24A LOGAN POND BMP MONITORING

BACKGROUND

Best management practices (BMPs) include procedures and structures designed to help reduce water pollution. In 2006, the MPRB continued monitoring one of the City of Minneapolis' stormwater ponds located in northern Minneapolis, Figure 24A. The pond was designed for flood mitigation purposes and to help reduce pollutants. The stormwater pond is referred to as Logan Pond which is located at 29th Ave. N. and Logan Ave. N. The drainage area to the pond is 165 acres consisting primarily of residential land use. Logan Pond has one main inlet, two small inlet pipes and one outlet. The small inlet pipes drain the adjacent residential alleys. The alleys are each one city block long. The pond was designed to remove greater than 90% suspended solids. The high water level was designed to be at an elevation of 891.00 ft while the normal water level was designed to be at 884.50 ft. The bottom of the pond was designed to have an elevation of 879.00 ft leading to a high water depth of 12.00 ft and a normal water depth of 5.50 ft.

Figure 24A. Map of Logan Pond located in Minneapolis, MN.

METHODS

The MPRB monitored Logan Pond located at 29th Ave. N. and Logan Ave. N. from June to October 2005 and from May to November in 2006. Samples were collected at the inlet, outlet, and two inlet pipes located in the alleys on the east and west sides of the pond. In 2006 equipment was similar to 2005 and included area/velocity pressure transducers with ISCO 4150 dataloggers at the inlet, outlet, and east alley. A level/pressure transducer with ISCO 4120 datalogger was initially installed at the west alley, which was changed on 6/14/06 to an area/velocity pressure transducer with ISCO 4150 datalogger. In 2005 the only difference was the west alley had an ISCO 4120 datalogger and level probe the entire monitoring season. Finally, two ISCO 3700 samplers were used at the inlet and outlet. In 2005 the outlet and alleys were installed on 6/30/05 and the inlet was installed on 7/7/05. In 2006 all the equipment was initially installed on 5/5/06. The inlet and outlet dataloggers were flow paced and adjusted accordingly to collect samples over the entire hydrograph. Samples collected from the east and west alleys were all grab samples.

The chemical parameters analyzed in 2005 and 2006 were total phosphorus (TP), total dissolved phosphorus (TDP), total Kjeldahl nitrogen (TKN), nitrate+nitrite (NO3NO2), ammonia (NH3), chloride (Cl), conductivity, carbonaceous biochemical oxygen demand (cBOD), total suspended solids (TSS), total dissolved solids (TDS), copper (Cu), lead (Pb), and zinc (Zn). In 2005, cadmium (Cd) and *E. coli* grab samples were collected. In 2006 neither Cd nor *E. coli* were collected. Fecal coliform grab samples were collected periodically throughout the sampling season. The pH was measured in the field. Depending on the time the samples were collected, certain parameters were not analyzed due to expired holding times. Holding times for all parameters are listed in Section 23, Table 23E.

In 2006, a bathymetric map of the pond was completed to allow for sedimentation analysis. MRPB personnel used a GPS unit and marked depth rod to assess the sedimentation that has occurred in the pond. Measurements were made from the top of the water to top of sediment. An established grid was followed to accurately identify the pond depth at each location. This was an initial baseline depth reading to determine how fast the pond is filling with sediment. In future years, MRPB personnel can return to the same grid system to measure the depth changes. A tape down measurement was recorded from a fixed point (top edge of the reinforced concrete pipe pond outlet structure) at the pond to the water surface which can later be surveyed for exact elevations.

RESULTS & DISCUSSION

In 2005 nine storm events were sampled at the inlet, ten at the outlet, and six at each alley. In 2006 ten storm events were sampled at the inlet, twelve at the outlet, and three at each alley. These 2006 data will be combined with the 2005 data to better asses the efficacy of the BMP. The dates and lab results are presented in Tables 24A and 24B.

Statistics were calculated and are presented in Tables 24C, 24D and 24F. Lab values reported below detection were divided in half for statistical calculations. Mean outlet values in Tables 24C, 24D and 24F show water quality improvement for most parameters. The only parameter with increased output was chloride. Winter salt use may be building up chloride that flushes out during the year. This may explain why the outlet has a higher value than the inlets.

When comparing the mean values of the east and west alleys most of the parameters were comparable except for chloride, fecal coliform, TSS and lead. With regards to these parameters the west alley concentrations were more than double the east alley. One possible explanation is that trash cans and surrounding debris were seen in the alleys which could contribute to high pollutant concentrations, but it is unknown exactly why this occurred.

Total volumes recorded at each monitored location are given in Tables 24F, 24G and 24H. The total inlet volume recorded for the sampling period 7/7/05 – 10/31/05 was 1,800,000 cf. The total inlet volume recorded for the sampling period 5/5/06 – 11/29/06 was 1,506,490 cf. It should be noted the inlet equipment was damaged. Data from 5/5/06 – 6/13/06 data were lost. To fill in this gap, and achieve an estimated mass balance, the outlet volume for this time period was added to the inlet. The east and west alley's contribute only approximately 10% of the total yearly volume. The total outlet volume recorded in 2005 was 1,040,000 cf and in 2006 was 1,510,996 cf.

Total pollutant load calculations are in Tables 24I, 24J and 24K. All parameters except NH3, hardness, chloride and TDS showed some water quality improvements. In 2005 fecal coliform showed the highest removal as die-off and settling would be expected, while TDS showed the least amount captured. In 2006 TP, TKN, Cl, fecal coliform, TDS and Pb all show a net export. This may be indicative of breakdown of gross solids (leaves, paper, cigarette butts) in the pond. The combined 2005 – 2006 load data show only Cl and TDS export, all other parameters show some removal. The unusual amount of rainfall in 2005 may not have left sufficient settling time for many parameters. 2006 had below normal precipitation which may have allowed more settling time for many parameters.

