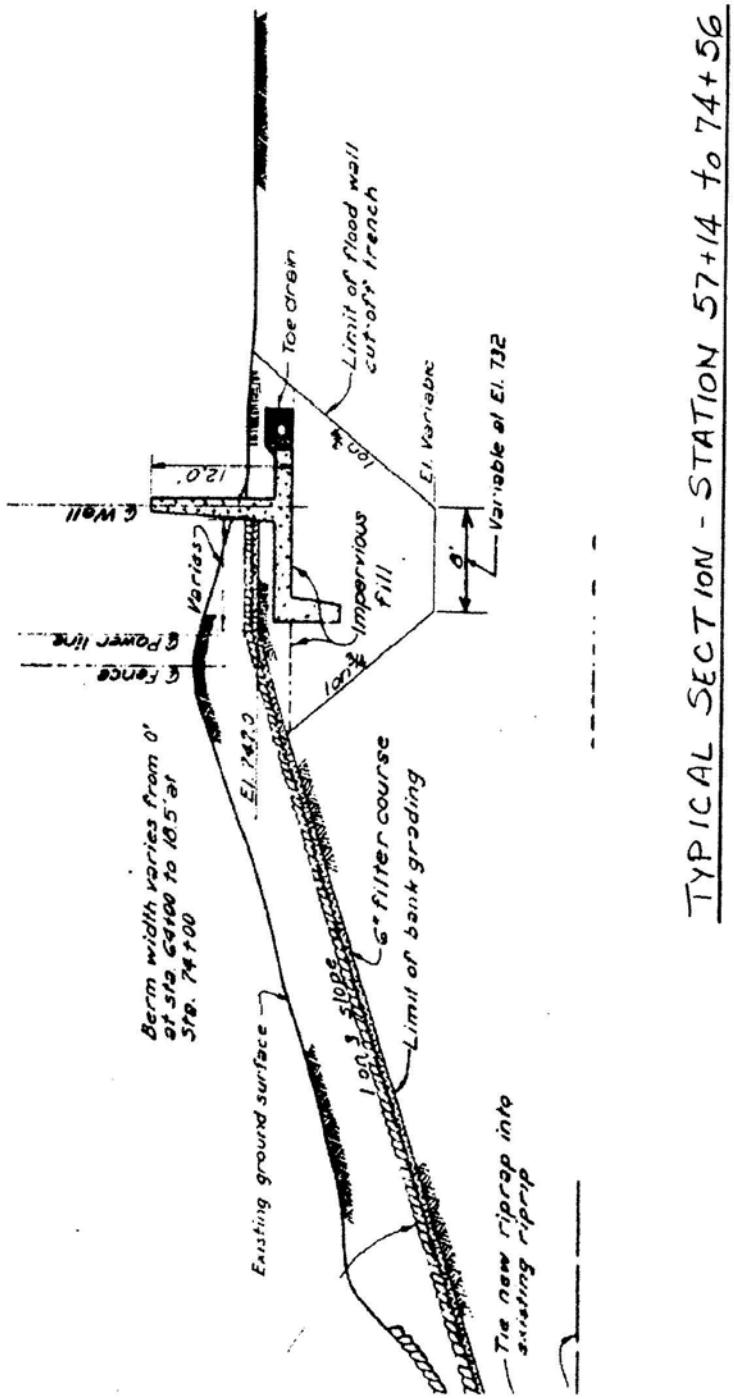
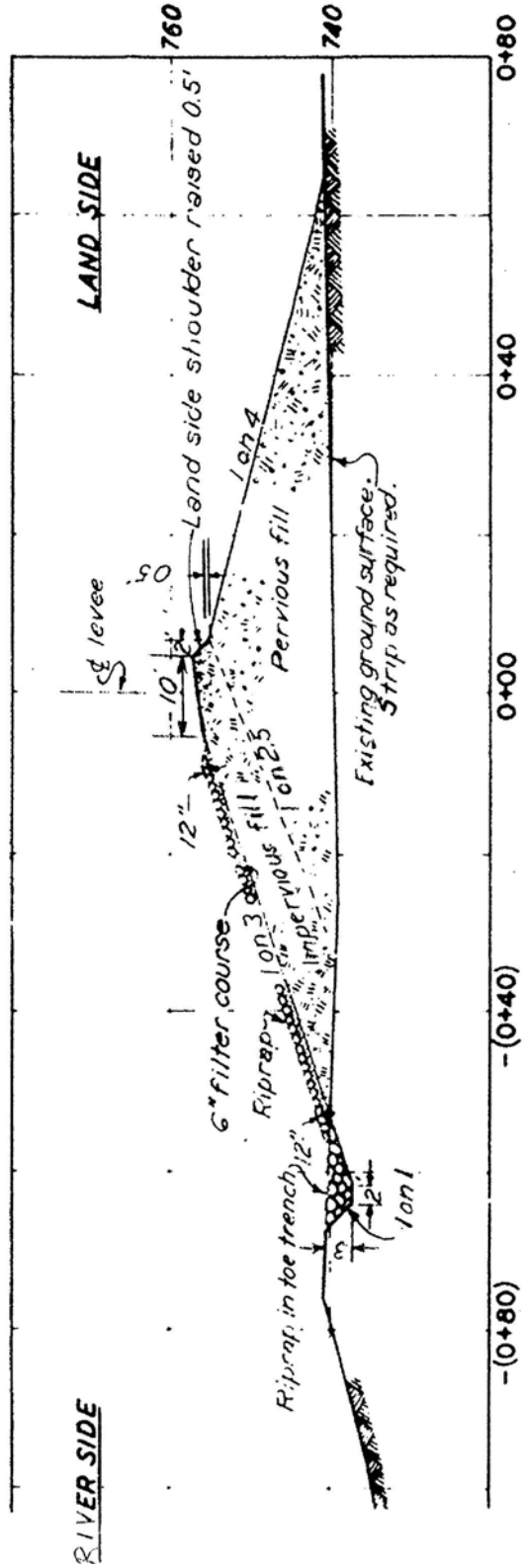

TYPICAL CROSS SECTION
STA. 0+00 TO STA. 57+26.02
LAND SIDE
760
740
720
0+80
0+40
0+00
-(0+40)
-(0+80)
-(1+20)
Existing ground surface
Strip as required
Impervious fill
Perforated pipe-see profile for size
Filter gravel
Approx elev 752.0
Pervious fill
Note: Slope protection Sta 51+00 - 57+26.02 only.
Land side and river side slopes seeded between
Sta's 0+00 and 51+00
Riprap Sta 51+00 to Sta 57+26.02
6" oil pipe line
12 way electrical conduit
(Leave in place)
Existing ground surface
Construction reference plane
U.S. harbor line
Sta 14+20 El 743.0
Sta 18+00 El 740.0

EXHIBIT A-6.3



TYPICAL SECTION - STATION 57+14 to 74+56

EXHIBIT A-6.4



TYPICAL CROSS SECTION

STA. 74+44.17 TO STA. 85+00

EXHIBIT A-6.5

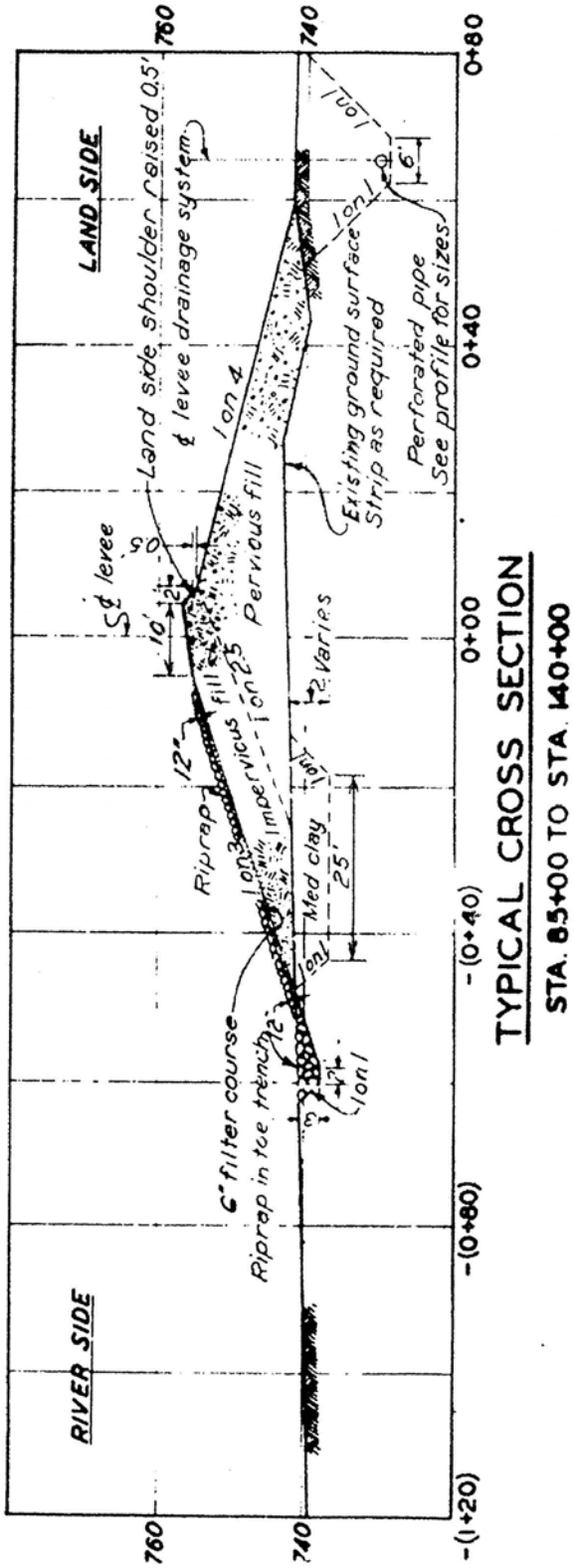
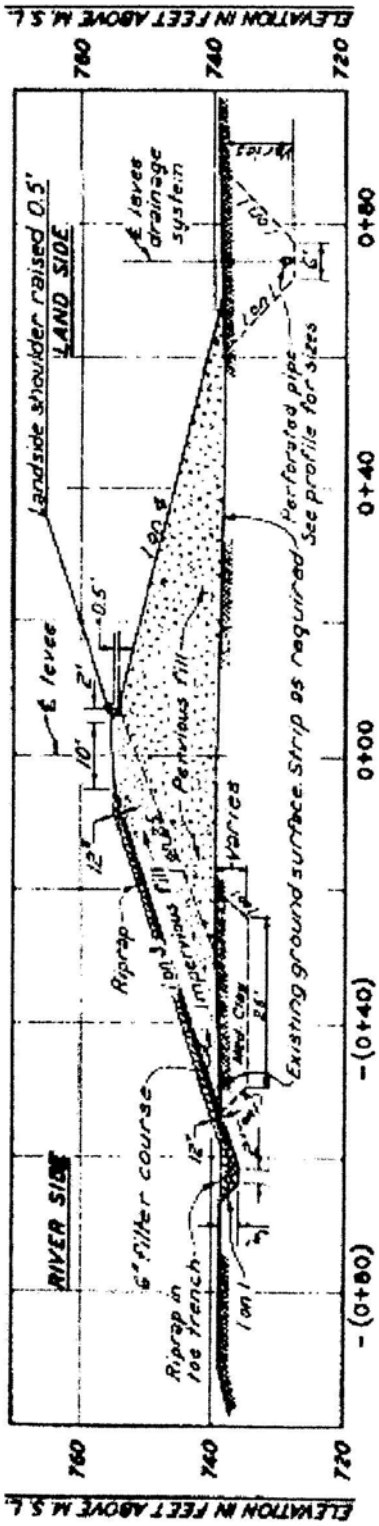

LAND SIDE
RIVER SIDE
760
740
0+80
0+40
0+00
-(0+40)
-(0+80)
-(1+20)
Land side shoulder raised 0.5'
℄ levee drainage system
1 on 4
Existing ground surface
Strip as required
Perforated pipe
See profile for sizes
℄ levee
Pervious fill
Impervious fill
1 on 2.5
Varies
Riprap
1 on 3
Med clay
25'
6" filter course
Riprap in toe trench
1 on 1
TYPICAL CROSS SECTION
STA. 85+00 TO STA. 140+00

EXHIBIT A-6.6



TYPICAL CROSS SECTION

STA. 140+00 TO STA. 174+27.5

Note: Levee drainage system from Sta. 160+00 to Sta. 174+27.5 only. Strip medium clay and backfill with impervious material between approximate stations 154+00 and 158+00.

EXHIBIT A-6.7

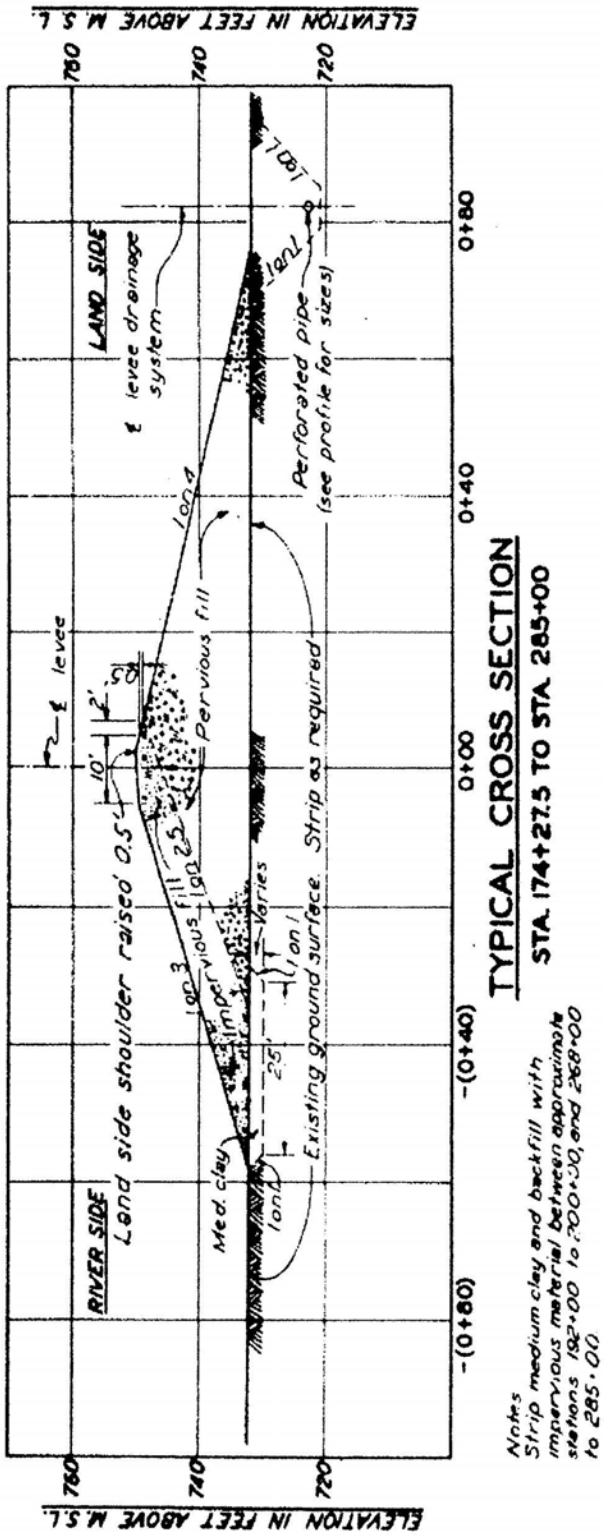
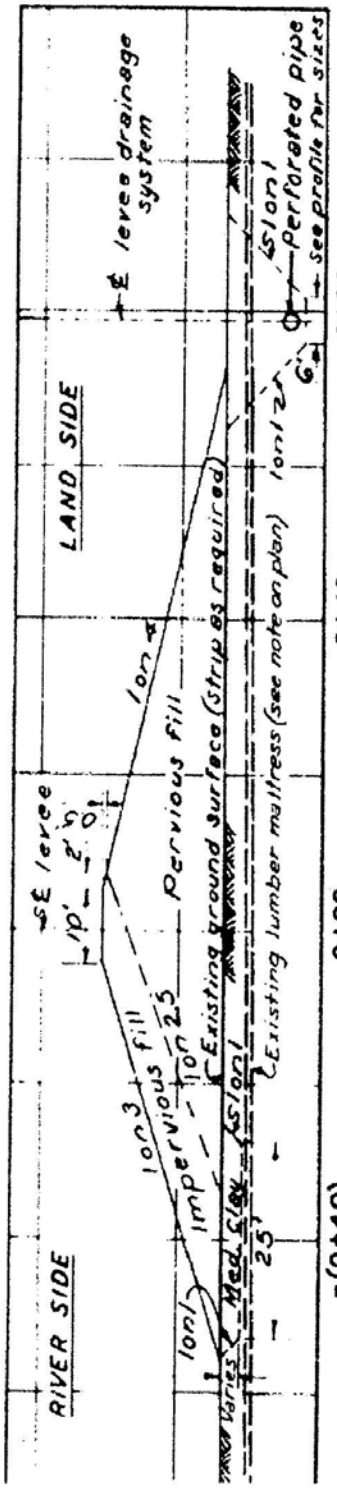

