

Appendix C: Stage-Area and Stage-Release Curves for the UNRBA Falls Lake Watershed Model

West Fork Eno River Reservoir

Data for West Fork Eno River Reservoir came from the Durham Eno River WARMF model.

Stage-Area Relationship		
Stage (meters)	Area (square meters)	Area (acres)
179.83	0	0.0
185.02	33,352	8.2
186.24	154,436	38.2
187.45	172,569	42.6
188.67	346,779	85.7
189.89	410,000	101.3
191.11	480,000	118.6
192.03	570,000	140.8
192.94	825,579	204.0

Stage-Discharge Relationship		
Stage (meters)	Discharge (m ³ /sec)	Discharge (ft ³ /sec)
192.94	0	0
193.13	8	283
193.32	23	812
193.51	42	1,483
193.70	65	2,295
193.89	91	3,214
194.08	119	4,202
194.27	150	5,297
194.46	184	6,498

Inflow-Outflow			
Description	Elevation	Width (m)	Type
Uncontrolled Spillway	192.94	65	Release to downstream
WestForkEno_release.FLO	183.64	1.83	Release to downstream

Lake Orange

Data for Lake Orange came from the Durham Eno River WARMF model.

Stage-Area Relationship		
Stage (meters)	Area (square meters)	Area (acres)
179.83	0	0.0
181.05	29,080	7.2
182.88	251,219	62.1
183.79	375,746	92.8
184.71	449,375	111.0
185.62	600,030	148.3
186.54	650,493	160.7
187.15	708,000	175.0
187.45	850,017	210.0

Stage-Discharge Relationship		
Stage (meters)	Discharge (m ³ /sec)	Discharge (ft ³ /sec)
187.45	0.0	0
187.64	4.0	141
187.83	11.0	388
188.02	20.0	706
188.21	30.0	1,059
188.40	42.0	1,483
188.60	55.0	1,942
188.79	70.0	2,472
188.98	85.0	3,002

Inflow-Outflow			
Description	Elevation	Width (m)	Type
Uncontrolled Spillway	187.45	30.5	Release to downstream
LakeOrange_release.FLO	182	1.5	Release to downstream

Little River Reservoir

Data for Little River Reservoir stage-area curve was adopted from the North Carolina DWR WARMF model.

Stage-Area Relationship		
Stage (meters)	Area (square meters)	Area (acres)
84.74	10,481	2.6
90.83	238,158	58.9
95.10	514,639	127.2
98.76	849,436	209.9
101.19	1,156,700	285.8
103.02	1,411,200	348.7
105.46	1,756,900	434.1
107.29	2,040,800	504.3
115.00	3,738,400	923.8

Stage-Discharge Relationship

Data for Little River Reservoir stage-discharge curve came from the Schnabel Engineering document titled “Operation and Maintenance Manual: Little River Dam and Pumping Station” (published May 21, 2019). While spillway information has been entered into the model, it doesn’t affect simulation output the way the model is currently configured. The Little River Reservoir spillway is a controlled ogee structure, with a series of gates that can be raised and lowered by reservoir operation personnel. WARMF is not set up to simulate discharge over/through hydraulic structures that can change according to reservoir operation. Therefore, discharge from this reservoir is prescribed using the “LittleRiver_release.FLO” file. The magnitude of release is equivalent to observed discharge at the USGS monitoring site (USGS 0208524975) located immediately downstream of the dam. However, a stage-discharge relationship was created to allow for comparison of model scenarios. Simulated discharge from Little River Reservoir will be run for the calibrated model and the management scenario; relative changes to the discharge can be transferred onto the prescribed outflows in the LittleRiver_release.FLO file.

Stage (meters)	Discharge (m ³ /sec)	Discharge (ft ³ /sec)
108.21	0	0
108.36	1	35
108.51	3	106
108.66	5	177
108.81	100	3,531
108.97	861	30,405
109.12	1,276	45,060
109.42	1,743	61,551
109.73	2,435	85,988

Inflow-Outflow			
Description	Elevation	Width (m)	Type
Uncontrolled Spillway	108.2	252	Release to downstream
LittleRiver_withdrawals.FLO	100.58	1.5	Diversion
LittleRiver_release.FLO	103.5	1.5	Release to downstream

Lake Michie

Data for Lake Michie stage-area curve was adopted from the North Carolina DWR WARMF model.

