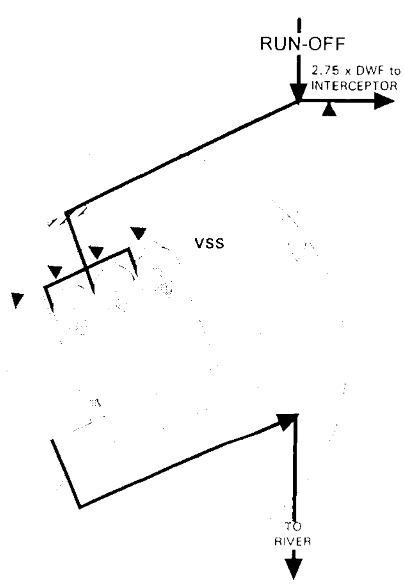
City of Winnipeg
Water and Waste Department

Combined Sewer Overflow Management Study

PHASE 2 Technical Memorandum No. 3

CONTROL ALTERNATIVES/ EXPERIENCE ELSEWHERE

APPENDICES



Internal Document by:

WARDROP Engineering Inc. and TetrES CONSULTANTS INC.

In Association With:

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TABLE OF CONTENTS

CONTROL ALTERNATIVES/EXPERIENCE ELSEWHERE

APPENDICES

APPENDIX A

G&S

CITY OF WINNIPEG

Combined Sewer Overflow Management Study

Technical Memorandum

PROJECT UNIT COSTS DEVELOPMENT

May 1995

PROJECT UNIT COSTS DEVELOPMENT

PROJECT UNIT COSTS DEVELOPMENT

1.0 PURPOSE AND BACKGROUND

To facilitate project costing for CSO alternatives evaluation, unit cost curves which represent CSO components of various sizes and complexities can be used. As part of the Winnipeg CSO Study, unit cost curves were developed for six CSO components. Each component is described below.

1.1 Detention Tanks

Subsurface storage involves an underground storage system using advanced tankage concepts and equipment. Subsurface tanks are most appropriate for storage of CSO due to potential health hazards of combined sewage. Subsurface storage is provided at the downstream end of a catchment area with facilities for draining by gravity or pumping to treatment. Tank facilities can vary in size and shape and can include mechanical components such as pumps and flushing systems.

1.2 Tunnels

Large diameter sewers or conduits bored deep below the ground surface provide for the collection, attenuation and conveyance of combined sewer overflows for treatment prior to discharge to receiving waters. Normally installed at the downstream end of a catchment area, tunnels can be used for storage of CSO where near surface space is unavailable due to existing services and/or is more economical where a number of CSO locations are in relatively close proximity to each other. Inflow to a tunnel is usually by deep shafts and outflow to the interceptor sewers/treatment facilities is by pumping. Primary treatment (solids settling) may be provided depending on the attenuation time of the CSO.

1.3 Sewers

Sewers provide for conveyance of sanitary sewage and stormwater to downstream treatment facilities and outlets. They also provide a viable alternative for areas which are serviced by combined sewers, that is sewer separation. Sewers installed in combined areas isolate the sewage flows from the generally less polluted stormwater flows so that each can be dealt with appropriately. Research indicates that sewer separation alone does not significantly reduce pollutant loadings to receiving waters, however, separation is highly effective for areas experiencing flooding problems. Large diameter in-line and/or off-line sewers can be constructed to store and release combined flows during wet weather events so that existing system capacity is not impacted. Sewers can also be applied to consolidate a number of CSO locations to a central location or connecting an existing CSO location to a more convenient location for connection to a tunnel or detention facility.

1.4 Forcemains

Forcemains provide the link between the storage facility, pumping station and the higher elevation facility being an existing sewer, outfall or treatment facility. Depending on the pumping rate and static head, varying pressure levels may be experienced by the forcemain.

1.5 Pumping Stations

These facilities include a wet well which houses one or more pumps that provide conveyance of sewage from a low elevation to a higherelevation. Depending on the CSO scheme, a single pump may lift settled solids to an interceptor or several pumps may lift effluent to a treatment facility.

1.6 High-Rate Treatment

High-Rate treatment of CSOs is a relatively new technology which may consist of a vortex separator, a disinfection unit and a coagulation installed at or near a combined sewer overflow. The objective is to catch and treat the overflow before it enters the receiving waters. The vortex separator provides for solids removal while the disinfection kills the bacteria associated with the effluent. Coagulation will enhance solids separation. Collected solids are directed to the sewer when capacity becomes available.

2.0 DEVELOPMENT OF COST ESTIMATION CURVES

The application of cost curves is considered when a planning level of cost estimation for the purpose of effectively evaluating alternatives is desired. To develop curves which reflect the construction cost of CSO components several steps were taken. The following sections outline these steps.

2.1 Unit Cost development

Cost curves which can be used to estimate the costs of various CSO schemes were developed for the six CSO components described. Project conditions including space constraints and limitations, soil conditions; method of construction; project materials are factors which become part of the overall cost of a project and hence reflect on the unit costs. The costs gathered for the curve development in this report include the varying conditions, however, identification of the specific factors affecting the units costs are unknown. Therefore, the costs associated with the projects are an average cost.

Unit costs for specific projects are established by review of actual project costs. To establish an overall range of unit costs which represents projects of varying size with varying construction conditions, several sources within the consultants library and experience were initially considered and secondly, project costs which have been constructed within the City of Winnipeg area were applied in augmenting our data on hand. The integration of these sources forms the basis of the unit cost curves. The sources of information include the following:

- construction contract information from the consultants libraries
- construction contract information held by municipal agencies
- equipment manufacturers
- literature

Information documented for each project include contract name; facility size; actual or estimated unit cost; total project cost; contract year and any other information associated with costs. This information was summarized for each of the six components described above.

2.2 E.N.R. Toronto Construction Cost Index

The Unit cost data gathered for the Toronto Area projects differ from those for the City of Winnipeg for many reasons. These may include material cost, site conditions; method of construction; labour rates; equipment costs etc. To bring the Toronto Area construction costs to the City of Winnipeg's unit construction cost, several Cost Index factors were considered.

Initially the Engineering News Record (E.N.R.) Toronto Construction Cost Index was applied to bring all Toronto area projects up to the 1991 unit rates. This Index has a table of factors which reflect cost changes on a monthly basis over several years. These factors are representative of all construction projects within the Toronto Area.

Figure Table A-1 provides the E.N.R. Toronto Construction Cost Index for various years based on the 1913 base of 100.

2.3 R.S. Means Index

To transfer the 1991 City of Toronto unit rates to the City of Winnipeg unit rates, the R.S. Means Construction Cost Index was applied to the data. The weighted average City Cost Indexes for Toronto and Winnipeg are outlined in Figure A-2. They are 117.3 and 102.9 respectively. The resultant factor of 0.877 was then applied to the Metro Toronto 1991 cost data to transpose these unit costs to reflect the City of Winnipeg realtive construction costs.

2.4 Southam Construction Cost Index

The Southam Construction Cost indexes for the City of Winnipeg were then referenced to generate City of Winnipeg present value construction costs for all projects considered. The month of March was used as a base to transpose City of Toronto values from 1991 to 1995. For specific City of Winnipeg projects the actual month and year of tender were referenced and the appropriate multiplier was established to bring these projects to March 1995 values.

Tables 2.1 to 2.6 summarize contract data considered in the development of cost curves. Included in the tables are 1995 unit costs, projected 1995 contract values and the information source.

TABLE 2.1

Detention Tank Unit Rates

	CONTRACT	VOLUME (m³)	UNIT COST ($/m³)	WATER RESER. ($/m³)	CONTRACT YEAR	VALUE ($ Mar, 1995) (Winnipeg)	COMMENTS / SOURCE
1	Eastern Beaches Tank - CSO	2250	$1,230		1989	$2,743,547	G&S
2	Eastern Beaches II - CSO	8000	$699		1994	$6,008,607	G&S - incl. piles, cleaning sys.,
3	Glendonwynne/Glen Lake - Storm	850	$678		1991	$575,905	MacViro
4	Keele Street Tank - CSO	43000	$267			$11,491,748	Paul Thiel & Assoc.
5	RedHill Creek Tank - CSO	68000	$70		1988	$4,705,105	City of Hamilton
6	Strachan Tank - CSO	20000	$379		1992	$7,522,033	Hamilton - Excl.disposal,contingency.
7	James Tank - CSO	2000	$647		1992	$1,293,716	City of Hamilton
8	North Maple Reservoir - water	11365		$85	1979	$895,417	MacViro Water Reservoir
9	North Richmond Hill - water	22700		$94	1978	$1,995,789	MacViro Water Reservoir
10	Richmond Hill Reservoir - water	31800		$99	1977	$2,938,301	MacViro Water Reservoir
11	Maple Reservoir - water	45500		$118	1978	$4,990,919	MacViro - precast struct.
12	Markham Reservoir - water	68000		$74	1978	$4,689,758	MacViro Water Reservoir
13	King St. Tank - CSO	75000	$245		1994	$18,357,179	City of Hamilton/R.V. Anderson
14	Devine St. Tank - CSO	10740	$440			$4,731,617	City of Sarnia - Tndr closed 06/10/95

TABLE 2.2

TUNNEL UNIT RATES

	CONTRACT	SIZE (dia. m.)	Other Projects UNIT COST ($/mm dia/m) Actual	Winnipeg Projects UNIT COST ($/mm dia/m) Actual	CONTRACT YEAR	VALUE ($ Mar, 1995) (Winnipeg)	COMMENTS / SOURCE
1	Lakeview Intake	2.55	1.52		1987	$7,528,168	G&S
2	Brantford	1.20	2.51		1988	$1,576,116	G&S
3	Sunnyside Storm	2.10	1.85		1978	$4,042,626	G&S
4	Toronto Heating System	3.00	1.55		1982	$5,858,477	G&S
5	Galley Avenue, Toronto	2.80	1.32		1978	$3,812,547	G&S
6	Yonge Street Storm Sewer, Toronto	2.00	1.91		1966	$6,023,758	G&S
7	Baby Point Trunk Storm Sewer, York	2.30	1.82		1980	$4,716,021	G&S
8	South Cedarvale Storm Sewer, York	1.95	1.44		1972	$1,569,623	G&S
9	Mortimer Avenue, East York	2.85	0.71		1978	$2,182,039	G&S
10	Sammon Avenue, East York	2.75	1.32		1979	$3,707,623	G&S
11	Westview Blvd., East York	2.25	2.26		1981	$572,969	G&S
12	Pape Avenue I, East York	2.10	0.90		1984	$796,104	G&S
13	Pape Avenue II, East York	2.10	1.39		1985	$876,091	G&S
14	Cosburn Avenue, East York	1.50	0.88		1984	$265,368	G&S
15	Queensdale Avenue, East York	2.25	1.01		1984	$902,251	G&S
16	Wilket Creek, North York	5.00	2.17		1972	$5,069,882	G&S
17	Wilket Creek/Hwy 401, North York	5.50	3.23		1971	$5,420,281	G&S
18	West Trunk, Sasketoon	2.40	0.72		1969	$1,348,144	G&S
19	Markham Road Sanitary Sewer, Markh	2.10	0.87		1982	$2,439,126	G&S
20	Walkley Road Sewer, Ottawa	3.10	1.99		1975	$6,080,050	G&S
21	Oakridges Trunk, Richmond Hill	2.10	1.08		1981	$781,763	G&S
22	Leslie Street Forcemain, MOE	3.90	2.72		1980	$2,991,506	G&S
23	South – West Collector, York/Durham	2.60	0.73		1980	$1,407,767	G&S
24	South – West Collector, York/Durham	2.50	1.69		1977	$10,411,456	G&S
25	South – West Collector, Toronto	2.80	1.72		1976	$11,600,907	G&S
26	Mid – Toronto Interceptor, Metro Toro	3.20	1.71		1972	$19,984,048	G&S
27	Carlaw Avenue, Metro Toronto	2.10	1.86		1973	$4,322,146	G&S
28	Chicago 1	10.60	1.66		–	$282,306,300	PBG&S – lined tunnel
29	Chicago 2	10.60	1.66		–	$141,153,150	PBG&S – unlined tunnel
30	College St.	2.90	1.75		1986	$3,336,860	City of Toronto – concrete lined
31	Toronto	0.38	5.24		1990	$1,967	City of Toronto micro – tunnel $/m
32	Heydon Park	0.60	6.63		1989	$3,983	City of Toronto micro – tunnel $/m
33	Rosedale	1.52	1.52		1974	$3,060,012	City of Toronto
34	Sandy Beach Collector	1.20	1.86		1975	$6,315,945	MacViro

TABLE 2.2

TUNNEL UNIT RATES

	CONTRACT	SIZE (dia. m.)	Other Projects UNIT COST ($/mm dia/m) Actual	Winnipeg Projects UNIT COST ($/mm dia/m) Actual	CONTRACT YEAR	VALUE ($ Mar, 1995) (Winnipeg)	COMMENTS / SOURCE
35	Petticoat Creek Coll.	0.60	1.83		1980	$678,288	MacViro
36	Leslie Street	1.20	2.21		1988	$3,886,417	MacViro
37	East York	2.40	1.55		1986	–	G&S – excludes shaft costs
38	City of York	1.50	1.63		1986	–	G&S – very short length in tunnel
39	Milwaukee	9.15	0.32		–	$2,932	PBG&S ($/m) – excludes shaft costs
40	Boston	9.15	0.75		–	$6,792	PBG&S ($/m) – excludes shaft costs
41	Simcoe	2.00	2.34		1991	$5,271,261	G&S – includes shafts and
42	Baltimore Sewer Relief Contract #5	1.35		1.02	Jan, 1995	$714,967	Cit misc equipment.
	Baltimore Sewer Relief Contract #5	1.50		1.00	Jan, 1995	$425,348	City of Winnipeg
	Baltimore Sewer Relief Contract #5	1.65		1.02	Jan, 1995	$319,160	City of Winnipeg
43	Baltimore Sewer Relief Contract #3	1.65		3.65	Dec, 1995	$288,964	City of Winnipeg
44	Linden Sewer Relief Contract #4	1.35		1.12	Oct, 1994	$371,712	City of Winnipeg (Jacked)
45	Mager Sewer relief Contract #5	1.35		2.55	Aug, 1994	$31,024	City of Winnipeg
	Mager Sewer relief Contract #5	1.95		1.08	Aug, 1994	$1,787,120	City of Winnipeg
46	N. E. Interceptor Ext. Contract #1	1.35		1.99	Dec, 1990	$295,107	City of Winnipeg (non–reinforced)
	N. E. Interceptor Ext. Contract #1	1.35		2.27	Dec, 1990	$122,574	City of Winnipeg (reinforced)

TABLE 2.3

FORCEMAIN UNIT RATES

	CONTRACT	SIZE (dia m)	COST ($/mm dia/m)	CONTRACT YEAR	VALUE ($ Mar, 1995) (Winnipeg)	COMMENTS / SOURCE
1	Elgin Mills Road	0.40	0.82	1982	$363,234	MacViro
2	South Maple	0.45	0.83	1983	$382,055	MacViro
3	East Richmond Hill	0.50	0.61	1980	$1,103,347	MacViro
4	North Richmond Hill	0.60	0.73	1978	$1,715,481	MacViro
5	Keele Area	0.75	0.72	1981	$1,123,579	MacViro
6	Markham Trunk Sewer	0.90	0.71	1978	$2,646,622	MacViro
7	14th Avenue	0.90	0.59	1981	$1,287,317	MacViro
8	Bayview/Younge	1.05	0.89	1978	$2,796,432	MacViro
9	City Tenders 150mm watermain	0.15	0.95	1990	$ 142 / m	City Tender
10	City Tenders 200mm watermain	0.20	0.78	1990	$ 155 / m	City Tender
11	City Tenders 300mm watermain	0.30	0.61	1990	$ 183 / m	City Tender
12	Matilda St watermain	0.30	0.55	1991	$84,692	City of Stratford
13	Serc Roads watermain	0.30	0.52	1991	$72,929	City of Stratford
14	Metcalfe forcemain relocation	0.20	1.35	1990	$113,079	City of Winnipeg (1990)

TABLE 2.4

SEWER UNIT RATES

	CONTRACT	SIZE (dia m)	COST ($/mm dia/m) Other Projects	COST ($/mm dia/m) Winnipeg Projects	CONTRACT YEAR	VALUE ($ Mar, 1995) (Winnipeg)	COMMENTS / SOURCE
1	Eastern Beaches 1	0.63	0.62		1989	$64,460	G&S
2	Eastern Beaches 2	0.80	0.65		1989	$175,877	G&S
3	Eastern Beaches 3	1.00	0.72		1989	$125,250	G&S
4	Eastern Beaches 4	1.40	0.81		1989	$21,549	G&S
5	Eastern Beaches 5	0.40	0.83		1989	$13,268	G&S
6	Wishing Well – Scar.	1.20	1.13		1988	$128,732	G&S
7	Brandford SWTSS	1.20	0.91		1988	$588,609	G&S
8	Sandy Beach Collector	1.22	1.86		1975	$6,315,945	MacViro
9	Central Duffin Collector	1.20	1.06		1983	$2,270,590	MacViro
10	Heydon Park	0.60	1.47			–	
11	Rosedale	1.52	1.20		1974	$1,835	MacViro (dollars/meter)
12	Rosedale	0.68	0.68		1974	$464	MacViro (dollars/meter)
13	Rosedale	0.53	0.75		1974	$399	MacViro (dollars/meter)
14	Rosedale	0.46	0.87		1974	$398	MacViro (dollars/meter)
15	Petticoat Creek Collector	0.67	0.61		1979	$1,237,631	MacViro
16	SE Trunk to Rosebank(1)	2.29	0.53		1979	$4,469,662	MacViro
17	SE Trunk to Rosebank(2)	2.44	0.42		1978	$2,767,072	MacViro
18	SE Trunk to Hydro Row	2.29	1.23		1979	$7,360,760	MacViro
19	SE Trunk to Bayly Street	3.05	0.88		1978	$5,210,621	MacViro
20	City Tenders	0.45	2.33			$1,050	City (dollars/meter)
21	City Tenders	0.60	1.06			$638	City (dollars/meter)
22	City Tenders < 3m depth	0.75	0.74			$559	City (dollars/meter)
23	City Tenders 3–4.5m depth	0.90	0.88			$795	City (dollars/meter)
24	City Tenders 4.5–6m depth	1.05	0.88			$928	City (dollars/meter)
25	Delaware Contract – Delaware	0.30	0.94		1991	$282	City (dollars/meter)
26	Delaware Contract – Delaware	0.45	0.83		1991	$376	City (dollars/meter)
27	Delaware Contract	0.25	1.81		1991	$452	City (dollars/meter)
28	N.W. Industrial Area 'A'	1.20	1.15		1992	$635,189	City of Brantford

TABLE 2.4

SEWER UNIT RATES

	CONTRACT	SIZE (dia m)	COST ($/mm dia/m) Other Projects	COST ($/mm dia/m) Winnipeg Projects	CONTRACT YEAR	VALUE ($ Mar, 1995) (Winnipeg)	COMMENTS / SOURCE
29	N.W. Industrial Area 'B'	1.05	0.49		1992	$1,072,764	City of Brantford
30	Matilda St. Sanitary	0.38	0.32		1992	$61,166	City of Stratford
31	Serc Road Storm	1.50	0.34		1992	$89,397	City of Stratford
32	North End W.P.C.C.	0.38		1.36	Apr, 1990	$101,992	City of Winnipeg
33	North End W.P.C.C. Part A	0.30		1.16	Feb, 1990	$192,352	City of Winnipeg
	North End W.P.C.C. Part A	0.38		1.07	Feb, 1990	$28,110	City of Winnipeg
34	Baltimore Sewer Relief Contract #8	0.38		0.86	Jan, 1995	$54,990	City of Winnipeg
	Baltimore Sewer Relief Contract #8	0.60		1.12	Jan, 1995	$231,536	City of Winnipeg
	Baltimore Sewer Relief Contract #8	0.75		1.06	Jan, 1995	$150,898	City of Winnipeg
	Baltimore Sewer Relief Contract #8	0.90		1.25	Jan, 1995	$219,760	City of Winnipeg
35	Mager Sewer relief Contract #8	0.30		0.98	Jan, 1995	$270,957	City of Winnipeg
	Mager Sewer relief Contract #8	0.38		0.94	Jan, 1995	$89,521	City of Winnipeg
	Mager Sewer relief Contract #8	0.45		1.01	Jan, 1995	$49,900	City of Winnipeg
	Mager Sewer relief Contract #8	0.60		1.00	Jan, 1995	$96,307	City of Winnipeg
36	Linden Sewer Relief Contract #6	0.30		1.64	Dec, 1994	$238,112	City of Winnipeg
	Linden Sewer Relief Contract #6	0.38		1.60	Dec, 1994	$90,370	City of Winnipeg
	Linden Sewer Relief Contract #6	0.45		1.89	Dec, 1994	$76,529	City of Winnipeg
	Linden Sewer Relief Contract #6	0.53		1.96	Dec, 1994	$46,238	City of Winnipeg
	Linden Sewer Relief Contract #6	0.60		2.12	Dec, 1994	$336,105	City of Winnipeg
	Linden Sewer Relief Contract #6	0.75		2.04	Dec, 1994	$396,185	City of Winnipeg
	Linden Sewer Relief Contract #6	0.90		2.37	Dec, 1994	$10,632	City of Winnipeg
37	Mager Sewer relief Contract #7	0.30		0.87	Dec, 1994	$148,344	City of Winnipeg
	Mager Sewer relief Contract #7	0.38		0.77	Dec, 1994	$98,394	City of Winnipeg
	Mager Sewer relief Contract #7	0.45		0.88	Dec, 1994	$37,613	City of Winnipeg
	Mager Sewer relief Contract #7	0.60		0.92	Dec, 1994	$49,548	City of Winnipeg
	Mager Sewer relief Contract #7	0.75		0.99	Dec, 1994	$272,615	City of Winnipeg
	Mager Sewer relief Contract #7	0.90		1.02	Dec, 1994	$110,731	City of Winnipeg
38	Mager Sewer relief Contract #6	0.30		1.40	Nov, 1994	$386,786	City of Winnipeg

TABLE 2.4

SEWER UNIT RATES

	CONTRACT	SIZE (dia m)	COST ($/mm dia/m) Other Projects	COST ($/mm dia/m) Winnipeg Projects	CONTRACT YEAR	VALUE ($ Mar, 1995) (Winnipeg)	COMMENTS / SOURCE
	Mager Sewer relief Contract #6	0.38		1.39	Nov, 1994	$320,120	City of Winnipeg
	Mager Sewer relief Contract #6	0.45		1.42	Nov, 1994	$150,550	City of Winnipeg
	Mager Sewer relief Contract #6	0.60		1.73	Nov, 1994	$26,026	City of Winnipeg
39	Linden Sewer Relief Contract #5	0.30		1.65	Nov, 1994	$144,244	City of Winnipeg
	Linden Sewer Relief Contract #5	0.38		1.41	Nov, 1994	$351,251	City of Winnipeg
	Linden Sewer Relief Contract #5	0.45		1.38	Nov, 1994	$131,031	City of Winnipeg
	Linden Sewer Relief Contract #5	0.60		1.24	Nov, 1994	$79,479	City of Winnipeg
	Linden Sewer Relief Contract #5	0.75		1.24	Nov, 1994	$97,798	City of Winnipeg
	Linden Sewer Relief Contract #5	0.90		1.30	Nov, 1994	$380,380	City of Winnipeg
40	Linden Sewer Relief Contract #4	0.30		1.69	Oct, 1994	$131,493	City of Winnipeg
	Linden Sewer Relief Contract #4	0.38		1.44	Oct, 1994	$292,475	City of Winnipeg
	Linden Sewer Relief Contract #4	0.45		1.40	Oct, 1994	$126,077	City of Winnipeg
40	Linden Sewer Relief Contract #4	0.60		1.25	Oct, 1994	$48,846	City of Winnipeg
	Linden Sewer Relief Contract #4	0.90		1.31	Oct, 1994	$135,104	City of Winnipeg
41	Linden Sewer Relief Contract #3	0.30		1.28	Jun, 1994	$313,549	City of Winnipeg
	Linden Sewer Relief Contract #3	0.38		1.10	Jun, 1994	$6,225	City of Winnipeg
	Linden Sewer Relief Contract #3	0.45		1.13	Jun, 1994	$51,003	City of Winnipeg
	Linden Sewer Relief Contract #3	0.60		1.16	Jun, 1994	$59,537	City of Winnipeg
	Linden Sewer Relief Contract #3	0.75		1.18	Jun, 1994	$13,353	City of Winnipeg
	Linden Sewer Relief Contract #3	0.90		1.26	Jun, 1994	$113,151	City of Winnipeg
42	Mager Sewer relief Contract #4	0.30		1.19	Jun, 1994	$91,766	City of Winnipeg
	Mager Sewer relief Contract #4	0.38		1.05	Jun, 1994	$143,873	City of Winnipeg
	Mager Sewer relief Contract #4	0.45		1.10	Jun, 1994	$149,596	City of Winnipeg
	Mager Sewer relief Contract #4	0.53		1.08	Jun, 1994	$73,995	City of Winnipeg
43	Tecumseh St. Storm Relief	1.05		1.36	Mar, 1994	$132,026	City of Winnipeg
	Tecumseh St. Storm Relief	0.75		0.81	Mar, 1994	$7,329	City of Winnipeg
44	Mager Sewer relief Contract #1	0.30		1.01	Feb, 1994	$1,802	City of Winnipeg
	Mager Sewer relief Contract #1	0.38		0.81	Feb, 1994	$294,294	City of Winnipeg

TABLE 2.4

SEWER UNIT RATES

	CONTRACT	SIZE (dia m)	COST ($/mm dia/m) Other Projects	COST ($/mm dia/m) Winnipeg Projects	CONTRACT YEAR	VALUE ($ Mar, 1995) (Winnipeg)	COMMENTS / SOURCE
	Mager Sewer relief Contract #1	0.45		0.82	Feb, 1994	$170,771	City of Winnipeg
	Mager Sewer relief Contract #1	0.53		0.87	Feb, 1994	$61,461	City of Winnipeg
	Mager Sewer relief Contract #1	0.60		0.92	Feb, 1994	$121,221	City of Winnipeg
	Mager Sewer relief Contract #1	0.75		1.08	Feb, 1994	$118,118	City of Winnipeg

City of Winnipeg 1995 Costs

TABLE 2.5

PUMPING STATIONS

	PROJECT	CONST. YEAR	ORIGINAL PRICE $	VALUE ($ Mar, 1995) (Winnipeg) ($ 1995)	CAPACITY L/s	POWER kW	TOTAL HEAD m	APPROX POWER REQUIRED INSTALLED kW/L/s
1	Main PS for MTI	1971–77	3587213	$14,509,603	12628	4457	27	0.353
2	Amherstview PS	1989	1373632	$1,447,290	270	127	36	0.470
3	Caledonia PS	1988	610000	$677,535	112	30	20	0.268
4	Maryport PS	Est.	750000	$705,766	139	133	73	0.549
5	Humber River PS	1982	2793000	$4,258,120	790	774	75	0.980
6	Dingman Creek PS	1967	324000	$2,296,091	284	168	31	0.591
7	Burlington PS No 6	1959	120000	$1,733,361	186	67	30	0.361
8	Halifax PS	1972	325000	$1,275,083	625	130	13	0.208
9	Finch / Valley Farm PS	1977	139000	$315,242	20	20	14	1.007
10	Finch / Liverpool PS	1977	168000	$379,231	183	50	10	0.273
11	Winnipeg Metro East PS	1962	1105000	$11,407,057	3678	2611	54	0.710
12	Brantford Albion PS	1968	110000	$722,704	442	224	38	0.506
13	Winnipeg McPhillips PS	1966	1470000	$11,813,578	4204	2798	54	0.665
14	Metro St. Albans PS	1966	1100000	$8,839,951	3153	1567	42	0.497
15	Turtle Creek PS	1964	383000	$3,690,684	841	597	44	0.710
16	Lake Erie Low Lift PS	1966	952000	$7,650,501	502	7	91	0.014
17	Niagra Falls Kent Ave PS	1973	1200000	$4,099,087	1051	740	57	0.710

City of Winnipeg 1995 Costs

TABLE 2.6

Vortex Separators/Swirl Concentrators

	CONTRACT/LOCATION	SIZE (MGD)	SIZE (DIA. m)	# OF VESSELS	UNIT COST ($Mar. 1995/MGD) (WINNIPEG)	CONTRACT YEAR	VALUE ($ Mar. 1995) (WINNIPEG)	Source/Comments
1	Decatur, IL – 7th Ward	94.9	13	1	$51,443	1990	$4,883,197	W.C. Pisano, 1990
2	Decatur, IL – Licoln Park	346.4	14	4	$37,593	1990	$13,021,860	W.C. Pisano, 1990
3	Hartford, CT	62.5	9	2	$31,053	1994	$1,939,265	R. Field, T.P. O'Connor, 1994 Draft
4	Decatur, IL – McKinley Park	33.3	8	1	$61,089	1994	$2,034,666	Technical Mem. #2 City of Winnipeg, 1994
5	Washington, D.C.	110.7	17	3	$49,222	1994	$5,451,046	Technical Mem. #2 City of Winnipeg, 1994
6	CS3 Lower Deck, New York	324.7	18	3	$113,949	1993	$37,003,983	URS Consultants, 1993 – estimate
7	Toledo, OH		10	3	$26,412	1994		Technical Mem. #2 City of Winnipeg, 1994

3.0 COST CURVES DEVELOPED

When plotted, the unit costs for the CSO components show a varying degree of scatter. As mentioned previously, this is due to the varying site constraints, physical conditions and construction practices which may have existed from one project to another. Curves were fitted to each data set to represent unit cost curves. Figures 3.1 to 3.6 represent these curves, which can be used to facilitate level 'A' screening of CSO alternatives. Each of the figures is discussed briefly.

3.1 Detention Tanks

Figure 3.1 represents the relationship between the unit cost of detention facilities and the total volume of the detention facility. Construction costs of two CSO stormwater tanks, one stormwater tank, and five CSO tanks were used to develop the relationship. The construction costs of five water reservoirs are shown in the lower portions of the graph, which clearly indicates that water reservoirs require lower operation requirements.

3.2 Tunnels

Figure 3.2 represents the relationship between the unit cost and the tunnel size. Forty-six sets of data representing actual contracts, were used to develop the relationship as shown. The source of the data points are shown in Table 2.2 under contract name and comments.

3.3 Forcemains

Figure 3.3 represents the relationship between the unit cost and forcemain diameter. Fourteen forcemain and watermain contracts were used to develop the relationship shown on the figure.

3.4 Sewers

Figure 3.4 represents the relationship between unit cost and sewer size. Forty-four storm and sanitary sewer contracts were used to develop the cost curve. In general, the points show a wide scatter since the unit costs are also dependant upon the sewer depth, soils condition and restoration requirements. These factors were not identified in the data collection procedure.