ELEVATION IN FEET ABOVE M.S.L.
760
740
720
RIVER SIDE
LAND SIDE
Land side shoulder raised 0.5'
℄ levee
℄ levee drainage system
Perforated pipe (see profile for sizes)
Pervious fill
Impervious fill
Med. clay
Varies
Existing ground surface. Strip as required
1 on 1
1 on 2.5
1 on 3
1 on 4
1 on 1
10'
2'
0.5'
25'
-(0+80)
-(0+40)
0+00
0+40
0+80
TYPICAL CROSS SECTION
STA. 174+27.5 TO STA. 285+00
Notes
Strip medium clay and backfill with impervious material between approximate stations 192+00 to 200+00, and 268+00 to 285+00

EXHIBIT A-6.8



TYPICAL CROSS SECTION

STA. 285+00 TO STA. 375+00

EXHIBIT A-6.9

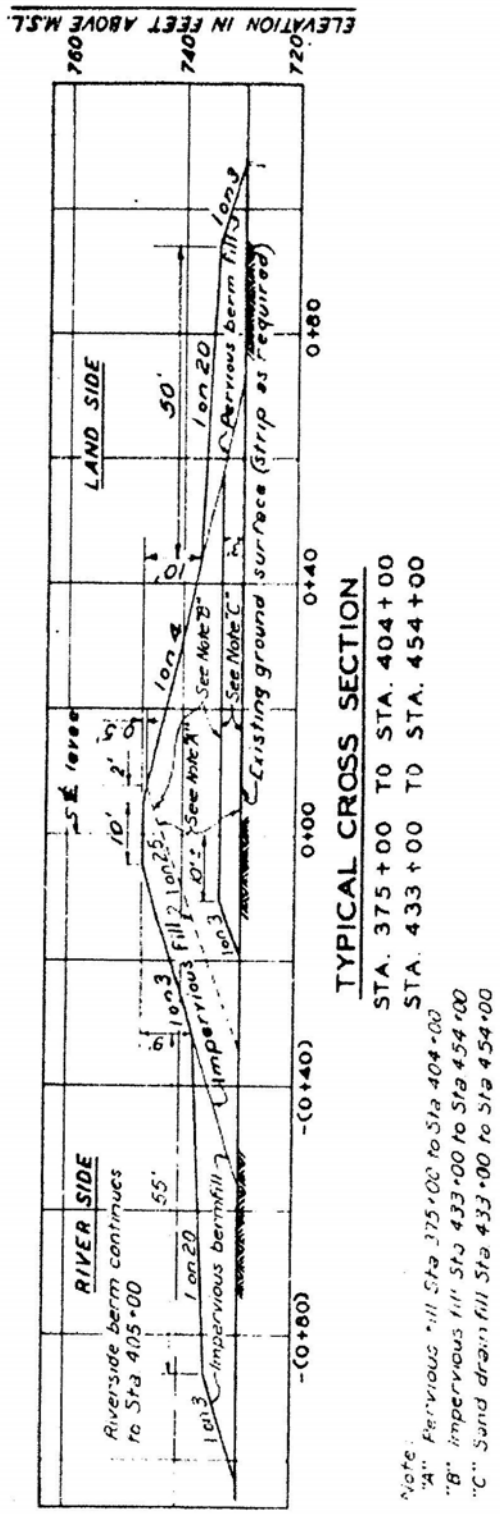

ELEVATION IN FEET ABOVE M.S.L.
760
740
720
RIVER SIDE
LAND SIDE
Riverside berm continues to Sta 405+00
55'
50'
1 on 20
1 on 3
1 on 4
1 on 25
Impervious bermfill
Impervious fill
Pervious berm fill
Existing ground surface (strip as required)
See Note "A"
See Note "B"
See Note "C"
-(0+80)
-(0+40)
0+00
0+40
0+80
TYPICAL CROSS SECTION
STA. 375+00 TO STA. 404+00
STA. 433+00 TO STA. 454+00
Note:
"A" Pervious fill Sta 375+00 to Sta 404+00
"B" Impervious fill Sta 433+00 to Sta 454+00
"C" Sand drain fill Sta 433+00 to Sta 454+00

EXHIBIT A-6.10

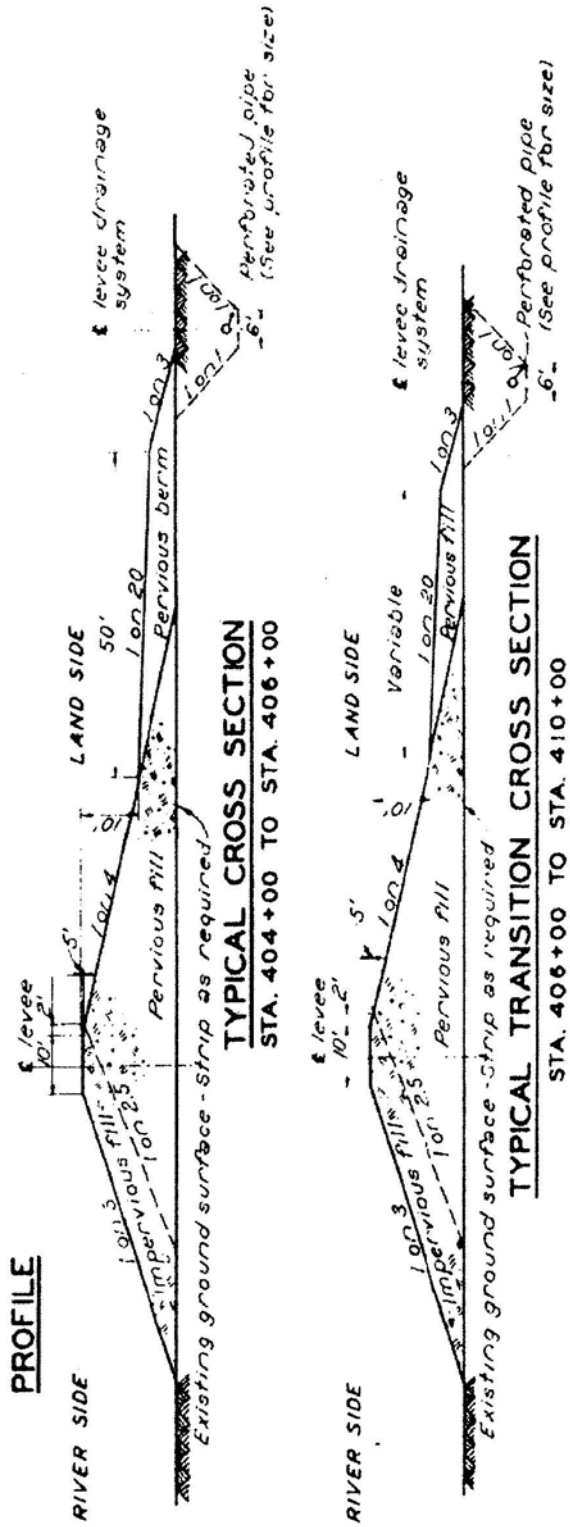


EXHIBIT A-6.11

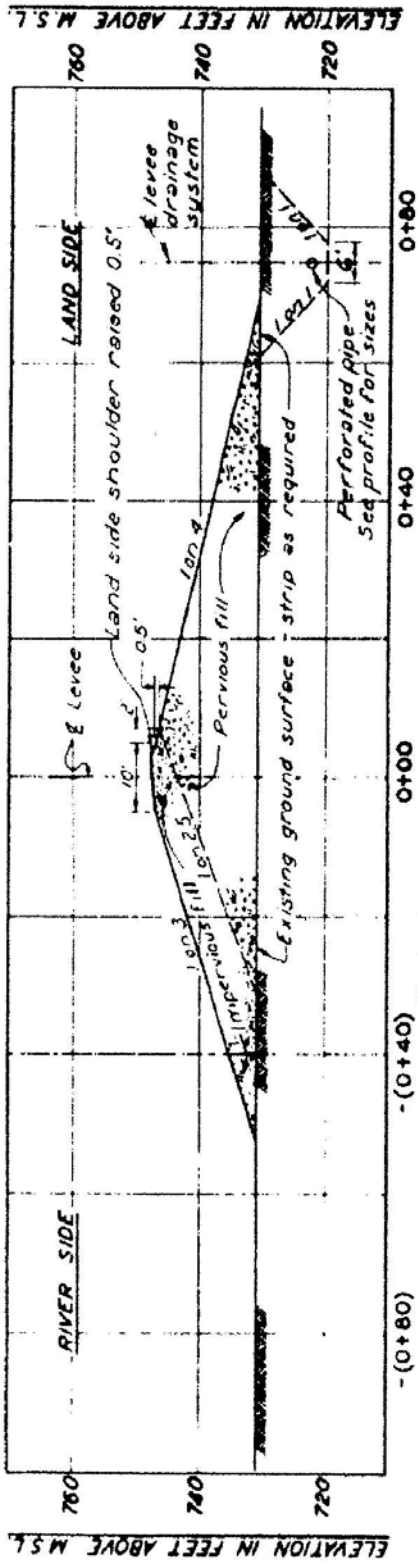


EXHIBIT A-6.12

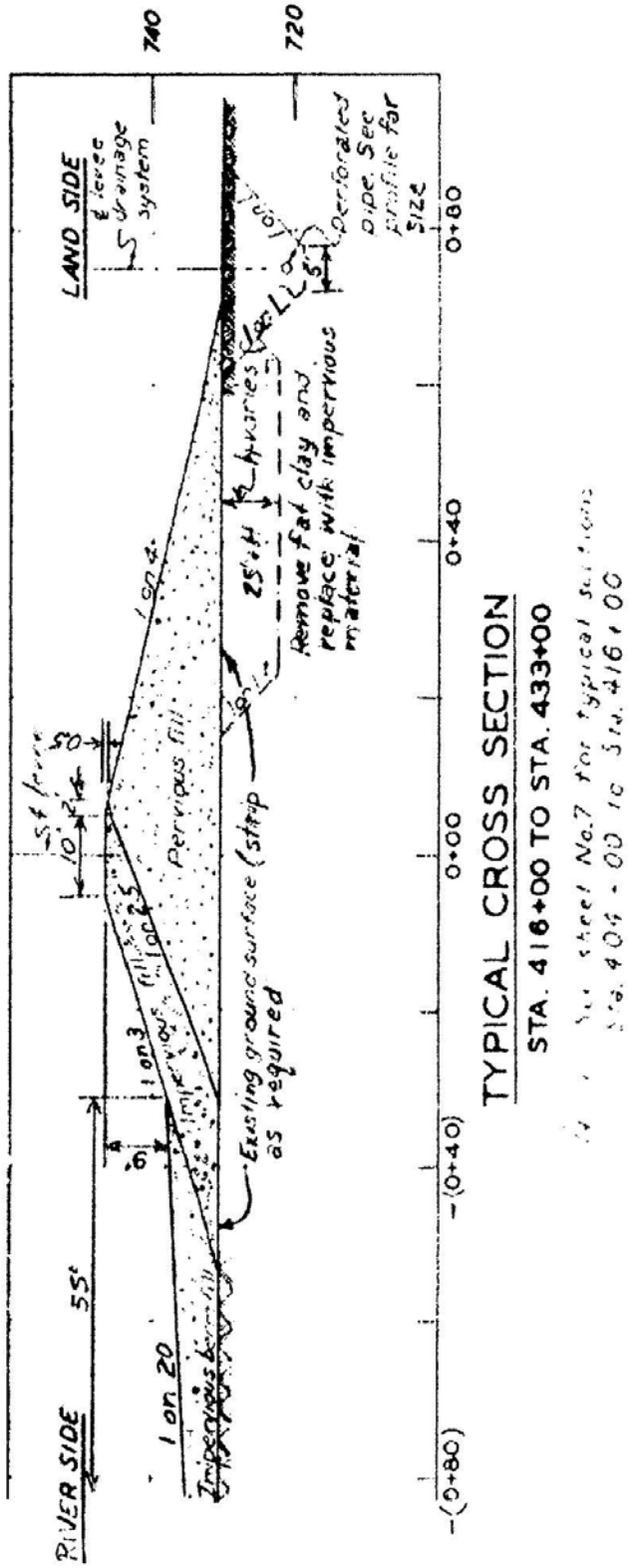
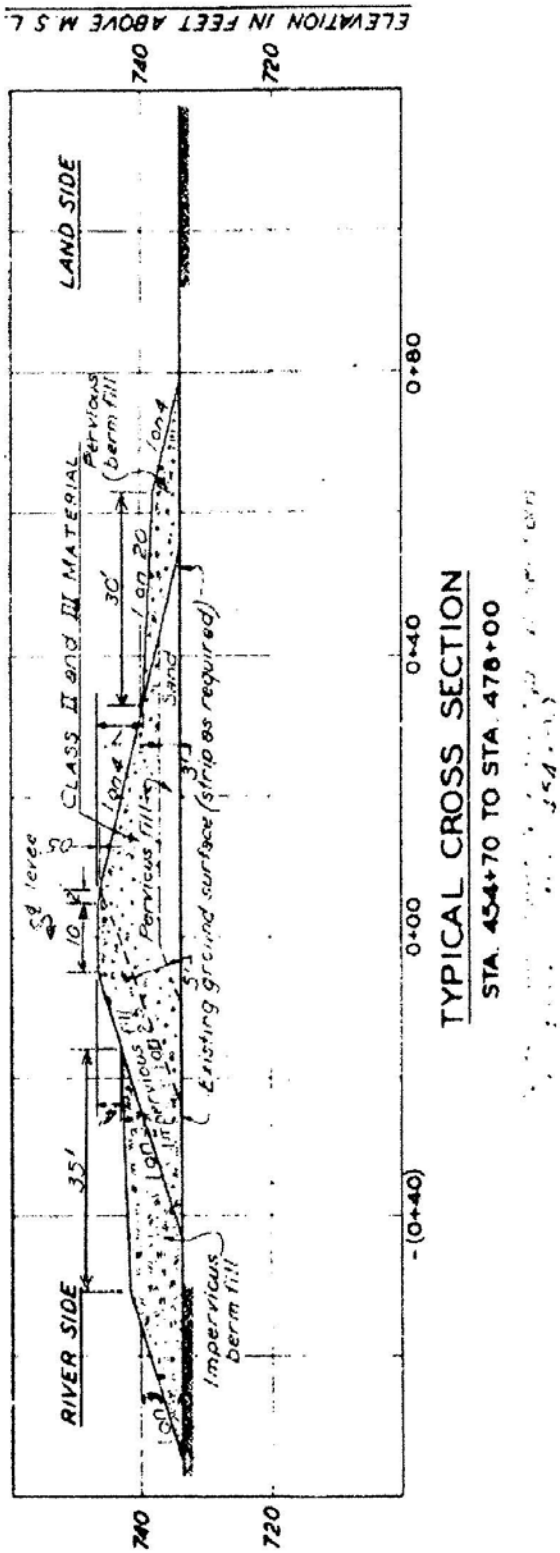


