Table A.2 (Continued)

Reach[a]	Survey ID[b] (Maps A.1,2)	Left Bank				Right Bank				Bankfull							
		Length (feet)	Height (feet)	Slope	Undercut (feet)	Length (feet)	Height (feet)	Slope	Undercut (feet)	Width (feet)	Depth-1 (feet)	Depth-2 (feet)	Depth-3 (feet)	Depth-4 (feet)	Depth-5 (feet)	Mean Depth (feet)	Max. Depth (feet)
Meadowbrook (2012)	200	0.3	1.6	5.33	0.2	0.7	1.6	2.29	--	21.4	1.8	2.0	2.5	2.5	2.2	2.20	2.5
Meadowbrook (2012)	201	--	--	--	--	0.0	--	--	--	--	--	--	--	--	--	--	0.0
Meadowbrook (2012)	202	2.1	1.2	0.57	--	2.1	1.0	0.48	--	15.3	1.3	1.5	1.5	1.4	1.3	1.40	1.5
Meadowbrook (2015)	203	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Meadowbrook (2015)	204	1.0	1.0	1.0	--	3.6	2.1	1.7	--	13.0	1.1	1.3	1.3	1.2	1.0	1.2	1.3
Meadowbrook (2015)	205	2.7	1.0	2.7	--	0.8	0.9	0.9	--	16.0	1.3	1.2	1.2	1.5	1.2	1.3	1.5
Meadowbrook (2015)	206	0.4	1.2	0.3	--	1.1	1.1	1.0	--	20.2	1.7	1.6	1.6	1.6	1.5	1.6	1.7
Meadowbrook (2015)	207	2.1	1.4	1.5	--	1.2	1.5	0.8	--	12.2	2.1	2.4	2.5	2.3	1.8	2.2	2.5
Meadowbrook (2015)	208	2.1	1.3	1.6	--	2.4	1.6	1.5	--	14.6	1.8	1.9	1.8	1.8	1.7	1.8	1.9
Meadowbrook (2015)	209	2.3	2.1	1.1	--	1.1	1.9	0.6	--	15.1	2.2	2.3	2.4	2.4	2.3	2.3	2.4
Meadowbrook (2015)	210	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Meadowbrook (2015)	211	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Meadowbrook (2015)	212	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Meadowbrook (2015)	213	1.9	1.9	1.0	--	1.6	1.8	0.9	--	15.3	2.6	3.2	3.1	2.5	2.1	2.7	3.2
Meadowbrook (2015)	214	2.7	1.4	1.9	--	2.1	1.4	1.5	--	16.4	1.7	2.0	2.0	1.8	1.5	1.8	2.0
Meadowbrook (2015)	215	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Meadowbrook (2015)	216	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Meadowbrook (2015)	217	0.7	0.6	1.2	--	0.7	0.7	1.0	--	17.7	0.9	1.2	1.3	1.1	1.1	1.1	1.3
Meadowbrook (2015)	218	1.1	1.7	0.6	--	1.4	0.7	2.0	--	10.3	0.7	1.2	0.9			0.9	1.2
Meadowbrook (2015)	219	0.6	1.8	0.3	--	2.0	2.0	1.0	--	13.9	2.2	2.4	2.4	2.3	2.2	2.3	2.4
Meadowbrook (2015)	220	2.8	2.5	1.1	--	3.2	2.5	1.3	--	17.4	2.6	2.7	2.8	2.8	2.6	2.7	2.8
Meadowbrook (2015)	221	2.3	1.8	1.3	--	1.7	2.1	0.8	--	15.3	1.9	2.1	2.2	2.2	2.2	2.1	2.2
Meadowbrook (2015)	222	1.0	1.2	0.8	--	0.8	1.2	0.7	--	10.5	1.3	1.4	1.6	1.4	1.3	1.4	1.6
Meadowbrook (2015)	223	0.3	0.8	0.4	--	0.7	0.6	1.2	--	9.6	1.1	1.2	1.0			0.8	1.2
Meadowbrook (2015)	224	1.6	1.5	1.1	--	2.4	1.4	1.7	--	13.8	1.7	1.9	2.1	2.0	1.7	1.9	2.1
Zion Creek (2015)	225	0.4	1.4	0.3	--	1.2	1.7	0.7	--	10.2	1.7	1.7	1.6	--	--	1.7	1.7
Zion Creek (2015)	226	0.2	1.2	0.2	--	0.6	1.1	0.5	--	5.4	1.3	1.3	1.3	--	--	1.3	1.3
Tributary to Meadowbrook (2012)	404	0.4	1.0	2.50	--	0.5	1.2	2.40	--	2.7	1.3	1.4	1.4	--	--	1.37	1.4
Tributary to Meadowbrook (2012)	405	0.2	1.1	5.50	--	0.5	10.9	21.80	--	10.3	1.0	1.2	1.0	1.0	1.1	1.06	1.2
Tributary to Meadowbrook (2012)	406	0.7	1.7	2.43	--	4.5	0.8	0.18	--	4.6	0.9	1.0	0.9	--	--	0.93	1.0

[a] *The table is color coded by instream habitat type- Pools (blue), Riffles (tan), and Runs (green).*

[b] *Cross-section surveys were not conducted in every pool habitat location, however maximum pool depths were recorded.*

Source: SEWRPC

Table A.3
Quantitative Instream Low Flow Characteristics Among Habitat Types in the Pewaukee Lake Tributaries: 2012 and 2015

Reach[a]	Survey ID[b] (Maps A.1,2)	Low Flow (feet)												
		Width	Depth-1	Depth-2	Depth-3	Depth-4	Depth-5	Depth-6	Depth-7	Depth-8	Depth-9	Depth-10	Mean Depth	Max. Depth
Coco Creek (2012)	1	--	1.2	2.2	1.6	0.9	1.0	0.8	0.9	0.9	0.8	0.5	1.10	2.2
Coco Creek (2012)	2	--	1.7	2.3	1.3	0.5	0.6	--	--	--	--	--	1.30	2.3
Coco Creek (2012)	3	--	1.0	1.6	2.3	1.8	1.1	--	--	--	--	--	1.60	2.3
Coco Creek (2012)	4	--	0.6	1.6	1.8	1.7	1.4	--	--	--	--	--	1.40	1.8
Coco Creek (2012)	5	25.0	1.4	1.7	2.0	2.1	1.4	--	--	--	--	--	1.70	2.1
Coco Creek (2012)	6	--	--	--	--	--	--	--	--	--	--	--	--	3
Coco Creek (2012)	7	17.5	2.1	2.3	2.0	2.1	1.0	--	--	--	--	--	1.90	2.3
Coco Creek (2012)	8	--	--	--	--	--	--	--	--	--	--	--	--	3.2
Coco Creek (2012)	9	12.6	1.7	1.8	2.4	2.3	1.6	--	--	--	--	--	2.00	2.4
Coco Creek (2012)	10	--	--	--	--	--	--	--	--	--	--	--	--	2.9
Coco Creek (2012)	11	11.4	1.2	1.3	1.3	1.3	1.2	--	--	--	--	--	1.30	1.3
Coco Creek (2012)	12	--	--	--	--	--	--	--	--	--	--	--	--	2.2
Coco Creek (2012)	13	16.7	1.2	1.5	1.5	1.2	1.1	--	--	--	--	--	1.30	1.5
Coco Creek (2012)	14	--	--	--	--	--	--	--	--	--	--	--	--	2.4
Coco Creek (2012)	15	14.3	1.3	1.5	1.7	1.8	1.2	--	--	--	--	--	1.50	1.8
Coco Creek (2012)	16	10.7	1.0	1.6	1.9	1.7	1.4	--	--	--	--	--	1.50	1.9
Coco Creek (2012)	17	9.9	1.0	1.1	1.0	1.0	0.9	--	--	--	--	--	1.00	1.1
Coco Creek (2012)	18	--	--	--	--	--	--	--	--	--	--	--	--	1.6
Coco Creek (2012)	19	--	--	--	--	--	--	--	--	--	--	--	--	3
Coco Creek (2012)	20	12.6	0.4	0.4	0.4	0.4	0.3	--	--	--	--	--	0.40	0.4
Coco Creek (2012)	21	--	--	--	--	--	--	--	--	--	--	--	--	1.5
Coco Creek (2012)	22	12.5	0.5	0.5	1.0	1.0	0.6	--	--	--	--	--	0.70	1.0
Coco Creek (2012)	23	--	--	--	--	--	--	--	--	--	--	--	--	2.1
Coco Creek (2012)	24	17.7	0.5	0.4	0.2	0.6	1.0	--	--	--	--	--	0.50	1.0
Coco Creek (2012)	25	--	--	--	--	--	--	--	--	--	--	--	--	2.8
Coco Creek (2012)	26	13.8	0.4	0.6	0.6	0.5	0.4	--	--	--	--	--	0.50	0.6
Tributary to Coco Creek (2012)	27	5.7	0.5	0.5	0.3	--	--	--	--	--	--	--	0.43	0.50
Tributary to Coco Creek (2012)	28	3.6	0.3	0.3	0.1	--	--	--	--	--	--	--	0.23	0.30
Tributary to Coco Creek (2012)	29	--	--	--	--	--	--	--	--	--	--	--	--	2
Tributary to Coco Creek (2012)	30	8.6	1.5	1.9	1.7	--	--	--	--	--	--	--	1.70	1.90
Coco Creek (2015)	31	10.9	0.6	0.9	1.1	1.1	1.0	--	--	--	--	--	0.9	1.1
Coco Creek (2015)	32	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	33	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	34	7.6	1.3	1.5	1.5	1.4	1.2	--	--	--	--	--	1.4	1.5
Coco Creek (2015)	35	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	36	7.0	1.5	1.7	1.3	0.9	0.3	--	--	--	--	--	1.1	1.7
Coco Creek (2015)	37	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	38	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	39	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	40	--	--	--	--	--	--	--	--	--	--	--	--	--

Table continued on next page.

Table A.3 (Continued)

Reach[a]	Survey ID[b] (Maps A.1,2)	Low Flow (feet) Width	Depth-1	Depth-2	Depth-3	Depth-4	Depth-5	Depth-6	Depth-7	Depth-8	Depth-9	Depth-10	Mean Depth	Max. Depth
Coco Creek (2015)	41	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	42	8.8	0.4	0.8	0.7	1.0	1.1	--	--	--	--	--	0.8	1.1
Coco Creek (2015)	43	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	44	12.5	0.5	0.7	0.7	0.9	0.6	--	--	--	--	--	0.7	0.9
Coco Creek (2015)	45	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	46	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	47	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	48	9.3	1.0	1.6	1.7	1.7	1.3	--	--	--	--	--	1.5	1.7
Coco Creek (2015)	49	12.6	1.1	1.3	1.2	1.2	0.9	--	--	--	--	--	1.1	1.3
Coco Creek (2015)	50	11.6	1.0	0.9	0.9	1.0	1.0	--	--	--	--	--	1.0	1.0
Coco Creek (2015)	51	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	52	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	53	12.5	1.3	1.6	1.8	1.7	1.6	--	--	--	--	--	1.6	1.8
Coco Creek (2015)	54	11.1	1.5	2.0	1.9	1.6	1.6	--	--	--	--	--	1.7	2.0
Coco Creek (2015)	55	9.0	0.4	1.0	1.4	1.6	1.4	--	--	--	--	--	1.2	1.6
Coco Creek (2015)	56	8.8	0.8	1.1	1.6	1.5	1.0	--	--	--	--	--	1.2	1.6
Coco Creek (2015)	57	8.8	0.8	1.1	1.6	1.5	1.0	--	--	--	--	--	1.2	1.6
Coco Creek (2015)	58	7.2	1.1	1.1	1.1	1.1	0.8	--	--	--	--	--	1.0	1.1
Coco Creek (2015)	59	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	60	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	61	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	62	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	63	11.6	0.3	0.4	0.5	0.5	0.4	--	--	--	--	--	0.4	0.5
Coco Creek (2015)	64	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	65	8.1	0.8	1.3	1.4	1.4	1.2	--	--	--	--	--	1.2	1.4
Coco Creek (2015)	66	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	67	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	68	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	69	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	70	7.4	0.8	1.1	1.4	1.4	1.1	--	--	--	--	--	1.2	1.4
Coco Creek (2015)	71	9.6	1.0	1.3	1.4	1.3	1.0	--	--	--	--	--	1.2	1.4
Coco Creek (2015)	72	4.7	0.8	1.2	0.6	--	--	--	--	--	--	--	0.9	1.2
Coco Creek (2015)	73	8.0	1.0	1.4	1.5	1.5	1.4	--	--	--	--	--	1.4	1.5
Coco Creek (2015)	74	10.8	0.5	1.2	1.7	1.7	1.3	--	--	--	--	--	1.3	1.7
Coco Creek (2015)	75	10.5	0.5		1.0	1.4	1.8	--	--	--	--	--	1.2	1.8
Coco Creek (2015)	76	4.2	0.5	0.7	1.0	--	--	--	--	--	--	--	0.7	1.0
Coco Creek (2015)	77	4.1	0.7	1.1	1.0	--	--	--	--	--	--	--	0.9	1.1
Coco Creek (2015)	78	6.0	0.3	1.4	1.6	--	--	--	--	--	--	--	1.2	1.6
Coco Creek (2015)	79	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	80	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	81	--	--	--	--	--	--	--	--	--	--	--	--	--

Table continued on next page.

Table A.3 (Continued)

Reach[a]	Survey ID[b] (Maps A.1,2)	Low Flow (feet)												
		Width	Depth-1	Depth-2	Depth-3	Depth-4	Depth-5	Depth-6	Depth-7	Depth-8	Depth-9	Depth-10	Mean Depth	Max. Depth
Coco Creek (2015)	82	5.6	1.0	1.1	1.1	1.0	0.8	--	--	--	--	--	1.0	1.1
Coco Creek (2015)	83	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	84	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	85	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	86	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	87	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	88	10.9	0.8	1.0	1.7	1.3	0.9	--	--	--	--	--	1.1	1.7
Coco Creek (2015)	89	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	90	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	91	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	92	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	93	13.8	0.6	1.0	0.9	0.5	0.5	--	--	--	--	--	0.7	1.0
Coco Creek (2015)	94	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	95	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	96	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	97	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	98	6.5	1.9	0.2	0.1	--	--	--	--	--	--	--	0.7	1.9
Coco Creek (2015)	99	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	100	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	101	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	102	6.2	0.2	0.2	0.1			--	--	--	--	--	0.2	0.2
Coco Creek (2015)	103	8.4	0.3	0.6	0.5	0.6	0.3	--	--	--	--	--	0.5	0.6
Coco Creek (2015)	104					--	--	--	--	--	--	--	--	--
Coco Creek (2015)	105	6.0	0.4	0.9	1.1	--	--	--	--	--	--	--	0.8	1.1
Coco Creek (2015)	106	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	107	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	108	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	109	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	110	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	111	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	112	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	113	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	114	5.5	0.0		0.1	0.2	0.4	--	--	--	--	--	0.2	0.4
Coco Creek (2015)	115	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	116	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	117	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	118	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	119	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	120	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	121	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	122	4.0	0.7	0.6	0.3	0.0	--	--	--	--	--	--	0.4	0.7

Table continued on next page.

Table A.3 (Continued)

Reach[a]	Survey ID[b] (Maps A.1,2)	Low Flow (feet)												
		Width	Depth-1	Depth-2	Depth-3	Depth-4	Depth-5	Depth-6	Depth-7	Depth-8	Depth-9	Depth-10	Mean Depth	Max. Depth
Coco Creek (2015)	123	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	124	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	125	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	126	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	127	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	128	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	129	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	130	10.6	0.3	0.3	0.5	0.2	0.2	--	--	--	--	--	0.3	0.5
Coco Creek (2015)	131	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	132	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	133	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	134	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	135	11.5	0.6	1.4	0.7	0.3	0.3	--	--	--	--	--	0.7	1.4
Coco Creek (2015)	136	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	137	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	138	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	139	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	140	8.9	0.3	0.1	0.0	0.2	0.2	--	--	--	--	--	0.2	0.3
Coco Creek (2015)	141	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	142	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	143	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	144	7.6	0.3	0.3	0.1	0.0	0.0	--	--	--	--	--	0.1	0.3
Coco Creek (2015)	145	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	146	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	147	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	148	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	149	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	150	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	151	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	152	9.7	0.3	0.2	0.3	0.2	0.2	--	--	--	--	--	0.2	0.3
Coco Creek (2015)	153	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	154	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	155	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	156	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	157	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	158	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	159	8.3	0.2	0.3	0.5	0.3	0.2						0.3	0.5
Coco Creek (2015)	160	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	161	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	162	6.0	0.1	1.1	0.5	0.0	--	--	--	--	--	--	0.4	1.1
Coco Creek (2015)	163	4.6	0.4	0.8	1.1	0.0	--	--	--	--	--	--	0.6	1.1

Table continued on next page.

Table A.3 (Continued)

Reach[a]	Survey ID[b] (Maps A.1,2)	Low Flow (feet)												
		Width	Depth-1	Depth-2	Depth-3	Depth-4	Depth-5	Depth-6	Depth-7	Depth-8	Depth-9	Depth-10	Mean Depth	Max. Depth
Coco Creek (2015)	164	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	165	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	166	3.8	1.0	1.4	1.3	0.0	--	--	--	--	--	--	0.9	1.4
Coco Creek (2015)	167	3.4	1.0	1.0	0.5	0.0	--	--	--	--	--	--	0.6	1.0
Coco Creek (2015)	168	14.7	0.4	0.8	1.1	0.5	0.4	--	--	--	--	--	0.6	1.1
Coco Creek (2015)	169	31.1	1.1	1.3	1.3	1.2	0.9	--	--	--	--	--	1.2	1.3
Coco Creek (2015)	170	15.7	0.6	0.4	0.9	0.0	--	--	--	--	--	--	0.5	0.9
Coco Creek (2015)	171	3.5	0.4	0.7	0.2	0.0	--	--	--	--	--	--	0.3	0.7
Coco Creek (2015)	172	14.2	1.4	2.2	2.2	1.8	1.5	--	--	--	--	--	1.8	2.2
Coco Creek (2015)	173	8.1	0.3	0.3	0.6	0.4	0.2	--	--	--	--	--	0.4	0.6
Coco Creek (2015)	174	8.0	0.2	0.3	0.3	0.3	0.2	--	--	--	--	--	0.3	0.3
Coco Creek (2015)	175	4.5	0.1	0.2	0.1	0.0	--	--	--	--	--	--	0.1	0.2
Coco Creek (2015)	176	3.0	0.4	0.8	0.3	0.0	--	--	--	--	--	--	0.4	0.8
Coco Creek (2015)	177	2.9	0.2	0.1	0.1	0.0	--	--	--	--	--	--	0.1	0.2
Coco Creek (2015)	178	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	179	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	180	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	181	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	182	--	--	--	--	--	--	--	--	--	--	--	--	--
Coco Creek (2015)	183	2.8	0.1	0.2	0.1	0.0	0.0	--	--	--	--	--	0.1	0.2
Coco Creek (2015)	184	2.3	0.2	0.2	0.3	0.0	--	--	--	--	--	--	0.2	0.3
Meadowbrook (2012)	185	--	1.3	1.5	2.7	2.5	2.7	2.5	2.5	2.4	2.3	1.4	2.20	2.7
Meadowbrook (2012)	186	--	1.1	1.3	2.0	2.2	2.7	2.5	2.5	2.6	2.0	1.0	2.00	2.7
Meadowbrook (2012)	187	45.9	1.1	1.3	1.3	1.4	0.9	--	--	--	--	--	1.20	1.4
Meadowbrook (2012)	188	26.8	1.5	1.9	1.4	0.9	0.4	--	--	--	--	--	1.20	1.9
Meadowbrook (2012)	189	--	0.6	0.7	0.7	1.4	0.7	--	--	--	--	--	0.80	1.4
Meadowbrook (2012)	190	--	1.0	1.7	3.5	2.2	1.0	--	--	--	--	--	1.90	3.5
Meadowbrook (2012)	191	23.2	0.7	1.1	1.3	1.5	1.2	--	--	--	--	--	1.20	1.5
Meadowbrook (2012)	192	26.7	0.9	1.1	1.1	1.0	0.9	--	--	--	--	--	1.00	1.1
Meadowbrook (2012)	193	33.2	1.0	1.2	1.1	0.8	0.7	--	--	--	--	--	1.00	1.2
Meadowbrook (2012)	194	18.3	1.2	1.4	1.6	1.5	1.2	--	--	--	--	--	1.40	1.6
Meadowbrook (2012)	195	15.2	0.8	0.9	1.0	0.8	0.6	--	--	--	--	--	0.80	1.0
Meadowbrook (2012)	196	--	--	--	--	--	--	--	--	--	--	--	--	2.2
Meadowbrook (2012)	197	--	1.3	1.8	2.2	2.1	1.7	--	--	--	--	--	1.80	2.2
Meadowbrook (2012)	198	--	0.7	1.4	1.8	2.0	1.3	--	--	--	--	--	1.40	2.0
Meadowbrook (2012)	199	--	1.2	2.1	2.0	1.7	1.0	--	--	--	--	--	1.60	2.1
Meadowbrook (2012)	200	20.5	0.5	0.8	1.3	1.2	0.8	--	--	--	--	--	0.90	1.3
Meadowbrook (2012)	201	--	1.4	2.5	2.1	1.6	1.0	--	--	--	--	--	1.70	2.5
Meadowbrook (2012)	202	10.9	0.3	0.5	0.6	0.5	0.5	--	--	--	--	--	0.50	0.6
Meadowbrook (2015)	203	--	--	--	0.0	0.0	--	--	--	--	--	--	0.0	0.0
Meadowbrook (2015)	204	6.4	0.2	0.3	0.3	0.3	0.1	--	--	--	--	--	0.2	0.3

Table continued on next page.

Table A.3 (Continued)

Reach[a]	Survey ID[b] (Maps A.1,2)	Low Flow (feet)												
		Width	Depth-1	Depth-2	Depth-3	Depth-4	Depth-5	Depth-6	Depth-7	Depth-8	Depth-9	Depth-10	Mean Depth	Max. Depth
Meadowbrook (2015)	205	10.1	0.3	0.2	0.2	0.5	0.2	--	--	--	--	--	0.3	0.5
Meadowbrook (2015)	206	14.7	0.4	0.4	0.3	0.3	0.2	--	--	--	--	--	0.3	0.4
Meadowbrook (2015)	207	8.8	0.8	1.1	1.2	0.3	0.4	--	--	--	--	--	0.8	1.2
Meadowbrook (2015)	208	9.5	0.5	0.5	0.4	0.4	0.2	--	--	--	--	--	0.4	0.5
Meadowbrook (2015)	209	10.7	0.2	0.3	0.5	0.4	0.2	--	--	--	--	--	0.3	0.5
Meadowbrook (2015)	210	--	--	--	--	--	--	--	--	--	--	--	--	--
Meadowbrook (2015)	211	--	--	--	--	--	--	--	--	--	--	--	--	--
Meadowbrook (2015)	212	--	--	--	--	--	--	--	--	--	--	--	--	--
Meadowbrook (2015)	213	11.8	0.9	1.5	1.4	0.9	0.5	--	--	--	--	--	1.0	1.5
Meadowbrook (2015)	214	11.4	0.4	0.8	0.7	0.5	0.3	--	--	--	--	--	0.5	0.8
Meadowbrook (2015)	215	--	--	--	--	--	--	--	--	--	--	--	--	--
Meadowbrook (2015)	216	--	--	--	--	--	--	--	--	--	--	--	--	--
Meadowbrook (2015)	217	13.3	0.3	0.6	0.6	0.3	0.3	--	--	--	--	--	0.4	0.6
Meadowbrook (2015)	218	6.0	0.2	0.6	0.4	--	--	--	--	--	--	--	0.4	0.6
Meadowbrook (2015)	219	10.4	0.3	0.5	0.5	0.5	0.3	--	--	--	--	--	0.4	0.5
Meadowbrook (2015)	220	11.0	0.2	0.4	0.5	0.6	0.4	--	--	--	--	--	0.4	0.6
Meadowbrook (2015)	221	10.8	0.2	0.4	0.5	0.4	0.3	--	--	--	--	--	0.4	0.5
Meadowbrook (2015)	222	5.2	0.0	0.1	0.3	0.2	0.0	--	--	--	--	--	0.1	0.3
Meadowbrook (2015)	223	5.0	0.3	0.4	0.2		0.0	--	--	--	--	--	0.2	0.4
Meadowbrook (2015)	224	7.3	0.2	0.4	0.6	0.4	0.2	--	--	--	--	--	0.4	0.6
Zion Creek (2015)	225	7.3	0.3	0.3	0.3	--	--	--	--	--	--	--	0.3	0.3
Zion Creek (2015)	226	3.8	0.2	0.2	0.2	--	--	--	--	--	--	--	0.2	0.2
Tributary to Meadowbrook (2012)	404	2.7	0.5	0.5	0.6	--	--	--	--	--	--	--	0.53	0.6
Tributary to Meadowbrook (2012)	405	10.3	0.3	0.4	0.3	0.2	0.3	--	--	--	--	--	0.30	0.4
Tributary to Meadowbrook (2012)	406	4.6	0.2	0.3	0.2	--	--	--	--	--	--	--	0.23	0.3

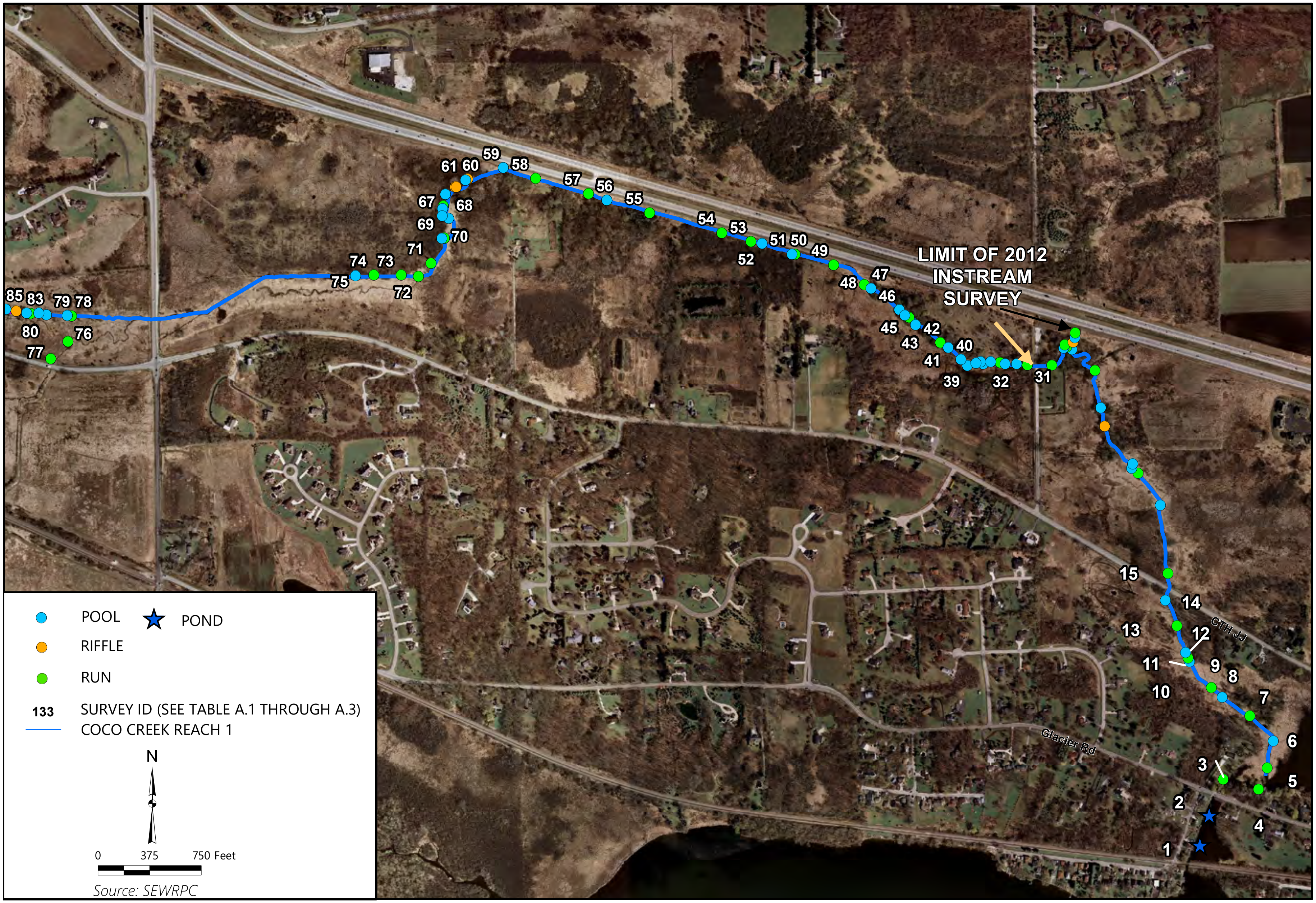
Note: The number of points at which water depths were measured within a cross-section was dependent upon stream width. In general, if wetted width was less than 10 feet, only three points per transect were taken; for widths ranging from 10 to 75 feet, five to 10 points per transect were taken; and where width was greater than 75 feet, 10 points were taken.