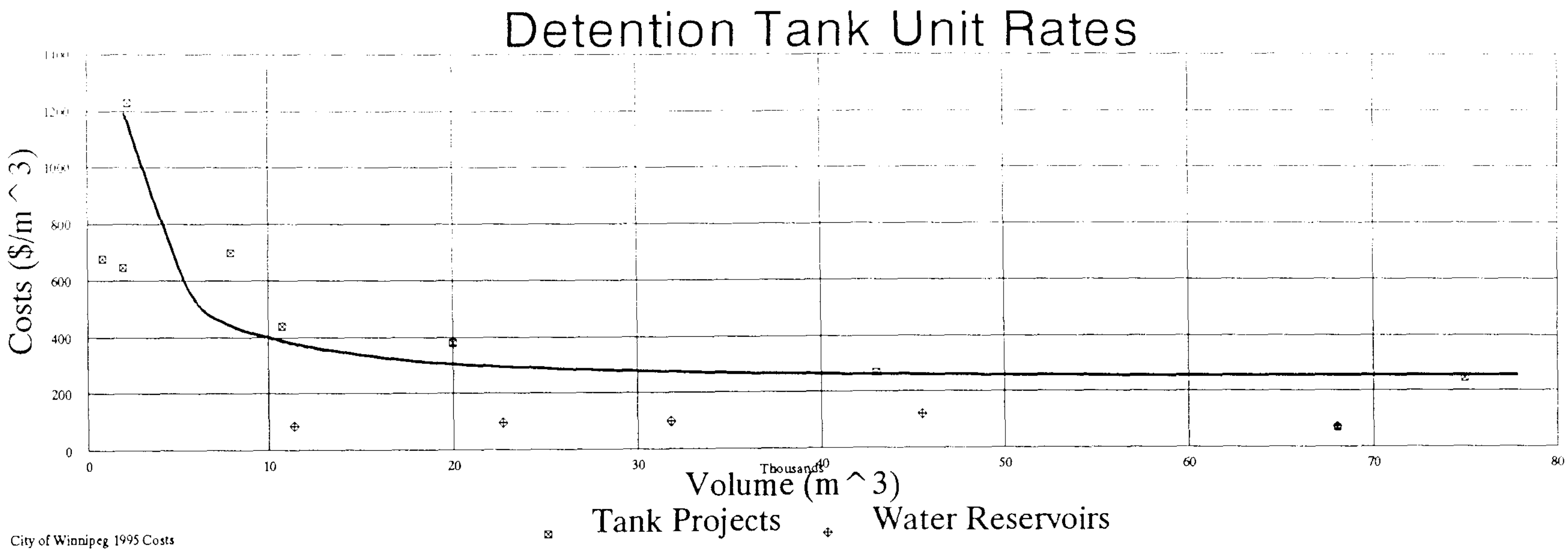
3.5 Pumping Stations

Figure 3.5 represents the relationship between the power requirement of a pumping station and the cost of such a facility. Cost was related to power since power is a function of both flow capacity of the station and the total lift head required. Seventeen pumping station contracts were used to develop the relationship shown in the figure.

Seventeen pumping station contracts were used to develop the relationship shown in the figure.

3.6 High-Rate Treatment

Figure 3.6 shows the relationship between unit cost and size for vortex separators and swirl concentrators. The curve is based on six projects which have been constructed in the United States which may have one or more components. For the purposes of this report the curve should only be considered as a very coarse estimating tool since unit costs vary significantly and may represent multiple component facilities.



Detention Tank Unit Rates
Costs ($/m ^ 3)
0
200
400
600
800
1000
1200
1400
0
10
20
30
40
50
60
70
80
Thousands
Volume (m ^ 3)
Tank Projects
Water Reservoirs
City of Winnipeg 1995 Costs

FIGURE 3.1

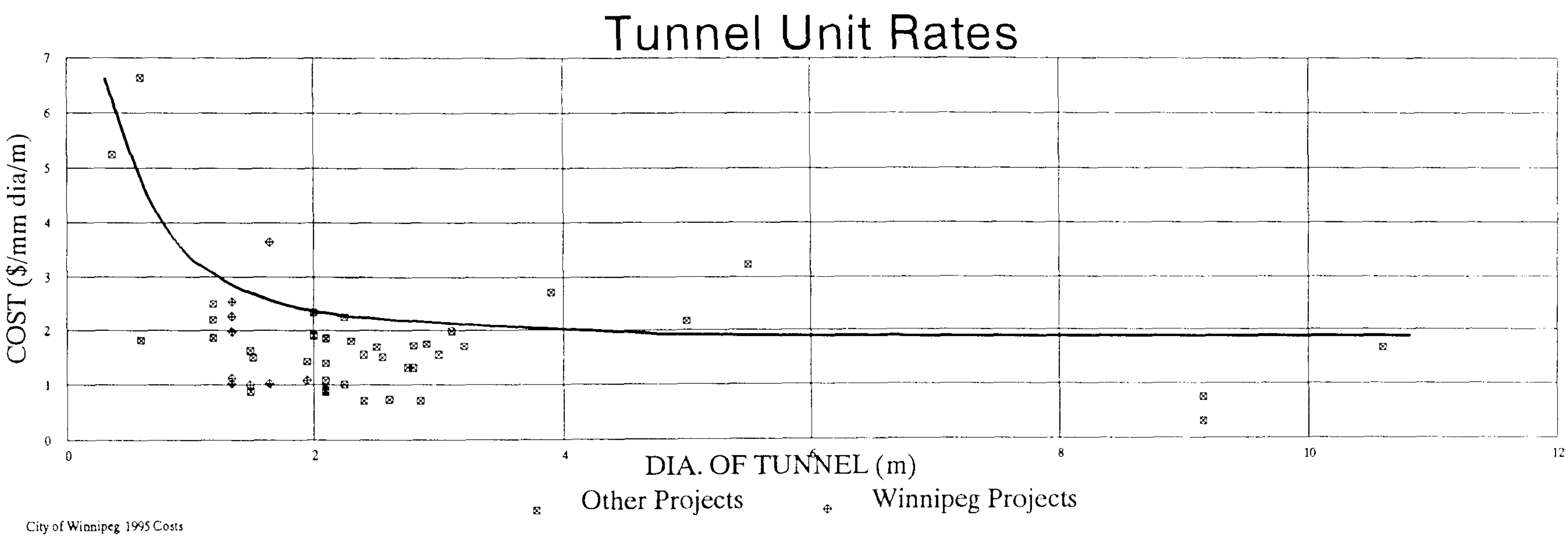
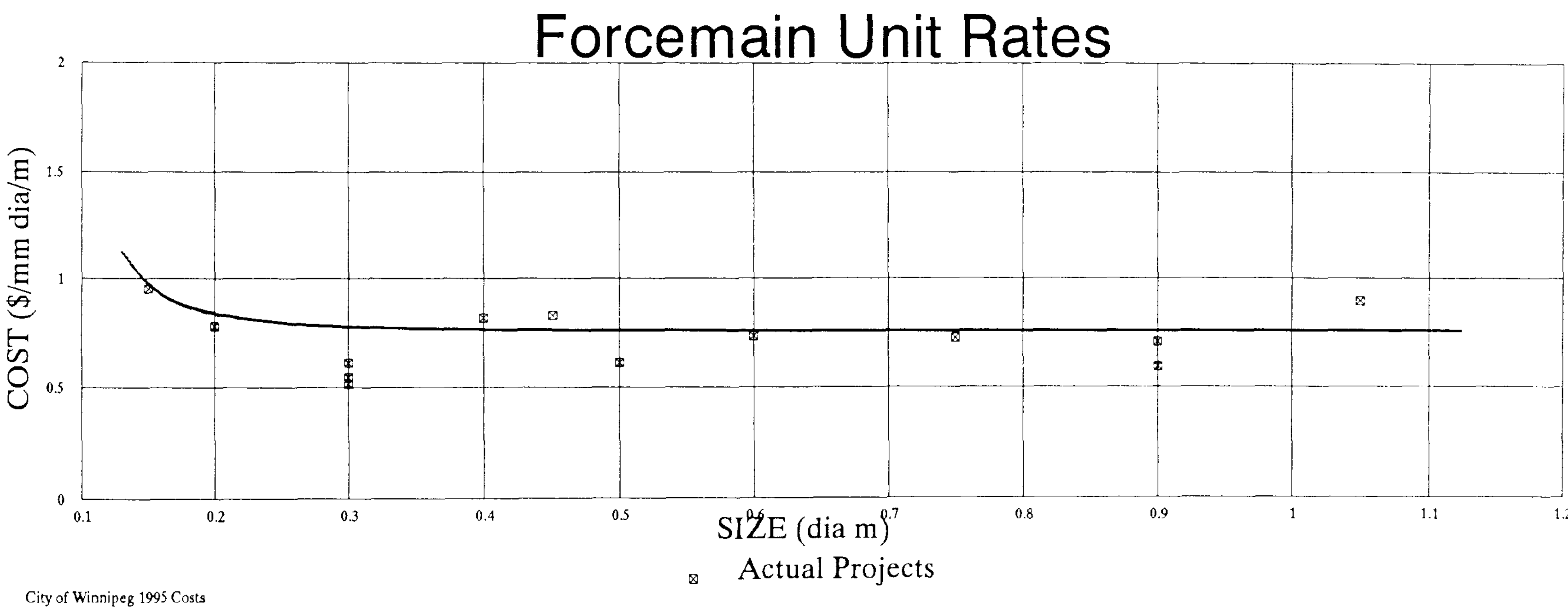

Tunnel Unit Rates
COST ($/mm dia/m)
DIA. OF TUNNEL (m)
0
1
2
3
4
5
6
7
0
2
4
6
8
10
12
Other Projects
Winnipeg Projects
City of Winnipeg 1995 Costs

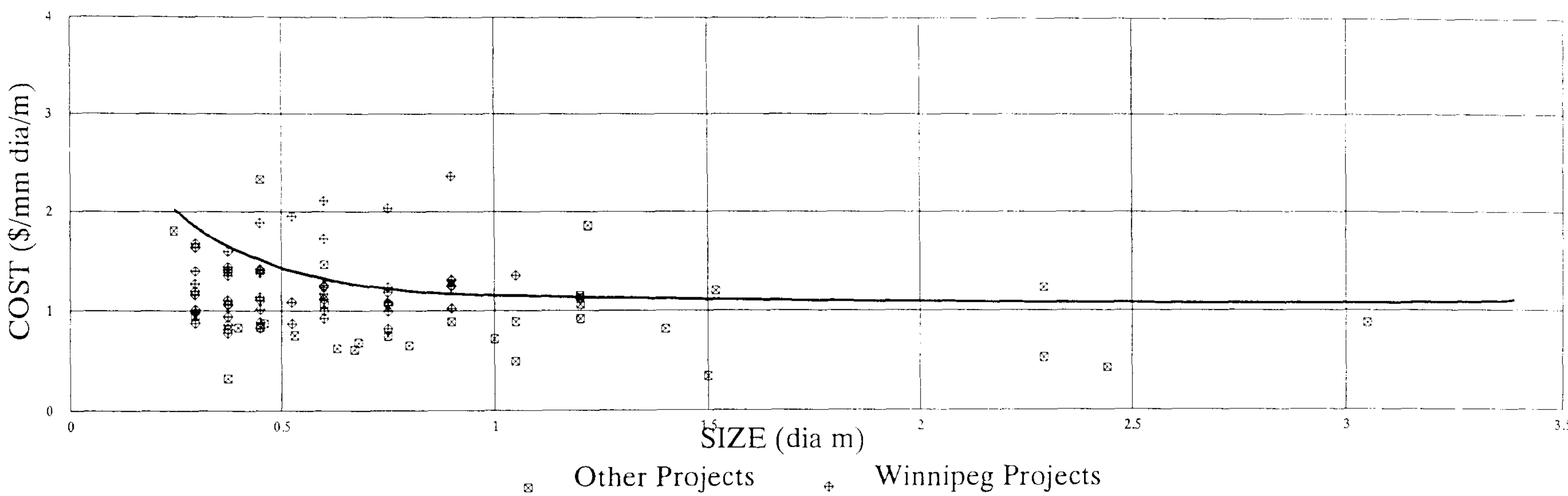
FIGURE 3.2



Forcemain Unit Rates
COST ($/mm dia/m)
2
1.5
1
0.5
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
SIZE (dia m)
Actual Projects
City of Winnipeg 1995 Costs

FIGURE 3.3

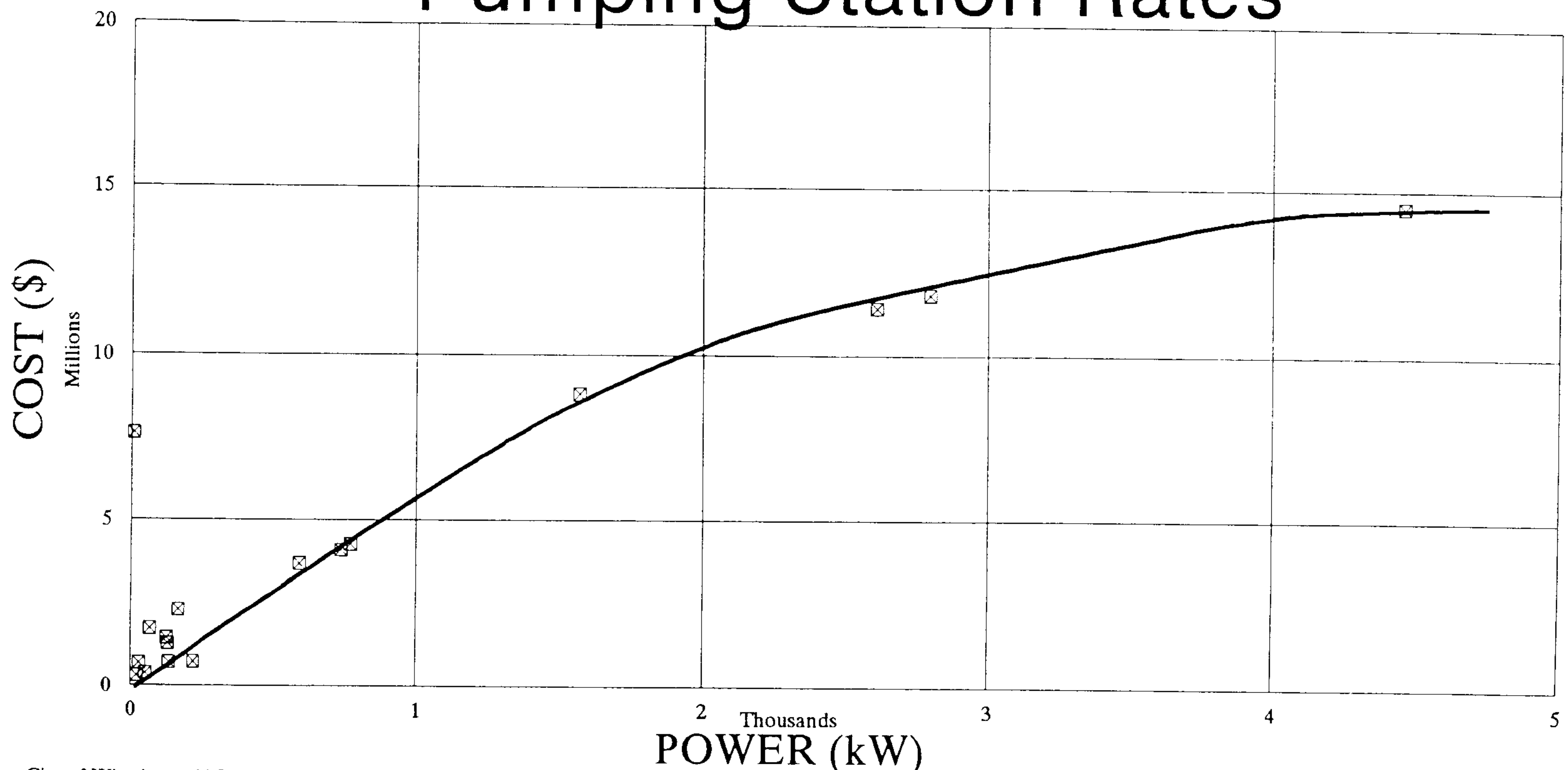
Sewer Unit Rates



City of Winnipeg 1995 Costs

FIGURE 3.4

Pumping Station Rates



City of Winnipeg 1995 Costs

Pumping Station size based on Power,
where Power (kW) $= \dfrac{Q \times 10 \times H}{33000 \times 0.6 \times 1.34}$

Q = gallons/minute
H = Head (ft)
0.6 = efficiency
33000 = convert lbs. to Hp
1.34 Hp = 1 kW
10lbs/gal = weight of water

FIGURE 3.5

Vortex Separator Unit Rates

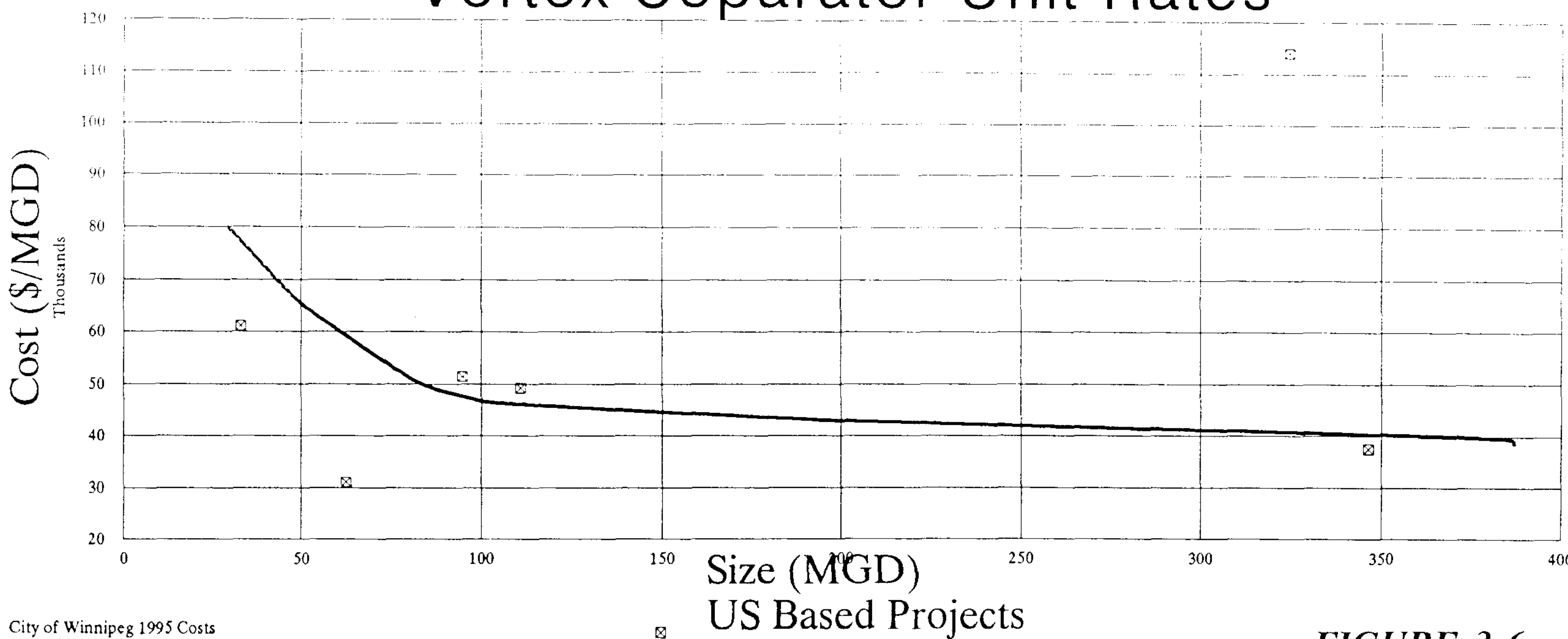


FIGURE 3.6

APPENDIX A

INDEX CHARTS

E.N.R. (TORONTO) CONSTRUCTION COST INDEX

(year 1913 = 100 base)

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AVG
1969	1044	1055	1086	1095	1094	1071	1091	1089	1078	1076	1082	1122	1082
1970	1115	1110	1114	1109	1192	1188	1221	1222	1226	1222	1221	1260	1183
1971	1259	1262	1268	1272	1276	1282	1342	1406	1404	1392	1396	1449	1334
1972	1449	1479	1479	1484	1484	1485	1469	1557	1606	1613	1645	1679	1536
1973	1673	1685	1706	1708	1753	1742	1791	1788	1803	1807	1850	1844	1763
1974	1844	1825	1825	1818	1850	1955	1939	1964	1972	2006	1982	1980	1913
1975	2004	2004	2016	1998	2007	2054	2076	2103	2218	2220	2213	2240	2096
1976	2251	2254	2269	2269	2364	2358	2462	2472	2461	2461	2523	2517	2388
1977	2530	2560	2565	2572	2571	2687	2702	2714	2724	2742	2792	2826	2665
1978	2839	2856	2867	2868	2877	2877	2906	2981	2988	2985	3015	3078	2928
1979	3110	3144	3121	3140	3152	3296	3308	3346	3382	3382	3354	3345	3257
1980	3332	3367	3363	3326	3295	3326	3512	3514	3500	3503	3506	3512	3421
1981	3573	3583	3613	3607	3761	3766	3779	3794	3756	3728	3747	3794	3708
1982	3824	3810	3813	3832	3838	3836	3857	3996	4133	4122	4137	4217	3951
1983	4220	4221	4215	4224	4231	4574	4573	4547	4520	4504	4504	4504	4403
1984	4522	4522	4522	4556	4527	4554	4554	4542	4555	4548	4541	4542	4540
1985	4563	4551	4568	4568	4753	4813	4774	5106	5111	5107	4770	4770	4788
1986	4781	4798	4808	4805	4848	4850	4822	5064	5101	5091	5080	4979	4919
1987	5086	5075	5075	5075	5254	5257	5240	5229	5257	5246	5264	5253	5193
1988	5263	5263	5280	5285	5280	5418	5451	5580	5585	5585	5569	5563	5427
1989	5558	5563	5558	5558	5484	5794	5794	5794	5794	5794	5799	5794	5690
1990	5794	5793	5793	5793	6017	5975	5975	5851	6401	6396	6401	6001	6016
1991	6402	6343	6343	6354	6342	6555	6570	6575	6575	not avilable	6537	6537	6467
1992	6537	6537	6537	6790	6732	not avilable	6732	6732	6731	6887	6887		6710
1993			7124	7254	7309	7319	7153		7199	7264	7388		7251
1994	7562	not avilable	7507	7507	7507	7617	7720	7720	7677	7693			7602

FIGURE A-1

CITY COST INDEXES

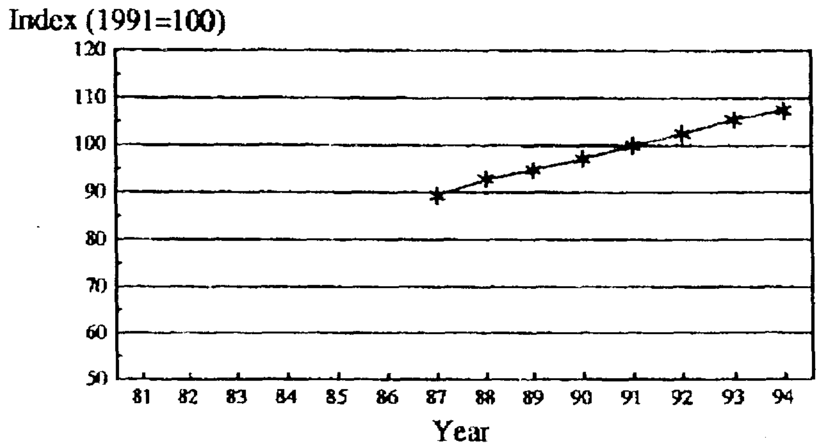
DIVISION	VIRGINIA												WASHINGTON					
	NEWPORT NEWS			NORFOLK			RICHMOND			ROANOKE			SEATTLE			SPOKANE		
	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL
2 SITE WORK	120.9	83.1	103.9	111.0	81.5	97.8	82.8	86.0	84.3	100.4	83.4	92.8	101.3	99.4	100.4	108.1	99.5	104.2
3.1 FORMWORK	102.6	62.2	71.1	107.0	62.1	72.0	99.4	66.8	74.1	105.2	55.5	66.5	82.8	100.1	96.3	106.4	93.0	96.0
3.2 REINFORCING	100.9	66.6	86.7	100.9	66.6	86.7	96.9	72.7	86.9	105.8	73.5	92.4	108.6	106.1	107.5	112.9	106.1	110.1
3.3 CAST IN PLACE CONC.	115.4	85.0	96.7	113.2	87.3	97.3	109.5	87.5	95.9	111.6	86.4	96.1	97.3	109.9	105.1	108.2	97.9	101.9
3 CONCRETE	109.6	74.4	87.0	109.2	75.5	87.6	104.7	78.0	87.6	109.0	73.1	86.0	96.9	105.7	102.6	108.9	96.7	101.1
4 MASONRY	104.0	63.0	72.5	103.5	63.0	72.4	100.9	79.1	84.2	102.4	57.7	68.1	125.5	106.9	111.2	115.5	88.0	94.4
5 METALS	86.7	72.9	81.7	86.6	73.4	81.9	96.0	77.2	89.3	96.7	78.3	90.1	105.9	106.9	106.2	102.9	102.4	102.7
6 WOOD & PLASTICS	103.6	65.1	82.0	103.3	65.1	81.8	103.0	70.7	84.8	102.4	56.8	76.7	76.9	97.8	88.7	102.2	91.6	96.3
7 MOISTURE PROTECTION	85.5	48.1	73.5	86.8	48.1	74.4	108.5	48.5	89.2	85.9	47.9	73.7	111.7	107.3	110.3	96.1	95.9	96.0
8 DOORS, WINDOWS, GLASS	90.5	63.6	76.4	89.5	63.6	76.0	90.0	64.6	76.7	94.6	57.5	75.2	94.4	96.3	95.4	100.3	91.7	95.8
9.2 LATH & PLASTER	113.6	64.1	76.1	98.2	64.4	72.6	105.4	65.0	74.8	107.3	53.2	66.3	99.4	105.7	104.1	115.4	89.2	95.6
9.2 DRYWALL	87.3	62.9	75.8	87.4	62.9	75.8	97.8	67.6	83.6	91.8	55.3	74.6	81.0	98.6	89.3	96.6	92.0	94.4
9.5 ACOUSTICAL WORK	97.4	63.8	79.0	94.6	63.8	77.8	104.4	69.8	85.4	96.7	55.1	74.0	99.2	97.5	98.3	105.0	91.7	97.8
9.6 FLOORING	98.7	60.6	88.3	94.5	60.6	85.3	88.0	75.6	84.6	103.3	54.0	89.9	90.1	105.0	94.2	106.2	91.4	102.1
9.9 PAINTING	91.0	56.0	63.4	101.7	59.2	68.1	96.7	53.9	62.9	90.8	51.0	59.4	83.7	98.1	95.0	100.9	91.0	93.1
9 FINISHES	91.6	60.5	74.9	91.3	61.6	75.4	96.2	63.5	78.7	94.9	53.6	72.8	85.1	99.2	92.7	100.2	91.4	95.5
10-14 TOTAL DIV. 10-14	100.0	73.3	92.1	100.0	73.5	92.2	100.0	74.1	92.4	100.0	72.5	91.9	100.0	107.6	102.2	100.0	99.9	99.9
15 MECHANICAL	102.7	61.8	82.2	102.5	63.6	83.0	101.5	71.6	86.6	103.1	68.0	85.6	99.7	106.0	102.8	103.0	100.3	101.7
16 ELECTRICAL	106.1	55.4	71.0	106.1	55.4	71.0	103.2	65.4	77.0	102.4	56.4	70.5	106.5	94.7	98.3	104.1	96.1	98.6
1-16 WEIGHTED AVERAGE	100.3	65.5	81.5	99.5	66.1	81.5	99.5	72.4	84.9	100.2	64.7	81.1	100.5	103.2	102.0	103.5	95.7	99.3

DIVISION	WASHINGTON			WEST VIRGINIA						WISCONSIN						WYOMING		
	TACOMA			CHARLESTON			HUNTINGTON			MADISON			MILWAUKEE			CHEYENNE		
	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL
2 SITE WORK	104.8	97.6	101.6	119.2	100.0	110.6	124.3	102.6	114.6	83.3	97.4	89.6	75.1	101.7	87.0	109.7	88.5	100.2
3.1 FORMWORK	113.4	99.9	102.9	118.1	93.9	99.2	99.2	98.9	99.0	109.2	84.6	90.0	105.4	103.0	103.5	110.8	67.4	77.0
3.2 REINFORCING	100.6	106.1	102.9	120.8	90.8	108.4	116.3	106.4	112.2	106.2	84.7	97.3	104.5	106.9	105.5	103.2	70.1	89.5
3.3 CAST IN PLACE CONC.	100.5	101.5	101.1	117.7	97.5	105.3	114.3	97.3	103.8	100.0	101.8	101.1	80.4	96.3	90.2	98.2	90.3	93.3
3 CONCRETE	103.1	101.3	101.9	118.5	95.5	103.7	111.7	98.8	103.4	103.2	93.5	97.0	90.8	99.8	96.6	101.9	79.5	87.5
4 MASONRY	123.1	92.5	99.6	90.7	93.8	93.1	102.6	85.1	89.2	101.5	77.5	83.1	103.8	103.2	103.3	112.0	61.8	73.5
5 METALS	99.1	103.6	100.7	111.6	93.5	105.1	102.3	102.9	102.5	96.6	90.2	94.3	95.5	103.5	98.3	87.3	77.8	83.9
6 WOOD & PLASTICS	102.2	97.6	99.6	118.0	95.4	105.3	103.8	99.7	101.5	100.0	85.0	91.6	95.4	100.7	98.4	96.7	68.2	80.6
7 MOISTURE PROTECTION	110.2	105.8	108.8	89.9	96.9	92.1	89.3	97.0	91.8	87.4	80.4	85.2	103.2	98.1	101.6	89.0	65.9	81.6
8 DOORS, WINDOWS, GLASS	103.2	96.3	99.6	106.7	88.7	97.3	112.4	94.2	102.8	97.7	82.2	89.6	95.2	101.1	98.3	108.4	70.5	88.5
9.2 LATH & PLASTER	108.1	104.9	105.6	118.7	90.0	96.9	116.0	90.2	96.5	105.3	78.3	84.8	103.2	100.3	101.0	107.8	89.3	93.8
9.2 DRYWALL	100.1	98.6	99.4	100.6	92.1	96.6	98.0	95.7	96.9	109.2	84.7	97.7	95.7	101.4	98.4	95.6	76.5	86.6
9.5 ACOUSTICAL WORK	105.0	97.5	100.9	108.8	94.3	100.9	110.5	100.3	104.9	108.5	84.5	95.4	100.1	101.1	100.6	95.5	67.1	80.0
9.6 FLOORING	98.1	84.8	94.4	85.4	95.7	88.2	81.3	88.0	83.1	96.6	77.1	91.3	102.6	94.5	100.4	93.2	63.7	85.2
9.9 PAINTING	109.8	98.1	100.5	124.0	80.5	89.7	114.6	81.8	88.7	98.9	82.7	86.1	103.7	98.1	99.2	100.3	88.1	90.7
9 FINISHES	101.2	97.7	99.4	100.8	88.5	94.2	97.5	90.4	93.7	105.2	83.1	93.4	98.6	99.6	99.2	95.8	79.6	87.1
10-14 TOTAL DIV. 10-14	100.0	107.5	102.2	100.0	93.6	98.1	100.0	91.3	97.4	100.0	87.3	96.2	100.0	92.1	97.7	100.0	80.8	94.3
15 MECHANICAL	101.6	99.7	100.7	101.7	87.1	94.4	104.1	90.1	97.1	101.7	86.0	93.8	100.3	92.2	96.3	102.8	67.0	84.9
16 ELECTRICAL	104.1	102.9	103.3	95.5	92.3	93.3	98.5	85.0	89.1	88.9	86.8	87.5	93.6	98.6	97.0	98.6	71.6	79.9
1-16 WEIGHTED AVERAGE	103.5	99.6	101.4	104.5	92.3	97.9	104.1	92.4	97.8	98.3	86.6	92.0	96.3	98.7	97.6	100.1	72.9	85.5