The 10/16/06 storm had some unusually high values which affected the overall performance and load calculations. For example, the TP inlet was 3.37 mg/L and outlet was 5.20 mg/L and the Pb inlet was 14.9 µg/L and outlet was 96.6 µg/L. It was decided to include this data. While the data are outliers, they are real samples. The explanation is elusive because the 10/16/06 storm was not unusually intense at 0.02 inch/hr or large at 0.21 inches. Public Works indicated this area was swept a week after this storm.

Resuspension of sediments due to large storms is a possible reason for low removal efficiency. Sediment accumulation can also cause resuspension by decreasing the depth of the pond which can reduce its effectiveness. The Minnesota Stormwater Steering Committee recommends a sediment forebay with a depth of 4 to 6 ft for each inlet provided there is no other upstream BMP. Shallower depths could result in resuspension of sediments (MSSC, 2005). Other possible reasons for resuspension include wind, lack of aquatic vegetation that can help stabilize sediments, or fish activity.

Another possible reason for lower removal efficiency is that the best currently available sampling equipment has limited capability. This may lead to an underrepresentation of inlet concentrations. The sampler intake strainer and tubing (3/8" inner diameter) does not allow the uptake of large debris such as leaves, tree seeds, paper, cigarettes, and small trash. This debris may decompose in the pond into small enough particles to be taken up by the sampling strainer at the outlet during future storm events. The stormwater sampling equipment and

protocols used are current state of the art and comparable to others in the stormwater profession.

Table 24A. Logan Pond sampled event data for 2005.

