Gabriola Streamkeepers—Water levels and quality

Observations at Coats Marsh, Gabriola Island

—with notes on Coats Marsh Creek, East Path Creek, and Stump Farm Streams.

Water balance and catchment area calculations

The master file is:

Observations at Coats Marsh RP , File 673 .

Observation files containing field notes are:

2015: Supplementary file "Field Observations 2015", File 673d.

2016 (Jan. - Mar.): Supplementary file "Field Observations 2016-1", File 673e.

2016 (Apr. - June): Supplementary file "Field Observations 2016-2", File 673f.

2016 (July - September): Supplementary file "Field Observations 2016-3", File 673g.

2016 (October - December): Supplementary file "Field Observations 2016-4", File 673h.

2017 (Jan. - Mar.): Supplementary file "Field Observations 2017-1", File 673j.

2017 (Apr. - September): Supplementary file "Field Observations 2017-2", File 673k.

2017 (October - December): Supplementary file "Field Observations 2017-3", File 673m.

2018: Supplementary file "Field Observations 2018", File 673n.

2019: (Jan. - June): Supplementary file "Field Observations 2019-1", File 673q.

2019: (July - December.): Supplementary file "Field Observations 2019-2", File 673r.

2020 (Jan - June): Supplementary file "Field Observations 2020-1", File 673s.

2020 (July - December): Supplementary file "Field Observations 2020-2", File 673v.

2021 (Jan. - July): Supplementary file "Field Observations 2021-1", File 673w.

2021 (July - September): Supplementary file "Field Observations 2021-2", File 673x.

2021 (October - December): Supplementary file "Field Observations 2021-3", File 673y.

2022 (Jan -): Supplementary file "Field Observations 2022", File 673z.

Budget 2016/17 winter analysis

Table key Yellow fields in the table indicate observed values. Pink fields indicated estimates in flood, snow, or ice-covered conditions - the estimates are nevertheless pretty good.

Day: Day number 0 = July 18, 2015 (Julian Day 2457222). Example Day = 458 (October 18, 2016)

A: Number of days between observations. All daily values assumed to be the average between observations. Example A = 3

B: Observed rainfall (mm).[8] Example: B = 40

BET (not tabulated): Estimated daily evapotranspiration loss (mm). [9] Example BET = 1.2

CW: West end, weir bay, area assumed to be a constant (m^2). [1] CW = 2300

DW: Observed rise (fall) in water level at west end (mm). Example: DW = 156

EW: Calc. net daily inflow (outflow) at west end (m^3/day) = CW * DW/(1000 * A). Example: EW = 120

FW: Daily net inflow of rain at west end (m^3/day) = CW * (B–BET*A)/(1000 * A). Example: FW = 28

GW: Calc. net daily inflow (outflow) at west end less rain (m^3/day) = EW – FW. Example: GW = 92

HW: Flow rate of Coats Marsh Creek on previous observation (L/s). Example: HW = 8.7

JW: Flow rate of Coats Marsh Creek on current observation (L/s). Example: JW = 46.7

KW: Estimated downstream inflow in Coats Marsh Creek on previous observation (L/s). [11] Example: KW = 0.0

LW: Estimated downstream inflow in Coats Marsh Creek rate on current observation (L/s). [2, 11] Example: LW = 2.0

MW: Estimated average weir discharge (L/s) = [(HW + JW)/2] – [(KW + LW)/2]. [3] Example: MW = 26.7

NW: Estimated average daily weir discharge (m^3/day) = (60*60*24) * (MW/1000). Example: NW = 2307

P: Leakage through the beaver dam from east to west daily (m^3/day) = NW + GW. [4] Example: P = 2399

PR: Leakage through the beaver dam from east to west (L/s) = P * 1000/(60*60*24). Example: PR = 27.8

CE: East end (main beyond the dam) area assumed to be a constant (m^2). [5] CE = 46500

DE: Observed rise (fall) in water level at east end (mm). Example: DE = 60

EE: Calc. net daily inflow (outflow) at east end (m^3/day) = CE * DE/(1000 * A). Example: EE = 930

FE: Daily net inflow of rain at east end (m^3/day) = CE * (B–BET*A)/(1000 * A). Example: FE = 564

GE: Calc. net daily inflow (outflow) at east end less rain (m^3/day) = EE – FE. Example: GE = 366

HE: Calc. net daily inflow from creeks (or ET outflow) (m^3/day) = GE + P.[8] Example: HE = 2764

JE: Flow rate of East Path Creek on previous observation (L/s). Example: JE = 7.0

KE: Flow rate of East Path Creek on current observation (L/s). Example: KE = 16.3

LE: Average inflow from East Path Creek (L/s) = (JE + KE)/2. Example: LE = 11.7

ME: Estimated average daily East Path Creek inflow (m^3/day) = (60*60*24)*(LE/1000).[8] Example: ME = 1007

NE: Calc. daily inflow (outflow) to east end from other sources (m^3/day) = HE – ME.[12 13] Example: NE = 1758

QE: Calc. inflow (outflow) to east end from other sources (L/s) = NE*1000/(60*60*24).[10] Example: QE = 20.3

RE: % of inflow from creeks attributable to East Path Creek = 100*ME/HE (%). [7] Example: RE = 36.

A change in level over the whole lake of 1 mm/day = 0.56 L/s. 1 L/s = 86.4 m^3/day.

Table notes:

1: A re-evaluation of CW, Nov. 18, 2016, gave a value of 1730 m^2. The original value has however been retained for consistency as its value varies and small changes have almost no effect on the budget.

2: Rough estimate only, downstream contribution apart from drainage pipe is likely rarely more than 0.5 L/s.

3: The theoretical discharge of the fully submerged pond leveller (8”dia., -1.67º over 7.8m) is around 47.8 L/s.

4: Assuming no direct creek inflow to the west end.

5: A re-evaluation of CE, Nov. 18, 2016, gave a value of 55116 m^2. The original value has however been retained for consistency as its value varies and small changes have little effect on the budget.

7. Note below the table.

8. Given accumulated values of HE (inflow from creeks), ME (inflow from East Path Creek), B (rainfall), and BET (evaporation), it should be possible to estimate the size of the catchment areas. See notes below these tables.

9. Evaporation from the lake and evapotranspiration from the catchment area are estimated based on figures for average temperature, relative humidity, and wind speed for the time of year. See File 673t for details.

10. Small negative values of QE when creeks are not flowing are due to leakage through the baffle that is insufficient to cause Coats Marsh Creek to flow at the downstream observation point. See point 11.

11. The values for KW and LW are taken to be the observed flow into the Coats Marsh Creek stream-bed from the residential property drainage pipe just downstream of the weir on the left bank. In summer, stagnant water often pools below where this pipe discharges as it does at the foot of the baffle. However, it has been observed that:

(i) there is sometimes a low flow in the creek where it passes through residential property roughly 140 metres upstream of the observation point when there is no flow from this drainage pipe and the observation point itself is dry. This water is coming from a reservoir of some kind, possibly including unobserved subsurface leakage from the marsh, or from the pond behind the rock wall/dam on residential property approximately 100 metres further upstream and about 100 metres below the weir. The flow is evidently less than the rate of infiltration into the creek-bed; and

(ii) there is sometimes no flow at the observation point even though there is flow from the drainage pipe. The flow is recharging a reservoir and/or is less than the rate of infiltration into the creek-bed.

These observations are only made when the marsh level is below the baffle. The flows are taken to be too small to materially affect the calculations when the creek is flowing in winter.

12. Major contributors are flow from the NE Arm, the wetland near the Stanley Place entrance, and from the inflow from the NE into the NE corner. The remainder is presumably from minor watertracks distributed around the marsh.

13. These observations ignore contributions from two small springs on the east side of the lake whose exact location was only discovered in the spring of 2020. Their effect is small. See File 673s for field notes.

