Attachment 3: Fragility Curve Determinations

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CELRC-TS-DG 4 October 2017

MEMORANDUM FOR PM-PL

SUBJECT: Fragility Curve Determination for McCook Levee North and South of 47th Street

Introduction

1. The McCook Levee is an existing levee being considered for repair by USACE. A fragility curve was developed by TS-DG (memo dated 16 November 2016) for the existing levee south of 47th Street based on the riverside erosion and how it may affect the sheetpile within the levee.

2. However, the levee north of 47th Street does not have sheetpile and would therefore not have the same vulnerability. To account for the different levee cross section, this memo was completed to determine a new fragility curve which applies to the existing McCook Levee north of 47th Street, only.

3. Additionally, this memo establishes a range of fragility curves for both sections of levee based on previous iterations. By picking low failure likelihoods and high failure likelihoods.

South of 47th Street Summary

4. The memo dated 16 November 2016 identified the below recommended Probable Failure Point (PFP) and Probable Non-failure Point (PNP) based on stability analyses of the sheetpile within the eroded levee. It also shows historical PFP and PNP elevations. Additional information can be found in the referenced documents.

5. However, based on new survey information, the lowest top of levee elevation is actually 600.6 ft NAVD88. This is a depression just south of the railroad lines. Therefore, the PFP has been revised to reflect this discovery.

	1980's Feasibility Elevations (ft NGVD29)	FID Elevations (ft NAVD88)	24 August 2016 Memo Elevations (ft NAVD88)	16 November 2016 Memo Elevations (ft NAVD88)	**New Recommended Elevations (ft NAVD88)**
PFP	597.0	600.5	602.5	602.5	**600.6**
PNP	594.0	596.5	599.0	593.5	**593.5**

Figure 1. Revised PFP and PNP Elevations for the McCook Levee south of 47th Street

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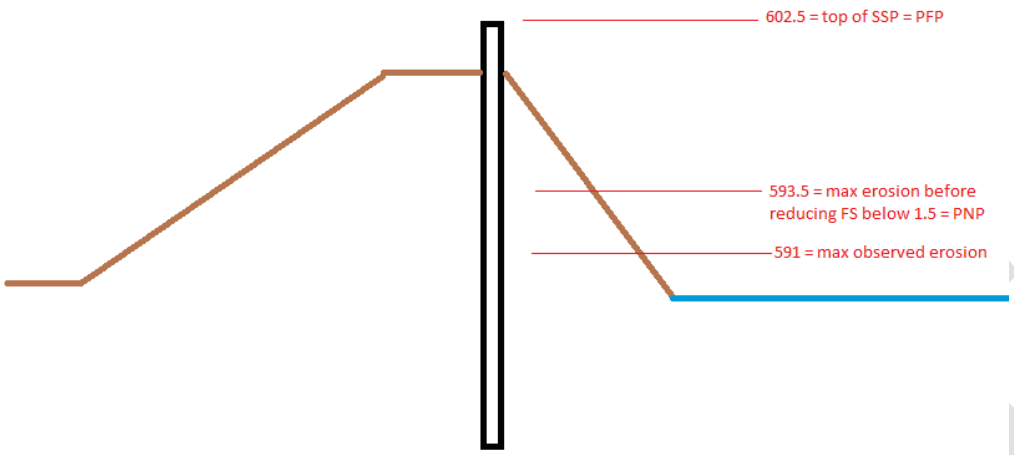

Figure 2: Cross section of PFP and PNP elevations south of 47th Street

Field Observations North of 47th Street

6. A field visit was completed on 14 November 2016 by Dan Ferris and Justin Griffeth to walk the levee north of 47th Street. As shown in the photo below, the crest of the levee has an asphalt bike path and wooden fence on the riverside. The slopes of the levee are covered in vegetation and some mature trees. The landside toe was investigated for features such as culverts, encroachments, etc. but none were identified. The date of construction is unknown, and there are no as-built drawings or soil borings available for the levee.

Figure 3: Typical photo of levee north of 47th St

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7. To determine the heights and dimensions of the levee north of 47th Street, LiDAR data was used to overlay the aerial image. A screenshot is shown below.

Figure 4: Aerial image of levee with LiDAR elevations

8. The cross section below was developed based on the LiDAR data, which shows the levee has a 20+ ft wide crest, 2:1 slopes, and is approximately 8 feet tall on the riverside, and 10 feet tall on the landside.

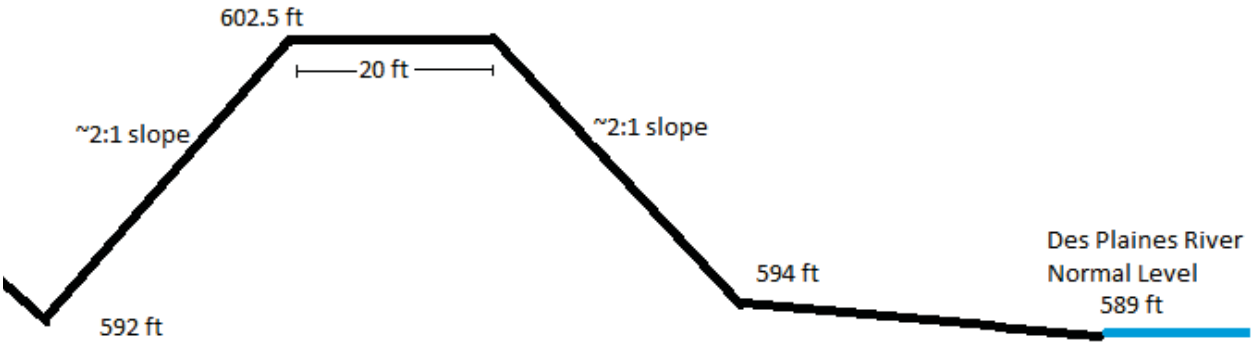

Figure 5: Drawing of typical cross section north of 47th St

Probable Failure Point Determination

9. The existing levee north of 47th Street was noted for the high amount of vegetation. This vegetation limited the inspection's ability to note additional deficiencies such as animal burrows, erosion, depressions, etc. although none of these were noted. The vegetation can also increase the risk to the levee, as tree roots create seepage paths through the berm and it makes inspection and flood-fighting during events difficult. Also, trees can fall over and pull their root wad out of the levee, creating possible instability, seepage, and erosion issues.

10. As measured in from the LiDAR data, the crest width is approximately 20 feet wide at the minimum. EM 1110-2-1905 recommends a minimum crest width of 10 feet. Since the actual crest is about twice the recommended width, the levee does have some resiliency.

11. Since there are no features that increase the risk other than the prevalent vegetation, the PFP is determined to be at the top of the levee, which is about 602.5 ft NAVD88. At this elevation, the levee would be overtopped and susceptible to erosion of the crest and landside slope, which could fail the levee.

12. To determine the PNP elevation, the vegetation present on the slopes was determined to be the controlling factor. Thick vegetation limits the ability for flood-fighting in two ways; to identify an issue and to combat an issue. So while the levee is wider than necessary, issues could arise such as seepage due to unknown fill of the levee, large animal burrows, or fallen/dead trees on the slope. But due to the vegetation, these issues may not be noticed or if they are noticed, they would be difficult to flood-fight during an event. The lowest elevation where homes may be affected is about elevation 596 ft NAVD88 should the levee breach. Therefore, this elevation was chosen as the PNP because this elevation is when flood-fighting activities would start, which may have limited success identifying and combating the issue due to the vegetation.

	North of 47th Street (ft NAVD88)
PFP	602.5
PNP	596

Figure 6. PFP and PNP Elevations for the McCook Levee North of 47th Street

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Range of PFP and PNP South of 47th Street

13. The economics analysis takes into account the most likely fragility curves that were established per the above sections. However, the economics analysis also uses two curves to cap the fragility as a high and low failure likelihood case scenarios for the levees.

14. For the PFP south of 47th St, the most likely point is at the top of the levee at 600.6 ft NAVD88. Therefore, the low failure likelihood scenario cannot be increased and will be the same as the most likely point. The high failure likelihood scenario is reduced to the PFP originally developed during the 1980's feasibility study, which is 597.0 ft NAVD88.

15. For the PNP, the most likely point was determined by the CWALSHT analysis at 593.5 ft NAVD88. The low failure likelihood scenario would increase the PNP to the highest PNP developed from the 24 August 2016 memo, which established the PNP based on historic loading. The high failure likelihood scenario reduces the PNP by 0.5 feet to the toe of the levee at 593.0 ft NAVD88.

Failure Node	Probability of Failure by Node	Elevation Assignment for Failure Condition		
		M. Likely P(f)	Low Likelihood of Failure P(f)	High Likelihood of Failure P(f)
Levee Crest	1.00	600.6	600.6	600.6
Probable Failure Point (PFP)	0.85	600.6	600.6	597.0
Probable Non-Failure Point (PNP)	0.15	593.5	599.0	593.0
Levee Toe	0.00	593.0	593.0	593.0

Figure 7. Summary of Fragility Curve south of 47th Street

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Range of PFP and PNP North of 47th Street

16. For the PFP north of 47th St, the most likely point is at the top of the levee at 602.5 ft NAVD88. Therefore, the low likelihood scenario cannot be increased and will be the same as the most likely point. Without an identifiable deficiency other than the vegetation and the fact that the crest is much wider than necessary, there does not appear to be a driving force in reducing the PFP by much. Therefore, the high failure likelihood scenario PFP is set at 601 ft NAVD88.

17. For the PNP, the most likely point was determined at the elevation where homes would start to be affected at 596.0 ft NAVD88. The low likelihood is increased to 599.0 ft NAVD88 based on the PNP developed from the 24 August 2016 memo, which established the low likelihood for south of 47th Street but could also apply to north of 47th St, as well. For the high likelihood failure scenario PNP, there is little reason to lower it from the most likely PNP for reasons stated in the previous paragraph on the PFP. Therefore, the low likelihood failure scenario PNP is set at 595.0 ft NAVD88.

Failure Node	Probability of Failure by Node	Elevation Assignment for Failure Condition		
		M. Likely P(f)	Low Likelihood of Failure P(f)	High Likelihood of Failure P(f)
Levee Crest	1.00	602.5	602.5	602.5
Probable Failure Point (PFP)	0.85	602.5	602.5	601.0
Probable Non-Failure Point (PNP)	0.15	596.0	599.0	595.0
Levee Toe	0.00	592.0	592.0	592.0

Figure 7. Summary of Fragility Curve south of 47th Street

References

1. USACE, Chicago District. "Revised Fragility Curve Determination for McCook Levee with respect to Sheetpile Stability." 16 November 2016 S:\LRC-Project\PRJ-205 McCook Levee\TS-DG\McCookLevee Frag Curve 11166.docx

2. USACE, Chicago District. "McCook Levee, McCook, Illinois Feasibility Study, Appendix C – Geotechnical Investigation." 1985.

3. USACE, Chicago District. "Fragility Curve determination for McCook Levee." 24 August 2016 S:\LRC-Project\PRJ-205 McCook Levee\TS-DG\McCookLevee Frag Curve 082416.docx

4. CWALSHT Run Results: S:\LRC-Project\PRJ-205 McCook Levee\TS-DG\CWALSHT trials

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CELRC-TS-DG 16 November 2016

MEMORANDUM FOR PM-PL

SUBJECT: Revised Fragility Curve Determination for McCook Levee with respect to Sheetpile Stability

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Introduction

1. The McCook Levee is an existing levee being considered for repair by USACE. A fragility curve was developed by TS-DG (memo dated 24 August 2016) for the existing levee based on global stability using SLOPE/W and historical floods. It did not take into account the riverside erosion that had been noted but not quantified in previous inspections.

2. Therefore, this memo examines the sheetpile stability with regard to riverside erosion and how that may affect the fragility curve. The vulnerability to the sheetpile is the landside soil load pushes the sheetpile towards the river when water is low and there is no riverside soil to resist.

3. Additionally, the cross section on the drawings was analyzed to ensure that without erosion, the floodwall is acceptable. This was done following ETL-1110-2-575 using CWALSHT.

Field Observations

4. A field visit was completed on 14 November 2016 by Dan Ferris and Justin Griffeth, where the riverside slope was noted to have two locations that show significant erosion. The more extreme case was near Sta. 20+25 where about 11.5 ft of sheetpile was exposed, as measured from the top of sheetpile to exposed toe. Another location near Sta. 12+50 measured about 6 ft of exposed sheetpile. A drawing and photo of the more extreme case is shown below.