Date	Time	Site Location	Sample Type	TP mg/L	TDP mg/L	TKN mg/L	NO3NO2 mg/L	NH3 mg/L	Cl mg/L	Hardness mg/L	Sp.Cond. µmhos/cm	F. Coli cfu/100mL	E. Coli mpn/100mL	Field pH	cBOD mg/L	TSS mg/L	TDS mg/L	Cd µg/L	Cu µg/L	Pb µg/L	Zn µg/L
7/23/2005	12:11	Logan - Inlet	composite	0.538	n/c	2.26	0.547	1.43	2.41	n/c	67.6	n/c		n/c	n/c	91	65	<5.00	21.3	35.7	91
7/25/2005	18:55	Logan - Inlet	composite	0.475	0.157	1.94	0.222	1.46	2.41	24.0	53.2	n/c		6.6	10.6	139	48	<5.00	21.6	45.9	97
8/16/2005	23:33	Logan - Inlet	composite	0.694	0.200	3.51	0.872	1.45	3.38	32.0	76.0	1,010,000		6.9	11.8	145	67	<5.00	29.7	41.2	90
8/26/2005	6:50	Logan - Inlet	composite	1.12	0.255	3.34	0.496	0.809	<2.00	28.0	52.5	n/c		7.7	8.16	288	51	<5.00	21.5	95.0	165
8/26/2005	9:33	Logan - Inlet	grab									32,000	39,900								
9/3/2005	20:25	Logan - Inlet	composite	0.483	n/c	2.02	0.639	0.720	<2.00	32.0	71.6	n/c		n/c	n/c	130	72	<5.00	24.8	41.9	58
9/13/2005	2:25	Logan - Inlet	composite	0.476	0.145	1.82	0.231	0.771	3.38	34.0	68.2	64,000		7.1	6.76	108	62	<5.00	16.6	41.9	<50
9/19/2005	8:11	Logan - Inlet	composite	0.364	0.184	1.75	0.508	0.618	2.38	24.0	55.0	n/c		n/c	10.8	55	39	<5.00	15.7	19.6	<50
9/21/2005	20:02	Logan - Inlet	composite	0.751	0.158	3.50	0.566	0.823	<2.00	30.0	62.1	n/c		7.7	12.7	207	49	<5.00	28.9	78.6	102
9/25/2005	6:59	Logan - Inlet	composite	0.273	n/c	1.58	0.246	<0.500	<2.00	n/c	58.4	n/c		n/c	n/c	44	47	<5.00	13.7	17.9	<50
9/28/2005	9:30	Logan - Inlet	grab									137,000									
8/8/2005	8:50	Logan - East	grab	0.673	0.470	3.05	1.17	2.16	2.56	48.0	119	1,500		8.2	18.7	29	137	<5.00	30.0	28.0	<50
8/18/2005	9:10	Logan - East	grab	0.425	0.290	1.36	0.547	0.603	2.38	58.0	9.00	86,600		n/c	11.2	16	145	<5.00	25.6	7.45	<50
8/19/2005	11:20	Logan - East	grab	0.708	0.241	3.67	1.52	1.65	3.12	48.0	131	37,000		7.5	21.0	80	109	<5.00	40.2	27.6	54
8/26/2005	9:00	Logan - East	grab	0.208	0.126	0.760	0.180	0.330	<2.00	24.0	50.7	1,200	1,460	7.5	2.09	23	48	<5.00	<5.00	17.9	28
9/7/2005	9:05	Logan - East	grab	0.342	0.168	1.65	1.28	0.526	<2.00	44.0	131	1,000		7.6	10.5	76	125	<5.00	20.8	37.4	<50
9/28/2005	9:05	Logan - East	grab	0.433	0.176	1.36	0.275	0.516	<2.00	40.0	85.6	128,000		n/c	8.40	65	72	<5.00	20.3	51.3	<50
8/18/2005	8:45	Logan - West	grab	0.719	0.395	2.78	0.502	1.06	3.38	58.0	184	27,600		n/c	10.1	86	140	<5.00	29.8	11.2	<50
8/19/2005	11:10	Logan - West	grab	0.443	0.308	2.31	1.17	1.05	<2.00	32.0	108	15,800		7.6	11.9	16	104	<5.00	19.4	5.70	<50
8/26/2005	9:10	Logan - West	grab	0.413	0.218	1.47	0.654	0.672	2.87	44.0	122	2,000	4,000	8.9	4.24	69	91	<5.00	17.1	18.5	50
9/7/2005	9:15	Logan - West	grab	0.312	0.202	1.88	1.06	0.853	2.14	46.0	123	1,200		7.6	7.70	44	116	<5.00	18.4	9.50	<50
9/8/2005	9:00	Logan - West	grab	0.286	0.205	1.08	0.697	0.455	2.14	<1.00	86.4	950		7.3	3.74	23	121	<5.00	16.4	6.10	<50
9/28/2005	9:10	Logan - West	grab	0.332	0.168	1.16	0.336	0.556	<2.00	44.0	93.5	43,000		n/c	11.2	31	77	<5.00	13.8	14.5	<50
7/23/2005	13:53	Logan - Outlet	composite	0.627	n/c	3.10	0.087	2.63	84.2	n/c	390	n/c		n/c	n/c	35	228	<5.00	8.75	13.3	<50
7/23/2005	10:15	Logan - Outlet	grab									1,000									
7/25/2005	18:46	Logan - Outlet	composite	0.726	0.230	2.84	0.167	2.73	35.5	36.0	168	n/c		n/c	9.45	173	120	<5.00	24.5	61.6	102
7/25/2005	11:35	Logan - Outlet	grab									16,000		7.0							
8/17/2005	10:30	Logan - Outlet	grab	0.497	0.094	2.66	0.152	0.775	55.4	50.0	264	86,100		7.6	8.35	31	163	<5.00	<5.00	6.30	<50
8/19/2005	9:20	Logan - Outlet	grab	0.358	0.133	1.68	0.062	0.832	55.4	68.0	302	<1		7.0	5.41	22	194	<5.00	9.70	8.60	<50
8/26/2005	7:25	Logan - Outlet	composite	0.538	0.218	2.14	0.327	0.912	29.9	32.0	174	n/c		n/c	6.83	108	117	<5.00	14.1	37.7	44
8/26/2005	8:45	Logan - Outlet	grab									19,000	20,100	6.9							
9/4/2005	6:56	Logan - Outlet	composite	0.505	n/c	2.31	0.362	0.915	20.8	40.0	79.3	n/c		n/c	n/c	92	95	<5.00	21.3	39.6	<50
9/13/2005	5:37	Logan - Outlet	composite	0.494	0.142	1.96	0.209	0.884	5.88	36.0	81.3	30,000		7.2	3.96	104	72	<5.00	20.2	44.0	<50
9/19/2005	7:25	Logan - Outlet	composite	0.515	0.187	2.54	0.453	<0.500	4.88	30.0	77.0	n/c		n/c	13.2	133	68	<5.00	25.3	28.3	50
9/21/2005	22:15	Logan - Outlet	composite	0.661	0.142	3.20	0.330	0.853	4.94	36.0	80.3	n/c		9.0	8.75	208	61	<5.00	30.4	86.0	82
9/25/2005	9:17	Logan - Outlet	composite	0.356	n/c	2.00	0.180	0.792	5.42	n/c	89.3	n/c		n/c	n/c	46	66	<5.00	19.2	16.3	<50
9/28/2005	9:15	Logan - Outlet	grab									5,000									

Notes: n/c = not collected due to limited sample volume or expired holding time.

Table 24B. Logan Pond sampled event data for 2006.