Day	A	B	CW	DW	EW	FW	GW	HW	JW	KW	LW	MW	NW	P
	PR	CE	DE	EE	FE	GE	HE	JE	KE	LE	ME	NE	QE	RE
444	5	5	2300	2	1	-1	2	0.0	0	0.0	0.0	0.0	0	2
	0.0	46500	-5	-47	-25	-21	-19	0.0	0.0	0	0	-19	-0.2	0
449	5	68	2300	93	43	28	15	0.0	0	0.0	0.0	0.0	0	15
	0.2	46500	73	679	567	112	127	0.0	0.0	0	0	127	1.5	0
450	1	0	2300	0	0	-3	3	0.0	0	0.0	0.0	0.0	0	3
	0.0	46500	4	186	-64	250	253	0.0	0.0	0	0	253	2.9	0
455	5	100	2300	234	108	43	64	0.0	8.7	0.0	0.0	4.4	376	440
	5.1	46500	169	1572	873	699	1139	0.0	7.0	3.5	302	837	9.7	27
458	3	40	2300	156	120	28	92	8.7	46.7	0.0	2.0	26.7	2307	2398
	27.8	46500	60	930	567	363	2762	7.0	16.3	11.7	1007	1755	20.3	36
462	4	29	2300	30	17	14	3	46.7	40.9	2.0	3.0	41.3	3568	3571
	41.3	46500	61	709	289	420	3992	16.3	15.6	16.0	1378	2614	30.3	35
465	3	11	2300	-30	-23	6	-30	40.9	29.0	3.0	1.5	32.7	2825	2796
	32.4	46500	7	109	126	-17	2779	15.6	1.3	8.5	730	2049	23.7	26
468	3	20	2300	21	16	13	3	29	29.7	1.5	1.0	28.1	2428	2431
	28.1	46500	19	295	267	28	2458	1.3	8.4	4.9	419	2039	23.6	17
472	4	15	2300	-15	-9	7	-16	29.7	25.9	1.0	2.0	26.3	2272	2257
	26.1	46500	15	174	139	35	2292	8.4	6.3	7.4	635	1657	19.2	28
474	2	42	2300	158	182	47	135	25.9	112.8	2.0	2.0	67.4	5819	5954
	68.9	46500	30	698	941	-243	5711	6.3	37.9	22.1	1909	3801	44.0	33
478	4	27	2300	-85	-49	14	-63	112.8	67.5	2.0	2.0	88.2	7616	7553
	87.4	46500	-11	-128	285	-413	7140	37.9	14.1	26.0	2246	4894	56.6	31
482	4	3	2300	-64	-37	0	-37	67.5	29.1	2.0	1.0	46.8	4044	4007
	46.4	46500	-4	-47	1	-48	3959	14.1	3.3	8.7	752	3207	37.1	19
486	4	23	2300	15	9	12	-3	29.1	33.6	1.0	1.0	30.4	2622	2619
	30.3	46500	7	81	243	-161	2458	3.3	8.3	5.8	501	1956	22.6	20
489	3	6	2300	-24	-18	4	-22	33.6	28.3	1.0	0.5	30.2	2609	2587
	29.9	46500	-9	-140	72	-212	2375	8.3	1.0	4.7	402	1974	22.8	17
495	6	65	2300	137	53	24	29	28.3	102.9	0.5	1.5	64.6	5581	5610
	64.9	46500	23	178	484	-305	5305	1.0	34.7	17.9	1542	3762	43.5	29
499	4	66	2300	-6	-3	37	-41	102.9	90.7	1.5	1.5	95.3	8234	8193
	94.8	46500	-4	-47	749	-796	7398	34.7	32.6	33.7	2907	4490	52.0	39
505	6	21	2300	-76	-29	7	-36	90.7	47.2	1.5	1.0	67.7	5849	5813
	67.3	46500	-8	-62	147	-209	5604	32.6	10.1	21.4	1845	3759	43.5	33
512	7	16	2300	-3	-1	5	-6	47.2	43.0	1.0	1.0	44.1	3810	3805
	44.0	46500	5	33	91	-58	3747	10.1	9.8	10.0	860	2887	33.4	23
517	5	0	2300	-9	-4	-1	-4	43	40.2	1.0	0.8	40.7	3516	3513
	40.7	46500	-9	-84	-12	-72	3441	9.8	9.4	9.6	829	2611	30.2	24
525	8	31	2300	41	12	8	3	40.2	51.4	0.8	1.0	44.9	3879	3883
	44.9	46500	1	6	170	-164	3718	9.4	12.8	11.1	959	2759	31.9	26

550	25	82	2300	-8	-1	7	-8	51.4	53.5	1.0	1.0	51.5	4445	4438
	51.4	46500	-14	-26	142	-168	4270	12.8	18.5	15.7	1352	2918	33.8	32
556	6	16	2300	-15	-6	5	-11	53.5	35.9	1.0	1.0	43.7	3776	3765
	43.6	46500	-5	-39	109	-148	3617	18.5	10.8	14.7	1266	2351	27.2	35
560	4	1	2300	-55	-32	0	-31	35.9	32.1	1.0	1.0	33.0	2851	2820
	32.6	46500	11	128	-6	134	2954	10.8	2.3	6.6	566	2388	27.6	19
576	4	88	2300	82	47	49	-2	32.1	63.7	1.0	1.0	46.9	4052	4050
	46.9	46500	2	23	999	-976	3074	0.0	18.9	9.5	816	2257	26.1	27
578	2	38	2300	369	424	42	382	63.7	293.0	1.0	2.0	176.9	15280	15662
	181.3	46500	36	837	857	-20	15642	18.9	85.0	52.0	4488	11154	129.1	29
581	3	13	2300	-341	-261	8	-270	293.0	97.7	2.0	1.0	193.9	16749	16479
	190.7	46500	-36	-558	166	-724	15755	85.0	25.7	55.4	4782	10973	127.0	30
584	3	8	2300	-64	-49	5	-54	97.7	44.4	1.0	1.0	70.1	6052	5998
	69.4	46500	-4	-62	100	-162	5836	25.7	16.1	20.9	1806	4030	46.6	31
589	5	12	2300	-40	-18	4	-22	44.4	26.5	1.0	1.0	34.5	2976	2954
	34.2	46500	8	74	81	-7	2947	16.1	4.1	10.1	873	2075	24.0	30
594	5	3	2300	-37	-17	0	-17	26.5	18.6	1.0	1.0	21.6	1862	1845
	21.4	46500	-4	-37	-3	-34	1811	4.1	1.5	2.8	242	1569	18.2	13
601	7	23	2300	6	2	6	-4	18.6	24.6	1.0	1.0	20.6	1780	1776
	20.6	46500	10	66	117	-51	1725	1.5	1.7	1.6	138	1587	18.4	8
606	5	26	2300	67	31	10	21	24.6	50.5	1.0	2.0	36.1	3115	3135
	36.3	46500	25	233	205	27	3163	1.7	18.0	9.9	851	2312	26.8	27
609	3	29	2300	40	31	20	10	50.5	63.7	2.0	2.0	55.1	4761	4771
	55.2	46500	7	109	410	-301	4470	18.0	18.9	18.5	1594	2876	33.3	36
613	4	9	2300	-34	-20	3	-22	63.7	42.8	2.0	2.0	51.3	4428	4406
	51.0	46500	8	93	59	34	4439	18.9	10.6	14.8	1274	3165	36.6	29
618	5	23	2300	0	0	8	-8	42.8	42.0	2.0	2.0	40.4	3491	3482
	40.3	46500	5	47	165	-119	3363	10.6	14.8	12.7	1097	2266	26.2	33
624	6	30	2300	0	0	9	-9	42.0	44.7	2.0	2.0	41.4	3573	3564
	41.2	46500	9	70	179	-109	3455	14.8	11.7	13.3	1145	2310	26.7	33
630	6	48	2300	125	48	15	32	44.7	74.7	2.0	2.0	57.7	4985	5018
	58.1	46500	30	233	313	-80	4938	11.7	29.2	20.5	1767	3171	36.7	36
635	5	41	2300	58	27	16	11	74.7	82.5	2.0	2.0	76.6	6618	6629
	76.7	46500	15	140	317	-177	6452	29.2	27.5	28.4	2449	4003	46.3	38
644	9	33	2300	-224	-57	5	-62	82.5	29.5	2.0	1.0	54.5	4709	4647
	53.8	46500	-8	-41	96	-137	4510	27.5	8.2	17.9	1542	2967	34.3	34
681	37	57	2300	-101	-6	-2	-4	29.5	1.4	1.0	0.0	15.0	1292	1288
	14.9	46500	-26	-33	-50	18	1306	8.2	0.0	4.1	354	951	11.0	27
695	14	16	2300	-21	-3	-4	1	1.4	0.0	0.0	0.0	0.7	60	61
	0.7	46500	-15	-50	-87	37	98	0.0	0.0	0.0	0	98	1.1	0
705	10	32	2300	-9	-2	0	-2	0.0	0.0	0.0	0.0	0.0	0	-2
	0.0	46500	-8	-37	0	-37	-39	0.0	0.0	0.0	0	-39	-0.5	0
714	9	0	2300	-85	-22	-8	-14	0.0	0.0	0.0	0.0	0.0	0	-14

	-0.2	46500	-44	-227	-156	-71	-85	0.0	0.0	0.0	0	-85	-1.0	0

7: The average daily value of RE since the East Path Creek started running is now 27 ± 7%. See comment below.

Budget 2015/16 winter analysis

A few of the entries in this table was originally recorded only qualitatively and these have been substituted with estimates; however, the overall effect of these approximations is judged to be quite small. Lake levels, Coats Marsh Creek flows, and rainfall are all as measured.

