TETRA TECH

Technical Memorandum

To:	Rick DiSalvo, Stephen Pitton, Mel Madril	From:	Jackie Blumberg, PE
Company:	U.S. Department of Energy	Date:	December 19, 2013
CC:	Tom Chapel, PE; Amber Kauffman, PE	Project No.:	114-181750
Re:	OLF Berm Height Evaluation Using Site-Specific Data		

INTRODUCTION

Tetra Tech performed statistical analyses on rainfall data collected at the Rocky Flats site over a period of 21 years and determined the 100-year, 24-hour rainfall depth to be 3.7 inches and the 1,000-year, 24-hour rainfall depth to be 5.5 inches. Tetra Tech developed design flow rates from these rainfall depths and evaluated the Original Landfill (OLF) berm heights considering the revised precipitation depths. The approach and results are presented within this memorandum.

DISCUSSION

Tetra Tech divided the OLF berm drainage areas into sub-basins and, consistent with previous studies (Tetra Tech, 2008), and applied the National Resource Conservation Service (NRCS) Graphical Peak Discharge method to determine peak flow rates for the 100-year and 1,000-year storms. Runoff was calculated using:

$$Q = \frac{(P - I_a)^2}{P + 0.8S}$$

where

Q = runoff (inches)
P = precipitation (inches)
I_a = initial abstraction (inches)
S = soil retention (inches)

and

$$S = (1{,}000/CN) - 10$$

and

$$I_a = 0.2S$$

A curve number, CN, equal to 86 was selected, consistent with previous studies (Tetra Tech, 2008), resulting in a soil retention value of 1.628 inches and an initial abstraction of 0.326 inches. Design precipitation depths of 3.7 and 5.5 inches yielded runoff depths of 2.3 and 3.9 inches for the 100-year and 1,000-year events, respectively. Times of concentration, or the travel time from the most remote point in each sub-basin to the outlet, were also assumed to be unchanged from previous studies. Given times of concentration and parameters calculated above, the following equation may be used to determine peak discharge:

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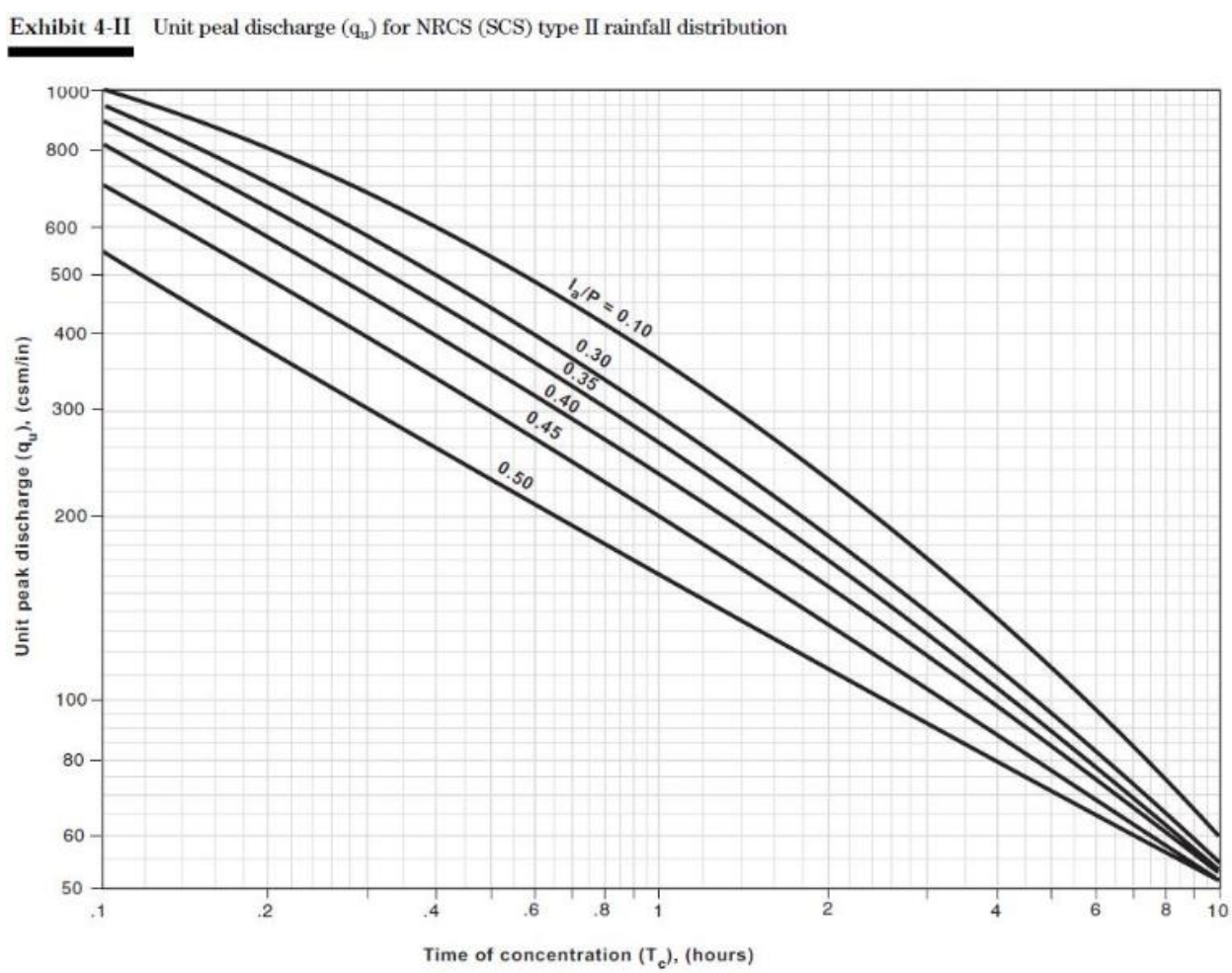
$$q_p = q_u A \mathrm{QF}_p$$