[a] *The table is color coded by instream habitat type- Pools (blue), Riffles (tan), and Runs (green).*

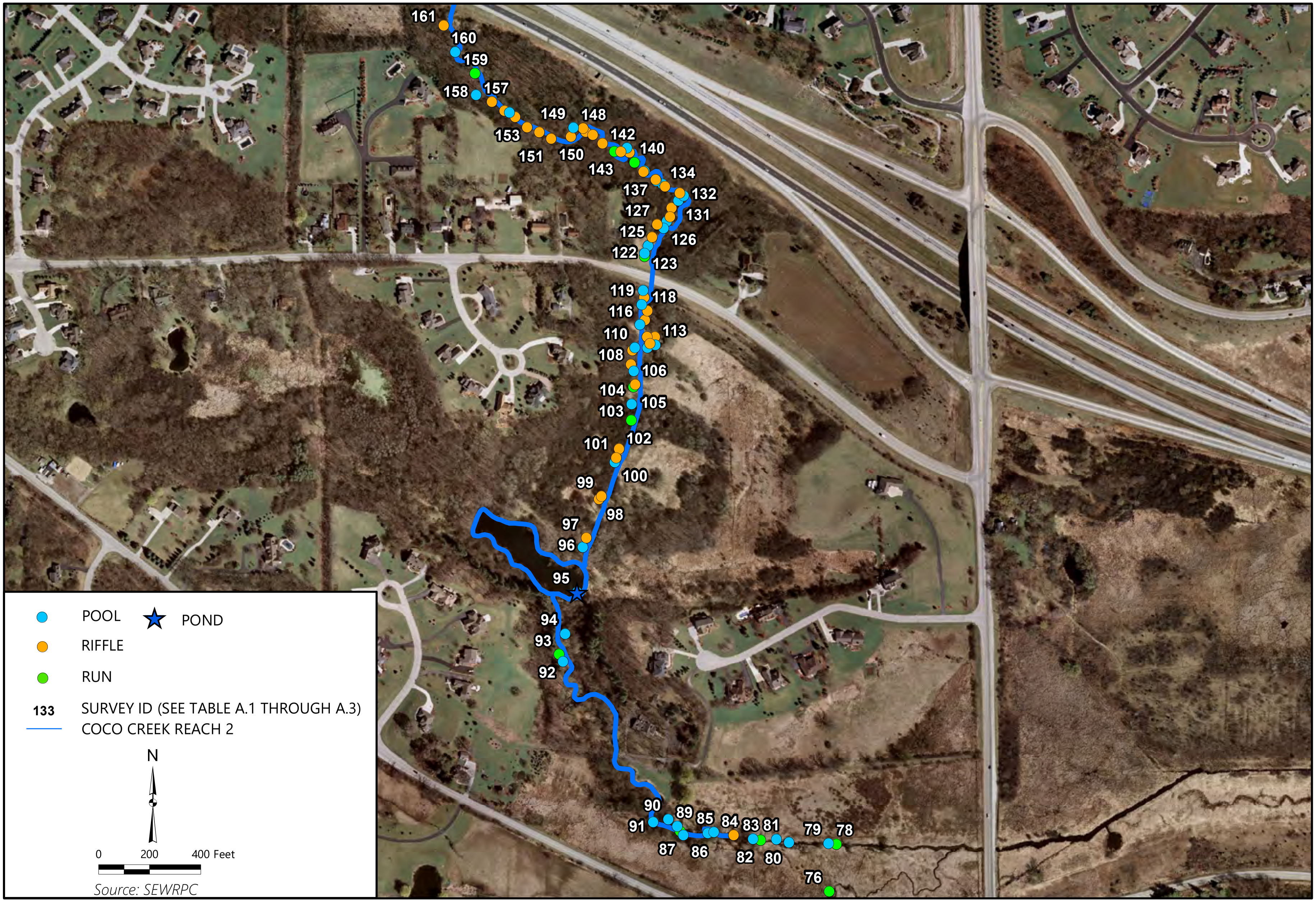
[b] *Cross-section surveys were not conducted in every pool habitat location, however maximum pool depths were recorded.*

Source: SEWRPC

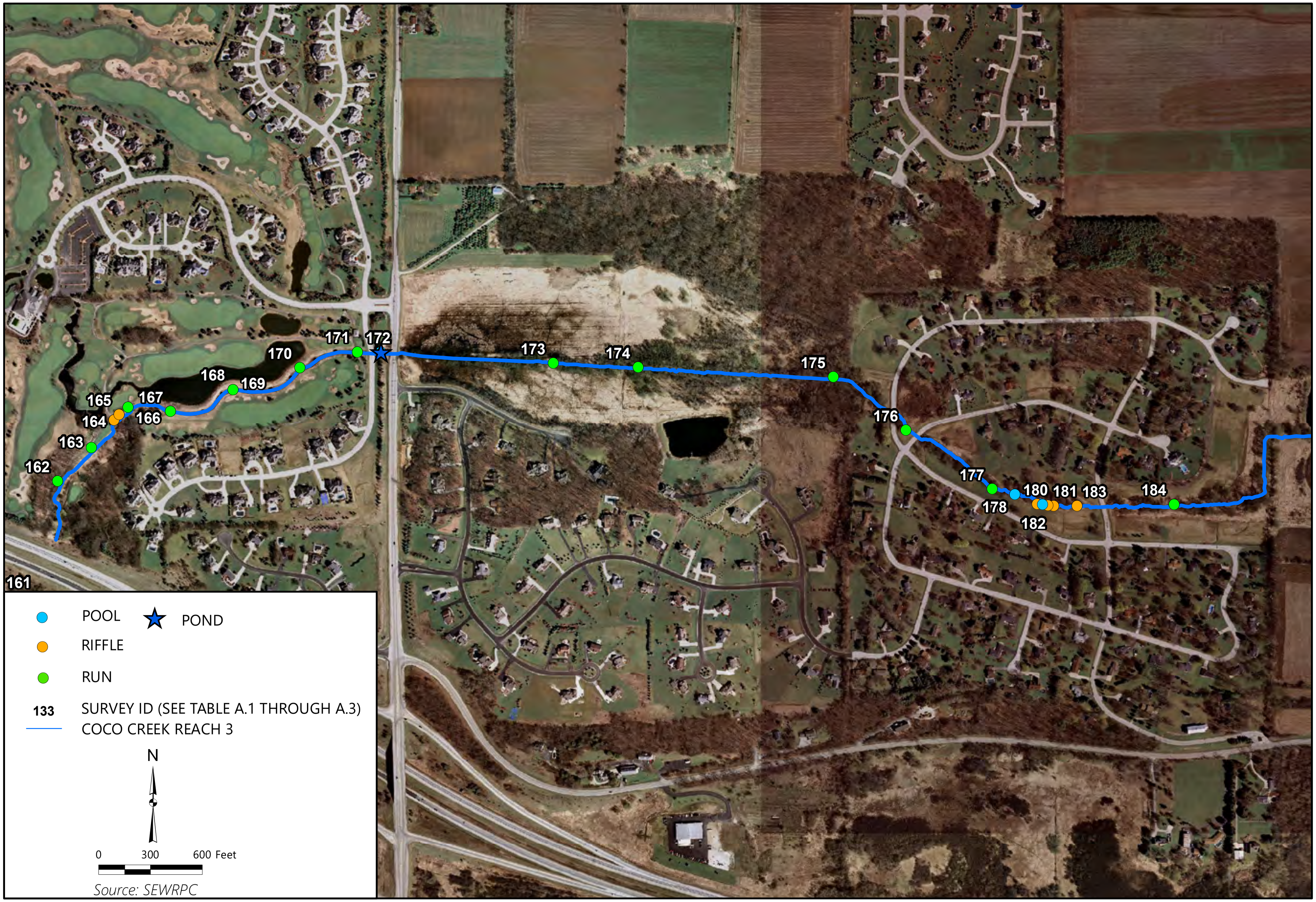
Map A.1
Aquatic Habitat Type Within Coco Creek Stream Reach 1: 2012 and 2015



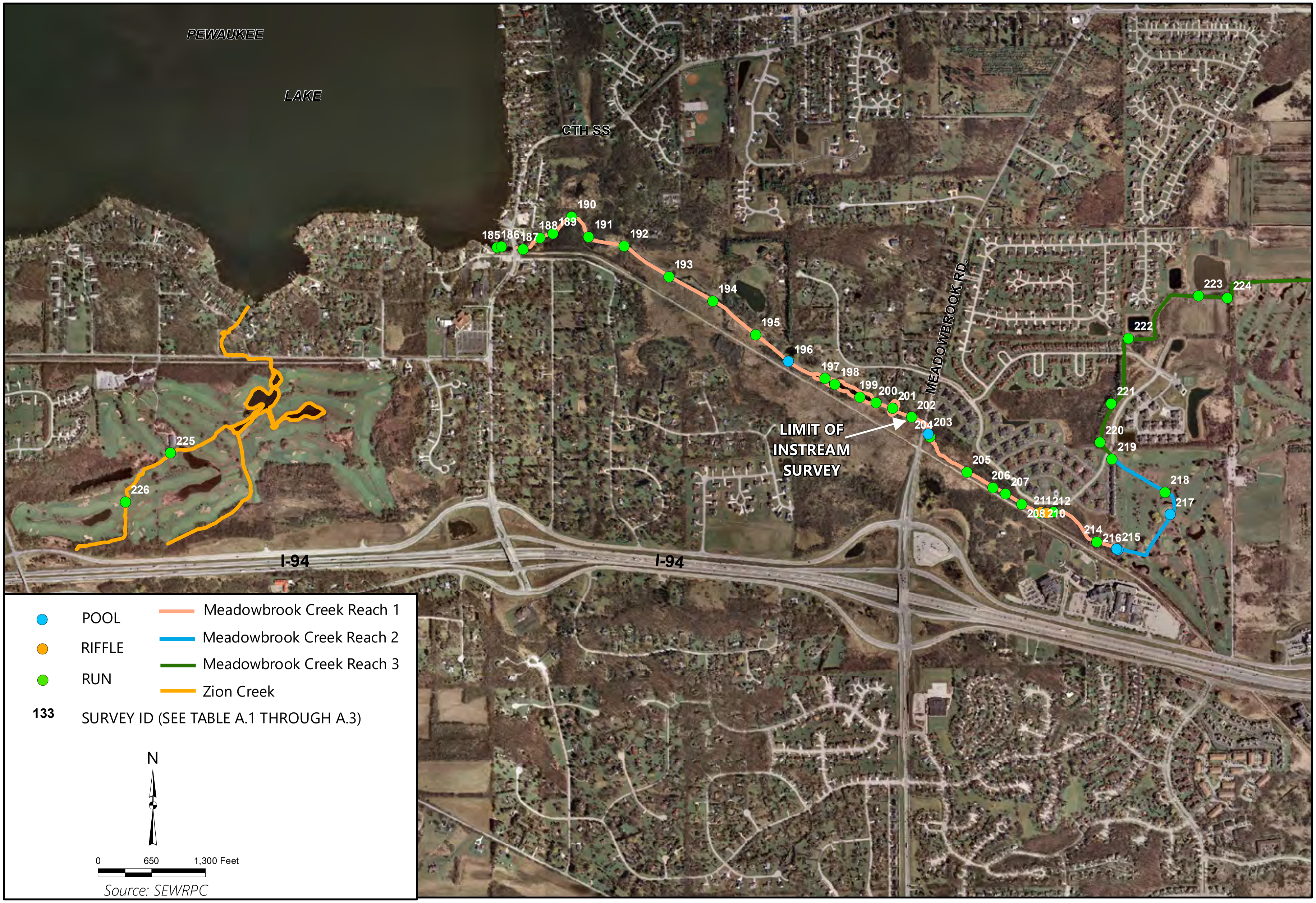
Map A.2
Aquatic Habitat Type Within Coco Creek Stream Reach 2: 2012 and 2015



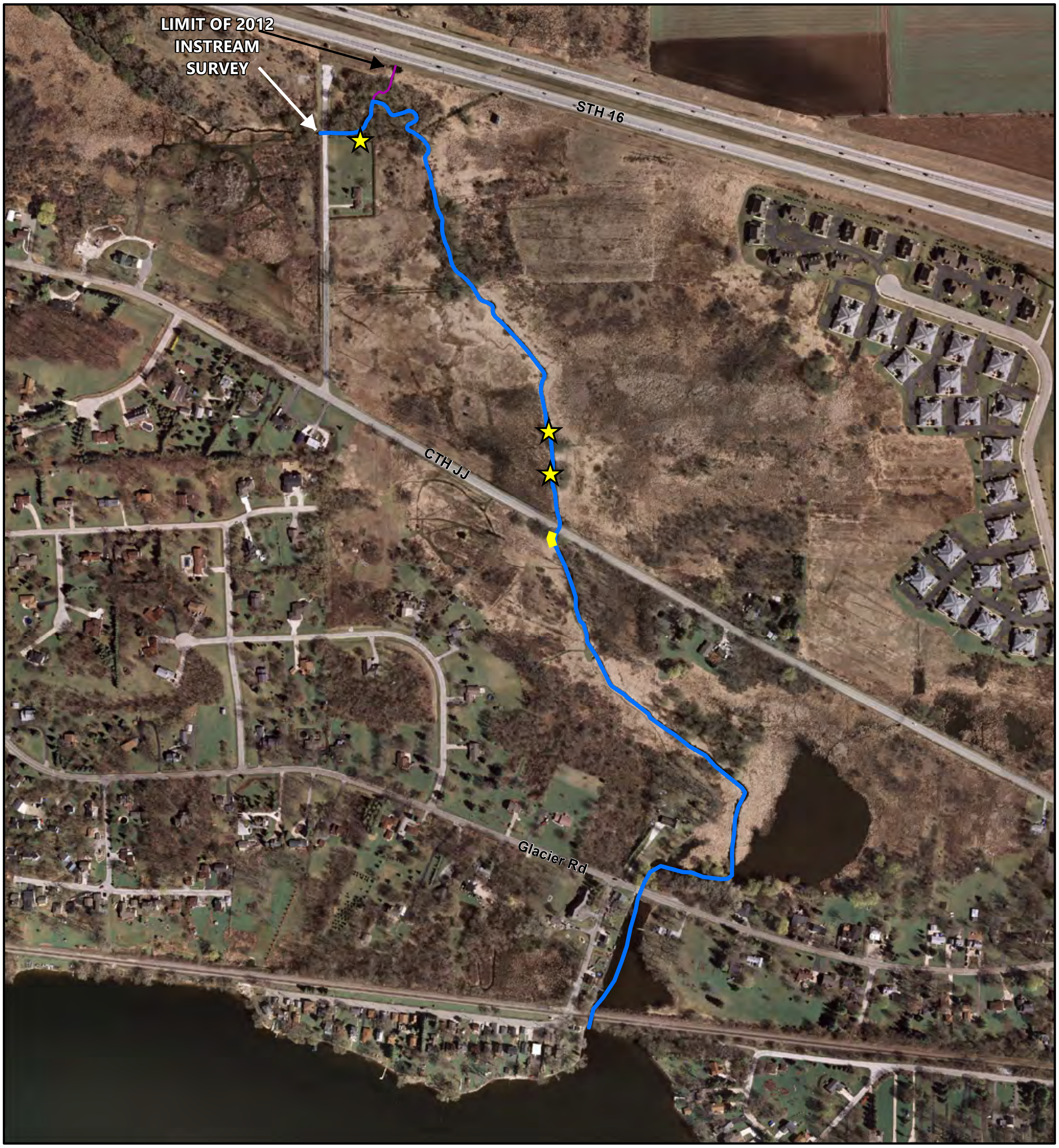
Map A.3
Aquatic Habitat Type Within Coco Creek Stream Reach 3: 2012 and 2015



Map A.4
Aquatic Habitat Type Within the Meadowbrook and Zion Creek Stream Reaches: 2012 and 2015

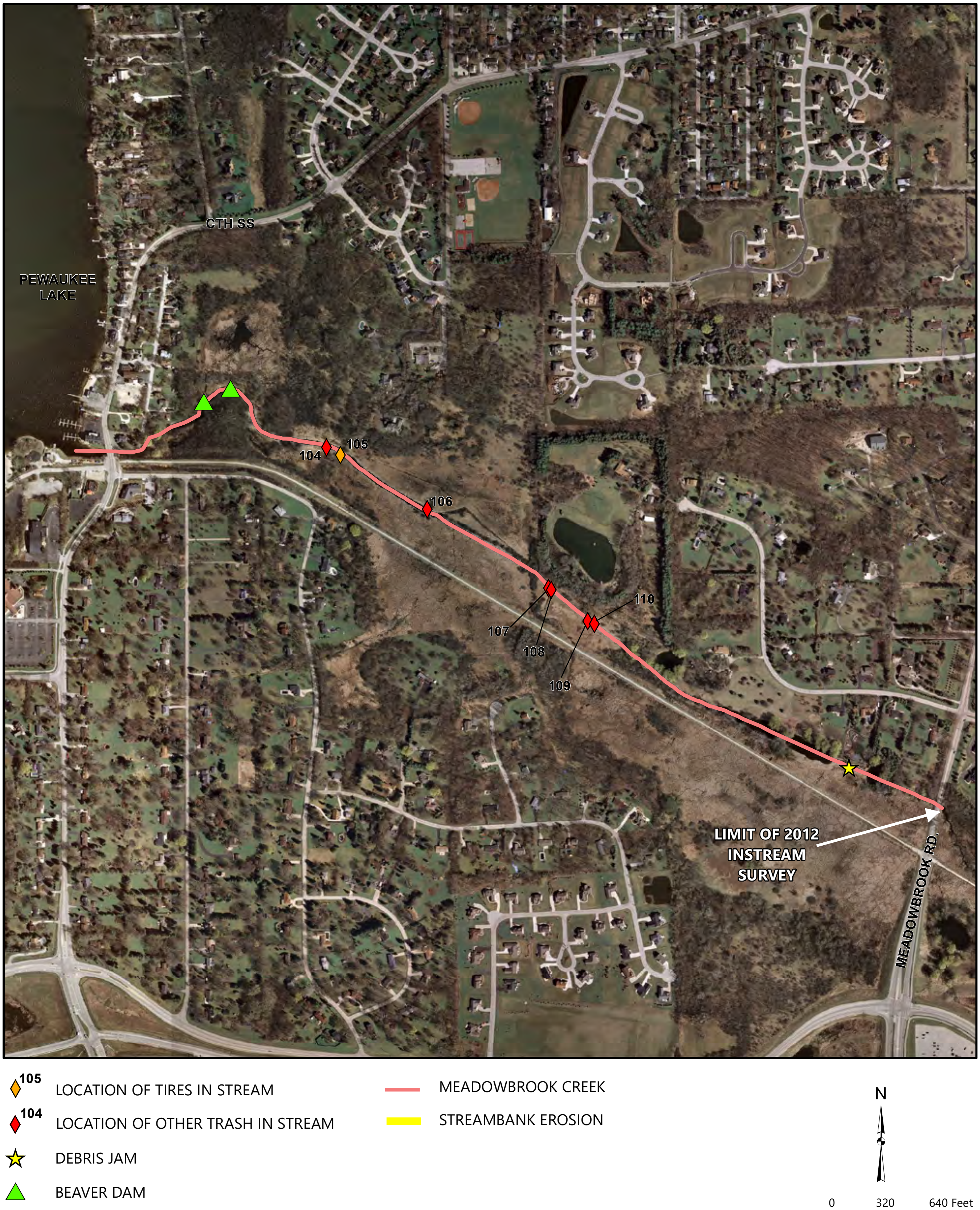


Map A.5
Debris Jams and Streambank Erosion Within the Coco Creek Stream Reach: 2012



Source: SEWRPC

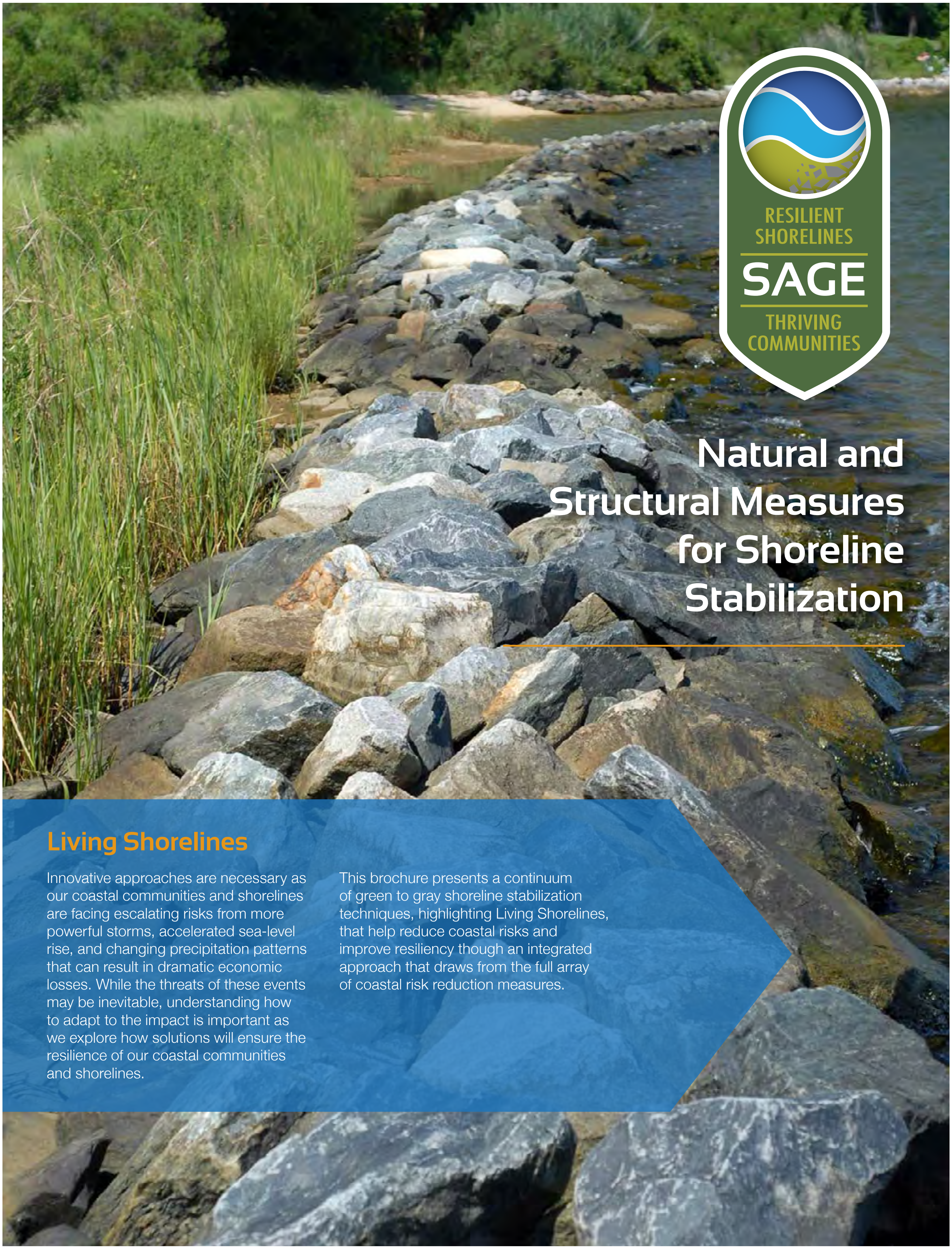
Map A.6
Trash, Debris Jams, Beaver Dams, and Streambank Erosion
Within the Meadowbrook Creek Stream Reach: 2012



Source: SEWRPC

NATURAL AND STRUCTURAL MEASURES FOR SHORELINE STABILIZATION

APPENDIX B



RESILIENT SHORELINES SAGE THRIVING COMMUNITIES

Natural and Structural Measures for Shoreline Stabilization

Living Shorelines

Innovative approaches are necessary as our coastal communities and shorelines are facing escalating risks from more powerful storms, accelerated sea-level rise, and changing precipitation patterns that can result in dramatic economic losses. While the threats of these events may be inevitable, understanding how to adapt to the impact is important as we explore how solutions will ensure the resilience of our coastal communities and shorelines.

This brochure presents a continuum of green to gray shoreline stabilization techniques, highlighting Living Shorelines, that help reduce coastal risks and improve resiliency though an integrated approach that draws from the full array of coastal risk reduction measures.

Coastal Risk Reduction and Living Shorelines

Coastal Risk Reduction

Coastal systems typically include both natural habitats and man-made structural features. The relationships and interactions among these features are important variables in determining coastal vulnerability, reliability, risk and resilience.

Coastal risk reduction can be achieved through several approaches, which may be used in combination with each other. Options for coastal risk reduction include:

- Natural or nature-based measures: Natural features are created through the action of physical, biological, geologic, and chemical processes operating in nature, and include marshes, dunes and oyster reefs. Nature-based features are created by human design, engineering, and construction to mimic nature. A living shoreline is an example of a nature-based feature.
- Structural measures: Structural measures include sea walls, groins and breakwaters. These features reduce coastal risks by decreasing shoreline erosion, wave damage, and flooding.
- Non-structural measures: Includes modifications in public policy, management practices, regulatory policy and pricing policy (e.g., structure acquisitions or relocations, flood proofing of structures, implementing flood warning systems, flood preparedness planning, establishment of land use regulations, emergency response plans).

The types of risk reduction measures employed depend upon the geophysical setting, the desired level of risk reduction, objectives, cost, reliability, and other factors.

SAGE – Systems Approach to Geomorphic Engineering

USACE and NOAA recognize the value of an integrated approach to risk reduction through the incorporation of natural and nature-based features in addition to non-structural and structural measures to improve social, economic, and ecosystem resilience. To promote this approach, USACE and NOAA have engaged partners and stakeholders in a community of practice called SAGE, or a Systems Approach to Geomorphic Engineering. This community of practice provides a forum to discuss science and policy that can support and advance a systems approach to implementing risk reduction measures that both sustain a healthy environment and create a resilient shoreline.

SAGE promotes a hybrid engineering approach that integrates soft or 'green' natural and nature-based measures, with hard or 'gray' structural ones at the landscape scale. These stabilization solutions include "living shoreline" approaches which integrate living components, such as plantings, with structural techniques, such as seawalls or breakwaters.

Living Shorelines achieve multiple goals, such as:

- Stabilizing the shoreline and reducing current rates of shoreline erosion and storm damage;
- Providing ecosystem services (such as habitat for fish and other aquatic species) and increasing flood storage capacity; and
- Maintaining connections between land and water ecosystems to enhance resilience.

In order to determine the most appropriate shoreline protection technique, several site-specific conditions must be assessed. The following coastal conditions, along with other factors, are used to determine the combinations of green and gray solutions for a particular shoreline.

REACH: A longshore segment of a shoreline where influences and impacts, such as wind direction, wave energy, littoral transport, etc. mutually interact.

RESILIENCE: The ability to avoid, minimize, withstand, and recover from the effects of adversity, whether natural or man made, under all circumstances of use. This definition also applies to engineering (i), ecological (ii), and community resilience (iii).

FETCH: A cross shore distance along open water over which wind blows to generate waves. For any given shore, there may be several fetch distances depending on predominant wind direction.

PHYSICAL CONDITIONS: The slope of the foreshore or beach face, a geologic condition or bathymetry offshore.

TIDAL RANGE: The vertical difference between high tide and low tide.