EXHIBIT A-6.13



TYPICAL CROSS SECTION

STA. 454+70 TO STA. 478+00

EXHIBIT A-6.14

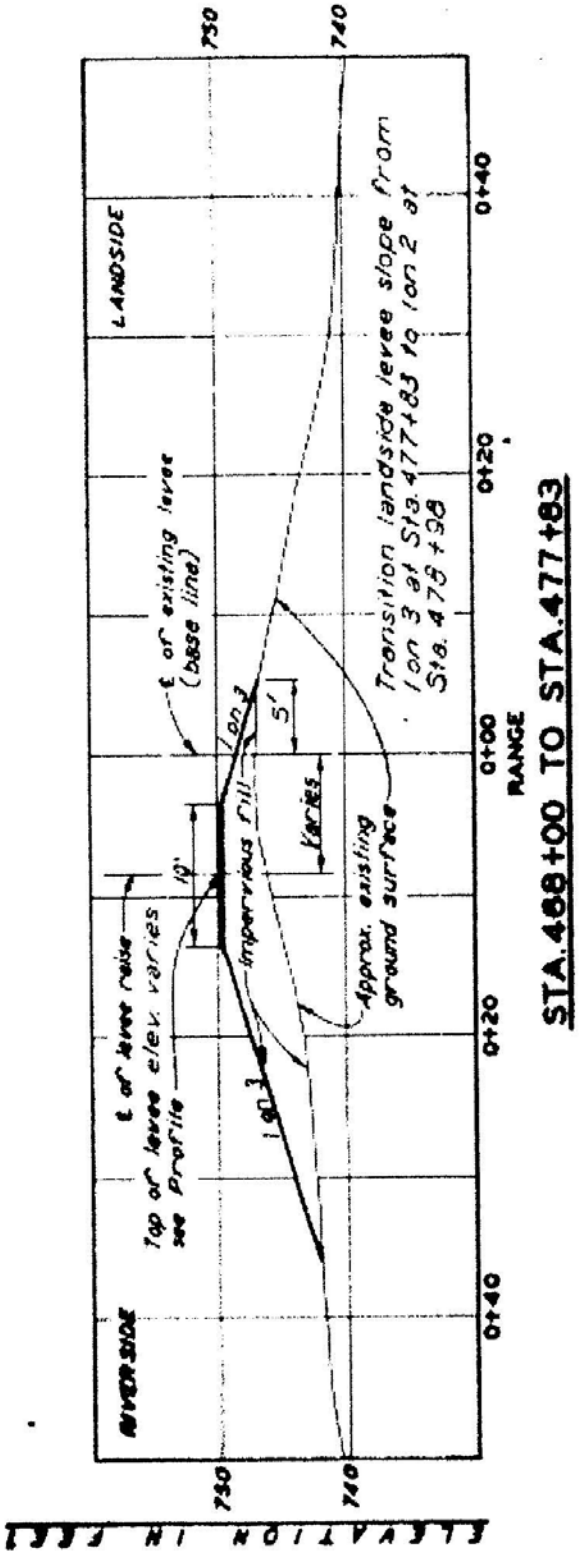
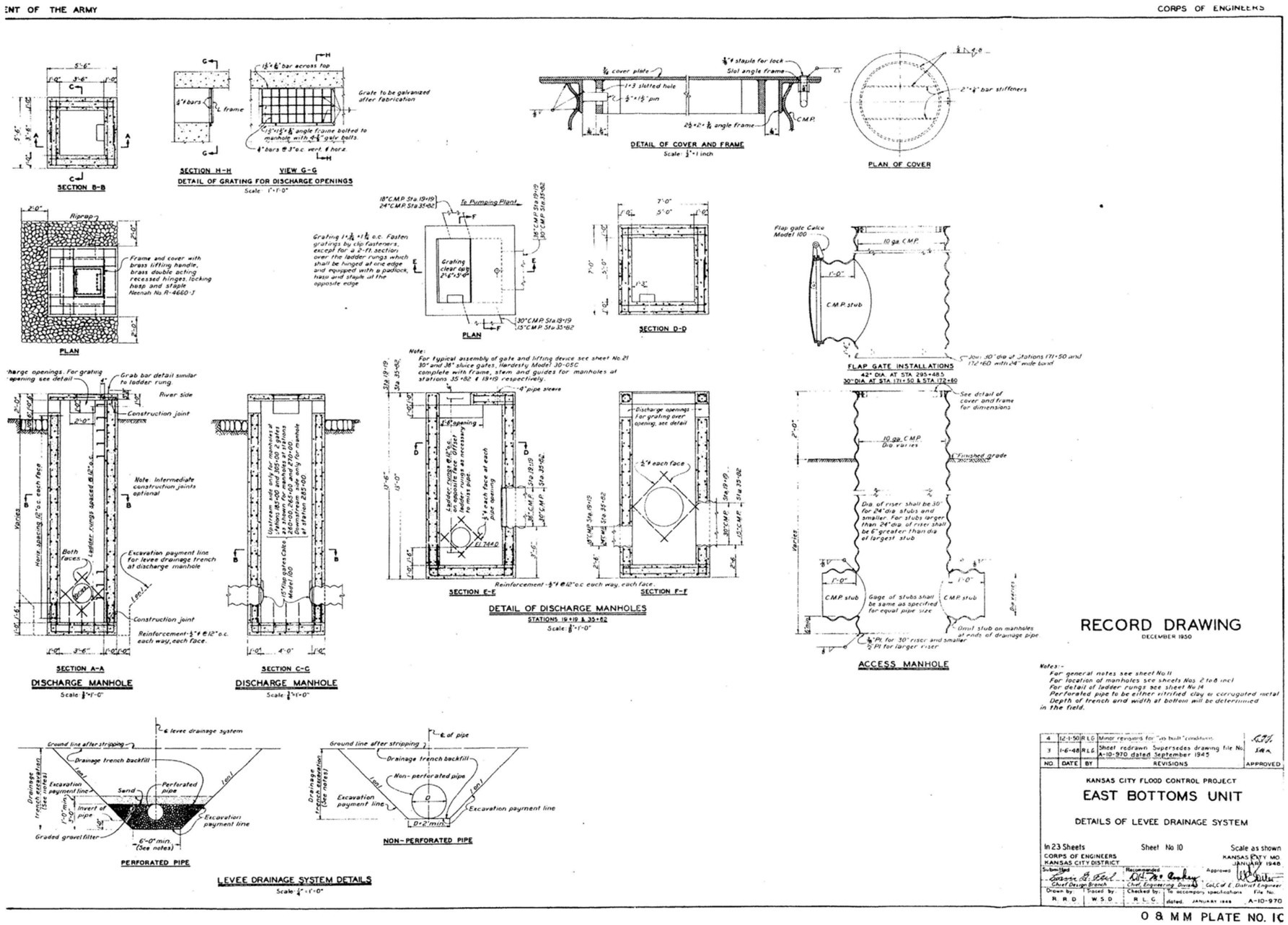


EXHIBIT A-6.15



Site Characterization Maps and Boring Information

EXHIBIT A-6.16

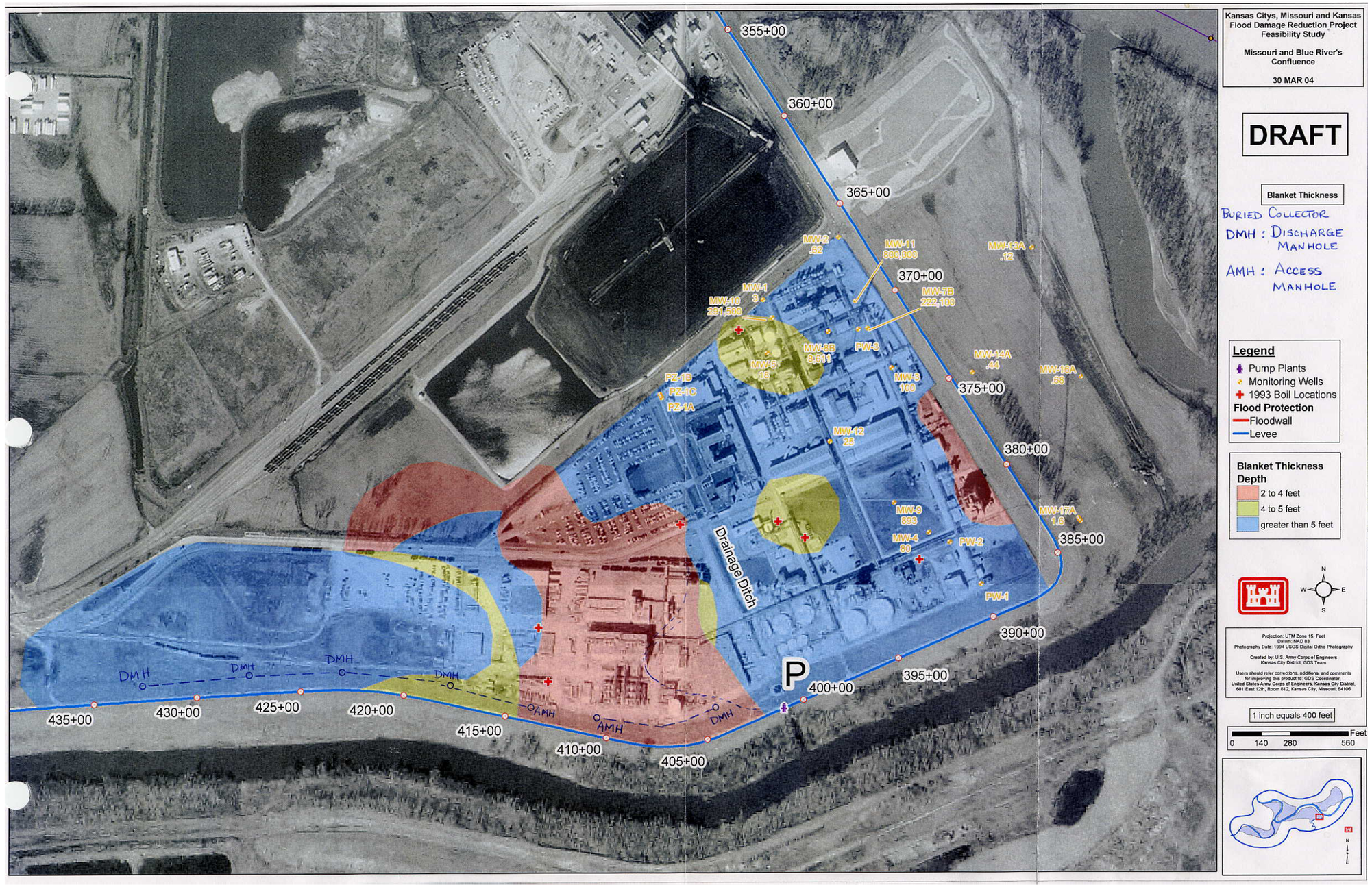
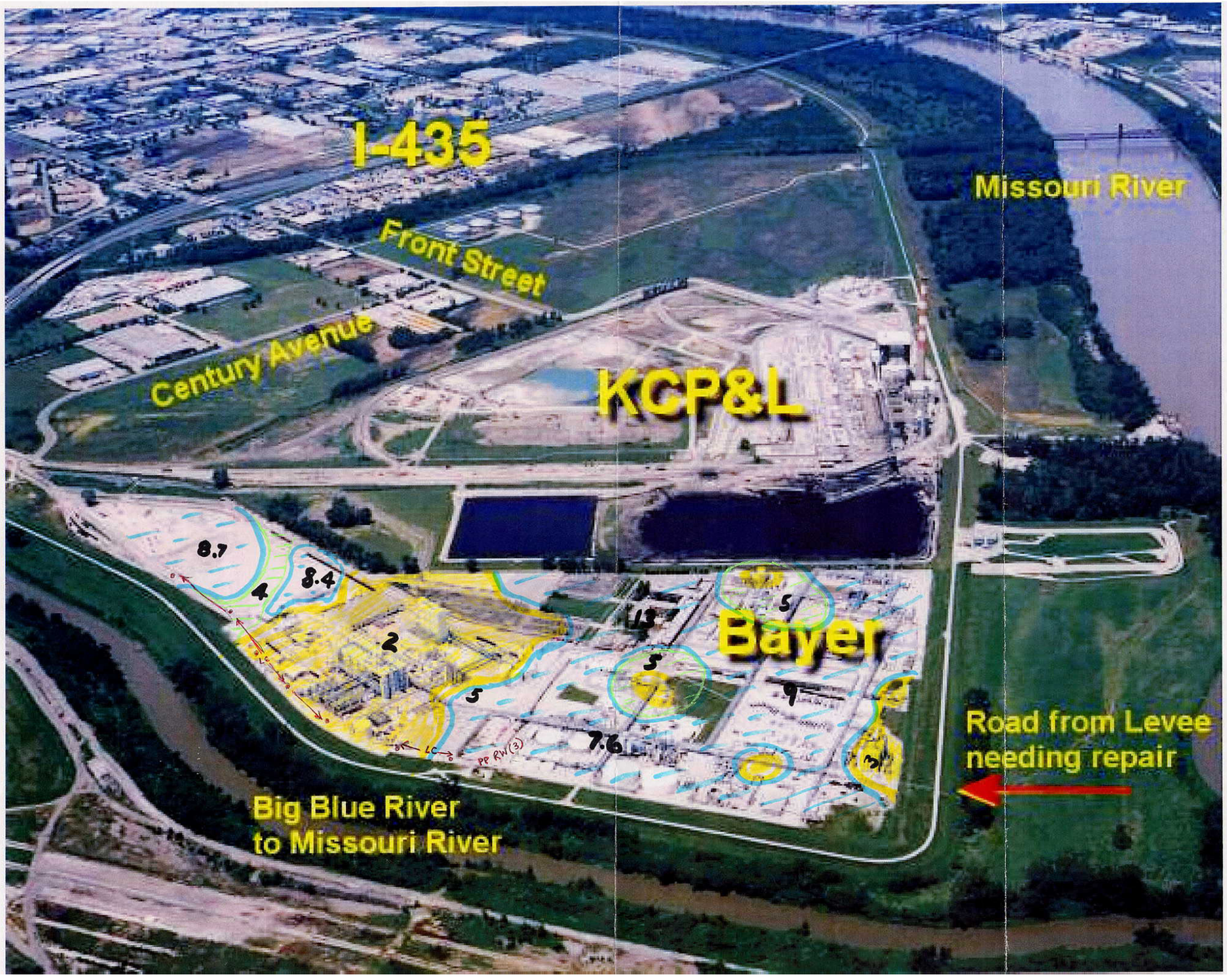