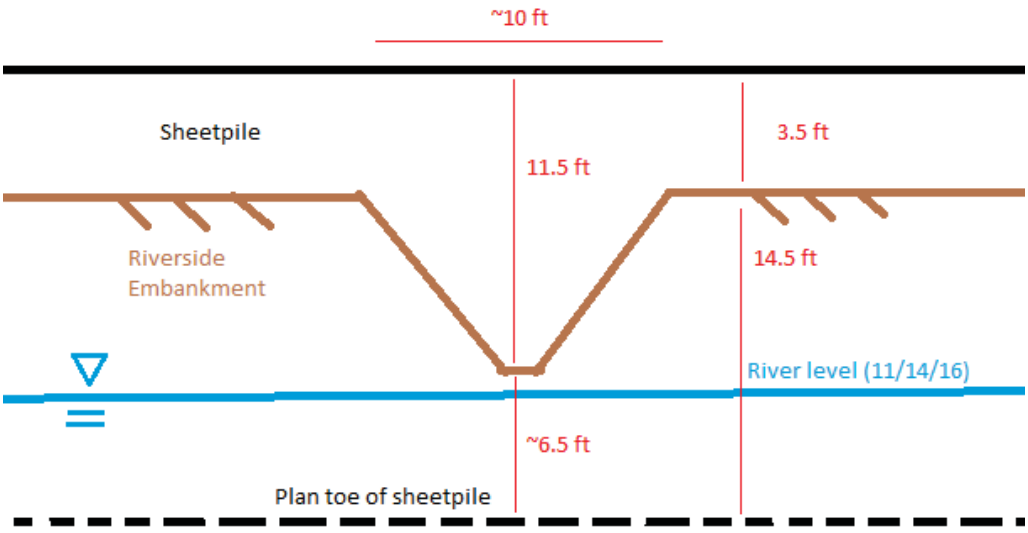

Figure 1: Drawing of worst erosion (Sta. 20+25) view from river

Figure 2: Photo of erosion near Sta. 20+25 with 11.5 ft dropoff from top of SSP to exposed toe

5. The less extreme erosion point with a dropoff of about 6 ft is noted for the sandbags along the riverside of the floodwall. It is unknown why these sandbags are here, but it is possible they were placed there to reduce riverside erosion during a flood.

Figure 3: Photo of erosion near Sta. 12+50 with 6 ft dropoff and sandbags

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Sensitivity Analysis for Fragility Curve

6. In order to determine a point which the existing sheetpile may become unstable, CWALSHT was used to run multiple iterations of the cross section at Sta. 23+00 with varying backfill heights on the riverside. At the cross section analyzed, the top material is Zone 4, middle is Zone 6, and bottom material is Zone 7 with values per the below table. This is representative for the levee between Stations 17+00 and 32+00. The soil characteristic values are from the original analyses completed for the 1980's Feasibility Report.

Soil Type	Saturated Unit Weight (pcf)	Unsaturated Unit Weight (pcf)	Phi (degrees)	Cohesion (psf)
Zone 4	125	120	0	250
Zone 6	120	120	0	300
Zone 7	140	140	28	0

Figure 4: Soil characteristics of CWALSHT calculations

7. Results from each run can be found in the referenced excel file. The critical height on the riverside occurs when between 6 and 6.5 feet of material has eroded, creating about a 9-foot drop from the sheetpile top tip to the exposed sheetpile toe. Refer to Wall5 and Wall6 in the analyses (Ref 3). This critical height was determined by running the case with 6 ft of erosion and inserting a minimum factor of safety = 1.5. The program calculated the sheetpile embedment depth in order to meet this factor of safety, which was above the actual embedment depth. Then, the case with 6.5 ft erosion was run under the same conditions, which resulted in a required embedment depth deeper than the actual condition. Therefore, it can be assumed that the existing sheetpile wall has a FS = 1.5 somewhere between 6 and 6.5 ft of erosion.

8. Figure 5 below is the output from CWALSHT, with the actual sheetpile depth and the minimum calculated depths to meet factor of safety = 1.5 based on different riverside erosion heights.

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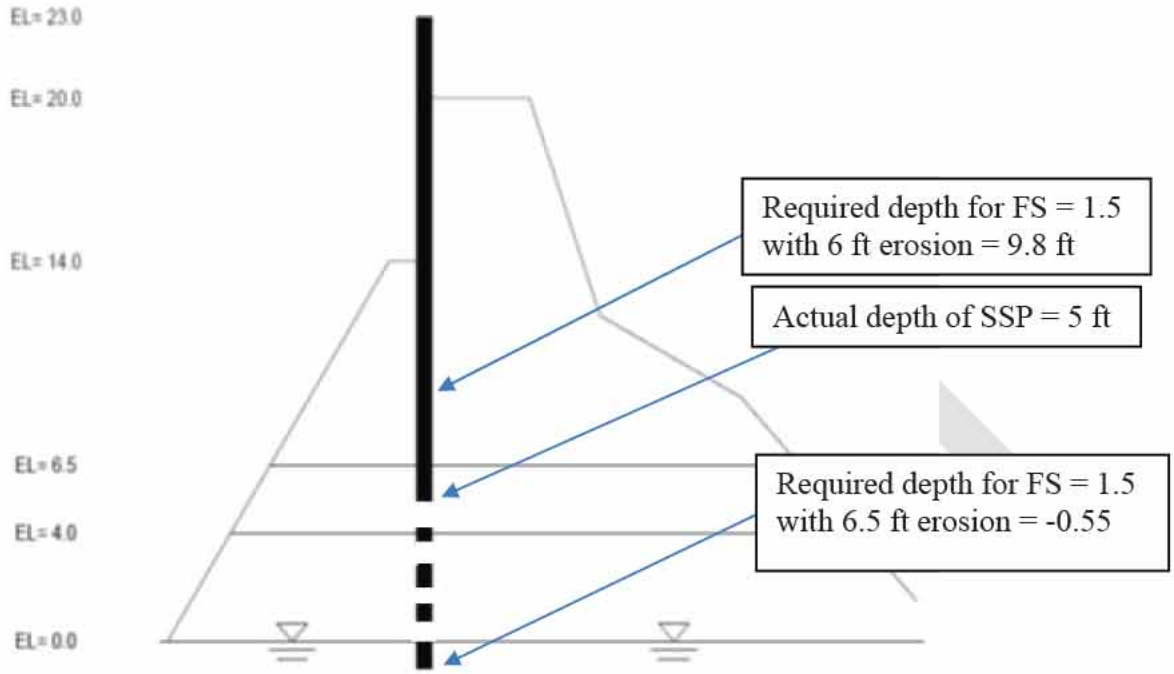

Figure 5: CWALSHT representative cross section with calculated and actual tip elevations

9. The vast majority of the wall does not have over 9 ft of exposed wall on the riverside. Only one spot was noted as having a greater amount of wall exposed, near Sta. 20+25 with around 11.5 ft exposed. This location is isolated, and the riverside slope immediately returns to normal grade around it. CWALSHT does not take into account any 3-D benefits that this location is likely receiving.

10. Another unknown failure mode is deflection. The plans call out sheetpile PSA-23, but this is a flat sheetpile type. The sheetpile onsite is a U-shape, which after measuring in the field it most closely resembles JSP-2. CWALSHT estimates the deflection of JSP-2 to be about ½ inch for the case at Sta. 20+25 Refer to Wall7_R (Ref 3). This is acceptable.

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Figure 6: Measurement of existing sheetpile, most closely resembles JSP-2

Gap Analysis

11. As part of this memo, it was determined that the sheetpile should be checked against ETL-1110-2-575 to ensure it would be acceptable once erosion is corrected. If it is not acceptable, then additional cost would have to go into retrofitting the sheetpile that is not currently in the cost estimate.

12. ETL-1110-2-575 was developed post-Hurricane Katrina and describes three failure modes that all floodwalls should be checked against. The first is creation of a flood-side gap in cohesive soils, second is rotational stability failure around the floodwall point considering this gap, and the third is rating the floodwall against criteria for consolidation of deflections. Each of these failure modes are checked in the analysis below.

    Flood-side Gap

13. The flood-side gap is caused when cohesive soils are present on the water side of the floodwall and a high water event occurs. Floodwaters enter the gap which extends to a depth of Z_0 defined below. A stability analysis was completed to determine how the gap filled with water affects the stability of the floodwall. The depth of a potential gap can be defined as $Z_0 = 2c/(\gamma_{sat} - \gamma_{water})$

    $$Z_0 = 2c/(\gamma_{sat} - \gamma_{water}) = 2*250/(125-62.4) = 8.0 \text{ ft}$$

14. Since the total height of the floodwall greater than Z_0 (20 > 8), the potential gap extends just 8 ft below the top of the levee (elevation 592 ft). The tip elevation is 584 ft, so there is 8 ft of active earth pressure acting on the bottom portion. The cross section was drawn without the floodwall and river side soils to determine how a saturated gap would act on the land side soils. A load of 62.4 psf was applied to represent the water, while a load of 749.6 psf was applied to represent the active earth pressure. The protected side is considered to be completely saturated to be overly conservative. Based on these characteristics, the gap analysis produces a factor of safety of 1.146, which is greater than the recommended 1.0. It is shown below, at Sta. 23+00. Refer to the Fragility Curve Analysis for soil cross section and properties.

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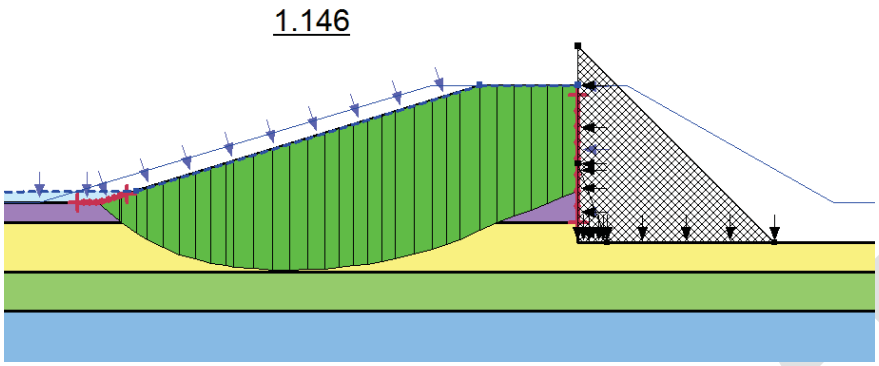

Figure 7: SLOPE/W gap analysis result

Rotational Failure

15. To determine the rotational stability of the floodwall, an analysis using CWALSHT was performed using the elevations developed in the gap analysis. The landside soil mass is great enough that the water pressure built up on the riverside does not allow a failure wedge to develop. Refer to the Wall4 run (Ref 3).

Deformation/Deflection Failure

16. The final check is based on maximum water levels for a deformation evaluation. The heights are shown on Table B-2 of ETL-1110-2-575, extracted below.

Table B-2. Maximum Water Heights (in feet (meters)) for Deformation Control

Annual Chance of Exceedance	Foundation Type			
	Sand $\varphi \geq 32.5$, $D_r = 0.50$	Soft Clay $S_u \leq 300$ psf (14.4 kPa)	Stiff Clay $S_u \geq 1{,}500$ psf (71.8 kPa)	I-wall on Levee
1% and above	7 (2.1)	5 (1.5)	8 (2.4)	4 (1.2)
0.2%	9 (2.7)	7 (2.1)	12 (3.7)	4 (1.2)
0.1% and below	11 (3.4)	8 (2.4)	15 (4.6)	4 (1.2)

Figure 8: Table B-2 from ETL 1110-2-575

17. This floodwall height is elevation 602.5 ft NAVD88, with a maximum of about 4 feet between the protected side ground and the flood height. The foundation type is 'I-wall on levee' and the protection level is equivalent to the 0.2% chance exceedance level (500-year storm), which equates to a maximum of 4 feet before permanent deflection of the soils occurs. Since that is the maximum height, permanent deflection is not anticipated and the McCook Levee is acceptable for this condition.

Conclusion

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18. The McCook Levee sheetpile passes the requirements of ETL-1110-2-575, aside from the erosion present on the riverside. Therefore, there will likely not be any additional rehabilitation requirements with respect to the sheetpile than what was originally estimated (tree removal and regrading).

19. Based on the measured erosion height on the riverside and the results of the sensitivity analysis with CWALSHT, the fragility curve established in the memo dated 24 August 2016 is being reevaluated. The CWALSHT analysis establishes an acceptable factor of safety (1.5) is achieved when there is less than 9 feet of sheetpile exposed from top to base. Station 20+25 has about 11.5 feet of erosion, so there is an increased chance of failure than what would be acceptable.