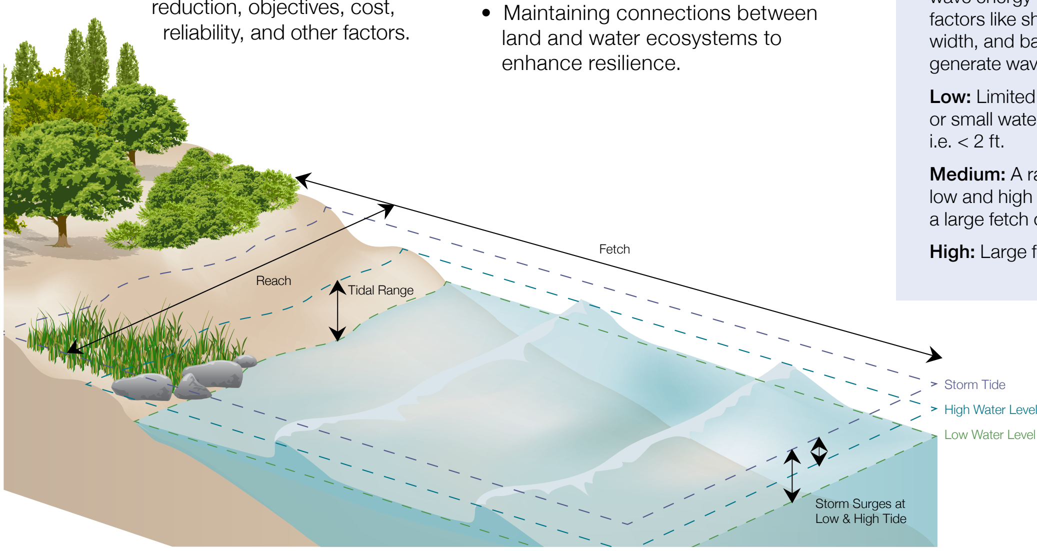
STORM SURGE: The resulting temporary rise in sea level due to the action of wind stress on the water surface and low atmospheric pressure created during storms which can cause coastal flooding. Surge is the difference from expected tide level. Storm tide is the total water level.

WAVE ENERGY: Wave energy is related to wave height and describes the force a wave is likely to have on a shoreline. Different environments will have lower or higher wave energy depending on environmental factors like shore orientation, wind, channel width, and bathymetry. Boat wakes can also generate waves.

Low: Limited fetch in a sheltered, shallow or small water body (estuary, river, bay) i.e. < 2 ft.

Medium: A range that combines elements of low and high energy (e.g., shallow water with a large fetch or partially sheltered) i.e. 2 - 5 ft.

High: Large fetch, deep water (open ocean).



2

HOW GREEN OR GRAY SHOULD YOUR SHORELINE SOLUTION BE?

GREEN - SOFTER TECHNIQUES

Small Waves | Small Fetch | Gentle Slope | Sheltered Coast

LIVING SHORELINE

VEGETATION ONLY

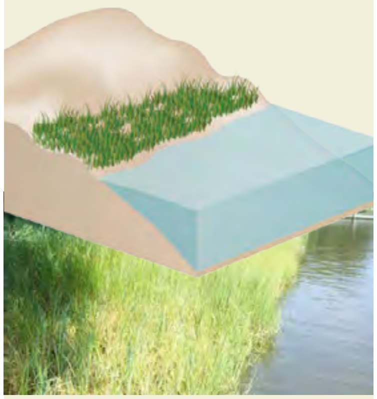


Photo Credit: Maryland Department of Natural Resources - Shoreline Conservation Service

Roots hold soil in place to reduce erosion. Provides a buffer to upland areas and breaks small waves.

Suitable For

Low wave energy environments.

Material Options

- Native plants*

Benefits

- Dissipates wave energy
- Slows inland water transfer
- Increases natural storm water infiltration
- Provides habitat and ecosystem services
- Minimal impact to natural community and ecosystem processes
- Maintains aquatic/terrestrial interface and connectivity
- Flood water storage

Disadvantages

- No storm surge reduction ability
- No high water protection
- Appropriate in limited situations
- Uncertainty of successful vegetation growth and competition with invasive

Initial Construction: ●
Operations & Maintenance: ●

EDGING

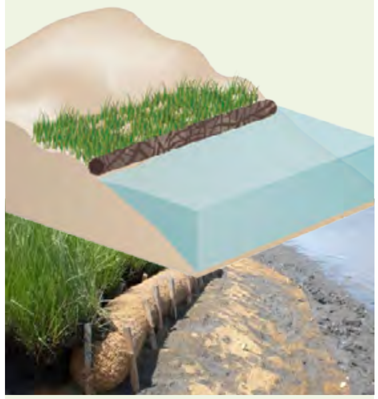


Photo Credit: Partnership for Delaware Estuary

Structure to hold the toe of existing or vegetated slope in place. Protects against shoreline erosion.

Suitable For

Most areas except high wave energy environments.

Vegetation* Base with Material Options

(low wave only, temporary)

- "Snow" fencing
- Erosion control blankets
- Geotextile tubes
- Living reef (oyster/mussel)
- Rock gabion baskets

Benefits

- Dissipates wave energy
- Slows inland water transfer
- Provides habitat and ecosystem services
- Increases natural storm water infiltration
- Toe protection helps prevent wetland edge loss

Disadvantages

- No high water protection
- Uncertainty of successful vegetation growth and competition with invasive

Initial Construction: ●●
Operations & Maintenance: ●

SILLS

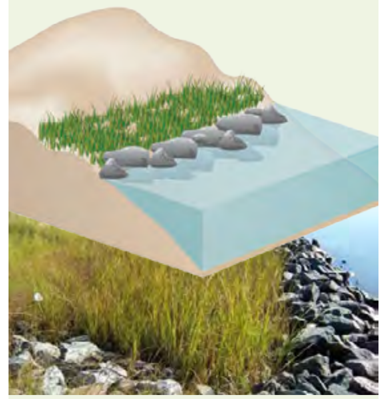


Photo Credit: Maryland Department of Natural Resources - Shoreline Conservation Service

Parallel to existing or vegetated shoreline, reduces wave energy and prevents erosion. A gapped approach would allow habitat connectivity, greater tidal exchange, and better waterfront access.

Suitable For

Most areas except high wave energy environments.

Vegetation* Base with Material Options

- Stone
- Sand breakwaters
- Living reef (oyster/mussel)
- Rock gabion baskets

Benefits

- Provides habitat and ecosystem services
- Dissipates wave energy
- Slows inland water transfer
- Provides habitat and ecosystem services
- Increases natural storm water infiltration
- Toe protection helps prevent wetland edge loss

Disadvantages

- Require more land area
- No high water protection
- Uncertainty of successful vegetation growth and competition with invasive

Initial Construction: ●●
Operations & Maintenance: ●

CONTINUED ON NEXT PAGE

* Native plants and materials must be appropriate for current salinity and site conditions.

Initial Construction: ● = up to $1000 per linear foot, ●● = $1001 - $2000 per linear foot, ●●● = $2001 - $5000 per linear foot, ●●●● = $5001 - $10,000 per linear foot
Operations and Maintenance (yearly for a 50 year project life): ● = up to $100 per linear foot, ●● = $101 - $500 per linear foot, ●●● = over $500 per linear foot

HOW GREEN OR GRAY SHOULD YOUR SHORELINE SOLUTION BE?

GREEN - SOFTER TECHNIQUES

Small Waves | Small Fetch | Gentle Slope | Sheltered Coast

LIVING SHORELINE

CONTINUED FROM LAST PAGE

BEACH NOURISHMENT ONLY

Photo Credit: USACE New York District Public Affairs

Large volume of sand added from outside source to an eroding beach. Widens the beach and moves the shoreline seaward.

Suitable For

Low-lying oceanfront areas with existing sources of sand and sediment.

Material Options

- Sand

Benefits

- Expands usable beach area
- Lower environmental impact than hard structures
- Flexible strategy
- Redesigned with relative ease
- Provides habitat and ecosystem services

Disadvantages

- Requires continual sand resources for renourishment
- No high water protection
- Appropriate in limited situations
- Possible impacts to regional sediment transport

Initial Construction: ●●●
Operations & Maintenance: ●●

BEACH NOURISHMENT & VEGETATION ON DUNE

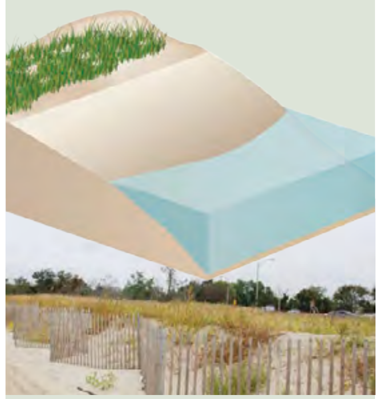


Photo Credit: USACE New York District Public Affairs

Helps anchor sand and provide a buffer to protect inland area from waves, flooding and erosion.

Suitable For

Low-lying oceanfront areas with existing sources of sand and sediment.

Material Options

Sand with vegetation
Can also strengthen dunes with:

- Geotextile tubes
- Rocky core

Benefits

- Expands usable beach area
- Lower environmental impact
- Flexible strategy
- Redesigned with relative ease
- Vegetation strengthens dunes and increases their resilience to storm events
- Provides habitat and ecosystem services

Disadvantages

- Requires continual sand resources for renourishment
- No high water protection
- Appropriate in limited situations
- Possible impacts to regional sediment transport

Initial Construction: ●●●
Operations & Maintenance: ●●

Initial Construction: ● = up to $1000 per linear foot, ●● = $1001 - $2000 per linear foot, ●●● = $2001 - $5000 per linear foot, ●●●● = $5001 - $10,000 per linear foot 4
Operations and Maintenance (yearly for a 50 year project life): ● = up to $100 per linear foot, ●● = $101 - $500 per linear foot, ●●● = over $500 per linear foot

HOW GREEN OR GRAY SHOULD YOUR SHORELINE SOLUTION BE?

GRAY - HARDER TECHNIQUES

Large Waves | Large Fetch | Steep Slope | Open Coast

COASTAL STRUCTURE

BREAKWATER

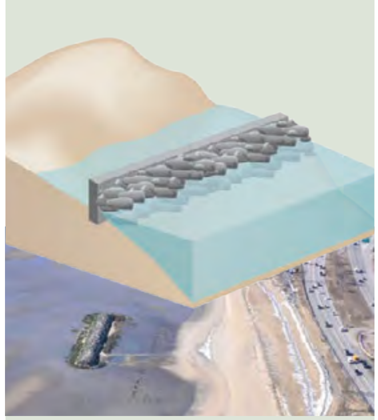


Photo Credit: USACE New York District Public Affairs

Offshore structures intended to break waves, reducing the force of wave action and encourages sediment accretion. Can be floating or fixed to the ocean floor, attached to shore or not, and continuous or segmented. A gapped approach would allow habitat connectivity, greater tidal exchange, and better waterfront access.

Suitable For

Most areas except high wave energy environments often in conjunction with marinas.

Material Options

- Grout-filled fabric bags
- Armorstone
- Pre-cast concrete blocks
- Living reef (oyster/mussel) if low wave environment
- Wood
- Rock†

Benefits

- Reduces wave force and height
- Stabilizes wetland
- Can function like reef
- Economical in shallow areas
- Limited storm surge flood level reduction

Disadvantages

- Expensive in deep water
- Can reduce water circulation (minimized if floating breakwater is applied)
- Can create navigational hazard
- Require more land area
- Uncertainty of successful vegetation growth and competition with invasive
- No high water protection
- Can reduce water circulation
- Can create navigation hazard

GROIN

Photo Credit: USACE New York District Public Affairs

Perpendicular, projecting from shoreline. Intercept water flow and sand moving parallel to the shoreline to prevent beach erosion and break waves. Retain sand placed on beach.

Suitable For

Coordination with beach nourishment.

Material Options

- Concrete/stone rubble†
- Timber
- Metal sheet piles

Benefits

- Protection from wave forces
- Methods and materials are adaptable
- Can be combined with beach nourishment projects to extend their life

Disadvantages

- Erosion of adjacent sites
- Can be detrimental to shoreline ecosystem (e.g. replaces native substrate with rock and reduces natural habitat availability)
- No high water protection

† Rock/stone needs to be appropriately sized for site specific wave energy.

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GRAY CAN BE GREENER: e.g., 'Living Breakwater' using oysters to colonize rocks or 'Greenwall/Biowall' using vegetation, alternative forms and materials

	Breakwater	Groin
Initial Construction	●●●●	●●●
Operations & Maintenance	●●●	●●

Initial Construction: ● = up to $1000 per linear foot, ●● = $1001 - $2000 per linear foot, ●●● = $2001 - $5000 per linear foot, ●●●● = $5001 - $10,000 per linear foot
Operations and Maintenance (yearly for a 50 year project life): ● = up to $100 per linear foot, ●● = $101 - $500 per linear foot, ●●● = over $500 per linear foot

HOW GREEN OR GRAY SHOULD YOUR SHORELINE SOLUTION BE?

GRAY - HARDER TECHNIQUES

Large Waves | Large Fetch | Steep Slope | Open Coast

COASTAL STRUCTURE

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REVETMENT

Photo Credit: Maryland Department of Natural Resources - Shoreline Conservation Service

Lays over the slope of a shoreline. Protects slope from erosion and waves.

Suitable For

Sites with pre-existing hardened shoreline structures.

Material Options

- Stone rubble‡
- Concrete blocks
- Cast concrete slabs
- Sand/concrete filled bags
- Rock-filled gabion basket

Benefits

- Mitigates wave action
- Little maintenance
- Indefinite lifespan
- Minimizes adjacent site impact

Disadvantages

- No major flood protection
- Require more land area
- Loss of intertidal habitat
- Erosion of adjacent unreinforced sites
- Require more land area
- No high water protection
- Prevents upland from being a sediment source to the system

‡ Rock/stone needs to be appropriately sized for site specific wave energy.

BULKHEAD

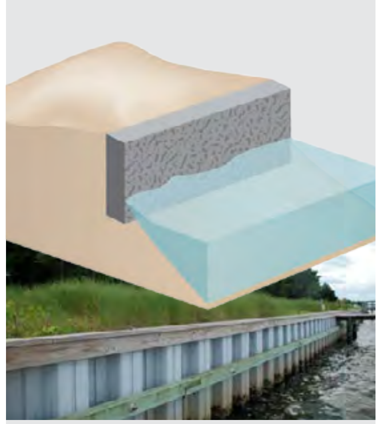


Photo Credit: North Carolina Department of Environment and Natural Resources

Parallel to the shoreline, vertical retaining wall. Intended to hold soil in place and allow for a stable shoreline.

Suitable For

High energy settings and sites with pre-existing hardened shoreline structures. Accommodates working water fronts (eg: docking for ships and ferries).

Material Options

- Steel sheet piles
- Timber
- Concrete
- Composite carbon fibers
- Gabions

Benefits

- Moderates wave action
- Manages tide level fluctuation
- Long lifespan
- Simple repair

Disadvantages

- No major flood protection
- Erosion of seaward seabed
- Erosion of adjacent unreinforced sites
- Loss of intertidal habitat
- May be damaged from overtopping oceanfront storm waves
- Prevents upland from being a sediment source to the system
- Induces wave reflection

SEAWALL

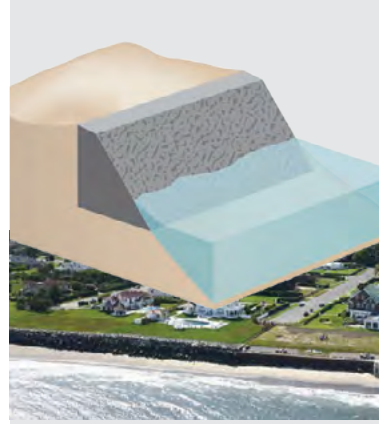


Photo Credit: USACE New York District Public Affairs

Parallel to shoreline, vertical or sloped wall. Soil on one side of wall is the same elevation as water on the other. Absorbs and limits impacts of large waves and directs flow away from land.

Suitable For

Areas highly vulnerable to storm surge and wave forces.

Material Options

- Stone
- Rock
- Concrete
- Steel/vinyl sheets
- Steel sheet piles

Benefits

- Prevents storm surge flooding
- Resists strong wave forces
- Shoreline stabilization behind structure
- Low maintenance costs
- Less space intensive horizontally than other techniques (e.g. vegetation only)

Disadvantages

- Erosion of seaward seabed
- Disrupt sediment transport leading to beach erosion
- Higher up-front costs
- Visually obstructive
- Loss of intertidal zone
- Prevents upland from being a sediment source to the system
- May be damaged from overtopping oceanfront storm waves

GRAY CAN BE GREENER: e.g., 'Living Breakwater' using oysters to colonize rocks or 'Greenwall/Biowall' using vegetation, alternative forms and materials

	Revetment	Bulkhead	Seawall
Initial Construction	●●●●	●●●	●●●●
Operations & Maintenance	●●	●●	●●●

Initial Construction: ● = up to $1000 per linear foot, ●● = $1001 - $2000 per linear foot, ●●● = $2001 - $5000 per linear foot, ●●●● = $5001 - $10,000 per linear foot
Operations and Maintenance (yearly for a 50 year project life): ● = up to $100 per linear foot, ●● = $101 - $500 per linear foot, ●●● = over $500 per linear foot

6

Is a Living Shoreline a Good Fit for What I Need?

Living Shorelines achieve multiple goals such as:

- Stabilizing the shoreline and reducing current rates of shoreline erosion and storm damage
- Providing ecosystem services, such as habitat for fish and other aquatic species and increasing flood storage capacity
- Maintaining connections between land and water ecosystems to enhance resilience

Site-specific conditions will influence your choice of shoreline protection technique (ex: wave energy level, fetch lengths, rate and pattern of erosion, etc). Here are some additional factors to keep in mind as you consider Living Shorelines.

WHAT ARE THE BENEFITS?

- Erosion control and shore stabilization.
- Restored and enhanced habitat which supports fish and wildlife populations.
- Increased property values.
- Enhanced community enjoyment.
- Opportunities for education.
- Improved public access to waterfront through recreational activities such as fishing, boating and birding. Can be used to satisfy zoning and permitting requirement for waterfront development projects.
- Complemented natural shoreline dynamics & movement; increased resilience and absorption of wave energy, storm surge and floodwaters; and an adaptive tool for preparation of sea level rise.
- Improved water quality from settling or trapping sediment (e.g. once established, a marsh can filter surface water runoff or oysters can provide coastal water filtration).

WHAT ARE SOME CHALLENGES?

- Uncertainty in risk because of lack of experience of techniques.
- Public funds are often tied to government permit compliance.
- Permitting processes can be lengthy and challenging. The existing regulatory process is centered on traditional "gray" or "hard" techniques. Regulators and project sponsors alike are learning how to design living shorelines projects. Talk with someone about your state's permitting process or to hear about their experiences.
- It takes time to develop and test new shoreline protection methods.
- There may be land ownership constraints. Consider where federal and state jurisdiction for the water body starts and ends.
- In urban environments, there is limited land (bulkheads may seem like the only option), a variety of upland uses (industrial past use may have left legacy contaminants) and high velocity waters.
- The overall sediment system needs to be taken into account to protect neighboring properties from experiencing starved down drift shorelines or other consequences as a result of a project.
- Lack of public awareness of performance and benefits of living shorelines.
- Not all techniques have the same level of performance or success monitoring. Less practiced techniques may require more monitoring.

WHAT INFLUENCES COST?

- The materials chosen for the project influence cost.
- Including green techniques can be cheaper than traditional gray techniques.
- Sometimes it's possible to install the project yourself, other times you will need help from a professional.
- Long term maintenance is required as any landscape project (e.g. replanting may be needed after a storm).

HOW TO FIND OUT MORE

If you have a Living Shorelines permitting question, contact your state's office of Environmental Protection, Conservation or Natural Resources, your coastal zone manager such as your state's Department of State, as well as your local U.S. Army Corps of Engineers (USACE) district office.

If you would like science or engineering advice, or to talk to people who have experience studying or constructing living shorelines, reach out to some of the following: your local universities, your City's Department of Planning and Department of Parks, Sea Grant Chapter, Littoral Society, The Nature Conservancy, The Trust for Public Land, The Environmental Protection Agency (EPA), National Oceanic and Atmospheric Administration (NOAA), USACE, engineering firms and other organizations that focus on your local waterfront.

These and other websites are good references to learn more about Living Shorelines:

SAGE
www.SAGEcoast.org

NOAA Restoration
www.habitat.noaa.gov/livingshorelines

USACE Engineer Research Development Center, Engineering with Nature
el.erdc.usace.army.mil/ewn

USACE North Atlantic Division, National Planning Center of Expertise for Coastal Storm Damage Reduction
www.nad.usace.army.mil/About/NationalCentersofExpertise/CoastalStormDamageReduction(Planning).aspx

Virginia Institute of Marine Science (VIMS) Center for Coastal Resources Management
ccrm.vims.edu/livingshorelines/index.html

Coasts, Oceans, Ports & Rivers Institute (COPRI)
www.mycopri.org/livingshorelines

The Nature Conservancy
www.nature.org/ourinitiatives/habitats/oceanscoasts/howwework/helping-oceans-adapt-to-climate-change.xml

US Army Corps of Engineers®

Developed with support and funding from SAGE, NOAA and USACE; February 2015

APPENDIX C

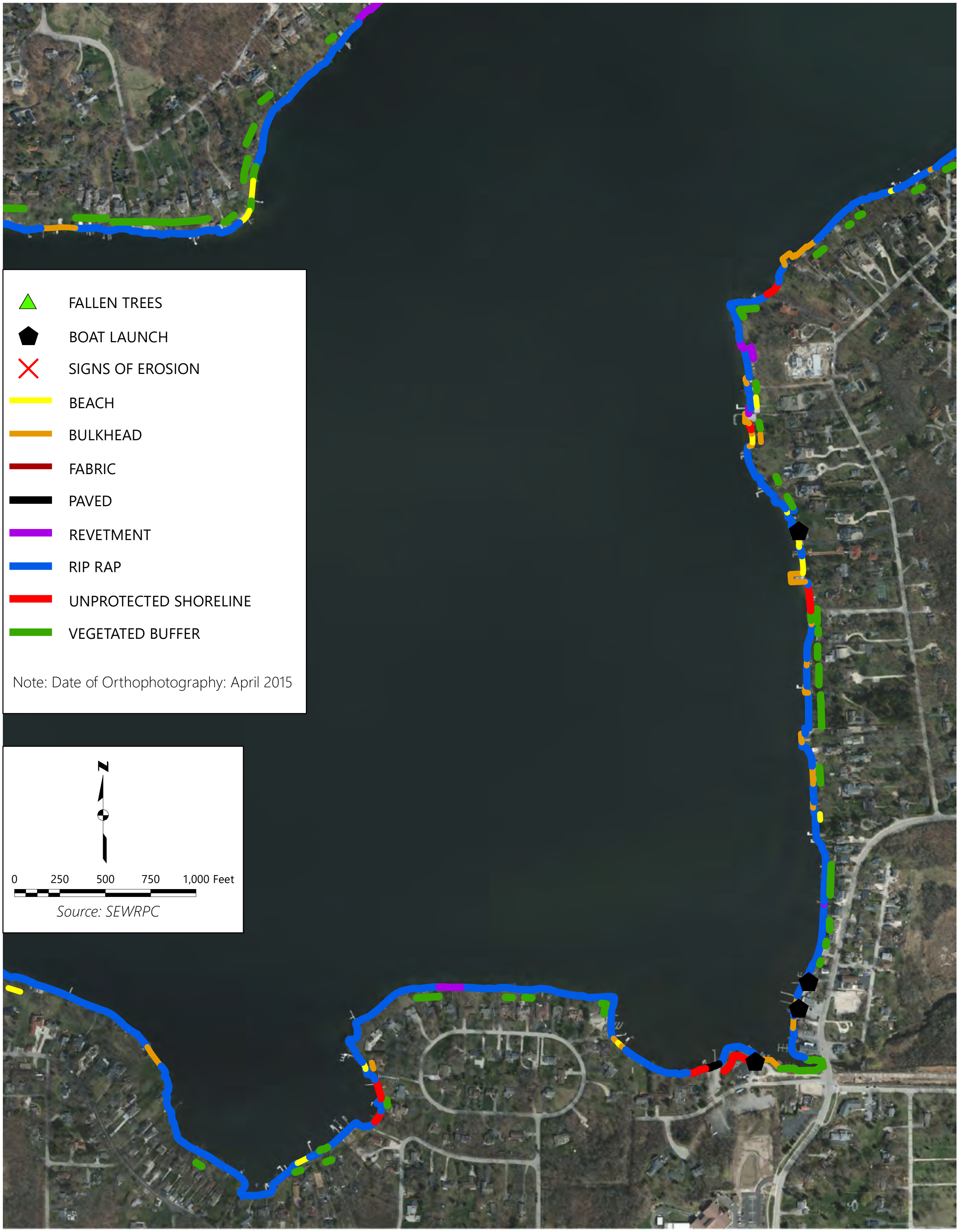
SHORELINE ASSESSMENT INSETS

Map C.1
Map 2.22 – Inset 1 (Eastern Pewaukee Lake Shoreline Conditions: 2015)

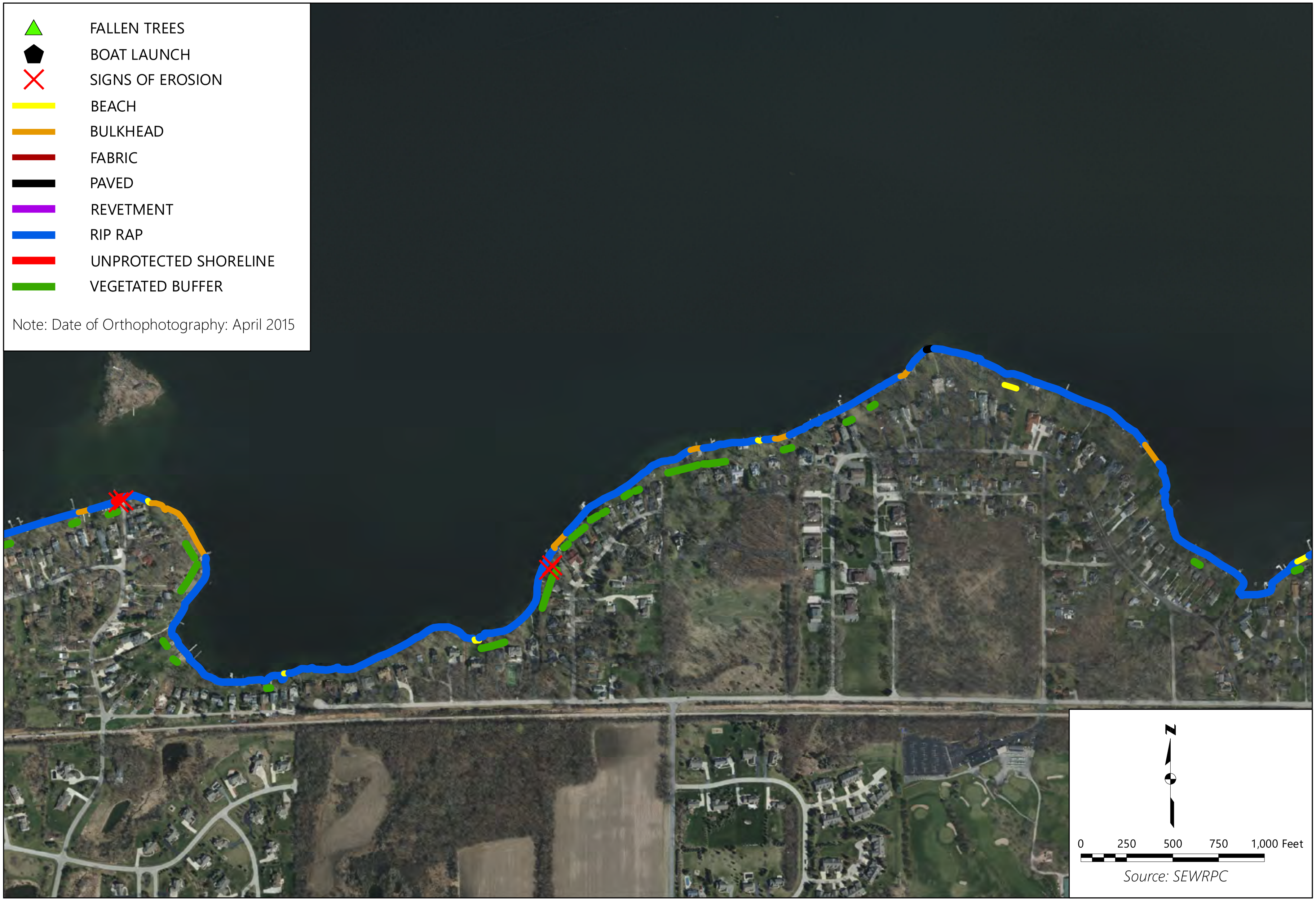
Map C.2
Map 2.22 – Inset 2 (Southeastern Pewaukee Lake Shoreline Conditions: 2015)