Day	A	B	CW	DW	EW	FW	GW	HW	JW	KW	LW	MW	NW	P
	PR	CE	DE	EE	FE	GE	HE	JE	KE	LE	ME	NE	QE	RE
139	2	31	2300	78	90	35	55	0.0	26.0	0.0	0.5	12.8	1102	1156
	13.4	46500	22	512	1162	-650	506	0.0	11.8	5.9	510	-4	0.0	101
142	3	70	2300	195	150	53	97	0.0	204.1	0.0	4.0	100.1	8644	8741
	101.2	46500	40	620	1760	-1140	7601	0.0	53.1	26.55	2294	5307	61.4	30
144	2	49	2300	232	267	55	211	0.0	192	0.0	4.0	94.0	8122	8333
	96.4	46500	21	488	1864	-1376	6957	0.0	53.7	26.85	2320	4637	53.7	33
150	6	42	2300	-329	-126	15	-141	0.0	113.9	0.0	2.0	56.0	4834	4693
	54.3	46500	19	147	523	-376	4317	0.0	11.6	5.8	501	3816	44.2	12
164	14	101	2300	37	6	16	-10	113.9	89.1	2.0	2.0	99.5	8597	8586
	99.4	46500	2	7	572	-565	8022	11.6	13.0	12.3	1063	6959	80.5	13
166	2	0	2300	-34	-39	0	-39	89.1	78.9	2.0	2.0	82.0	7086	7047
	81.6	46500	8	186	-6	192	7239	13.0	4.3	8.7	747	6492	75.1	10
173	7	11	2300	-64	-21	4	-25	78.93	39.7	2.0	1.5	57.6	4974	4949
	57.3	46500	-11	-73	124	-197	4752	4.3	0.0	2.2	186	4567	52.9	4
178	5	17	2300	24	11	8	3	39.7	40.8	1.5	1.5	38.8	3348	3351
	38.8	46500	5	47	270	-223	3128	0.0	0.0	0.0	0	3128	36.2	0
181	3	28	2300	94	72	22	50	40.8	116.0	1.5	2.0	76.7	6623	6673
	77.2	46500	14	217	767	-550	6123	0.0	15.8	7.9	683	5441	63.0	11
187	6	65	2300	64	25	25	0	116	232.1	2.0	4.0	171.1	14779	14778
	171.0	46500	4	31	877	-846	13933	15.8	50.0	32.9	2843	11090	128.4	20
189	2	27	2300	198	228	31	196	232.1	240.4	4.0	4.0	232.3	20066	20263
	234.5	46500	17	395	1104	-708	19554	50.0	60.0	55.0	4752	14802	171.3	24
202	13	84	2300	-244	-43	15	-58	240.4	115.3	4.0	2.0	174.9	15107	15049
	174.2	46500	6	21	510	-489	14561	60.0	40.0	50.0	4320	10241	118.5	30
208	6	13	2300	-83	-32	4	-36	115.3	49.7	2.0	1.0	81.0	6998	6962
	80.6	46500	3	23	153	-130	6833	40.0	1.0	20.5	1771	5061	58.6	26
214	6	62	2300	280	107	23	84	49.7	244.0	1.0	4.0	144.4	12472	12556
	145.3	46500	33	256	793	-538	12018	1.0	40.0	20.5	1771	10247	118.6	15
220	6	25	2300	-222	-85	9	-94	244	93.8	4.0	2.0	165.9	14334	14240
	164.8	46500	5	39	293	-254	13986	40.0	10.0	25.0	2160	11826	136.9	15
224	4	7	2300	-56	-32	3	-35	93.8	45.4	2.0	1.0	68.1	5884	5848
	67.7	46500	0	0	108	-108	5740	10.0	32.6	21.3	1840	3900	45.1	32
228	4	53	2300	346	199	29	170	45.4	208.5	1.0	4.0	124.5	10752	10922
	126.4	46500	28	326	963	-637	10285	32.6	38.8	35.7	3084	7200	83.3	30
230	2	22	2300	-26	-30	23	-53	208.5	170.4	4.0	3.0	186.0	16066	16013
	185.3	46500	-4	-93	773	-866	15147	38.8	50.0	44.4	3836	11311	130.9	25

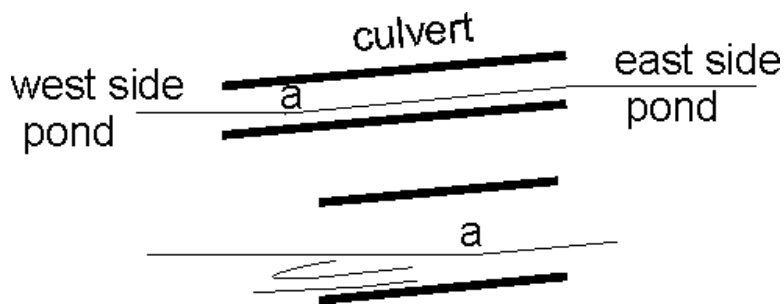
233	3	52	2300	53	41	39	2	170.4	221.8	3.0	4.0	192.6	16641	16642
	192.6	46500	10	155	1265	-1110	15532	50.0	55.0	52.5	4536	10996	127.3	29
236	3	72	2300	98	75	53	22	221.8	529.0	4.0	5.0	370.9	32046	32068
	371.2	46500	47	729	1724	-996	31072	55.0	80.0	67.5	5832	25240	292.1	19
242	6	27	2300	-314	-120	9	-129	529	73.0	5.0	2.0	297.5	25704	25575
	296.0	46500	-35	-271	272	-543	25032	80.0	20.0	50.0	4320	20712	239.7	17
244	2	0	2300	-98	-113	-2	-111	73	65.4	2.0	2.0	67.2	5806	5695
	65.9	46500	-8	-186	-63	-123	5573	20.0	7.5	13.8	1188	4385	50.7	21
251	7	22	2300	-85	-28	5	-33	65.4	23.9	2.0	0.5	43.4	3750	3717
	43.0	46500	5	33	146	-112	3605	7.5	0.0	3.8	324	3281	38.0	9
255	4	2	2300	-12	-7	-2	-5	23.9	19.8	0.5	0.5	21.4	1845	1840
	21.3	46500	0	0	-54	54	1893	0.0	0.0	0.0	0	1893	21.9	0
258	3	0	2300	12	9	-3	12	19.8	24.0	0.5	0.5	21.4	1849	1861
	21.5	46500	-15	-233	-86	-146	1715	0.0	0.0	0.0	0	1715	19.8	0
268	10	7	2300	-91	-21	-2	-19	24	5.7	0.5	0.0	14.6	1261	1242
	14.4	46500	11	51	-54	105	1348	0.0	0.0	0.0	0	1348	15.6	0
271	3	3	2300	-3	-2	-1	-1	5.7	5.7	0.0	0.0	5.7	492	492
	5.7	46500	3	47	-37	84	575	0.0	0.0	0.0	0	575	6.7	0
275	4	0	2300	-18	-10	-4	-6	5.7	3.8	0.0	0.0	4.8	410	404
	4.7	46500	-4	-47	-112	66	470	0.0	0.0	0.0	0	470	5.4	0
278	3	3	2300	-39	-30	-2	-28	3.8	1.7	0.0	0.0	2.8	238	210
	2.4	46500	-6	-93	-62	-31	179	0.0	0.0	0.0	0	179	2.1	0
282	4	9	2300	6	3	1	3	1.7	1.1	0.0	0.0	1.4	121	124
	1.4	46500	1	12	23	-11	112	0.0	0.0	0.0	0	112	1.3	0
285	3	0	2300	-6	-5	-5	0	1.1	0.0	0.0	0.0	0.6	48	48
	0.6	46500	-14	-217	-125	-92	-44	0.0	0.0	0.0	0	-44	-0.5	0

Comment: Inflow data (note 7)

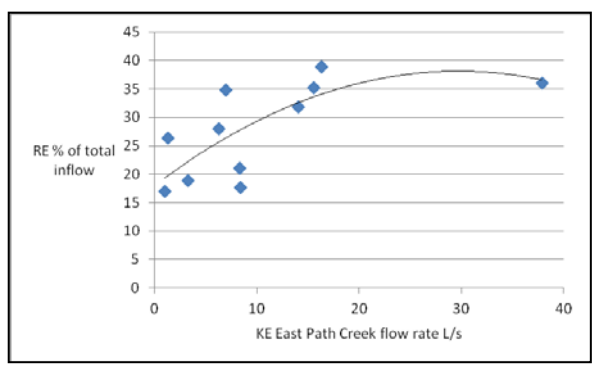
The table up to Day 489 indicated that the contribution to the total inflow to the lake by the East Path Creek (RE) is 28%, which is puzzling as it raises the question as to where the other 72% is coming from given that the NE Arm spillway is often reported to be dry in the period covered by the table.

EPC error

On Day 489, there an error was found in the flow rate measurements through the East Path Creek culvert.



The error arises when the difference between the level of the pond on the east side of the track at the culvert inlet, and the level of the pond on the west side of the culvert at the culvert outlet, is less than the difference in height between the culvert inlet and outlet. In this situation, there is a point "a" within the culvert where the incoming water reaches the pond level on the west side. A float being sent from the east to west sides can then be caught in a surface eddy at the west side, which may considerably prolong the time the float needs to travel through the culvert. On Day 489, the floats never emerged from the culvert due to this effect. As a consequence of this error, all low values of flow of the East Path Creek are almost certainly underestimates of the flow rate.



Evidence of this effect is provided by plotting the percentage RE against the flow rate KE. In principle, the percentage to the total inflow contributed by the East Path Creek should be independent of its flow, on the assumption that the factors that affect the flow in the East Path Creek affect all other creeks in the same way. A plot of RE against KE however, shows that at low flow rates, the percentage drops. A good explanation for this is that the low flow rates are underestimates.

The correct value of RE is probably around 35%.