Date	Time	Site Location	Sample Type	TP mg/L	TDP mg/L	TKN mg/L	NO3NO2 mg/L	NH3 mg/L	Cl mg/L	Sp.Cond. µmho/cm	F. Coli cfu/100mL	cBOD mg/L	TSS mg/L	TDS mg/L	Cu µg/L	Pb µg/L	Zn µg/L
6/25/2006	8:44	Logan Inlet	Composite	0.372		1.13	0.179	0.583	10.2	81.8			42	82	13	11.4	<50.0
7/16/2006	9:14	Logan Inlet	Composite	0.943	0.263	5.74	0.047	2.38	24.1	228		21	132	204	36.8	36.9	<50.0
7/19/2006	12:34	Logan Inlet	Composite	0.633	0.189	3.83	0.242	1.27	7.24	97.8		13	113	109	30.4	35.0	97.0
7/24/2006	21:52	Logan Inlet	Composite	0.583	0.161	3.03	0.507	0.687	4.44	67.5		9	144	82	25.1	39.5	87.0
8/1/2006	6:16	Logan Inlet	Composite	0.598	0.139	3.47	0.325	1.17	6.92	95.3		18	119	86	26.2	31.0	100
8/2/2006	1:19	Logan Inlet	Composite	0.468	0.176	1.50	0.276	0.672	5.64	55.9		7	117	50	17.3	32	67.0
9/18/2006	18:51	Logan Inlet	Composite	0.573	n/c	2.60	0.126	0.365	8.40	114		n/c	83	94	23.1	21.1	<50
9/23/2006	18:33	Logan Inlet	Composite	0.324	n/c	n/c	n/c	n/c	4	87.1		n/c	29.3	60.6	13	13.6	<50
10/16/2006	8:03	Logan Inlet	Composite	3.374	2.768	5.028	0.372	1.055	<2.0	214		198	72.7	336	25.8	14.9	85
11/28/2006	10:55	Logan Inlet	Grab								3100						
12/12/2006	10:55	Logan Inlet	Grab	0.876	0.653	2.270	0.648	<0.500	133.0	567	8000	47.1	35.3	338	18.1	12.10	<50
7/19/2006	11:05	Logan East	Grab	0.397	0.214	2.20	0.831	0.714	3.61	114	5600		42	109	20.5	7.90	<50.0
9/22/2006	8:30	Logan East	Grab	0.134	0.073	0.672	0.418	<0.500	<2.0	78.5	1400	4.2	12.8	46.8	5.4	<5.00	<50
11/28/2006	10:50	Logan East	Grab	0.202	0.114	0.810	0.187	<0.500	<2.0	70.3	160	5.38	11.6	63	5.7	<5.00	<50
7/19/2006	10:45	Logan West	Grab	0.412	0.256	2.16	0.881	0.701	7.02	128	3500		251	120	15.0	11.9	<50.0
9/22/2006	8:35	Logan West	Grab	0.169	0.118	0.512	0.405	<0.500	<2.0	82.6	30000	3.9	15.2	39.6	5.9	6.4	<50
11/28/2006	10:45	Logan West	Grab	0.289	0.083	0.890	0.128	<0.500	<2.0	77.0	600	27.2	19	81	9.4	7.5	50
5/8/2006	22:19	Logan Outlet	Composite	0.752	0.101	3.76	0.220	1.17	715	1055		13	308	574	33.8	102	151
6/6/2006	9:44	Logan Outlet	Composite	0.530	0.222	2.89	0.127	0.644	245	990		13	34	566	17.5	16.6	<50.0
6/16/2006	21:16	Logan Outlet	Composite	0.608	n/c	2.05	0.155	1.02	198	348		n/c	92	380	15.2	24.8	<50.0
7/24/2006	10:29	Logan Outlet	Composite	0.470	0.134	2.49	0.145	0.511	95.2	472		9	30	290	8.00	10.1	<50
8/2/2006	3:49	Logan Outlet	Composite	0.850	0.138	2.42	0.076	1.094	60.1	331		9	65	207	11.2	15	<50
8/2/2006	19:45	Logan Outlet	Composite	0.659	0.148	1.73	0.046	0.527	49.9	262		9	21	174	5.10	5.10	<50
8/24/2006	20:01	Logan Outlet	Composite	0.593	0.176	2.89	0.220	1.03	21.4	145		5	134	90	18.7	45.1	<50
9/3/2006	22:17	Logan Outlet	Composite	0.554	n/c	2.56	n/c	n/c	24.2	174		n/c	54	120	13.9	20.4	<50
9/17/2006	13:15	Logan Outlet	Composite	0.736	n/c	3.80	0.154	0.220	23.4	190		n/c	123	143	31	31.0	<50
9/24/2006	0:00	Logan Oulet	Composite	0.432	n/c	n/c	n/c	n/c	23	172		n/c	28	98.7	8.2	7.5	<50
10/16/2006	7:15	Logan Outlet	Composite	5.200	2.215	17.290	n/c	2.490	n/c			150			66.8	96.6	292
11/28/2006	11:05	Logan Outlet	Grab								1300						
12/12/2006	10:45	Logan Outlet	Grab	0.988	0.525	2.740	0.122	0.921	58.0	388	11000	15.8	24	232	5.7	7.70	<50

Notes: n/c = not collected due to limited sample volume or expired holding time. May TKN data failed monthly blind performance standard, data underlined and marked suspect.

Table 24C. Event mean concentration statistics for Logan Pond in 2005.