Map C.3

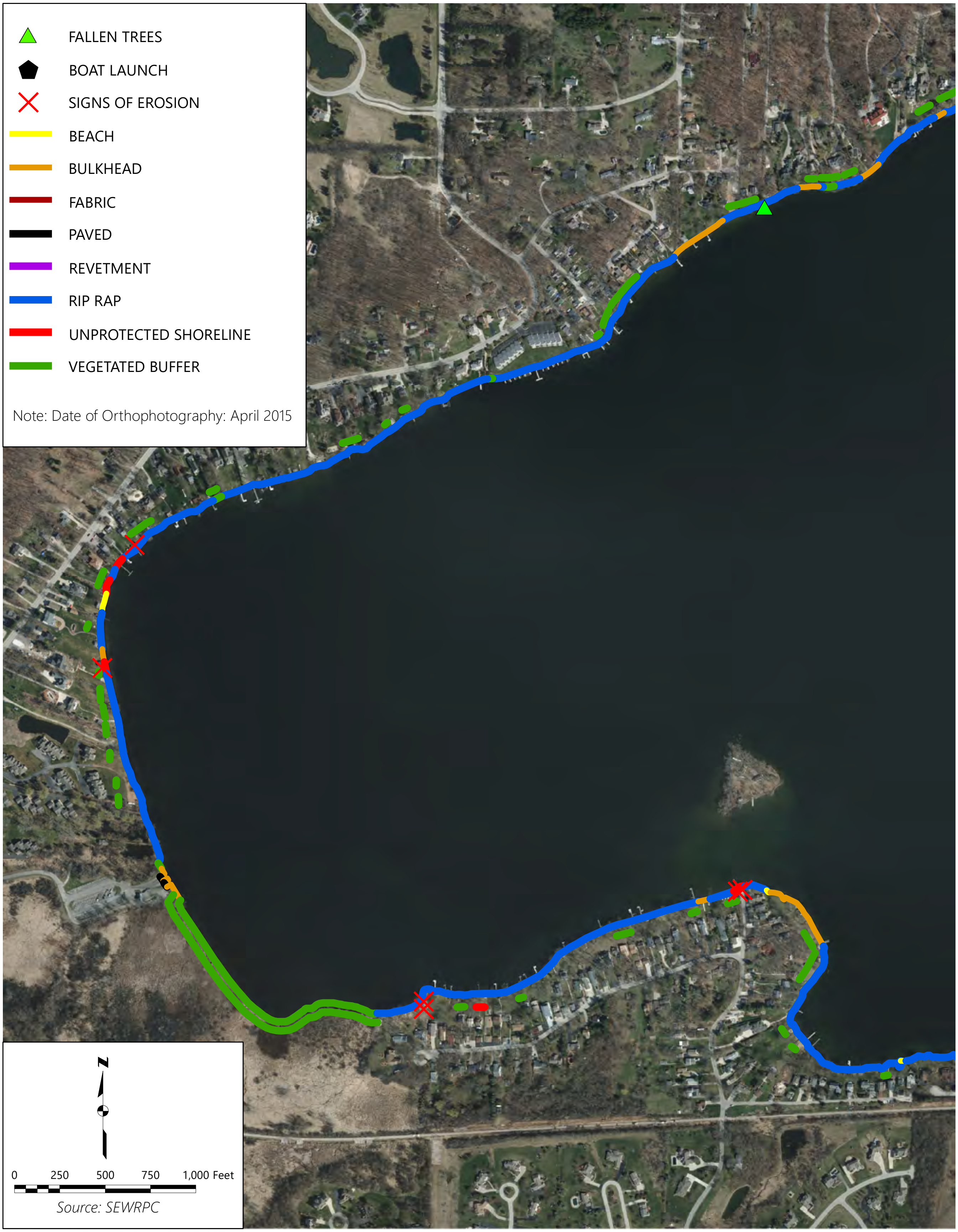
Map 2.22 – Inset 3 (Central Pewaukee Lake Shoreline Conditions: 2015)



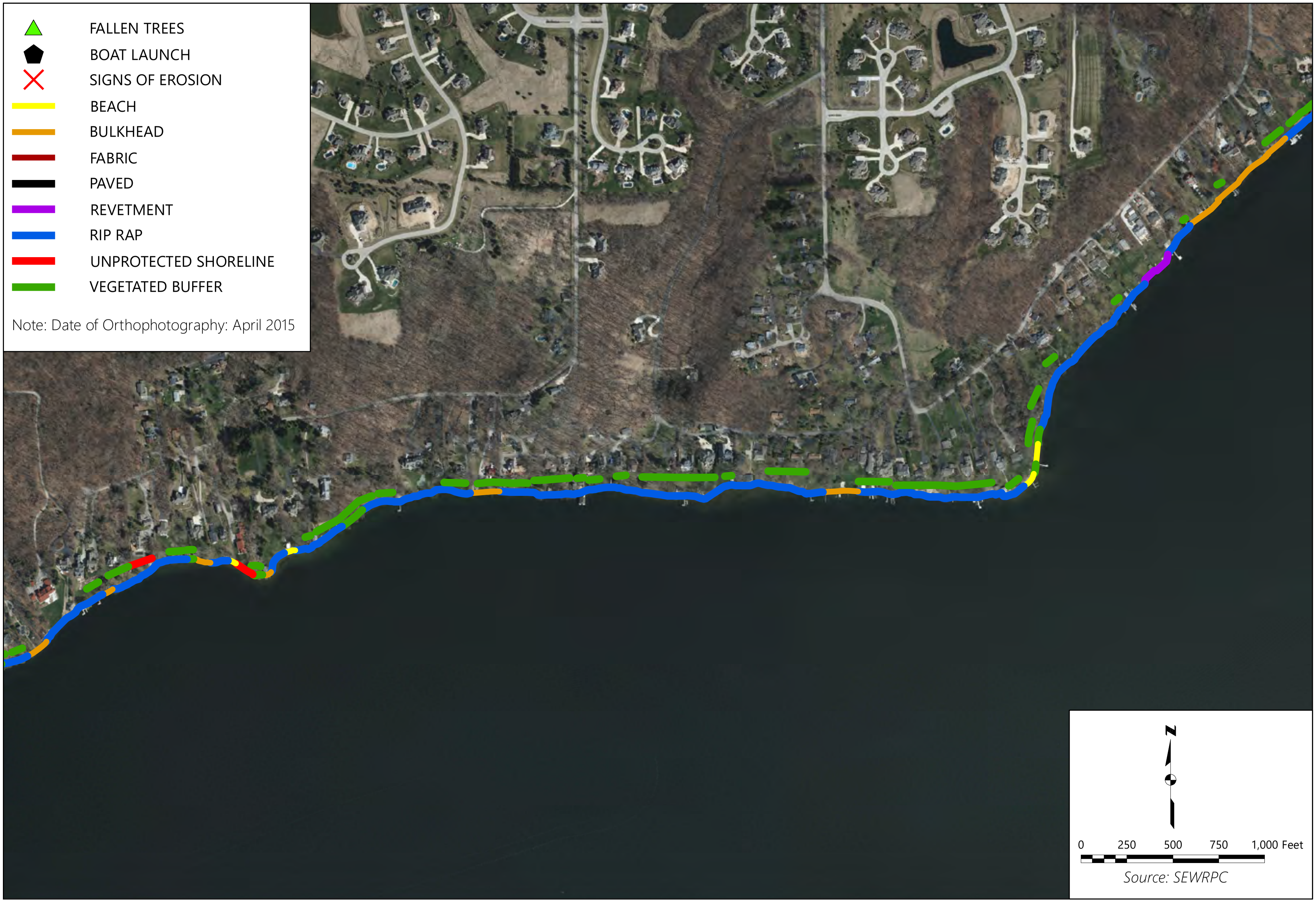
Map C.4
Map 2.22 – Inset 4 (Southwestern Pewaukee Lake Shoreline Conditions: 2015)



Map C.5
Map 2.22 – Inset 5 (Western Pewaukee Lake Shoreline Conditions: 2015)



Map C.6
Map 2.22 – Inset 6 (Northwestern Pewaukee Lake Shoreline Conditions: 2015)

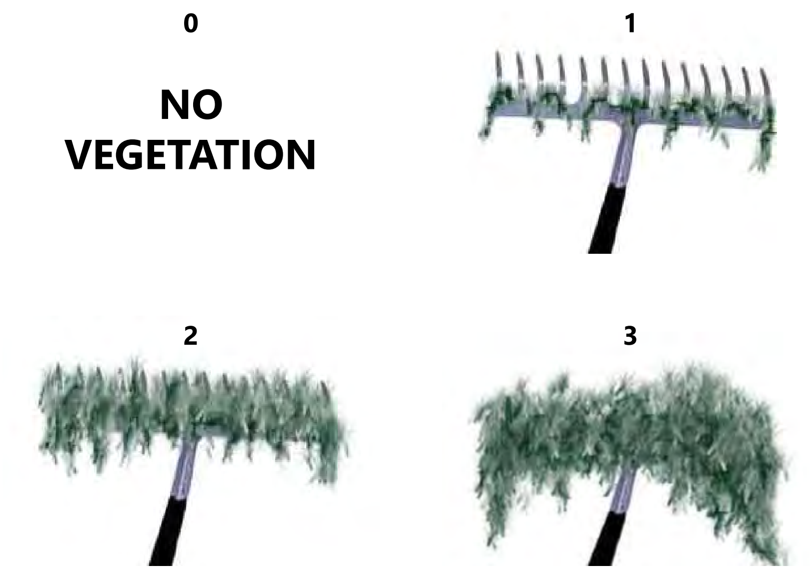


Map C.7
Map 2.22 – Inset 7 (Northeastern Pewaukee Lake Shoreline Conditions: 2015)

APPENDIX D

PEWAUKEE LAKE AQUATIC PLANT SPECIES DETAILS

Figure D.1
Rake Fullness Ratings



Source: Wisconsin Department of Natural Resources and SEWRPC

SOURCES OF INFORMATION:

Borman, S., Korth, R., & Temte, J. (2014). Through the Looking Glass: A Field Guide to Aquatic Plants, Second Edition. Stevens Point, WI, USA: Wisconsin Lakes Partnership.

Robert W. Freckman Herbarium: wisplants.uwsp.edu

Skawinski, P. M. (2014). Aquatic Plants of the Upper Midwest: A Photographic Field Guide to Our Underwater Forests, Second Edition. Wausau, Wisconsin, USA: Self-Published.

University of Michigan Herbarium: michiganflora.net/home.aspx

UW-System WisFlora. 2016. wisflora.herbarium.wisc.edu/index.php

Ceratophyllum demersum
Native

Coontail

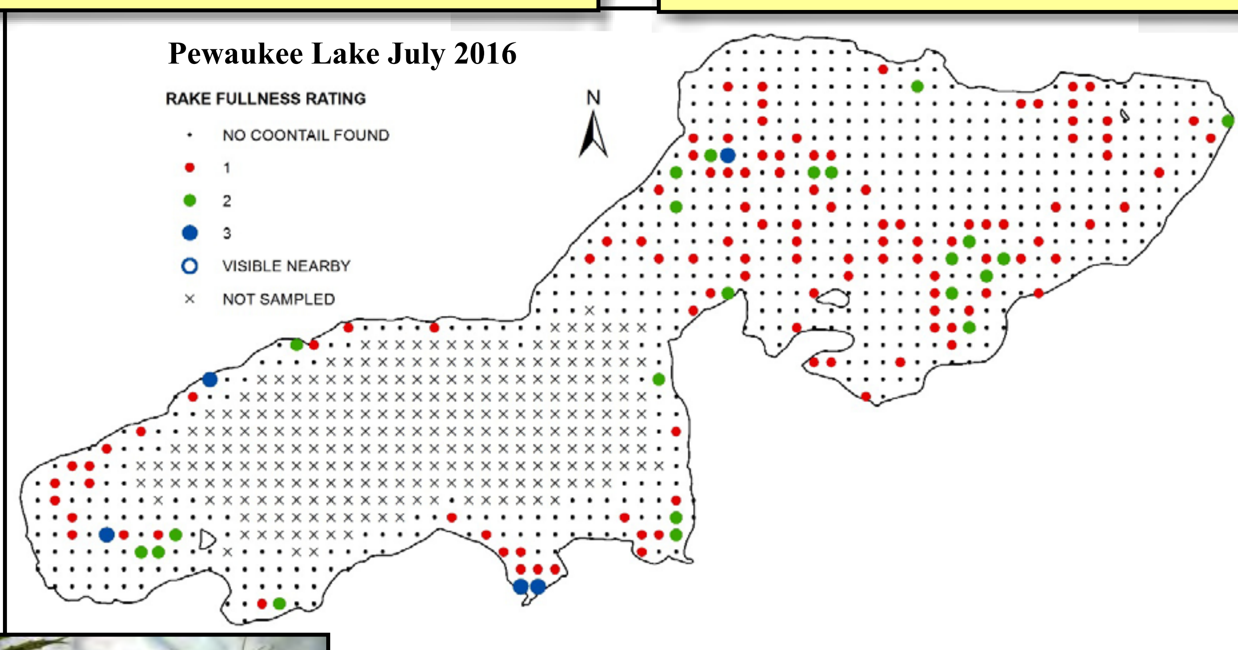
Identifying Features

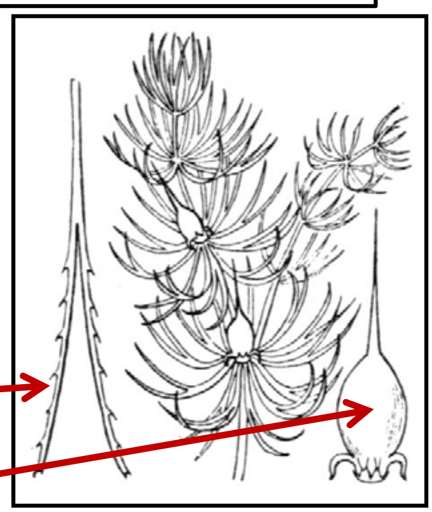
- Often bushy near tips of branches, giving the raccoon tail-like appearance ("coontail")
- Whorled leaves with one to two orders of branching and small teeth on their margins
- Flowers (rare) small and produced in leaf axils

Coontail is similar to spiny hornwort (*C. echinatum*) and muskgrass (*Chara* spp.), but spiny hornwort has some leaves with three to four orders of branching, and coontail does not produce the distinct garlic-like odor of muskgrass when crushed

Ecology

- Common in lakes and streams, both shallow and deep
- Tolerates poor water quality (high nutrients, chemical pollutants) and disturbed conditions
- Stores energy as oils, which can produce slicks on the water surface when plants decay
- Anchors to the substrate with pale, modified leaves rather than roots
- Eaten by waterfowl, turtles, carp, and muskrat





Second-Order Leaf Branching

First-Order Leaf Branching

Toothed Leaf Margins

Fruit (rare)

Ceratophyllum echinatum — Spiny Hornwort

Native

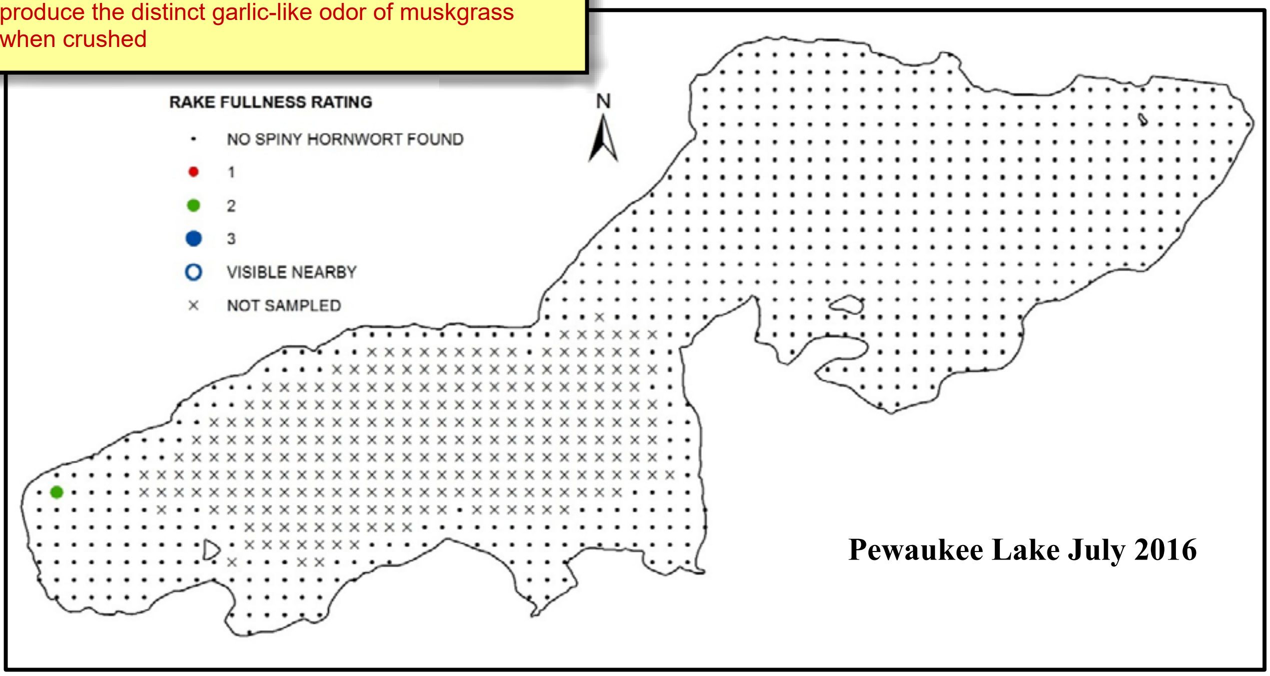
Identifying Features

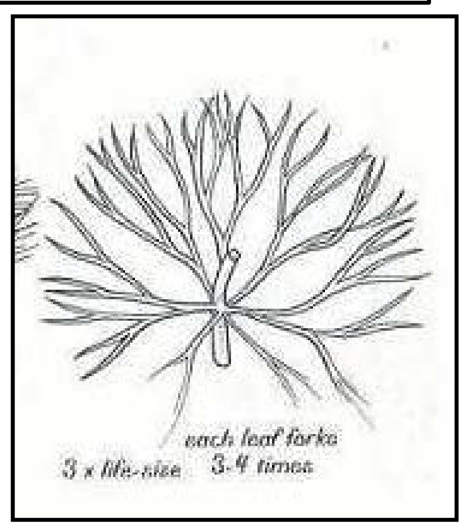
- Often heavily branched
- Delicate whorled leaves branch 3 to 4 times
- Edges of leaves toothless but with some spines
- Fruits have rough surface and several spines of varying lengths around margin

Spiny hornwort is similar to coontail (*C. demersum*) and muskgrass (*Chara* spp.), but spiny hornwort has some leaves that are delicate and have three to four orders of branching, and spiny hornowort does not produce the distinct garlic-like odor of muskgrass when crushed

Ecology

- Uncommon and found in acidic, soft water lakes and ponds
- Anchors to the substrate with pale, modified leaves rather than roots
- Bushy stems harbor many invertebrates and provide shelter and foraging for fish





Chara spp. — Muskgrasses

Native

Algae (not vascular plants)

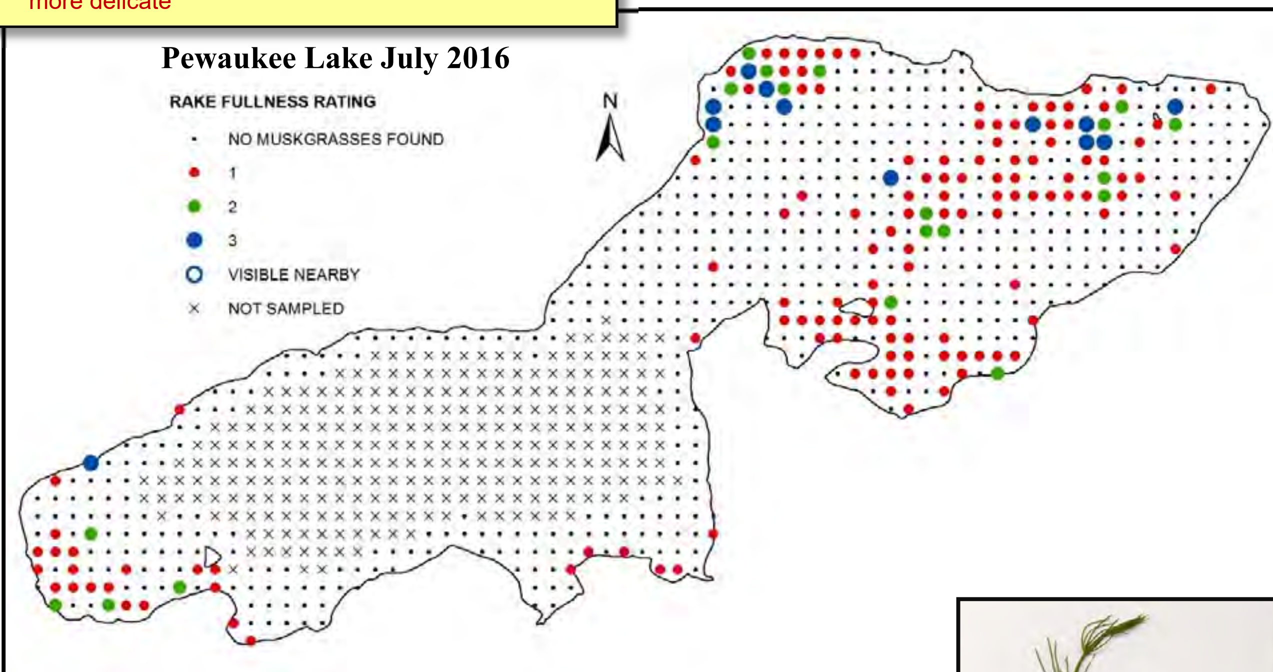
Identifying Features

- Leaf-like, ridged side branches develop in whorls of six or more
- Often encrusted with calcium carbonate, which appears white upon drying (see photo on left, below)
- Yellow reproductive structures develop along the whorled branches in summer
- Emits a garlic-like odor when crushed

Stoneworts (*Nitella* spp.) are similar large algae, but their branches are smooth rather than ridged and more delicate

Ecology

- Found in shallow or deep water over marl or silt, often growing in large colonies in hard water
- Overwinters as rhizoids (cells modified to act as roots) or fragments
- Stabilizes bottom sediments, often among the first species to colonize open areas
- Food for waterfowl and excellent habitat for small fish



Elodea canadensis — Common Waterweed

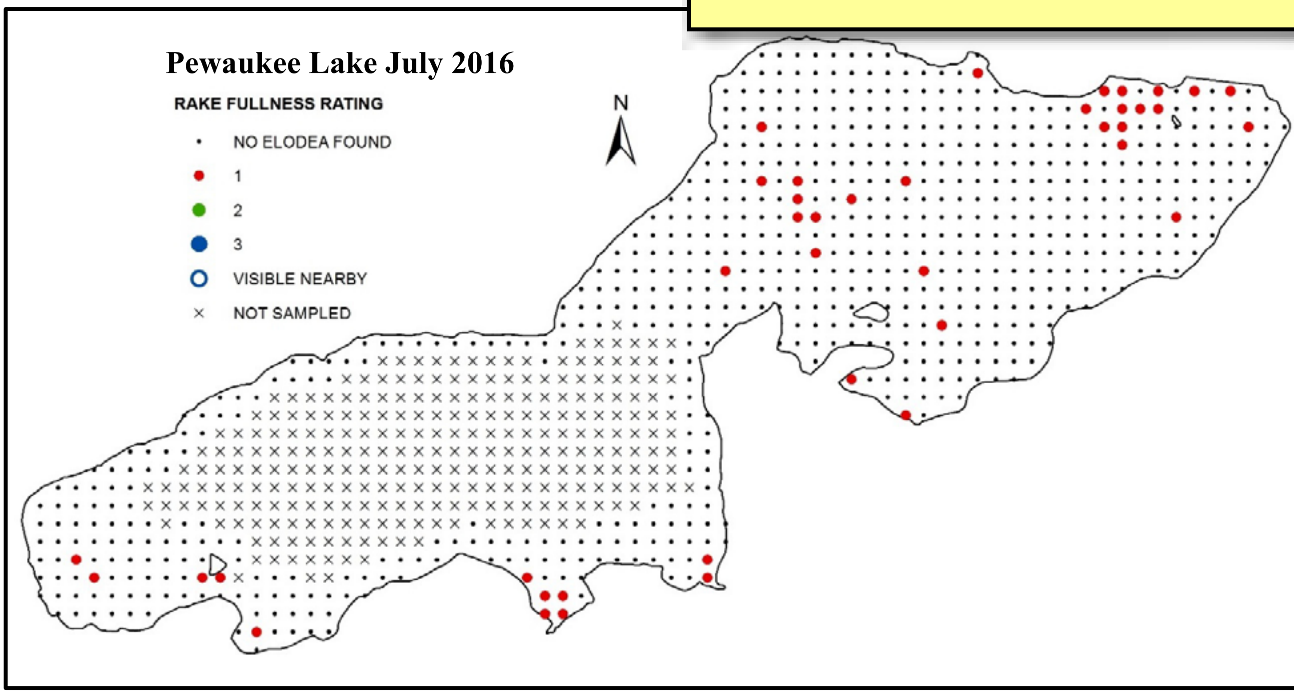
Native

Identifying Features

- Slender stems, occasionally rooting
- Leaves lance-shaped, in whorls of three (rarely two or four), 6.0 to 17 mm long and averaging 2.0 mm wide
- When present, tiny male and female flowers on separate plants (females more common), raised to the surface on thread-like stalks

Ecology

- Found in lakes and streams over soft substrates tolerating pollution, eutrophication and disturbed conditions
- Often overwinters under the ice
- Produces seeds only rarely, spreading primarily via stem fragments
- Provides food for muskrat and waterfowl
- Habitat for fish or invertebrates, although dense stands can obstruct fish movement



Heteranthera dubia — Water Stargrass

Native

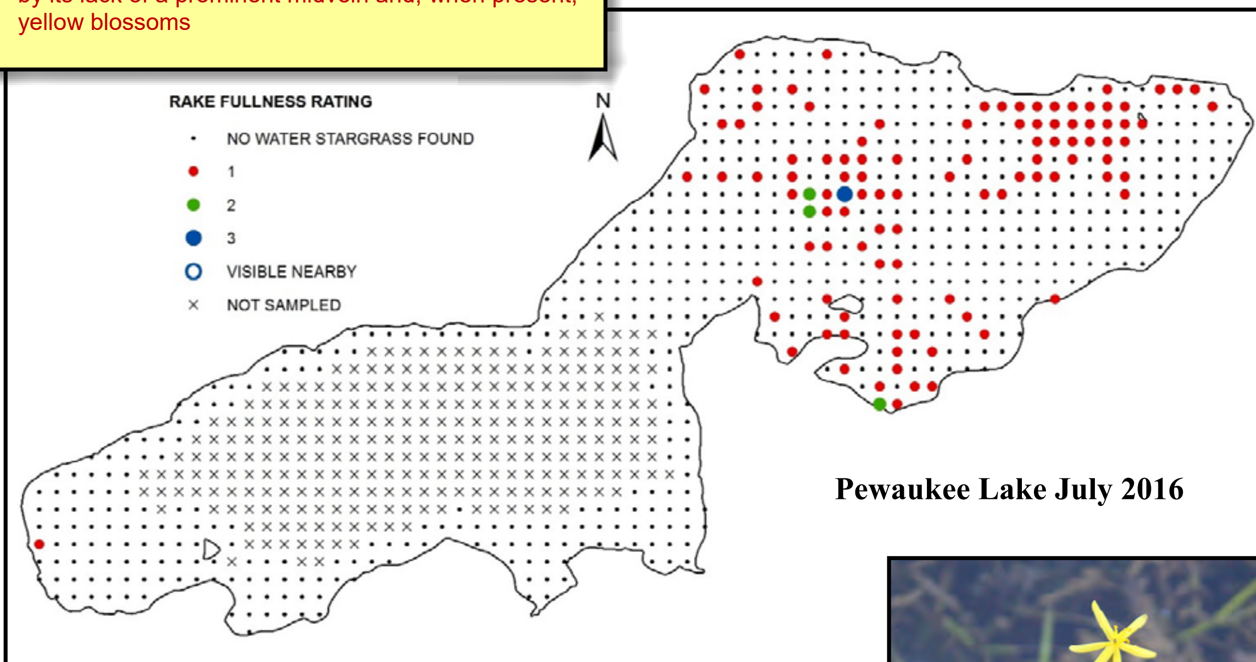
Identifying Features

- Stems slender, slightly flattened, and branching
- Leaves narrow, alternate, with no stalk, and lacking a prominent midvein
- When produced, flowers conspicuous, yellow, and star-shaped (usually in shallow water) or inconspicuous and hidden in the bases of submersed leaves (in deeper water)