Stage-Area Relationship		
Stage (meters)	Area (square meters)	Area (acres)
79.90	0	0.0
89.90	260,569	64.4
94.50	556,227	137.4
97.80	851,191	210.3
99.70	1,125,000	278.0
101.20	1,393,900	344.4
102.40	1,658,700	409.9
103.90	1,951,100	482.1
107.29	2,920,600	721.7

Stage-Discharge Relationship

Data for Lake Michie stage-discharge curve was derived from dam specifications provided in the Schnabel Engineering document titled “Operation and Maintenance Manual: Lake Michie Dam and Pumping Station” (published May 21, 2019). This document provides the following relevant information:

- The spillway is an uncontrolled ogee overflow section with a crest elevation of 341 feet mean sea level
- The spillway crest length is approximately 300 feet
- The spillway is flanked by concrete gravity non-overflow sections that have parapet walls with a top elevation of 355.8 feet mean sea level
- The spillway has a hydraulic capacity of 68,400 cfs

Spillway discharge was calculated from stage information using the Ogee weir equation:

$$Q = \frac{2}{3} C_d \cdot L \sqrt{2g} \cdot H^{\frac{3}{2}}$$

Where:

Q = discharge (m³/sec)

C_d = coefficient of discharge (0.86, calculated from Lake Michie spillway design specifications)

L = spillway crest length (89 m)

g = acceleration due to gravity (9.81 m/s²)

H = depth of water flowing over the spillway (m)

The coefficient of discharge (C_d) was solved for using the spillway characteristics provided above. Next, discharge was calculated for other water elevations ranging between the reservoir crest elevation and the top elevation of the parapet walls. These calculations resulted in the relationship between stage and discharge provided in the table below.

Stage (meters)	Discharge (m ³ /sec)	Discharge (ft ³ /sec)
103.94	0	0
104.24	39	1,377
104.55	110	3,884
105.16	312	11,018
105.77	574	20,270
106.38	884	31,217
106.99	1,235	43,612
107.60	1,623	57,314
108.05	1,937	68,402

Inflow-Outflow			
Description	Elevation	Width (m)	Type
Uncontrolled Spillway	103.94	90	Release to Downstream
Michie_withdrawals.FLO	95	1.5	Diversion

Lake Butner (Lake Holt)

Stage-area data are from the spreadsheet titled, "Bathy_LakeHold_Butner.xls" were provided by Lindsay Mize at SGWASA in August 2018.

Stage-Area Relationship		
Stage (meters)	Area (square meters)	Area (acres)
89.92	0	0.0
94.49	27,591	6.8
97.54	99,760	24.7
99.00	150,000	37.1
100.58	456,360	112.8
102.70	750,000	185.3
104.30	1,250,000	308.9
105.46	1,500,600	370.8
108.51	2,500,000	617.8

Stage-Discharge Relationship

Lake Butner spillway characteristics were provided in the spreadsheet titled, "Bathy_LakeHold_Butner.xls" provided by Lindsay Mize at SGWASA in August 2018. The elevation of the weir crest is 356 feet (108.5 meters). Based on measurements performed in Google Earth, the width of the spillway crest is 89 meters. Spillway discharge was calculated from stage information using the Ogee weir equation:

$$Q = \frac{2}{3} C_d \cdot L \sqrt{2g} \cdot H^{\frac{3}{2}}$$

Where:

Q = Discharge (m³/sec)

C_d = Coefficient of discharge (0.86, based on Lake Michie spillway design specifications)

L = Spillway crest length (89 m)

g = acceleration due to gravity (9.81 m/s²)

H = depth of water flowing over the spillway (m)

Stage (meters)	Discharge (m ³ /sec)	Discharge (ft ³ /sec)
108.50	0.0	0
108.60	7.1	252
108.70	20.2	714
108.90	57.2	2,019
109.10	105.0	3,709
109.30	161.7	5,711
109.50	226.0	7,982
109.70	297.1	10,492
109.90	374.4	13,221

Inflow-Outflow			
Description	Elevation	Width (m)	Type
Uncontrolled Spillway	108.5	89	Release to Downstream
Butner_withdrawals.FLO	91	1.5	Diversion

Other Impoundments in the Falls Lake Watershed

Other impoundments in the Falls Lake Watershed were simulated as river reaches because of their small sizes. WARMF curves for Falls Lake will be provided in the lake modeling report.