20. The type of failure expected with loss of riverside slope would occur when water is low, as the sheetpile is more prone to tipping into the river without a water surcharge. Therefore, the PFP will remain as what was previously determined in the prior memo. However, the PNP will be reduced to show the increased risk of erosion on the riverside which would cause instability of the sheetpile wall. The presence of sandbags on the riverside slope (Figure 3) indicate that there may have been previous backfilling. Also, the existing erosion at Sta. 20+25 shows that erosion can extend deep to expose a significant portion of the sheetpile. Any future high water would exacerbate this problem.

21. It is determined that the PNP elevation should be reduced to the level that produces a factor of safety less than 1.5 for wall stability. Each event to this elevation will erode the riverside slope, especially at Sta. 20+25, increasing the likelihood of failure where sheetpile tips into the river. A chart tracking the PFP and PNP is shown below, as well as, a simple cross section indicating the new elevations.

	1980's Feasibility Elevations (ft NGVD29)	FID Elevations (ft NAVD88)	24 August 2016 Memo Elevations (ft NAVD88)	**New Recommended Elevations (ft NAVD88)**
PFP	597.0	600.5	602.5	**602.5**
PNP	594.0	596.5	599.0	**593.5**

Figure 9. Revised PFP and PNP Elevations for the McCook Levee

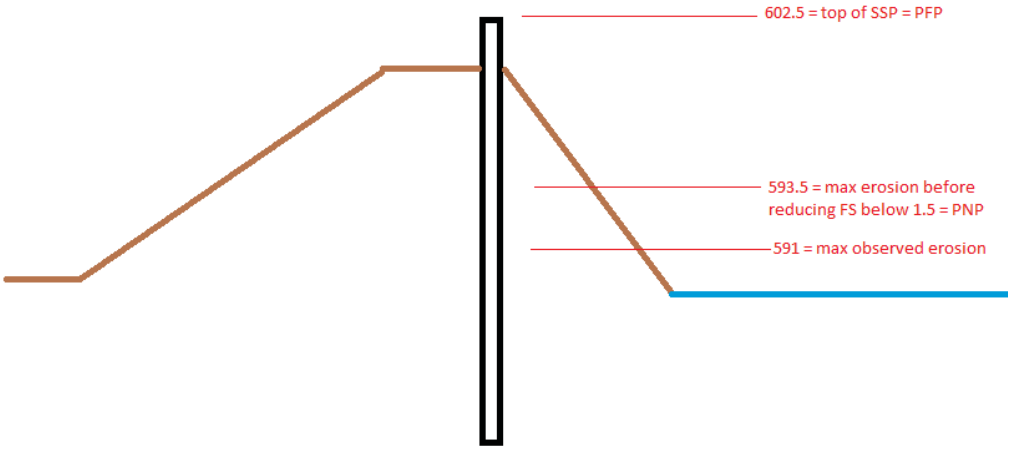

Figure 10: Cross section of PFP and PNP elevations

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References

1. USACE, Chicago District. “McCook Levee, McCook, Illinois Feasibility Study, Appendix C – Geotechnical Investigation.” 1985.
2. USACE, Chicago District. “Fragility Curve determination for McCook Levee.” 24 August 2016 S:\LRC-Project\PRJ-205 McCook Levee\TS-DG\McCookLevee Frag Curve 082416.docx
3. CWALSHT Run Results: S:\LRC-Project\PRJ-205 McCook Levee\TS-DG\CWALSHT trials

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CELRC-TS-DG 24 August 2016

MEMORANDUM FOR PM-PL

SUBJECT: Fragility Curve Determination for McCook Levee

Purpose

1) This memorandum was prepared to discuss the fragility curve of the existing McCook Levee. A fragility curve, as defined in EM 1110-2-1619, 'Risk-Based Analysis for Flood Damage Reduction Studies' is a statistical distribution of levee failure which is used to develop the stage-damage function and description of the overall uncertainty of that function.

2) The fragility curve is defined by determining two points on a graph; the probable failure point (PFP) and probable non-failure point (PNP). The PFP is defined as the water elevation above which the levee is highly likely to fail, set at 85% failure rate in the EM. The PNP is defined as the water elevation below which the levee has a low likelihood of failure, set at 15% failure rate in the EM. Figure 7-4 is extracted from EM 1110-2-1619 to illustrate the fragility curve, as shown below.

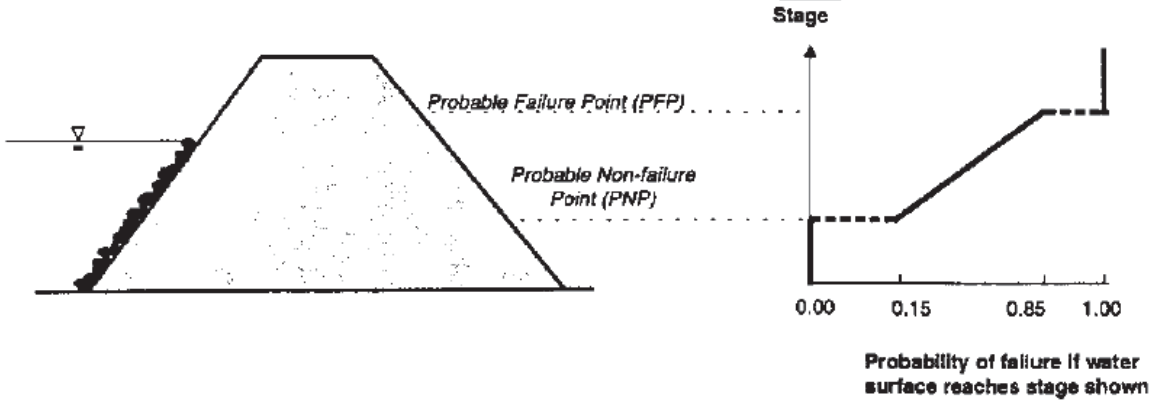

Figure 1. Levee failure probability function from EM 1110-2-1619, Figure 7-4

Levee Background Information

3) The McCook Levee is an existing levee along the Des Plaines River which reduces the risk of flooding in the communities of McCook, Lyons, and Summit, Illinois. It was originally constructed in the early 1900's as a berm but was breached in 1979. After the breach, the levee was repaired and sheetpile was installed to increase the height. Since 1979, the levee has been loaded many times and while there were some instances of noted seepage, the levee has not failed or overtopped. A typical cross section is shown below.

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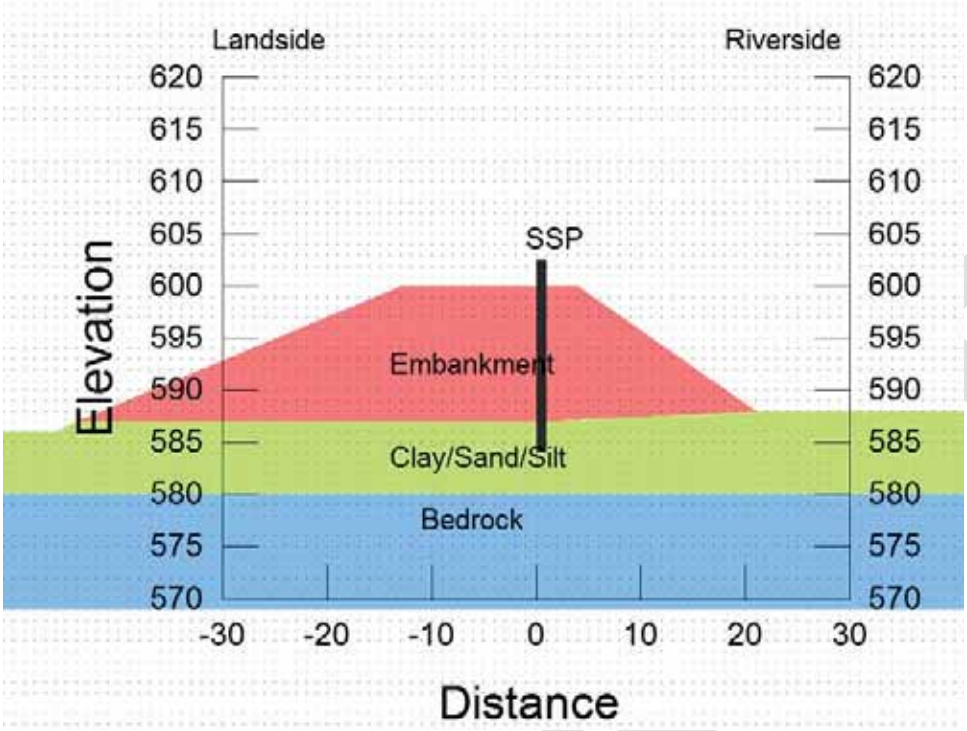

Figure 2. Typical McCook Levee Cross Section

1980's PFP and PNP Determination

4) The McCook Levee was part of a feasibility study in the early 1980's (Reference 1). This study included the development of a fragility curve. Stability analyses with varying riverside water elevations were completed to calculate a range of factors of safety. This found that when the river elevation was above 597.0 ft NGVD29, the factor of safety dropped below 1.4, which is the recommended minimum for steady-state seepage per EM 1110-2-1913. Therefore, 597.0 ft NGVD29 was determined to be the PFP. The PNP was assigned elevation 594.0 ft NGVD29, which is roughly the 1.0 ACE flood.

5) This 1980's analysis effectively ignored the seepage cutoff abilities of the sheetpile that was installed in 1979 to be conservative. However by ignoring the effectiveness, the resulting PFP and PNP are very low; about 5 and 8 ft below the levee crest, respectively. Therefore, the cross section was reanalyzed with current software to account for the sheetpile cutoff.

SLOPE/W Reanalysis

6) A model was recreated to match the dimensions and use the same material properties. Figure 3 below shows the 1980's model and Figure 4 shows the new one created. Figure 5 includes the soil properties used by both.

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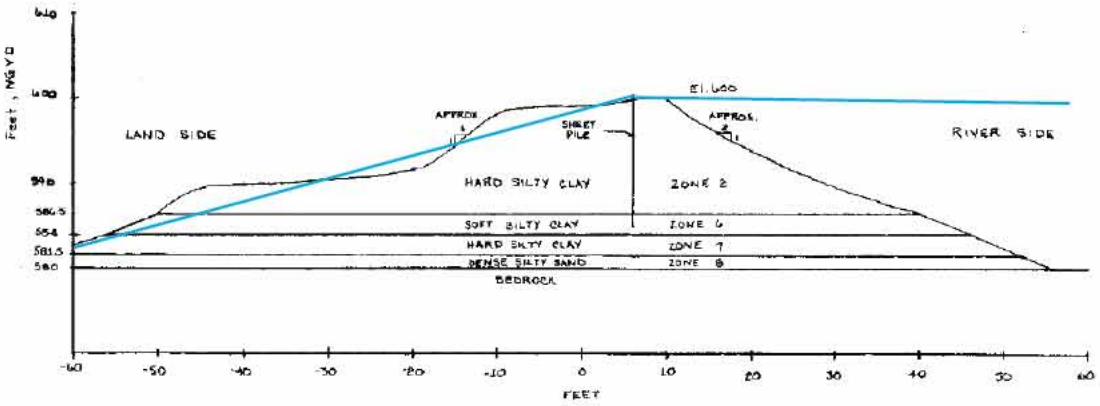

Figure 3. 1980's Cross Section with phreatic line drawn "...high straight line from 600 elevation to tailwater in the drainage ditch."