Site Location	Statistical Function	TP mg/L	TDP mg/L	TKN mg/L	NO3NO2 mg/L	NH3 mg/L	Cl mg/L	Hardness mg/L	Sp.Cond. µmhos/cm	F. Coli cfu/100mL	Field pH	cBOD mg/L	TSS mg/L	TDS mg/L	Cd µg/L	Cu µg/L	Pb µg/L	Zn µg/L
Logan Inlet	MEAN	0.575	0.183	2.41	0.481	0.925	2.00	29.1	62.7	311,000	7.2	10	134	55	2.50	21.5	46.4	100
Logan Inlet	MEDIAN	0.483	0.171	2.02	0.508	0.809	2.38	30.0	62.1	100,000	7.1	11	130	51	2.50	21.5	41.9	90
Logan Inlet	STDEV	0.253	0.041	0.801	0.217	0.426	1.02	3.98	8.55	469,000	0.5	2	76	11	0.00	5.61	25.3	47
Logan Inlet	MAXIMUM	1.12	0.255	3.51	0.872	1.46	3.38	34.0	76.0	1,010,000	7.7	13	288	72	2.50	29.7	95.0	165
Logan Inlet	MINIMUM	0.273	0.145	1.58	0.222	0.250	1.00	24.0	52.4	32,000	6.6	7	44	39	2.50	13.7	17.9	25
Logan Inlet	NUMBER	9	6	9	9	9	9	7	9	4	5	6	9	9	9	9	9	9
Logan East	MEAN	0.465	0.245	1.97	0.829	0.965	1.84	43.7	87.7	42,600	7.7	12	48	106	2.50	23.2	28.3	30
Logan East	MEDIAN	0.429	0.209	1.51	0.858	0.564	1.69	46.0	102	19,200	7.6	11	47	117	2.50	23.2	27.8	25
Logan East	STDEV	0.193	0.125	1.13	0.567	0.753	0.956	11.3	49.6	53,600	0.3	7	29	38	0.00	12.5	15.2	12
Logan East	MAXIMUM	0.708	0.470	3.67	1.52	2.16	3.12	58.0	131	128,000	8.2	21	80	145	2.50	40.2	51.3	54
Logan East	MINIMUM	0.208	0.126	0.760	0.180	0.330	1.00	24.0	9.00	1,000	7.5	2	16	48	2.50	2.50	7.45	25
Logan East	NUMBER	6	6	6	6	6	6	6	6	6	4	6	6	6	6	6	6	6
Logan West	MEAN	0.418	0.249	1.78	0.736	0.774	2.09	37.4	119	15,100	7.9	8	45	108	2.50	19.1	10.9	29
Logan West	MEDIAN	0.373	0.212	1.68	0.676	0.762	2.14	44.0	115	8,900	7.6	9	37	110	2.50	17.8	10.4	25
Logan West	STDEV	0.160	0.085	0.671	0.321	0.254	0.965	19.9	34.9	17,300	0.7	4	28	22	0.00	5.57	4.96	10
Logan West	MAXIMUM	0.719	0.395	2.78	1.16	1.06	3.38	58.0	184	43,000	8.9	12	86	140	2.50	29.8	18.5	50
Logan West	MINIMUM	0.286	0.168	1.08	0.336	0.455	1.00	0.5	86.4	950	7.3	4	16	77	2.50	13.8	5.70	25
Logan West	NUMBER	6	6	6	6	6	6	6	6	6	4	6	6	6	6	6	6	6
Logan Outlet	MEAN	0.528	0.164	2.44	0.233	1.16	30.2	41.0	171	22,400	7.5	8	95	118	2.50	17.6	34.2	43
Logan Outlet	MEDIAN	0.510	0.142	2.43	0.195	0.869	25.3	36.0	129	16,000	7.1	8	98	106	2.50	19.7	33.0	25
Logan Outlet	STDEV	0.119	0.049	0.510	0.128	0.825	27.5	12.5	113	30,100	0.8	3	63	59	0.00	8.66	25.4	28
Logan Outlet	MAXIMUM	0.726	0.230	3.20	0.453	2.73	84.2	68.0	390	86,100	9.0	13	208	228	2.50	30.4	86.0	102
Logan Outlet	MINIMUM	0.356	0.094	1.68	0.062	0.250	4.88	30.0	77.0	0.5	6.9	4	22	61	2.50	2.50	6.30	25
Logan Outlet	NUMBER	10	7	10	10	10	10	8	10	7	6	7	10	10	10	10	10	10

Table 24D. Event mean concentration statistics for Logan Pond in 2006.

Site Location	Statistical Function	TP mg/L	TDP mg/L	TKN mg/L	NO3NO2 mg/L	NH3 mg/L	Cl mg/L	Sp.Cond. µmhos/cm	F. Coli cfu/100mL	Field pH	cBOD mg/L	TSS mg/L	TDS mg/L	Cu µg/L	Pb µg/L	Zn µg/L
Logan Inlet	MEAN	0.874	0.621	3.18	0.302	1.02	22.7	161	5550	7.2	44.7	89	144	22.9	24.8	87.2
Logan Inlet	MEDIAN	0.591	0.189	3.03	0.276	0.871	7.24	96.6	5550	7.2	18.0	98	90	24.1	26.1	87.0
Logan Inlet	STDEV	0.900	0.963	1.53	0.188	0.631	41.8	154	3465		68.9	42	110	7.63	11.2	13.0
Logan Inlet	MAXIMUM	3.37	2.77	5.74	0.648	2.38	133	567	8000	7.2	198	144	338	36.8	39.5	100
Logan Inlet	MINIMUM	0.324	0.139	1.13	0.047	0.365	4.00	55.9	3100	7.2	7.0	29	50	13.0	11.4	67.0
Logan Inlet	NUMBER	10	7	9	9	8	9	10	2	1	7	10	10	10	10	5
Logan East	MEAN	0.244	0.134	1.23	0.479	0.405	1.87	87.6	2387	7.2	4.79	22	73	10.5	4.30	25.0
Logan East	MEDIAN	0.202	0.114	0.810	0.418	0.250	1.00	78.5	1400	7.2	4.79	13	63	5.70	2.50	25.0
Logan East	STDEV	0.137	0.073	0.845	0.326	0.268	1.51	23.2	2851		0.834	17	32	8.63	3.12	0.0
Logan East	MAXIMUM	0.397	0.214	2.20	0.831	0.714	3.61	114	5600	7.2	5.38	42	109	20.5	7.90	25.0
Logan East	MINIMUM	0.134	0.073	0.672	0.187	0.250	1.00	70.3	160	7.2	4.20	12	47	5.40	2.50	25.0
Logan East	NUMBER	3	3	3	3	3	3	3	3	1	2	3	3	3	3	3
Logan West	MEAN	0.290	0.152	1.19	0.471	0.400	3.01	95.9	11367	7.9	15.6	95	80	10.1	8.60	33.3
Logan West	MEDIAN	0.289	0.118	0.890	0.405	0.250	1.00	82.6	3500	7.9	15.6	19	81	9.40	7.50	25.0
Logan West	STDEV	0.122	0.091	0.863	0.381	0.260	3.48	28.0	16202.0		16.5	135	40	4.59	2.91	14.4
Logan West	MAXIMUM	0.412	0.256	2.16	0.881	0.701	7.02	128	30000	7.9	27.2	251	120	15.0	11.9	50.0
Logan West	MINIMUM	0.169	0.083	0.512	0.128	0.250	1.00	77.0	600	7.9	3.90	15	40	5.90	6.40	25.0
Logan West	NUMBER	3	3	3	3	3	3	3	3	1	2	3	3	3	3	3
Logan Outlet	MEAN	1.03	0.457	4.06	0.141	0.963	138	412	6150	7.0	28.0	83	261	19.6	31.8	57.8
Logan Outlet	MEDIAN	0.634	0.162	2.74	0.145	0.971	58.0	331	6150	7.0	11.2	54	207	14.6	18.5	25.0
Logan Outlet	STDEV	1.32	0.723	4.43	0.058	0.619	206	319	6859		49.4	85	175	17.5	33.5	82.2
Logan Outlet	MAXIMUM	5.20	2.22	17.3	0.220	2.49	715	1055	11000	7.0	150	308	574	66.8	102	292
Logan Outlet	MINIMUM	0.432	0.101	1.73	0.046	0.220	21.4	145	1300.0	7.0	5.30	21	90	5.10	5.10	25.0
Logan Outlet	NUMBER	12	8	11	9	10	11	11	2	1	8	11	11	12	12	12