NE Arm flow

On Day 489, I also looked at flow at the NE Arm spillway in more detail. There was no flow over the track and the pond on the east side was about a metre below the level of the track. However, when I made my way down the creek bed on the west side of the track, I very quickly came across flowing water. The flow was not great, but was about as much as was flowing in East Path Creek. It is evident that water easily flows from east to west through the barrier formed by the track and that any observation that there is no flow at the spillway, i.e. across the

surface of the track, does not mean that there is no flow from the NE Arm into the lake. In fact, such a flow could be substantial. On Day 146 last year, I measured the flow into the lake at the lake. It was 85 L/s. On the same day, the East Path Creek flow was 19.5 L/s. On Day 230, flow from the NE Arm at the lake was 57 L/s, which although no measurement was made, likely equalled or exceeded the flow in East Path Creek.

The flow from the NE Arm is complicated by the "cracked saucer effect" (Day 150 notes), but in general I think it safe to say that the contribution to the inflow from the NE Arm is at least equal to, and probably more than that from the SE Arm, and that it is easy to underestimate the NE Arm contribution because water percolates freely out-of-sight beneath the track at the NE Arm spillway. The rubble subgrade of the track is acting as a culvert.

N inflow

In addition to the flow from the NE Arm into the lake, which is sometimes measured, there is also a substantial flow from the north, seldom visited and never measured. It merges with the flow from the NE Arm shortly before the confluence with the lake.

Catchment area

On Day 489, I also traced the flow from East Path Creek down to the lake. By the time the bed of the creek had reached the area where it fans out into several drainage channels, the observable flow had ceased. Even though flooded, the lake did not reach up to the area that is underlain with gleysol.

This I think supports the conjecture (Days 121 and 123) that some rain water enters the lake unseen by flowing over that portion of the lake-bed's gleysol layer that lies beyond the immediate perimeter of the present-day open-water area. The lake was evidently somewhat larger than it is now in the post-glacial period.

Comment: Catchment areas (note 8)

Definition

Before using the water budget information to compute catchment areas we first have to define what we mean by a "catchment area". The conventional idea that these are time-invariant numbers based solely on the local topography is not useful on Gabriola. On the island, catchment areas, meaning the areas in which all precipitation funnels into a particular creek, lake, or wetland are a function of how full the local fractured-rock aquifers are, and to a much lesser extent how saturated the soil is.

At the start of the rainy season, the ground is dry and the aquifers are low; consequently relatively little water runs off over the surface. Some areas within the catchment area, as defined by the local topography, may even be completely isolated from the creek, lake, or wetland.

Conversely, at the end of the rainy season, the ground is saturated and the aquifers are full to overflowing; consequently practically all of the precipitation runs off over the surface or in subsurface flows. Areas, as defined by the local topography that were earlier not connected to the creek, lake, or wetland become connected by ephemeral watercourses that were earlier dry.

A definition of catchment area is as follows:

Let the precipitation in the general catchment area be R(t) m/day for days numbered t, t=1,2,3…T.

Divide this precipitation into a fraction $\varepsilon(t).R(t)$ m/day where $\varepsilon(t)$ is dimensionless and represents the fraction of R(t) that does not evaporate and is not transpired by trees and vegetation. $\varepsilon(t).R(t)$ is the <u>effective precipitation</u> in the catchment area.

Let the general catchment area be divided into P small polygons numbered p, p=1,2,3…P that don't overlap and completely cover the area. Let each polygon have a common area dA m^2.

Further divide the effective precipitation into a second fraction $\eta(p,t).\varepsilon(t).R(t)$ m/day where $\eta(p,t)$ is dimensionless and represents the fraction of the effective precipitation falling on polygon p that does not enter the ground to become groundwater and is not otherwise prevented from reaching the creek, lake, or wetland.

Put $\eta(p,t) = 0$ for $p > P$ and all t, thereby restricting the maximum size of the catchment area to P polygons. However we allow that it might be that $\eta(p,t) = 0$ for some t even when $p \leq P$.

In this part of the analysis I should strictly speaking be taking account of the delay between rain falling and the run-off entering the lake, but analysis shows that the average delay is only around 3 to 4 days. My precipitation records also only count snow when it melts, not when it falls. So to avoid cluttering the equations with not much improvement in accuracy, I will assume that T is significantly greater than the delay and so it can be ignored.

Then the volume V(t) m^3/day of water entering the creek, lake or wetland is:

$V(t) = \Sigma_p [\ \eta(p,t)\ \varepsilon(t)\ R(t).\ dA]$

which we can write as:

$V(t) = \Sigma_p[\eta(p,t)/P]\ .P\ dA.\ \varepsilon(t)\ R(t)\ . = g(t)\ C_G\ .\ \varepsilon(t)\ R(t)$

where:
$g(t) = \Sigma_p[\eta(p,t)/P]$ the averaged value of $\eta(p,t)$ at time t for all $p \leq P$;
C_G m^2 is P dA, the conventionally-defined geographically-fixed catchment area; and
$\varepsilon(t)$ R(t) m/day is the daily effective precipitation.

The function $g(t).C_G$ m^2 is here defined as the <u>effective catchment area</u>.

Note that increases in the effective catchment area can be the result of an actual physical expansion of the land area contributing to run off, but also the result of land within the established catchment area becoming less effective at absorbing the precipitation thereby also increasing run off.

Evaluation

For the sake of discussion, suppose that g(t) has the form:
$g(t) = 1 - \exp(-\Sigma_t[\varepsilon(t)\ R(t)]\ /G)$

that is:
—at the start of the season g(t) is 0 by virtue of $\exp(-\Sigma_t[\varepsilon(t)\ R(t)]) = 1$ for t = 0
at this moment all of the precipitation that is not evaporated or used by vegetation goes into the ground to dampen the soil and recharge aquifers
—as the season progresses, the fraction of the precipitation lost decreases exponentially (for mathematical convenience) with a decay constant of G metres of accumulated precipitation.
When aquifers are fully charged and the soil saturated, all of the precipitation not evaporating or used by vegetation, which is mostly dormant in the wet season, is available as run-off to the creek, lake, or wetland.

We can then write the accumulated flow of water into the lake Σ_T V(t) m^3 from time t = 1 to T as:

$$\Sigma_T\ V(t) = \Sigma_T[\ \varepsilon(t)\ R(t).\ g(t)\ C_G]$$
$$= \Sigma_T\ [\varepsilon(t).\ R(t)\ \{1 - \exp(-\Sigma_t[\varepsilon(t)\ R(t)]\ /G)\}\ C_G\ ]$$

Among the measured variables are V(t) and R(t).[1]

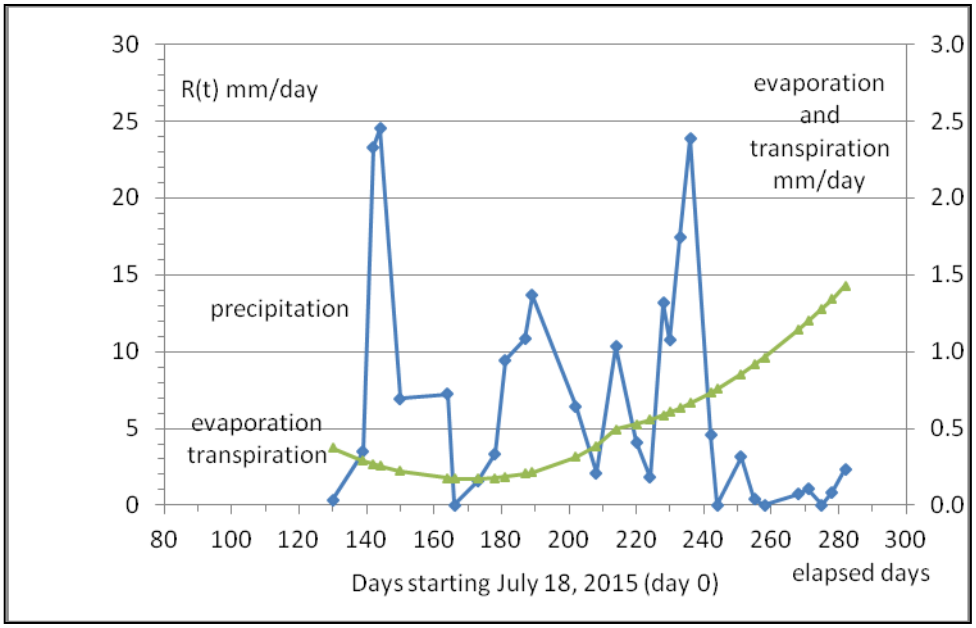
The function $\varepsilon(t)$ can be estimated based on seasonal mean parameters including relative humidity, temperature, and wind velocity. See File 673t for details.

The constants G and C_G are unknown and have to be found by matching the value of function Σ_T V(t) with the value of Σ_T V(t) actually observed at various stages in the wet season—that is for various values of T.