where

q_p	=	peak discharge (cubic feet per second [cfs])
q_u	=	unit peak discharge (cfs/square-mile/inch)
A	=	sub-basin area (square-mile)
Q	=	runoff (inches)
F_p	=	ponding factor (1 for this analysis)

Unit peak discharge is obtained from Figure 1, assuming an NRCS Type II storm distribution, which is both regionally applicable and conservative. The parameter, I_a/P is equal to 0.1 for the 100-year and the 1,000-year storms.

Figure 1: NRCS Unit Peak Discharge Determination



Tetra Tech calculated peak flows using the above equations and values. Peak flows for each sub-basin are presented in Table 1.

Table 1: 100-Year and 1,000-Year Sub-Basin Peak Flow Rates and Depths

Area ID	Sub-basin ID	T_c (hours) from 2008 Study	Basin Area (acres)	Min Slope (%)	1,000-Year Discharge (cfs)	1,000-Year Normal Depth (feet)	100-Year Discharge (cfs)	100-Year Normal Depth (feet)
DB-1	A	0.064	0.53	2.22	11.56	0.99	6.69	0.81
DB-1	B	0.051	0.8	0.44	8.30	1.19	4.80	0.97
DB-1	C	0.029	0.55	0.55[1]	3.38	0.81	1.96	0.66
DB-2	A	0.077	0.58	2.03	14.27	1.09	8.25	0.89
DB-2	B	0.058	0.69	0.24	10.70	1.46	6.19	1.19
DB-2	C	0.036	1.05	0.06	6.46	1.57	3.73	1.28
DB-3	A	0.061	0.75	0.85[1]	9.29	1.1	5.37	0.89
DB-3	B	0.038	0.76	0.76	4.67	0.86	2.70	0.7
DB-4	A	0.113	0.27	1.74	9.29	0.96	5.37	0.78
DB-4	B	0.095	0.3	0.48	7.63	1.13	4.41	0.92
DB-4	C	0.073	0.33	0.08	5.78	1.43	3.34	1.16
DB-4	D	0.051	0.33	1.43	3.75	0.71	2.17	0.58
DB-4	E	0.028	0.28	1.86[1]	1.72	0.5	1.00	0.41
DB-5	A	0.118	0.36	1.08	14.64	1.24	8.46	1.01
DB-5	B	0.1	0.51	0.41	12.42	1.4	7.18	1.14
DB-5	C	0.077	0.53	0.53	9.29	1.2	5.37	0.97
DB-5	D	0.055	0.51	1.11	6.03	0.89	3.49	0.72
DB-5	E	0.033	0.47	1.61	2.89	0.63	1.67	0.51
DB-6	A	0.128	0.73	0.81[1]	16.81	1.38	9.72	1.12
DB-6	B	0.1	0.55	1.32	12.55	1.13	7.26	0.92
DB-6	C	0.078	0.55	0.56	9.16	1.18	5.30	0.96
DB-6	D	0.055	0.52	0.85	5.78	0.92	3.34	0.75
DB-6	E	0.033	0.42	0.89	2.58	0.67	1.49	0.55
DB-7	A	0.118	0.69	1.96	16.79	1.17	9.71	0.95
DB-7	B	0.098	0.6	1.7	12.55	1.08	7.26	0.88
DB-7	C	0.075	0.5	1	8.86	1.04	5.12	0.85
DB-7	D	0.053	0.51	0.55	5.78	0.99	3.34	0.81
DB-7	E	0.031	0.43	0.76	2.64	0.7	1.53	0.57

[1]Localized segments containing adverse slopes could not be analyzed. Evaluation used limiting non-adverse slopes.

Tetra Tech evaluated the peak flows using Bentley's FlowMaster software. Berm side slopes of 3 Horizontal to 1 Vertical (3H:1V) and 5.6H:1V were assumed to be unchanged from previous studies (U.S. Department of Energy, 2009). Minimal longitudinal slopes were identified within the 2013 Plan and Profile drawings (Tetra Tech, 2013). Several localized channel segments contained adverse longitudinal slopes that do not allow positive drainage along the channel. Limiting non-adverse slopes were analyzed in these zones. A bed roughness analogous to a "very rough channel, with grass" was assumed, yielding a Manning's N-value of 0.05. The flow depths resulting from the hydraulic analysis are summarized in Table 1. Sub-basins are ordered from the most downstream (outlet) location, A, and progress upstream. FlowMaster summary reports for the berm outlets are presented as attachments to

this memorandum. The minimum berm requirements from the 2008 study are compared to the 2013 site-specific results in

Table 2 below. The site-specific results indicate a lower berm height requirement for all locations with the exception of Diversion 4, sub-basin C. The 2008 study indicated that the limiting slope for sub-basin C was 0.8 percent. The 2013 drawings indicate that the limiting slope for sub-basin C is 0.08 percent, resulting in a greater flow depth. The previous berm height was specified as 1.29 feet; the required berm height determined in the current analysis was 1.43 feet, indicating a required additional height of 0.14 feet.