Yellow stargrass may be confused with pondweeds that have narrow leaves, but it is easily distinguished by its lack of a prominent midvein and, when present, yellow blossoms

Ecology

- Found in lakes and streams, shallow and deep
- Tolerates somewhat turbid waters
- Overwinters as perennial rhizomes
- Limited reproduction by seed
- Provides food for waterfowl and habitat for fish



Myriophyllum sibiricum — Northern Water Milfoil

Native

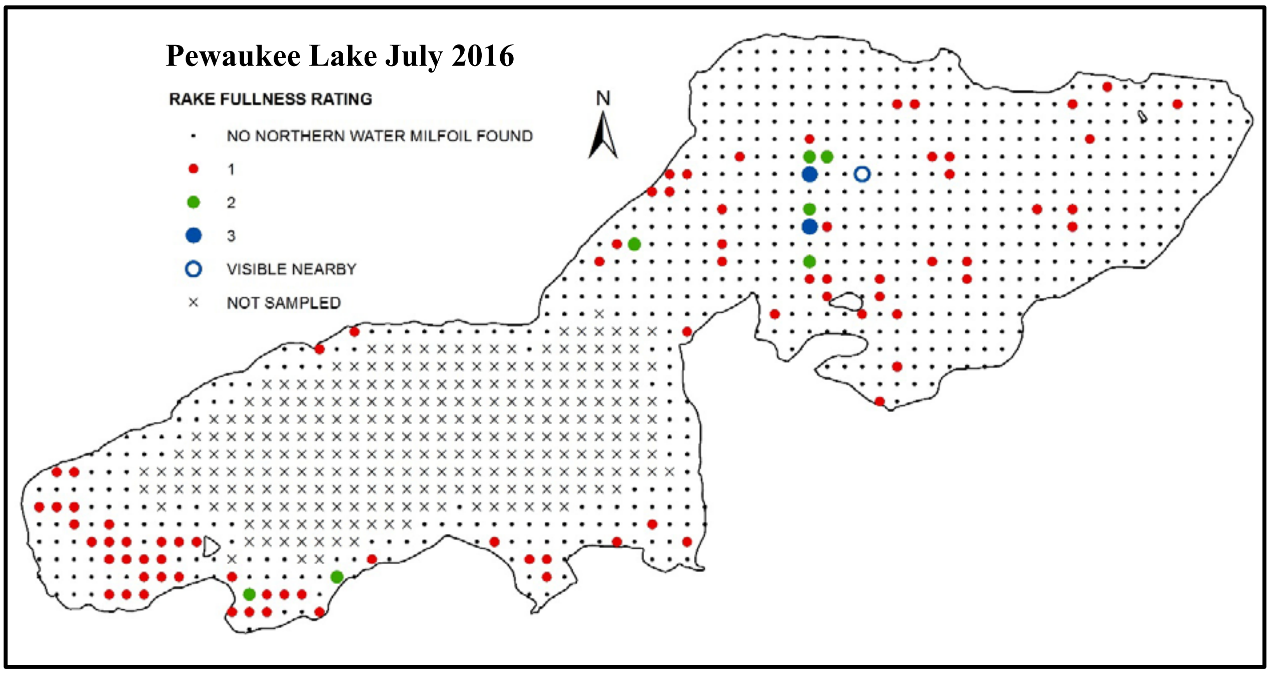
Identifying Features

- Light-colored, stout stems
- Leaves in whorls of four to five, divided into four to 12 pairs of leaflets, lower leaflets longer than the upper ones
- Forms winter buds (turions) in autumn

Northern water milfoil is similar to other water milfoils. Eurasian water milfoil (*M. spicatum*) tends to produce more leaflets per leaf and have more delicate, pinkish stems

Ecology

- Found in lakes and streams, shallow and deep
- Overwinters as winter buds and/or hardy rootstalks
- Consumed by waterfowl
- Habitat for fish and aquatic invertebrates
- Hybridizes with Eurasian water milfoil, resulting in plants with intermediate characteristics



Myriophyllum heterophyllum — Various-leaved Water Milfoil

Native

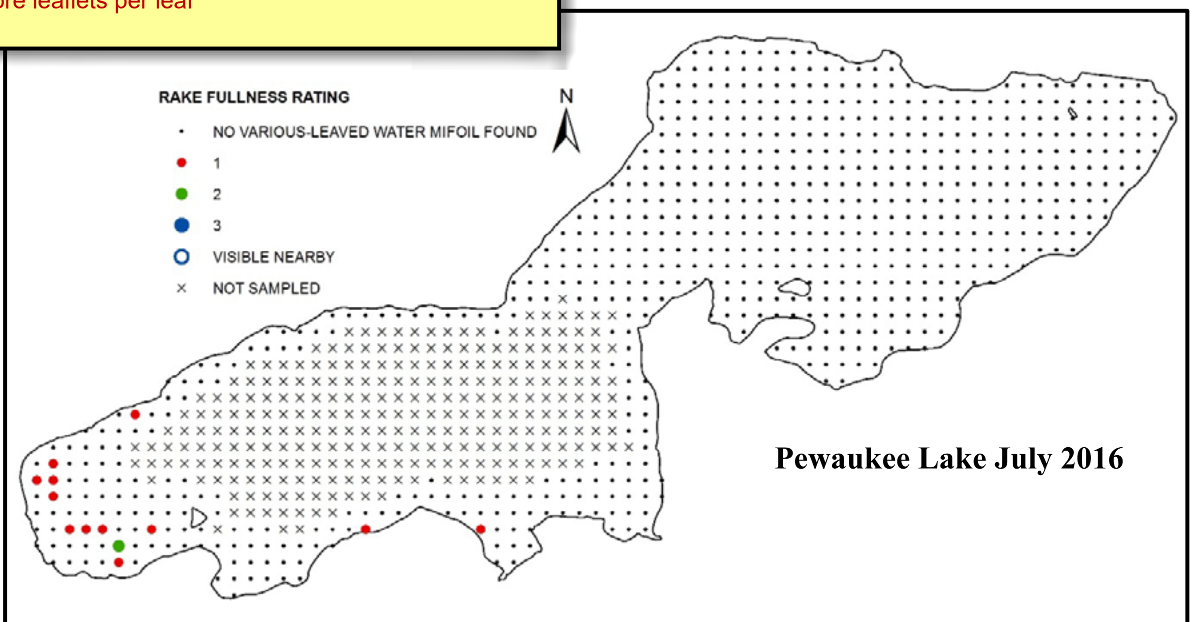
Identifying Features

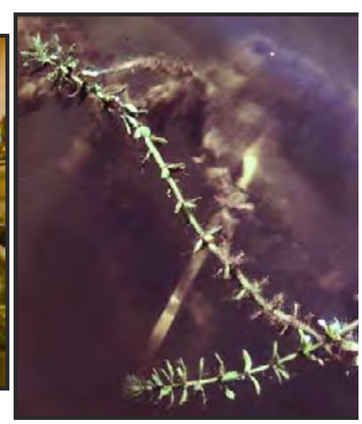
- Very short internodes lead to very bushy appearance
- Leaves in whorls of four to six, with some scattered on stem, divided into seven to 14 pairs of leaflets
- No winter buds are formed
- Flower bracts are larger than flowers and have smooth or slightly serrated edges

Various-leaved water milfoil is similar to other water milfoils. Eurasian water milfoil (*M. spicatum*) tends to be less bushy, limp out of water, and produce more leaflets per leaf

Ecology

- Found in lakes and streams, up to 15 feet but mostly shallower
- Plants on wet shorelines may produce deeply serrate "terrestrial" leave or bracts
- Consumed by waterfowl
- Provides habitat for aquatic invertebrates and shade, shelter, and foraging for fish





Myriophyllum spicatum — Eurasian Water Milfoil

Nonnative/Exotic

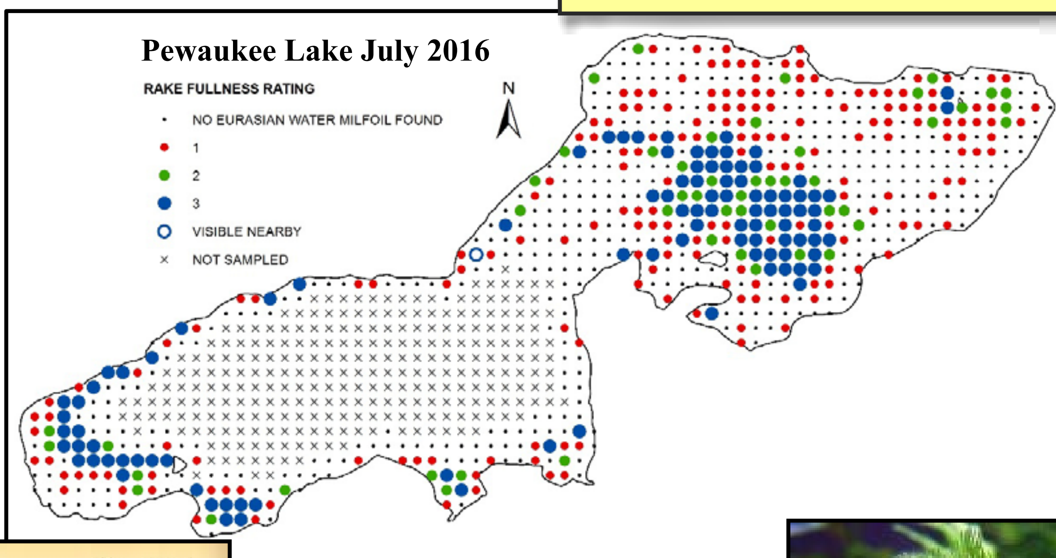
Identifying Features

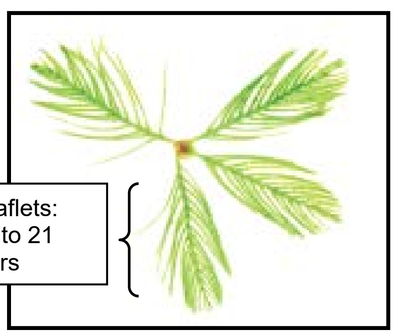
- Stems spaghetti-like, often pinkish, growing long with many branches near the water surface
- Leaves with 12 to 21 pairs of leaflets
- Produces no winter buds (turions)

Eurasian water milfoil is similar to northern water milfoil (*M. sibiricum*). However, northern water milfoil has five to 12 pairs of leaflets per leaf and stouter white or pale brown stems

Ecology

- Hybridizes with northern (native) water milfoil, resulting in plants with intermediate characteristics
- Invasive, growing quickly, forming canopies, and getting a head-start in spring due to an ability to grow in cool water
- Grows from root stalks and stem fragments in both lakes and streams, shallow and deep; tolerates disturbed conditions
- Provides some forage to waterfowl, but supports fewer aquatic invertebrates than mixed stands of aquatic vegetation





Leaflets: 12 to 21 pairs

Najas guadalupensis — Southern Naiad

Native

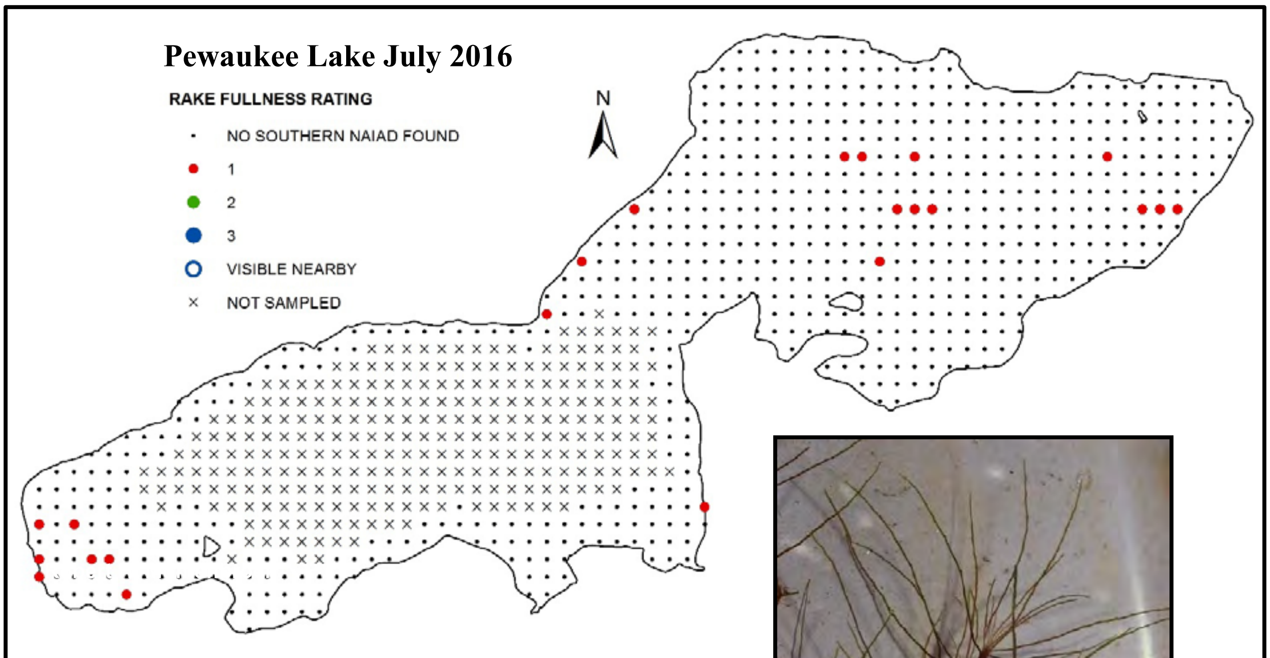
Identifying Features

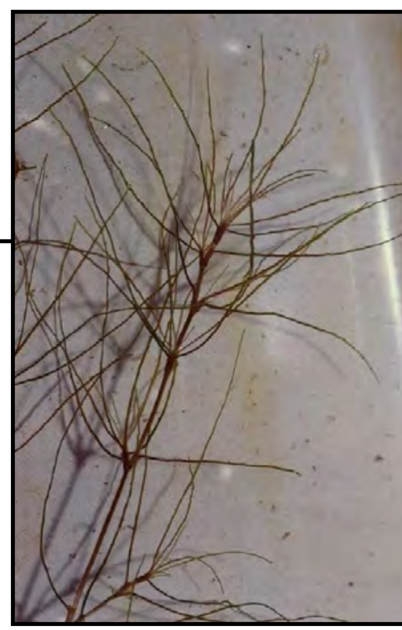
- Leaves 0.2 to 2.0 mm wide and blunt with slight shoulder bases where they attach to the stem and finely serrated margins
- Flowers, when present, tiny and located in leaf axils
- Leaves opposite and may appear loosely whorled

Two other *Najas* occur in southeastern Wisconsin. Slender naiad (*N. flexilis*) has narrower leaves (to 0.6 mm) with a pointed tip. Spiny naiad (*N. marina*) has coarsely toothed leaves with spines along the midvein below

Ecology

- In shallow to deep lakes and sandy, gravelly soil
- An annual plant that completely dies back in fall and regenerates from seeds each spring; also spreading by stem fragments during the growing season





Nymphaea odorata — White Water Lily

Native

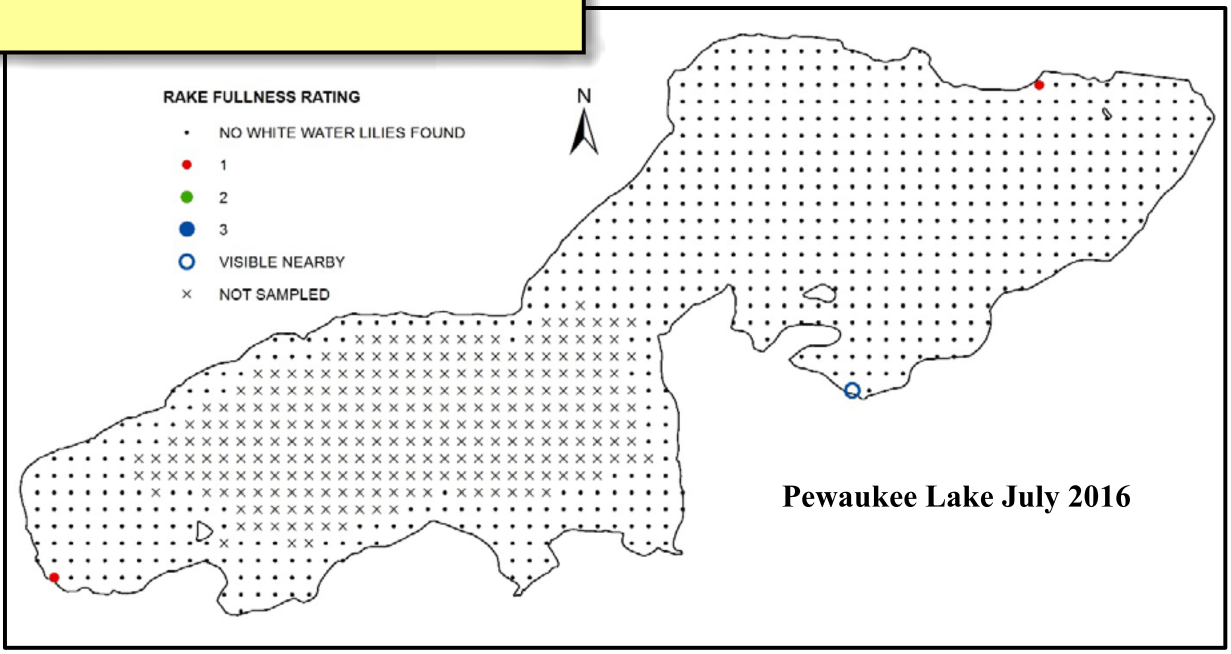
Identifying Features

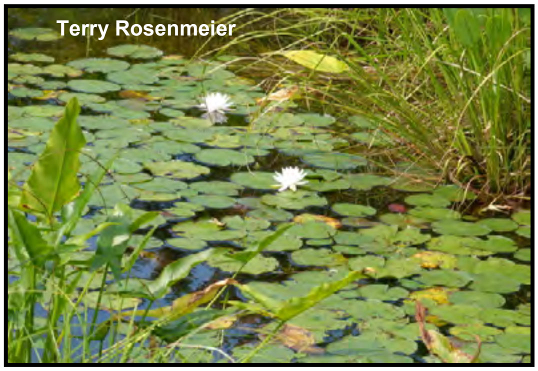
- Leaf stalks round in cross-section with four large air passages
- Floating leaves round (four to 12 inches wide under favorable conditions), *with a notch* from the outside to the center, and reddish-purple underneath
- Flowers white with a yellow center, three to nine inches wide

Pond lilies (*Nuphar* spp.) are superficially similar, but have yellow flowers and leaves somewhat heart-shaped. American lotus (*Nelumbo lutea*) is also similar, but its leaves are *unnotched*

Ecology

- Found in shallow waters over soft sediments
- Leaves and flowers emerge from rhizomes
- Flowers opening during the day, closing at night
- Seeds consumed by waterfowl, rhizomes consumed by mammals





Potamogeton amplifolious — Large-Leaf Pondweed

Native

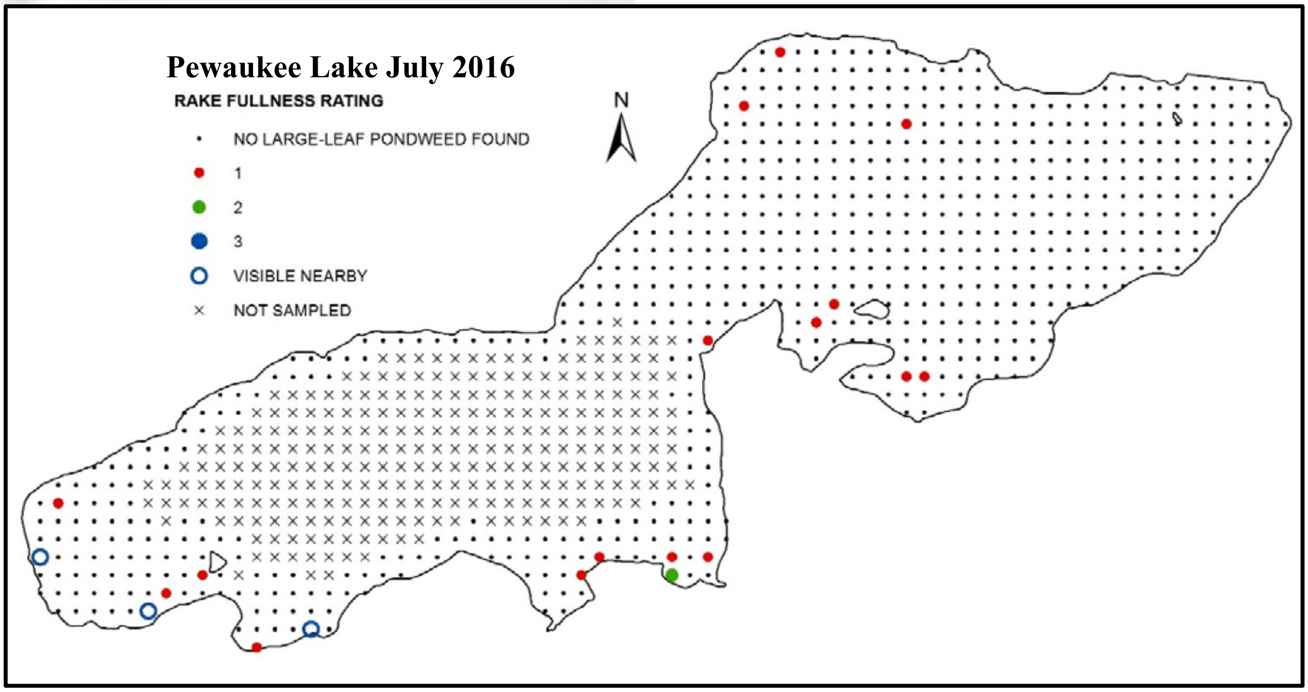
Identifying Features

- When produced, floating leaves 2-23 cm long *with 27-49 veins* and petiole longer than leaf blade
- Submersed leaves large and sickle-shaped, 4-7 cm wide, 8-20 cm long, *with more than 19 veins*, and folded upwards along the sides
- White stipules up to 12 cm long

Large-leaf pondweed may be distinguished from Illinois pondweed (*P. illinoensis*) by the greater number of veins on submersed and floating leaves.

Ecology

- Soft substrate, shallow and deep lakes
- Emerges in spring from buds formed along rhizomes
- Provides food for waterfowl, muskrat, beaver, and deer
- Provides habitat and/or food for fish, muskrat, waterfowl, and insects



Potamogeton crispus Curly-Leaf Pondweed

Nonnative/Exotic

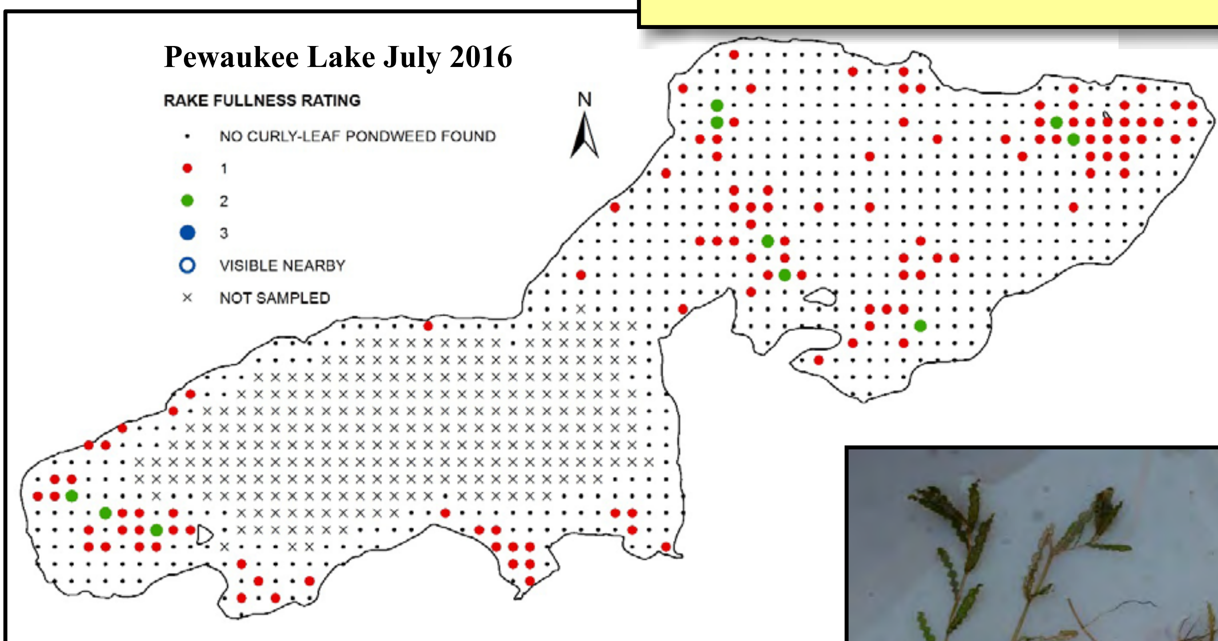
Identifying Features

- Stems slightly flattened and both stem and leaf veins often somewhat pink
- Leaf margins very wavy and finely serrated
- Stipules (3.0 to 8.0 mm long) partially attached to leaf bases, disintegrating early in the season
- Produces pine cone-like overwintering buds (turions)

Curly-leaf pondweed may resemble clasping-leaf pondweed (*P. richardsonii*), but the leaf margins of the latter are not serrated

Ecology

- Found in lakes and streams, both shallow and deep
- Tolerant of low light and turbidity
- Disperses mainly by turions
- Adapted to cold water, growing under the ice while other plants are dormant, but dying back during mid-summer in warm waters
- Produces winter habitat, but mid-summer die-offs can degrade water quality and cause algal blooms
- Maintaining or improving water quality can help control this species, because it has a competitive advantage over native species when water clarity is poor



Zofia Noe

Zofia Noe

Potamogeton illinoensis — Illinois Pondweed

Native

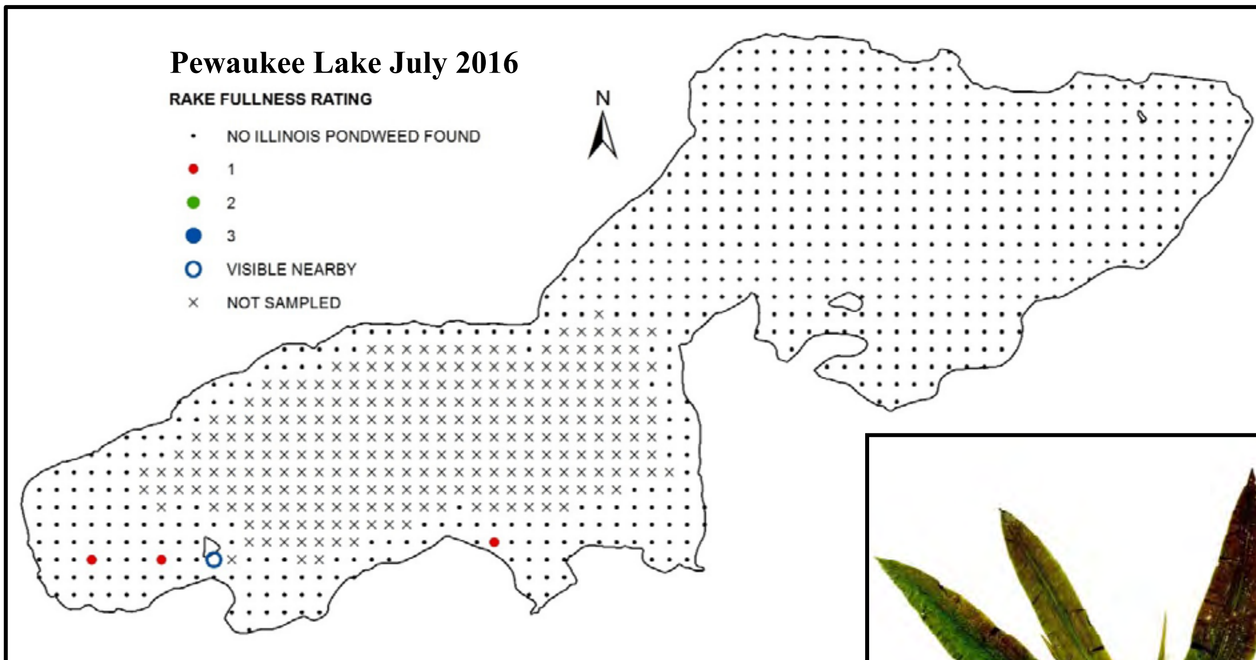
Identifying Features

- Stout stems up to 2.0 m long, often branched
- Submerged leaves with nine to 19 veins (midvein prominent) on short stalks (up to 4.0 cm) or attached directly to the stem
- Floating leaves, if produced, elliptical, with 13 to 29 veins
- Often covered with calcium carbonate in hard water