DIVISION	CANADA																	
	EDMONTON			MONTREAL			QUEBEC			TORONTO			VANCOUVER			WINNIPEG		
	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL	MAT.	INST.	TOTAL
2 SITE WORK	107.4	102.6	105.2	96.3	99.7	97.8	101.4	77.1	90.5	117.1	111.4	114.5	116.3	108.0	112.6	109.2	103.3	106.5
3.1 FORMWORK	121.0	105.8	109.2	121.3	113.0	114.8	114.3	113.1	113.3	119.3	139.8	135.3	109.8	120.9	118.5	108.3	100.7	102.4
3.2 REINFORCING	119.7	101.8	112.3	119.4	102.9	112.6	117.7	102.9	111.6	80.1	121.3	97.2	100.1	112.0	105.0	117.8	91.0	106.7
3.3 CAST IN PLACE CONC.	119.1	99.6	107.1	109.0	102.8	105.2	145.5	78.6	104.4	164.1	111.5	131.7	117.1	107.4	111.1	108.5	112.5	111.0
3 CONCRETE	119.6	102.2	108.5	113.8	106.8	109.3	133.1	94.3	108.3	136.3	123.5	128.1	111.8	113.1	112.7	110.6	105.9	107.6
4 MASONRY	112.8	96.5	100.3	117.7	113.6	114.5	108.7	113.6	112.4	123.3	134.8	132.1	125.6	115.6	117.9	128.6	95.6	103.3
5 METALS	102.0	100.9	101.6	88.9	104.0	94.3	86.6	96.6	90.2	103.5	117.9	108.7	104.6	108.4	106.0	108.3	103.9	106.7
6 WOOD & PLASTICS	93.5	104.1	99.5	109.9	113.2	111.8	106.9	113.2	110.4	104.7	136.6	122.7	93.3	116.5	106.4	94.7	101.4	98.5
7 MOISTURE PROTECTION	98.9	100.7	99.5	93.1	109.9	98.5	92.4	118.7	100.8	97.7	136.2	110.1	106.6	122.3	111.6	103.7	94.8	100.8
8 DOORS, WINDOWS, GLASS	100.7	101.2	101.0	101.3	94.0	97.5	102.1	105.5	103.8	95.9	131.8	114.7	107.8	116.0	112.1	111.5	91.8	101.1
9.2 LATH & PLASTER	109.1	95.0	98.4	98.9	110.3	107.5	94.9	110.3	106.6	100.2	101.4	101.1	111.2	114.0	113.3	111.7	98.1	101.4
9.2 DRYWALL	108.7	100.6	104.9	111.8	109.3	110.7	114.6	109.3	112.1	107.6	116.1	111.6	112.6	112.2	112.4	105.9	99.7	103.0
9.5 ACOUSTICAL WORK	80.0	104.4	93.3	101.5	113.6	108.1	101.5	113.6	108.1	101.5	138.3	121.6	83.1	117.1	101.7	100.6	100.9	100.7
9.6 FLOORING	99.6	96.9	98.9	92.2	115.8	98.6	88.9	115.8	96.2	95.7	129.4	104.9	99.9	116.3	104.4	109.4	95.9	105.7
9.9 PAINTING	112.4	108.0	108.9	124.2	102.8	107.3	134.3	114.4	118.5	117.7	136.3	132.4	121.2	123.4	122.9	115.8	87.7	93.6
9 FINISHES	104.8	102.8	103.8	107.7	108.0	107.8	109.6	111.9	110.8	105.4	124.9	115.9	108.3	116.8	112.9	107.4	95.3	100.9
10-14 TOTAL DIV. 10-14	100.0	102.6	100.7	100.0	100.2	100.0	100.0	107.3	102.1	100.0	100.6	100.1	100.0	112.7	103.7	100.0	96.2	98.9
15 MECHANICAL	99.3	97.2	98.3	101.0	95.9	98.5	100.2	100.1	100.1	103.3	123.6	113.5	97.9	106.9	102.4	98.7	101.8	100.3
16 ELECTRICAL	108.3	99.9	102.5	104.2	94.5	97.5	106.0	105.0	105.3	104.5	123.0	117.3	100.7	110.1	107.2	111.4	105.5	107.3
1-16 WEIGHTED AVERAGE	104.7	100.1	102.3	102.6	103.1	102.9	105.0	102.8	103.8	108.9	124.4	117.3	105.6	112.4	109.2	105.9	100.1	102.9

FIGURE A-2

WINNIPEG: COMPOSITE



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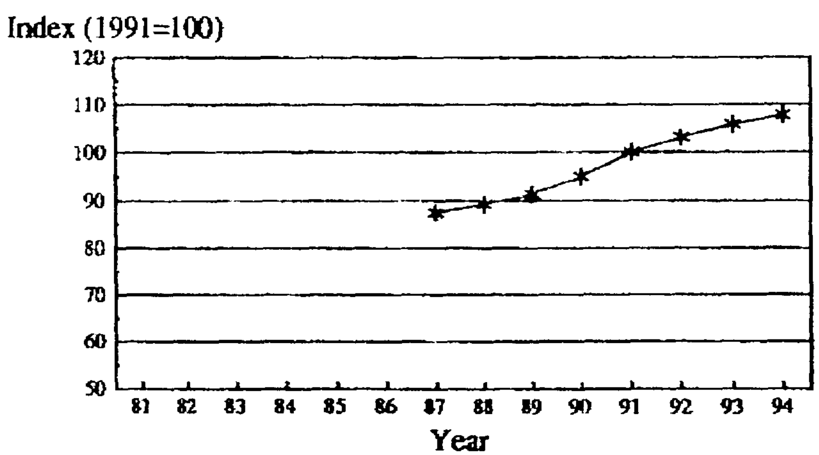
or

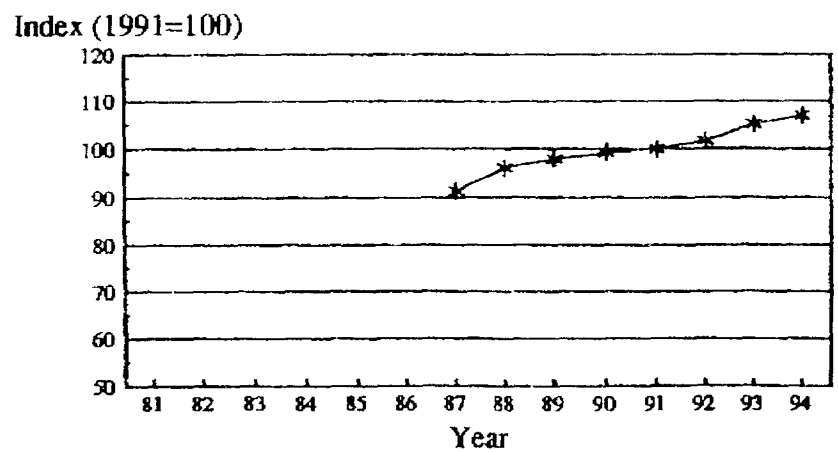
Take the number from the new series (1991=100) and multiply it by the appropriate magic number to derive an equivalent value in terms of the old base (1981=100).

For the Series:	Magic Number
Winnipeg:	
Composite	1.134
Wages	1.161
Materials	1.110

WINNIPEG: WAGES



WINNIPEG: MATERIALS



CANADATA® **Southam Construction Cost Index**

Published By:
Southam Construction Information Services

Reflecting Structural Construction Costs Up To:
December 15, 1994

Winnipeg Series

December 1994

For "Magic Number", see over →

Composite

Month	Index (1991 Annual Average = 100) 1993	1994	% Change Month to Month	Year to Year
January	103.6	107.7	0.5%	4.0%
February	105.0	107.6	-0.1%	2.5%
March	105.4	107.3	-0.3%	1.8%
April	105.2	107.3	0.0%	2.0%
May	105.2	107.6	0.3%	2.3%
June	105.2	107.3	-0.3%	2.0%
July	105.0	107.3	0.0%	2.2%
August	105.2	107.3	0.0%	2.0%
September	105.7	107.1	-0.2%	1.3%
October	106.2	107.4	0.3%	1.1%
November	107.1	107.6	0.2%	0.5%
December	107.2	107.4	-0.2%	0.2%

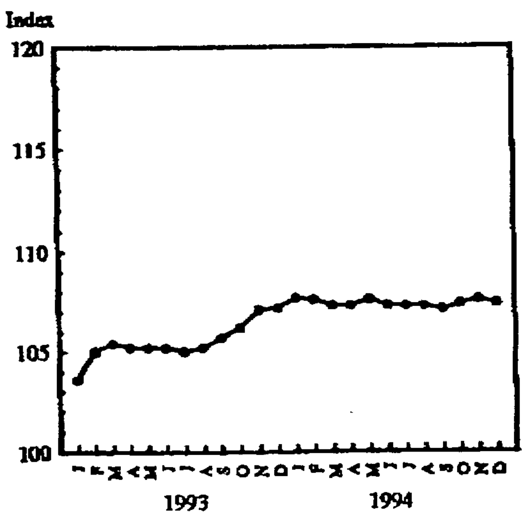
Wages

Month	Index (1991 Annual Average = 100) 1993	1994	% Change Month to Month	Year to Year
January	104.7	107.0	0.0%	2.2%
February	104.7	107.0	0.0%	2.2%
March	104.7	107.0	0.0%	2.2%
April	104.7	107.0	0.0%	2.2%
May	106.3	108.0	0.9%	1.6%
June	106.3	108.0	0.0%	1.6%
July	106.3	108.0	0.0%	1.6%
August	106.3	108.0	0.0%	1.6%
September	106.3	108.0	0.0%	1.6%
October	106.9	108.4	0.4%	1.4%
November	107.0	108.6	0.2%	1.5%
December	107.0	108.6	0.0%	1.5%

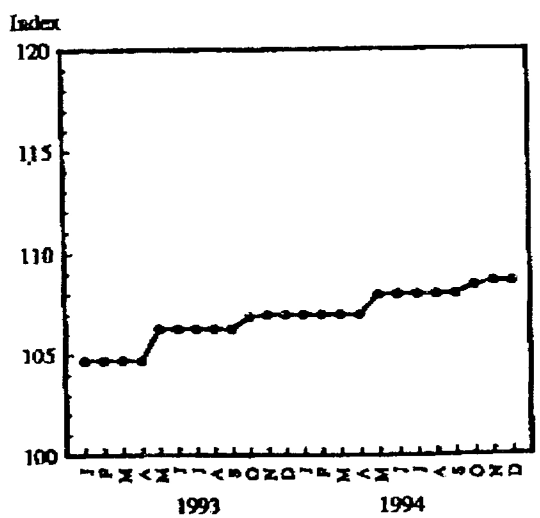
Materials

Month	Index (1991 Annual Average = 100) 1993	1994	% Change Month to Month	Year to Year
January	102.7	108.2	0.8%	5.4%
February	105.4	108.1	-0.1%	2.6%
March	106.1	107.6	-0.5%	1.4%
April	105.7	107.5	-0.1%	1.7%
May	104.3	107.2	-0.3%	2.8%
June	104.3	106.7	-0.5%	2.3%
July	103.9	106.7	0.0%	2.7%
August	104.2	106.7	0.0%	2.4%
September	105.2	106.3	-0.4%	1.0%
October	105.6	106.4	0.1%	0.8%
November	107.1	106.7	0.3%	-0.4%
December	107.3	106.3	-0.4%	-0.9%

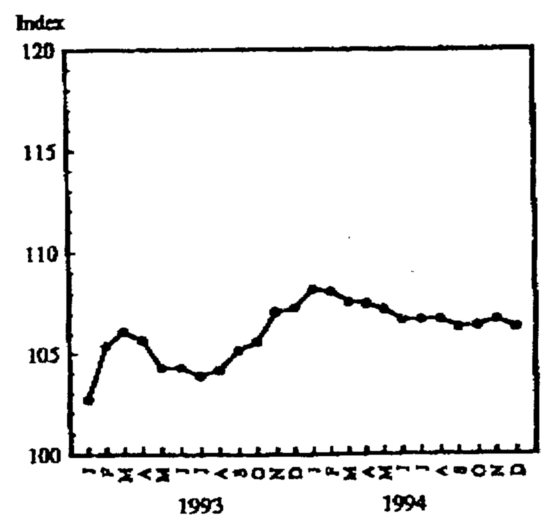
Winnipeg: Composite



Winnipeg: Wages



Winnipeg: Materials



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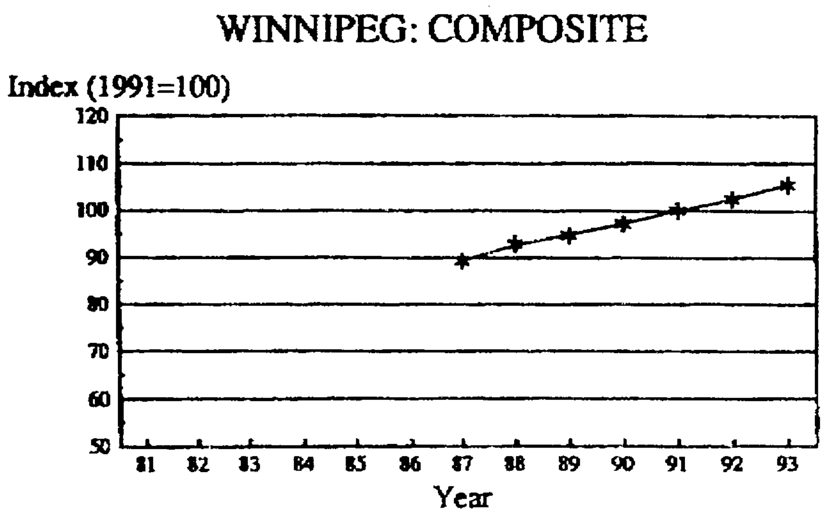
Historical Data



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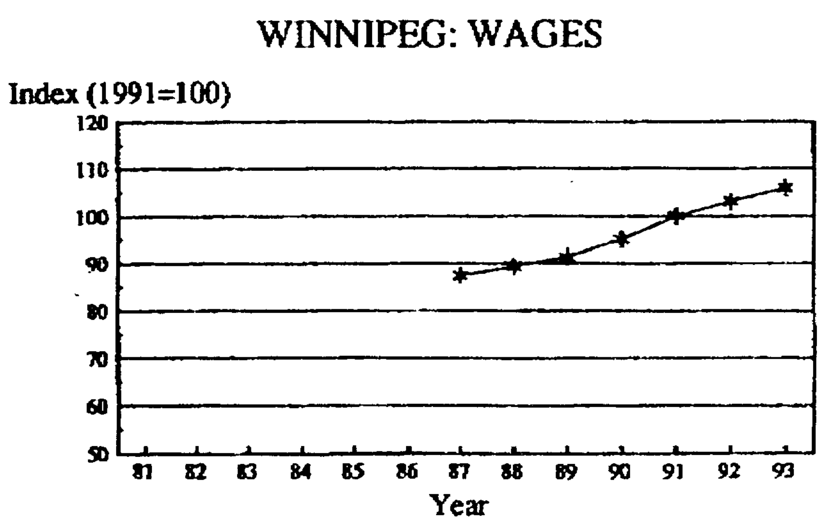
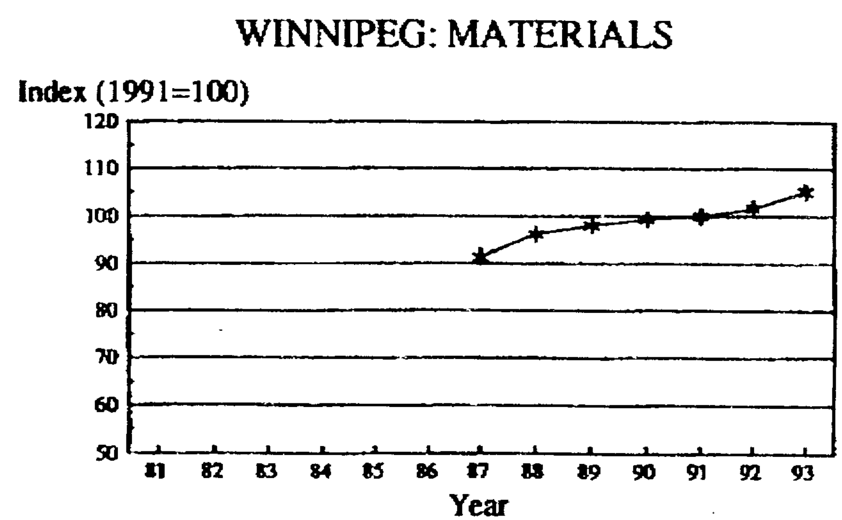
For the Series:	Magic Number
Winnipeg:	
Composite	1.134
Wages	1.161
Materials	1.110





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Southam Construction Cost Index

Published By:
Southam Construction Information Services

Reflecting Structural Construction Costs Up To:
December 15, 1993

Winnipeg Series

December 1993

For "Magic Number", see over →

Composite

Month	Index (1991 Annual Average = 100) 1992	1993	% Change Month to Month	Year to Year
January	101.5	103.6	0.3%	2.1%
February	101.9	105.0	1.4%	3.0%
March	102.2	105.4	0.4%	3.1%
April	102.1	105.2	−0.2%	3.0%
May	102.2	105.2	0.0%	2.9%
June	102.2	105.2	0.0%	2.9%
July	102.1	105.0	−0.2%	2.8%
August	102.1	105.2	0.2%	3.0%
September	102.5	105.7	0.5%	3.1%
October	102.9	106.2	0.5%	3.2%
November	103.2	107.1	0.8%	3.8%
December	103.3	107.2	0.1%	3.8%

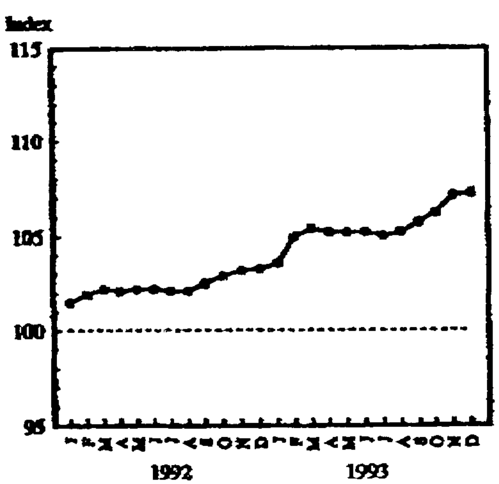
Wages

Month	Index (1991 Annual Average = 100) 192	1993	% Change Month to Month	Year to Year
January	10.2	104.7	0.0%	2.4%
February	10.2	104.7	0.0%	2.4%
March	10.2	104.7	0.0%	2.4%
April	10.2	104.7	0.0%	2.4%
May	10.2	106.3	1.5%	4.0%
June	10.6	106.3	0.0%	3.6%
July	10.0	106.3	0.0%	3.2%
August	10.0	106.3	0.0%	3.2%
September	10.1	106.3	0.0%	2.1%
October	10.5	106.9	0.6%	2.3%
November	10.7	107.0	0.1%	2.2%
December	10.7	107.0	0.0%	2.2%

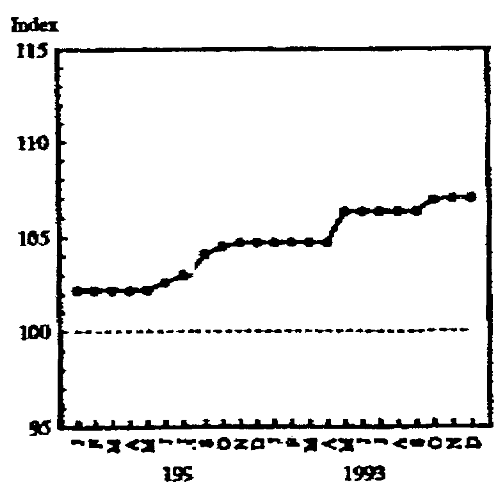
Materials

Month	Index (1991 Annual Average = 100) 1992	1993	% Change Month to Month	Year to Year
January	100.9	102.7	0.6%	1.8%
February	101.7	105.4	2.6%	3.6%
March	102.2	106.1	0.7%	3.8%
April	102.1	105.7	−0.4%	3.5%
May	102.2	104.3	−1.3%	2.1%
June	101.8	104.3	0.0%	2.5%
July	101.3	103.9	−0.4%	2.6%
August	101.3	104.2	0.3%	2.9%
September	101.1	105.2	1.0%	4.1%
October	101.5	105.6	0.4%	4.0%
November	101.9	107.1	1.4%	5.1%
December	102.1	107.3	0.2%	5.1%

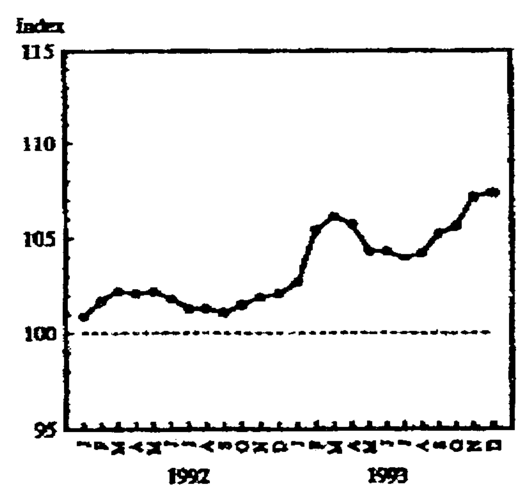
Winnipeg: Composite



Winipeg: Wages



Winnipeg: Materials



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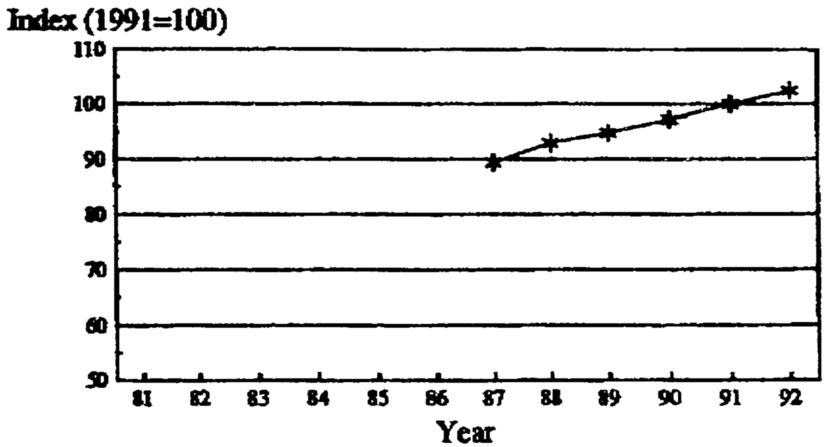
CANADATA® **Historical Data**

WINNIPEG: COMPOSITE



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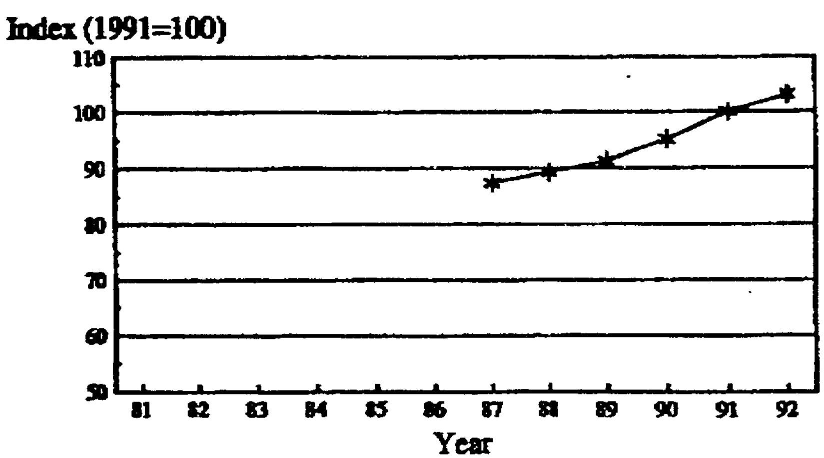
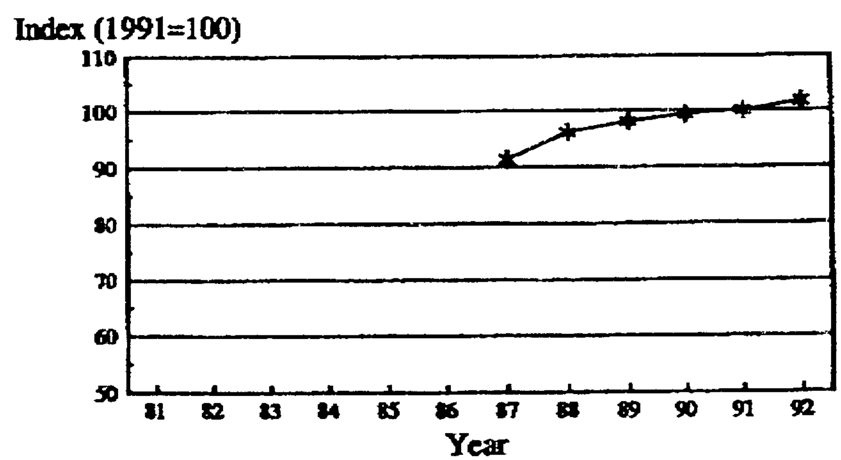
For the Series:	Magic Number
Winnipeg:	
Composite	1.134
Wages	1.161
Materials	1.110

WINNIPEG: WAGES



WINNIPEG: MATERIALS



Winnipeg - December 19.