Table 24E. Event mean concentration statistics for Logan Pond in 2005 and 2006 combined.

Site Location	Type	TP mg/L	TDP mg/L	TKN mg/L	NO3NO2 mg/L	NH3 mg/L	Cl mg/L	Hardness mg/L	Sp.Cond. µmhos/cm	F. Coli cfu/100mL	E. Coli MPN/100mL	Field pH	cBOD mg/L	TSS mg/L	TDS mg/L	Cd µg/L	Cu µg/L	Pb µg/L	Zn µg/L
Logan Inlet	MEAN	0.733	0.419	2.80	0.392	0.931	11.7	29.1	114	209183	39900	7.2	28.8	110	102	2.50	22.9	24.8	56.1
Logan Inlet	MEDIAN	0.573	0.184	2.44	0.349	0.790	3.38	30.0	71.6	48000	39900	7.2	11.8	113	67	2.50	24.1	26.1	46.0
Logan Inlet	STDEV	0.676	0.719	1.25	0.217	0.530	29.9	3.98	120	395863		0.438	51.9	63.2	90	0.00	7.63	11.2	33.9
Logan Inlet	MAXIMUM	3.37	2.77	5.74	0.872	2.38	133	34.0	567	1011000	39900	7.7	198	288	338	2.50	36.8	39.5	100
Logan Inlet	MINIMUM	0.273	0.139	1.13	0.047	0.25	1	24.0	52.4	3100	39900	6.6	6.76	29.3	39	2.50	13	11.4	25.0
Logan Inlet	NUMBER	19	13	18	18	18	19	7	19	6	1	6	13	19	19	9	10	10	10
Logan East	MEAN	0.391	0.208	1.73	0.712	0.778	1.85	43.7	87.7	29162	1460	7.6	10.2	39.6	95.0	2.50	19.0	20.3	28.6
Logan East	MEDIAN	0.397	0.176	1.36	0.547	0.526	1.00	46.0	85.6	1500	1460	7.5	9.45	29.2	109	2.50	20.5	17.9	25.0
Logan East	STDEV	0.200	0.119	1.05	0.508	0.671	1.07	11.3	40.9	46953		0.367	6.76	27.6	38.1	0.00	12.5	17.0	9.59
Logan East	MAXIMUM	0.708	0.470	3.67	1.52	2.16	3.61	58.0	131	128000	1460	8.2	21.0	80.5	145	2.50	40.2	51.3	54.0
Logan East	MINIMUM	0.134	0.073	0.672	0.180	0.250	1.00	24.0	9.00	160	1460	7.2	2.09	11.6	46.8	2.50	2.50	2.50	25.0
Logan East	NUMBER	9	9	9	9	9	9	6	9	9	1	5	8	9	9	6	9	9	9
Logan West	MEAN	0.375	0.217	1.58	0.648	0.650	2.39	37.4	112	13850	3995	7.9	9.99	61.5	98.9	2.50	16.1	10.1	30.5
Logan West	MEDIAN	0.332	0.205	1.47	0.654	0.672	2.14	44.0	108	3500	3995	7.6	8.89	30.8	105	2.50	16.4	9.50	25.0
Logan West	STDEV	0.154	0.095	0.745	0.344	0.304	1.95	19.9	33.1	16019		0.619	7.71	75.3	30.3	0.00	6.71	4.34	10.9
Logan West	MAXIMUM	0.719	0.395	2.78	1.17	1.06	7.02	58.0	184	43000	3995	8.9	27.2	251	140	2.50	29.8	18.5	50.0
Logan West	MINIMUM	0.169	0.083	0.512	0.128	0.250	1.00	0.500	77.0	600	3995	7.3	3.74	15.2	39.6	2.50	5.90	5.70	25.0
Logan West	NUMBER	9	9	9	9	9	9	6	9	9	1	5	8	9	9	6	9	9	9
Logan Outlet	MEAN	0.802	0.320	3.29	0.189	1.06	86.5	41.0	297	18822	20140	7.4	18.7	88.8	193	2.5	18.7	32.9	51.0
Logan Outlet	MEDIAN	0.574	0.148	2.56	0.155	0.898	35.5	36.0	190	11000	20140	7.0	8.96	65.3	143	2.5	16.4	22.6	25.0
Logan Outlet	STDEV	0.994	0.534	3.26	0.109	0.717	157	12.5	268	27135		0.749	36.5	73.6	149	0	13.9	29.4	62.7
Logan Outlet	MAXIMUM	5.20	2.22	17.3	0.453	2.73	715	68.0	1055	86100	20140	9.0	150	308	574	2.5	66.8	102	292
Logan Outlet	MINIMUM	0.356	0.094	1.68	0.046	0.22	4.88	30.0	77.0	0.500	20140	6.9	3.96	21.3	61.0	2.5	2.50	5.10	25.0
Logan Outlet	NUMBER	22	15	21	19	20	21	8	21	9	1	7	15	21	21	10	22	22	22

Table 24F. Volumes recorded for Logan Pond, 7/7/05 – 10/31/2005.