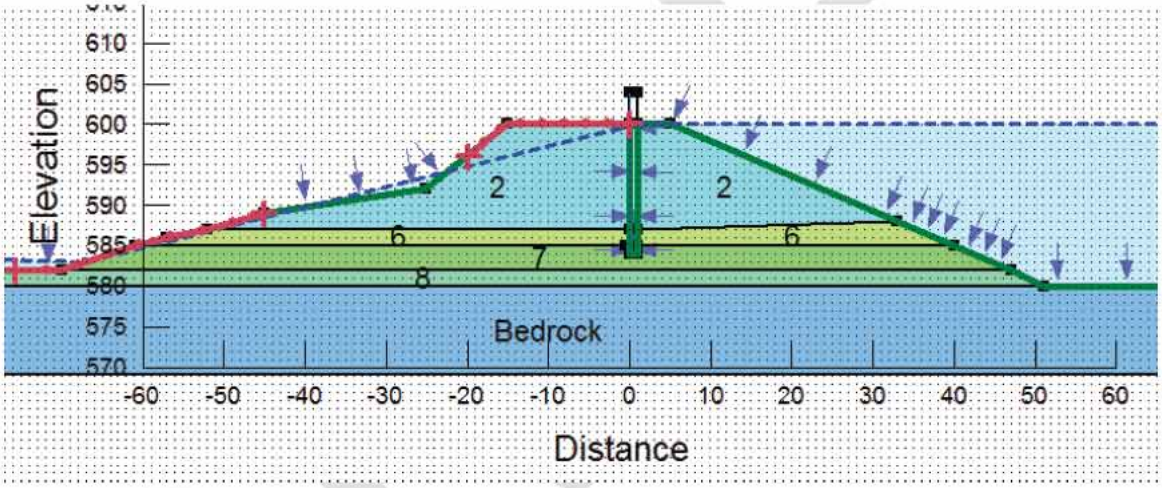

Figure 4. SLOPE/W Cross Section to mirror 1980's

Soil	Unit Weight (pcf)	Cohesion (psf)	Phi Angle (deg)
2 (Very Stiff to Hard Silty Clay)	125	0	30
6 (Soft Brown and Gray Silty Clay)	120	0	26
7 (Very Stiff to Hard Silty Clay Borderline Clayey Silt)	140	0	28
8 (Extremely Dense Silty Sand)	145	0	40
Bedrock	NA	NA	NA

Figure 5. Soil Properties as established in 1980's report

7) Running the SLOPE/W model with the high water level resulted in a factor of safety at 1.038. This is similar to the 1980's result, which calculated 1.11.

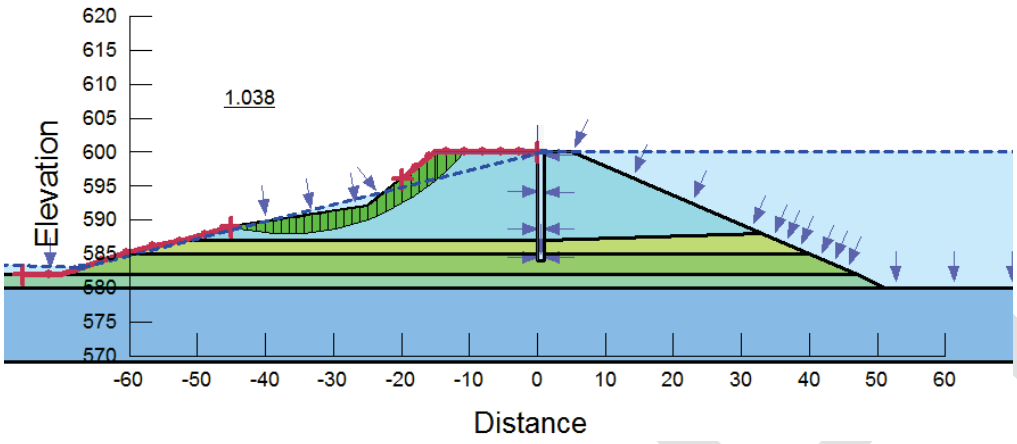

Figure 6. Stability re-run with 1980's Cross section and phreatic line

8) This model ignores the benefits the sheetpile wall affords. The sheetpile should cut off, or significantly reduce through seepage and lower the phreatic line to the sheetpile toe. Therefore, this case was run, which results in a much higher factor of safety at 1.529.

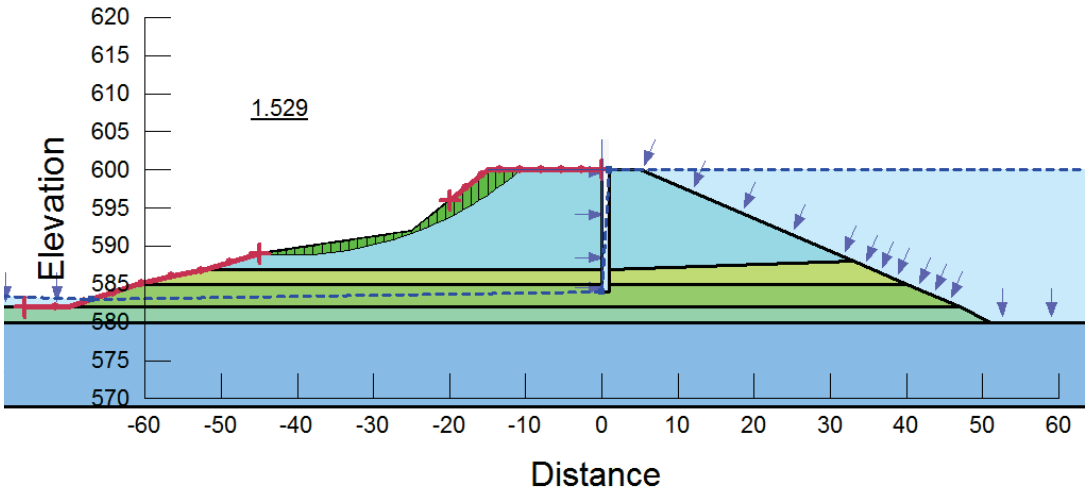

Figure 7. Stability run with revised phreatic line accounting for sheetpile

9) Rerunning this analysis with a water level at the top of the sheetpile (elevation 602.5 ft NAVD88) results in the same factor of safety. Therefore, it does not appear that slope instability would occur on the landside slope when the levee is loaded to the top.

Historical Floods

10) Since 1944, the Des Plaines River has had many high water events which are recorded at the Riverside gage (Reference 2). To adjust this gage elevation to the location of McCook Levee, 3 ft is subtracted as shown on the chart provided by MWRD (Column 5 minus Column 12).

DESPLAINES RIVER LEVEE EVALUATION WITHIN THE SUMMIT CONDUIT WATERSHED

DesPlaines River at Riverside Gauge							DesPlaines River along McCook Ditch				
594.68 Ft. Elevation in NGVD 29 at Gauge Height = 0							All Elevations shown are NAVD88				
DesPlaines River Historic Crests Date	DesPlaines River @ Riverside Gauge Height	** DesPlaines River @ Riverside Gauge Height Corrected for Readings after January 2011	DesPlaines River@ Riverside Elevation NGVD 29	DesPlaines River @ Riverside Elevation NAVD88	DesPlaines River at Riverside FEMA 100 Year Highwater NAVD88	DesPlaines River @ Riverside 100 Year Elevation MWRD DWP NAVD88	DesPlaines River Projected Flood Stages South of McCook Ditch Overflow to IHB RR Levee Elevation varies (597.0-600.0)	DesPlaines River Projected Flood Stages @ * McCook Ditch Overflow Levee Elevation 598.4	DesPlaines River Projected Flood Stages @ Dip in Levee under Il-171 Bridge Levee Elevation 599.3	DesPlaines River Projected Flood Stages South of Lawndale Avenue Levee Elevation 600.3	DesPlaines River Projected Average Flood Stages Between North of Lawndale and 47th Street Top of Sheet Pile Wall Levee Elevation varies (602.0-603.0)
					603.5	605.25	601.6	601.8	601.9	601.9	(601.9-602.6)
4/18/2013	11.42	10.57	605.25	604.95			601.30	601.50	601.60	601.60	601.95
8/15/1987	9.90	9.90	604.58	604.28			600.63	600.83	600.93	600.93	601.28
9/14/2008	9.87	9.87	604.55	604.25			600.60	600.80	600.90	600.90	601.25
1/26/1969	9.82	9.82	604.50	604.20			600.55	600.75	600.85	600.85	601.20
7/24/2010	9.24	9.24	603.92	603.62			599.97	600.17	600.27	600.27	600.62
1/25/1960	8.89	8.89	603.57	603.27			599.62	599.82	599.92	599.92	600.27
10/4/1986	8.80	8.80	603.48	603.18			599.53	599.73	599.83	599.83	600.18
7/24/2011	8.47	7.77	602.45	602.15			598.50	598.70	598.80	598.80	599.15
2/22/1997	8.45	8.45	603.13	602.83			599.18	599.38	599.48	599.48	599.83
2/20/1966	8.30	8.30	602.98	602.68			599.03	599.23	599.33	599.33	599.68
3/20/1948	8.28	8.28	602.96	602.66			599.01	599.21	599.31	599.31	599.66
10/11/1954	8.15	8.15	602.83	602.53			598.88	599.08	599.18	599.18	599.53
4/26/1950	8.15	8.15	602.83	602.53			598.88	599.08	599.18	599.18	599.53
6/16/2015	8.10	7.44	602.12	601.82			598.17	598.37	598.47	598.47	598.82
5/10/1990	8.01	8.01	602.69	602.39			598.74	598.94	599.04	599.04	599.39
12/5/1982	8.01	8.01	602.69	602.39			598.74	598.94	599.04	599.04	599.39
7/14/1957	8.00	8.00	602.68	602.38			598.73	598.93	599.03	599.03	599.38

* McCook Ditch Overflow is located approximately 7500 feet south of 47th Street along DesPlaines River

Denotes Recent Storms after January 2011

Denotes MWRDGC DWP 100 YEAR HW ELEVATION NAVD88

Denotes Overtopping of the Levee

** Prior to January 2011, the gage was located 400 feet downstream of the current location. Gage height values at the current location are higher than those at the old location, given the same discharge. The difference in gage heights between the two locations is variable ranging from about +0.45 ft at gage heights around 6 feet to+0.85 ft at gage heights around 10 feet . (For Example: a current reading of 6.00 ft would approximately equate to a reading of 5.55 ft at the old location and a current reading of 10.00 ft would approximately equate to a reading of 9.15 at the old location.

Figure 8. MWRD Provided Elevation Table of Des Plaines Gage versus McCook Levee

11) This chart only shows the largest 17 events recorded on the Des Plaines Riverside gage. For additional events, the NOAA page (Reference 2) was checked. In order for the gage readings on the website to be converted to elevations at McCook Levee, the following calculations were completed. (NGVD29 – 0.3 = NAVD88).

Gage '0.00' reading = 594.68 ft NGVD29 - 0.3 = 594.38 ft NAVD88

Subtract 3 from gage location to get elevation at McCook Levee, so

594.38 ft NAVD88 @ gage – 3 = 591.38 ft NAVD88 @ McCook Levee

So 591.38 ft NAVD88 @ McCook Levee = 0.00 Gage reading

12) With this conversion, the following table was created to show the number of events that have exceeded certain elevations at McCook Levee using the Riverside gage historic loads, particularly the ones after the levee was repaired in 1979.

Flood Elevation (ft NAVD88)	Number of Occurrences without failure (1979 – 2016)
601+	3
600+	5
599+	10
598+	22
597+	32

Figure 9. Table showing number of historic event exceedances

13) Another calculation was completed to determine the gage height of the hypothetical PFP from the 1980's report at McCook Levee.

For the PFP elevation at 597.0 ft NGVD29 = 596.7 ft NAVD88 @ McCook Levee

596.7 ft NAVD88 @ McCook Levee + 3 = 599.7 ft NAVD88 @ gage

599.7 ft NAVD88 @ gage – 594.38 ft NAVD88 gage '0.00' reading = 5.32 ft

Therefore, any gage readings greater than 5.32 ft likely exceed the 1980's PFP.

14) According to the historical crests (Reference 2), a gage reading of 5.32 ft exceeded the 1980's PFP 70 times, 33 of which occurred since the 1979 repairs were completed. If levee failure with a probability of 85% didn't occur after 33 occurrences, then the 1980's PFP is considered overly conservative and not realistic.

Revised PFP and PNP

15) Since the previous fragility curve is not realistic, a new one must be developed to properly model the probability of levee failure.

16) Additional analysis could be completed on slope stability, but the results from the revised stability analysis above met the minimum factor of safety set by EM 1110-2-1913. Also, since the levee has withstood several high water events it can be assumed that the factor of safety is at least 1 in all cases to this point.

17) The other failure method to calculate is seepage and uplift. Constructing a seepage model would be an effective way to show the various factors of safety while changing the flood levels.

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However in this case, the amount of uncertainty in developing such a model would not produce accurate PFP and PNP elevations for the following reasons:

a) An accurate survey of the levee is not available, so the contours may not accurately reflect the actual site conditions. There are a few cross sections available in the 1980's report, but these appear to be idealized without accounting for the ditch on the landside, erosion on the riverside, and are at locations with low seepage concerns.
b) All of the borings were completed on the crest of the levee, so any changes in the subsurface at the landside or riverside toes would not be captured.
c) Several permeability tests were run during the 1984 subsurface investigation. Within the sand portion between Sta. 30+00 to 45+00, values ranging from 10^{-2} to 10^{-5} cm/sec were obtained from falling head tests within the hole. An additional test was attempted at Sta. 1+00 but the permeability was too high to measure. The variation in these measurements make it difficult to model accurately, especially when each varies by several orders of magnitude. Additionally, the permeable zones are not well delineated.
d) How the landside ditch is modeled would also affect the results. The more the ditch is filled with water, the less head differential between the land and river sides of the levee. Lower head differential reduces the risk of seepage. During the 2013 event, end-around overtopping occurred which inundated the ditch and may have limited/prevented seepage. This end-around flooding did not occur during the 1986 event when seepage was noted.
e) The model cannot take into account features such as the trees prevalent on the levee. Trees provide seepage paths along their root systems, particularly after a tree dies and the roots rot away.