EXHIBIT A-6.17



August 2003

EXHIBIT A-6.18

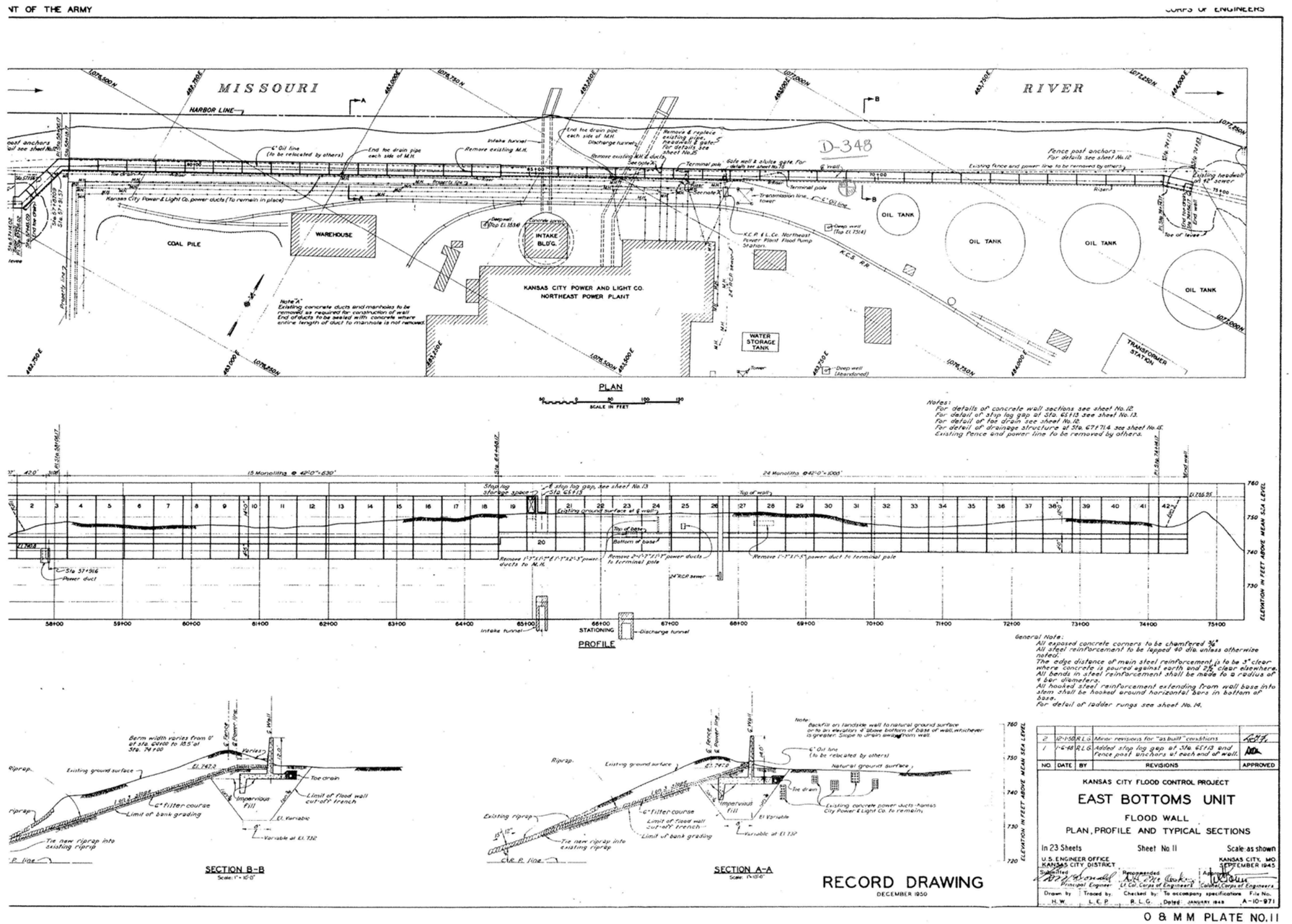


EXHIBIT A-6.19

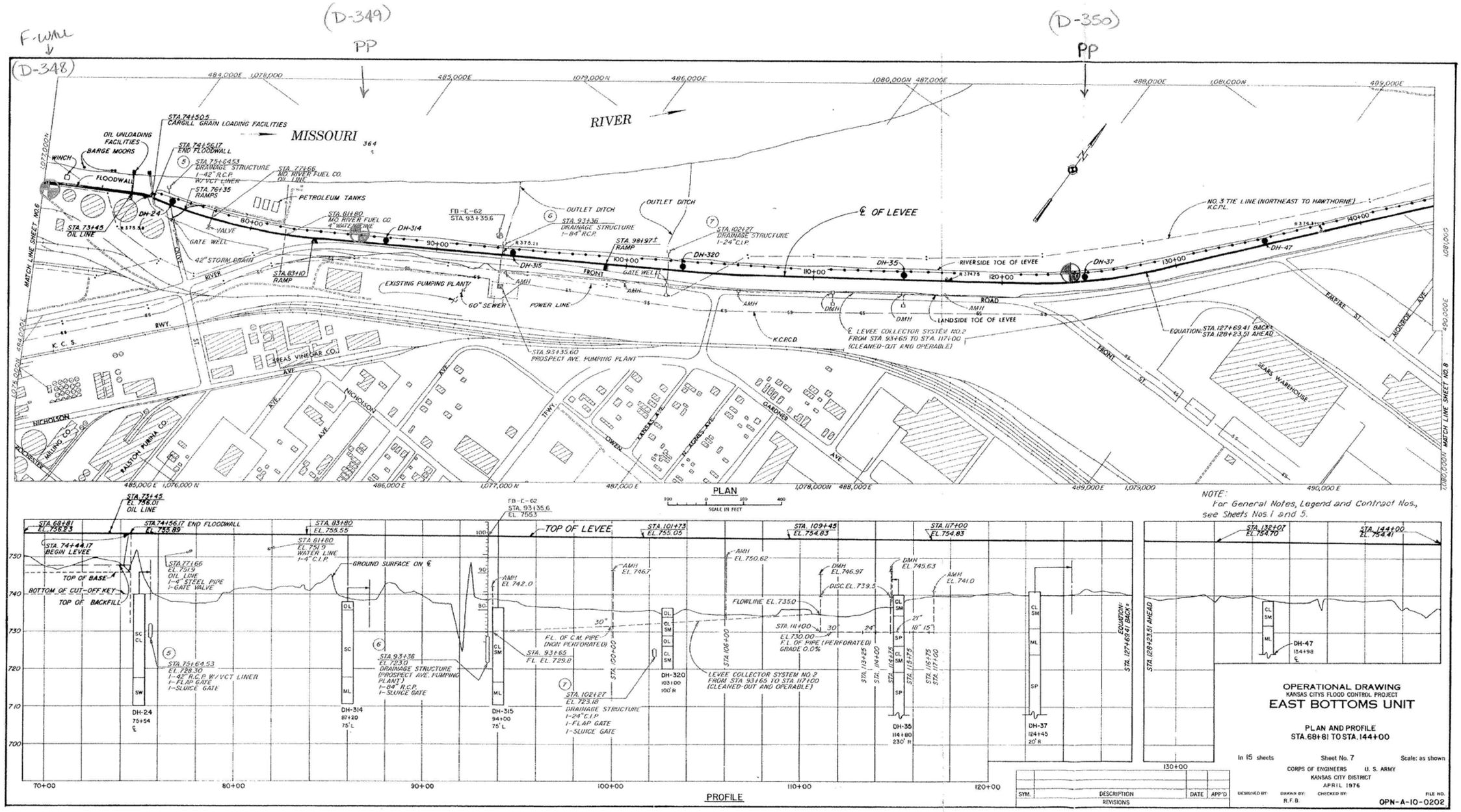


EXHIBIT A-6.20

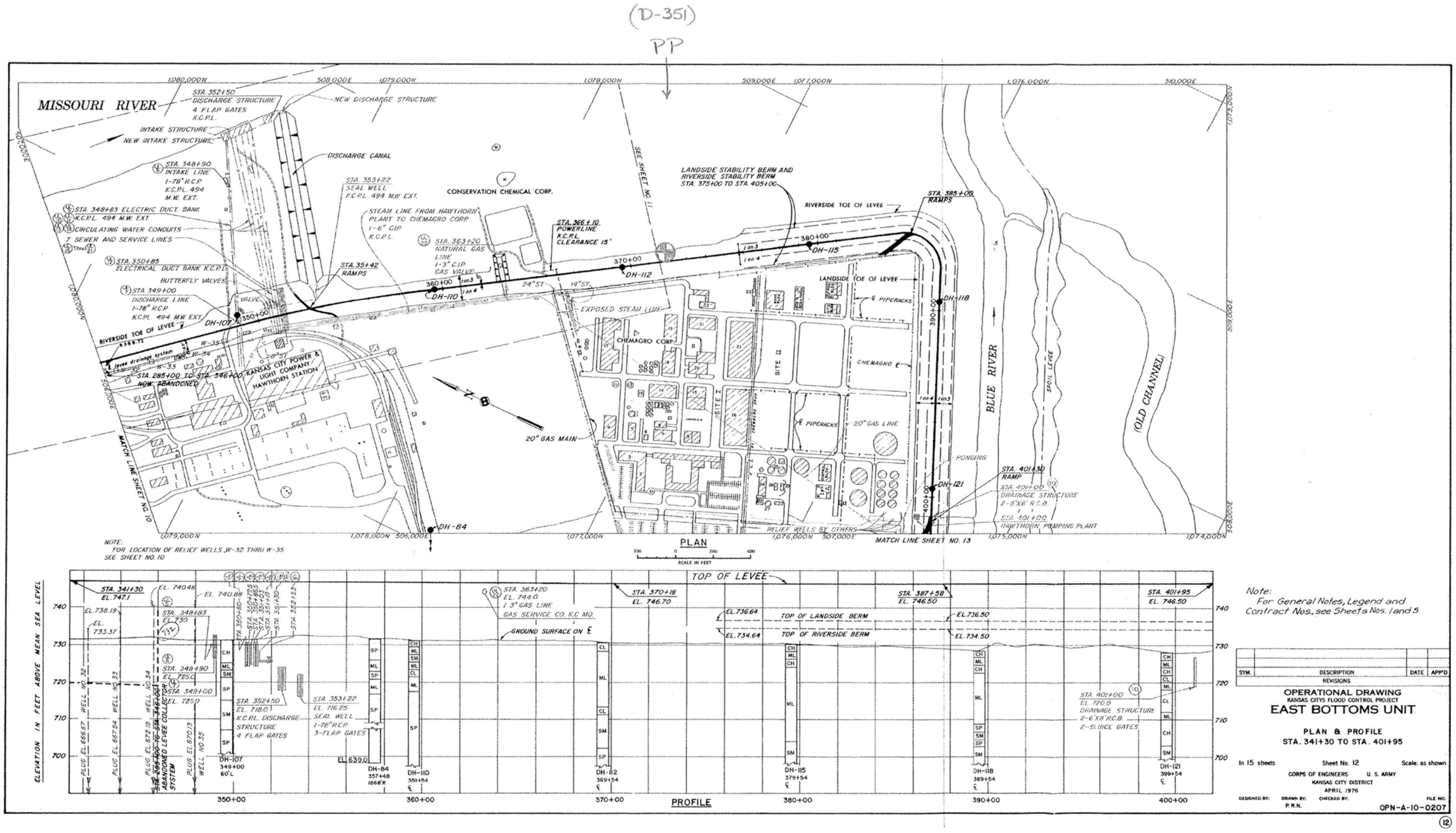


EXHIBIT A-6.21

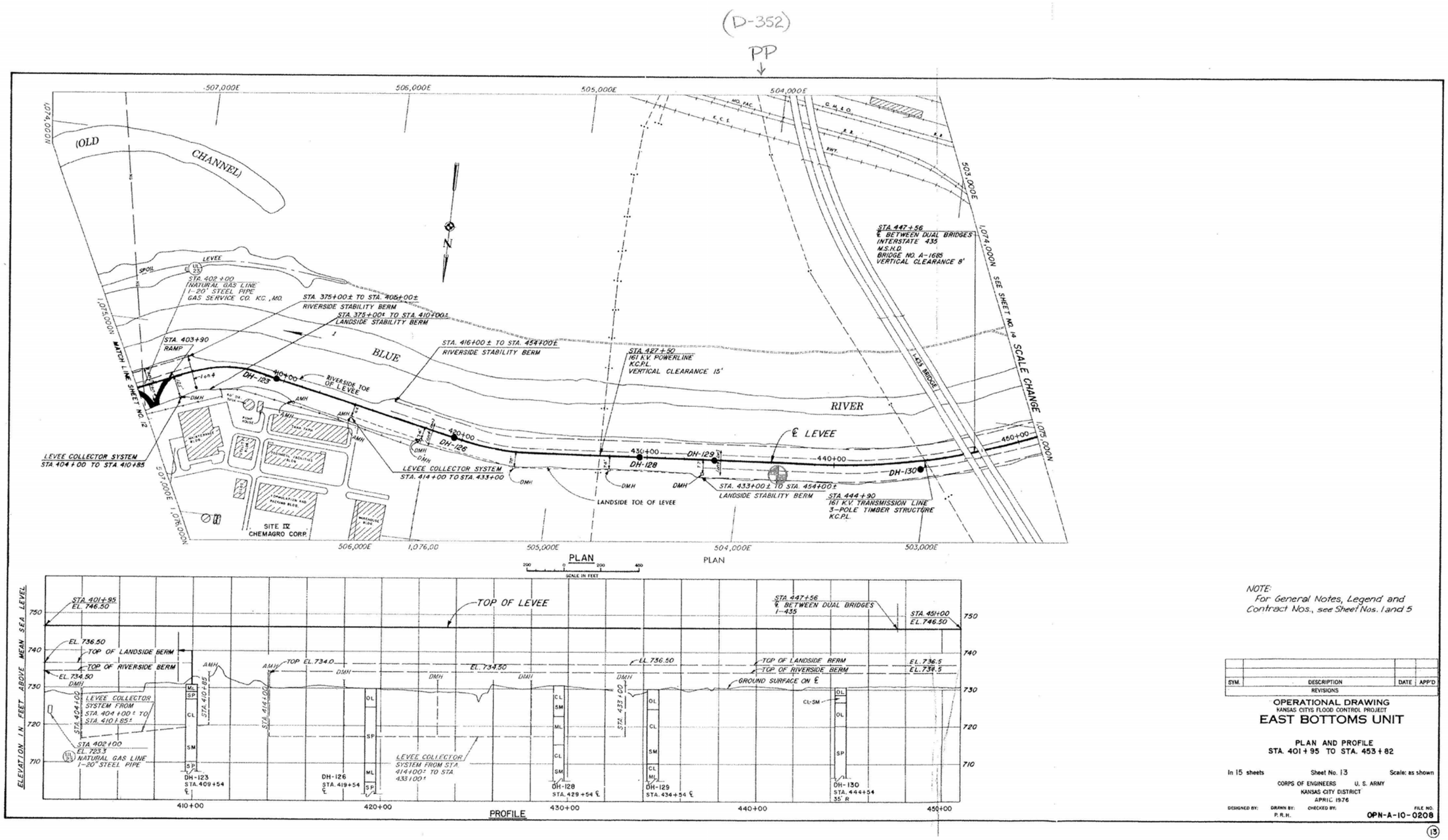