Variable pondweed (*P. gramineus*) is similar to Illinois pondweed, but differs in having three to seven veins on submerged leaves

Ecology

- Lakes with clear water, shallow or deep, neutral or hard, over soft sediments
- Overwinters as rhizomes or remains green under the ice
- Provides food for waterfowl, muskrat, deer, and beaver
- Provides excellent habitat for fish and aquatic invertebrates



Potamogeton natans — Floating-Leaf Pondweed

Native

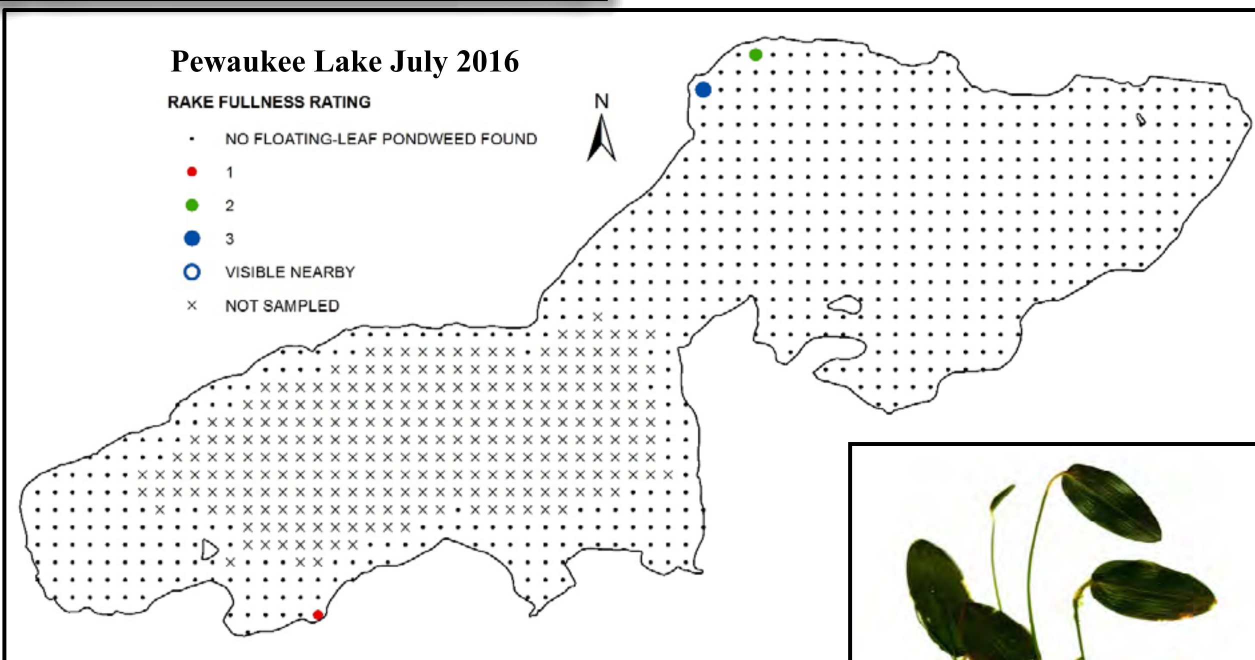
Identifying Features

- Floating leaves (5.0 to 10 cm long) with heart-shaped bases and 17 to 37 veins
- Floating leaf stalks bent where they meet the leaf, causing the leaf to be held at roughly a 90-degree angle to the stalk
- Submersed leaves (1.0 to 2.0 mm wide) linear and stalk-like, with three to five veins

Floating-leaf pondweed is similar to Oakes' pondweed (*P. oakesianus*) and spotted pondweed (*P. pulcher*). Oake's pondweed is smaller, with floating leaves 2.5 to 6.0 cm long and submersed leaves 0.25 to 1.0 mm wide. Spotted pondweed differs in having small black spots on its stems and leaf stalks and lance-shaped submersed leaves with wavy margins

Ecology

- Usually in shallow waters (<2.5 m) over soft sediment
- Emerges in spring from buds formed along rhizomes
- Provides food for waterfowl, muskrat, beaver, and deer
- Holds fruit on stalks until late in the growing season, which provides valuable feeding opportunities for waterfowl
- Provides good fish habitat



Potamogeton nodosus
Native

Long-Leaf Pondweed

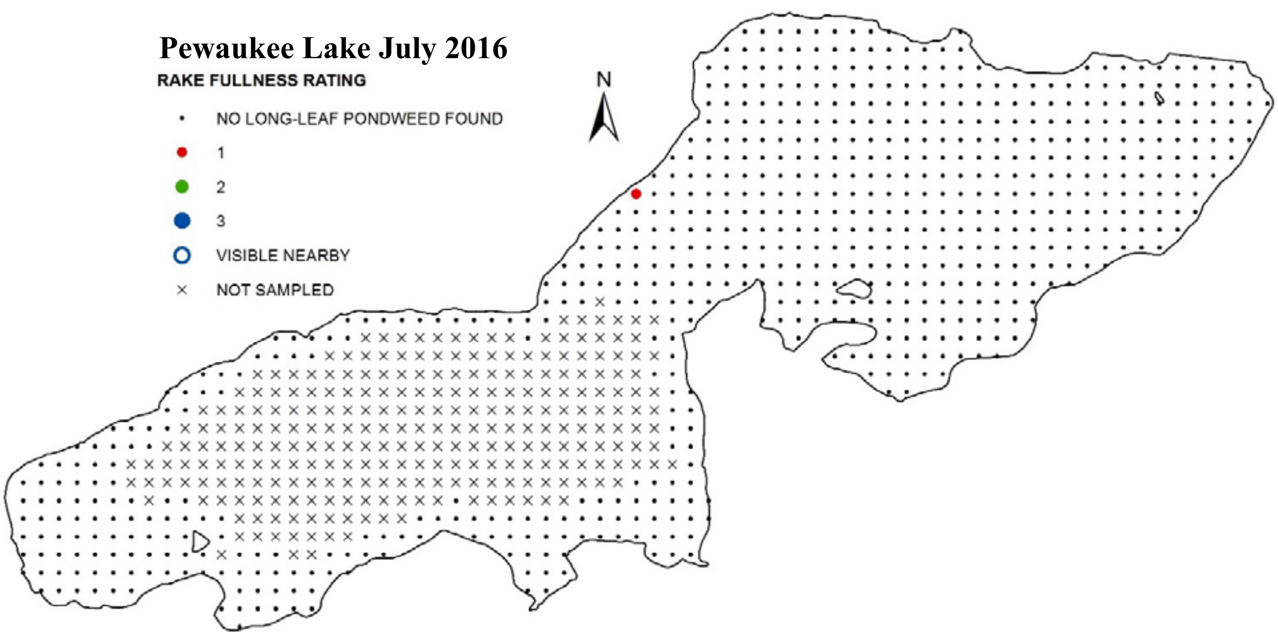
Identifying Features

- Floating leaves 5.0 to 13 cm long, tapering to leaf stalks that are longer than the attached leaf blades
- Submersed leaves up to 30 cm long and 1.0 to 2.5 mm wide, with seven to 15 veins, and long leaf stalks
- Stipules 4.0 to 10 cm long, free from the leaves, disintegrating by mid-summer

Long-leaf pondweed may be distinguished from other pondweeds that have similar floating leaves (e.g. *P. illinoensis* and *P. natans*) by the long leaf stalks of its submersed leaves. The floating leaves of *P. natans* also differ by having a heart-shaped base and by being held to the leaf stalks at roughly 90-degree angles. In *P. illinoensis* the stalks of floating leaves, if produced, are shorter than the leaf blades

Ecology

- Streams and lakes, shallow and deep, but more often in flowing water
- Emerges in spring from buds formed along rhizomes
- Provides food for waterfowl, muskrat, beaver, and deer
- Harbors large numbers of aquatic invertebrates, which provide food for fish



Potamogeton praelongus — White-Stem Pondweed

Native

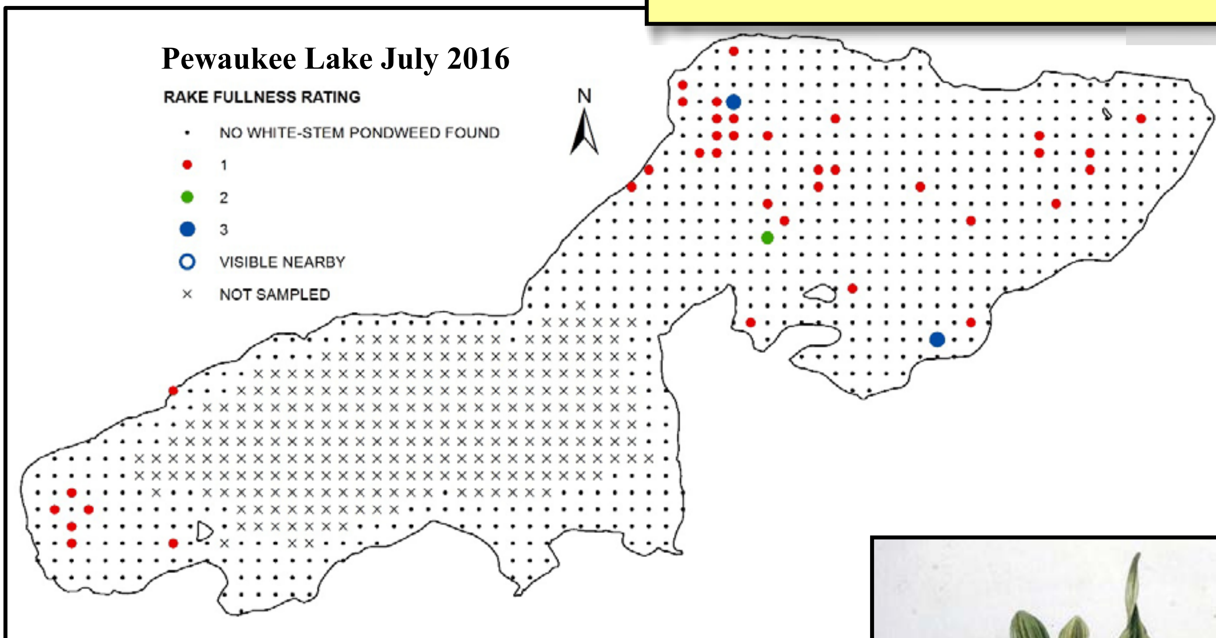
Identifying Features

- Stems usually pale and zig-zagging
- Leaves clasping, alternate, with three to five prominent veins and 11 to 35 smaller ones, with boat-shaped tips that often split when pressed between fingers

White-stem pondweed is similar to clasping pondweed (*P. richardsonii*), but the leaves of clasping pondweed do not have boat-shaped tips that split when pressed

Ecology

- Found in clear lakes in water three to 12 feet deep over soft sediments
- *"Indicator species"* due to its sensitivity to water quality changes; its disappearance indicating degradation; requires more natural areas that receive little disturbance
- Sometimes remains evergreen beneath the ice
- Provides food for waterfowl, muskrat, beaver, and deer
- Provides habitat for trout and muskellunge



Potamogeton pusillus — Small Pondweed

Native

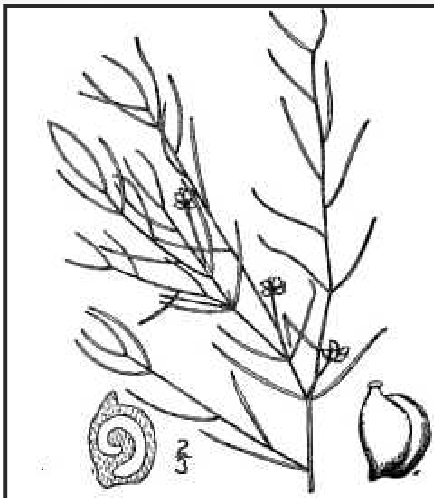
Identifying Features

- Narrow, submersed leaves (1-7 cm long and 0.2-2.5 mm wide), attaching directly to the stem, with 3 veins, leaf tips blunt or pointed, and often with raised glands where the leaf attaches to the stem
- Produces no floating leaves
- Numerous winter buds (turions) produced with rolled, inner leaves resembling cigars
- Flowers and fruits produced in whorls spaced along slender stalk

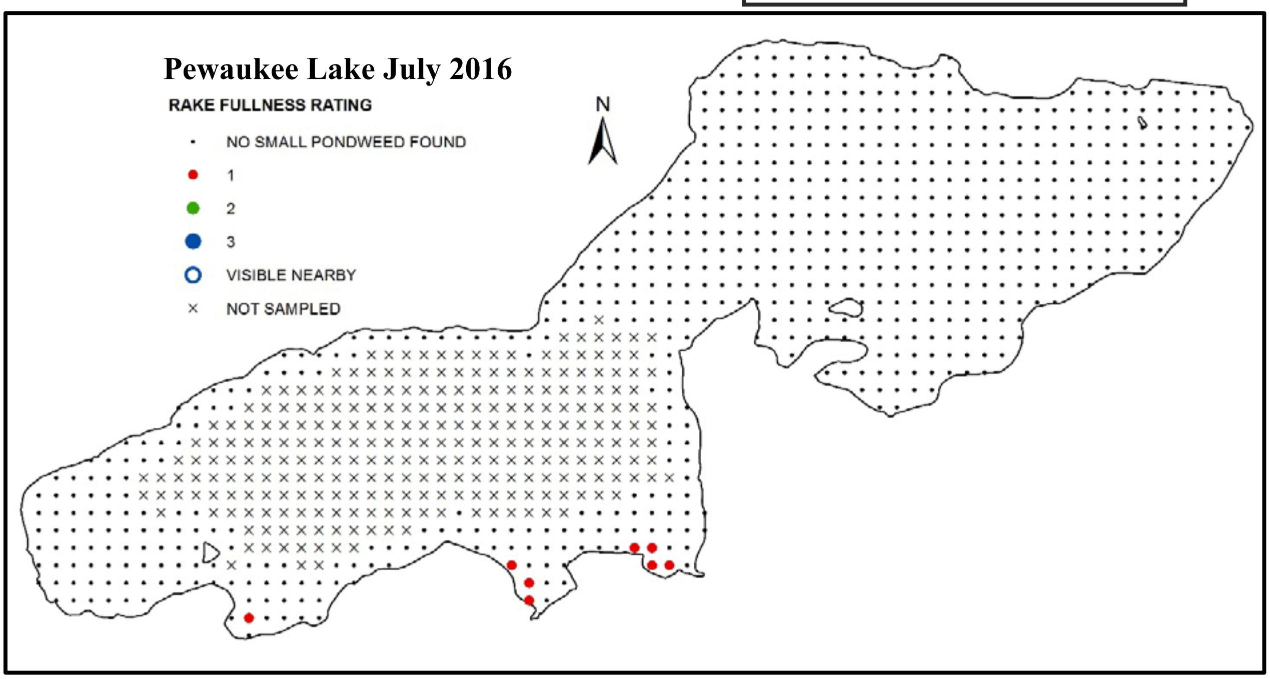
Small pondweed is similar to leafy pondweed (*P. foliosus*), when not in flower and fruit. However, unlike leafy pondweed, it often has raised glands where the leaves meet the stem. The flowers and fruits of small pondweed are also borne on longer, more slender stalks and in whorls that are spaced apart.

Ecology

- Shallow or deep waters over soft sediments in lake and streams
- Overwinters as rhizomes or winter buds (turions)
- Food for waterfowl, muskrat, deer, and beaver
- Cover for invertebrates and fish



USDA-NRCS PLANTS Database
Britton, N.L., and A. Brown. 1913. Illustrated flora of the northern states and Canada. Vol. 1: 84.



Potamogeton richardsonii — Clasping-Leaf Pondweed

Native

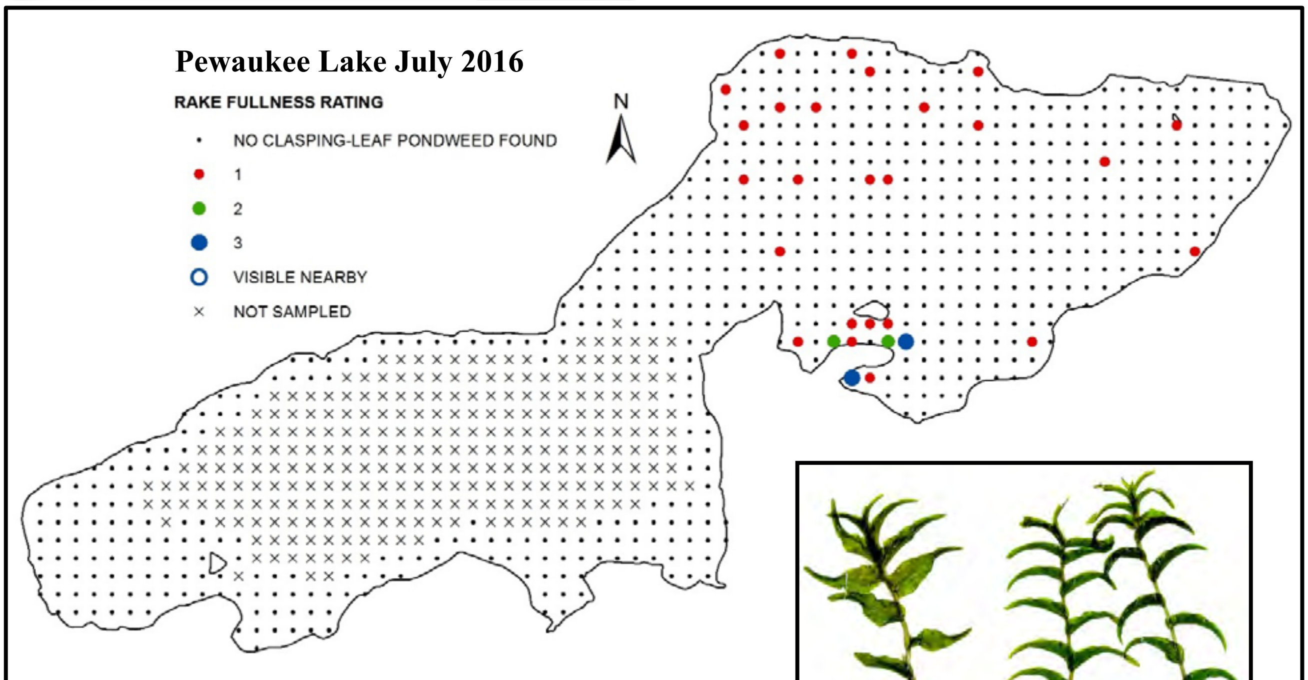
Identifying Features

- Leaves alternating along and clasping the stem, with wavy edges, coming to a point at the tip, and often with three to five veins prominent among many more that are faintly visible
- Produces no floating leaves

Clasping pondweed is similar to white-stem pondweed (*P. praelongus*), but the latter has boat-shaped leaf tips that split when pressed between one's fingers. The exotic curly-leaf pondweed (*P. crispus*) may appear similar, but differs by having serrated leaf margins

Ecology

- In lakes and streams, shallow and deep, often in association with coontail
- Tolerant of disturbance
- Fruits a food source for waterfowl and plants browsed by muskrat, beaver, and deer
- Stems emerging from perennial rhizomes



Potamogeton robbinsii — Robbins Pondweed or Fern Pondweed

Native

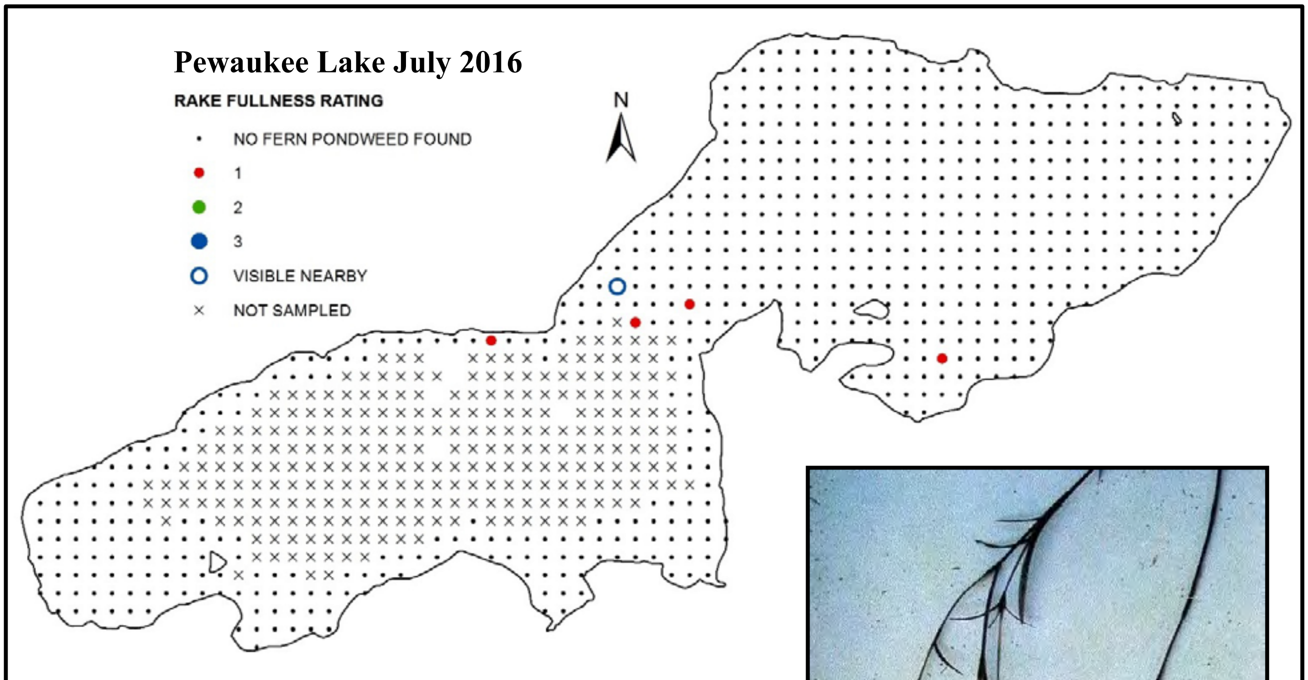
Identifying Features

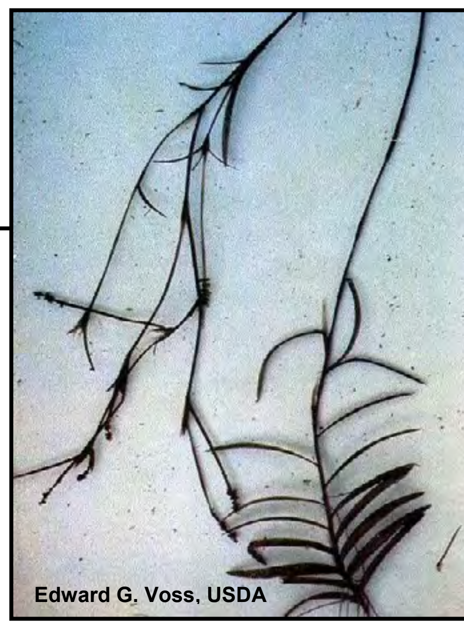
- Robust stems; stems and leaves often dark green to brown
- Leaves two-ranked (in opposite directions) along the stem, long and pointed, wrapping around the stem at the base, with edges finely serrated
- No floating leaves

Robbins pondweed is similar to flat-stem pondweed (*P. zosteriformis*) and water stargrass (*Zosterella dubia*), but is distinguished from both by its round stem

Ecology

- Lakes, often deeper than other pondweeds; requires more natural areas that receive little disturbance
- Plants often remaining green over the winter
- Regenerates from rhizomes and winter buds (turions), fruit only rarely produced
- Provides food for waterfowl
- Provides habitat for invertebrates and fish, particularly pike





Potamogeton zosteriformis Flat-Stem Pondweed

Native

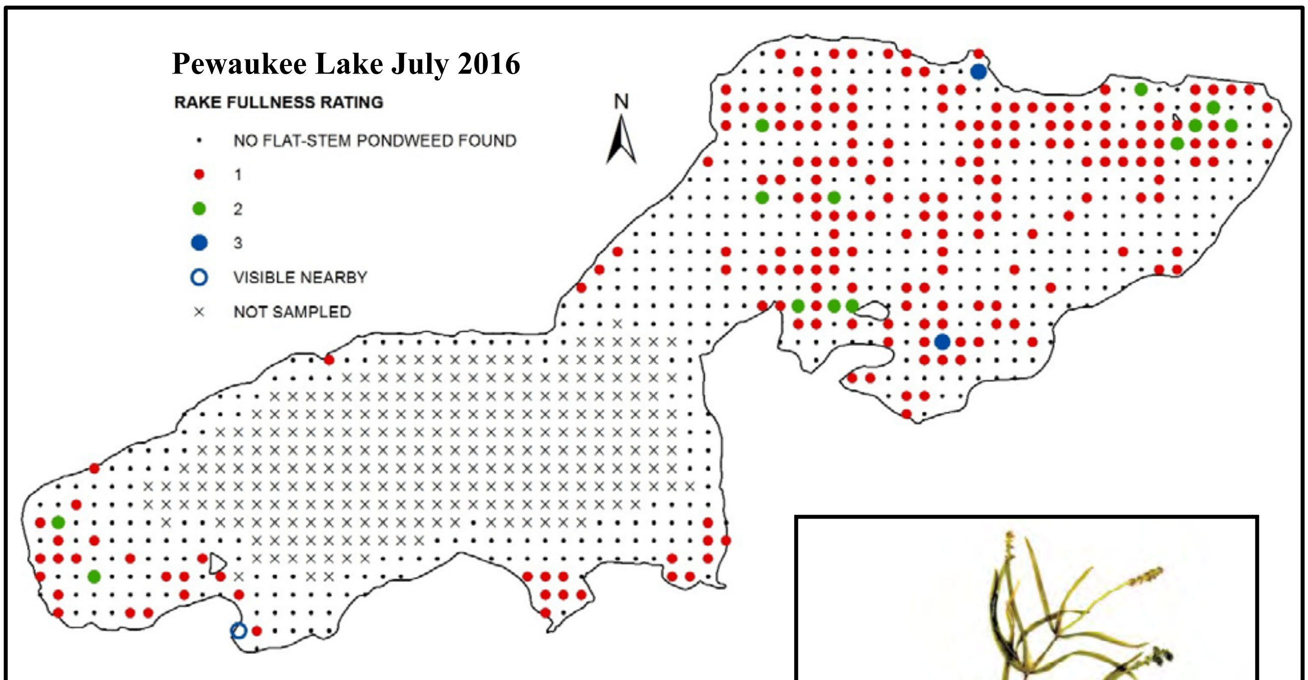
Identifying Features

- Stems strongly flattened
- Leaves up to four to eight inches long, pointed, with a prominent midvein and many finer, parallel veins
- Stiff winter buds consisting of tightly packed ascending leaves

Flat-stem pondweed may be confused with yellow stargrass (*Zosterella dubia*), but the leaves of yellow stargrass lack a prominent midvein.