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Published By:
Southam Construction Information Services

Southam Construction Cost Index

Reflecting Structural Construction Costs Up To:
December 15, 1992

Winnipeg Series

December 1992

For "Magic Number", see over →

Composite

Month	Index (1991 Annual Average = 100) 1991	1992	% Change Month to Month	Year to Year
January	98.4	101.5	0.4%	3.2%
February	98.7	101.9	0.4%	3.2%
March	98.7	102.2	0.3%	3.5%
April	98.6	102.1	-0.1%	3.5%
May	100.4	102.2	0.1%	1.8%
June	100.4	102.2	0.0%	1.8%
July	100.7	102.1	-0.1%	1.4%
August	100.4	102.1	0.0%	1.7%
September	100.4	102.5	0.4%	2.1%
October	101.1	102.9	0.4%	1.8%
November	101.1	103.2	0.3%	2.1%
December	101.1	103.3	0.1%	2.2%

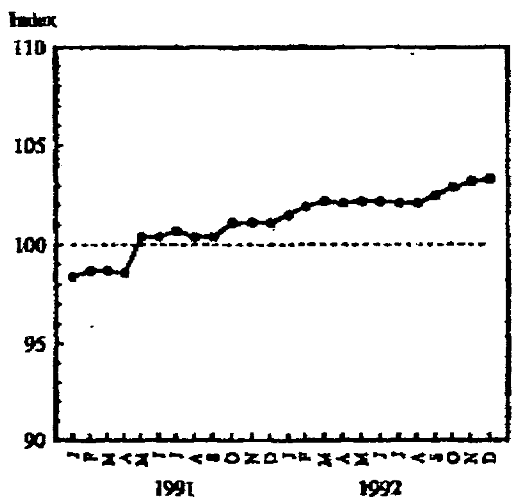
Wages

Month	Index (1991 Annual Average = 100) 1991	1992	% Change Month to Month	Year to Year
January	97.5	102.2	0.0%	4.8%
February	97.5	102.2	0.0%	4.8%
March	97.5	102.2	0.0%	4.8%
April	97.5	102.2	0.0%	4.8%
May	100.7	102.2	0.0%	1.5%
June	100.7	102.6	0.4%	1.9%
July	100.7	103.0	0.4%	2.3%
August	100.7	103.0	0.0%	2.3%
September	100.7	104.1	1.1%	3.4%
October	102.2	104.5	0.4%	2.3%
November	102.2	104.7	0.2%	2.4%
December	102.2	104.7	0.0%	2.4%

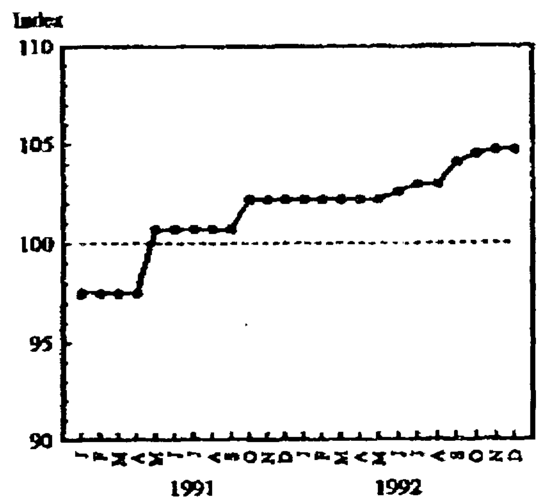
Materials

Month	Index (1991 Annual Average = 100) 1991	1992	% Change Month to Month	Year to Year
January	99.4	100.9	0.7%	1.5%
February	99.9	101.7	0.8%	1.8%
March	99.7	102.2	0.5%	2.5%
April	99.5	102.1	-0.1%	2.6%
May	100.2	102.2	0.1%	2.0%
June	100.1	101.8	-0.4%	1.7%
July	100.7	101.3	-0.5%	0.6%
August	100.2	101.3	0.0%	1.1%
September	100.2	101.1	-0.2%	0.9%
October	100.2	101.5	0.4%	1.3%
November	100.2	101.9	0.4%	1.7%
December	100.2	102.1	0.2%	1.9%

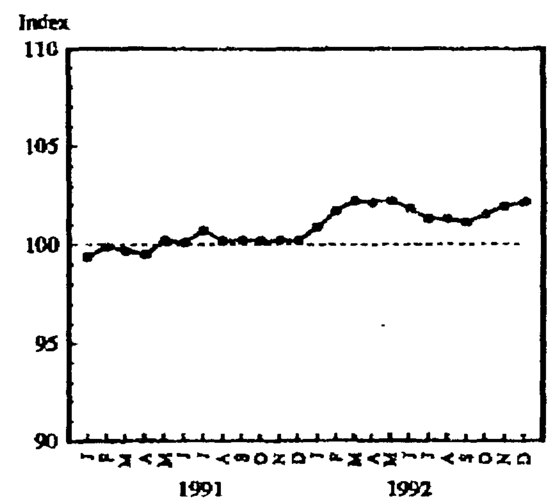
Winnipeg: Composite



Winnipeg: Wages



Winnipeg: Materials



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Southam Construction Cost Index

REFLECTING STRUCTURAL CONSTRUCTION COSTS UP TO DECEMBER 15, 1991

WINNIPEG SERIES

DECEMBER 1991

Composite

Month	Index (Feb. 1987 = 100) 1990	1991	% Change Month to Month	Year to Year
January	108.4	111.6	-0.2%	3.0%
February	108.4	111.9	0.3%	3.2%
March	108.4	111.9	0.0%	3.2%
April	109.0	111.8	-0.1%	2.6%
May	110.4	113.9	1.9%	3.2%
June	110.9	113.8	-0.1%	2.6%
July	110.8	114.2	0.4%	3.1%
August	110.6	113.9	-0.3%	3.0%
September	110.6	113.9	0.0%	3.0%
October	111.8	114.7	0.7%	2.6%
November	111.8	114.7	0.0%	2.6%
December	111.8	114.7	0.0%	2.6%

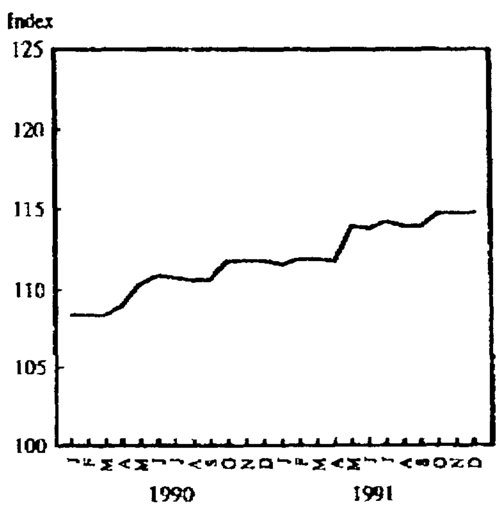
Wages

Month	Index (Feb. 1987 = 100) 1990	1991	% Change Month to Month	Year to Year
January	107.1	113.2	0.0%	5.7%
February	107.1	113.2	0.0%	5.7%
March	107.1	113.2	0.0%	5.7%
April	107.1	113.2	0.0%	5.7%
May	110.6	116.9	3.3%	5.7%
June	111.4	116.9	0.0%	4.9%
July	111.4	116.9	0.0%	4.9%
August	111.4	116.9	0.0%	4.9%
September	111.4	116.9	0.0%	4.9%
October	113.2	118.7	1.5%	4.9%
November	113.2	118.7	0.0%	4.9%
December	113.2	118.7	0.0%	4.9%

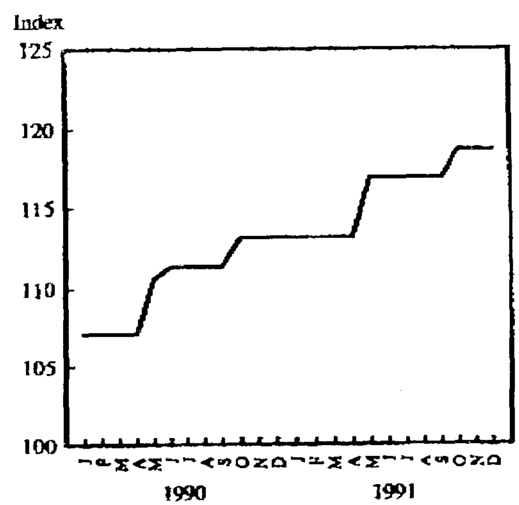
Materials

Month	Index (Feb. 1987 = 100) 1990	1991	% Change Month to Month	Year to Year
January	109.6	110.3	-0.3%	0.6%
February	109.6	110.9	0.5%	1.2%
March	109.6	110.7	-0.2%	1.0%
April	110.6	110.5	-0.2%	-0.1%
May	110.2	111.2	0.6%	0.9%
June	110.5	111.1	-0.1%	0.5%
July	110.2	111.8	0.6%	1.5%
August	109.9	111.2	-0.5%	1.2%
September	109.9	111.2	0.0%	1.2%
October	110.6	111.2	0.0%	0.5%
November	110.6	111.2	0.0%	0.5%
December	110.6	111.2	0.0%	0.5%

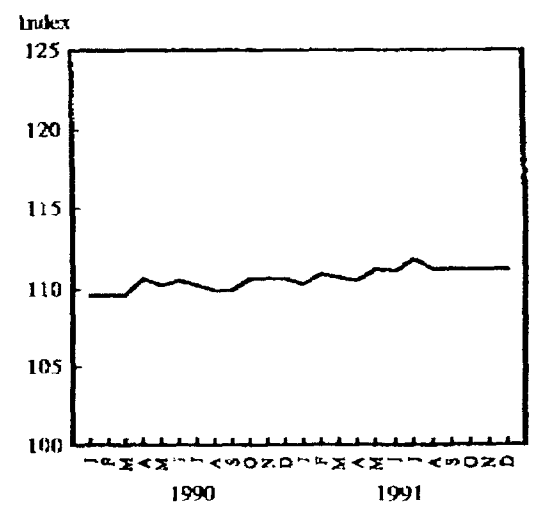
Winnipeg: Composite



Winnipeg: Wages



Winnipeg: Materials



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Second Class Registration No. 6060

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Southam Construction Cost Index

REFLECTING STRUCTURAL CONSTRUCTION COSTS UP TO DECEMBER 15, 1990

WINNIPEG SERIES **DECEMBER 1990**

Composite

Month	Index (Feb. 1987 = 100) 1989	1990	% Change Month to Month	Year to Year
January	106.1	108.4	-0.1%	2.2%
February	106.3	108.4	0.0%	2.0%
March	106.3	108.4	0.0%	2.0%
April	106.3	109.0	0.6%	2.5%
May	107.7	110.4	1.3%	2.5%
June	107.7	110.9	0.5%	3.0%
July	108.0	110.8	-0.1%	2.6%
August	108.0	110.6	-0.2%	2.4%
September	108.0	110.6	0.0%	2.4%
October	108.5	111.8	1.1%	3.0%
November	108.5	111.8	0.0%	3.0%
December	108.5	111.8	0.0%	3.0%

Wages

Month	Index (Feb. 1987 = 100) 1989	1990	% Change Month to Month	Year to Year
January	104.9	107.1	0.0%	2.1%
February	104.9	107.1	0.0%	2.1%
March	104.9	107.1	0.0%	2.1%
April	104.9	107.1	0.0%	2.1%
May	106.2	110.6	3.3%	4.1%
June	106.2	111.4	0.7%	4.9%
July	106.2	111.4	0.0%	4.9%
August	106.2	111.4	0.0%	4.9%
September	106.2	111.4	0.0%	4.9%
October	107.1	113.2	1.6%	5.7%
November	107.1	113.2	0.0%	5.7%
December	107.1	113.2	0.0%	5.7%

Materials

Month	Index (Feb. 1987 = 100) 1989	1990	% Change Month to Month	Year to Year
January	107.1	109.6	0.1%	2.3%
February	107.4	109.6	0.0%	2.1%
March	107.6	109.6	0.0%	1.9%
April	107.6	110.6	0.9%	2.8%
May	109.1	110.2	-0.4%	1.0%
June	109.1	110.5	0.3%	1.3%
July	109.7	110.2	-0.3%	0.5%
August	109.7	109.9	-0.3%	0.2%
September	109.7	109.9	0.0%	0.2%
October	109.7	110.6	0.6%	0.8%
November	109.7	110.6	0.0%	0.8%
December	109.7	110.6	0.0%	0.8%

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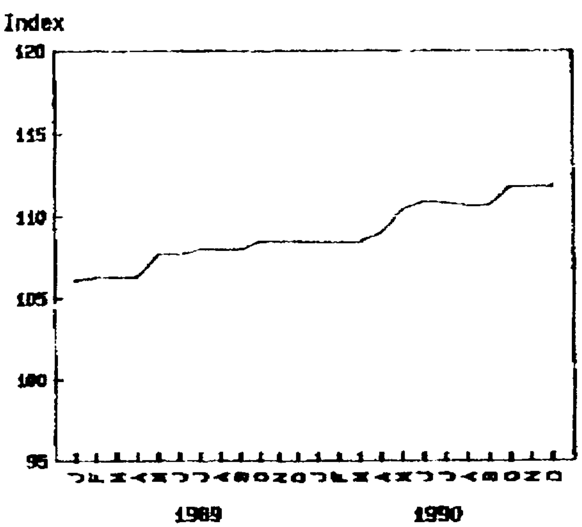

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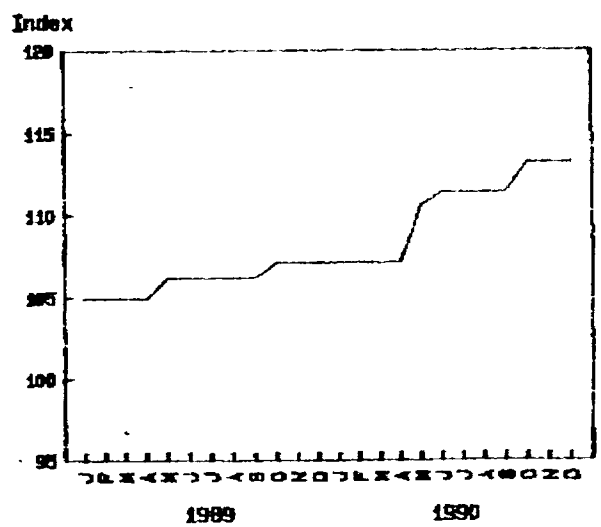

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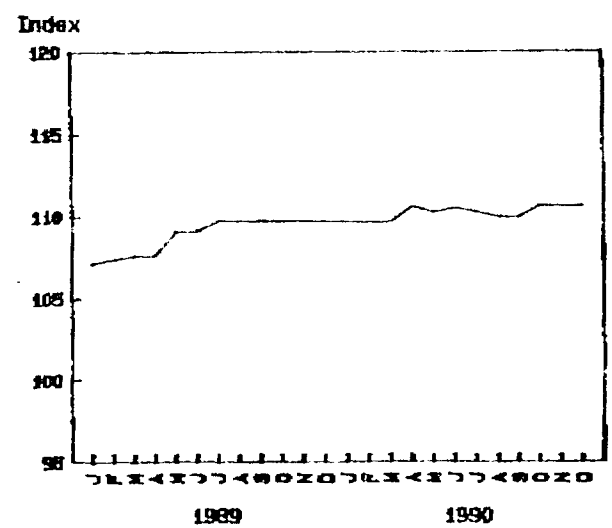

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Month	Index (Feb. 1987 = 100) 1989	1990	% Change Month to Month	Year to Year
January	106.1	108.4	−0.1%	2.2%
February	106.3	108.4	0.0%	2.0%
March	106.3	108.4	0.0%	2.0%
April	106.3	109.0	0.6%	2.5%
May	107.7	110.4	1.3%	2.5%
June	107.7	110.9	0.5%	3.0%
July	108.0	110.8	0.1%	2.6%
August	108.0	110.6	−0.2%	2.4%
September	108.0	110.6	0.0%	2.4%
October	108.5	111.8	1.1%	3.0%
November	108.5	111.8	0.0%	3.0%
December	108.5	111.8	0.0%	3.0%

Wages

Month	Index (Feb. 1987 = 100) 1989	1990	% Change Month to Month	Year to Year
January	104.9	107.1	0.0%	2.1%
February	104.9	107.1	0.0%	2.1%
March	104.9	107.1	0.0%	2.1%
April	104.9	107.1	0.0%	2.1%
May	106.2	110.6	3.3%	4.1%
June	106.2	111.4	0.7%	4.9%
July	106.2	111.4	0.0%	4.9%
August	106.2	111.4	0.0%	4.9%
September	106.2	111.4	0.0%	4.9%
October	107.1	113.2	1.6%	5.7%
November	107.1	113.2	0.0%	5.7%
December	107.1	113.2	0.0%	5.7%

Materials

Month	Index (Feb. 1987 = 100) 1989	1990	% Change Month to Month	Year to Year
January	107.1	109.6	−0.1%	2.3%
February	107.4	109.6	0.0%	2.1%
March	107.6	109.6	0.0%	1.9%
April	107.6	110.6	0.9%	2.8%
May	109.1	110.2	−0.4%	1.0%
June	109.1	110.5	0.3%	1.3%
July	109.7	110.2	−0.3%	0.5%
August	109.7	109.9	−0.3%	0.2%
September	109.7	109.9	0.0%	0.2%
October	109.7	110.6	0.6%	0.8%
November	109.7	110.6	0.0%	0.8%
December	109.7	110.6	0.0%	0.8%

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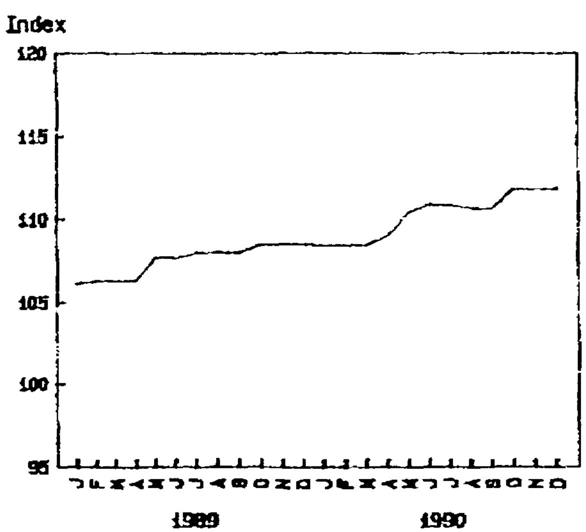

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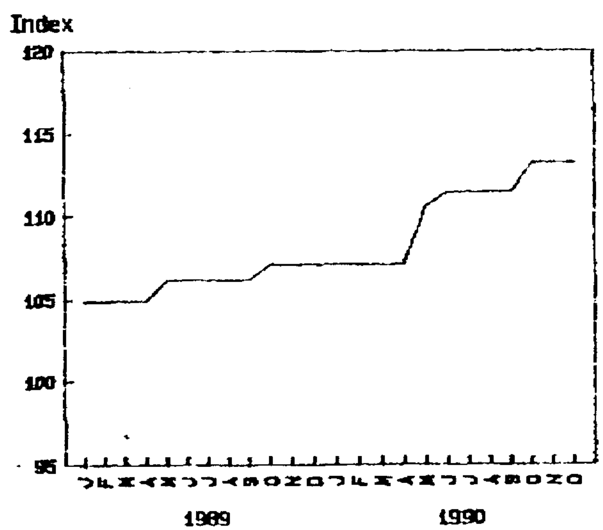

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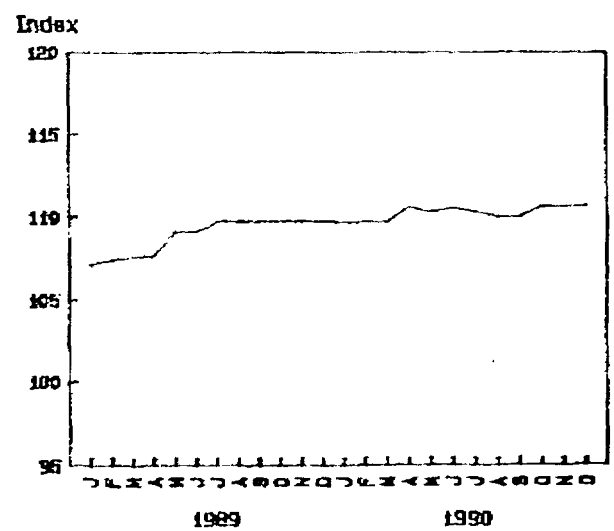

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Month	Index (1981 = 100) 1988	1989	% Change Month to Month	Year to Year
January	103.2	106.1	0.1%	2.8%
February	104.3	106.3	0.2%	1.9%
March	104.3	106.3	0.0%	1.9%
April	104.8	106.3	0.0%	1.4%
May	105.5	107.7	1.3%	2.1%
June	105.7	107.7	0.0%	1.9%
July	105.8	108.0	0.3%	2.1%
August	105.8	108.0	0.0%	2.1%
September	105.7	108.0	0.0%	2.2%
October	106.0	108.5	0.5%	2.4%
November	106.0	108.5	0.0%	2.4%
December	106.0	108.5	0.0%	2.4%

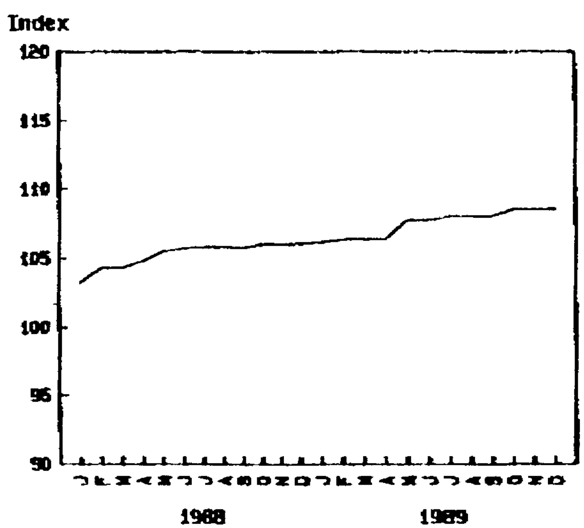
Wages

Month	Index (1981 = 100) 1988	1989	% Change Month to Month	Year to Year
January	102.1	104.9	0.0%	2.7%
February	102.1	104.9	0.0%	2.7%
March	102.1	104.9	0.0%	2.7%
April	102.1	104.9	0.0%	2.7%
May	103.9	106.2	1.2%	2.2%
June	104.2	106.2	0.0%	1.9%
July	104.2	106.2	0.0%	1.9%
August	104.2	106.2	0.0%	1.9%
September	104.2	106.2	0.0%	1.9%
October	104.9	107.1	0.8%	2.1%
November	104.9	107.1	0.0%	2.1%
December	104.9	107.1	0.0%	2.1%

Materials

Month	Index (1981 = 100) 1988	1989	% Change Month to Month	Year to Year
January	104.2	107.1	0.2%	2.8%
February	106.3	107.4	0.3%	1.0%
March	106.2	107.6	0.2%	1.3%
April	107.2	107.6	0.0%	0.4%
May	107.0	109.1	1.4%	2.0%
June	107.0	109.1	0.0%	2.0%
July	107.1	109.7	0.5%	2.4%
August	107.1	109.7	0.0%	2.4%
September	107.0	109.7	0.0%	2.5%
October	107.0	109.7	0.0%	2.5%
November	106.9	109.7	0.0%	2.6%
December	106.9	109.7	0.0%	2.6%

Winnipeg: Composite



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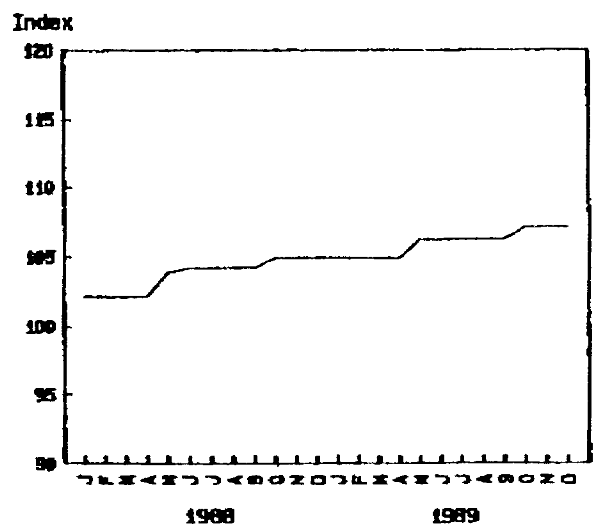

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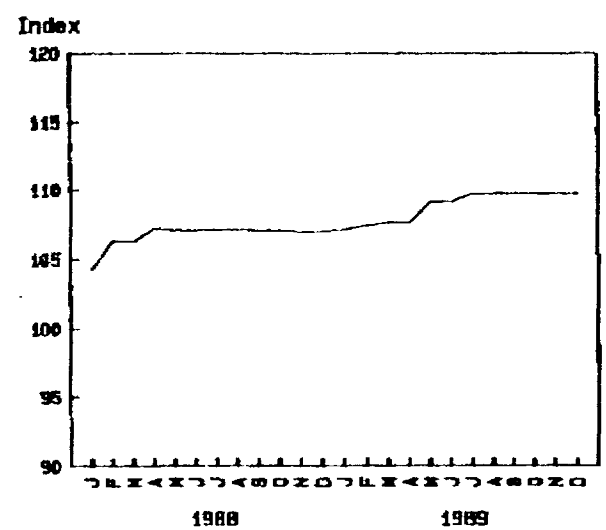

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Month	Index (1981 = 100) 1987	Index (1981 = 100) 1988	% Change Month to Month	% Change Year to Year
January	—	103.2	0.8%	—
February	100.0	104.3	1.1%	4.3%
March	100.0	104.3	0.0%	4.3%
April	100.4	104.8	0.5%	4.4%
May	101.3	105.5	0.7%	4.1%
June	101.7	105.7	0.2%	3.9%
July	101.8	105.8	0.1%	3.9%
August	101.8	105.8	0.0%	3.9%
September	101.9	105.7	−0.1%	3.7%
October	101.9	106.0	0.3%	4.0%
November	102.2	106.0	0.0%	3.7%
December	102.4	106.0	0.0%	3.5%

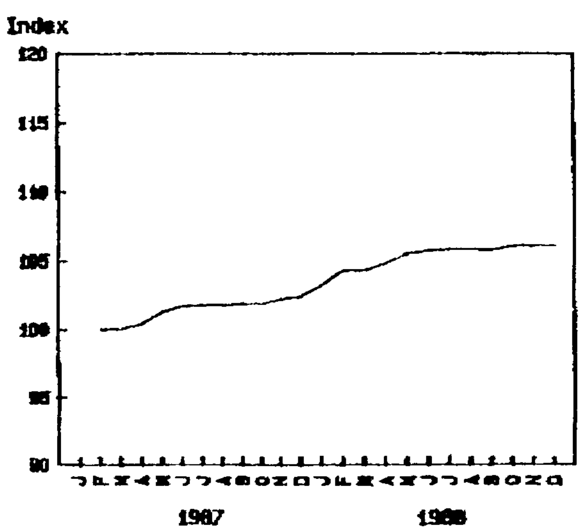
Wages

Month	Index (1981 = 100) 1987	Index (1981 = 100) 1988	% Change Month to Month	% Change Year to Year
January	—	102.1	0.0%	—
February	100.0	102.1	0.0%	2.1%
March	100.0	102.1	0.0%	2.1%
April	100.0	102.1	0.0%	2.1%
May	102.1	103.9	1.8%	1.8%
June	102.1	104.2	0.3%	2.1%
July	102.1	104.2	0.0%	2.1%
August	102.1	104.2	0.0%	2.1%
September	102.1	104.2	0.0%	2.1%
October	102.1	104.9	0.7%	2.7%
November	102.1	104.9	0.0%	2.7%
December	102.1	104.9	0.0%	2.7%

Materials

Month	Index (1981 = 100) 1987	Index (1981 = 100) 1988	% Change Month to Month	% Change Year to Year
January	—	104.2	1.6%	—
February	100.0	106.3	2.0%	6.3%
March	100.0	106.2	−0.1%	6.2%
April	100.7	107.2	0.9%	6.5%
May	100.5	107.0	−0.2%	6.5%
June	101.3	107.0	0.0%	5.6%
July	101.5	107.1	0.1%	5.5%
August	101.5	107.1	0.0%	5.5%
September	101.7	107.0	−0.1%	5.2%
October	101.7	107.0	0.0%	5.2%
November	102.3	106.9	−0.1%	4.5%
December	102.6	106.9	0.0%	4.2%

Winnipeg: Composite



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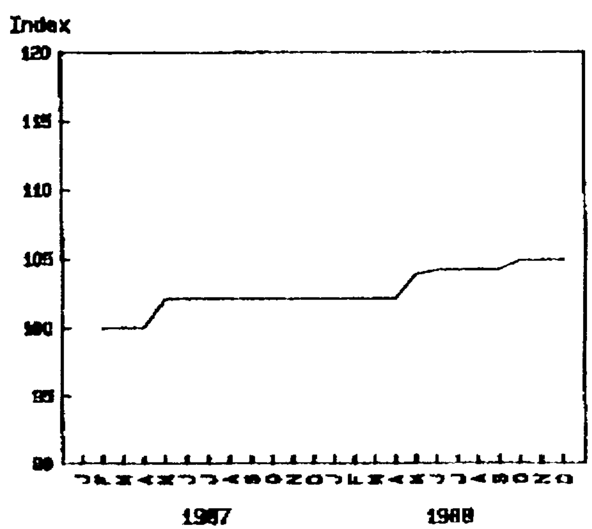

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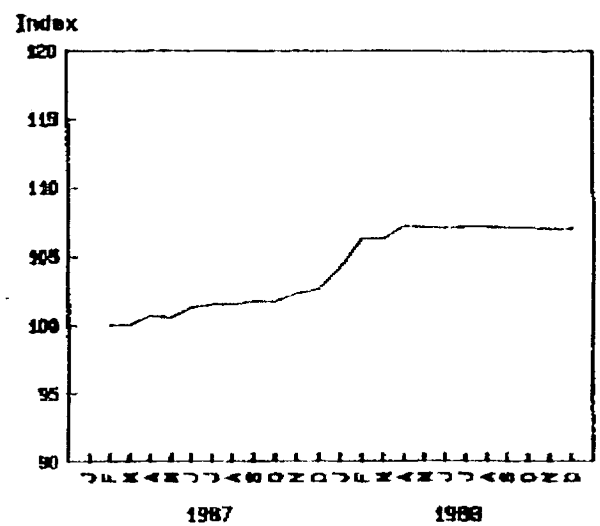

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Month	Index (1981 = 100) 1987	% Change Month to Month
January	—	—
February	100.0	—
March	100.0	0.0%
April	100.4	0.4%
May	101.3	0.9%
June	101.7	0.4%
July	101.8	0.1%
August	101.8	0.0%
September	101.9	0.1%
October	101.9	0.0%
November	102.2	0.3%
December	102.4	0.2%

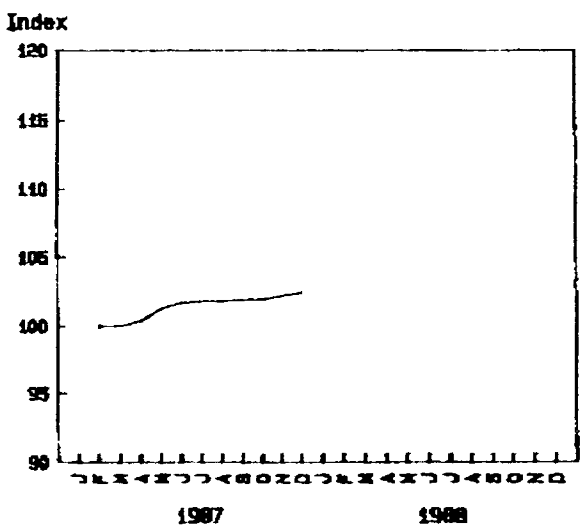
Wages

Month	Index (1981 = 100) 1987	% Change Month to Month
January	—	—
February	100.0	—
March	100.0	0.0%
April	100.0	0.0%
May	102.1	2.1%
June	102.1	0.0%
July	102.1	0.0%
August	102.1	0.0%
September	102.1	0.0%
October	102.1	0.0%
November	102.1	0.0%
December	102.1	0.0%

Materials

Month	Index (1981 = 100) 1987	% Change Month to Month
January	—	—
February	100.0	—
March	100.0	0.0%
April	100.7	0.7%
May	100.5	−0.2%
June	101.3	0.8%
July	101.5	0.2%
August	101.5	0.0%
September	101.7	0.2%
October	101.7	0.0%
November	102.3	0.6%
December	102.6	0.3%

Winnipeg: Composite



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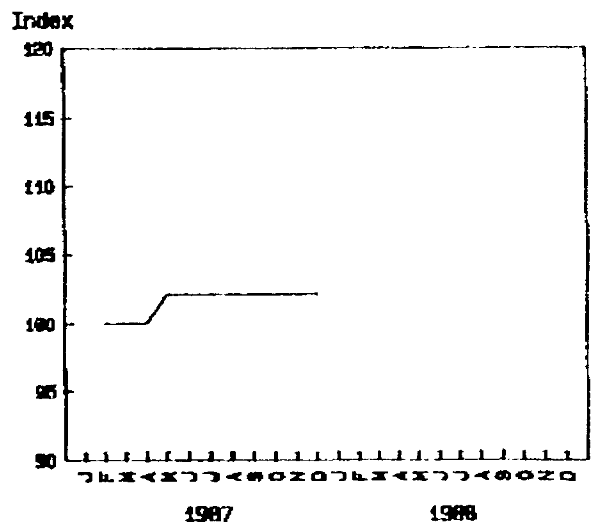

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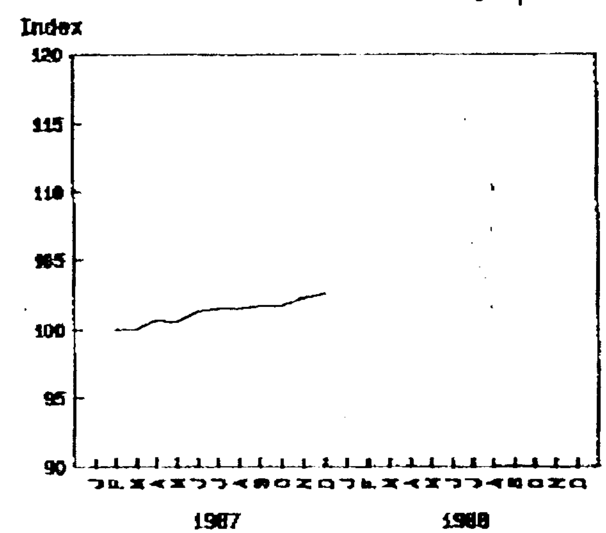

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Southam Construction Information Services

Reflecting Structural Construction Costs Up To:
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Winnipeg Series

March 1995

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Month	Index (1991 Annual Average = 100) 1994	1995	% Change Month to Month	Year to Year
January	107.7	107.9	0.5%	0.2%
February	107.6	107.9	0.0%	0.3%
March	107.3	107.7	-0.2%	0.4%
April	107.3			
May	107.6			
June	107.3			
July	107.3			
August	107.3			
September	107.1			
October	107.4			
November	107.6			
December	107.4			

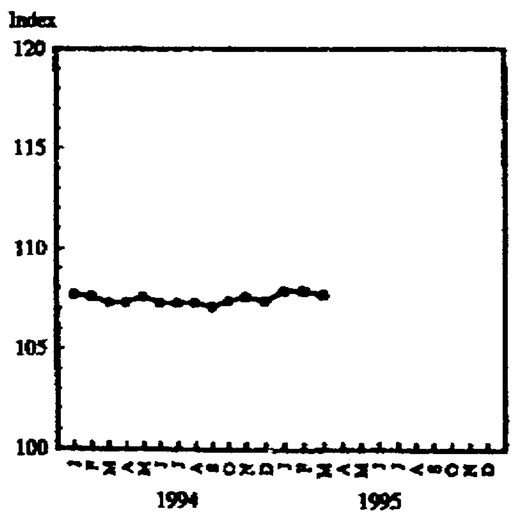
Wages

Month	Index (1991 Annual Average = 100) 1994	1995	% Change Month to Month	Year to Year
January	107.0	108.6	0.0%	1.5%
February	107.0	108.6	0.0%	1.5%
March	107.0	108.6	0.0%	1.5%
April	107.0			
May	108.0			
June	108.0			
July	108.0			
August	108.0			
September	108.0			
October	108.4			
November	108.6			
December	108.6			

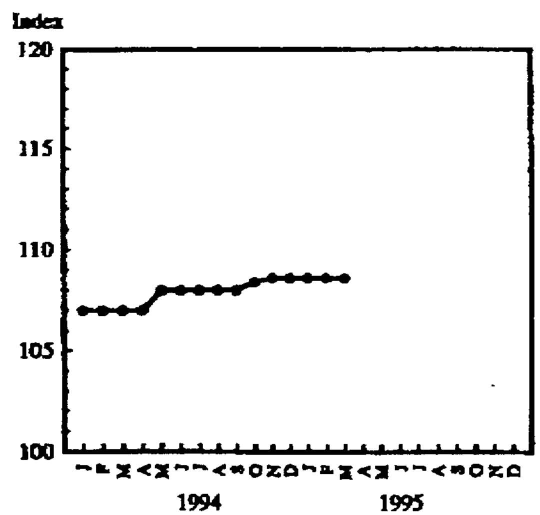
Materials

Month	Index (1991 Annual Average = 100) 1994	1995	% Change Month to Month	Year to Year
January	108.2	107.4	1.0%	-0.7%
February	108.1	107.3	-0.1%	-0.7%
March	107.6	107.0	-0.3%	-0.6%
April	107.5			
May	107.2			
June	106.7			
July	106.7			
August	106.7			
September	106.3			
October	106.4			
November	106.7			
December	106.3			

Winnipeg: Composite



Winnipeg: Wages



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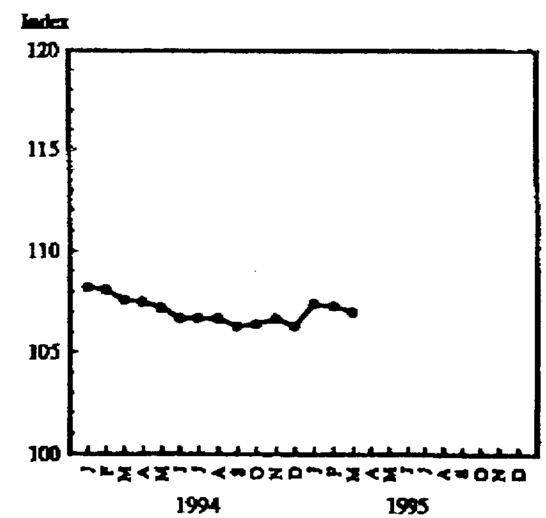

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APPENDIX B

W2O

REVIEW OF TECHNOLOGIES FOR THE REMOVAL OF FLOATABLES FROM COMBINED SEWER OVERFLOWS

Prepared for:

TetrES Consultants
603 - 386 Broadway
Winnipeg, Manitoba
R3C 3R6

Prepared by:

W2O Inc.
1 Port Street East, Suite 201
Mississauga, Ontario
L5G 4N1

May 16, 1995

CONTENTS

Appendix 2 - Figure Tables (Cont')

TABLES

Page

1.0 *INTRODUCTION*

Floatables in combined sewer overflows (CSOs) and stormwater runoff can be classified into three basic categories:

i) those materials remaining on the water surface, such as styrofoam,

ii) those materials which have neutral buoyancy and do not sink or rise in the water column, called "swimmers", and

iii) oil and grease.