18) With all of this uncertainty, creating a seepage model to determine the risk of seepage and uplift of McCook Levee would be subjected to many different judgement calls. Combining these judgement calls may not represent the actual field condition, especially for the purpose of selecting specific flood elevations for the PFP and PNP.

Historical Approach

19) Instead of calculating the PFP and PNP via modeling floods, these elevations will be looked at in an historical context. All of the occurrences shown in Figure 9 above did not have a failure of the levee, and the only damage noted to the levee has been minor seepage and riverside erosion.

20) To establish the PNP, the historic loadings were examined. The only record of adverse conditions occurring was some seepage observed in the October 1986 event; which peaked at about 600 ft NAVD88. In general, if seepage has been observed, then subsequent events would require less head to recreate the seepage, as the path has already been established. Therefore, the PNP is determined to be 1 foot lower than the 1986 event, at 599.0 ft NAVD88. At this elevation, the levee has been loaded about 10 times since the repairs in 1979.

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21) Historic loadings were also examined to establish the PFP. The levee has been loaded within about 1-½ ft of the crest without major issues 3 times since the repairs in 1979. The PFP is defined as the elevation where the levee is 85% likely to fail. Since the McCook Levee has survived these extreme loading events, the elevation where it would likely meet this definition would be the top of the levee. If McCook Levee overtopped, then additional damage would be realized from erosion on the landside and would likely cause levee failure. Therefore, the PFP is determined to be at the levee crest, or 602.5 ft NAVD88.

Summary

22) The original PFP and PNP calculated in the 1980's feasibility report are overly conservative based on the fact that the analysis ignored the sheetpile to calculate a lower factor of safety than what is likely occurring. Additionally, with an additional 30 years of observations since that report was written, the levee has experienced loading greater than the PFP over 30 times without failure. The new PFP and PNP established by this memo are shown in Figure 10 below.

	1980's Feasibility Elevations (ft NGVD29)	FID Elevations (ft NAVD88)	**New/Recommended Elevations (ft NAVD88)**
PFP	597.0	600.5	**602.5**
PNP	594.0	596.5	**599.0**

Figure 10. Revised PFP and PNP Elevations for the McCook Levee

23) It should be noted that these points for the Fragility Curve are based on existing knowledge and field observations. Each subsequent flood event will continue to degrade the levee and lead to more issues with seepage, erosion, and eventually instability and failure. There are three major concerns of the condition of the existing levee:

a) The riverside slope has experienced significant erosion when compared to the as-built cross section. The sheetpile does not extend much deeper than the base of the levee, so as the riverside slope continues to erode, the sheetpile will lose its embedment and could tip toward the river.
b) Seepage was first documented during the 1986 flood and there have been many events after this that probably experienced seepage as well, despite the lack of field observations. In events such as 2013, the high water & vegetation in the ditch likely limited the inspector's ability to document any seepage. Also, the permeability test that was attempted near Sta. 1+00 that could not record a result is an indication that seepage will be a concern.
c) The large trees present on the levee also present a significant risk. As trees continue to grow, they are more likely to fall over, which would take a significant root ball and chunk of levee with them.

Attachments

DRAFT

1. Plan and Profile View of McCook Levee based on 1979 and 1984 Borings

References

1. USACE, Chicago District. "McCook Levee, McCook, Illinois Feasibility Study, Appendix C – Geotechnical Investigation." 1985.
2. NOAA, Advanced Hydrologic Prediction Service. "Des Plaines River at Riverside." <http://water.weather.gov/ahps2/hydrograph.php?wfo=lot&gage=rvri2>

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Attachment 4: Field Observations and Photos of October 1986 Flood Event

DRAFT

VW81 126 2024 0000

MFR 4 OCT 86

SUBJECT: INSPECTION OF McCOOK LEVEE

1. ON THIS DATE CHRIS QUIRK AND THE UNDERSIGNED INSPECTED McCOOK LEVEE IN RESPONSE TO INQUIRIES FROM LOCAL AGENCIES (FIRE / POLICE) REGARDING BOILS AND SEEPAGE.

2. THE DES PLAINES RIVER NEAR McCOOK CRESTED ON 3-4 OCTOBER. DURING THIS TIME, THE ILLINOIS NATIONAL GUARD, WITH TECHNICAL ASSISTANCE FROM MARTIN KOTSCH & SKIP BERGMAN PLACED SAND BAGS TO REDUCE OVERTOPPING OF THE LEVEE NEAR THE INDIANA HARBOR BELT R.R. TRACKS. THE RIVER APPEARS TO BE 3'6" BELOW CREST BASED ON WATER MARKS ON THE SSP AT STA 4+00 (N. OF LAWNDALE) AND A TEMPORARY STAGE GAGE SET UP BY THE SANTA FE RR.

3. THE SAND BAG LEVEE APPEARS TO BE IN GOOD CONDITION. THERE IS SOME SEEPAGE THROUGH IT, BUT THIS IS NOT CAUSING FLOODING AND IS NOT ENDANGERING THE STRUCTURAL STABILITY OF THE LEVEE.

4. TWO MINOR SEEPAGE AREAS WERE NOTED - ONE APX. 100' S. OF LAWNDALE AVE, ONE APX 400' N. OF LAWNDALE. NEITHER WERE CONSIDERED TO BE A PROBLEM AT THIS POINT, BUT SHOULD BE MONITORED IN THE FUTURE.

5. THE SANTA FE R.R. HAS BEEN MONITORING ITS BRIDGES ON THE NORTH SIDE OF McCOOK LEVEE. THEY HAVE SET UP

A TEMPORARY STAGE GAGE ON THE NORTHERN R.R. BRIDGE. PEAK STAGE WAS @ ABOUT 1'9" ABOVE LOW STEEL. STAGE AT THE TIME OF INSPECTION WAS 1'3".

David Handwerk

G AND TRANSMITTAL SLIP Date 10/10/85

ice symbol, room number, gency/Post)	Initials	Date
1. Priscilla Tsang	MMA 10/15	
2. Paul Mahrhardt		
3. Dave Hawkins		
4. Kayman Jungman		
5.		

	Action		File		Note and Return
	Approval		For Clearance		Per Conversation
	As Requested		For Correction		Prepare Reply
	Circulate		For Your Information		See Me
	Comment		Investigate		Signature
	Coordination		Justify		

REMARKS

DO NOT use this form as a RECORD of approvals, concurrences, disposals, clearances, and similar actions

FROM: (Name, org. symbol, Agency/Post)	Room No.—Bldg.
	Phone No.

5041-102

☆ GPO : 1983 O - 381-529 (301)

OPTIONAL FORM 41 (Rev. 7-76)
Prescribed by GSA
FPMR (41 CFR) 101-11.206

ROUTING AND TRANSMITTAL SLIP Date 10/7/86

TO: (Name, office symbol, room number, building, Agency/Post)	Initials	Date
1. Lee		
2. Don		
3. Jack		
4. Kirk Murdock		
5. Jim Simpson to Chicago Dist		

Action	File	Note and Return
Approval	For Clearance	Per Conversation
As Requested	For Correction	Prepare Reply
Circulate	X For Your Information	See Me
Comment	Investigate	Signature
Coordination	Justify	

REMARKS The record of this flood shows conclusively that this levee can stand more than the 50 year flood. It can confidently be predicted that the levee and sheet pile wall will take a flood to its top (100 year + event) To say less could reflect on the integrity of the C.O.E.

DO NOT use this form as a RECORD of approvals, concurrences, disposals, clearances, and similar actions

FROM: (Name, org. symbol, Agency/Post) Jim Simpson

Room No.—Bldg.

Phone No.

5041-102

☆ GPO : 1983 O - 381-529 (301)

OPTIONAL FORM 41 (Rev. 7-76)
Prescribed by GSA
FPMR (41 CFR) 101-11.206

[redacted]

DISPOSITION FORM

For use of this form, see AR 340-15; the proponent agency is TAGO.

REFERENCE OR OFFICE SYMBOL	SUBJECT
NCDED-TG	Trip Report - Field Inspection of Flooding Along the Des Plaines River from the McCook Levee Northward to Gurnee, IL

TO	FROM	DATE	CMT 1
Files	Jim Simpson Jim Mazanec Jose Ordonez Hari Singh	6 October 1986	

1. Purpose:

a. Ascertain McCook levee flood performance.

b. Inspect flood damage and areas of flooding which regard to possible future projects.

2. Place and Date: This field inspection was made on 1 October 1986, along the Des Plaines River, starting at the McCook levee at Lawndale Avenue near McCook, Illinois and ending at Gurnee, Illinois in Lake County. The weather was cloudy with light to heavy showers and a temperature of about 70 F.

3. Attendees:

Jim Mazanec	NCDED-WC
Hari Singh	NCDED-TG
Jose Ordonez	NCDED-WC
Jim Simpson	NCDED-TG

4. Background: The Des Plaines River was in flood stage from about 23 September to 8 October 1986 from its source in Wisconsin through Gurnee, Illinois all the way to its confluence with the Illinois River near McCook, Illinois. The maximum measured flood heights were as follows:

LOCATION	FLOOD STAGE	MAX. LEVEL	FLOOD EVENT
Gurnee, IL	7 ft.	11 ft. (30 Sep)	100 years
Des Plaines, IL (Dempster)	5.5 ft.	11.1 ft. (1 Oct)	N/A
Riverside, IL (near McCook levee)	5.5 ft.	8.8 ft. (4 Oct)	63 years

Generally the flood north of Salt Creek can be generalized as one having a recurrence interval of once every 100 years, whereas south of this juncture it can be describe as having a recurrence of once in 50 years.

5. Observations:

a. McCook levee

(1) The flood level observed on 1 October 1986 at the McCook levee was near elevation 599.0 feet or about 6 inches below the levee embankment crest and also the same distance

below the sheet pile-ground line juncture. The water at this time did not extend up on the cantilever sheet pile wall. Later, water was noted to be 1 foot up on the sheet pile wall. It should be noted that this first elevation 599.0 ft. is the same as the Chicago District's probably failure point (PFP) where NCC predicted a 100% likelihood of failure. There was no sign of failure. Later in the event the following observations were made by Mr. Mazanec.

Date/Time	Upstream end of Project Santa Fe RR (elevation ft. msl)	Lawndale Avenue (elevation ft. msl)
1 Oct 86 9:30 a.m.	599.0	598.2
3 Oct 86 7:00 p.m.	600.14	N/A
4 Oct 86 7:30 p.m.	600.14	599.8
4 Oct 86 2:00 p.m.	N/A	599.7

(2) The combined levee and sheet pile wall is apparently doing an excellent job in holding back the water. There were no significant signs of slope instability, through seepage, settlement, etc.

(3) The embankment was carefully checked for saturation (the surface is spongy with soft areas present when saturated) and none was found. These would indicate that the levee material and sheet pile wall are effectively cutting off through seepage.

(4) Water was noted to be ponding on the landward toe about (station 3+50 as marked on the sheet pile wall) 1,000 ft. from the Lawndale avenue end in one 25 foot area. Leaves were seen floating but no pin boils, bubbling or signs of uplift were observed. This could indicate that some limited underseepage (1-2 gpm) could be taking place. This area should bare watching if an increased differential head develops.

(5) The trees on the forefront of the levee are effectively shielding the levee's riverward slope from most of the river current as well as preventing debris from reaching the levee. The river current near the embankment is very low and non-erosional.

(6) At one location an 8 inch diameter tree trunk or limb had fallen and was lying across the sheet pile wall. There was no damage or reduced sheet pile wall effectiveness noted.

(7) The interior drainage system was observed to be working well and no ponded water or damage was seen. The Summit Conduit, an inverted siphon carrying interior drainage water from the drainage ditch behind the levee under the river to the Sanitary and Ship Canal, was flowing freely.

b. Railroad bridges. The flood water at this time was touching the bottom flange of two railroad bridges near the 47th street end of the McCook levee. A further rise of the river could result in an obstruction and a higher flood level which could jeopardize the McCook levees.

c. Enclosure 1 provides stage-discharge, discharge-frequency, and stage-frequency curves for locations at the USGS gages at Gurnee and Riverside. Frequency curve analyses are taken from the NCC report and a second analysis was done using the Watstore computer system; therefore, neither analysis utilizes the 1986 flood data.