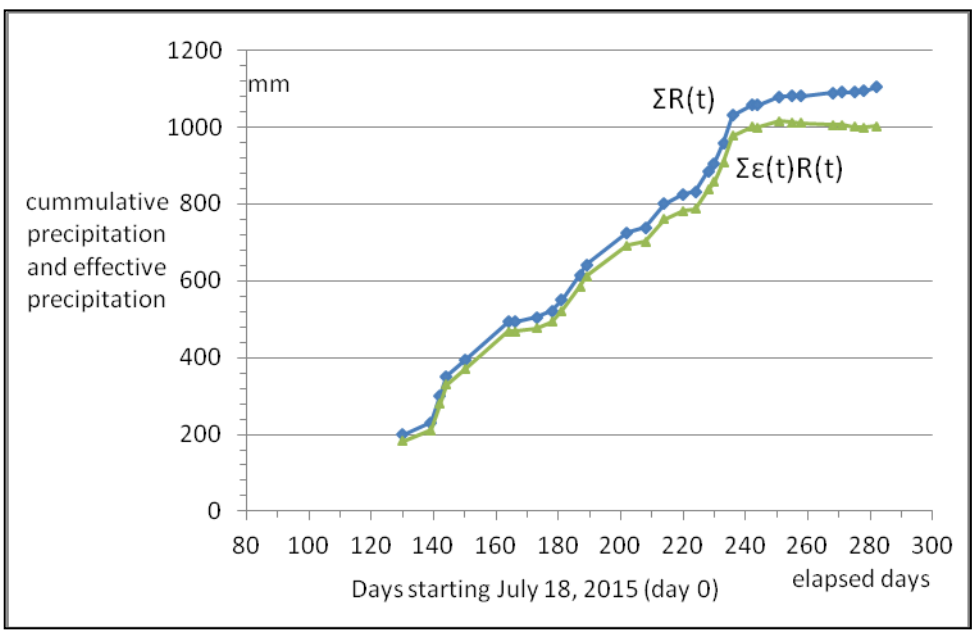
In the following graphs t = 0 corresponds to July 18 in the middle of the dry season so a complete cycle includes the whole of the wet season.

[1] R(t) in the following is as measured at Coats Marsh. This is up to 20% greater than the recorded precipitation at the Environment Canada site for Gabriola Island.

Precipitation for the 2015/16 season

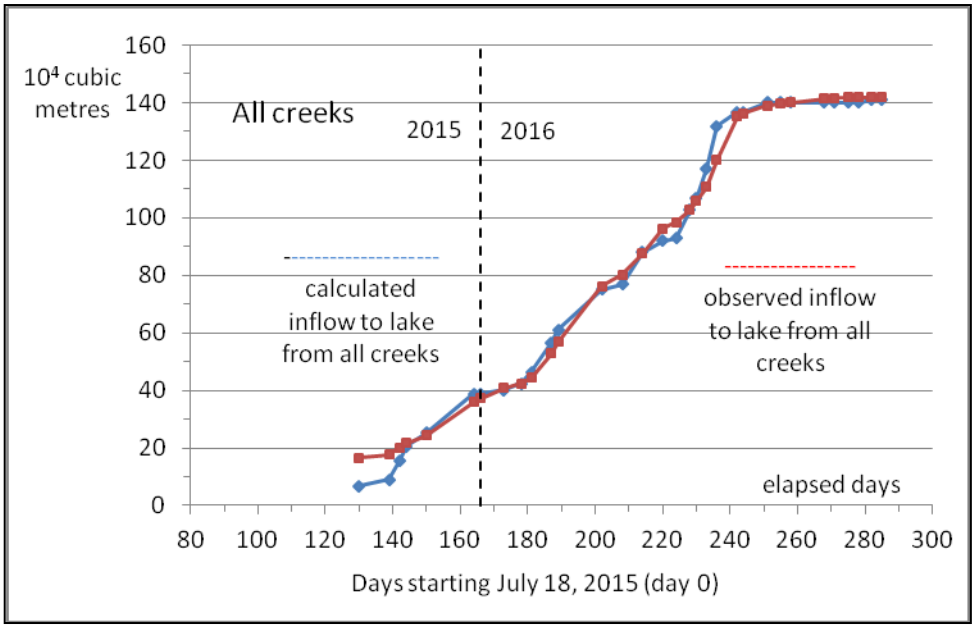


Observed daily precipitation (averaged between observation dates) R(t) mm/day and estimated daily evapotranspiration E(t) mm/day (scale on the right). $\Sigma[R(t)-E(t)] = \Sigma[\varepsilon(t).R(t)]$



Observed cumulative precipitation $\Sigma R(t)$ mm and effective precipitation $\Sigma[\varepsilon(t).R(t)]$ mm as they progress through the season.

Total creek inflow to the Coats Marsh lake 2015/16



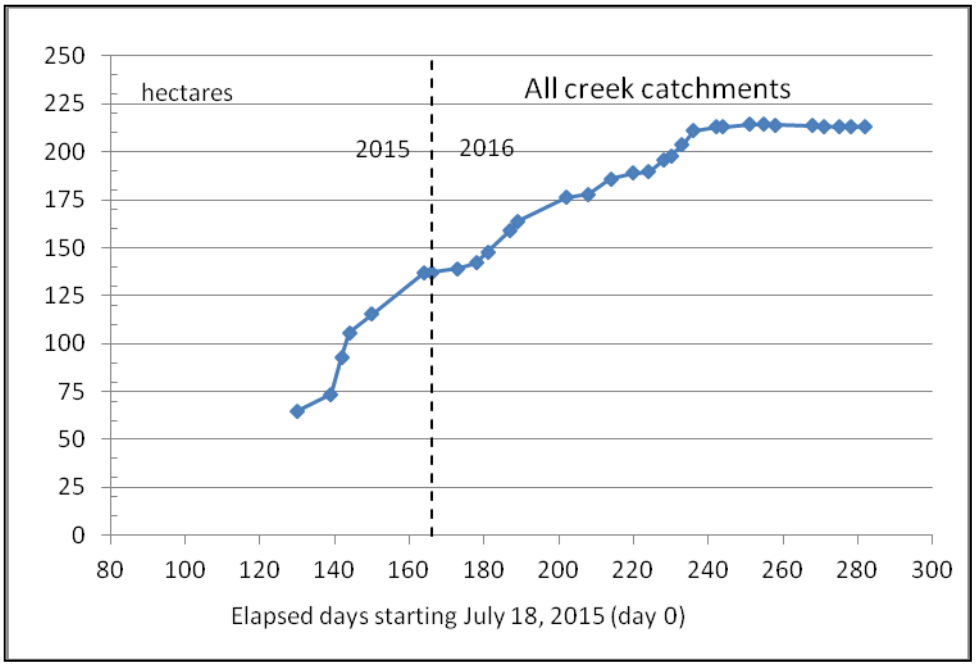
Note: the vertical scale is 10^4 cubic metres = 1 metre of rain on one hectare.

The red line shows observed values of Σ_T V(t).

The blue line shows calculated values of Σ_T V(t).

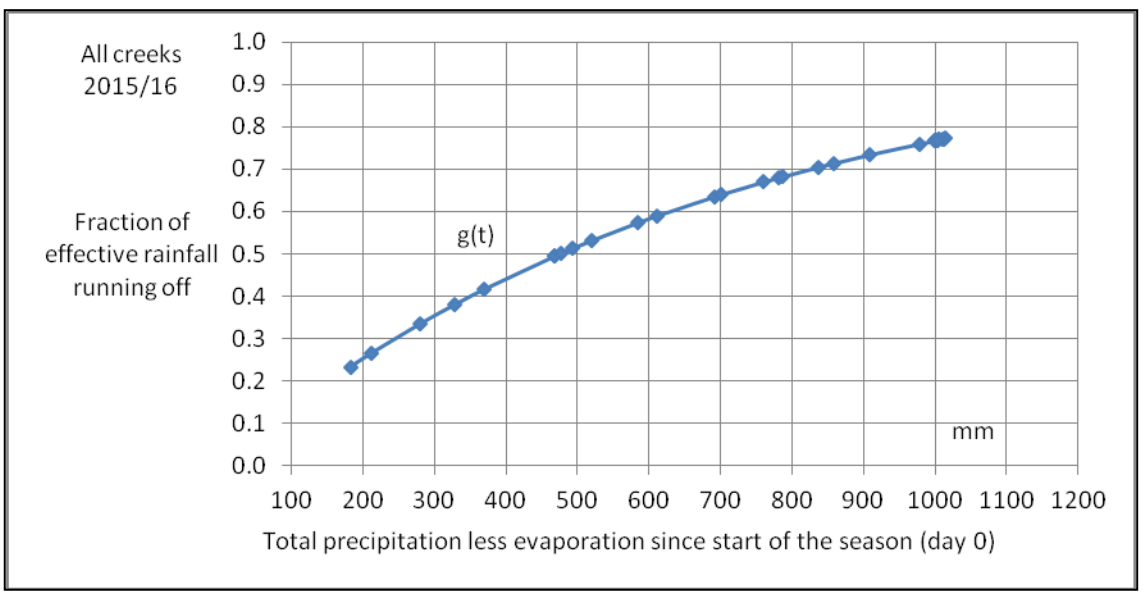
Calculations are based on
—observations of R(t);
—estimations of ε(t) from Environment Canada statistics scaled so that
$\Sigma\,[1 - \varepsilon(t)]\,R(t) = \Sigma\,E(t)$ for the whole year is 500 mm, where E(t) is the daily loss mm/day;
—an empirically determined value of G = 686 mm needed to match the two curves; and
—an empirically determined value of C_G = 277.7 ha needed to match the two curves.