EXHIBIT A-6.22

(D-353)
S-GAP

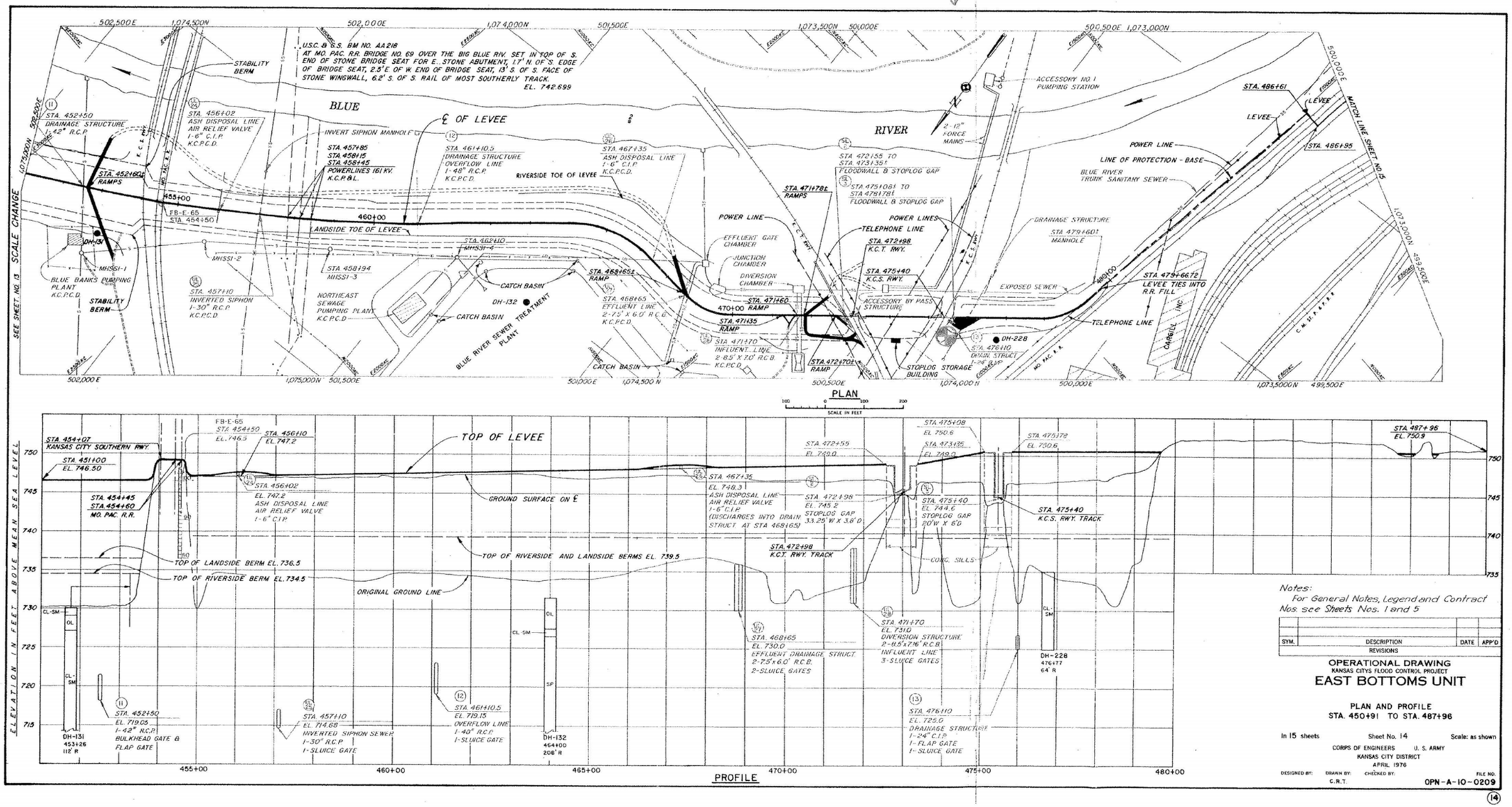


EXHIBIT A-6.23

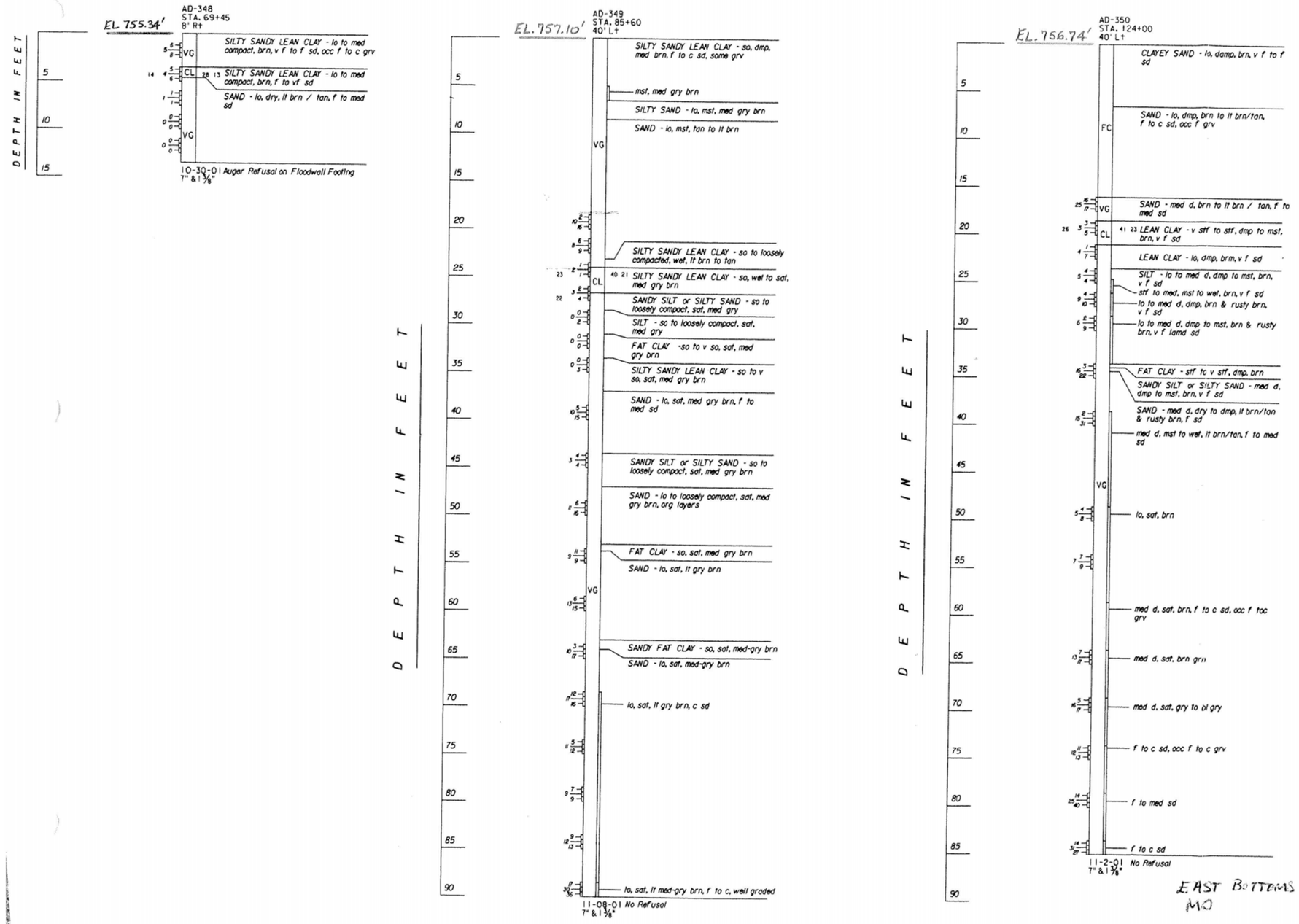
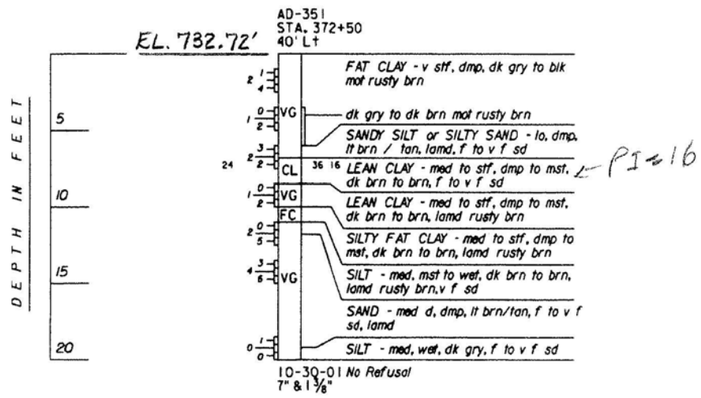
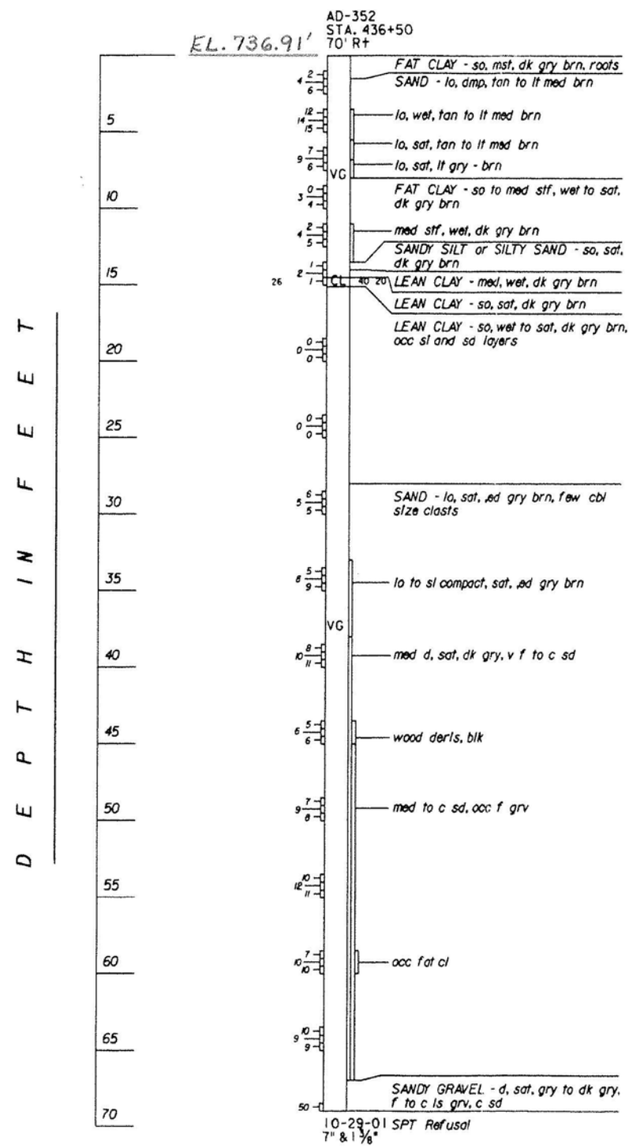
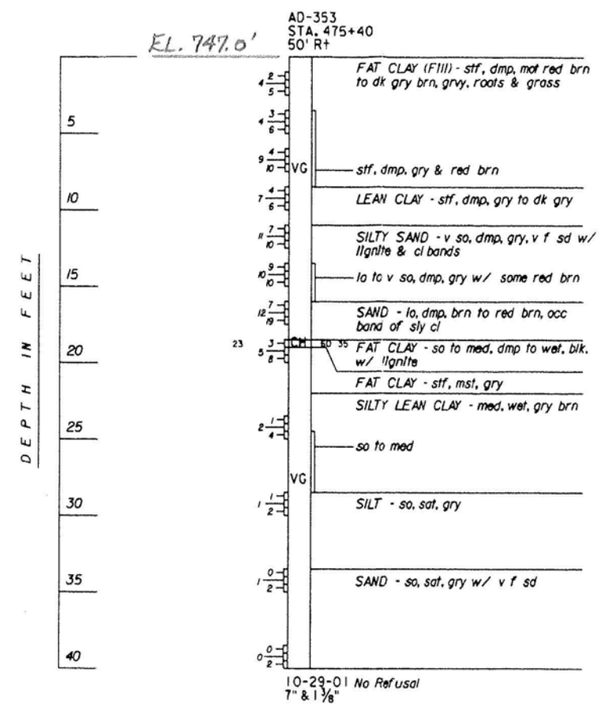