McCook Levee - Based on the Riverside gage data and the 1986 flood stage data it is concluded that the backwater model at McCook levee may be calibrated 0.8 - 1.4 feet too high for free a flow condition. A review of the Riverside gage records suggests that ice jam conditions do occur downstream of the gage. In addition, Santa Fe RR personnel who were monitoring the RR bridge on 3-4 October 1986 noted that they had observed higher stages in the past. The District should review there profile analysis for this site based on the above information.

Upper Des Plaines - As can be seen from the attachment, there is a signifcant difference between the NCC and Watstore developed discharge-frequency curves. Some of the difference may be resolved when the 1986 event is added to the record; however, if the District is basing any studies in the upper part of the Des Plains on the discharge-frequency curve as presented for the Gurnee Gage in the McCook Report those analyses should be reviewed carefully.

d. Riverside Levee. A small 4 foot high City levee was being overtopped.

e. Riverside to Gurnee. Hundreds of homes, industrial plants, streets, highways, business and public buildings, etc. were under water with significant damage from Riverside to Gurnee.

6. Conclusions:

a. The McCook levee upstream of Lawndale Avenue is working fine and has proven it can at least withstand a flood to about elevation 600 feet.

b. Chicago District now has the potential for many worthwhile projects along this flood route.

c. The NCC probable failure point (PFP) McCook Levee has been shown to be in error for present conditions.

d. NCC should review the potential effect of the low railroad bridges on the project profiles as well as ice jam and debris conditions in order to justify the current profiles or else lower the stage-frequency profiles.

NCDED-TG
SUBJECT: Trip Report - Field Inspection of Flooding Along the
Des Plaines River from the McCook Levee Northward to Gurnee, IL

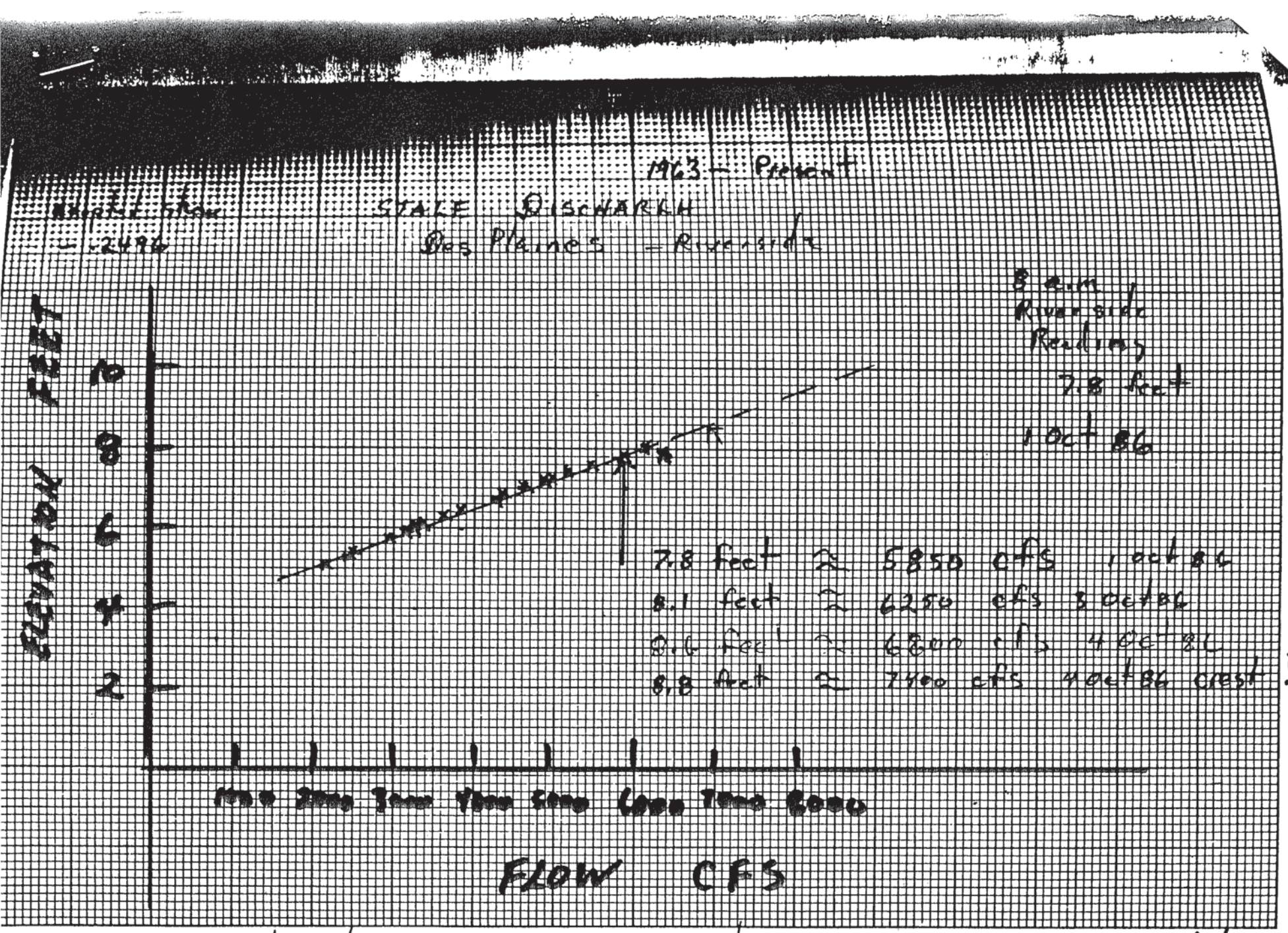
e. The results of the 1986 flood should be used by the District in responding to statements in the MSDGS preliminary report entitled: "Evaluation of the feasibility of diverting water from the Des Plains River to the Sanitary and Ship Canal." The report currently states that our 100 year profile is 4.5 feet too high.

Jim Simpson

Hari Singh

Jim Mazanec

Jose Ordonez

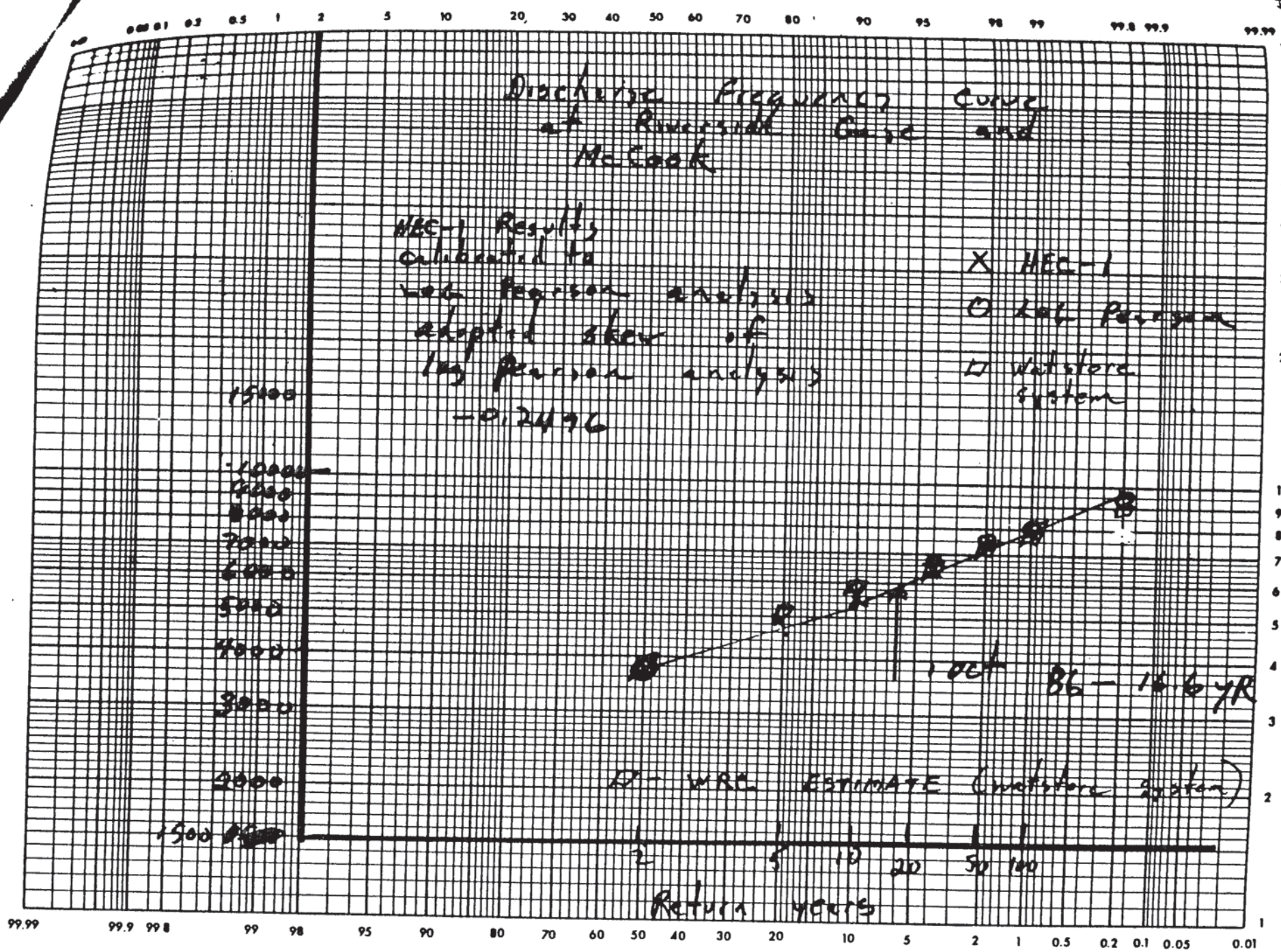


4 oct readings
Backwater may be calibrated 1.2 - 1.4 feet high at McCook Levee

1 oct readings

conclusion Backwater model may be calibrated 0.8 feet high at McCook Levee

16 Divisions/Inch 5th, 10th Accent


Discharge Frequency Curve
at Riverside Canal and
McCook
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○ - WRC ESTIMATE (Historic 20 stem)
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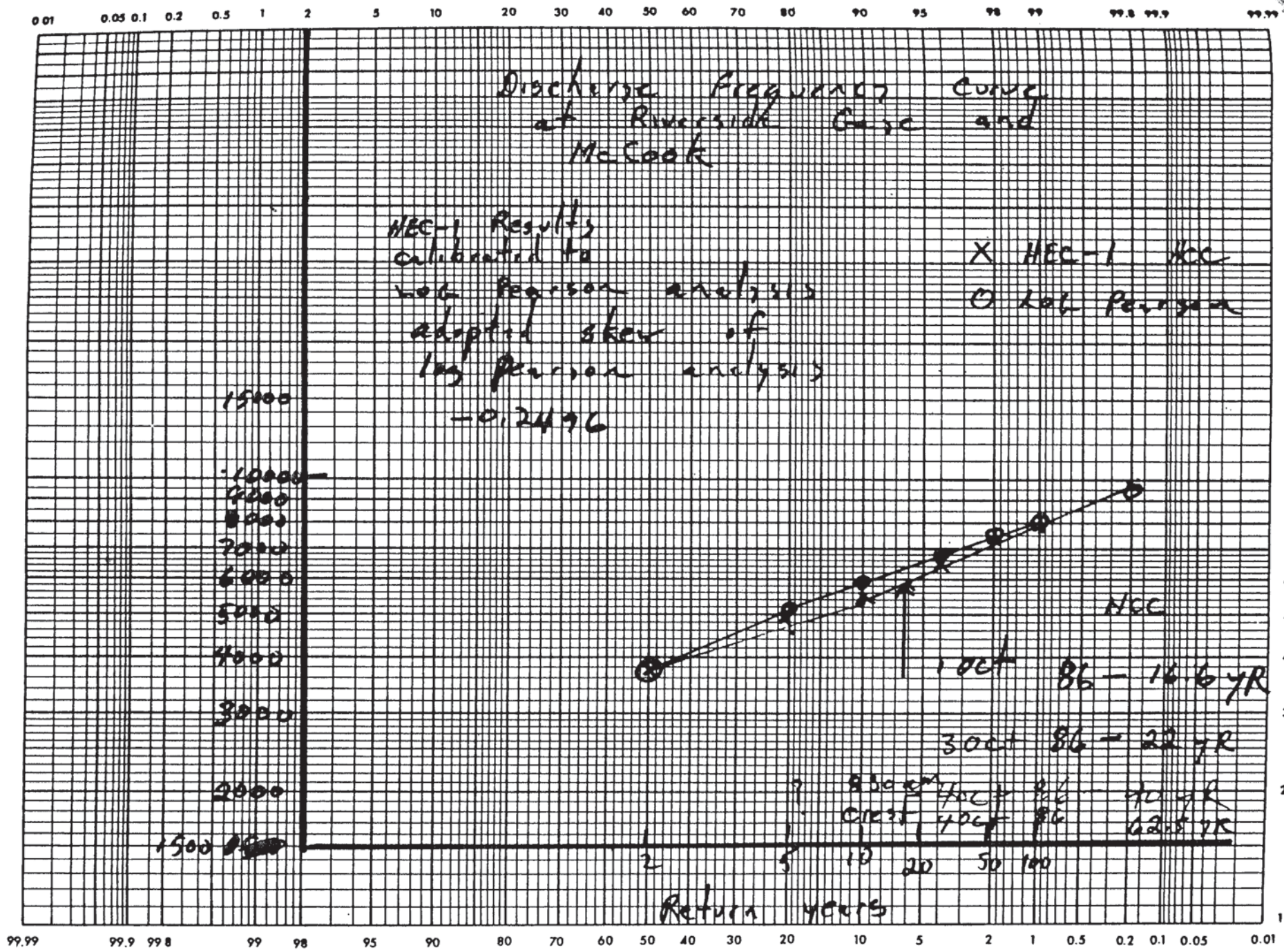
Probability by 2 Cycle Log