Ecology

- Found at a variety of depths over soft sediment in lakes and streams
- Overwinters as rhizomes and winter buds
- Has antimicrobial properties
- Provides food for waterfowl, muskrat, beaver, and deer
- Provides cover for fish and aquatic invertebrates



Ranunculus aquatilis
Native

White Water Crowfoot

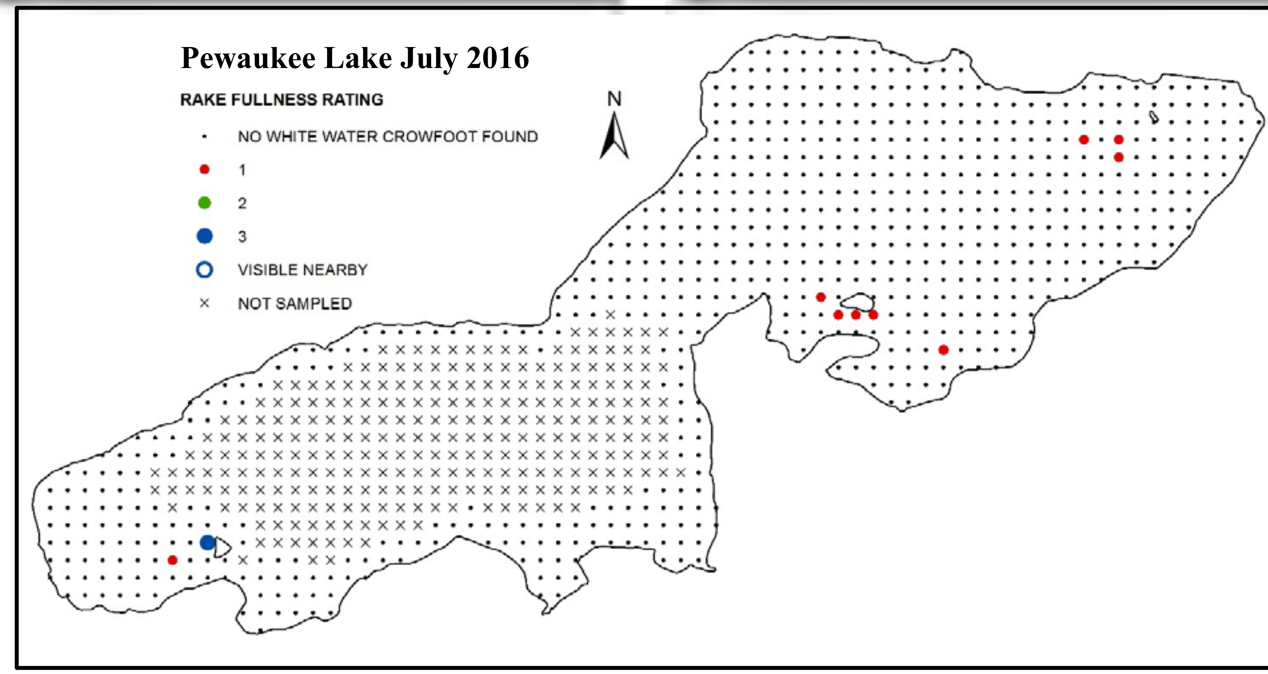
Identifying Features

- Submersed leaves finely divided into thread-like sections, and arranged alternately along the stem
- Flowers white, with five petals
- May or may not produce floating leaves

White water crowfoot is similar to other aquatic *Ranunculus* spp. However, the latter have yellow flowers and leaf divisions that are flat, rather than thread-like

Ecology

- Shallow water in lakes or streams, often with high alkalinity
- Often forms dense patches near springs or sand bars
- Emerges from rhizomes in the spring
- Fruit and foliage consumed by waterfowl and upland birds alike
- Habitat for invertebrates that are food for fish like trout



Stuckenia pectinata — Sago Pondweed

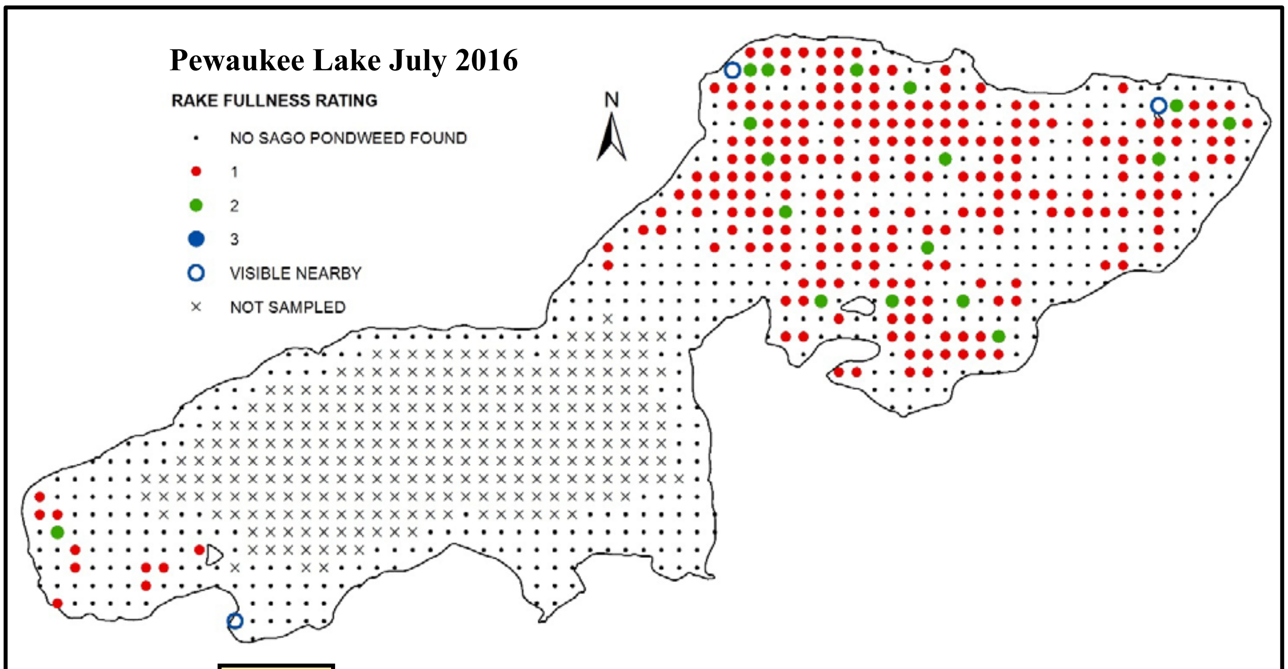
Native

Identifying Features

- Stems often *slightly zig-zagged* and forked multiple times, yielding a fan-like form
- Leaves one to four inches long, very thin, and ending in a sharp point
- Whorls of fruits spaced along the stem may appear as beads on a string

Ecology

- Lakes and streams
- Overwinters as rhizomes and starchy tubers
- Tolerates murky water and disturbed conditions
- Provides abundant fruits and tubers, which are an *important food for waterfowl*
- Provides habitat for juvenile fish



Fruits

Utricularia spp. — Bladderworts

Native

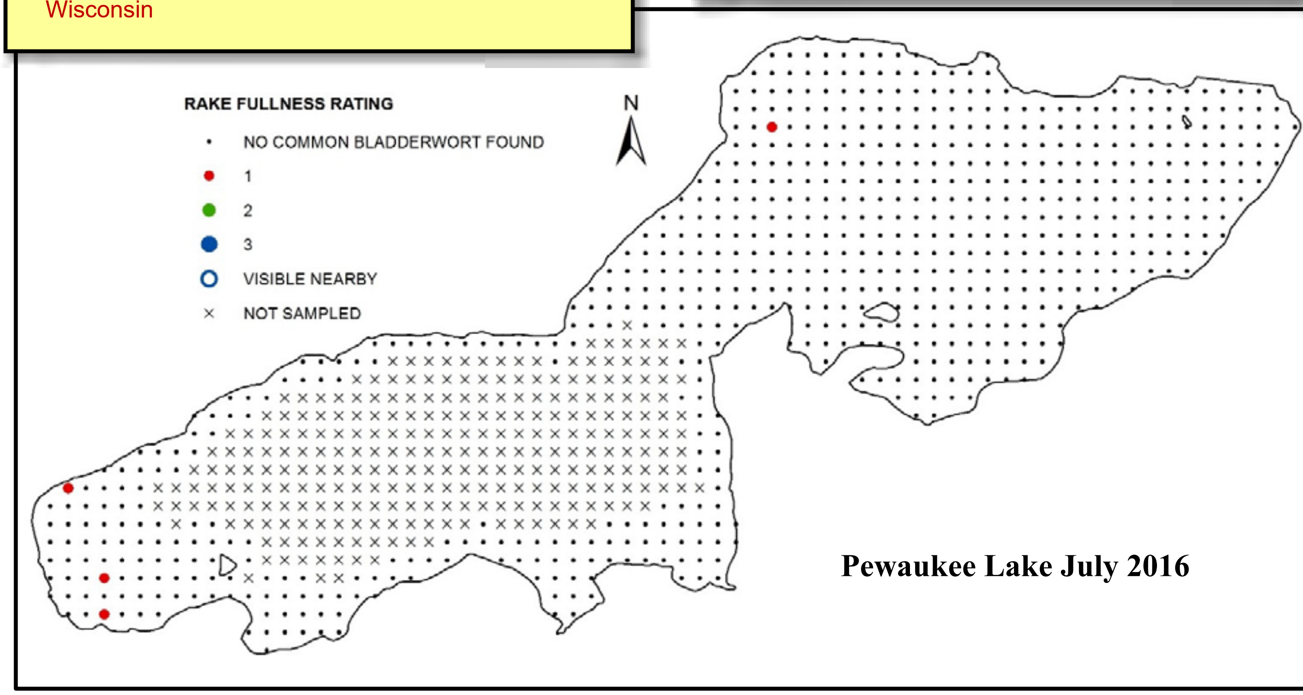
Identifying Features

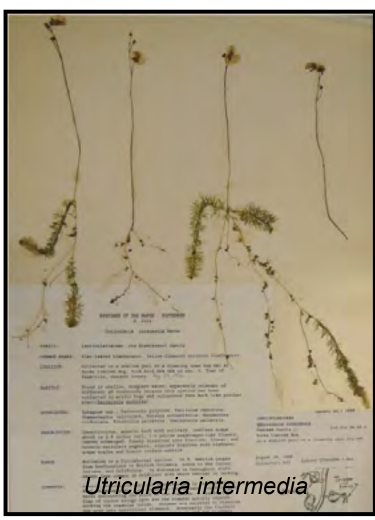
- Flowers snapdragon-like, yellow or purple, held on stalks above the water surface
- *Producing bladders* (small air chambers on the stem) that capture prey and give buoyancy to the stem
- Stems either floating (due to air bladders) or anchored in the substrate; branches finely divided, if floating

Several similar bladderworts occur in southeastern Wisconsin

Ecology

- Most species found in quiet shallows and along shores, but common bladderwort (*Utricularia vulgaris*) sometimes occurring in water several feet deep
- Provides forage and cover for a wide range of aquatic organisms
- Bladders capture and digest prey, including small invertebrates and protozoans




Utricularia intermedia


Utricularia gibba
David Midgley


Utricularia vulgaris
Kirill Ignatyev


Utricularia purpurea

Vallisneria americana — Eelgrass

Native

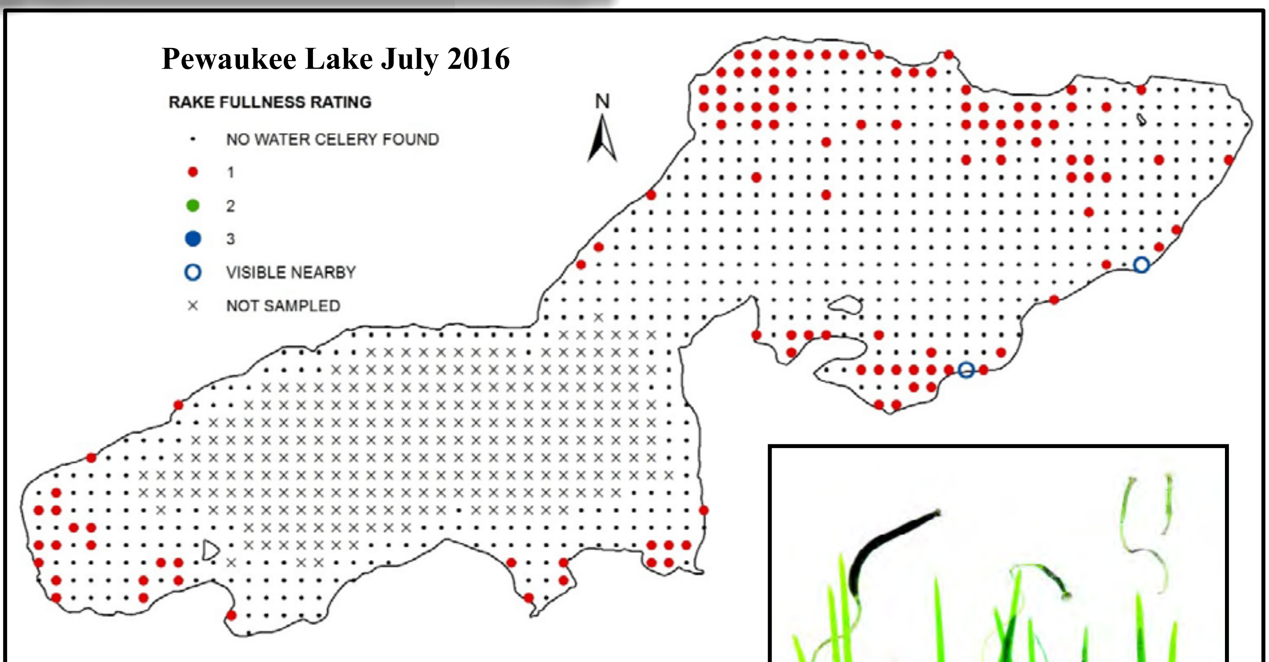
Identifying Features

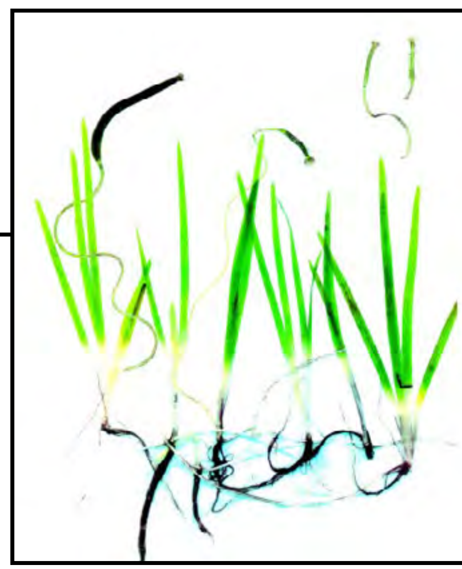
- Leaves ribbon-like, up to two meters long, with a prominent stripe down the middle, and emerging in clusters along creeping rhizomes
- Male and female flowers on separate plants, female flowers raised to the surface on spiral-coiled stalks

The foliage of eelgrass could be confused with the submersed leaves of bur-reeds (*Sparganium* spp.) or arrowheads (*Sagittaria* spp.), but the leaves of eelgrass are distinguished by their prominent middle stripe. The leaves of ribbon-leaf pondweed (*Potamogeton epihydrus*) are also similar to those of eelgrass, but the leaves of the former are alternately arranged along a stem rather than arising from the plant base

Ecology

- Firm substrates, shallow or deep, in lakes and streams
- Spreads by seed, by creeping rhizomes, and by offsets that break off and float to new locations in the fall
- All portions of the plant consumed by waterfowl; an especially important food source for Canvasback ducks
- Provides habitat for invertebrates and fish





APPENDIX E

STREAM CROSSING DESCRIPTION, LOCATION, CONDITION, FISH PASSAGE, AND NAVIGATION RATING ASSESSMENT IN THE PEWAUKEE LAKE TRIBUTARIES: 2012 AND 2015

Table E.1
Structure Description, Location, Condition, Fish Passage and Navigation Rating Assessment Within the Pewaukee Lake Watershed: 2012 and 2015

Structure Number on Map E.1 and Figure E.1	Description	Road Crossing	River Mile	Culvert/ Bridge Length (feet)	Ditch Erosion	General Condition	Limiting Water Depth (feet)[a]	Embedded Depth (feet)	Priority Rating and Recommendation Summary for Site: Fish Passage Rating	Recommended Actions	Navigation Hazard	Survey Year
					Coco Creek							
1	Metal and concrete bridge with abutments	Canadian Pacific Railway	0.00	40.9	Minor	Fair	3.3	--	Passable	None	No	2012
2	Concrete bridge with abutments	Glacier Road	0.11	36.5	Stable	Good	2.6	--	Passable	None	No	2012
3	Three seven-foot-wide, 4.7-foot-high corrugated metal pipe arch culverts	CTH JJ	0.52	46.0	Minor	Lannon stone wall surrounding culvert is failing	0.3	0.4	Passable	Debris removal, general maintenance	N/A	2012
4	One three-foot-diameter; one four-foot-diameter round corrugated metal culverts	Private culverts	0.81	14.0	Stable	Fair	0.4	0.0	Partial barrier at low flows	Remove	N/A	2012
6	One 5.6-foot-wide, 3.2-foot-high; one 5.6-foot-wide, two-foot-high corrugated metal pipe arch culverts	Yench Road	1.00	34.0	Stable	Lannon stone wall surrounding culvert is failing	1.0	0.5	Passable	General maintenance on structure headwall	N/A	2012
7	Four-3.0-foot-diameter concrete round projecting culverts	City of Pewaukee Private crossing	1.13	17.0	Moderate	Poor	0.9	0.0	Restricted Passage	Remove. All flow directed in culvert 2. Culverts 1, 3, and 4 are perched at inlet and outlet	N/A	2015
8	Span wood foot bridge	City of Pewaukee Private crossing	1.86	5.0	Moderate	Fair	--	--	Passable	Replace	N/A	2015
9	One eight-foot-wide, four-foot-high concrete box culvert	CTH KE Primary culvert	2.43	48.0	Stable	Good	1.0	1.5	Passable	None	N/A	2012
10	One eight-foot-wide, four-foot-high concrete box culvert	CTH KE Secondary culvert	2.43	48.0	Stable	Good	1.0	1.5	Passable	None	N/A	2015
12	Wood foot bridge with abutment on one side	Abandoned private crossing	2.69	8.0	Moderate	Fair	--	--	Passable	Remove, not necessary	N/A	2015
13	Three 3.5-foot-diameter smooth concrete headwall culverts	Underground	2.94	N/A	Minor	Fair	--	--	Barrier	Remove and daylight that stretch of stream	N/A	2015
14	One 12.4-foot-wide, six-foot-high concrete box culvert	CTH JK (Lisbon Avenue)	3.20	84.6	Stable	Good	0.2	0.0	Partial barrier at low flows	Remove or reconstruct rock weir	N/A	2012
15	Wood span walking bridge	Private crossing	3.54	--	Moderate	Poor	--	--	Passable	None	N/A	2015
16	Two eight-foot-wide, six-foot-high concrete box culverts	STH 16	3.56	298.0	Stable	Good	0.2	0.0	Passable	Debris removal at inlet	N/A	2012
17	One three-foot-diameter round smooth concrete culvert with apron	Juniper Drive	4.09	68.0	Stable	Fair	--	0.7	Passable	Replace culvert with more appropriate capacity	N/A	2015
18	One three foot diameter plastic round corrugated pipe at inlet. One three foot-wide, 2.5 foot-high square concrete culvert at outlet	Jungbluth Road	4.12	60.0	Stable	Fair	--	0.0	Passable	Replace culvert with more appropriate capacity	N/A	2015
19	One three-foot-diameter round smooth concrete culvert completely exposed	No Road	4.37	16.0	Stable	Poor. Split at seams	--	0.0	Passable	Remove, not necessary	N/A	2015

Table continued on next page.

Table E.1 (Continued)

Structure Number on Map E.1 and Figure E.1	Description	Road Crossing	River Mile	Culvert/ Bridge Length (feet)	Ditch Erosion	General Condition	Limiting Water Depth (feet)[a]	Embedded Depth (feet)	Priority Rating and Recommendation Summary for Site			
									Fish Passage Rating	Recommended Actions	Navigation Hazard	Survey Year
Coco Creek (continued)												
20	Two three-foot-diameter round corrugated metal culverts	South Willow Creek Drive	4.68	43.0	Minor	Fair	--	0.2	Partial barrier at low flows	General maintenance	N/A	2015
21	Two three-foot-diameter round corrugated metal culverts	North Courtland Circle	4.72	44.0	Stable	Fair	--	0.3	Partial barrier at low flows	General maintenance	N/A	2015
22	Two three-foot-diameter round corrugated metal culverts	Lynndale Lane	4.95	41.0	Stable	Fair	--	0.5	Partial barrier at low flows	General maintenance	N/A	2015
Tributary to Coco Creek												
5	Four five-foot-diameter round concrete culverts	STH 16	0.04	200.0	Stable	Good	1.6	0.6	Partial barrier	Replace culverts with more appropriate capacity	N/A	2012
11	One three-foot-diameter round corrugated metal culvert	CTH JJ (Capitol Drive)	0.18	35.5	Stable	Good	--	0.4	Partial barrier at low flows	Reconstruct around apron	N/A	2015
23	Two four-foot-diameter round corrugated metal culverts	CTH KF (Ryan Road)	1.34	94.0	Minor	Fair	0.2	0.2	Partial barrier at low flows	Remove boulder/ cobble pile at inlet	N/A	2012
Meadowbrook Creek												
24	One 10-foot-wide, seven-foot-high corrugated metal pipe arch culvert	CTH SS	0.00	38.0	Moderate	Fair	1.6	0.0	Passable	General maintenance, erosion control at inlet	N/A	2012
25	One 5.3-foot-wide, 5.9-foot-high ellipse corrugated metal culvert	CTH G	1.11	58.7.0	Minor	Concrete wall surrounding culvert is failing	3.0	0.1	Passable	General maintenance, debris clearing downstream of outlet	N/A	2012
25a (not pictured)	Man-made weir made of riprap and cobble	Man-made weir	1.45	--	--	--	--	--	Partial barrier at low flows	Removal	N/A	2012
25b (not pictured)	Man-made weir made of riprap and cobble	Man-made weir	1.64	--	--	--	--	--	Partial barrier at low flows	Removal	N/A	2012
26	One four-foot-wide, 3.4-foot-high ellipse corrugated metal culvert	Pewaukee Golf Club bridge #1	1.68	20.0	Moderate	Fair	--	0.0	Passable	General maintenance, inlet has minor lip, restricted flow	N/A	2015
27	One four-foot-diameter round corrugated metal culvert	Pewaukee Golf Club bridge #2	1.76	20.0	Stable	Poor, crushed	--	1.0	Barrier	Replace, severely crushed in center. Inlet end raised.	N/A	2015
28	One three-foot-diameter round corrugated metal culvert	Pewaukee Golf Club bridge #3	1.82	20.0	Minor	Poor, rusted through	--	0.3	Passable	Replace	N/A	2015
29	One three-foot-diameter round corrugated metal culvert	Pewaukee Golf Club bridge #4	1.92	20.0	Stable	Fair	--	0.1	Passable	None	N/A	2015
30	One three-foot-diameter round corrugated metal culvert	Pewaukee Golf Club bridge #5	2.02	20.0	Stable	Poor, rusted through	--	0.0	Passable	Replace	N/A	2015
31	One 10-foot-wide, six-foot-high concrete box culvert	Fieldhack Drive	2.10	65.0	Stable	Good	0.3	0.9	Passable	General maintenance, debris removal upstream	N/A	2012
32	One 10-foot-wide, six-foot-high concrete box culvert	Milkweed Lane	2.35	65.0	Minor	Good	0.1	0.2	Partial barrier at low flows	Erosion control at inlet	N/A	2012

Table continued on next page.

Table E.1 (Continued)

Structure Number on Map E.1 and Figure E.1	Description	Road Crossing	River Mile	Culvert/ Bridge Length (feet)	Ditch Erosion	General Condition	Limiting Water Depth (feet)[a]	Embedded Depth (feet)	Priority Rating and Recommendation Summary for Site: Fish Passage Rating	Recommended Actions	Navigation Hazard	Survey Year
Meadowbrook Creek (continued)												
33	One three-foot-diameter round corrugated metal culvert at inlet. Outlet is cement	Private crossing	2.55	20.0	Moderate	Fair	--	0.0	Passable	Remove, not necessary	N/A	2015
Zion Creek												
34	Two six-foot-wide, 4.8-foot-high corrugated metal pipe arch culverts	Louis Avenue	0.04	35.7	Minor	Fair	1.7	0.5	Passable	Erosion control at inlet	N/A	2012
35	One eight-foot-wide, five-foot-high concrete box culvert	Oakton Avenue	0.19	52.6	Stable	Good	0.3	0.0	Passable	Monitor condition of adjacent Lannon stone walls	N/A	2012
36	Metal weir at span golf cart bridge	Western Lakes Golf Club	0.32	--	--	--	--	--	Barrier	Remove	N/A	2015
37	One 4.7-foot-wide, 3.0-foot-high ellipse corrugated metal culvert	Western Lakes Golf Club	0.53	30.0	Minor	Fair	--	0.0	Passable	None	N/A	2015
38	One 4.7-foot-wide, 3.0-foot-high ellipse corrugated metal culvert	Western Lakes Golf Club	0.57	24.0	Moderate	Fair, bent inlet	--	0.0	Passable	General maintenance, remove wooden ledge from inlet	N/A	2015
39	One 4.7-foot-wide, 3.0-foot-high ellipse corrugated metal culvert	Western Lakes Golf Club	0.64	24.0	Minor	Fair	--	0.0	Passable	None	N/A	2015
40	One 3.0-foot-wide, 2.0-foot-high ellipse corrugated metal culvert	Western Lakes Golf Club	0.74	30.0	Minor	Fair	--	0.0	Barrier	Reconstruct, outlet perched 0.7-feet, inlet is being undercut; above streambed	N/A	2015
41	One 3.0-foot-wide, 2.0-foot-high ellipse corrugated metal culvert	Western Lakes Golf Club	0.84	30.0	Minor	Fair	--	0.0	Passable	None	N/A	2015
42	One 12-foot-wide, six-foot-high concrete box culvert	Gof Road and Interstate 94	1.00	250.0	Minor	Good	--	0.2	Passable	None	N/A	2015

Note: The yellow and red colors indicate moderate and high priority ratings or problems to address fish passage and navigation hazards in the watershed.