EXHIBIT A-6.24







EAST BOTTOMS - MO

Underseepage Calculations

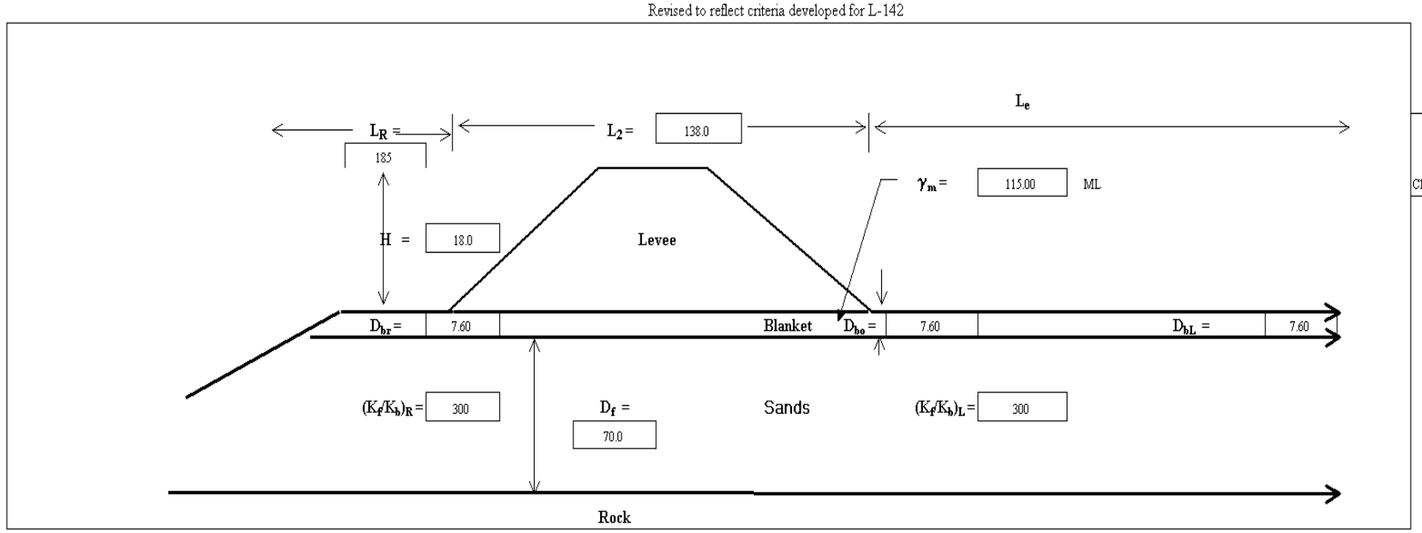
EXHIBIT A-6.25

UNDERSEEPAGE ANALYSIS

Note : This spreadsheet analysis should be used only if the blanket thickness is at least 1/4 of the height of the levee.

Bayer: East Bottoms	Name :	Loehr	EC-GD	Reviewed : Jones
	Date :	11/5/2003	Revised 4/7/2004	Date : 7/23/2004

Revised to reflect criteria developed for L-142



Recommended Permeability Ratio
For Foundation Blanket Materials
Chapter Underseepage Revision dated Oct 1998

Blanket Material	Assumed Permeability Ratio, (Kf/Kb)
SM	100
ML	200 to 400
ML-CL	400
CL	400 to 600
CH	800 to 1000

NOMENCLATURE

$(K_f/K_b)_R$ = riverside permeability
$(K_f/K_b)_L$ = landside permeability
D_{br} = riverside blanket thickness

D_{bo} = levee toe blanket thickness
D_{bL} = landside blanket thickness
D_f = thickness of pervious foundation
L_R = length of riverside blanket
L_L = length of landside blanket
H = max head or levee height
$H(W_T)$ = head above tailwater at end of underseepage berm
$H(W_T) = H(W_T/2)*e^{(-W_T/(2*CL))}$
$H(W_{T/2})$ = head above tailwater midpoint of underseepage berm
$= H * L_e / L'_t$
W_T = berm width
i_o = seepage gradient
C_r = riverside effective length coefficient
C_L = landside effective length coefficient
where $C = [(Kf/Kb) * Df * Db]^{1/2}$
H'o = head above tailwater at levee toe (w/ berm)
i_c = critical seepage gradient
L_1 = riverside effective length
where $L_1 = C * (e^{(2LR/C-1)}) / (e^{(2LR/C+1)})$
L_2 = levee base width
L_e = landside effective length
L_t = total effective length
L'_t = Total Effective Length + 1/2 of Berm

t' = required Berm thickness at toe
Sc = calc'd slope of underseepage berm
q = seepage /unit Length

Q = cummulated seepage
$FS_i = i_c / i_o$

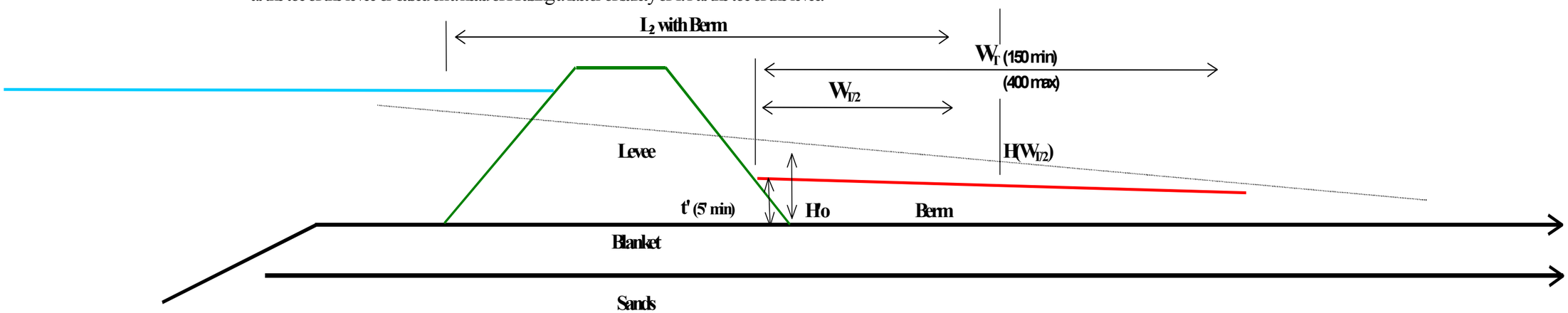
EXHIBIT A-6.26

Input Parameters												Analysis of Without Berm Conditions												
Station	Begin Station Feet	End Station Feet	$(K_f/K_b)_R$	$(K_f/K_b)_L$	D_{bL}	D_{bo}	D_{br}	D_f	L_R	H	Remarks	Station Feet	C_R Feet	C_L Feet	L_1 Feet	L_2 Feet	L_e Feet	L_t Feet	h_o Feet	i_o Ft/Ft	i_c Ft/Ft	Check #1 Full Head Toe FSi (need 1.1)	Check #1 Reduced Head Toe FSi (need 1.5)	Remarks
Current Condition:																								
Example			300	300	7.6	7.6	7.6	70.0	185	18.0	Example		399	399	173	138	399	710	10.12	1.33	0.84	0.63	0.76	
366+00 to 375+00	36600.00	37500.00	300	300	7.6	12.0	18.0	70.0	1000	15.0	No berm	366+00 to 375+00	615	399	569	120	399	1089	5.51	0.46	0.84	1.83	2.29	No control needed
											Okay													
375+00 to 385+00	37500.00	38500.00	300	300	6.8	6.8	18.0	70.0	800	15.0	Has 50' Berm	375+00 to 385+00	615	378	530	170	378	1078	5.26	0.77	0.84	1.09	1.36	Has Exist Berm
											Okay													
385+00 to 404+00	38500.00	40400.00	300	300	7.6	12.0	20.0	70.0	185	15.0	Has 50' Berm	385+00 to 404+00	648	399	180	170	399	750	7.99	0.67	0.84	1.26	1.58	Has Exist Berm
											Okay													
404+00 to 406+00	40400.00	40600.00	100	100	2.0	2.0	5.0	63.0	150	17.0	Exist Berm and Buried Collector	404+00 to 406+00	177	112	122	120	112	354	5.38	2.69	0.84	0.31	0.38	Has Exist Berm and Buried Collector Need Collector Drawdown
406+00 to 410+00	40600.00	41000.00	100	100	2.0	2.0	5.0	63.0	150	17.0	Exist Berm and Buried Collector	406+00 to 410+00	177	112	122	120	112	354	5.38	2.69	0.84	0.31	0.38	Has Exist Berm and Buried Collector Need Collector Drawdown
410+00 to 416+00	41000.00	41600.00	200	200	4.0	4.0	5.0	63.0	150	17.0	No Berm partial Collector	410+00 to 416+00	251	224	134	120	224	479	7.97	1.99	0.84	0.42	0.51	Has No Berm and Part of the alignmetn has Buried Collector Need Collector Drawdown
416+00 to 422+00	41600.00	42200.00	200	200	4.3	4.3	4.3	63.0	150	16.5	Exist : Buried	416+00 to 422+00	233	233	132	175	233	540	7.11	1.65	0.84	0.51	0.62	Has Buried Collector
																								Assess Collector 50% efficient
																								Assess Collector 100% efficient
422+00 to 433+00	42200.00	43300.00	200	200	8.7	8.7	8.7	63.0	150	16.5	Exist : Buried	422+00 to 433+00	331	331	141	175	331	647	8.45	0.97	0.84	0.86	1.06	Has Buried Collector
433+00 to 454+00	43300.00	45400.00	200	200	8.7	8.7	8.7	63.0	150	16.5	Has berm	433+00 to 454+00	331	331	141	175	331	647	8.45	0.97	0.84	0.86	1.06	No control

Analysis of Existing Conditions: This portion uses full head for the check #1 for FS_i= 1.1 and Full Head less 3 feet for the Check #2 for FS_i= 1.5.
If either of these two columns indicate that the required FS_i is not met then the underseepage berm design is needed.

Berm Design Information: The Excessive head columns provides the designer with a feel for which check case control.

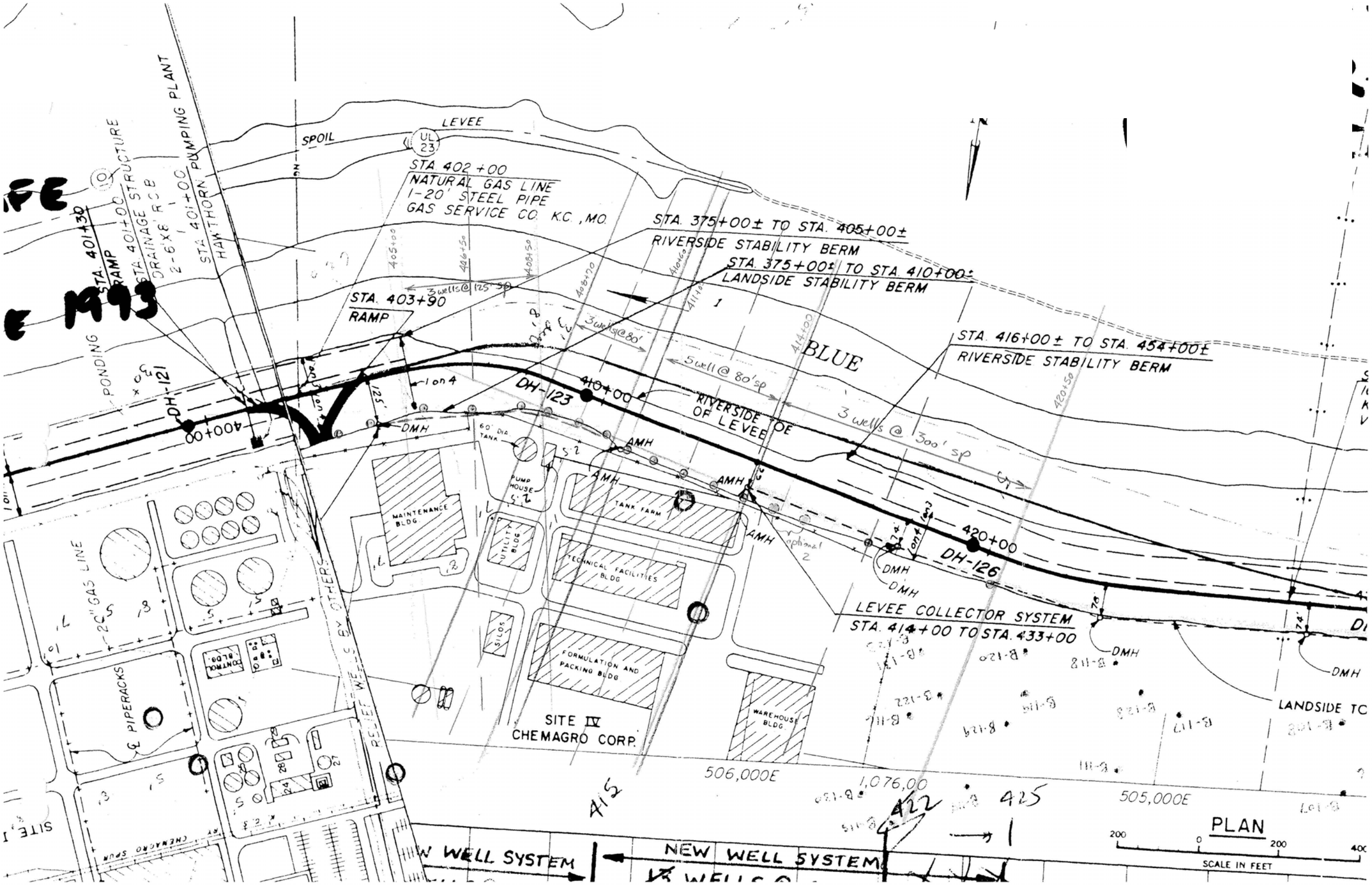
The design of the berm at the toe of the levee requires a FS_i of at least 1.5 for the controlling case, using the reduced head (87% of full head).
The design of the extension of the berm is controlled using full head and a required FS_i of 1.1 at the toe of the berm
If the FS_i = 1.1 is not met with the width = 400 feet minimum, then the 400 feet is used. The berm thickness required at the toe of the levee is controlled using an Ho at the levee toe set based on FS_i = 1.1, projecting back to the width less than 400 feet, with no adjustment made to Ho.
If the trail width is less than 400 feet, no adjustment to Ho is made. The minimum berm thickness is 5 feet (EM 1110-2-1913). The calculated berm thickness will be based on full head less 3 feet using a Factor of safety of 1.5 at the toe of the levee or based on a head of H using a factor of safety of 1.1 at the toe of the levee.