Floatables removal from CSOs can be achieved by preventing extraneous solids and floatables from entering the collection system, i.e., source control, by removal after introduction into the collection system, and by removal from the receiving water body after CSO discharge, i.e., outfall booms and skimming systems.

The purpose of the present study was to examine control technologies for the removal of floatable materials, excluding oil and grease, from CSOs. Source control approaches were not reviewed.

Specifically, the following categories of CSO treatment technologies were reviewed:

- Coarse Screen Technologies (screen openings of 6 mm or greater)
- Fine Screen Technologies (screen openings less than to 6 mm)
- Weir-mounted Screens
- Trap Systems

An extensive data gathering program was conducted, including collection of product literature and design information from manufactures, suppliers and consultants, a comprehensive literature review, and communications with selected municipalities which have installed equipment suitable for floatables removal from CSOs.

2.0 *CHARACTERIZATION OF FLOATABLES AND SCREENINGS*

2.1 *Characterization of Floatables*

The characterization of floatables provides valuable information regarding the suitability of different control technologies and options for ultimate disposal.

Figure 1 illustrates the material composition of floatables from CSOs and storm sewers reported in a 1993 study for the New York City Department of Environmental Protection (NYCDEP), (HydroQual, 1993). As seen in Figure 1, the majority of floatable materials in CSOs and storm sewer discharges were reported to be plastic (42%), paper (26%), and polystyrene (26%), based on number of items. The predominant types of plastic items were found to be candy wrappers (29%), plastic bags/fragments (18%), straws (18%), and cigarette butts (12%).

Less than 1 percent of floatable material was reported to be sanitary waste and only 0.2 percent was attributed to medical waste. Approximately 95 percent of floatables in CSOs were found to originate as street litter. The remaining 5 percent included personal hygiene items disposed through household toilets.

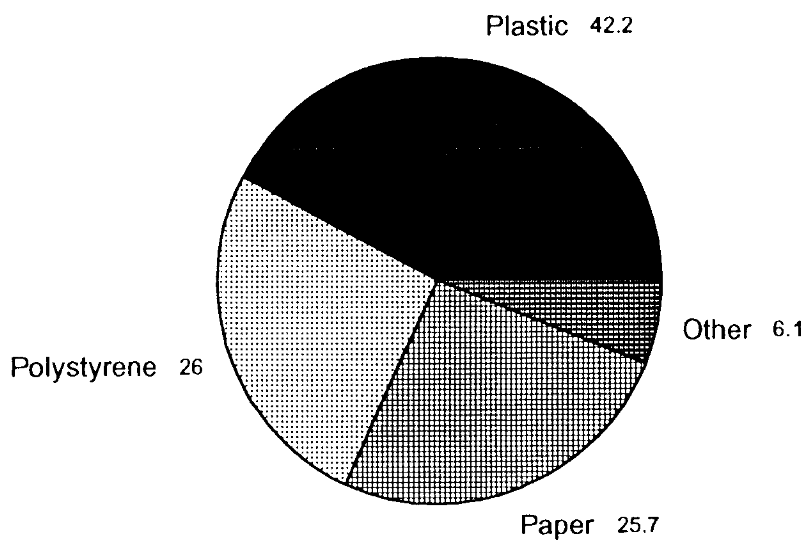
With respect to size, 95 percent of the floatable material in the NYCDEP study was reported to be 13 mm or greater (Figure 2). In addition, 80 percent of the material below this size was paper which is biodegradable.

Based on the results of the NYCDEP study, it would appear that control technologies designed to remove items 13 mm or larger would remove at least 95 percent of the floatable material in CSO, assuming the floatable characteristics reported in the New York study to be representative of typical CSOs.

2.2 *Quantities of Floatables in CSOs*

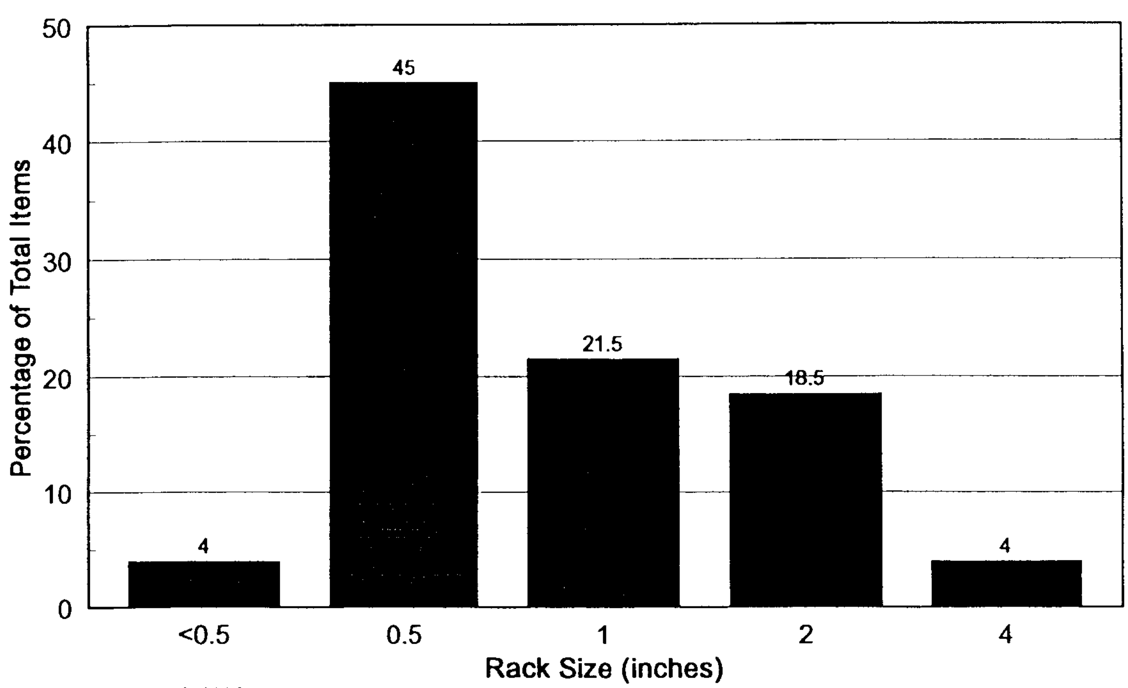
Few studies have quantified the floatables content in CSOs. However, one such evaluation was performed for the City of Newark, NJ in 1994 as part of a CSO floatable control demonstration project (Parsons Engineering, 1994). The project involved evaluation of end-of-pipe netting structures installed at two sites. The total amount of floatables generated during several CSO events was quantified in order to assess the removal efficiency of the process.

Figure 1
Composition of Floatable Materials in New York CSOs
By Percentage



Source: HydroQual, 1993

Figure 2
Size Distribution of Floatable Materials in New York CSOs



Source: HydroQual, 1993

Table 1 presents the results of the floatables quantification analysis. Prior to weighing, the netted floatables were removed from the flow stream and allowed to drain for at least five minutes or until the weight changed less than 2.3 kg per minute. The average floatables content at the two Newark outfalls was 14.4 and 5.4 kg/1,000 m^3 of CSO. When floatable quantities are normalized for the amount of rainfall and drainage area sizes, the floatables generation rates were at the two outfalls were very similar. The average generation rate at the two sites was about 60 g of floatables per mm of rainfall per hectare of drainage area.

Table 2-1
Quantities of Floatables Generated at Three CSOs in New York State

CSO Site	Drainage Area (ha)	No. of CSO events	Total CSO Volume (m^3)	Total Floatables (kg)[3]	Average Floatables Content (kg/1,000 m^3)	Floatable Loading Rate (g floatables/mm rain.ha)
Peddie Outfall[1]	628	9	300,000	4,324	14.4	51.8
Saybrook Outfall[1]	115	14	253,000	1,374	5.4	70.2
Fresh Creek, Brooklyn[2]	880	19	492,000	3,855	9[4]	-

Notes:

1. Source: Parsons Engineering Science, 1994. Monitoring program was conducted between June and September, 1994.
2. Source: Forndran et al, 1994. Monitoring program was conducted between April and November, 1993.
3. Value shown was measured after the netted floatables were allowed to drain for at least 5 minutes or until the weight changed less than 2.3 kg per minute.
4. The amount of fugitive floatables i.e. those escaping capture in the nets, was not measured in this study and thus were estimated based on a typical floatables removal efficiency of 90 to 95 per cent for the netting technology. The value shown in Table 1 represents the total floatables content of the Fresh Creek CSO outfall.

In a similar study, in which floatables were captured in an in-stream netting system at a CSO outfall at Fresh Creek, in Brooklyn, NY, the average floatables content of the CSO was found to be about 9 kg/1,000 m^3 (Forndran, 1994).

2.3 *Characterization of Coarse Screenings*

Screening of raw sewage at sewage treatment plants to remove coarse solids including floatables is standard practice but screening of CSOs for floatables control is relatively new. Consequently, there is little information pertaining directly to the characteristics and quantities of screenings removed at CSO treatment facilities.

As an approximation of CSO screenings quantities, however, it is instructive to review screenings data for sewage treatment plants (STPs) which handle flows from combined sewer systems. Typical quantities of screenings from such facilities are summarized in Table 2. The screenings characteristics indicated in Table 2, however, do not relate specifically to STPs with combined sewer collection systems.

Screenings quantities will tend to be greater with short, gently sloping collection systems with low turbulence than with lengthy, steep interceptor systems and/or systems with pump stations. This trend is due to the fact that solids tend to disintegrate when exposed to long-term turbulence. The impact of such turbulence will be greater for screens with smaller openings which tend to capture more organic solids (WEF, 1992). For coarse screens with bar spacings close to 6 mm, fecal matter and other organic materials are captured. The organic portion of the screenings may contain pathogenic organisms and will readily decompose, potentially giving rise to strong odours.

With respect to facilities designed specifically for CSO treatment, the quantities of screenings removed will likely depend on the configuration of the drainage system, the time of year, the interval between storms, as well as other factors.

Table 2-2
Typical Properties of Coarse Screenings

Parameter	Typical Value
Screenings Quantities	
Screenings quantities STPs with combined sewer systems:	
• Average, L/1,000 m^3	4-80
• Peaking factor (hourly flows)	2:1 - > 20:1
Screenings Characteristics[1]	
Bulk density, kg/m^3	640-1120
Solids content, % dry solids	10-20%
Volatile content of solids, % of dry solids	70-95

Note:

1. Values shown do not pertain specifically to screenings removed from combined sewer systems.

Source: WEF/ASCE, 1992.

3.0 *TECHNOLOGY REVIEW*

3.1 *Coarse Screen Technologies*

3.1.1 *Trash Racks and Manual Bar Screens*

Technology Description and Design Information

Trash racks are bar screens with openings of 38 to 150 mm and are generally used to protect pumps, valves, pipelines, and other appurtenances from damage or clogging by rags and large objects. Trash racks can be manually or mechanically cleaned and are typically followed by bar screens with smaller openings. They are typically used on combined sewer systems that carry large quantities of logs, timbers, stumps and other large debris. The use of trash racks ahead of coarse screens for treatment plants serving separate sewer systems is no longer common.

Manually cleaned bar screens have 25 to 50 mm openings with the bars set at 30 to 35 degrees from the vertical to facilitate cleaning. They are most often found in older, small (less than 3,785 m^3/d) treatment facilities and in bypass channels of mechanically cleaned bar screens and communitors. During cleaning, the screenings are drainage prior to disposal.

Manually cleaned screens require little or no maintenance but do require frequent raking to avoid clogging. Infrequent cleaning may cause flow surges due to the release of backwater created by the build up of a solids mat (WEF, 1992). Such high velocity surges can reduce the solids capture efficiency of downstream treatment processes.

Experience with manually cleaned and mechanically cleaned bar screens has shown the latter to reduce labour costs, improve flow conditions and screening capture and to be better able to handle the large quantities of debris and screenings associated with wet weather flows. For these reasons, mechanically cleaned screens are generally recommended for CSO facilities (US EPA, 1993).

Operating Experience

At the Intrenchment Creek CSO Facility in Atlanta, CSOs are screened with catenary type trash racks (75 mm bar spacings) and then screened with 13 mm catenary type bar screens prior to conveyance to a downstream facility for further treatment. Heavy sedimentation has occurred in the channels upstream of and around the trash racks and bar screens, which has been attributed mainly to the broad approach sections in the channels. The design of more recent CSO treatment facilities in Atlanta allowed for convenient removal of deposited sediments.

Coarse screenings at Intrenchment Creek are discharged onto a conveyor for transport to storage bins. Although designed for unmanned operation, this handling system required operator attention during virtually every storm because of constant spillage of debris onto the floor and frequent jamming of the conveyor belt. The newer designs did not utilize conveyor belts (West, 1990).

At a CSO control facility in Grand Rapids, Michigan, two 6 m wide IDI reciprocating rake-type screens with 75 mm bar spacings were installed upstream of CSO pumps. The facility, commissioned in March, 1992 has a total capacity of 1050 US mgd. During CSO events, screened wastewater is pumped into a 30 million gallon (US) retention basin. Retention basin overflows are chlorinated prior to discharge to the receiving water. Once downstream treatment capacity is available, stored CSO is returned back to the trunk sewer.

In 1994, the Grand Rapids facility handled about 40 CSO events and 10 discharges from the retention basin to the receiving water. Due to bar spacings, most of the material retained on the screens consists of logs, rags, plastic items and some leaves. Screenings are discharged onto the floor and loaded by a Bobcat into a 20 yd^3 container which is hauled to a landfill.

No supplemental cleaning, i.e. in addition to that provided by the cleaning mechanism, is provided. Operating staff report no incidences of jamming or other malfunctions in the three years of screen operation. Routine preventative maintenance is provided every three months and consists chiefly of greasing and routine inspection (Smith, 1995).

Costs

Budget pricing for an E and I Corp. catenary bar screen with 50 mm bar spacings capable of handling a peak flow of 500 L/s is $30,000 Cdn, excluding sales taxes. This quotation includes equipment costs only.

3.1.2 *Mechanically Cleaned Bar Screens*

Technology Description

Mechanically cleaned bar screens have clear spacings of 6 to 38 mm and are generally specified for new treatment facilities of all sizes.

The various types of mechanically cleaned screens are differentiated on the basis of the cleaning mechanism. The most common types are the chain or cable driven, reciprocating rake, continuous, and catenary. In the U.S., the catenary type is most often selected for CSO facilities because of its ruggedness and reliability.

Diagrams and/or drawings for each type of mechanically-cleaned screen are presented in Appendix 1.

Chain or cable driven screens are the oldest type of mechanized screening device and are used extensively in treatment plants handling separate sanitary flows. They can be designed with front or back cleaning, with the front clean/rear return configuration best suited to heavy duty applications. In both designs, the raking mechanism includes submerged sprockets or other mechanical devices and are thus subject to fouling by grit and rags and require frequent inspection and maintenance. Inspection and maintenance of the drive mechanism is usually required on a frequent basis and, for some designs, may necessitate channel dewatering.

In the reciprocating rake type screen, the screen is cleaned by the up and down reciprocating motion of the rake. This technology can also be equipped with a back clean/back return or front clean/front return mechanism which minimizes solids carryover during cleaning. Reciprocating rake screens do not have any submerged moving parts and therefore allow for easy inspection and maintenance without channel dewatering. The main limitation of this technology is the inability to handle extreme screenings loads because of the single rake, particularly for deep channels where cycle times are long. They also typically require more headroom than other types of screens.

Newer reciprocating rake designs employ a cogwheel-type drive whereby the rake assembly is mounted on a carriage that travels on cog wheels along a fixed pin or gear rack. If the rake encounters objects too large to be removed, it will disengage from the bar rack and re-engage the rack above the object.

Continuous self-cleaning screens are capable of handling higher solids loading and yield lower, relatively constant headlosses compared to traditional designs because screenings are continuously removed. Screenings are collected and removed via a moving belt of steel or plastic filter elements which are pulled through the channel. Screen openings can be as large as 76 mm and as small as 1 mm, a level of treatment approaching primary treatment, because of the high solids handling capacity of the design. Unlike most other bar screens for which the bar spacings refer only to the horizontal distance, screen elements in continuous screens are sized in both the horizontal and vertical dimensions.

The screen elements are supported at the bottom of the channel with a gear sprocket or guide rail. Access for screen maintenance is achieved by pivoting the screen up and out of the channel. Additional cleaning is provided in some designs via spray bars and brushes, particularly for screens with smaller openings.

Catenary bar screens were specifically designed to be more rugged and dependable than the reciprocating rake type screens. To achieve a higher level of reliability, catenary bar screens were designed to be jam-proof and require a minimum of operator attention. The cleaning mechanism of a catenary screen consists of heavy tooth rakes held against the screen only by the weight of its chain, allowing the rake to be dragged over large objects which might be stuck in the bars and potentially jam the mechanism. All sprockets, shafts, and bearings are located out of the flow stream, reducing wear and corrosion and facilitating routine maintenance.

Design Considerations

Determination of the screen location for CSO control will depend on the collection system configuration and the need to protect downstream equipment. Screen design may be governed to some extent by space restrictions, particularly with respect to headroom. The amount of headroom required is determined by the discharge height of screenings and the type of screen. A typical discharge height is 1.2 m, although some designs have incorporated discharge heights as low as 0.6 m where headroom was restricted.

It is recommended that mechanically cleaned screens be installed in straight channels in order to provide a uniform flow distribution and solids distribution across the screen. A standby screen, usually manually cleaned and the ability to isolate each screen from the flow should be incorporated into the design so that peak flow to the facility can be maintained with one unit out of service and maintenance to the off-line screen provided.

In climates with freezing temperatures, enclosure of the screening equipment in a heated structure will likely be necessary to protect the equipment and also to ease maintenance and improve aesthetics. Adequate ventilation for acceptable working conditions will also be required.

Table 3 lists the key design parameters for mechanically cleaned bar screens.

Table 3-1
Typical Design Information For Mechanically Cleaned Coarse Bar Screens

Parameter	Typical Value
Size of openings[1], mm	6-38
Bar Size: • Width, mm • Depth, mm	 5-15 25-38
Slope from vertical, degrees	0-30
Allowable headloss, mm	150
Approach Velocity: • Maximum, m/s[2] • Minimum, m/s[3]	 0.6-1.2 0.3-0.6

Notes:

1. A clear spacing of 9 mm is considered satisfactory for protection of downstream equipment.
2. The maximum velocity refers to the velocity through the screen bars. At flow velocities higher than about 1 m/s, entrained solids may be forced through the bars.
3. Required to prevent accumulation grit accumulation in the channel. A minimum velocity of 0.9 m/s may be required where significant stormwater is to be handled.

Source: WEF, 1992; Metcalf and Eddy, 1991; manufacturers.

For CSO control facilities in the U.S., bar spacings of 13 to 25 mm are typical. A bar opening of 19 mm is generally considered adequate to protect downstream equipment. For reasons mentioned earlier, the selection of screen openings smaller than 13 mm for facilities served by gently sloping gravity collection systems may result in increased capture of fecal and other organic matter and thus may necessitate more advanced solids handling systems for odour control, screenings washing to remove organics, and/or dewatering.

Representatives from both manufacturers of cog-rake type screens contacted for the present study, IDI and FMC, recommend a minimum bar spacing of 13 mm and 19 mm, respectively. Although screens with 6 mm openings can be supplied, it was felt that the 3 mm wide rake teeth required for such a design would be prone to excessive wearing and breakage.

Peak flows at CSO control facilities usually occur at the start of the storm, followed by a period when the flow gradually tails off. Also, as flows subside, backwater from downstream weirs may create quiescent conditions in the bar screen channel, leading to sedimentation in the screen channel. For these reasons, it is recommended that the design incorporate some means of flushing the screenings channel (US EPA, 1993).

Clear water headlosses through the screens are a function of the approach velocity in the channel and the velocity through the bars, which in turn is determined by the bar openings, bar widths, and bar geometry. As screenings accumulate, the upstream head will increase causing new screen areas to be submerged. Cleaning cycles are normally automatically initiated when the headloss across the screen reaches 150 mm of water.

The activation of screen operation is usually based on remote sensing of flow into the facility or water level in the screening channel. Controls will normally include an automatic start/stop based on a timer or differential head as well as a manual start/stop.

Handling of solids is conducted in a variety of ways depending on site-specific conditions. Screenings can be discharged into a storage bin, either directly or via a conveyor, and later collected for disposal, usually in a landfill. Alternatively, screenings can be washed to reduce the organic content and the potential for odour problems, and/or dewatered prior to disposal. In some installations where solids handling is limited by space and/or the remote location of the screens, screenings are returned to the originating interceptor or sewer trunk.

Washing of screenings is more common for screens with smaller bar spacings which remove more fecal matter and is often provided by retrofitting the screen frame with external spray bars. Alternatively, the screenings can be washed in a separate operation after being discharged, although the later option is much more expensive.

Dewatering can reduce screenings volumes by as much as 75% and produce 40-50% dry solids in the discharge, depending on the nature of the feed solids.

Operation Experience

The following case studies are presented to provide insights into the operation and maintenance requirements and solids handling methods utilized at mechanically cleaned bar screen installations.

Large catenary-type bar screens were installed at the Lincoln Park CSO facility in Decatur, Ill. which at the time of commissioning in 1992 was the largest such facility in North America. The design flow is 416 USmgd. Smaller flows to the facility are directed to a first-flush storage tank without screening while larger flows are screened and then treated in four vortex separators. The screening facilities consist of four E and I Corp. screens with 25 mm openings and were designed mainly to protect the vortex separators. Bypass channels around the catenary screens are equipped with 25 mm manual screens. After testing several level detectors, a float switch located in the screening channel was selected as the remote sensor for activating the screens.

In the 13 month period from December 1, 1993 to January 1, 1994, a total of 36 events were handled at the facility. Since commissioning, the catenary screens have never been bypassed.

Screenings are discharged into a hopper and then collected by a vacuum truck and transported back to a nearby sewage treatment plant. After being allowed to drain on a perforated pad for a day, the screenings are lifted by backhoe into a semi-trailer and hauled to a landfill for disposal.

After each event, the screens are hosed down with a firehose, mainly to remove plastic bags and other plastic materials which are not removed during normal cleaning. Labour required for the cleaning procedure is about 15 minutes per screen per event. Routine preventative maintenance, primarily consisting of greasing and oiling is performed every six months, based on the manufacturers recommendation.

The initial screen design called for 19 mm bar spacings but was found to be prone to clogging, particularly in the fall, with leaves. Although the cleaning rake would not jam, it would disengage when encountering a large mat of solids on the screens, which would gradually accumulate and clog the screen. This problem was rectified when the bar spacing was increased to 25 mm. (Boland, 1995)

At the City of Victoria Currie Rd. pump station, two continuous self-cleaning Wiessman screens were installed in bypass channels for the pump station. Wastewater flow to the pump station is mainly sanitary but is subject to large amounts of infiltration during wet weather. During large storm events, typically three or four times a year, flow is bypassed around the pump station wet well into two screening channels and then discharged to the receiving water. Each screen was sized to handle flows of 15 USmgd and has clear openings of 6 mm. They are activated by a float switch with a delay timer located in the wet well.

Because of limited headroom, the screens were designed with a discharge height of only 0.62 m. Screenings are not handled on-site. Instead, screenings are discharged onto a 2.3 m long screw conveyor and returned back to the wet well for processing at downstream treatment facilities. After each event, the screens are hosed down to provide additional cleaning, a process which takes two men approximately two hours. The screens were designed with a pivot mechanism to allow them to be swung out of the channel for easy maintenance (Paulson, 1995).

Two, three feet wide, continuous self-cleaning Parkson Aqua Guard screens with 6 mm openings are employed at the new Smith Falls Water Pollution Control Plant commissioned in 1994. This sewage treatment plant was designed to treat an average day flow of 14,700 m^3/d from a combined collection system which experiences large amounts of extraneous flow during wet weather. No trash racks were installed upstream of the continuous screens.

The screens are controlled by a SCADA system which activates the screens based on the water level in the screening channel. Screenings are discharged into an inclined screw conveyor which delivers the screenings to a storage bin and also provides some dewatering. Once full, the bins are collected in compactor trucks used for solid waste collection and hauled to a landfill.

Due to the large industrial contribution of oily, greasy wastewater to the plant, the screens are subject to grease build up. Initially, these accumulations necessitated daily manual washing by operation staff with a fire hose. To reduce the amount of operator maintenance, the screens were retrofitted with spray bars which use tertiary effluent and operate continuously while the screen is operating. Manual screen cleaning is now only required once per week, primarily to dislodge debris from the frame structure and top end of the unit. Labour required for screen cleaning is approximately one hour each week (Bligdon, 1995).

Costs

In order to compare the capital costs of the various coarse screening technologies, a hypothetical design flow of 500 L/s was selected and quotations were obtained from five manufacturers of coarse screens. Based on the characterization of floatables presented earlier and discussions with the manufacturers, bar spacings of 6 to 13 mm were selected, depending on the specific technology. Based on the design flow, the manufactures identified appropriate channel dimensions and screen designs. Budget pricing provided by the manufacturers and assumed channel dimensions are shown in Table 3-2.

Table 3-2
Budget Pricing For Various Mechanically Cleaned Screen Technologies
Based on a Design Flow of 500 L/s

Coarse Screen Technology	Manufacturer	Assumed Channel Dimensions[1], Width (mm) x Depth (mm)	Bar Spacing (mm)	Capital Cost[2] (Cdn. $)
Reciprocating rake (cog rake type)	FMC	914 x 1829	9.5	$85,000
Reciprocating rake (cog rake type)	IDI	1200 x 1500	13	$155,00
Continuous self-cleaning	Wheelabrator/ Weisemann	700 x 1900	6	$50,000
Continuous self-cleaning	Parkson Corp.	914 x 1829	6	$70,000
Catenary	E and I Corp.	914 x 914	13	$35,000

Notes:

1. Screen channel dimensions selected by manufacturers, based on design flow. Discharge height for all designs was approximately 1220 mm.
2. Prices indicated include equipment costs only; installation costs, taxes, and any other costs are not included.

Additional capital costs may be incurred for screenings handling equipment such as washers, conveyors, and compactors. For example, the quoted price for a Rotopress screenings compactor, supplied by Parkson Corporation, capable of handling screenings at the design flow of 500 L/s is $35,000 Cdn. To add a Parkson screenings washer would cost an additional $25,000 Cdn.

Based on discussions with municipal supervisory staff, costs associated with the operation and maintenance of mechanically cleaned bar screens are usually small.

3.2 *Fine Screen Technologies*

For the purposes of this report, fine screens are defined as those screens with openings of 0.25 mm to 6 mm. In wastewater treatment, fine screens are typically used in lieu of sedimentation for primary treatment or to upgrade existing primary sedimentation facilities. They are generally preceded by mechanically-cleaned bar screens, trash racks, or other protective devices.

Technology Description

Fine screen technologies used in wastewater treatment include inclined, self-cleaning static screens, rotary drum screens, rotary disc screens, and band screens. For CSO applications, rotary drum screens tend to the most popular type of fine screening equipment.