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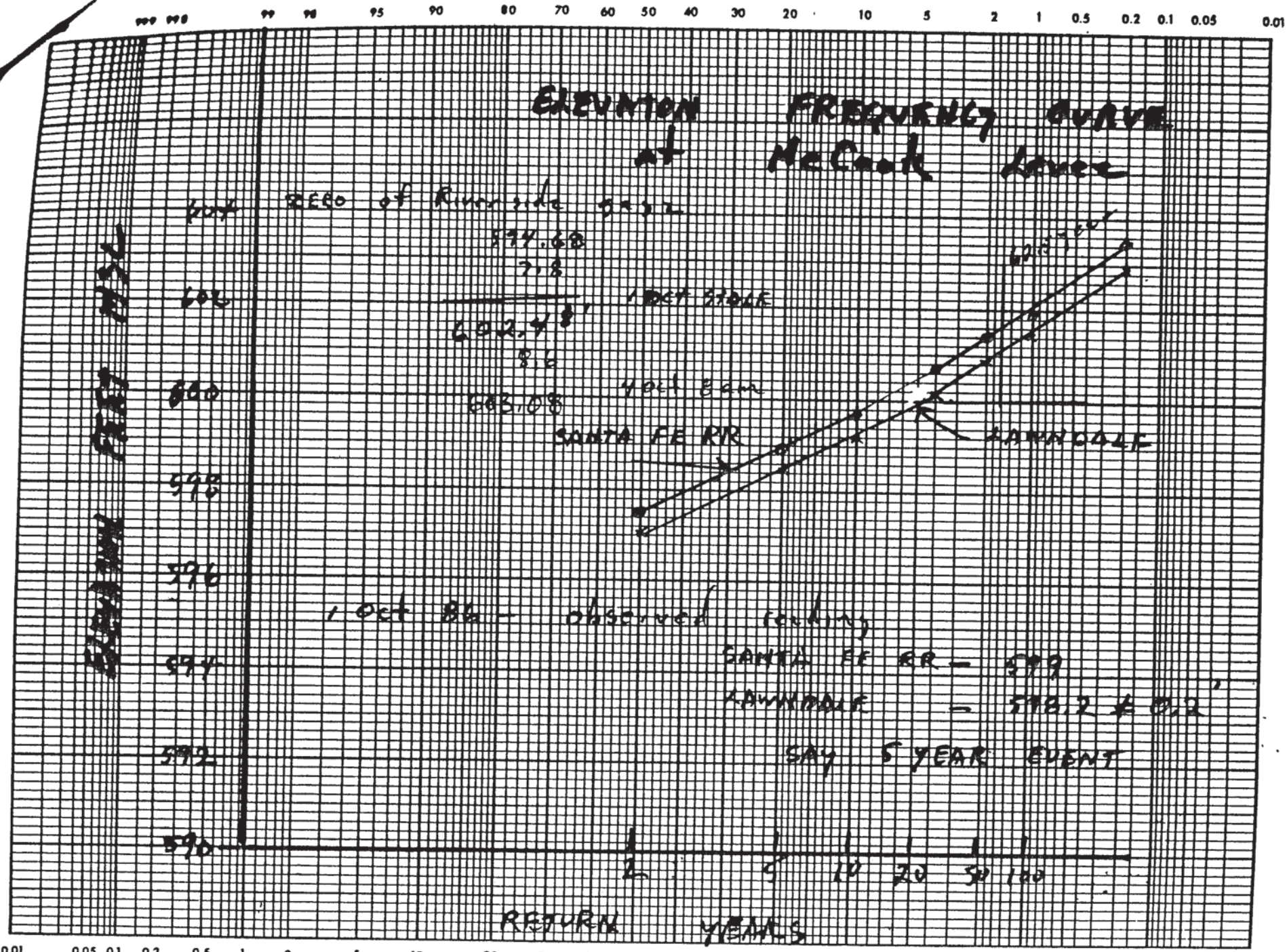
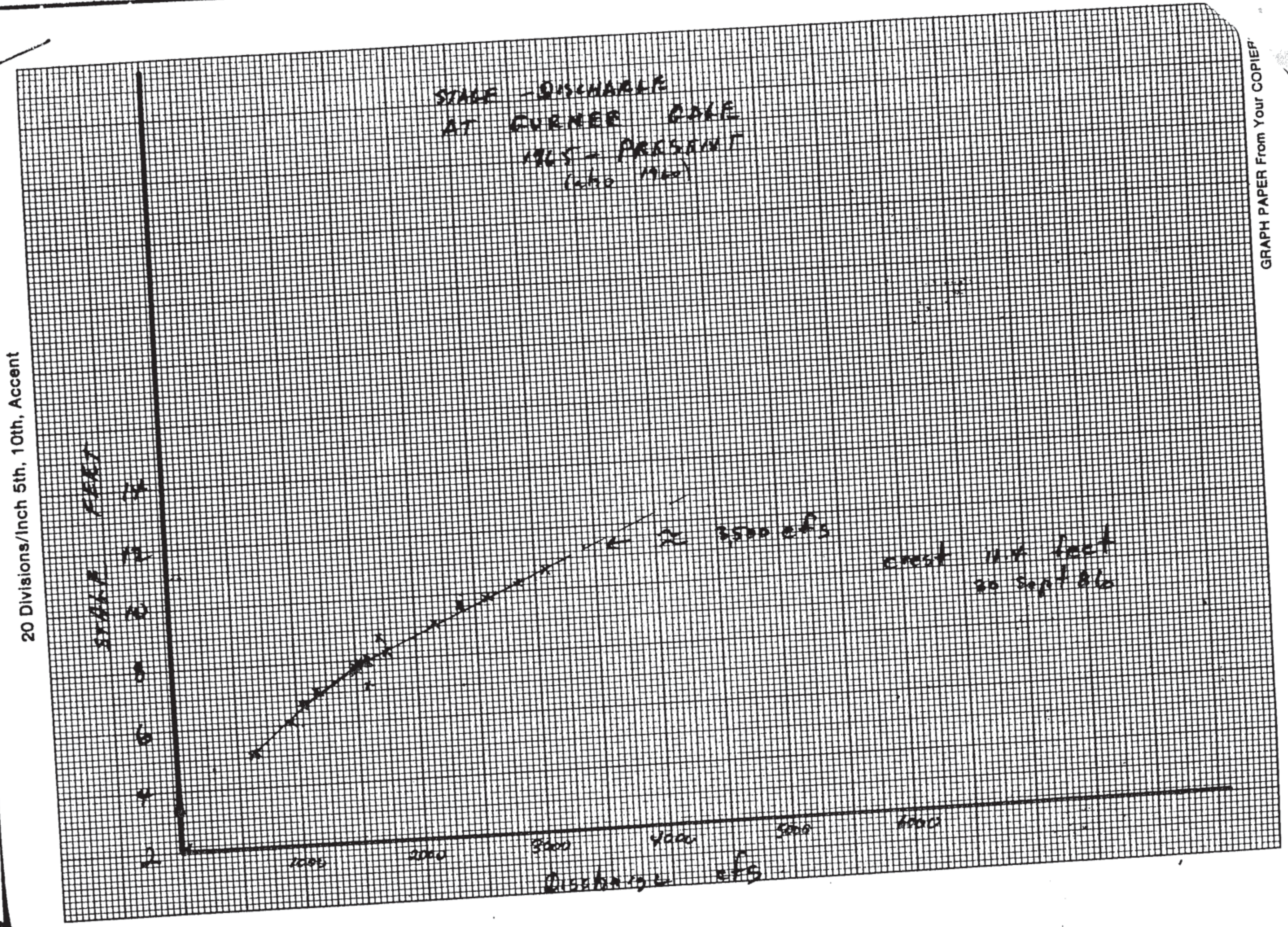

ELEVATION FREQUENCY CURVE
AT McCOOK, NEBR.
Probability by 100 Divisions
RETURN YEARS
SAY 5 YEAR EVENT
SANTA FE RR
DOWNDRAFT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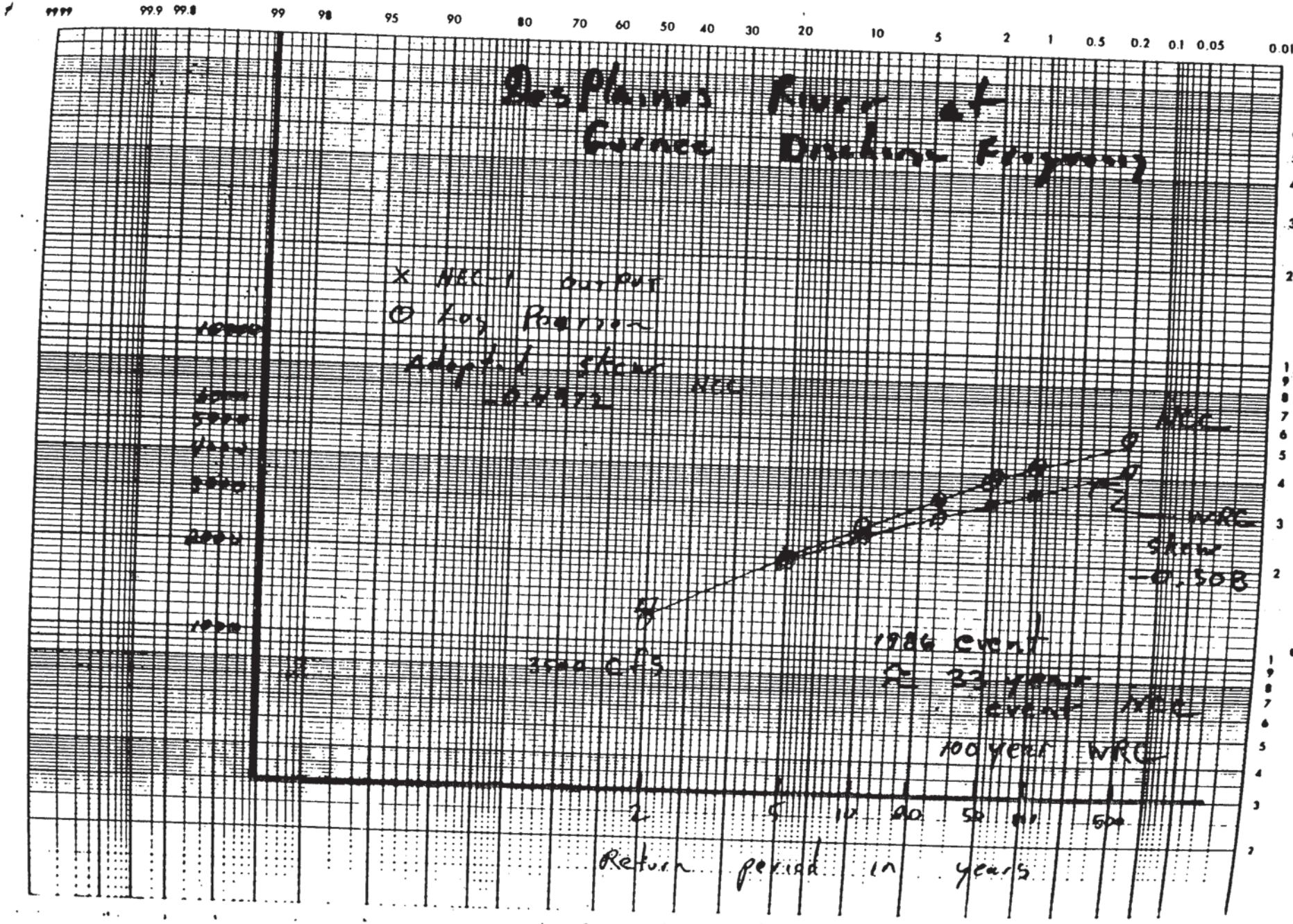

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NCCED-S

09 October 1986

MEMORANDUM FOR RECORD

SUBJECT: Levee Inspection on the Des Plaines River in the Vicinity of Village of McCook, Cook County, Illinois

1. On 6 October 1986, 6:00 to 7:30 PM, a field inspection of the flood control levees was made by Priscilla Trigg. Another inspection on the following morning, 9:00 to 10:30 AM was made by Priscilla Trigg and Skip Bergmann, NCCCO-R.