Berm Design Information													
Berm Width Design									Berm Thickness Design				
Station	Excessive Head Control (Feet)		Existing Width of Berm	Effective Length	Mid Berm Head, ft	$H(W_T)$ Feet	Berm Toe Gradient	Safety Factor	H'o at Levee Toe	Trial Minimum Berm Thickness	Levee Toe Gradient	Safety Factor Check at Levee Toe	
	FS_i = 1.1	FS_i = 1.5	W_T	L'_t	$H(W_{T/2})$		I_{Berm}	Berm Toe	Feet	t'	I'o	For 1.5	For 1.1
Current Condition:													
Example	4.30	4.17	1	711	10.12	10.10	1.33	**0.63**	8.44	0	1.11	0.76	Example
									10.13	0	1.33	Example	0.63
366+00 to 375+00	NA	NA	1	1089	5.50	5.50	0.72	**1.16**	4.41	0	0.37	**2.29**	
									5.51	0	0.46		**1.83**
375+00 to 385+00	0.07	0.40	50	1103	5.14	4.81	0.71	**1.19**	4.38	**5**	0.37	**2.26**	**Exist Berm**
Exist Berm									5.48	**5**	0.46	**Exist Berm**	**1.81**
385+00 to 404+00	NA	NA	50	775	7.74	7.27	0.96	**0.88**	6.58	**5**	0.39	**2.17**	**Exist Berm**
									8.22	**5**	0.48	**Exist Berm**	**1.74**
404+00 to 406+00	3.86	3.31	50	379	5.03	4.02	2.01	**0.42**	5.06	**5**	0.72	**1.16**	**Exist Berm & collector (0.96)**
		Buried Collect 50% efficient				3.26	1.63	**0.52**				**Toe check**	
		Buried Collect 100% efficient				2.50	1.25	**0.67**					
406+00 to 410+00	3.86	3.31	25	367	5.20	4.65	2.33	**0.36**	4.76	**5**	0.68	**1.24**	**Exist Berm (1.02)**
		Buried Collect 50% efficient				3.58	1.79	**0.47**				**Toe check**	
		Buried Collect 100% efficient				2.5	1.25	**0.67**					
410+00 to 416+00	4.92	4.32	1	479	7.96	7.94	1.99	**0.42**	6.57	0	1.64	**0.51**	**Part collector**
									7.98	0	1.99	**Part Collector**	**0.42**
416+00 to 422+00	3.83	3.41	1	540	7.11	7.09	1.65	**0.51**	5.83	0	1.36	**0.62**	**Collector**
		Buried Collect 50% efficient				4.80	1.12	**0.75**				**Toe Check**	
		Buried Collect 100% efficient				2.50	0.58	**1.44**					
422+00 to 433+00	1.81	2.04	1	647	8.44	8.43	0.97	**0.87**	6.92	0	0.80	**1.06**	
		Buried Collect 50% efficient				5.47	0.63	**1.34**				**Toe check**	
		Buried Collect 100% efficient				2.50	0.29	**2.92**					
433+00 to 454+00	1.81	2.04	50	672	8.13	7.54	0.87	**0.97**	7.16	4.7	0.53	**1.57**	**Berm**
									8.75	3.1	0.74	**Berm**	**1.13**

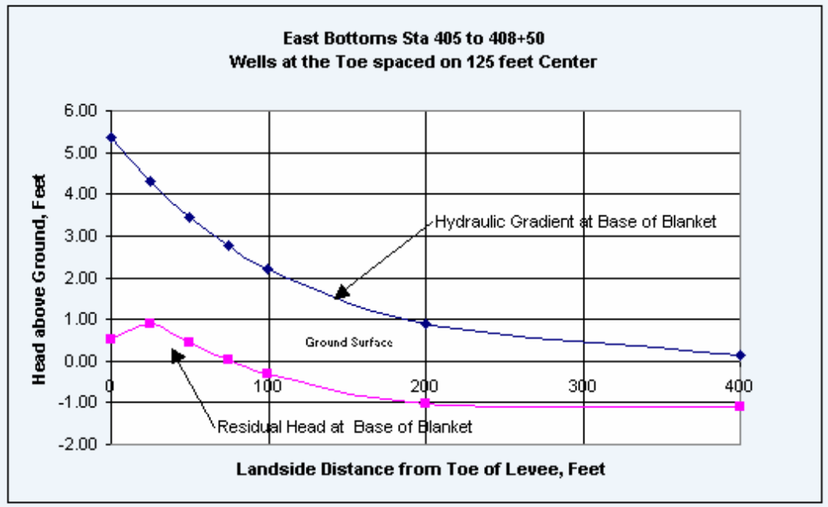
Finite Relief Well Calculations

EXHIBIT A-6.29
Proposed Relief Wells at Missouri and Blue Rivers Confluence Area



Well Design Calculations
Loehr : EC-GD 6/23/2004
Checked By :

Reviewed : Jones
Date : 7/23/2004

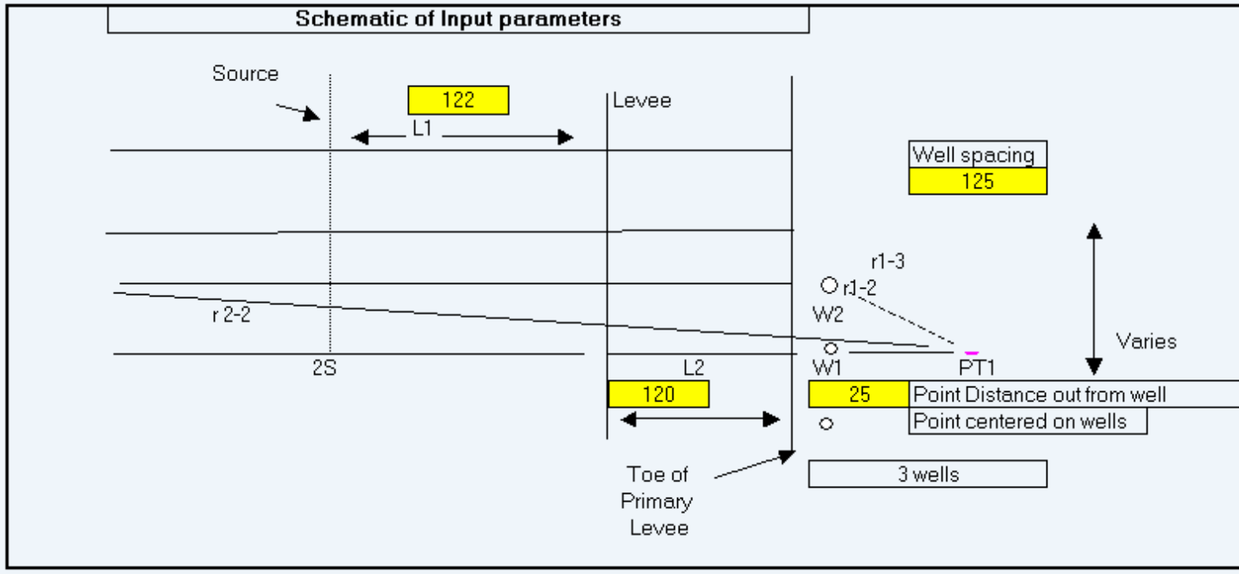


Well Drawdown Influence Table

East Bottoms : Station 405 to 408+50

		ic =	0.84	Well losses	1.3	(entrance, velocity bends)	
	Ground = 0			Discharge elev loss	-1.25	Dbl=	2	Feet
	Location of points at the base of the blanket perpendicular to the center well			DD at Well	3.40	Qw =	1.25	cfs
				X_L	112	k =	0.0052	ft /sec
				h0	5.38	Df =	63.0	feet
Toe	**Distance**	**Head**	**Well 0**	**DDwx**	**Residual Head**	**Gradient Factor**	
Distance	**gx**	**hx**	**wx**	**Feet**	**Feet**	**of Safety**	
Levee	0	5.38	2	4.87	0.51	3.29	**Ignoring**
Berm	25	4.30	25	3.4	0.90	1.86	**Berm**
	50	3.44	50	2.99	0.45	3.71	
	75	2.75	75	2.73	0.02	70.07	
	100	2.20	100	2.52	-0.32	>>1.5	
	200	0.90	200	1.91	-1.01	>>1.5	
	400	0.15	400	1.25	-1.10	>>1.5	

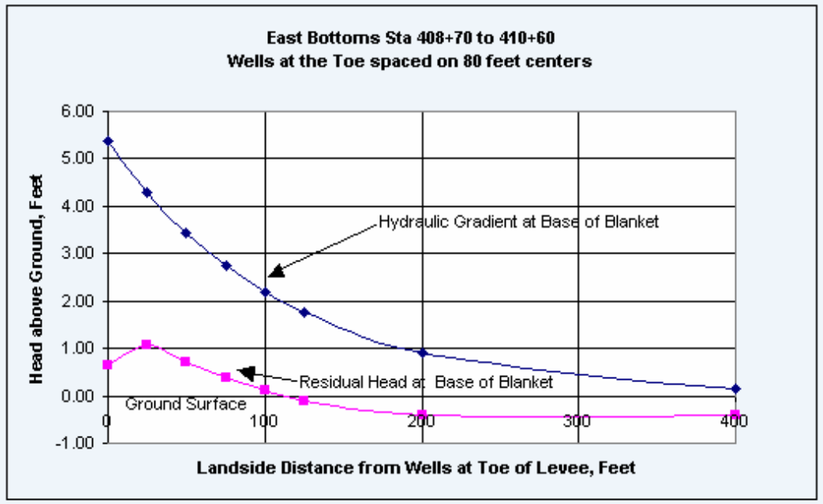
Schematic of Input parameters

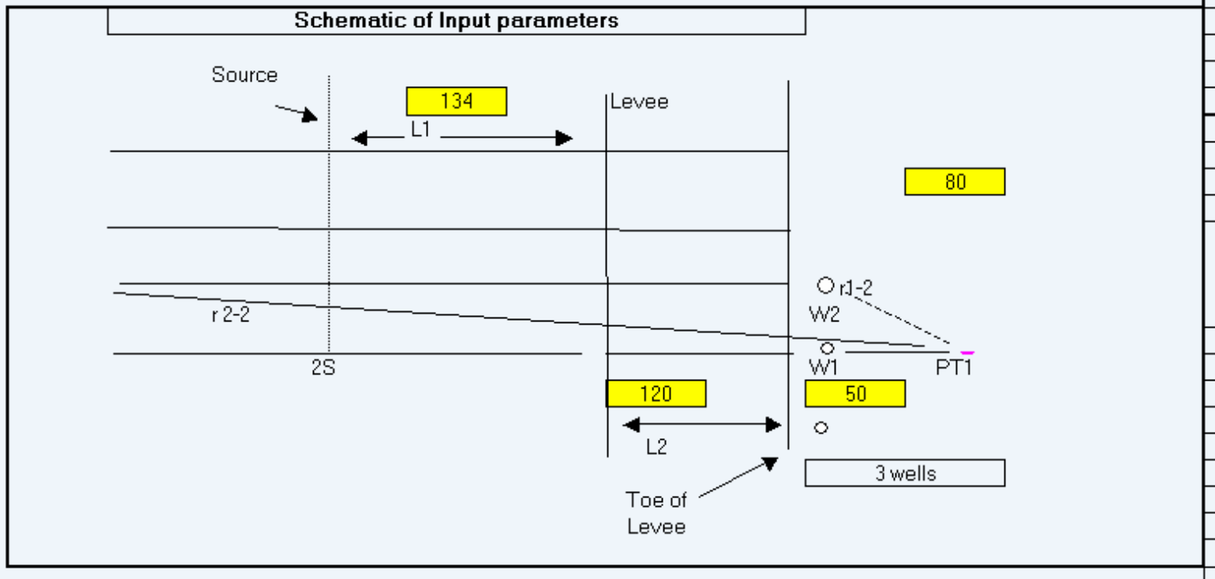


Example Calculation

		PT1				
		data	well 1		well 2	
			S =	242		
			r2-1=	509	r2-2=	524
			r1-1=	25	r1-2 =	127
			DDw1=	1.83	DDw2=	0.86
			well 3		well4	
			r2-3 =	567	r2-4=	632
			r1-3=	251	r1-4=	376
			DDw3=	0.49	DDw4=	0.32
	Dist x	DDwx	Headlosses	Number	All DD	
	25	1.83	0.05	1	1.78	
		0.86	0.05	2	1.62	
		0.49	0.05	0	0.00	
		0.32	0.05	0	0.00	
			PT1 Sum DD =	3.40	feet	

Well Design Calculations
Loehr EC-GD 6/23/2004
Checked by : Jones 7/26/2004





Well Drawdown Influence Table

East Bottoms : Station 408+70 to 410+60

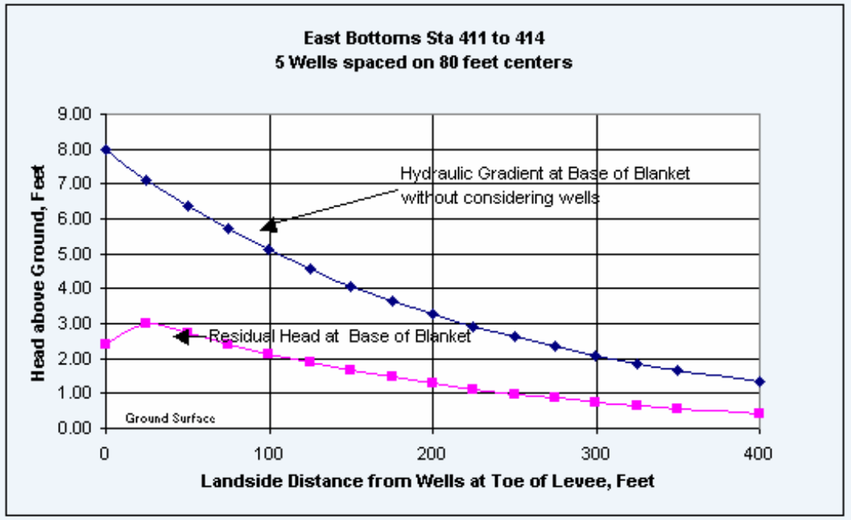
	ic =	0.84	Well losses	1.3	(entrance, velocity bends)	
Ground = 0			Discharge elev loss	-1	Dbl=	2	Feet
Location of points at the base of the blanket perpendicular to the center well			DD at Well	4.73	Qw =	1.25	cfs
			X_L	112	k =	0.0052	ft/sec
			h0	5.38	Df =	63.0	feet

Distance gx	Head hx	Well 0 wx	DDwx Feet	Residual Head Feet	Gradient Factor of Safety
0	5.38	2	4.73	0.65	2.58
25	4.30	25	3.22	1.08	1.55
50	3.44	50	2.74	0.70	2.39
75	2.75	75	2.39	0.36	4.62
100	2.20	100	2.1	0.10	16.31
125	1.76	125	1.86	-0.10	Okay
200	0.90	200	1.32	-0.42	Okay
400	0.15	400	0.57	-0.42	Okay
600	0.03	600	0.21	-0.18	Okay