The average difference between the curves at the data points is $2.7.10^4$ m^3.



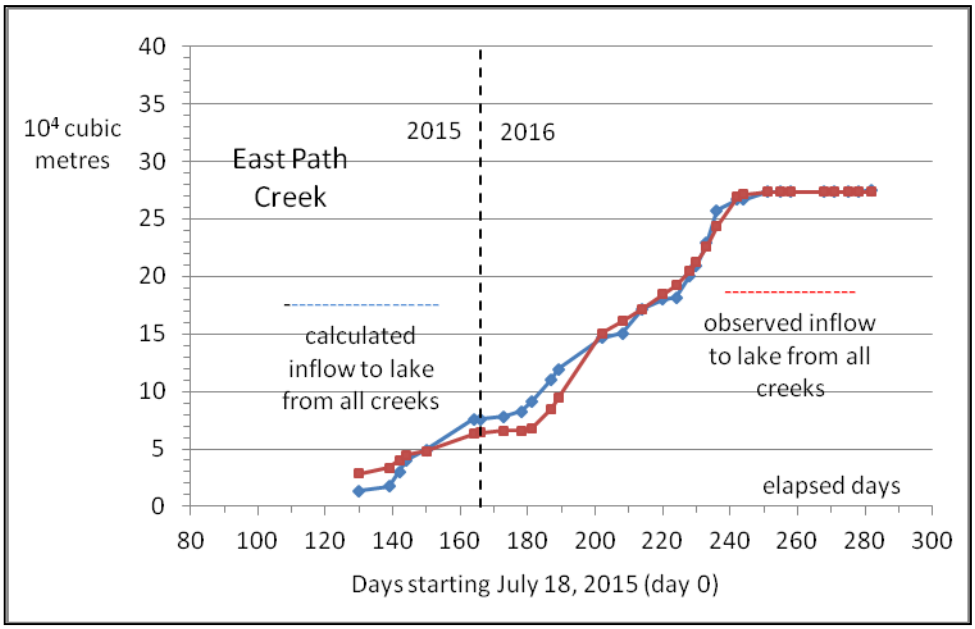
The effective catchment area g(t) C_G as a function of t, all values as for the previous graph.

Although the effective catchment area appears to reach a limit toward the end of the season, we have to be a little cautious here as this apparent limit may just be a result of the cessation of both rainfall and creek flow at the end of the season.



The postulated fraction g(t) of the effective precipitation reaching the lake as a function of accumulated effective precipitation to date Σ [ε(t).R(t)].

East Path Creek inflow to the Coats Marsh lake 2015/16



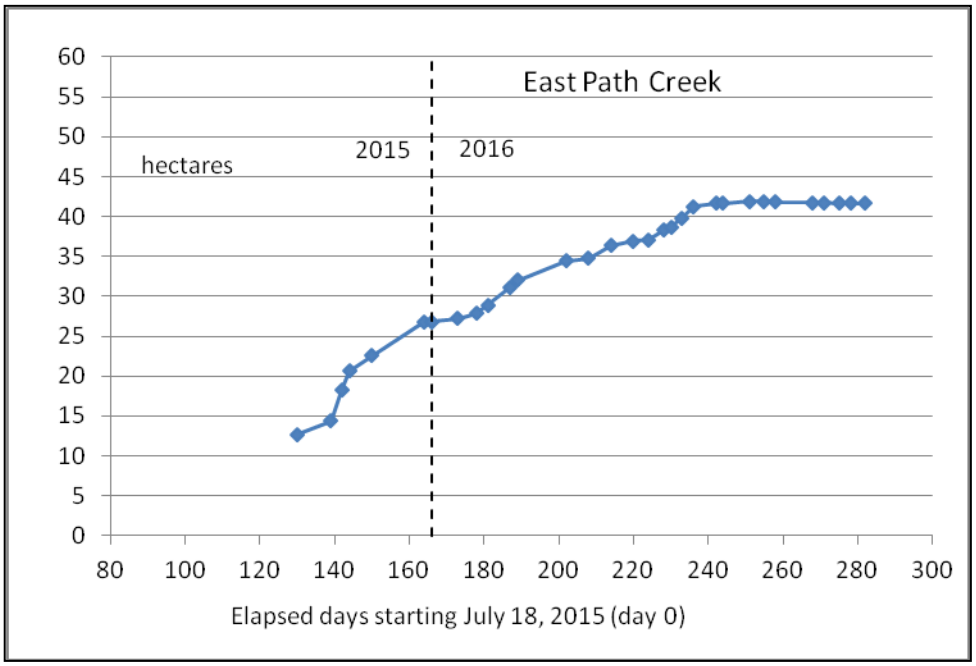
Note: the vertical scale is 10^4 cubic metres = 1 metre of rain on one hectare.

The red line shows observed values of Σ_T V(t).

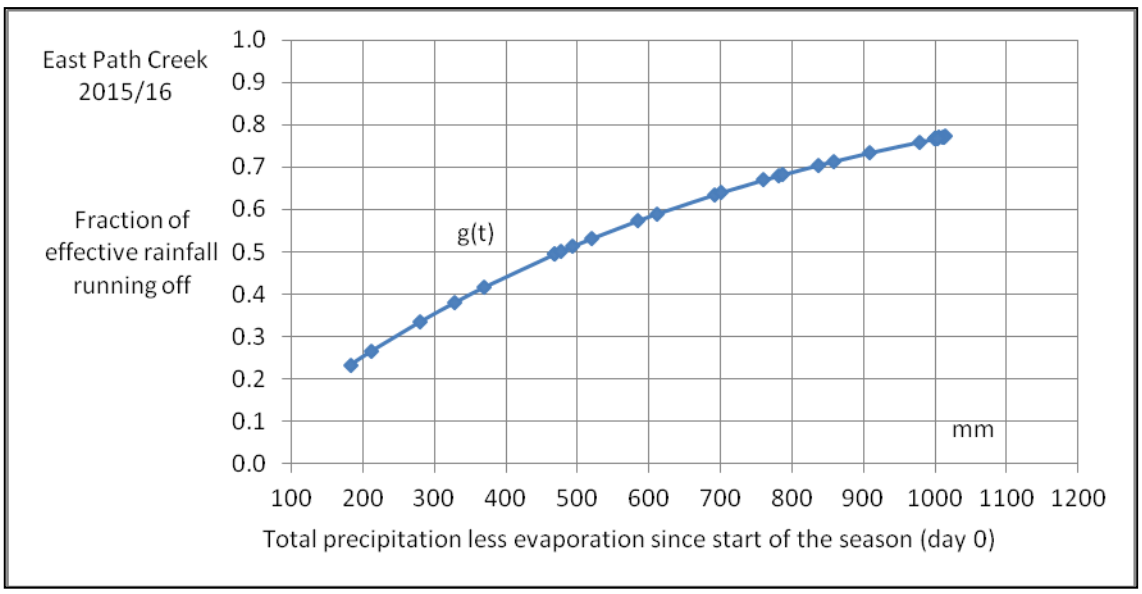
The blue line shows calculated values of Σ_T V(t).

Calculations are based on
—observations of R(t);
—estimations of ε(t) from Environment Canada statistics scaled so that
$\Sigma\,[1 - \varepsilon(t)]\,R(t) = \Sigma\,E(t)$ for the whole year is 500 mm, where E(t) is the daily loss mm/day;
—an empirically determined value of G = 686 mm (identical to the value for all creeks); and
—an empirically determined value of C_G = 54.3 ha.

The average difference between the curves at the data points is $0.8.10^4$ m^3.



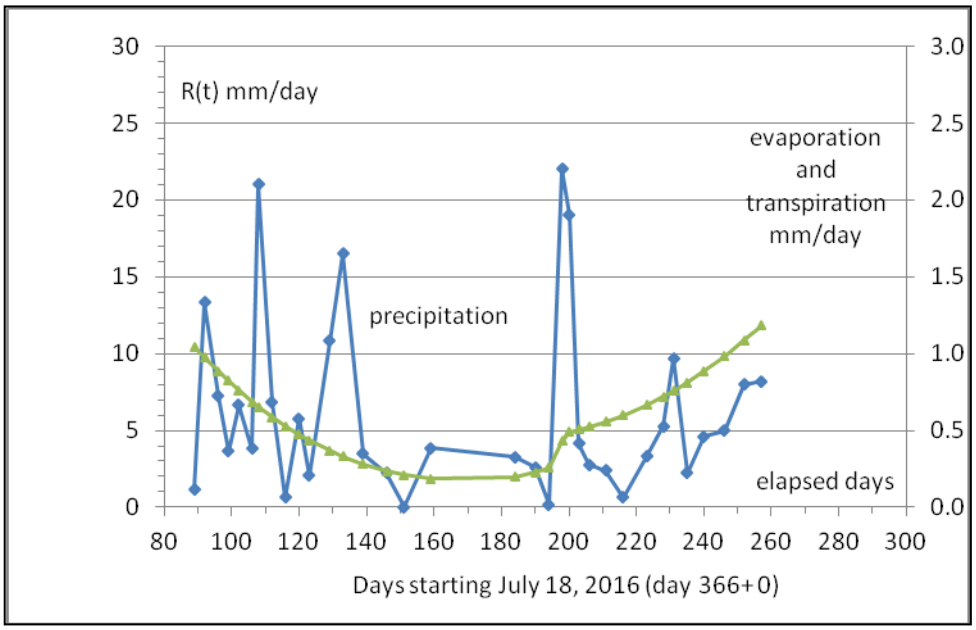
The effective catchment area g(t) C_G as a function of t, all values as for the previous graph.