Diagrams and/or drawings for these fine screen technologies are presented in Appendix 1.

Static screens stand upright and are usually curved slightly such that the upper portion, where influent is introduced is very steep and the lower portion is flatter. As the flow cascades over the screen, the screenings are pushed to the bottom of the screen where they are collected in a trough.

With drum screen technologies, the screening medium is mounted on a rotating cylinder which sits in a flow channel. Influent flows either into one end of the drum and outward through the screen with screenings collected on the interior surface or, from the top of the unit and outward through the interior with screenings collected on the exterior surface. Screenings are continuously discharged and water spray bars are used to clean the screening medium, either automatically or on manual control.

Rotary disc screens are positioned perpendicular to the direction of flow with approximately one half the screen submerged. Cleaning is provided by spray bars which wash the screenings into a collector plate.

A fourth type of fine screen is the band screen in which screening is provided by a series of polyurethane mesh panels attached together to form a closed loop or band. The band is attached to main chains, supported by two sprockets above the channel, which travel along guides located in a free standing steel frame. The screen sits in a channel with the panels parallel to the direction of flow. Influent flows into the open end of the band and then laterally through the panels. Screenings are retained on the inside and carried upwards to the top of the screen where they are removed by backwashing into a reject water trough.

Design Considerations

Table 3-3 summarizes the key design parameters for fine screen installations.

Table 3-3
Typical Design Information For Fine Screen Technologies

Item	Type of Screen			
	Static, Inclined	**Rotary drum**	**Rotary Disc**	**Band**
Screening Surface • Size range, mm • Screen material	0.25-1.5 Stainless steel, wedge wire	0.25-1.5 (typical) Stainless steel, wedge wire	0.025-0.25 Stainless steel, woven wire	2-6 Polyurethane mesh, with round holes
Clear water headloss, m	1.2-2.1	0.8-1.4	n.a.	n.a.
Hydraulic Capacity, $m^3/m^2.h$	35-150	0.3-2.5	0.2-2.5	approx. 550
Composition of Waste Solids, solids by weight, %	10-15	10-15	6-12	n.a.
Suspended Solids Removal, %	15-30	15-30	40-50	n.a.

Notes:

Source: WEF, 1992; Metcalf and Eddy, 1991; product manufacturers.
n.a. not available

Clear water headloss information, shown in Table 3-3, is available from manufacturers and is useful to compare different technologies. However, determination of headloss during operation with wastewater is more appropriate for design purposes. Head loss during operation will depend on the quantity and type of solids in the wastewater, the size of the screen openings, and the frequency of screen cleaning.

Each installation should have a minimum of two units, with each being able to treat peak flows independently, when it is necessary to service the other unit.

Grease build up on fine screens, especially in colder climates requires periodic cleaning. Hosing equipment should, therefore, be included in the design (WEF).

Operation Experience

An example of a wet weather treatment facility design utilizing fine screens for removal of floatables and solids is the Village of Deerfield, Illinois facility, which was designed to treat sanitary sewer overflows caused by high levels of infiltration and inflow during storm events. Two satellite treatment plants, one rated at 20 USmgd and the other at 15 USmgd were constructed on separate sewer trunk lines. The facilities were constructed on residential lots and were designed to resemble large houses. During large storms, pumped flow from surcharged sewers is treated in Hycor Rotoshear rotating drum screens, three in each building, with 1 mm screen openings. Screened water is then disinfected via chlorination in the basement of the facility before discharge into the Chicago River. Screenings are ground and then returned to the sanitary sewer for treatment at the downstream sewage treatment plant (Soyka, 1995).

Initially, manually-cleaned bar screens were installed upstream of the pumps but due to the high maintenance requirement, they were removed. No impacts on the operation of the pumps or the fine screens have been observed after this design change.

The total installed cost, including engineering fees, for the Deerfield. Ill. facility installed in 1990 and 1991 was $4.2 million (US), or approximately $0.12 US per USgpd of capacity.

In the Deerfield, Ill. installation, the rotating drum screens go on-line automatically and are unmanned. Typically, the facility is in operation for four events per year. Manual cleaning with a spray washer is provided after each overflow event which takes approximately 15 minutes per screen (Soyka, 1995). No odour problems or noise problems associated with operation of the grinders have been observed.

At the recently commissioned Tanyard Creek CSO facility in Atlanta, one 8.5 m diameter Brackett Green drum screen provides fine screening for a design flow of 400 USmgd. The drum screen has clear openings of 5 mm and is constructed from special fibre mesh panels. Upstream, cog rake type trash racks with 75 mm bar spacings remove large debris and protect downstream equipment. After fine screening, CSOs are disinfected and then discharged to Tanyard Creek. In 1994, the facility treated 71 CSOs.

Fine screenings are discharged to large hopper baskets for dewatering and storage, with the filtrate returned to the drum screen. In addition to the automatic cleaning provided, manual cleaning with a fire hose is practised after each CSO event in order to prevent accumulation of materials on the screen surface. Manual cleaning requires approximately two hours for each CSO event (Nuckolls, 1995).

The use of static screens and rotary disc screens in CSO applications appears to be rare, particularly in newer facilities. Static screens installed at the Intrenchment Creek CSO Treatment Facility in Atlanta were prone to blinding during the initial period of high solids loading and when the overflows carried heavy grease loads (West, 1990). Based on this experience, subsequent CSO treatment facility designs adopted by the City of Atlanta replaced the 0.3 mm static screens with 5 mm rotating drum screens.

Costs

Table 3-4 lists quotations for two fine screen technologies capable of treating a peak flow of 500 L/s.

Table 3-4
Budget Pricing For Fine Screen Technologies Based on a Design Flow of 500 L/s

Fine Screen Technology	Manufacturer	Screen Size	Clear Spacing (mm)	Capital Cost (Cdn. $)
Rotating Drum Screen	FMC	2.4 m dia. x 1.2 m long	0.23-3	$52,000
Rotating Drum Screen	Hycor	1.8 m dia. x 3.5 m long	1	$145,000
Rotating Drum Screen	Andritz Sprout-Bauer	2.26 m long; Channel dimensions: 1.9 m wide x 1.8 m high	1.5	$115,000
Band Screen	Brackett Green	Approx. band dimensions: 0.9 m wide x 3.0 m high[2]	2-6	$110,000

Notes:

1. Prices indicated include equipment costs only; installation costs, taxes, and any other costs are not included.
2. Assumed channel width was 2.0 m and depth of flow, 2.3 m at design flow.

3.3 *Weir-mounted CSO Screens*

Technology Description and Design Information

As an alternative to bar screens and fine screens which generally require significant headroom and/or floor space, weir-mounted screens can be mounted directly on a weir at the point of overflow.

An illustration of the layout of two such weir-mounted screen technologies is presented in Appendix 1.

The main advantage of this type of screen is the low headroom requirement. Two examples of such technologies are the Jones and Attwood/Romag (Romag) and John Meunier storm overflow screens, both of which were specifically designed to screen wet weather flows. In both technologies, screenings are mechanically returned to the underflow and thus screenings handling facilities are not required.

The Romag screen has a long narrow profile and can be mounted horizontally or vertically on the overflow structure. The screen structure consists of long grid bars without any transverse members. Bar spacings of 3-4 mm are typical and the whole screening system is submersible. Screen cleaning is provided by hydraulically driven cleaning carriages mounted on the discharge side of the screen which carries screened material along the length of the screen and discharges it back into the underflow. The carriages also support the grid bars and maintain a constant distance between the bars. The screen grid and plastic cleaning combs are assembled from 100 mm wide modules. Screen cleaning is continuous for the duration of the event and is automatically controlled by water levels. Romag screens do not require enclosing.

For emergency overflows during intense storms or periods of equipment failure, a high level weir allows for overflow of the entire screen.

The Romag screens are sized such that the screen velocity at peak flow is approximately 1.5 m/s.

The Meunier Storm Overflow Screen consists of a mechanically raked bar screen mounted horizontally on the overflow weir sill. The bar screen is curved, with the concave face of the screen facing upstream, in order to increase the screening area for a given weir length. Depending on the overflow configuration, single or double-sided overflow weir layouts can be utilized. Accumulated screenings are raked, from the inlet side of the screen, back into the main flow channel. The most common bar spacings are 13 and 19 mm and usually the screening structure is enclosed.

The principal limitation of the Meunier design is the requirement that a maximum of 85% of the peak flow will overflow the weir to ensure sufficient velocity in the sewer to carry away the screenings.

Operating Experience

The Romag storm overflow screen is a relatively new technology and thus operating experience is limited. Most installations are located in Switzerland, where the technology was developed, and Germany and are typically used to screen overflows from storm water or CSO storage tanks. In some such designs, a scum baffle is installed at the tank outlet, upstream of the overflow screen. The baffle captures a large portion of the floatables with the exception of the "swimmers", which must be removed by the overflow screens. In most cases, a bar spacing of 4 mm was selected.

Table 3-5
Budget Pricing for Two Weir-Mounted Overflow Screen Technologies Based on a Design Peak Flow of 500 L/s

Technology	Screen Configuration	Screen Dimensions	Bar Spacings (mm)	Budget Pricing (Cdn. $)
Jones and Attwood/Romag	RSW (vertically mounted)	2,000 mm long x 520 mm high	3	50,000
John Meunier	Double-sided overflow	944 mm long x 189 mm high	9.5	36,000

Notes:

1. Prices shown are for equipment costs only, excluding taxes and do not include installation costs.

Most installations of the John Meunier SOS screen are located in Quebec. Based on discussions with the manufacturer, screen clogging has been reported in some installations and has been attributed to inadequate through-flow velocities.

Costs

Table 3-5 presents budget capital costs for Romag and Meunier screens capable of treating a peak flow of 500 L/s.

3.4 *Netting Trap Systems*

Technology Description and Design Information

Netting trap systems consist of disposable nylon mesh bags installed at a CSO outfall or within a channel or overflow structure. Floatables and coarse solids are strained from the CSO and captured in the bags. Once full, the bag is removed and hauled to a landfill for disposal.

The physical configuration of two trap system technologies is presented in Appendix 1.

The application of netting trap systems for CSO treatment in the North America is relatively new. In the United kingdom, trap systems have been installed in various wastewater applications but mainly for fine screening of clarifier effluent and final effluent from activated sludge treatment plants, and for coarse screening of storm overflows and CSOs.

Two netting technologies will be reviewed, namely the TrashTrap manufactured by Fresh Creek Technologies, West Caldwell, NJ and the Copatrawl manufactured by Copa Products, Tonbridge, England.

The standard TrashTrap system is installed in the receiving water at an outfall. The bags are mounted on a floating pontoon structure from which heavy duty PVC curtains are suspended and weighted down in order to contain the CSO. The pontoons are fixed in place by attachment to the face of the outfall with steel cable or struts. During a CSO, the flow is directed into steel funnels at the front of the pontoon structure and then into the mouth of the bags which are supported by a wood frame and are positioned approximately 60 cm into the water. Typically, the curtain facing the outfall is designed to release during intense storm events when the discharge velocities exceed a critical level.

Several methods of net removal have been employed to date. At the first installation site in Brooklyn, the design included a rail mounted davit hoist and cart to facilitate placement of the full nets in an adjacent dumpster. The nets were changed after every four storm events and never less frequently than once a month. Nets can also be lifted by a boom crane and placed in a container or be picked up by a skimmer vessel or workboat.

Copatrawls are generally installed in channels and were designed to handle high volume storm discharges.

Table 3-6 lists key design parameters for TrashTrap and Copatrawl technologies.

Table 3-6
Design Information for Two Netting Trap Technologies

Parameter	Technology	
	Copatrawl, by Copa Products Ltd	**Trash Trap, by Fresh Creek Technologies**
Type of installation	in-line	outfall or in-line
Mesh size, mm	6-25	6-13
Design criteria for determining number of bags required	Based on a maximum flow rate per unit of 150 L/s	Based on CSO floatables content and desired frequency of net changing
Sac size	Available in circumferences of 1.9 m, 3 m, and 3.4 m. Sac length: 2 m	Sized to hold 0.7 m^3 and 227 kg of floatables
Typical floatables removal efficiency, %	n.a.	90-95 %

Note:

1. n.a. = not available

Operating Experience

At the two Newark installations, the floatable removal efficiency of the netting systems was determined by measuring the amount of floatables captured in the nets, in terms of drained weight and the amount which escaped, which were contained by a secondary boom structure and collected with a skimmer vessel. The removal efficiencies of both 6 mm and 13 mm mesh nets were evaluated at both sites.

Removal efficiencies at the two sites ranged from 92 to 98 per cent, with the Peddie site exhibiting slightly better removals. Removal efficiency with the 6 mm net at Peddie was marginally better compared to removal with the 13 mm net while at Saybrook the 13 mm net provided marginally higher removals (Parsons Engineering, 1994).

Based on the limited operation experience gained with netting trap systems, it appears that the tensile strength and aperture of the nets are important considerations which may impact process efficiency and reliability. During a trial period at the Brooklyn, NY installation, a net with 6 mm mesh ruptured during an intense storm where peak flows reached 20 m^3/s. Replacement with a higher tensile strength mesh with 13 mm openings prevented any further failures with similar intensity discharges.

At the Saybrook CSO outfall in Newark, NJ, recurring tears were recorded in the 13 mm mesh bags. After installing heavier mesh nets and minor modifications to the bag support structure, further tears were prevented.

Costs

Table 3-7 indicates budget costs for end-of-pipe and in-line TrashTrap systems.

Based on discussions with the manufacturer, the TrashTrap systems indicated in Table would likely be capable of treating a CSO with a peak flow of 500 L/s. However, in order to verify sizing, site specific information with respect to outfall configuration, floatables content of the CSO, peak volumes, and flow velocities, is required.

Operation and maintenance costs for two Newark, NY netting system installations, which were evaluated as part of a demonstration project, have been estimated. At both sites, the bags were removed with a boom truck. For the four bag system at the Peddie outfall, the total operating cost, including labour, supervisory labour, and replacement of all four nets, but excluding crane and haulage vehicle costs, was calculated to be $US 546 per CSO event. The largest cost item was the nets, priced at $95 US each, which were replaced after each event to allow monitoring of per event floatables quantities.

Table 3-7
Budget Costs for Trap Systems

Type of Installation	Number of bags	Budget Pricing[1] (Cdn. $)	
		Cost for equipment and engineering support	Installation costs
End-of-pipe TrashTrap	2	$118,000	$35,000
In-line TrashTrap	1	$83,000	$28,000

Note:

1. The above pricing assumes use of a boom truck to service the system, so there is no need for the electrical power at the site. If a dedicated floatables handling system is required, the cost would be an additional $30,000 to $80,000, depending on the size and complexity of the system.

It was noted that during normal operation, net changes could be conducted less frequently, and the labour requirement would also be lower, since a majority of the labour was devoted to system monitoring for the demonstration project which would not otherwise be required. Consequently, it was predicted that operating costs during normal operation would be significantly lower.

Total operating costs at the 2 bag Saybrook outfall installation were $326 US per CSO event, including the same cost components.

4.0 *SUMMARY*

This report examined several categories of treatment technologies for the removal of floatables from combined sewer overflows (CSOs).

Firstly, the composition and quantities of floatables in CSOs, based on a study in New York City, were reviewed in order to assess the suitability of different control technologies. It was found that the major materials in CSOs were plastic (42% of all items), paper (26%), and polystyrene (26%). With respect to size, 95 percent of the floatable material was reported to be 13 mm or greater.

Based on the monitoring results of three trap system demonstration projects in Newark, NJ and Brooklyn, NY, the total amount of floatables generated during CSO events ranged from 5 to 14 kg/1,000 m^3 of CSO.

Table 4-1 presents a summary of the typical applications and key design and operation considerations for the treatment technologies reviewed in this report.

The most common technologies for the removal of coarse solids (greater than 6 mm) from CSOs are catenary and continuous mechanically-cleaned bar screens. Catenary type screen designs are often installed where large debris will be encountered and where a high degree of reliability is required. Although jamming of the rake is uncommon, screen clogging may result when a heavy solids mat accumulates on the screen and causes the rake to disengage.

Because of their higher solids handling capacity, continuous screens can be used for the removal of smaller solids but such designs may necessitate supplemental cleaning, (i.e. cleaning used manual in addition to that provided during normal screen operation). Equipment costs for catenary and continuous screens capable of treating a design peak flow of 500 L/s were estimated to be between $35,000 and $70,000, not including installation costs, taxes, or any other costs.

Where the removal of floatables smaller than 6 mm is desired, rotating drum fine screens are typically installed. Such installations require upstream treatment to remove coarser solids. Most fine screen technologies are susceptible to grease build-up and will require supplemental cleaning. In addition, as bar spacings are reduced, the proportion of organic material removed tends to increase so that solids washing and/or odour control facilities may be needed. An alternative fine screening technology specifically designed for CSO treatment is the band screen. Quotations for equipment costs for rotating drum and band screen technologies ranged from $50,000 to $110,000.

Table 4-1
Summary of Applications and Key Design and Operating Considerations for Floatable Removal Technologies

Technology	Size of Bar Spacing/Mesh (mm)	Application	Design Considerations	Equipment Costs[1]	O&M Considerations
Trash Racks	38-150	Removal of large debris; protection of downstream unit processes	Manually cleaned designs inferior to mechanically cleaned designs	$30,000	
Coarse Screens					
• chain or cable driven	6-38 (13-25[2] typical)	Used extensively in STPs		N/A	Submerged parts subject to fouling. Frequent inspection and maintenance required
• reciprocating rake		Not suitable for high solids loads	Require more headroom than other coarse screen technologies		
• continuous		Higher solids handling capacity allows smaller openings to be used		$85,000-155,000 $50,000-70,000	Supplemental cleaning[3] may be required, especially for smaller bar spacings. Some employ potential for carryover of solids
• catenary		Removal of large debris (typically > 25 mm) with minimal operator attention		$35,000	With smaller bar spacings, clogging may occur whan a heavy solids mat accumulates on the screen
Fine Screens (rotating drum and static, inclined)	0.25-1.5	Removal of finer solids (< 6 mm)	Require upstream treatment to remove coarse solids	$52,000-145,000 $115,000	Susceptible to grease build-up. Supplemental cleaning[3] generally required. Solids washing may be required to remove organics
Weir-mounted Screens					
• Romag	3-4	Screening of overflows from CSO storage tanks	No screenings handling facilities required	$50,000	Screens may clog if through flow too low
• John Meunier	13-19	Screening at point of overflow	Requires a minimum through flow of 15% of total flow. No screening handling facilities required	$36,000	Screen may clog if through flow low
Trap Systems	6-25	Removal of coarse solids after discharge to receiving water or, in-line removal	Little design data available for CSO treatment. Full bags can be removed by boom trucks or via a dedicated solids handling system	$80,000-120,000	O&M costs associated with bag replacement can be relatively high. Operating experience for CSO treatment limited

Notes:

1. For an installation capable of treating a peak flow of 500 L/s. Costs indicated include equipment costs only.
2. Selection of bar spacings less than 13 cm may result in increase capture of fecal and other organic matter.
3. Supplemental cleaning refers to cleaning which is provided, usually manually, in addition to that provided during normal screen operation.

Alternate screen technologies are also available for installation on the weir at the point-of-overflow. In Europe, such designs are typically installed to provide screening of overflows from CSO and stormwater storage tanks. Baffles located upstream of the overflow screens are often installed to remove buoyant floatables with the screens being used to remove the "swimmers".

Because the screenings are mechanically cleaned and returned to the underflow, screenings handling facilities are not required for weir-mounted screens. One design (John Meunier) requires a minimum throughflow equivalent to 15% of the total flow to carry screened materials away from the screen. Otherwise, clogging can occur.

The final technology reviewed was trap systems. These systems are designed to remove coarse solids, which are collected in a disposable bag, either from a partitioned area of the receiving water at the CSO outfall or from an overflow channel. Mesh sizes available range from 6 to 25 mm. The application of this technology for CSO treatment is relatively new and as such little design data or operating experience has been documented. However, based on the results of demonstration projects, receiving water-based trap systems provide excellent removal efficiency of floatable materials.

The estimated capital costs for the necessary equipment required to handle flows up to 500 L/s will depend largely on the type of solids handling system used. Instead of a dedicated solids handling system, a boom truck can be employed for net replacement, which is typically performed at least once a month which would lower capital costs.

5.0 *REFERENCES*

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W2O

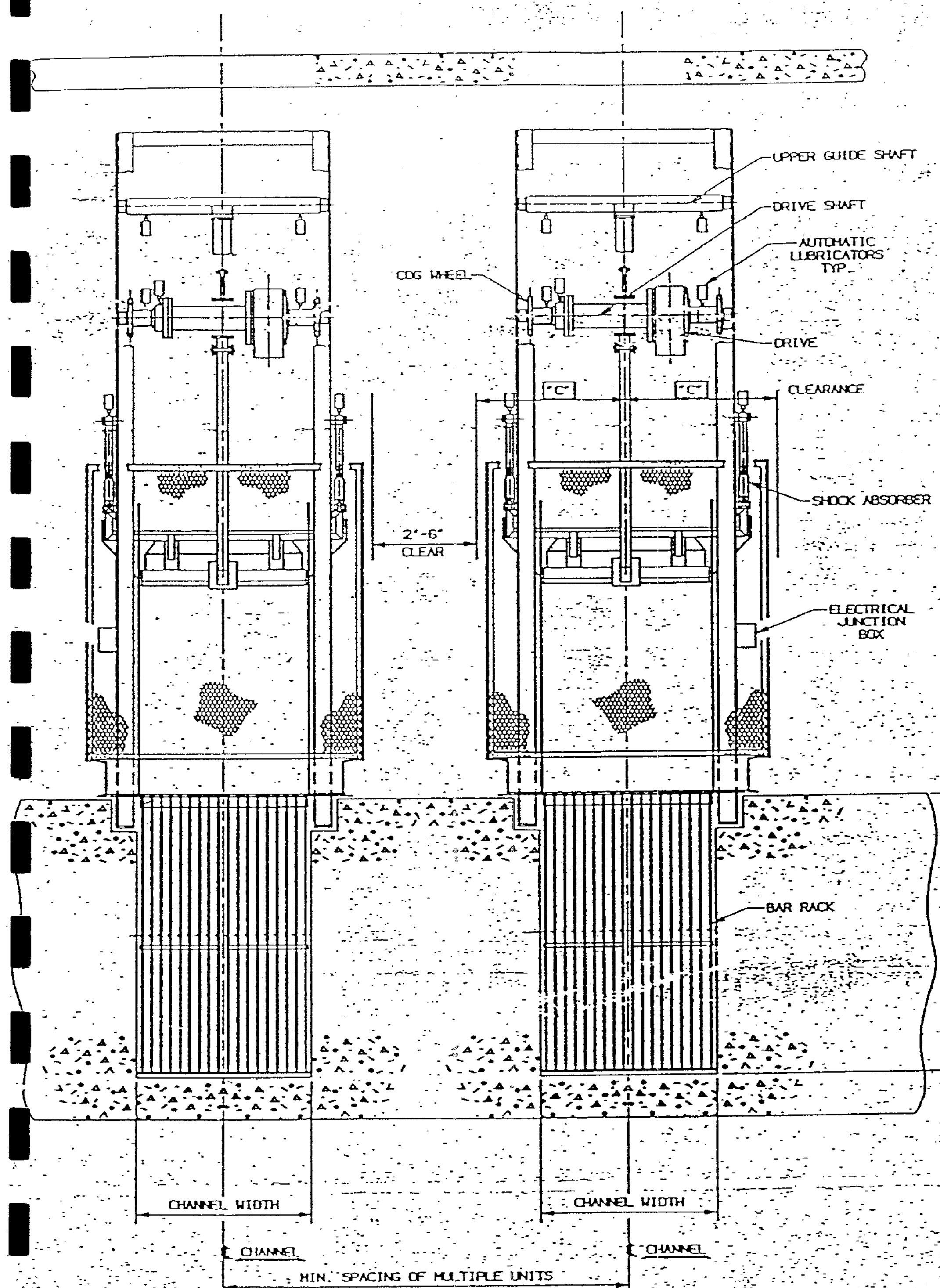
APPENDIX A

Illustrations of Floatables Removal Technologies

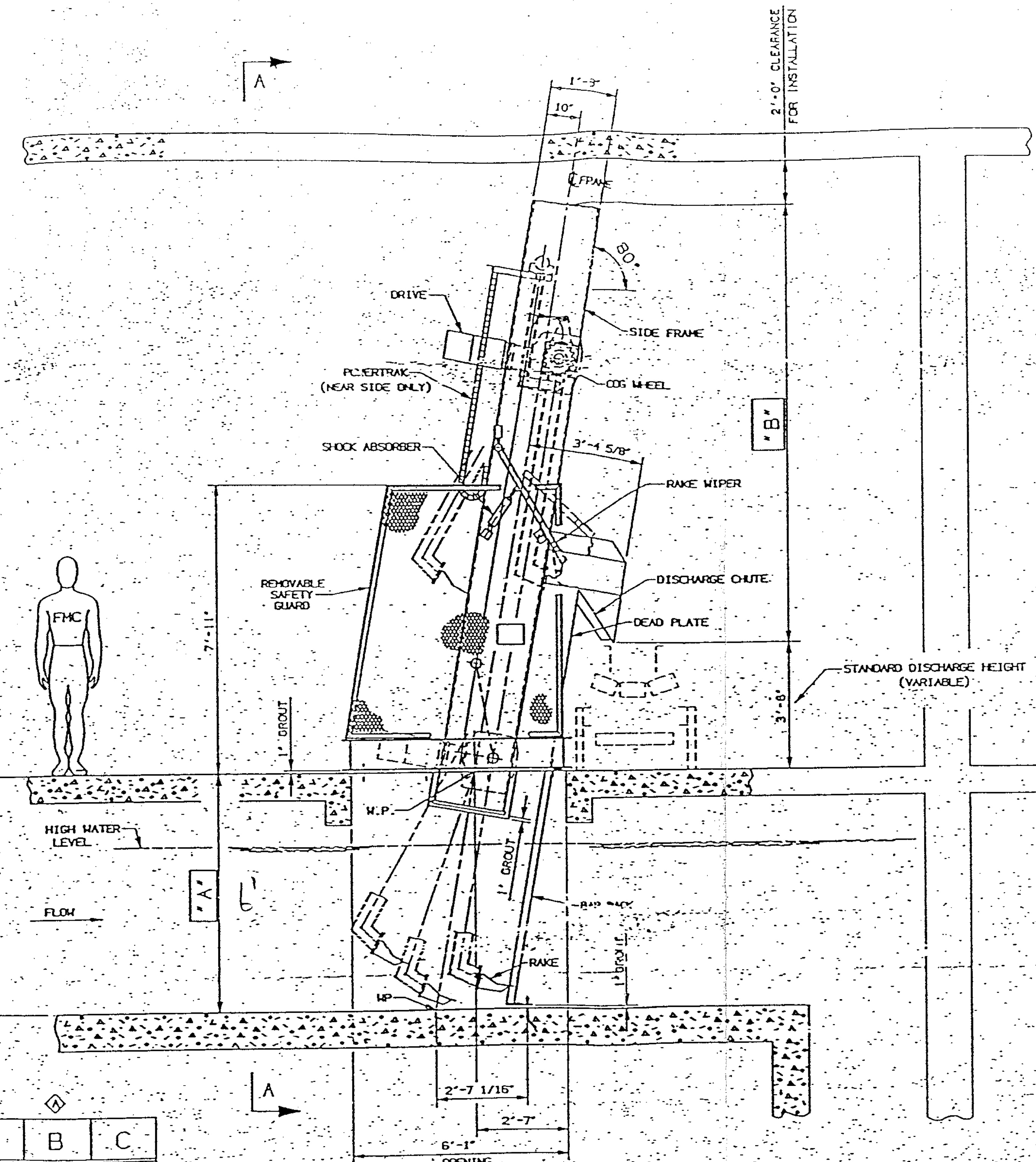
APPENDIX A - FIGURE TITLES

FIGURE A1

FMC Cog Rake Bar Screen



SECTION A-A



ELEVATION VIEW

UNIT SIZE	CHANNEL WIDTH	HP	A	B	C
1'-6"	1'-6"	1 1/2	WATER LEVEL PLUS 2'-0"	HIGH WATER DEPTH PLUS 5'-6"	CHANNEL WIDTH / 2 PLUS 1'-5"
2'-0"	2'-0"				
3'-0"	3'-0"				
4'-0"	4'-0"	3			
5'-0"	5'-0"				

NOTE:

FOR SIZES 6'-0" THRU 12'-0" SEE FMC DRAWINGS 1082Z5, 1082Z6

MATERIAL NOT FURNISHED BY FMC

[illegible]UNDATIONS, INSTALLATIONS OF FOUNDATION BOLTS (BOLTS [illegible]HC): PITS AND CONCRETE WORK: GROUT AND GROUTING: [illegible]DING ALTERATIONS IF SO REQUIRED: WEIRS: BAFFLES: [illegible] AND PIPING: EXTERNAL WIRE AND WIRING: CONDUIT: [illegible]LVES: GRATING: HANDRAILS: GATES: WALKWAYS: REFUSE [illegible]NTAINERS: FIELD PAINT AND PAINTING: UNLOADING AND [illegible]ECTION OF EQUIPMENT: ASSEMBLY OF COMPONENTS [illegible]ISHED BY FMC AND OR OTHERS: AND ANY OTHER [illegible]SSORIES NOT SPECIFICALLY INCLUDED HEREIN ABOVE

DESIGN NOTES:

1. WIDTH OF CHANNEL SHOULD NEVER BE LESS THAN DIA. OF SEWER
2. UNITS SHOULD GENERALLY BE DESIGNED FOR A NORMAL STREAM VELOCITY OF 2 FPS THROUGH THE BARS, WITH A MAXIMUM OF 4 FPS
3. STANDARD CLEAR OPENING BETWEEN BARS IS 1", HOWEVER 5/8" MIN. TO 3" MAX. IS AVAILABLE UPON REQUEST
4. CHANNEL WIDTHS CAN VARY

FOR ANCHOR BOLTS AND FDNS. SEE DRAWING 1082Z6

FOR ELECTRICAL SCHEMATIC SEE DRAWING 1082Z7

REV	DATE	DRAWN	CHECKED	APPROVED	DESCRIPTION OF REVISION
A	6-13-89	KEHOE	B.S.	PY	CHG. B DIMENSION TO 5'-6"
0	1-12-89	SHARBAUGH	RDU	PY	

SCALE: NONE

DIMENSION TOLERANCES EXCEPT AS SPECIFIED: FRACTIONAL ±1/16", MACHINED FRACTIONAL ±1/32"

TYPICAL GENERAL ARRANGEMENT OF INCLINED COG RAKE WIDTHS 1'-6" THRU 5'-0"