Table 2: 2008 Study and 2013 Site-Specific Minimum Berm Requirement Comparison

Area ID	Sub-basin ID	2008 100-Year Normal Depth (ft)	2013 100-Year Normal Depth (ft)	2008 Minimum Berm Height (1,000-Year Depth) (ft)	2013 Minimum Berm Height (1,000-Year Depth) (ft)	1,000-Year Depth Difference (2008-2013) (ft)
DB-1	A	1.37	0.81	1.48	0.99	0.49
	B	1.56	0.97	1.68	1.19	0.49
	C	1.35	0.66	1.46	0.81	0.65
DB-2	A	1.55	0.89	1.66	1.09	0.57
	B	1.58	1.19	1.69	1.46	0.23
	C	1.47	1.28	1.57	1.57	0.00
DB-3	A	1.51	0.89	1.62	1.1	0.52
	B	1.23	0.7	1.34	0.86	0.48
DB-4	A	1.24	0.78	1.33	0.96	0.37
	B	1.42	0.92	1.52	1.13	0.39
	C	1.2	1.16	1.29	1.43	-0.14
	D	0.97	0.58	1.06	0.71	0.35
	E	1	0.41	1.06	0.5	0.56
DB-5	A	1.68	1.01	1.8	1.24	0.56
	B	1.56	1.14	1.67	1.4	0.27
	C	1.39	0.97	1.51	1.2	0.31
	D	1.28	0.72	1.39	0.89	0.50
	E	1.44	0.51	1.52	0.63	0.89
DB-6	A	1.87	1.12	2.01	1.38	0.63
	B	1.84	0.92	1.97	1.13	0.84
	C	1.44	0.96	1.55	1.18	0.37
	D	1.24	0.75	1.33	0.92	0.41
	E	1.14	0.55	1.21	0.67	0.54
DB-7	A	1.76	0.95	1.9	1.17	0.73
	B	1.56	0.88	1.67	1.08	0.59
	C	1.64	0.85	1.74	1.04	0.70
	D	1.36	0.81	1.47	0.99	0.48

Area ID	Sub-basin ID	2008 100-Year Normal Depth (ft)	2013 100-Year Normal Depth (ft)	2008 Minimum Berm Height (1,000-Year Depth) (ft)	2013 Minimum Berm Height (1,000-Year Depth) (ft)	1,000-Year Depth Difference (2008-2013) (ft)
	E	1.14	0.57	1.23	0.7	0.53

CONCLUSION

Tetra Tech evaluated berm heights at the OLF using site specific rainfall depths for the 100-year and 1,000-year storm events. The greatest runoff depths associated with the 100-year storm occurred at the outlets from Diversion Berms 6 and 7 to the East Perimeter Channel and did not exceed 1.3 feet. These areas also exhibited the greatest 1,000-year runoff depths, which did not exceed 1.6 feet. The runoff depths presented in Table 1 are lower than the values presented in the 2008 study, which are based on National Oceanic and Atmospheric Administration data and are included as an attachment to this memorandum for comparison. Tetra Tech recommends the use of site specific runoff depths and berm heights as shown on Table 2, for OLF berm height evaluation.

REFERENCES

Haan CT, Barfield BJ, Hayes JC. 1994. Design Hydrology and Sedimentology of Small Catchments. Academic Press, San Diego, California.

[NRCS] National Resource Conservation Service. June, 1986. Urban Hydrology for Small Watersheds, Technical Report 55.

Tetra Tech. November, 2013. Statistical Analysis of Rocky Flats Site-Specific Data.

Tetra Tech. August, 2008. OLF Design Berm Analyses.

[USDOE] United States Department of Energy. September, 2009. Original Landfill Monitoring and Maintenance Plan.

ATTACHMENT A
HYDRAULIC SUMMARY REPORT

RFETS OLF 100-YR & 1,000-YR Report

Label	Solve For	Friction Method	Roughness Coefficient	Channel Slope (ft/ft)	Normal Depth (ft)
DB1-A-100YR	Normal Depth	Manning Formula	0.050	0.02220	0.81
DB2-A-100YR	Normal Depth	Manning Formula	0.050	0.02030	0.89
DB3-A-100YR	Normal Depth	Manning Formula	0.050	0.00850	0.89
DB4-A-100YR	Normal Depth	Manning Formula	0.050	0.01740	0.78
DB5-A-100YR	Normal Depth	Manning Formula	0.050	0.01080	1.01
DB6-A-100YR	Normal Depth	Manning Formula	0.050	0.00810	1.12
DB7-A-100YR	Normal Depth	Manning Formula	0.050	0.01960	0.95
DB1-A-1000YR	Normal Depth	Manning Formula	0.050	0.02220	0.99
DB2-A-1000YR	Normal Depth	Manning Formula	0.050	0.02030	1.09
DB3-A-1000YR	Normal Depth	Manning Formula	0.050	0.00850	1.10
DB4-A-1000YR	Normal Depth	Manning Formula	0.050	0.01740	0.96
DB5-A-1000YR	Normal Depth	Manning Formula	0.050	0.01080	1.24
DB6-A-1000YR	Normal Depth	Manning Formula	0.050	0.00810	1.38
DB7-A-1000YR	Normal Depth	Manning Formula	0.050	0.01960	1.17