[a] *The 2015 instream survey data does not contain limiting water depth.*

Source: SEWRPC

Figure E.1
Stream Crossings and Dam Locations in the Pewaukee Lake Tributaries: 2012 and 2015

1- CANADIAN PACIFIC RAILWAY
COCO CREEK (RM 0.00)

2-GLACIER ROAD
COCO CREEK (RM 0.11)

3- CTH JJ
COCO CREEK (RM 0.52)

4- PRIVATE CULVERTS
COCO CREEK (RM 0.81)

5- STH 16
COCO CREEK **TRIBUTARY** (RM 0.04)

6- YENCH ROAD
COCO CREEK (RM 1.00)

7- CITY OF PEWAUKEE CROSSING
COCO CREEK (RM 1.13)

8- PRIVATE WALKING BRIDGE
COCO CREEK (RM 1.86)

9- CTH KE PRIMARY CULVERT
COCO CREEK (RM 2.43)

10- CTH KE **SECONDARY** CULVERT
COCO CREEK (RM 2.43)

11 CTH JJ
COCO CREEK **TRIBUTARY** (RM 0.18)

12- ABANDONED PRIVATE CROSSING
COCO CREEK (RM 2.69)

Figure E.1 (Continued)

13- UNDERGROUND CULVERTS
COCO CREEK (RM 2.94)

14- CTH JK (LISBON AVENUE)
COCO CREEK (RM 3.20)

15-PRIVATE WALKING BRIDGE
COCO CREEK (RM 3.54)

16- STH 16
COCO CREEK (RM 3.56)

17- JUNIPER WAY
COCO CREEK (RM 4.09)

18- JUNGBLUTH ROAD
COCO CREEK (RM 4.12)

19- ABANDONED CULVERT
COCO CREEK (RM 4.37)

20- S. WILLOW CREEK DRIVE
COCO CREEK (RM 4.68)

21- N. COURTLAND CIRCLE
COCO CREEK (RM 4.72)

22- LYNNDALE LANE
COCO CREEK (RM 4.95)

23- CTH KF (RYAN ROAD)
COCO CREEK **TRIBUTARY** (RM 1.34)

24- CTH SS
MEADOWBROOK (RM 0.00)

Figure E.1 (Continued)

25- CTH G
MEADOWBROOK (RM 1.11)

26- PEWAUKEE GOLF CLUB BRIDGE 1
MEADOWBROOK (RM 1.68)

27- PEWAUKEE GOLF CLUB BRIDGE 2
MEADOWBROOK (RM 1.76)

28- PEWAUKEE GOLF CLUB BRIDGE 3
MEADOWBROOK (RM 1.82)

29- PEWAUKEE GOLF CLUB BRIDGE 4
MEADOWBROOK (RM 1.92)

30- PEWAUKEE GOLF CLUB BRIDGE 5
MEADOWBROOK (RM 2.02)

31- FIELDHACK DRIVE
MEADOWBROOK (RM 2.10)

32- MILKWEED LANE
MEADOWBROOK (RM 2.35)

33- PRIVATE CULVERT
MEADOWBROOK (RM 2.55)

34- LOUIS AVENUE
ZION CREEK (RM 0.04)

35- OAKTON AVENUE
ZION CREEK (RM 0.19)

36- WESTERN LAKES GOLF CLUB WEIR
ZION CREEK (RM 0.32)

Figure E.1 (Continued)


37- WESTERN LAKES GOLF CLUB CULVERT 1 ZION CREEK (RM 0.53)


38- WESTERN LAKES GOLF CLUB CULVERT 2 ZION CREEK (RM 0.57)


39-WESTERN LAKES GOLF CLUB CULVERT 3 ZION CREEK (RM 0.64)

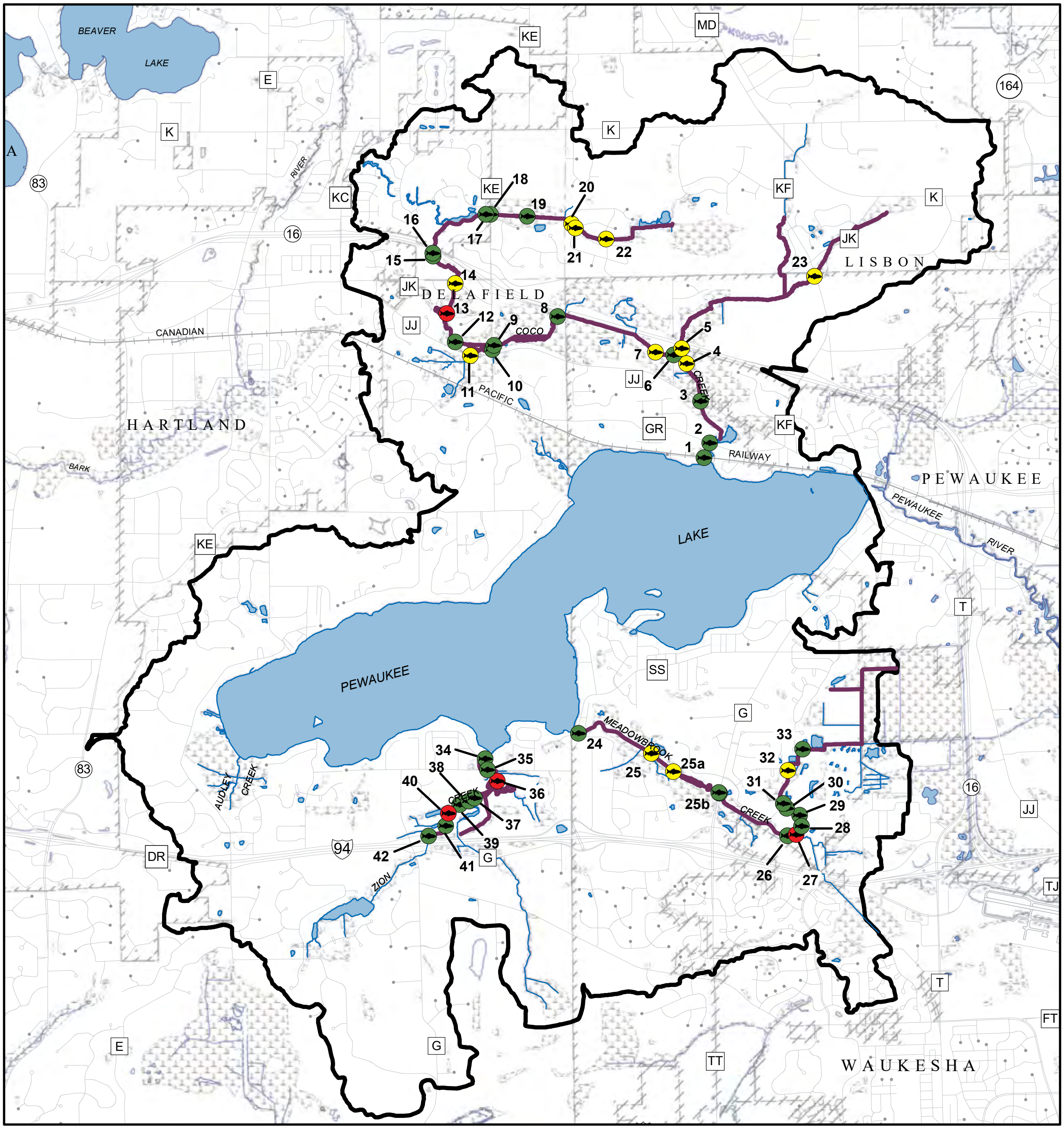

40- WESTERN LAKES GOLF CLUB CULVERT 4 ZION CREEK (RM 0.74)


41- WESTERN LAKES GOLF CLUB CULVERT 5 ZION CREEK (RM 0.84)


42- I-94 ZION CREEK (RM 1.00)

Source: SEWRPC

Map E.1
Fish Passage Assessments at Stream Crossings in the Pewaukee Lake Tributaries: 2012 and 2015



FISH PASSAGE RATING:
(see Table E.1 and Figure E.1 for details of each crossing)

3 PASSABLE

7 PARTIAL BARRIER AT ALL TIMES OR DURING LOW FLOW PERIODS

13 SIGNIFICANT BARRIER

SURFACE WATER

STREAM (NOT SURVEYED)

WATERSHED BOUNDARY

WETLAND

STREAM (SURVEYED)

0 1,250 2,500 5,000 Feet

Source: SEWRPC

Note: Structures were surveyed during the summer of 2012 and 2015, indicating fish passage ratings may have changed since the survey was taken.

TYPES OF CROSSINGS[1]

- The number of stream crossings should be minimized.

- If a crossing is necessary, structures that maintain to the extent possible the existing streambed and bank conditions are preferable; therefore, bridges spanning streams are preferable to other structures.

- If a culvert is necessary, open bottom structures are preferable to closed bottom structures.

- If a closed bottom culvert is necessary, box culverts, elliptical, or pipe arch culverts are preferable to round pipe culverts, because round pipes generally reduce stream width to a much larger degree than the aforementioned structures, causing long term upstream and downstream passage limitations (see physical considerations below).

- Offsetting Multiple Culverts—If multiple culverts are necessary, it is recommended that the culvert inverts be offset vertically and only one culvert be designed to provide passage during low flow conditions and the additional culverts be used to pass the higher flow events (see Figure E.2). Therefore, the low flow culvert will be the only culvert, in a series of two or more culverts, designed to provide fish passage during low flows and shall meet the physical requirements of passage above.

BIOLOGICAL CONSIDERATIONS[2]

- Contact the area WDNR fisheries manager prior to design and construction to minimize impacts.[3]

- Species of fish present (coldwater, warmwater, threatened, endangered, species of special concern).

- Life stages to potentially be impacted (e.g., egg development within substrates should be avoided).

- Migration timing of affected species/ life stages (e.g., adult spawning times should be avoided).

PHYSICAL CONSIDERATIONS[4]

It is important to note that in order to achieve the minimum physical criteria outlined below, the culvert(s) will need to be oversized as part of the design to ensure adequate long-term fish passage as well as the ability to pass the design period rainfall event.

It is understood that it may not be possible to achieve some of the minimum passage criteria below based upon specific on-site conditions or constraints, however, the closer the designed and completed culvert can meet these criteria the better the long-term passage and overall sustainability of the fishery will be achieved in this region.

Figure E.2
Considerations for Culvert Design and Placement

Source: Minnesota Department of Natural Resources

Provide Adequate Depth

- Slope—Culvert should be installed with a slope that matches the riffle slope as measured in the thalweg[5] (see Minnesota DNR guidelines)[6]

- Water Depth and Velocity—Water depths and velocities should be comparable to those found in the natural channel at a variety of flows. Depths should maintain the determined thalweg depth at any point within the culvert during low flow periods (see Minnesota DNR guidelines).

- Installation Below Grade—The culvert should be installed so that the bottom of the structure is buried to a depth equal to 1/6th the bankfull width of the stream (up to two feet) below the natural grade line elevation of the stream bottom (see Minnesota DNR guidelines). The culvert should then be filled to stream grade with natural substrates. The substrates should consist of a variety of gravel ranging from one to four inches in diameter and either mixed with nonuniformly laid riprap or uniformly placed alternate riprap baffles, large enough to be stable during the culvert design discharge, which will ensure stability of substrates during high flow events.

Provide Adequate Width and Openness

- Crossing Span (see Massachusetts Stream Crossings Handbook):[7]

  - General—Spans channel width (a minimum of 1.2 times the bankfull with of the stream).

  - Optimum—Spans the streambed and banks (at least 1.3 times the bankfull width) with sufficient capacity to provide dry passage for wildlife (see Figure E.3). Culvert width shall match the bankfull width (minimum) of the existing channel.

- Openness (see Massachusetts Stream Crossings Handbook):[8]

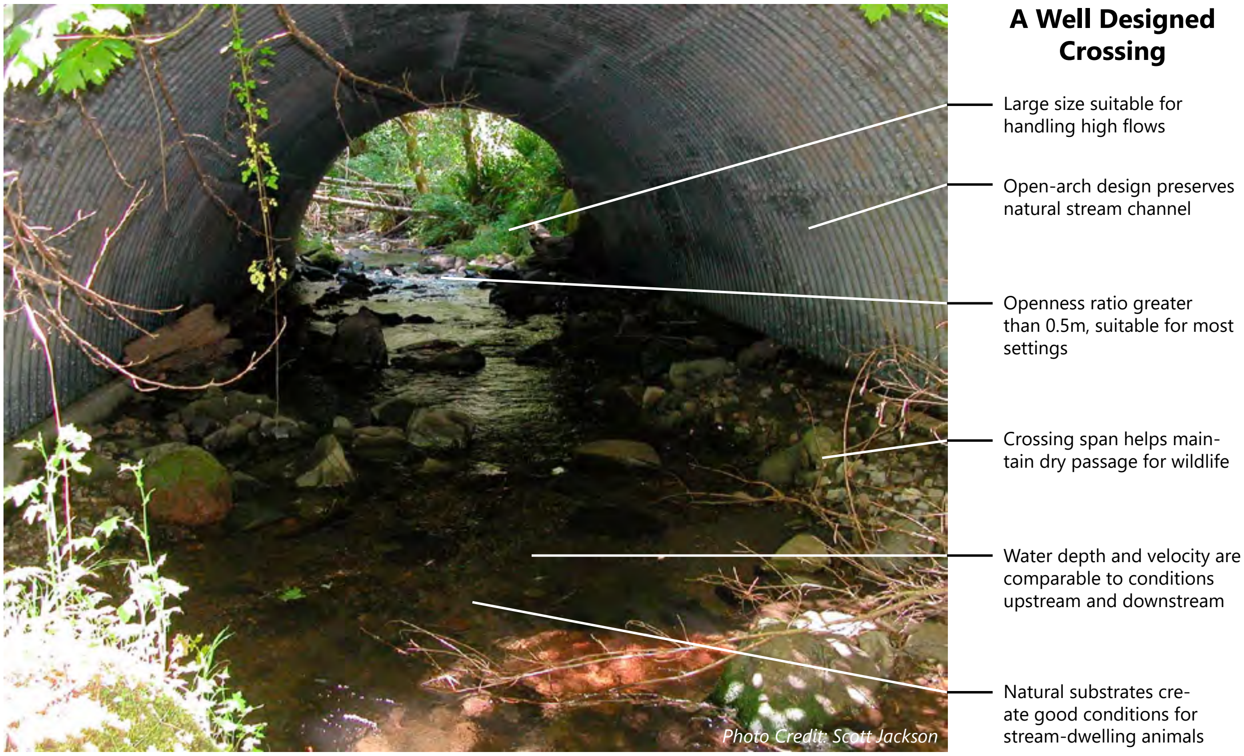
  - General—Openness ratio (cross sectional area/crossing length) of at least 0.82 feet. The crossing should be wide and high relative to its length.

  - Optimum—Openness ratio of at least 1.64 feet and minimum height of six feet. If conditions significantly reduce wildlife passage near a crossing (e.g. steep embankments, high traffic volumes, or other physical barriers), maintain a minimum height of eight feet and openness ratio of 2.46 feet.

[5] *The thalweg is the lowest point of the streambed.*

[6] *Minnesota DNR,* Best Practices for Meeting DNR General Public Waters Work Permit GP *2004-0001, March 2006.*

Figure E.3
Key Features that Promote Fish and Wildlife Passage



Source: Department of Fish and Game, Massachusetts Stream Crossings Handbook, *June 2012*

Provide Adequate Resting Areas

- Length—Culverts that exceed more than 75 feet in length need to provide additional resting areas (e.g., installation of baffles or weirs) within the culvert to facilitate passage.[9]

Inlet and Outlet Protection

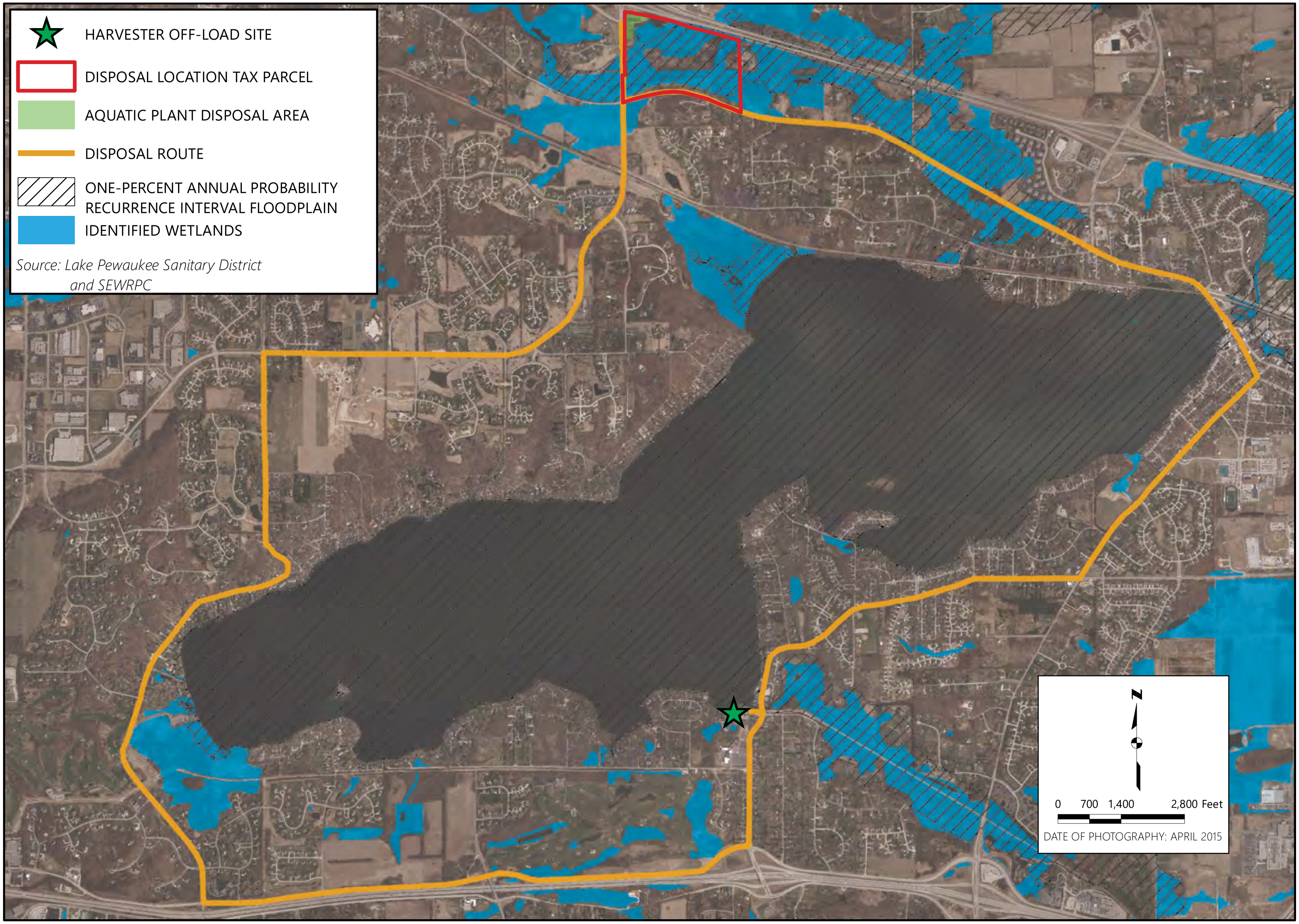
- Align the culvert with the existing stream alignment (e.g., 90 degree bends at the inlet or outlet should be avoided, even though this will increase culvert length, see Minnesota DNR guidelines).[10]
- The low flow culvert should be centered on the thalweg of the channel to ensure adequate depths inside the culvert.
- Provide grade control where there is potential for head-cuts that could degrade the channel.
- It may be necessary to install riprap protection on the outside bank below the outlet to reduce bank erosion during high flow events.

[9] *Thomas Slawski and Timothy Ehlinger, "Habitat Improvement in Box Culverts: Management in the Dark?,"* North American Journal of Fisheries Management, *Volume 18:676-685, 1998.*

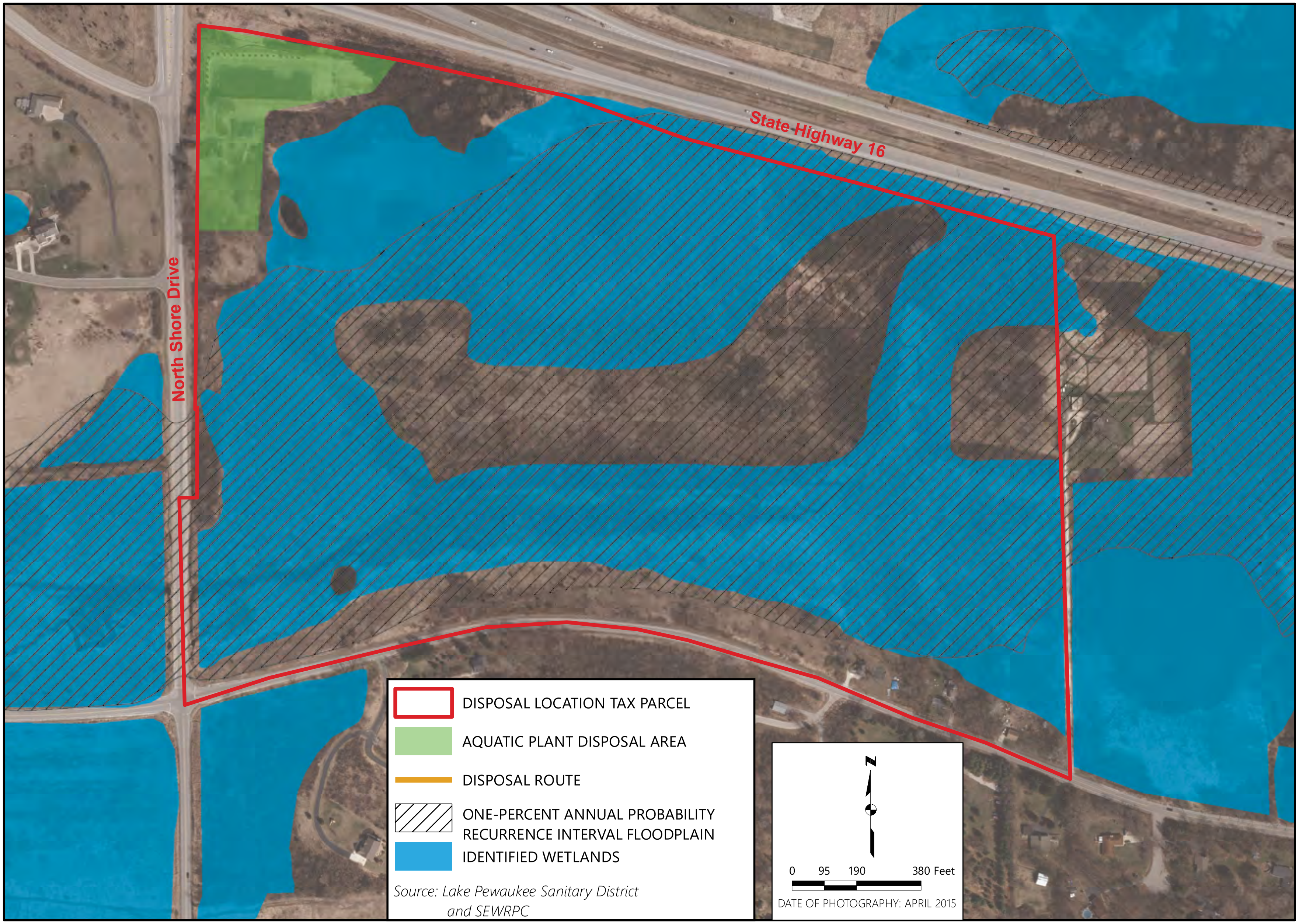
APPENDIX F

HARVESTING INFORMATION

Map F.1
Mechanical Harvesting Disposal Site Location, Off-Load Site, and Haul Routes for Lake the Pewaukee Sanitary District, Pewaukee Lake: 2017-2021

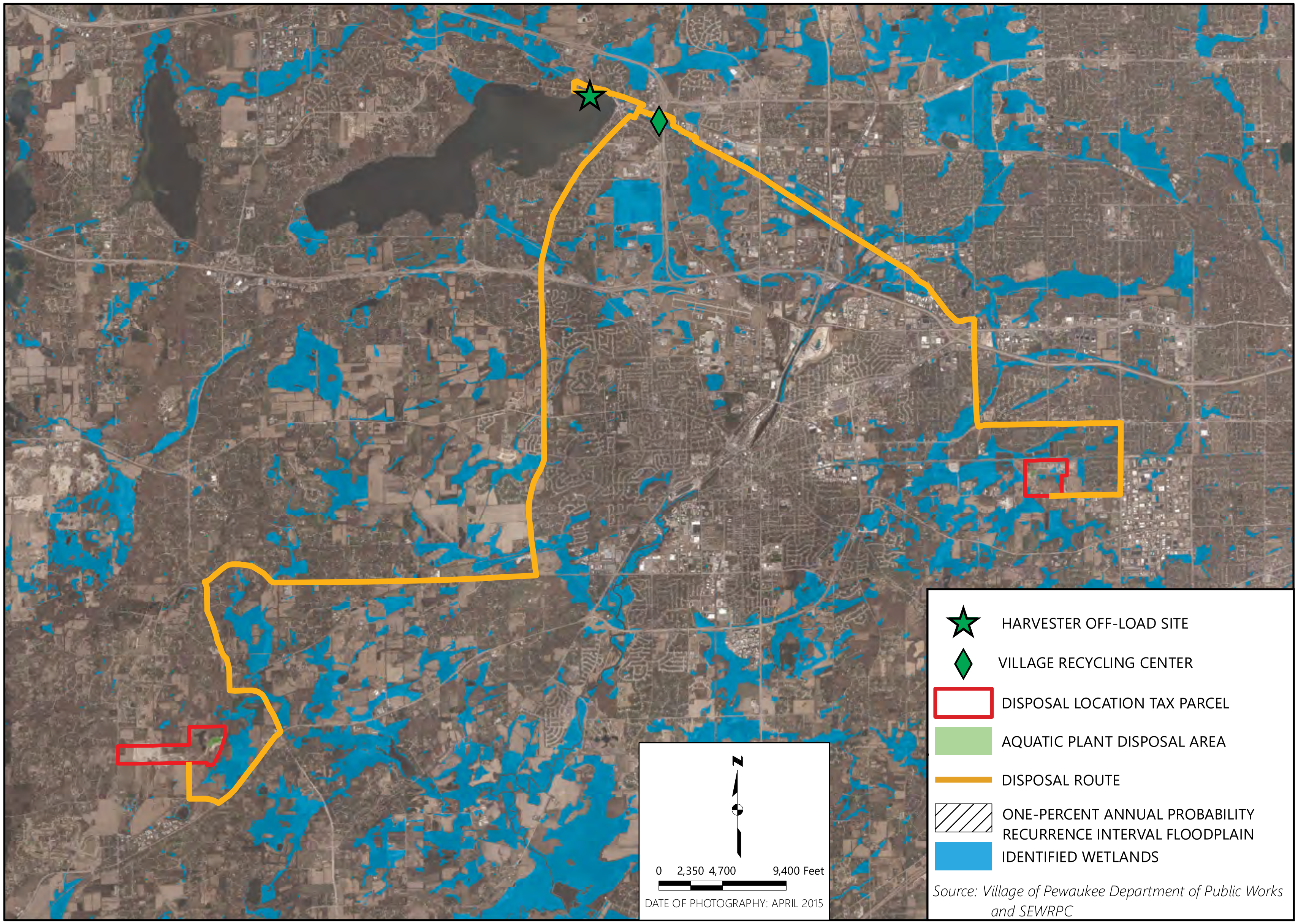


Map F.2
Mechanical Harvesting Disposal Site Location for the Lake Pewaukee Sanitary District, Pewaukee Lake: 2017-2021



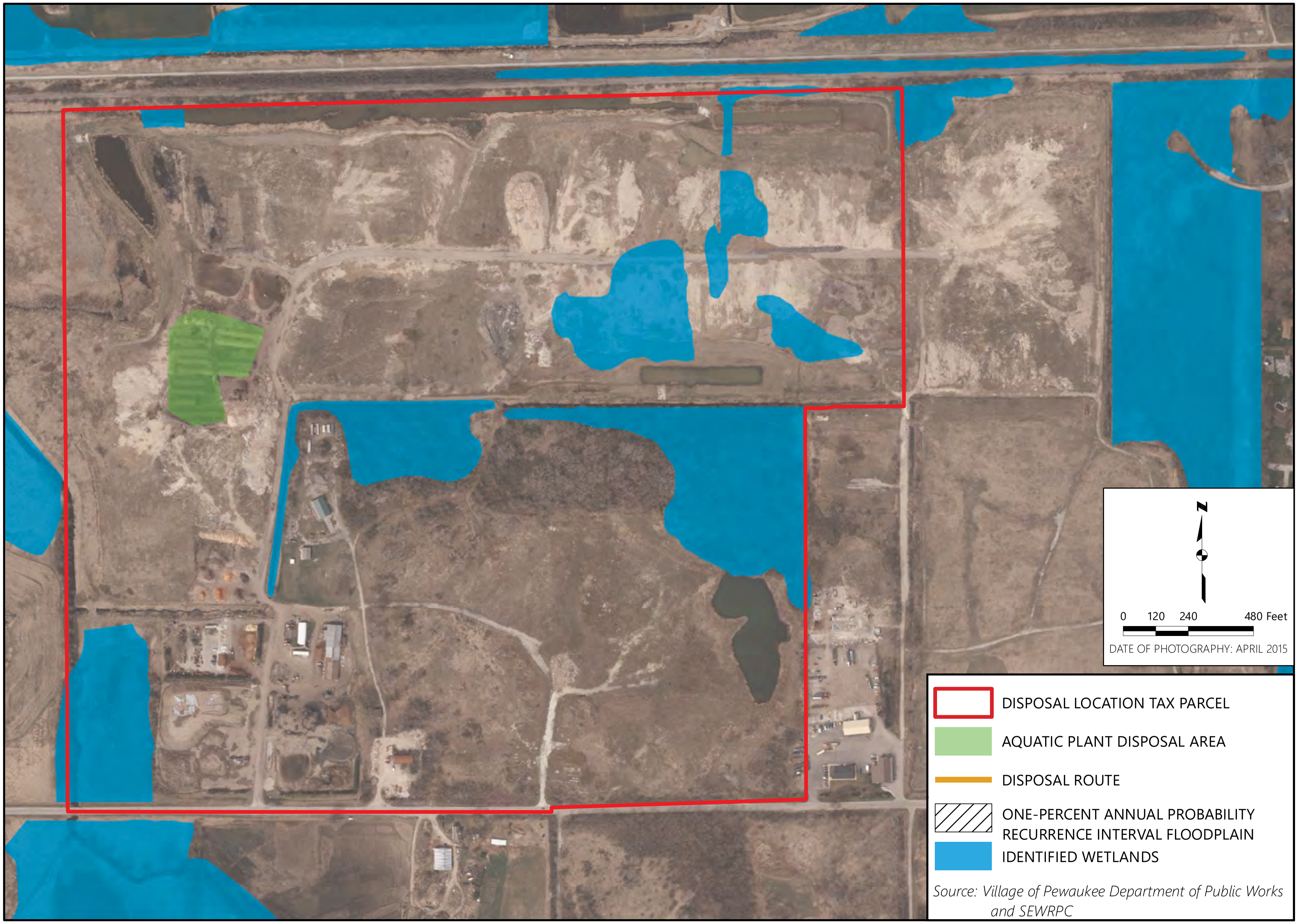
Source: Lake Pewaukee Sanitary District and SEWRPC

Map F.3
Mechanical Harvesting Disposal Site Location, Off-Load Site, and Haul Routes for the Village of Pewaukee Department of Public Works, Pewaukee Lake: 2017-2021



Source: Village of Pewaukee Department of Public Works and SEWRPC

Map F.4
Southeastern Mechanical Harvesting Disposal Site Location for the Village of Pewaukee Department of Public Works, Pewaukee Lake: 2017-2021



Source: Village of Pewaukee Department of Public Works and SEWRPC

Map F.5

Southern Mechanical Harvesting Disposal Site Location for the Village of Pewaukee Department of Public Works, Pewaukee Lake: 2017-2021