Example Calculation

		PT1 data				
			well 1		well 2	
			S =	254		
			r2-1=	558	r2-2=	564
			r1-1=	50	r1-2 =	94
			DDw1=	1.46	DDw2=	1.09
			well 3		well4	
			r2-3 =	580	r2-4=	607
			r1-3=	168	r1-4=	245
			DDw3=	0.75	DDw4=	0.55
	Dist x	DDwx	Headlosses	Number	All DD	
	50	1.46	0.30	1	1.16	
		1.09	0.30	2	1.57	
		0.75	0.30	0	0.00	
		0.00	0.30	0	0.00	
			PT1 Sum DD =	2.74	feet	

Well Design Calculations
Loehr EC-GD 6/23/2004
Checked by : Jones 7/26/2004



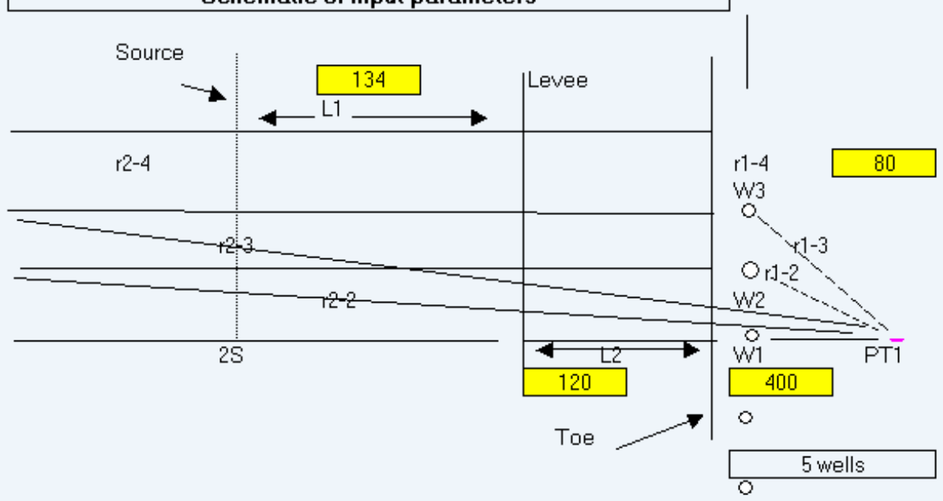
Well Drawdown Influence Table

East Bottoms : Station 411 to 414

	ic =	0.84	Well losses	1.3	(entrance, velocity bends)	
Ground = 0			Discharge elev loss	-1	Dbl=	4 Feet
Location of points at the base of the blanket perpendicular to the center well			DD at Well	5.59	Qw =	1.25 cfs
			X_L	224	k =	0.0052 ft/sec
			h0	7.97	Df =	63.0 feet

Distance gx	Head hx	Well 0 wx	DDwx Feet	Residual Head Feet	Gradient Factor of Safety
0	7.97	2	5.59	2.38	1.41
25	7.13	25	4.12	3.01	1.12
50	6.38	50	3.64	2.74	1.23
75	5.70	75	3.28	2.42	1.39
100	5.10	100	2.96	2.14	1.57
125	4.56	125	2.68	1.88	1.79
150	4.08	150	2.42	1.66	2.02
175	3.65	175	2.19	1.46	2.30
200	3.26	200	1.99	1.27	2.64
225	2.92	225	1.8	1.12	3.00
250	2.61	250	1.63	0.98	3.43
275	2.33	275	1.48	0.85	3.93
300	2.09	300	1.34	0.75	4.49
325	1.87	325	1.22	0.65	5.19
350	1.67	350	1.1	0.57	5.89
400	1.34	400	0.9	0.44	7.70

Schematic of Input parameters

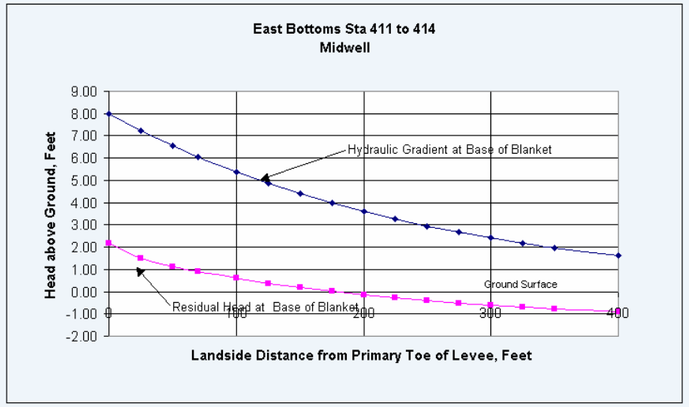


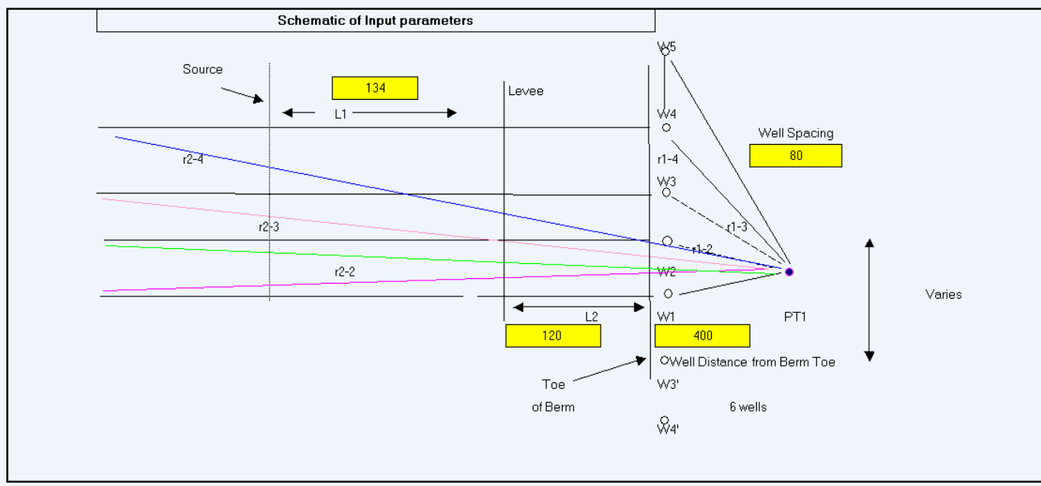
Example Calculation

		PT1 data				
			well 1		well 2	
			S =	254		
			r2-1=	908	r2-2=	912
			r1-1=	400	r1-2 =	408
			DDw1=	0.50	DDw2=	0.49
			well 3		well4	
			r2-3 =	922	r2-4=	939
			r1-3=	431	r1-4=	466
			DDw3=	0.46	DDw4=	0.42
	Dist x	DDwx	Headlosses	Number	All DD	
	400	0.50	0.30	1	0.20	
		0.49	0.30	2	0.38	
		0.46	0.30	2	0.32	
		0.42	0.30	0	0.00	
			PT1 Sum DD =	0.90	feet	

EXHIBIT A-6.33

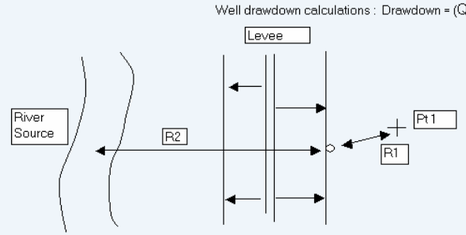
Well Design Calculations





Equations utilized for

Well drawdown calculations : Drawdown = (Q/(2*pi*k*Df)) ln (R2/R1)



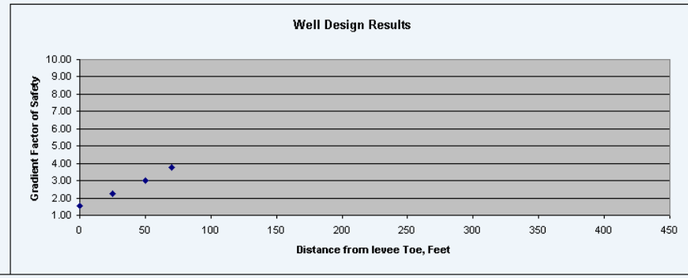
Well Drawdown Influence Table

East Bottoms : Station 411 to 414

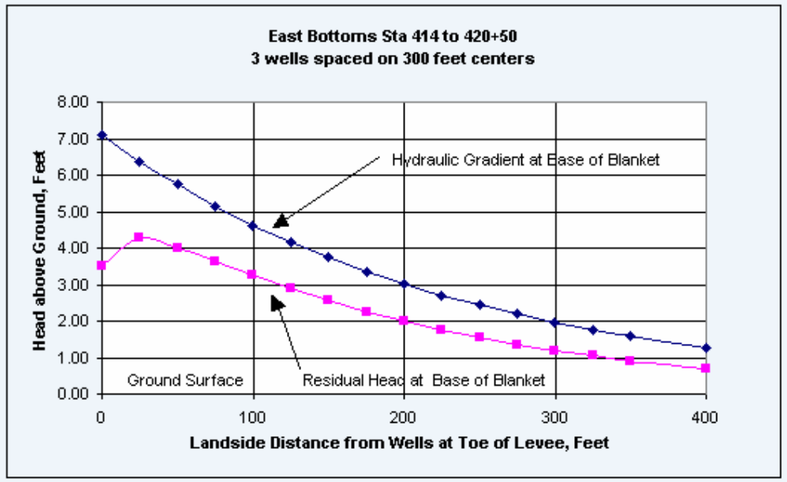
	ic =	0.84	Well losses	1.3	(entrance, velocity bends)		
Ground = 0			Discharge elev loss	-1.25	Dbl=	4.0	Feet
Location of points at the base of the blanket perpendicular to the center well			DD at Well	5.81	Qw =	1.25	cfs
			XL	251	k =	0.0052	ft/sec
			h0	7.98	Df =	63.0	feet
Distance	**Head**	**Well 0**	**DDwx**	**Residual Head**	**Gradient Factor**		
gx	**hx**	**wx**	**Feet**	**Feet**	**of Safety**		
0	7.98	2	5.81	2.17	1.55		
25	7.22	25	5.73	1.49	2.25		
50	6.54	50	5.42	1.12	3.01		
70	6.04	70	5.14	0.90	3.74		
100	5.36	100	4.76	0.60	15.47		
125	4.85	125	4.47	0.38	24.36		
150	4.39	150	4.2	0.19	48.75		
175	3.97	175	3.96	0.01	690.12		
200	3.60	200	3.74	-0.14	>700		
225	3.26	225	3.54	-0.28	>700		
250	2.95	250	3.36	-0.41	>700		
275	2.67	275	3.19	-0.52	>700		
300	2.41	300	3.04	-0.63	>700		
325	2.19	325	2.9	-0.71	>700		
350	1.98	350	2.77	-0.79	>700		
400	1.62	400	2.54	-0.92	>700		

Example Calculation

		PT1				
		data	well 1		well 2	
			S =	254		
			r2-1=	910	r2-2=	910
			r1-1=	402	r1-2 =	402
			DDw1=	0.50	DDw2=	0.50
			well 3		well4	
			r2-3 =	917	r2-4=	930
			r1-3=	418	r1-4=	447
			DDw3=	0.48	DDw4=	0.44
Well 5	r2-5 =	951	r1-5 =	488	DDw5 =	0.40
	Dist x	DDwx	Headlosses	Number	All DD	
W1 & W2	400	0.50	0.05	2	0.89	
W3 & W3'		0.48	0.05	2	0.85	
W4 & W4'		0.44	0.05	2	0.79	
W5		0.40	0.05	0	0.00	
			PT1 Sum DD =	2.54	feet	



Well Design Calculations
Loehr EC-GD 6/23/2004
Checked By : Jones 7/26/04

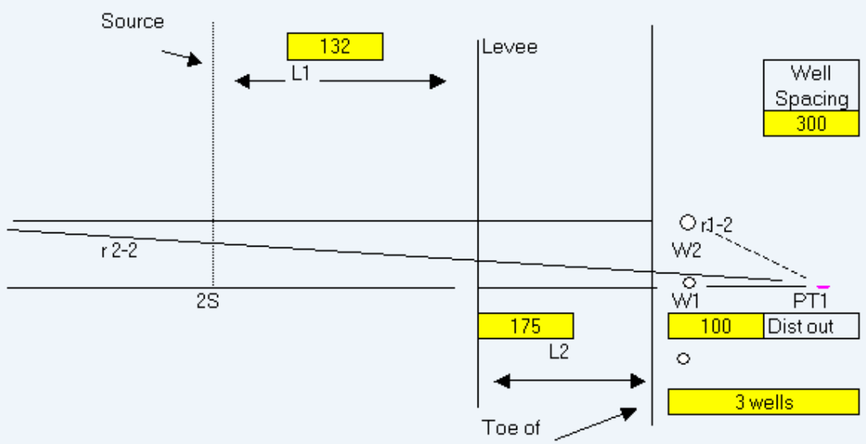


Well Drawdown Influence Table

East Bottoms : Station 414 to 420+50

	ic =	0.84	Well losses	1.3	(entrance, velocity bends)			
Ground = 0			Discharge elev loss	-1	Dbl=	4.3	Feet	
Location of points at the base of the blanket perpendicular to the center well			DD at Well	3.58	Qw =	1.25	cfs	
			X_L	233	k =	0.0052	ft /sec	
			h0	7.11	Df =	63.0	feet	
Distance	**Head**	**Well 0**	**DDwx**	**Residual Head**	**Gradient Factor**			
gx	**hx**	**wx**	**Feet**	**Feet**	**of Safety**			
0	7.11	2	3.58	3.53	2.21			
25	6.39	25	2.1	4.29	1.82			
50	5.74	50	1.73	4.01	1.95			
75	5.15	75	1.53	3.62	2.16			
100	4.63	100	1.38	3.25	2.40			
125	4.16	125	1.27	2.89	2.71			
150	3.73	150	1.18	2.55	3.06			
175	3.35	175	1.09	2.26	3.45			
200	3.01	200	1.02	1.99	3.92			
225	2.71	225	0.95	1.76	4.45			
250	2.43	250	0.89	1.54	5.07			
275	2.18	275	0.83	1.35	5.77			
300	1.96	300	0.77	1.19	6.55			
325	1.76	325	0.72	1.04	7.49			
350	1.58	350	0.67	0.91	8.56			
400	1.28	400	0.57	0.71	11.04			

Example Calculation

		PT1						
		data	well 1		well 2			
			S =	307				
			r2-1=	714	r2-2=	774		
			r1-1=	100	r1-2 =	316		
			DDw1=	1.19	DDw2=	0.54		
			well 3		well 4		well 5	
			r2-3 =	933	r2-4=	1149	r2-5=	1396
			r1-3=	608	r1-4=	906	r1-5=	1204
			DDw3=	0.26	DDw4=	0.14	DDw5=	0.09
	Dist x	DDwx	Headlosses	Number	All DD			
	100	1.19	0.3	1	0.89			
		0.54	0.3	2	0.49			
		0.26	0.3	0	0.00			
		0.14	0.3	0	0.00			
		0.09	0.3	0	0.00			
		PT1 Sum DD =		1.38	feet			

Schematic of Input parameters