Location	Volume Recorded (cubic feet)	Percent of Total Input
Logan Inlet	1,800,000	83%
Logan East	37,800	2%
Logan West	320,000	15%
Total Input	2,157,800	--
Logan Outlet	1,040,000	48%

Table 24G. Volumes recorded for Logan Pond, 5/5/06 – 11/29/2006.

Location	Volume Recorded (cubic feet)	Percent of Total Input
Logan Inlet	1,506,490	97%
Logan East	26,108	2%
Logan West	15,550	1%
Total Input	1,548,148	--
Logan Outlet	1,510,996	98%

Table 24H. Volumes recorded for Logan Pond, 2005 – 2006 combined.

Location	Volume Recorded (cubic feet)	Percent of Total Input
Logan Inlet	3,306,490	89%
Logan East	63,908	2%
Logan West	335,550	9%
Total Input	3,705,948	
Logan Outlet	2,550,996	69%

Table 24I. Estimated pollutant loads for Logan Pond, 7/7/05 – 10/31/2005.

Location	TP kg	TDP kg	TKN kg	NO3NO2 kg	NH3 kg	Cl kg	F. coli cfu	cBOD kg	TSS kg	TDS kg	Cd kg	Cu kg	Pb kg	Zn kg
Logan Inlet	29.3	9.33	123	24.5	47.1	102	1.58E+14	516	6,830	2,820	0.127	1.10	2.36	5.09
Logan East	0.602	0.318	2.56	1.07	1.25	2.39	5.52E+11	16	62.7	137	0.003	0.030	0.037	0.039
Logan West	3.78	2.26	16.1	6.67	7.01	18.9	1.37E+12	74	405	980	0.023	0.173	0.099	0.263
Logan Outlet	15.5	4.82	71.9	6.85	34.0	890	6.59E+12	235	2,800	3,480	0.074	0.518	1.01	1.26
Total Removed:	**18.2**	**7.08**	**69.7**	**25.4**	**21.4**	**-767**	**1.54E+14**	**371**	**4,500**	**459**	**0.080**	**0.783**	**1.49**	**4.14**
Percent Removed:	**54%**	**60%**	**49%**	**79%**	**39%**	**-624%**	**96%**	**61%**	**62%**	**12%**	**52%**	**60%**	**60%**	**77%**

Table 24J. Estimated pollutant loads for Logan Pond, 5/5/06 – 11/28/2006.

Location	TP kg	TDP kg	TKN kg	NO3NO2 kg	NH3 kg	Cl kg	F. coli cfu	cBOD kg	TSS kg	TDS kg	Cu kg	Pb kg	Zn kg
Logan Inlet	37.3	26.5	135	12.9	43.6	966	236,617	1,907	3,780	6,139	0.975	1.06	3.72
Logan East	0.181	0.099	0.907	0.354	0.299	1.382	1,763	3.539	16.4	53.9	0.008	0.003	0.018
Logan West	0.128	0.067	0.523	0.207	0.176	1.32	5,002	6.84	41.8	35.3	0.004	0.004	0.015
Logan Outlet	44.1	19.6	173	6.01	41.2	5,882	262,981	1,197	3,550	11,176	0.838	1.36	2.47
Total Removed:	**(6.5)**	**7.1**	**(37)**	**7.4**	**2.9**	**(4,914)**	**(19,599.0)**	**721**	**288**	**(4,948)**	**0.150**	**(0.299)**	**1.28**
Percent Removed:	**-17%**	**27%**	**-27%**	**55%**	**7%**	**-507%**	**-8%**	**38%**	**7%**	**-79%**	**15%**	**-28%**	**34%**

Table 24K. Estimated pollutant loads for Logan Pond, 2005 – 2006 combined.

Location	TP kg	TDP kg	TKN kg	NO3NO2 kg	NH3 kg	Cl kg	F. coli cfu	cBOD kg	TSS kg	TDS kg	Cd kg	Cu kg	Pb kg	Zn kg
Logan Inlet	68.6	39.2	262	36.6	87.1	1,098	19,574,052	2,692	10,312	9,549	0.234	2.14	2.32	5.25
Logan East	0.708	0.376	3.12	1.29	1.41	3.35	52,743	18	71.7	172	0.005	0.034	0.037	0.052
Logan West	3.56	2.06	15.0	6.15	6.17	22.7	131,521	95	584	939	0.024	0.153	0.096	0.290
Logan Outlet	57.9	23.1	237	13.7	76.5	6,241	1,358,840	1,347	6,411	13,952	0.180	1.35	2.37	3.68
Total Removed:	14.92	18.5	42.4	30.4	18.2	-5117	18,399,475	1,458	4,557	(3,292)	0.082	0.980	0.075	1.91
Percent Removed:	**20%**	**44%**	**15%**	**69%**	**19%**	**-455%**	**93%**	**52%**	**42%**	**-31%**	**31.2%**	**42.1%**	**3.05%**	**34.2%**

Bacteria grab samples collected during the 2005 – 2006 sampling seasons are presented in Table 24L. Most fecal coliform samples were comparable to samples collected from the NPDES stormwater monitoring (Table 23F, Section 23).