2. There were three separate areas inspected. One area was the McCook Levee identified as being between 47th Street and Lawndale Avenue on the west side of the Des Plaines River in the Village of McCook. The second area was located south of Lawndale Avenue to Ill. highway 171, and third, the area south of I-171 in the town of Summit, Illinois. (See Figure 1).

3. There had been a great deal of rainfall in northern Illinois for several weeks before the site visit. Record floodings had occurred along the rivers in this part of the state. Monday morning, 06 October 1986, this branch was informed that on the previous Friday evening the Des Plaines River had flooded and Corps' employees, National Guardsmen, and local personnel had been called out to sandbag the levee south of I-171. The levee had overtopped along a 400' section and water was flowing over the levee and into the drainage ditch on the landward side of the levee. The crown was eroding and several areas on the landward slope of the levee were breaching due to the velocity of the water flowing over the levee.

4. It appears the river peaked Friday night, 03 October 1986, or early Saturday morning. Reports indicate that the river had risen on McCook Levee to reach up to 6 inches (approx.) on the steel sheet pile.

5. The area inspected 06 October 1986 was the McCook Levee area between Lawndale Avenue and I-171. The water had dropped to several feet below the top of the levee. The crown of McCook Levee is concave and there was standing water in many spots. It was impossible to see if much erosion occurred on the river face of the levee since the river was still very high. This section of the levee had not overtopped. There is erosion beneath the overpasses due to surface drainage from the overpass directly onto the levee crown, and side slopes.

6. Skip Bergmann, NCCCO-R, was assigned to watch the McCook Levee on Friday and was present during the sandbagging operation, so he was asked to attend the second field trip on 07 October 1986 to point out problem areas that had been discovered by the flood fighting team.

7. The first thing that Skip pointed out was the gauge just south of Lawndale Avenue. The river had dropped between 2.5-3 feet since Friday afternoon.

8. At the base of the landward side of McCook Levee, at approx. Sta. 3+60 to 4+50, a large area of seepage had developed. The water was flowing from the ponded seepage area to the drainage ditch. According to Skip Bergmann, the seepage developed Friday afternoon. It was impossible to tell if the seepage was from one source and spreading out on the ground surface or if the seepage was emanating all along the 90 foot area.

9. Just to the south of Lawndale Avenue, south of the McCook project limit, there was an area where seepage had erupted from the side slopes and erosion had occurred. Sand bags had been placed on the levee side slope to prevent further degradation. No water was seeping through the eroded section of the levee on Tuesday morning, 07 October 1986.

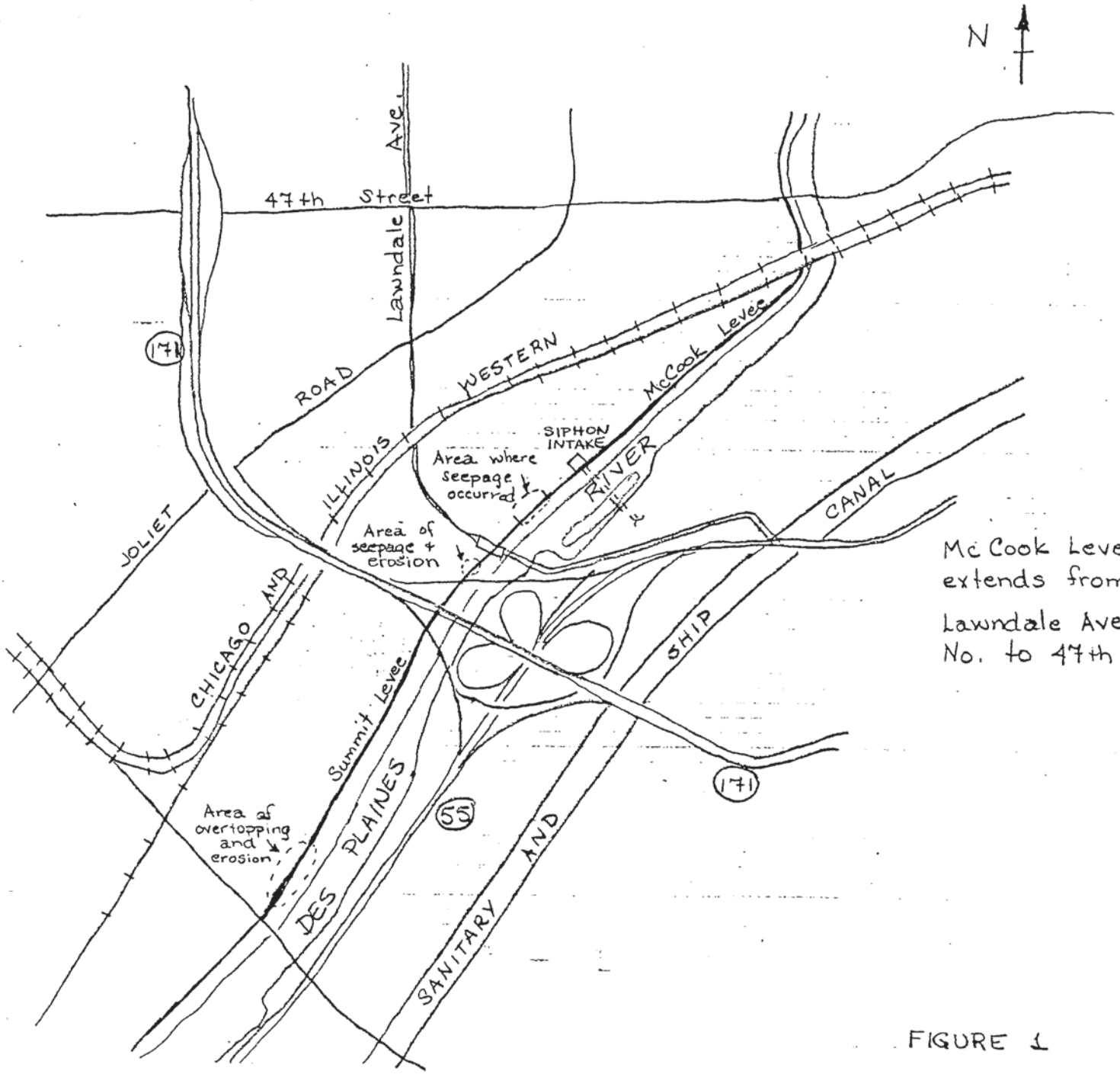
10. The final area inspected was the levee south of I-171 where the overtopping had occurred along a 400' section. A front end loader had placed sand, earth and spoil along the river as far as the machine could drive and a sand bag levee was placed by hand along the rest of the stretch. The river was lower but there was still water standing on the crown of the levee and behind the temporary sandbag levee in most areas. The places where the water had eroded on the landward slope were evident.

11. Pictures will be available showing the condition of the site as it was 06-07 October 1986.

Priscilla Trigg

Priscilla Trigg
Civil Engineer
NCCED-S

COMPUTATION SHEET	DATE 10/8/86	PAGE OF	FILE NUMBER
NAME OF OFFICE NCCED-S		COMPUTATION	
SUBJECT McCook & Summit Levees		SOURCE DATA	
COMPUTED BY PAT	CHECKED BY		APPROVED BY



McCook Levee extends from Lawndale Ave. No. to 47th St.

FIGURE 1

McCook Levee
Oct. 1986

Near R.R. tracks at ~ Sta. 41+00.

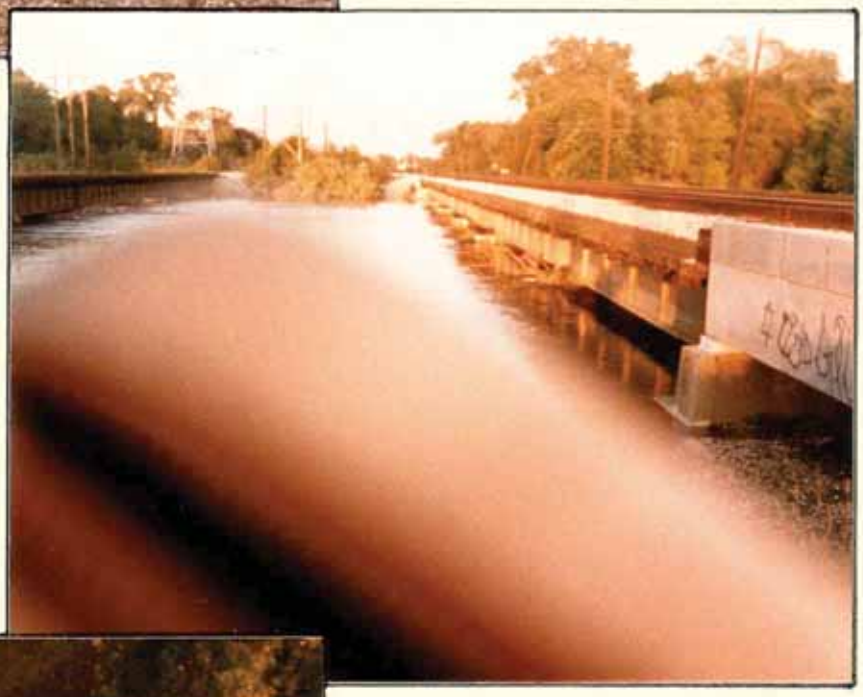
Note flooded area near petroleum plant.

Ponded area on landward side of levee between 47th St. and R.R. tracks

R.R. tracks at ~ Sta. 41+00

McCook Levee
Oct. 1986

Drainage ditch behind R.R. at ~Sta. 41+00



River near R.R. tracks at Sta. 41+00

On R.R. tracks at Sta. 41+00 looking south at Des Plaines River. Water level very high.

McCook Levee
Oct. 1986

Looking toward ponded water on landward side of levee at ~ Sta. 35+00

Crown of levee near Sta. 30+00. Concave top allows ponded water.

Steel sheet pile condition

McCook Levee
Oct. 1986

Erosion on landward side of levee

Sta. 37+00 - River side of levee

Small tree fallen across steel sheet pile

McCook Levee
Oct. 1986

Siphon Intake - looking landward

Siphon Intake - looking riverward

Drainage ditch

McCook Levee
Oct. 1986

Riverward side of levee. Des Plaines ~2' from crest (down ~ 2 1/2' from previous week-end)

Erosion on river side of levee near Lawndale Ave.

Seepage on landward side near Sta. 3+60 thru 4+50. Standing near drainage ditch, looking toward levee.

McCook Levee Oct. 1986

Seepage exit to drainage ditch ~ Sta. 3+60 thru 4+50. Drainage ditch in upper left hand corner of photo.

Seepage Sta. 3+60 thru 4+50. Looking toward levee on landward side

Seepage area, Sta. 3+60 to 4+50 landward side

McCook Levee
Oct. 1986

Gauge on telephone pole just south of Lawndale Ave.

Blow out filled in with sand bags, just south of Lawndale Ave.

Sand bag filled blow out section on landward side of levee slope just south of Lawndale Ave.

McCook Levee
Oct. 1986

Area where sandbags were filled for over-topped levee south of I-171

Temporary rubble levee placed by front end loader to control overtopping. Looking toward Des Plaines R.

Sandbag dike placed 10/3/86 looking south, river on left side of photo. Drainage ditch to right.

McCook Levee
Oct. 1986

Looking north at sandbag dike hand placed 10/3/86

Temporary rubble levee placed 10/3/86

Standing water on crown of levee. River on right side of photo.