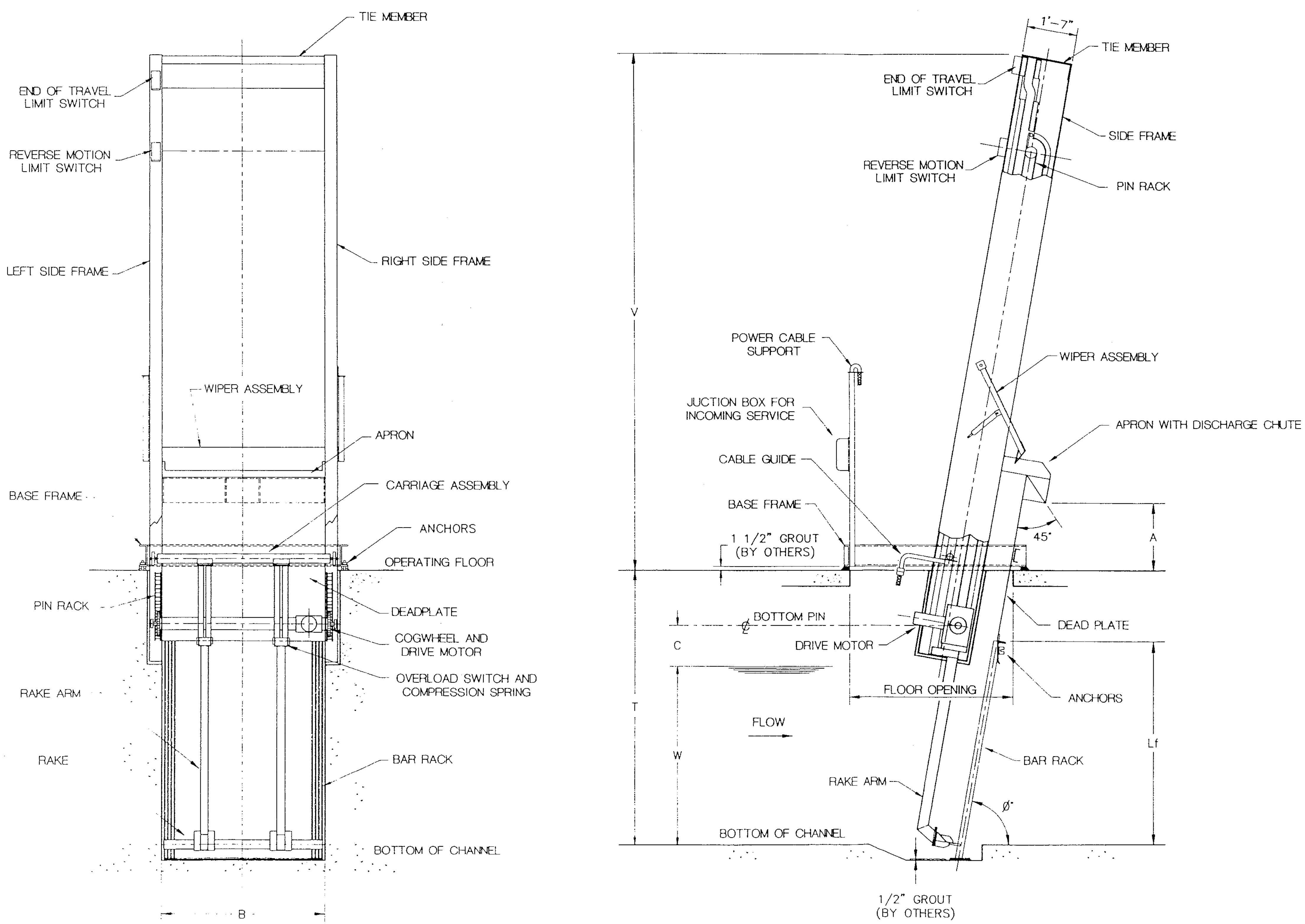
FORM REFERENCE

FMC Corporation

1082Z8

FIGURE A2

IDI Climber Screen



MODEL	CHANNEL WIDTH	MOTOR H.P.	C	D
TYPE I	1'-6" TO 3'-0"	1.5	1'-4"	1'-7"
TYPE II	3'-1" TO 6'-6"	3.0	1'-4"	1'-7"
TYPE III	6'-7" TO 11'-6"	5.0	1'-10"	2'-0"

PROJECT DATA		
B	CHANNEL WIDTH	
T	CHANNEL DEPTH	
W	MAXIMUM WATER LEVEL	
E	BAR RACK OPENINGS	
A	DISCHARGE HEIGHT	
V	FRAME HEIGHT ABOVE FLOOR	
Ø°	ANGLE OF INCLINATION	
Lf	BAR RACK HEIGHT	

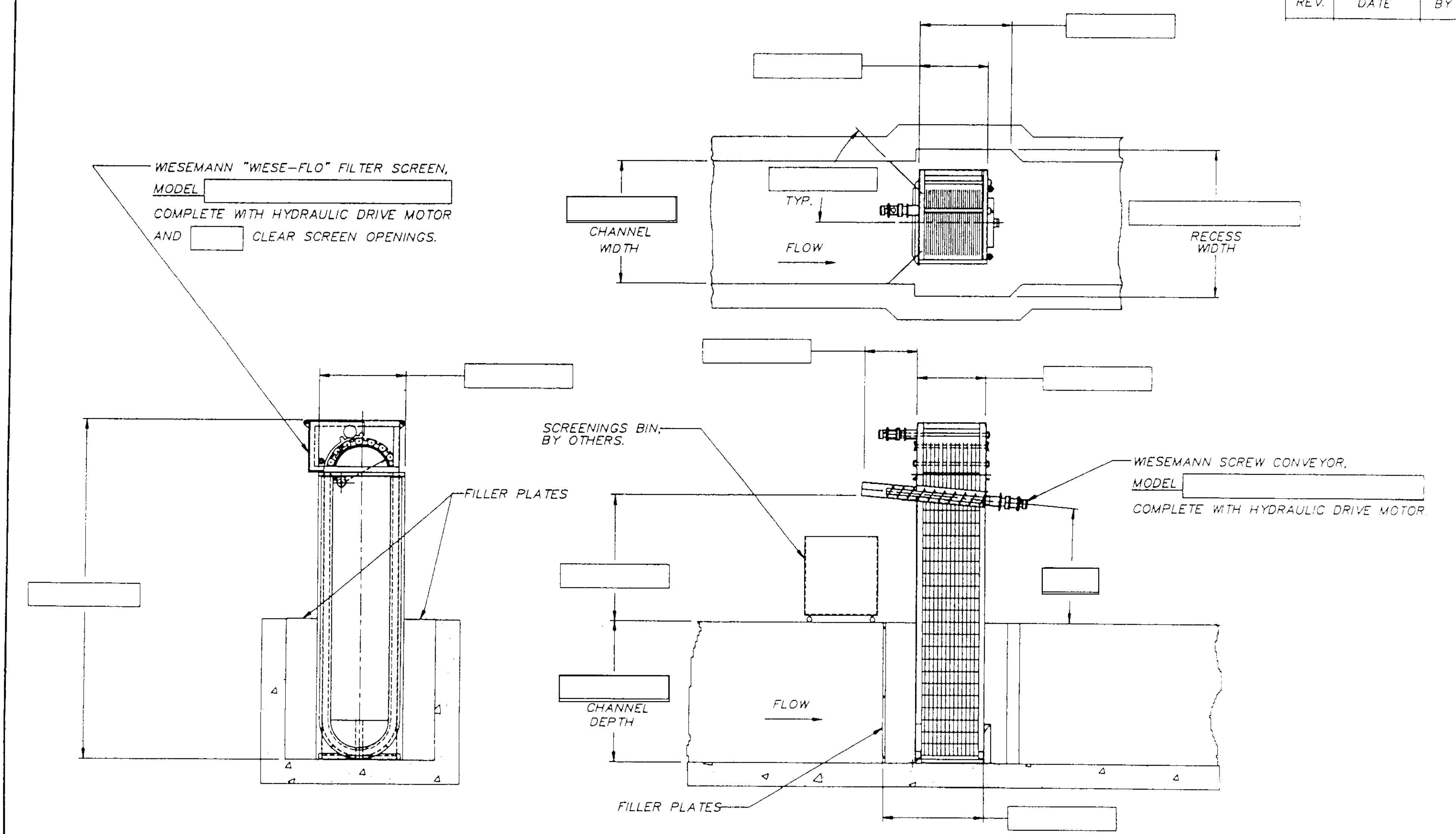
NOTES:

1. STANDARD ANGLE OF INCLINATION (Ø°) IS 80°.
2. ANCHORS IN CHANNEL WALL AS REQUIRED.
3. DESIGN AND CONSTRUCTION OF CONCRETE STRUCTURES NOT BY INFILCO DEGREMONT.
4. UNITS FOR WIDER CHANNELS ARE AVAILABLE. CONSULT INFILCO DEGREMONT INC. FOR DETAILS.
5. STANDARD CARRIAGE VELOCITY IS 20 FPM. WHERE CYCLE TIME EXCEEDS 2 MINUTES, VELOCITY WILL BE ADJUSTED AS REQUIRED. CONTACT INFILCO DEGREMONT INC. FOR DETAILS.
6. THIS DRAWING IS FOR PRELIMINARY DESIGN USE ONLY AND NOT FOR CONSTRUTION.

FIGURE A3

Wiesemann Wiese-Flo®
Self-Cleaning Filter Screen

REV.	DATE	BY

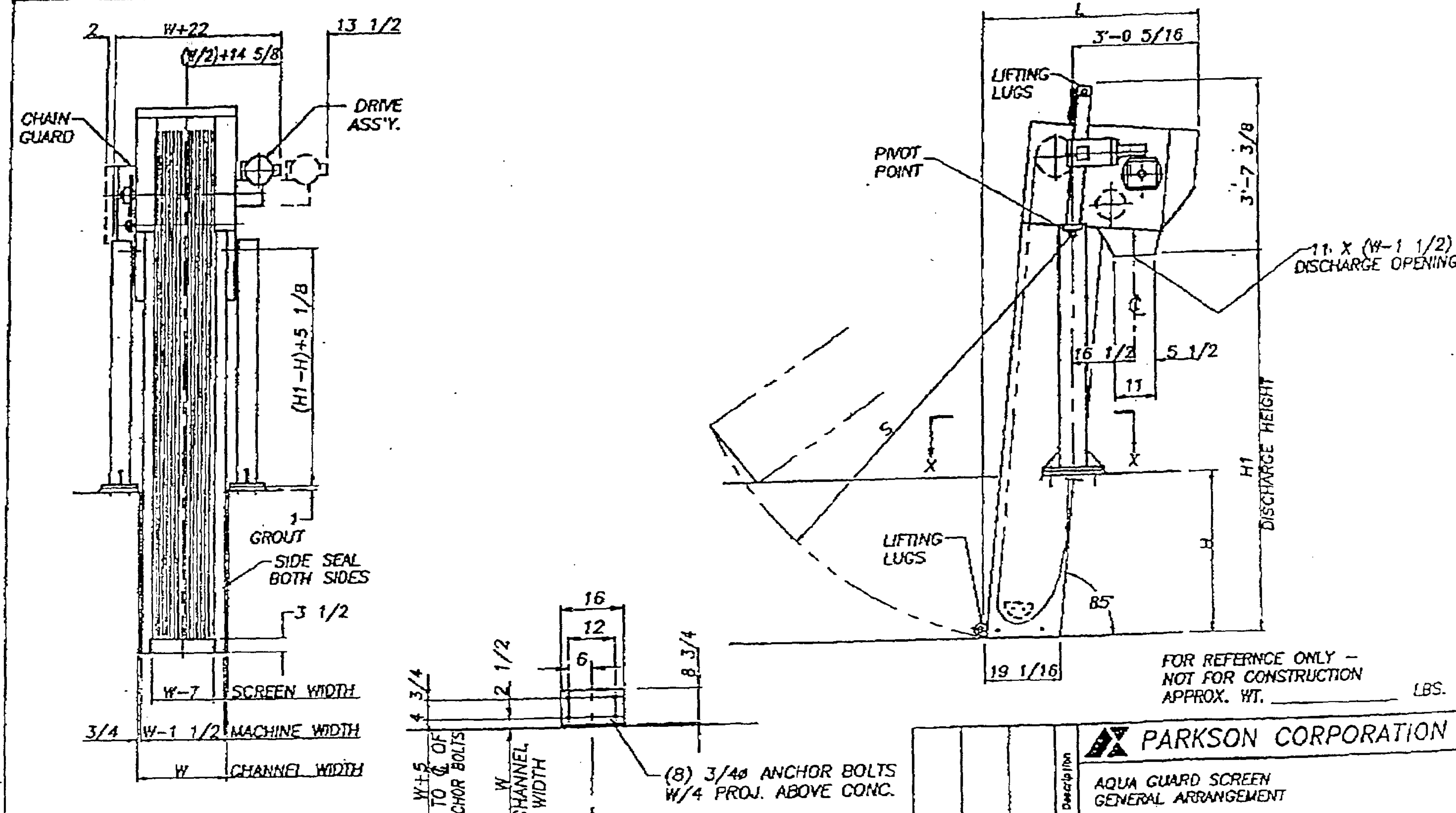


JOB:

Wheelabrator Engineered Systems Inc. **Wiesemann** products™ Largo, Fl.	DRN. BY: ES	DATE: 10/04/93	TITLE: CONCEPTUAL INSTALLATION DRAWING	NO.: WIESEFLO100
	SCALE: 1/4"=12"	ENG. APPR.:		SHT. 1 OF 1 — EST. WT N/A

FIGURE A4

Parkson Aqua Guard® Bar/Filter Screen



W	3'-0"
H1	10'-0"
H	6'-0"
L	4'-10"
S	10'-9"

FOR REFERNCE ONLY – NOT FOR CONSTRUCTION

APPROX. WT. ________ LBS.

PARKSON CORPORATION

AQUA GUARD SCREEN
GENERAL ARRANGEMENT

Drawn By	Chkd. By	Approved By	Micro Ans.	
VB	T Zu	T Zu		1A-6219
Date 8-6-93	Date 8-29-93	Date 8-29-93	Date	Scale

AG-MN-A 85°
WINNIPEG

Drw. No. 1A-6220

Rev.

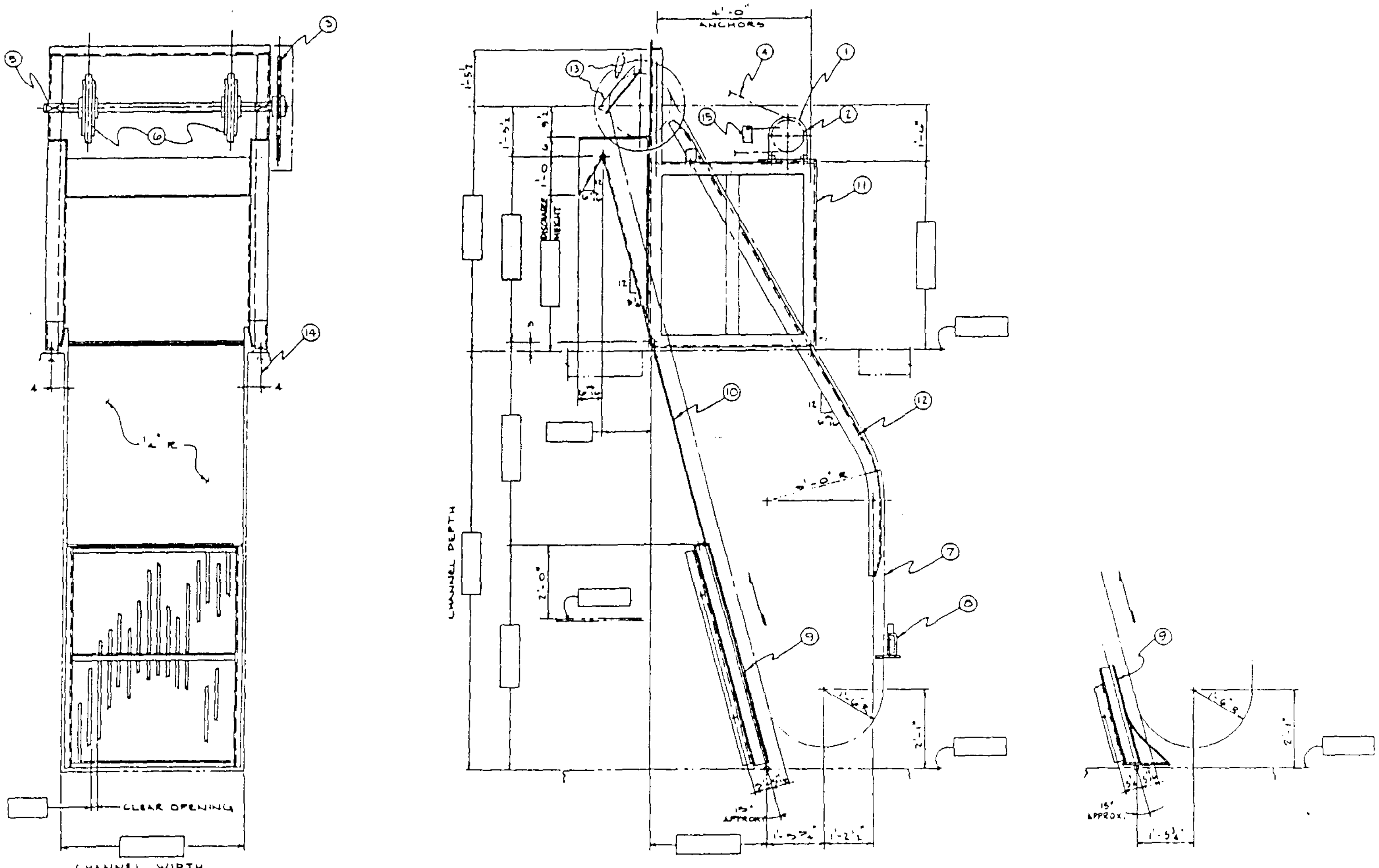
Revision | Description | By | Chkd | Date

W₂O 27 FEB '95

FIGURE A5

E & I Corporation Catenary Bar Screen

REV. #	DESCRIPTION	DATE
1	UPDATED	2-90



DESCRIPTION OF EQUIPMENT

1. DRIVE UNIT, ____ HORSEPOWER, ________ VOLTS, ___ PHASE, ___ HERTZ
2. DRIVE SPROCKET W/ FAILSAFE DEVICE
3. DRIVEN SPROCKET
4. DRIVE CHAIN
5. HEADSHAFT BEARING
6. HEADSHAFT SPROCKET
7. SCREEN CHAIN
8. RAKE
9. BAR RACK
10. DEAD PLATE
11. HEADFRAME
12. RETURN RAIL
13. WIPER W/ PVC BLADE & SHOCK ABSORBER
14. ANCHOR BOLT
15. LIMIT SWITCH

NOTE:
ALL DIMENSIONS [ ] ARE APPROXIMATE PENDING ACTUAL CONTRACT PLANS & SPECS.

ALSO AVAILABLE: CURVED BOTTOM BAR RACK

E & I Corporation

EQUIPMENT: 15° SINGLE SHAFT CATENARY BAR SCREEN

CUSTOMER:

STD DWG N: 40509

SCALE	DRAWN BY	DATE	CHECKED BY	DATE	DRAWING NO
X	LRB	5-06			

FIGURE A6

FMC Revolving Drum Screen

LINK-BELT. PRODUCTS

APPLICATION DRAWING NO 664Z17

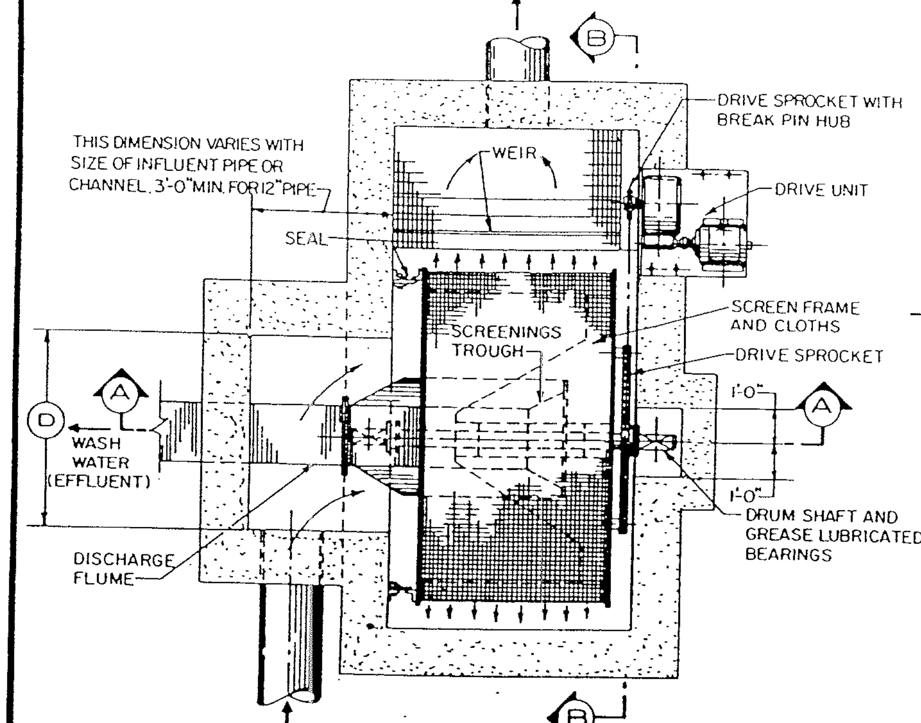
SHEET OF SHEETS

SECTION 12310.4

ARRANGEMENT OF

REVOLVING DRUM SCREEN

FMC Environmental Equipment Division



PLAN
(SPLASH GUARD NOT SHOWN)

TABLE OF DIMENSIONS

SCREEN SIZE DIA.X LENGTH (FT.)	INSIDE OUTLINE OF CONCRETE PIT FOR SCREEN (A)	(B)	(C)	(D)	(E)	DISCHARGE FLUME: WASH WATER REQUIRED	FLUME SIZE WIDTH x DEPTH	SLOPE INCHES PER FT.
4' x 2'	3'-0"	5'-6"	3'-3"	2'-6"	4'-3"	60 GPM	10" X 6"	3/8"
6' x 3'	4'-0"	7'-6"	4'-3"	4'-0"	2'-9"	90 GPM		
7' x 4'	5'-0"	8'-6"	4'-9"	4'-6"	3'-0"	120 GPM	12" X 8"	1/4"
8' x 4'		9'-6"	5'-3"	5'-0"	3'-3"			
9' x 4'-6"	5'-6"	10'-6"	5'-9"	5'-6"	3'-6"	135 GPM	15" X 9"	
10' x 5'	6'-0"	11'-6"	6'-3"	6'-0"		150 GPM		

A = SCREEN LENGTH + 1'-0"
B = SCREEN DIAMETER + 1'-6" MIN.
C = SCREEN RADIUS + 1'-3"

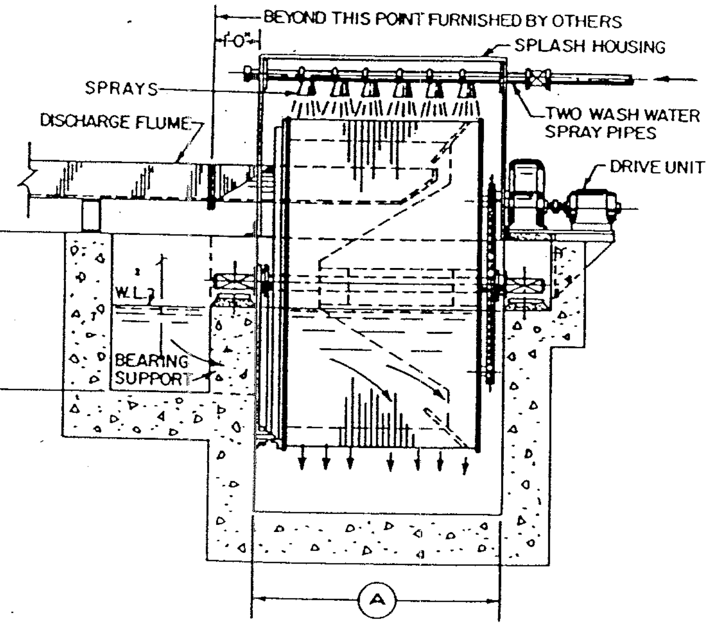
SPECIFICATIONS 664X18

LIST OF EQUIPMENT FURNISHED BY E.E.D.

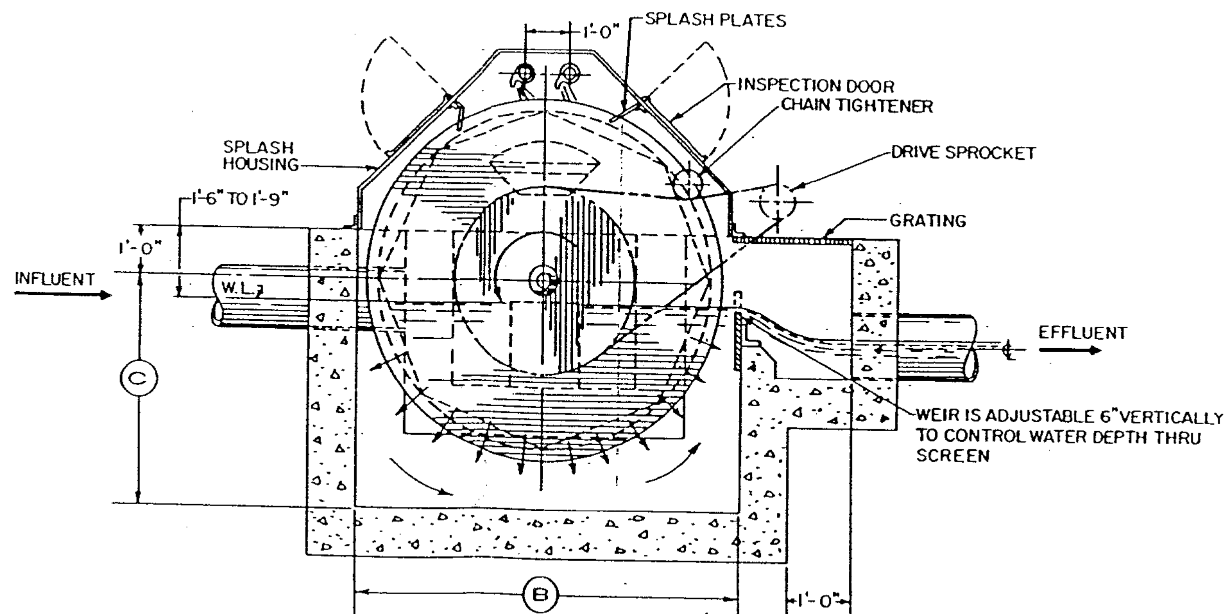
QTY. ____ REVOLVING DRUM SCREEN(S) COMPLETELY SHOP ASSEMBLED INCLUDING:
- SCREEN FRAME AND SCREEN CLOTHS
- DRUM SHAFT AND BEARINGS
- CHAIN DRIVE AND DRIVE UNIT
- SPRAYS
- PIPES AND VALVES AS SHOWN
- SCREENINGS TROUGH
- HOUSING
- ANCHOR BOLTS
- ONE SHOP PRIMER COAT OF PAINT

EQUIPMENT NOT FURNISHED BY E.E.D.

CONCRETE AND DESIGN THEREOF, ERECTION, FIELD PAINT AND PAINTING, PIPING, DISCHARGE FLUME, GRATING, GROUT AND GROUTING, ELECTRIC WIRING AND CONDUITS, MOTOR CONTROL AND SUPPORTS, OIL GREASE FOR DRIVE.



SECTION A-A



SECTION B-B

NOTES:

1. THE FMC-E.E.D. REVOLVING DRUM SCREEN IS HIGHLY EFFECTIVE IN THE REMOVAL OF LARGE QUANTITIES OF VERY FINE SOLIDS FROM WATER USED IN MANUFACTURING PROCESSES AND FROM INDUSTRIAL WASTE.
2. THESE SCREENS ARE ESPECIALLY ADAPTED TO LOCATIONS WHERE THE VOLUME OF WATER IS LARGE, THE VARIATIONS IN WATER LEVEL ARE SLIGHT, AND WHERE THE LOSS OF HEAD THRU THE SCREEN MUST BE KEPT TO A MINIMUM.
3. THE SCREEN DATA AND SIZE TABLE BELOW IS BASED ON THE FOLLOWING ASSUMPTIONS:
   a.) VELOCITY THRU THE SCREEN = 2 FT. PER SECOND.
   b.) 50% OF OPEN AREA BLINDED BY SOLIDS & SCREEN FRAME
   c.) 50% OF SCREEN SUBMERGED APPROX.
   THE CAPACITY OF SCREEN CAN BE COMPUTED BY THE COMMON HYDRAULIC RELATION, $Q = AV$.
   THE LOSS OF HEAD IS COMPUTED BY THE COMMON ORIFICE FORMULA, $Q = CA\sqrt{2gh}$, WHEN $h_c = \frac{1}{2g}\left(\frac{Q}{CA}\right)^2$ WHEN
   - Q = DISCHARGE THRU SCREEN IN C.F.S.
   - C = COEFFICIENT OF DISCHARGE
   - A = EFFECTIVE OPEN AREA IN SQ.FT. (NET OPEN AREA X 50%)
   - g = 32.2, ACCELERATION DUE TO GRAVITY.
   - $h = h_c$ = HEAD OF WATER OVER ORIFICE OR LOSS OF HEAD, IN FEET.
4. CARE MUST BE EXERCISED IN SELECTING A SCREEN FOR WATER CONTAINING MORE THAN ONE % SOLIDS, BY WEIGHT, AS EXCESSIVE "BLINDING" WILL REDUCE THE CAPACITY.
5. THE DRUM SCREEN WILL NOT HANDLE:
   a.) LIQUIDS CONTAINING GREASE FROM PACKING AND RENDERING OPERATIONS.
   b.) WASTE WITH EXCESSIVE LIME
   c.) GUMMY WASTES.
6. SPEED: PERIPHERAL SPEED 10 TO 20 FT. PER MIN., 20 F.P.M. MAX.
7. WASH WATER REQUIRED: 30 G.P.M. X SCREEN LENGTH AT 60 POUNDS PRESSURE - FOR AVERAGE CONDITIONS.
8. CONSULT FMC-E.E.D. FOR FLOW CONDITIONS IN EXCESS OF THOSE LISTED.