Table 24L. Bacteria grab samples from Logan Pond in 2006.

Date	Time	Site Location	F. Coli cfu/100mL	E. Coli mpn/100mL
7/23/2005	10:15	Outlet	1000	
7/25/2005	11:35	Outlet	16000	
8/26/2005	9:33	Inlet	32000	39900
8/26/2005	9:10	West	2000	3995
8/26/2005	8:45	Outlet	19000	20140
9/28/2005	9:30	Inlet	137000	
9/28/2005	9:15	Outlet	5000	
7/19/2006	11:05	East	5600	
7/19/2006	10:45	West	3500	
9/22/2006	8:30	East	1400	
9/22/2006	8:35	West	30000	
11/28/2006	10:55	Inlet	3100	
11/28/2006	10:50	East	160	
11/28/2006	10:45	West	600	
11/28/2006	11:05	Outlet	1300	
12/12/2006	10:55	Inlet	8000	
12/12/2006	10:45	Outlet	11000	

Six rain events in 2005 and four rain events in 2006 resulted in pipe surcharges at Logan Pond. Surcharged events are listed in Table 24M. There were no recorded surcharges in 2006 for the inlet, west alley or outlet.

Table 24M. Surcharged events at Logan Pond 2005 – 2006. Daily rainfall was recorded from the MPRB rain gage located at 3800 Bryant Ave. S., Minneapolis.

Date	Daily Rainfall (inches)	East Alley	West Alley	Outlet
7/25/2005	1.78	X		
8/26/2005	2.00	X		
9/4/2005	0.77	X		
9/21/2005	0.60	X		
10/4/2005	4.31	X	X	X
10/5/2005	0.50	X		
5/8/2006	0.57	X		
6/17/2006	0.11	X		
8/2/2006	3.88	X		
8/23/2006	0.92	X		

In 2005 negative velocities were recorded at the inlet, outlet and east alley. It was unknown if negative velocities occurred at the west alley because an area/velocity probe was not used at that location. The invert of the west alley pipe was designed to be 2.75 ft above the normal water level which should have been sufficient enough to prevent backflow from the pond. Negative velocities were recorded for the inlet on 9/5/05, 9/6/05 and 9/12/05 (sampled).

Negative velocities were recorded at the outlet on 6/29/05, 7/20/05, 7/23/05 (sampled), 7/25/05 (sampled), 8/4/05 and 8/8/05. The outlet probe was not recording velocities after 8/8/05 but was recording level accurately. Therefore, the outlet datalogger was reprogrammed to use Manning's formula to calculate flow rates on 8/22/05. Negative velocities were recorded at the east alley on 7/3/05, 7/20/05, 7/23/05, 7/24/05, 7/25/05, 8/4/05, 8/26/05, 9/3/05, 9/4/05, 9/6/05, 9/19/05, 9/22/05, 9/24/05, 9/25/05, 9/28/05, 10/4/05, and 10/5/05.

In 2006 negative velocities were recorded at the inlet, outlet and east alley. Area velocity probes were used at both alleys. Negative velocities were recorded at the inlet on 12/6/06 and outlet on 6/6/06 (sampled), 6/16/06 (sampled), 6/27/06, 7/22/06, 8/1/06, 8/13/06, 8/23/06, 8/24/06 (sampled) and 11/28/06 (sampled). The east alley frequently had standing water in the pipe during both years. The invert of the pipe was designed to be 0.3 ft above the natural water level which could have made it vulnerable to standing water during a wet season. It is also possible that the outlet grate plugs with debris. It was difficult to obtain accurate velocity and discharge readings for the east alley due to these issues. Negative velocities at the inlet and east alley are most likely attributed to water backing up from the pond into the pipe.

Many rain events were unusually large in 2005 resulting in greater than normal flow volumes. 2006 was a drier year than normal but there were a few large storms. It is uncertain why the outlet recorded negative velocities in 2005. The pipe could have backed up from further downstream. After 8/8/05, velocities were not recorded for the outlet due to equipment failure, and it is unknown if further negative velocities occurred.

There is a grate at the outlet to prevent large debris from entering the sewer system. The pond outlet grate seems to clog often with debris and trash. When the outlet is clogged, the pond increases in depth which limits the volume storage capacity. Upstream areas could then become more susceptible to flooding.

Due to precipitation variation between years, it is difficult to draw conclusions about the monitoring results based on the 2005 –2006 events sampled. Evaluating the pollutant load estimates, it seems Logan Pond offered some definite water quality benefits. For the time period 2005 – 2006 Logan Pond provided roughly 40 to 50 percent removal of many pollutants including total dissolved phosphorus, nitrate+nitrite, cBOD and TSS which would have otherwise entered downstream water bodies. Further monitoring with continued maintenance will help better determine how effective Logan Pond is at improving water quality.

Additional monitoring in the future can help better characterize pond performance efficiency. Sediment depths were measured and mapped during 2006 summer months to identify how fast the pond accumulated sediment. Other recommendations for future monitoring and design efficiency include:

- Increase litter pickup to reduce chance of outlet clogging and reduce the risk of alley backups
- Continue to measure depth of pond sediment to ensure proper function and decrease risk of sediment resuspension
- Add a staff gage to record depth of the pond in relation to standing water in pipes