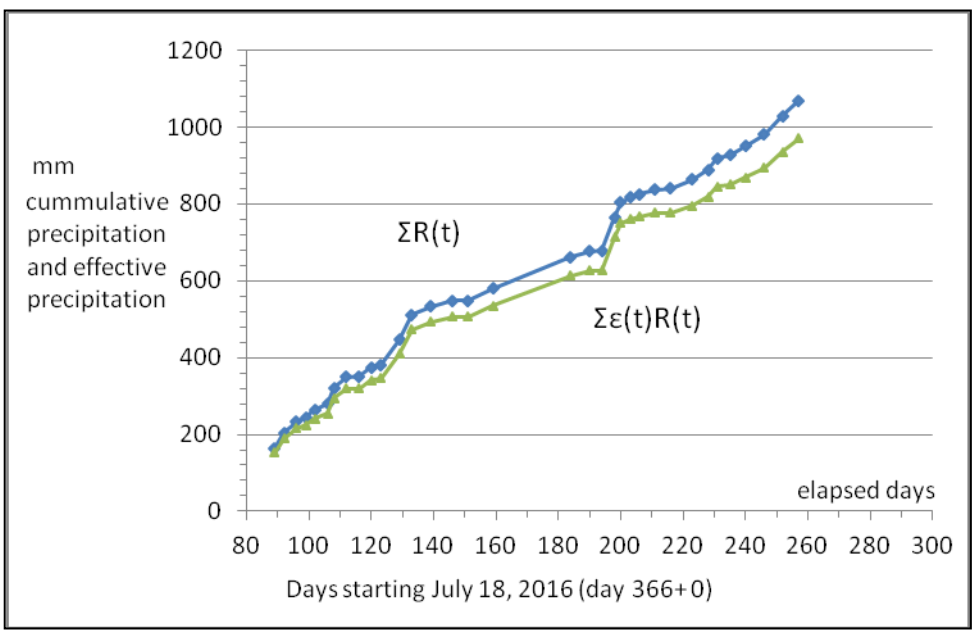
The postulated fraction g(t) of the effective precipitation reaching the lake as a function of accumulated effective precipitation to date Σ [ε(t).R(t)] was empirically determined to be exactly the same for East Path Creek as for all the creeks.

Precipitation for the 2016/17 season

The season is not yet over, but here are the results so far.



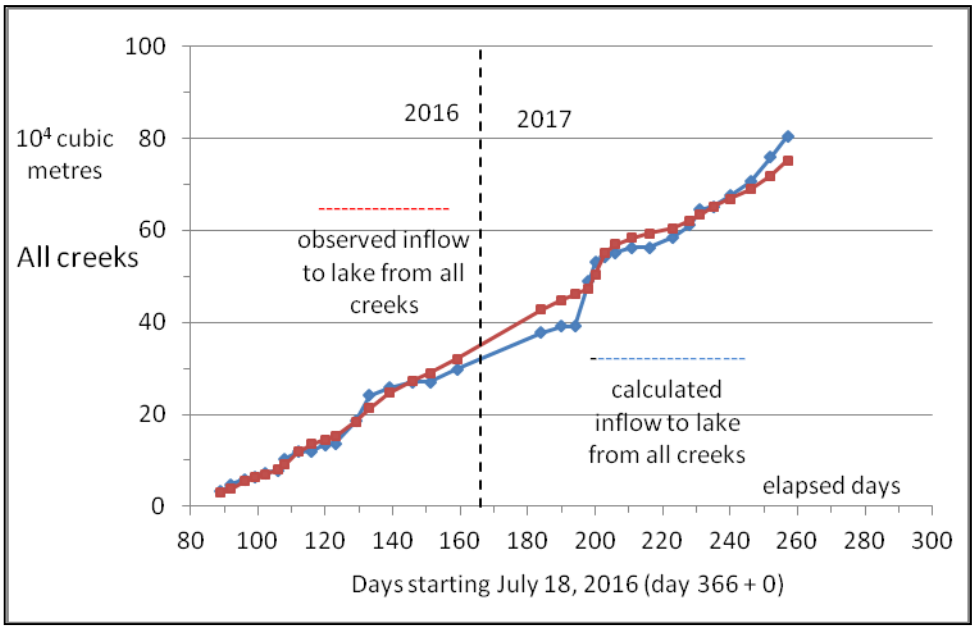
Observed daily precipitation (averaged between observation dates) R(t) mm/day and estimated daily evapotranspiration E(t) mm/day (scale on the right). $\Sigma[R(t)-E(t)] = \Sigma[\varepsilon(t).R(t)]$



Observed cumulative precipitation $\Sigma R(t)$ mm and effective precipitation $\Sigma[\varepsilon(t).R(t)]$ mm as they progress through the season.

Total creek inflow to the Coats Marsh lake 2016/17

Note: the vertical scale is 10^4 cubic metres = 1 metre of rain on one hectare.

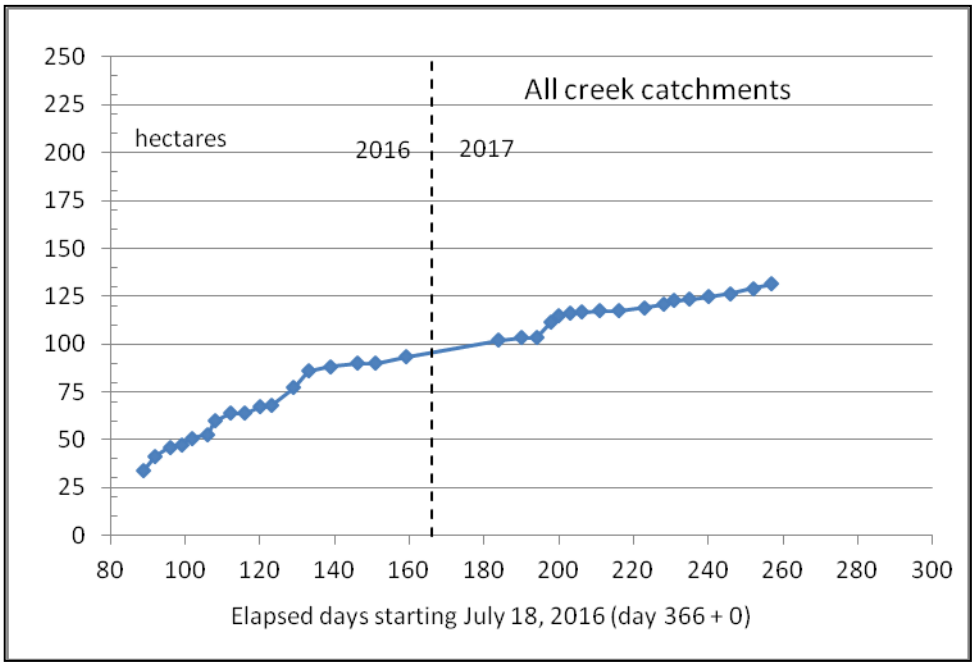


The red line shows observed values of Σ_T V(t).

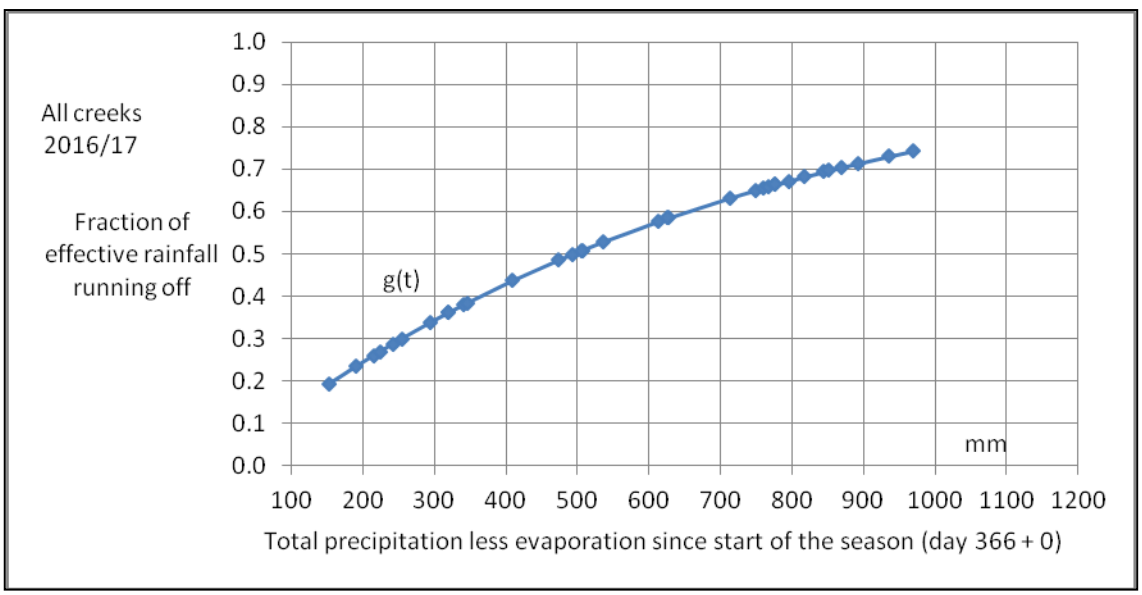
The blue line shows calculated values of Σ_T V(t).