Left Side Slope (ft/ft (H:V))	Right Side Slope (ft/ft (H:V))	Discharge (ft^3/s)	Flow Area (ft^2)	Wetted Perimeter (ft)	Hydraulic Radius (ft)
3.00	5.60	6.69	2.82	7.16	0.39
3.00	5.60	8.25	3.41	7.88	0.43
3.00	5.60	5.37	3.42	7.90	0.43
3.00	5.60	5.37	2.62	6.90	0.38
3.00	5.60	8.46	4.40	8.95	0.49
3.00	5.60	9.72	5.44	9.95	0.55
3.00	5.60	9.71	3.90	8.43	0.46
3.00	5.60	11.56	4.24	8.79	0.48
3.00	5.60	14.27	5.14	9.68	0.53
3.00	5.60	9.29	5.16	9.70	0.53
3.00	5.60	9.29	3.95	8.48	0.47
3.00	5.60	14.64	6.64	11.00	0.60
3.00	5.60	16.81	8.20	12.22	0.67
3.00	5.60	16.79	5.88	10.35	0.57

RFETS OLF 100-YR & 1,000-YR Report

Top Width (ft)	Critical Depth (ft)	Critical Slope (ft/ft)	Velocity (ft/s)	Velocity Head (ft)	Specific Energy (ft)
6.96	0.68	0.05411	2.38	0.09	0.90
7.66	0.74	0.05262	2.42	0.09	0.98
7.67	0.63	0.05572	1.57	0.04	0.93
6.71	0.63	0.05572	2.05	0.07	0.85
8.70	0.75	0.05244	1.92	0.06	1.07
9.67	0.80	0.05148	1.79	0.05	1.17
8.19	0.79	0.05149	2.49	0.10	1.05
8.54	0.85	0.05031	2.73	0.12	1.11
9.40	0.93	0.04891	2.78	0.12	1.21
9.42	0.78	0.05180	1.80	0.05	1.15
8.24	0.78	0.05179	2.35	0.09	1.04
10.68	0.94	0.04875	2.21	0.08	1.32
11.88	0.99	0.04786	2.05	0.07	1.45
10.06	0.99	0.04786	2.85	0.13	1.30

Froude Number	Flow Type	Notes	Messages
0.66	Subcritical		
0.64	Subcritical		
0.41	Subcritical		
0.58	Subcritical		
0.48	Subcritical		
0.42	Subcritical		
0.64	Subcritical		
0.68	Subcritical		
0.66	Subcritical		
0.43	Subcritical		
0.60	Subcritical		
0.49	Subcritical		
0.43	Subcritical		
0.66	Subcritical		

ATTACHMENT B
TETRA TECH 2008 OLF BERM DESIGN SUMMARY TABLE

BERM HEIGHT SUMMARY
ROCKY FLATS - ORIGINAL LANDFILL

Area ID		Maximum Flow Depth, ft	
		100-YR	1,000-YR
DB-1	A	1.37	1.48
	B	1.56	1.68
	C	1.35	1.46
DB-2	A	1.55	1.66
	B	1.58	1.69
	C	1.47	1.57
DB-3	A	1.51	1.62
	B	1.23	1.34
DB-4	A	1.24	1.33
	B	1.42	1.52
	C	1.20	1.29
	D	0.97	1.06
	E	1.00	1.06
DB-5	A	1.68	1.80
	B	1.56	1.67
	C	1.39	1.51
	D	1.28	1.39
	E	1.44	1.52
DB-6	A	1.87	2.01
	B	1.84	1.97
	C	1.44	1.55
	D	1.24	1.33
	E	1.14	1.21
DB-7	A	1.76	1.90
	B	1.56	1.67
	C	1.64	1.74
	D	1.36	1.47
	E	1.14	1.23