Calculations are based on
—observations of R(t);
—estimations of ε(t) from Environment Canada statistics scaled so that
$\Sigma\,[1 - \varepsilon(t)]\,R(t) = \Sigma\,E(t)$ for the whole year is 500 mm, where E(t) is the daily loss mm/day;
—an empirically determined value of G = 714 mm; and
—an empirically determined value of C_G = 177.0 ha.

The average difference between the curves at the data points is 1.8 10^4 m^3.



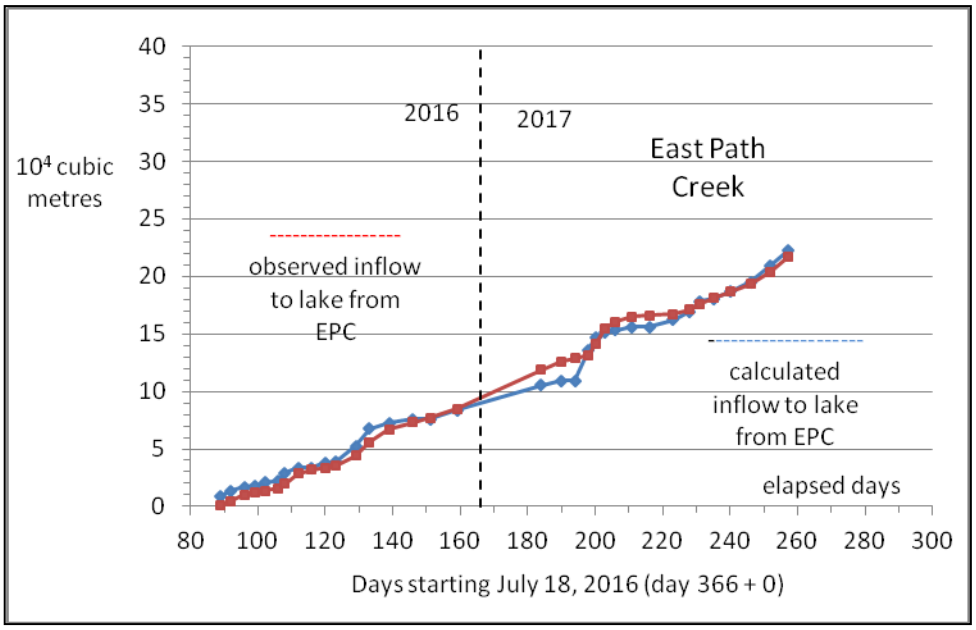
The effective catchment area g(t) C_G as a function of t, all values as for the previous graph. Note how the effective catchment area, so far, is considerably smaller than it was last year.



The postulated fraction g(t) of the effective precipitation reaching the lake as a function of accumulated effective precipitation to date $\Sigma\ [\varepsilon(t).R(t)]$.

East Path Creek inflow to the Coats Marsh lake 2016/17

Note: the vertical scale is 10^4 cubic metres = 1 metre of rain on one hectare.

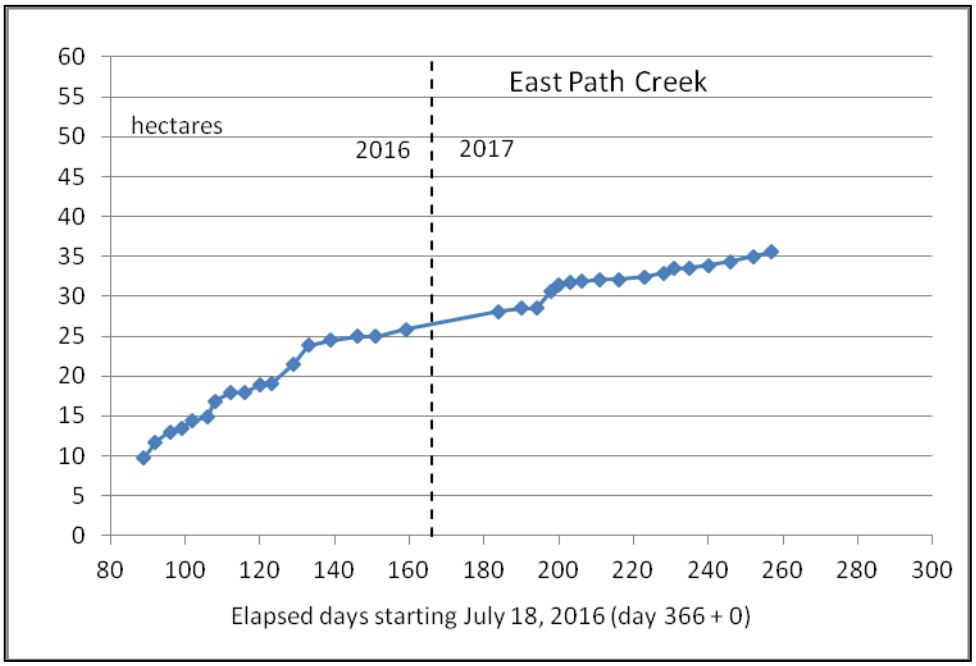


The red line shows observed values of Σ_T V(t).

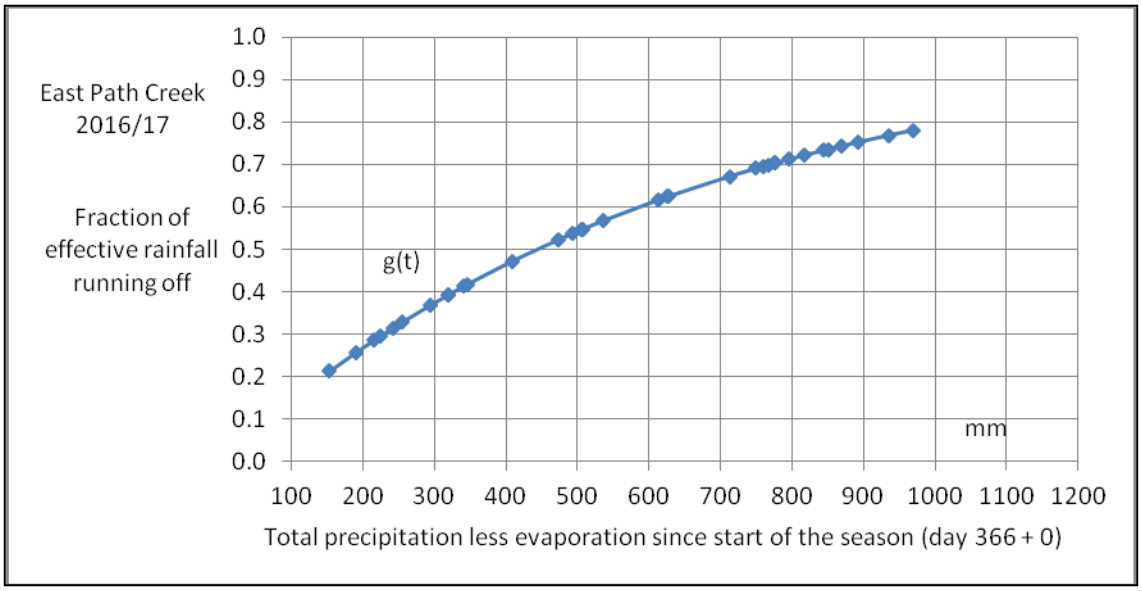
The blue line shows calculated values of Σ_T V(t).

Calculations are based on
—observations of R(t);
—estimations of ε(t) from Environment Canada statistics scaled so that
$\Sigma\,[1 - \varepsilon(t)]\,R(t) = \Sigma\,E(t)$ for the whole year is 500 mm, where E(t) is the daily loss mm/day;
—an empirically determined value of G = 640 mm; and
—an empirically determined value of C_G = 45.6 ha.

The average difference between the curves at the data points is $0.6.10^4\ m^3$.



The effective catchment area g(t) C_G as a function of t, all values as for the previous graph. Again the catchment area is smaller than it was last year. This accords with the observation that last year, water was observed flowing down from the High Point Meadows and beneath Coats Drive into the SE Arm headwaters of East Path Creek, ~~while no such flow has been observed so far this year~~ observed late March . See File 673e, day 239.



The postulated fraction g(t) of the effective precipitation reaching the lake from the East Path Creek catchment as a function of accumulated effective precipitation to date $\Sigma\ [\varepsilon(t).R(t)]$. Evidently, the soil and aquifers are not yet full to capacity. ◊