SCREEN DATA / SIZE OF SCREEN - DIAMETER X LENGTH

CLEAR OPENING INCHES	MESH OPENINGS PER INCHES	SIZE WIRE INCHES	PERCENT NET OPEN AREA*	LOSS OF HEAD FEET	"C" IN LOSS OF HEAD FORMULA	4'X2' CAP. C.F.S.	4'X2' CAP. GPM	6'X3' CAP. C.F.S.	6'X3' CAP. GPM	7'X4' CAP. C.F.S.	7'X4' CAP. GPM	8'X4' CAP. C.F.S.	8'X4' CAP. GPM	9'X4'-6" CAP. C.F.S.	9'X4'-6" CAP. GPM	10'X5' CAP. C.F.S.	10'X5' CAP. GPM
0.126 3mm	6	0.041	37.5	0.172	0.600	4.72	2120	10.60	4800	16.50	7400	18.84	8500	24.0	10800	29.50	13200
0.075	10	0.025	35.2	0.188	0.575	4.42	2000	10.00	4500	15.50	7000	17.70	8000	22.4	10100	27.70	12500
0.035	20	0.015	30.6	0.205	0.550	3.86	1740	8.66	3900	13.46	6000	15.40	6920	19.5	8800	24.00	10800
0.016	40	0.009	25.6	0.225	0.525	3.22	1450	7.24	3260	11.26	5060	12.90	5800	16.06	7200	19.80	8900
0.009	60	0.0075	19.1	0.248	0.500	2.40	1080	5.40	2400	8.40	3800	9.60	4320	12.16	5500	15.00	6760

* NET OPEN AREA IS OBTAINED FROM THE PRODUCT OF THE OPEN AREA OF SCREEN CLOTH AND THE OPEN AREA OF BACK-UP CLOTH. 2 MESH-.105 DIA. WIRE 62.4% OPEN AREA.

ISSUE	DATE	CHKD.			
A	1-54				
F	4-78	A.M.			
G	10-70	J.L.			

DWG. NO. 664Z17 DRN. BY M.K.

664Z17

FIGURE A7

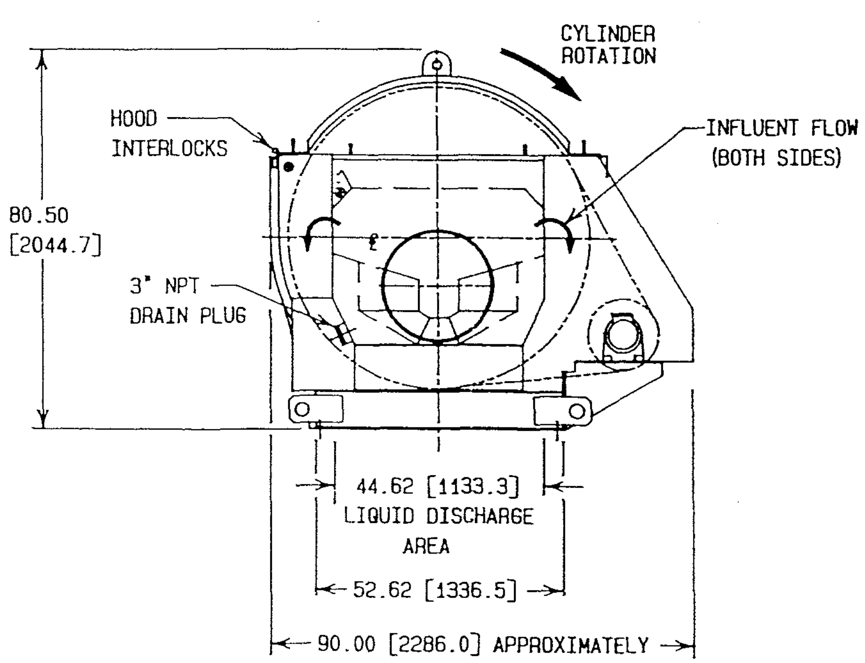
Hycor Rotosheer®
Screen

NOTE:

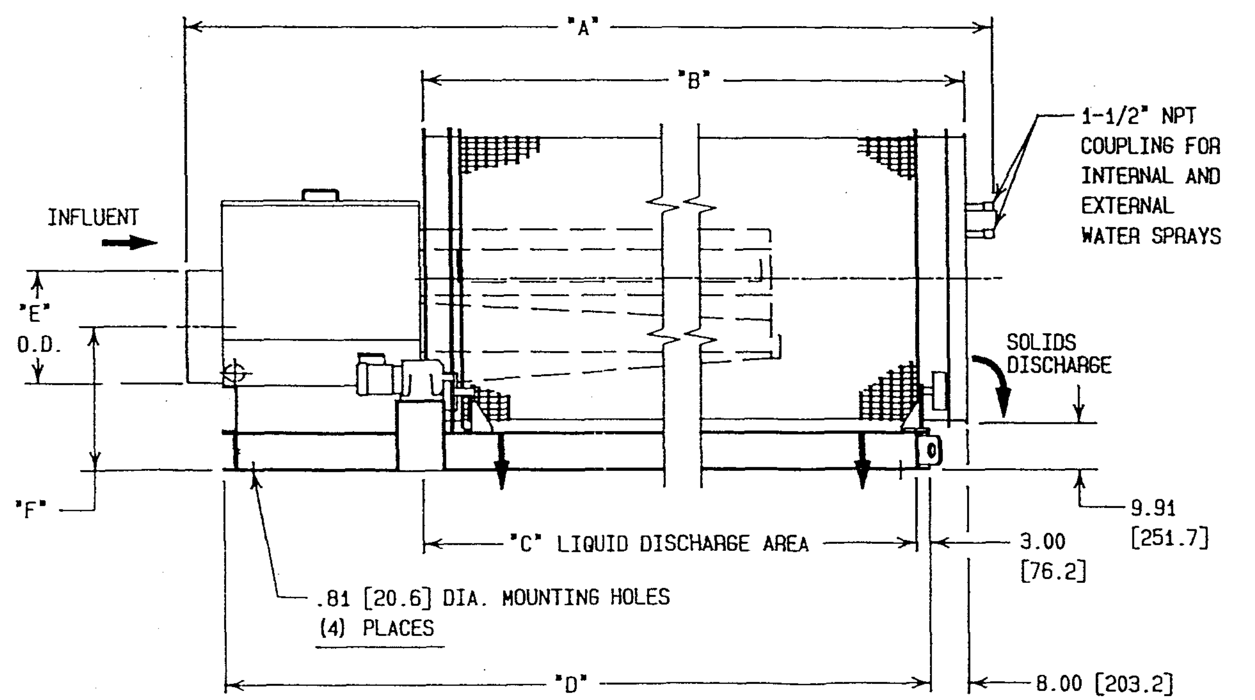
1. ALL TYPE 304 STAINLESS STEEL CONSTRUCTION EXCEPT FOR BASE, TRUNNIONS, CLEANOUT DOOR, TRUNNION MOUNTING BRACKETS, DRIVE MOUNTING BRACKET, DRIVE CHAIN, SPROCKETS, LUBRICATION LINES, DRAIN PLUG, INTERLOCK SWITCH SUBASSY, CYLINDER STABILIZERS, GEARMOTOR, WEAR BLOCK AND HEADBOX WEIRS.
2. GEARMOTOR: HP [kW] (SEE TABLE), 1800 RPM, 230/460 V, 3 PH, 60 HZ, TEFC, SEVERE DUTY.
3. CYLINDER SPEED: 6 RPM.
4. CYLINDER SCREEN OPENING: ______________
5. RECOMMENDED CLEARANCE TO BE 24.00 [609.6] AROUND UNIT AND 36.00 [914.4] ABOVE UNIT.
6. ALL EXTERNAL PIPING TO BE SUPPORTED INDEPENDENTLY OF ROTOSHEAR UNIT.
7. HOOD INTERLOCKS: 120 V, 1 PH, 60 HZ OR 100 V DC.
8. DIMENSIONS WRITTEN AS INCH [mm] UNLESS OTHERWISE SPECIFIED.
9. DO NOT USE FOR CONSTRUCTION PURPOSES.

MODEL	"A"	"B"	"C"	"D"	"E"	"F"	MOTOR HP [kW]	WEIGHT LBS. [kg] DRY	WEIGHT LBS. [kg] WET	SPRAY WATER USE* GPM [L/s]
HRS6072T	146.31 [3716.3]	90.81 [2306.6]	80.50 [2044.7]	125.81 [3195.6]	20.00 [508.0]	28.53 [724.7]	1 [.75]	3200 [1452]	7600 [3447]	22 [1.3]
HRS6096T	170.31 [4325.9]	114.81 [2916.2]	104.50 [2654.3]	149.81 [3805.2]	24.00 [609.6]	30.53 [775.5]	1-1/2 [1.1]	3680 [1669]	8580 [3891]	30 [1.8]
HRS60120T	194.31 [4935.5]	138.81 [3525.8]	128.50 [3263.9]	173.81 [4414.8]	30.00 [762.0]	33.53 [851.7]	2 [1.5]	4225 [1916]	9625 [4365]	38 [2.3]

* TOTAL GPM [L/s] BASED ON 1 GPM [0.06L/s] PER NOZZLE AT 40 PSI [2.8 BAR]



INFLUENT END VIEW



SIDE VIEW

HOOD AND GUARDS NOT SHOWN FOR CLARITY

HYCOR® LIQUID/SOLID SEPARATION

HRS6000 ROTOSHEAR UNIT
SECTION 3000.31.6000T.594

W2O

FIGURE A8

Andritz Sprout-Bauer
Subscreen

Andritz Sprout-Bauer Contra-Shear® Suboscreen

The Suboscreen is an "in-channel" rotary screen designed to efficiently remove suspended solids from liquids. With its low head loss, the Suboscreen can be added to most existing channels, as well as new construction.

Principle of Operation

Flow enters the upstream end of the screen cylinder. The solids are removed by lifting staves, carried to the top of the screen and deposited into a flume for further dewatering by an integral drainer screw. The screen has a low head loss, eliminating the need for lift pumps. The screen slots are perpendicular to the flow, creating a change in flow direction. The change in direction and the geometry of the screen wire ensures a 85% capture of solids larger than the slots and discourages stapling of stringy or fibrous materials. Standard screen openings are .040" - .250" (1 - 6 mm). Simple installation — lower onto prepared pads and bolt into position.

Applications

- Municipal Sewage
- Industrial Wastewater
- Pulp & Paper
- Slaughter Houses
- Tanneries
- Fruit and Vegetable Processors
- Poultry, Fish and Seafood
- Textiles
- Breweries
- All Types of Solids:
  Particulate, Fibrous, etc.

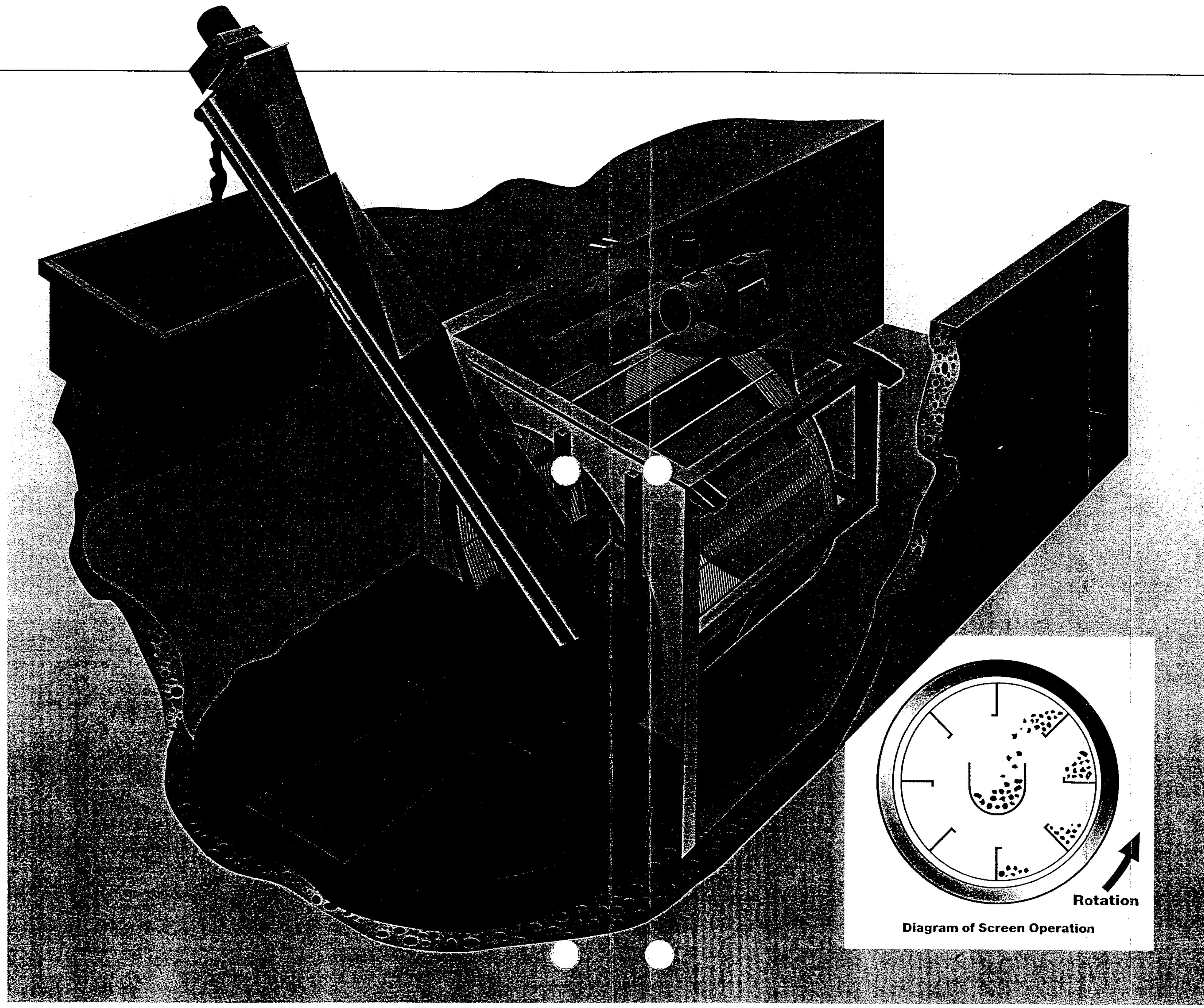


Diagram of Screen Operation

Features

- Wedge Wire Screen — rugged, non-blinding, long wearing precise openings, high open area
- Only the screen cylinder is immersed. All bearings, drive, etc. are above liquid
- Two adjustable screen spray bars
- Heavy duty drive shaft and HTD belt drive
- Flexible rubber coupling for easy attachment of drainer screw
- Stainless steel or galvanized trough drainer screw with removable top covers
- Replaceable drainer section in trough
- Fecal matter disintegrator in drainer screw for sewage installations
- Simple installation

Advantages

- Proven technology
- Low head loss
- High solids recovery 85% vs. rake bar at 40 - 45%
- Self-cleaning screen
- Less space requirements
- Long life, low operation and maintenance costs
- 304 SST screen and spray bars, epoxy coated frame
- Rugged long life trunnions with lubricated bearings

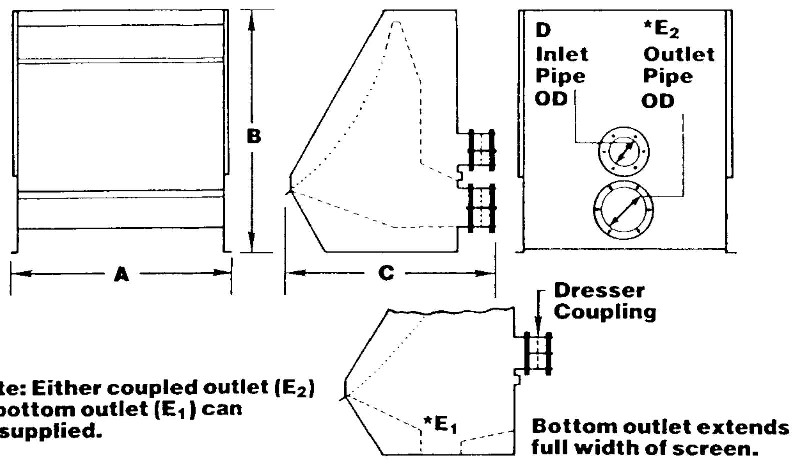
Options and Accessories

- 304/316 SST Construction
- Automatic Shower Control
- Press Section for Drainer Screw
- Auto Reverse

FIGURE A9

Andritz Sprout-Bauer
Hydrasieve® Screen

Hydrasieve® Screen Specifications and Dimensions



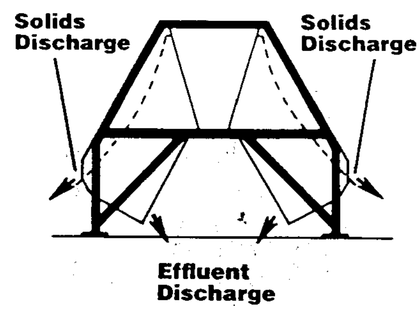
***Note: Either coupled outlet (E_2) or bottom outlet (E_1) can be supplied.**

▪ Sizes and Construction

Individual Hydrasieve screens are available in sizes to handle flows from 5 GPM to over 1 MGD. Compact modular systems, combining two or more Hydrasieve screens back-to-back, increase flow capacity to several hundred MGD, as required in many municipal systems.

Standard material of construction is either No. 304 or No. 316 stainless steel. Reinforced fiberglass construction is also available.

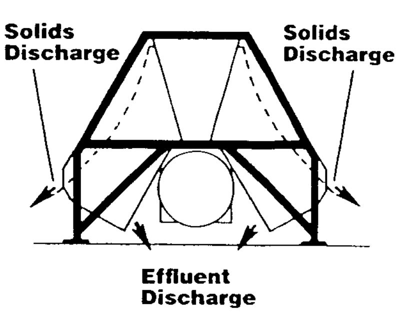
End View



Standard Hydrasieve Screen Dimensions in Inches
Weights in Pounds—Individual Units
(All figures are approximate and subject to change)

Model No.	Screen Width	A	B	C	D	E_1*	E_2*	Shipping Weight (LBS)
Stainless Steel Frame Construction								
554— 28"	28	32½	80½	71½	8⅝	14	10¾	700
554— 48"	48	52	80½	71½	8⅝	14	10¾	950
554— 72"	72	76¼	80½	71½	10¾	14	14	1200
554—120"	120	124	80½	77¾	12¾	14	16	1700
Fiberglass Frame Construction								
554F—72"	72	78	84	74¾	10¾	14	14	840

End View



Modular Hydrasieve Screens With Built-in Feed Influent Channel
Dimensions in Inches
Weight in Pounds

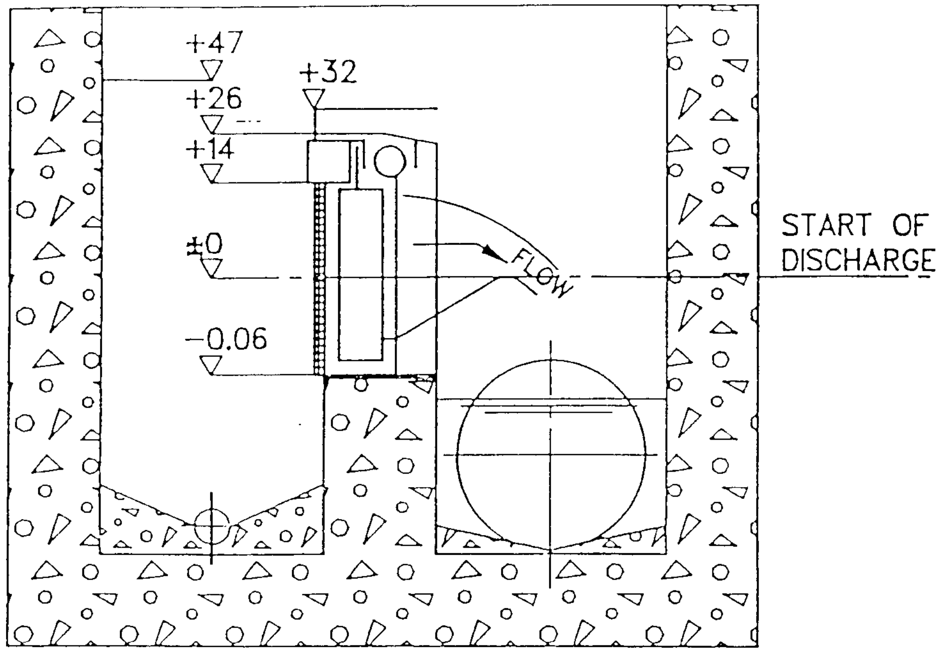
Model No. 554-M-72 or 120	
Screen Width	72" or 120"
Height	86"
Depth	111"
Weight	3000

Back-to-Back Hydrasieve Screens
Dimensions in Inches
Weight in Pounds

Model Nos. 552-5 and 552-6*		
Screen Width	72"	*Any number of Model 552-6 Modules may be incorporated into a single assembly to increase capacity and conserve space.
Height	86"	
Depth	111"	
Outlets (2)	14½x72"	
Weight	2850	

FIGURE A10

Jones & Altwood/Romag Storm Overflow Weir Screen



INLFUX LEVEL	SCREEN SURFACE	OVER–PRESSURE	SCREEN VELOCITY	FLOW
±0				
+14	0.27	7	0.8	0.22
+26	0.27	19	1.35	0.36
+32	0.27	25	1.54	0.41

ISS	REVISION NOTICE / MODIFICATION Nº	DATE	BY

PURCHASE ORDER ____
CONTRACT Nº ____ QUANTITY ____

PLEASE DESTROY ALL PREVIOUS ISSUES OF THIS DRAWING Nº. DRAWING SHALL BE RETURNED WITH GOODS FOR G.C.PURPOSES

THIRD ANGLE PROJECTION

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DO NOT SCALE
IF IN DOUBT ASK
ALL DIMENSIONS IN MILLIMETRES
MACHINED DIMENSIONS ± 0.25mm, OTHER DIMENSIONS ± 1.00mm, ALL ANGLES ± 0.50° UNLESS OTHERWISE STATED
SURFACE FINISH MICROMETRES C.L.A.
REMOVE ALL SHARP EDGES

JONES | ATTWOOD
JONES & ATTWOOD LIMITED, TITAN WORKS, STOURBRIDGE, WEST MIDLANDS, DY8 4LR
Telephone : (0384) 392181 Fax : (0384) 371837

TITLE: STORM OVERFLOW WIER SCREEN

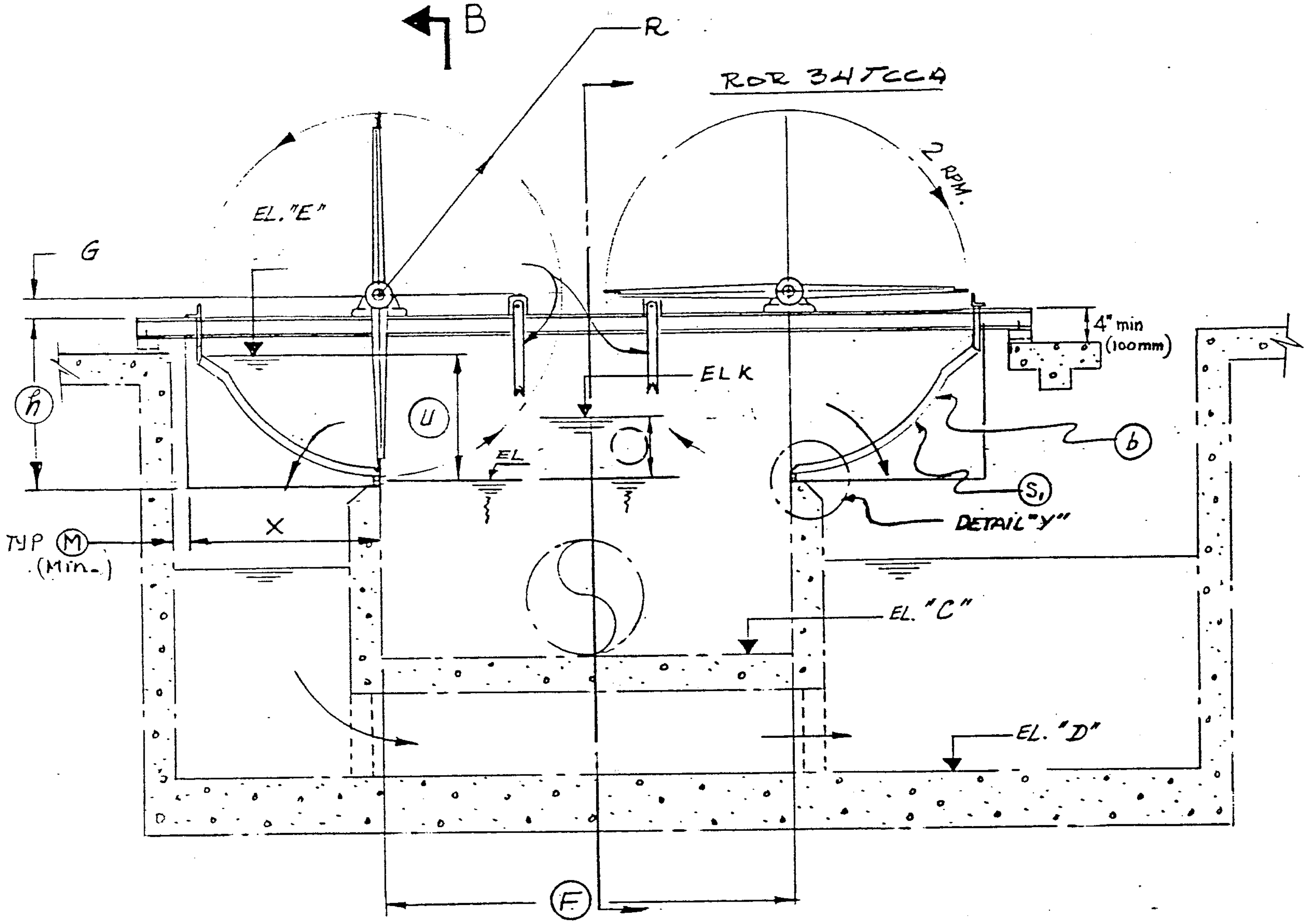
PROJECT/CUSTOMER

SCALE	MATERIAL	DRAWN	PAE	11/6/93
N.T.S	FINISH	DIMENSIONS CHKD		
		PROCESS CHKD		

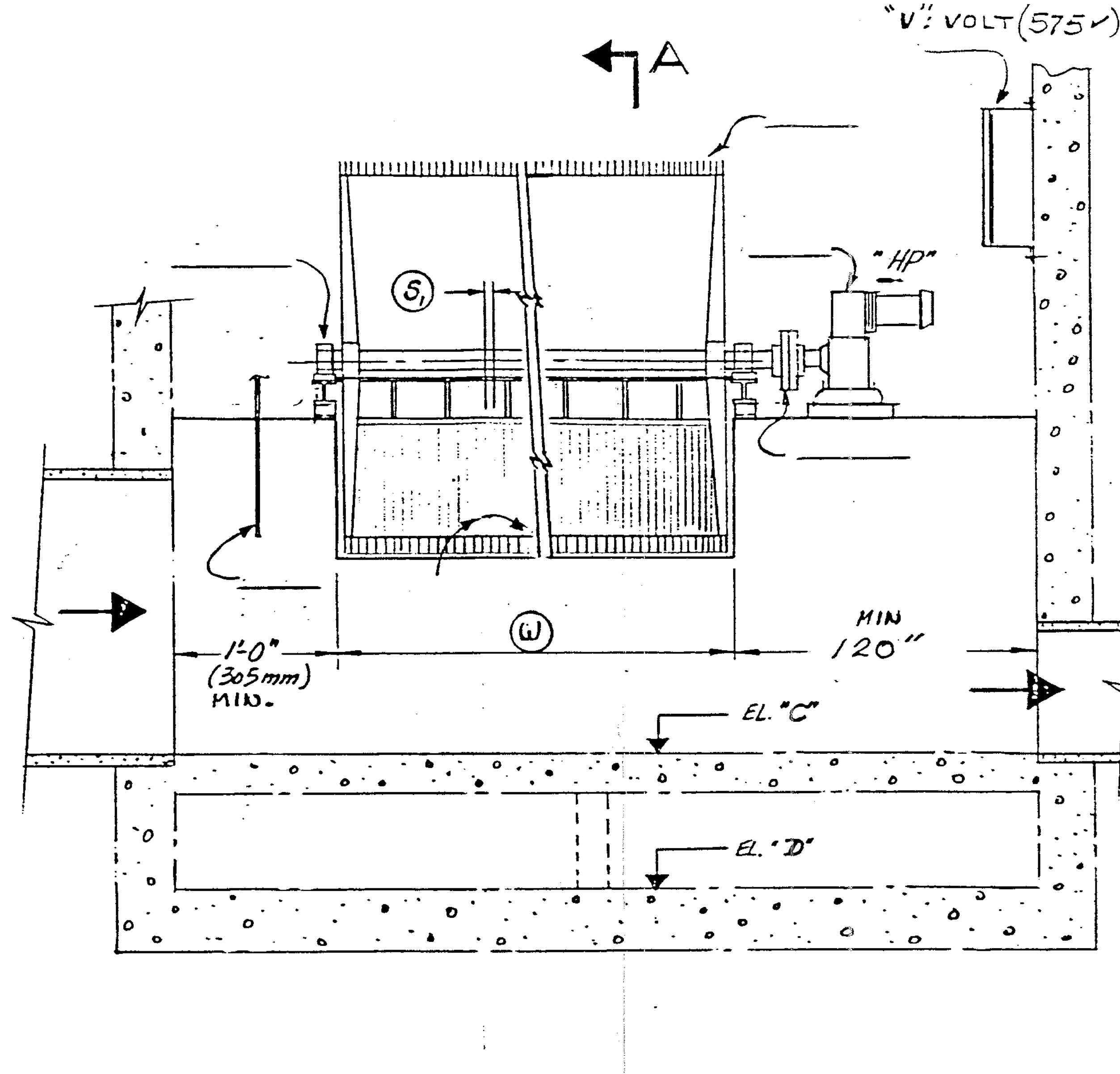
USED ON
DRG. No.
ISSUE No. 2 SHEET No. 1 OF 2

FIGURE A11

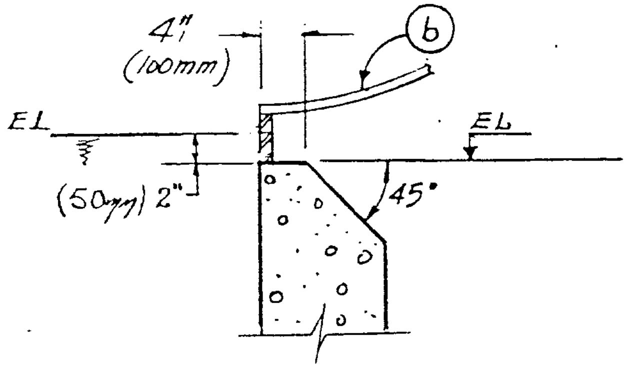
John Meunier Storm Overflow Screen



"A-A"



"B-B"



DETAIL "Y"

$Q_{overflow} = 500$ l/s
$Q_{peak} = 575$ l/s
Control panel NEMA 4X

DIMENSIONS (mm).

(b)	(F)	C (EL)	D (EL)	E (EL)	G	(h)	K (EL)	M	R	(S1)	(U)	(W)	HP	X	V
12.7 x	920.75	420.7					323.85	50.8	1000	19	189	914.4	1/3	123.8	

No	Date	Revisions

JOHN MEUNIER INC.

Projet / Project: W20 (MANITOBA)

Titre / Title: ROR-34 TCCA

Date	Echelle / Scale	Dossier / File	Dessin / Drawing No
	NIL		892-N
Dessiné / Drawned: P. BÉLISLE	Vérification	Approbation	

FIGURE A12

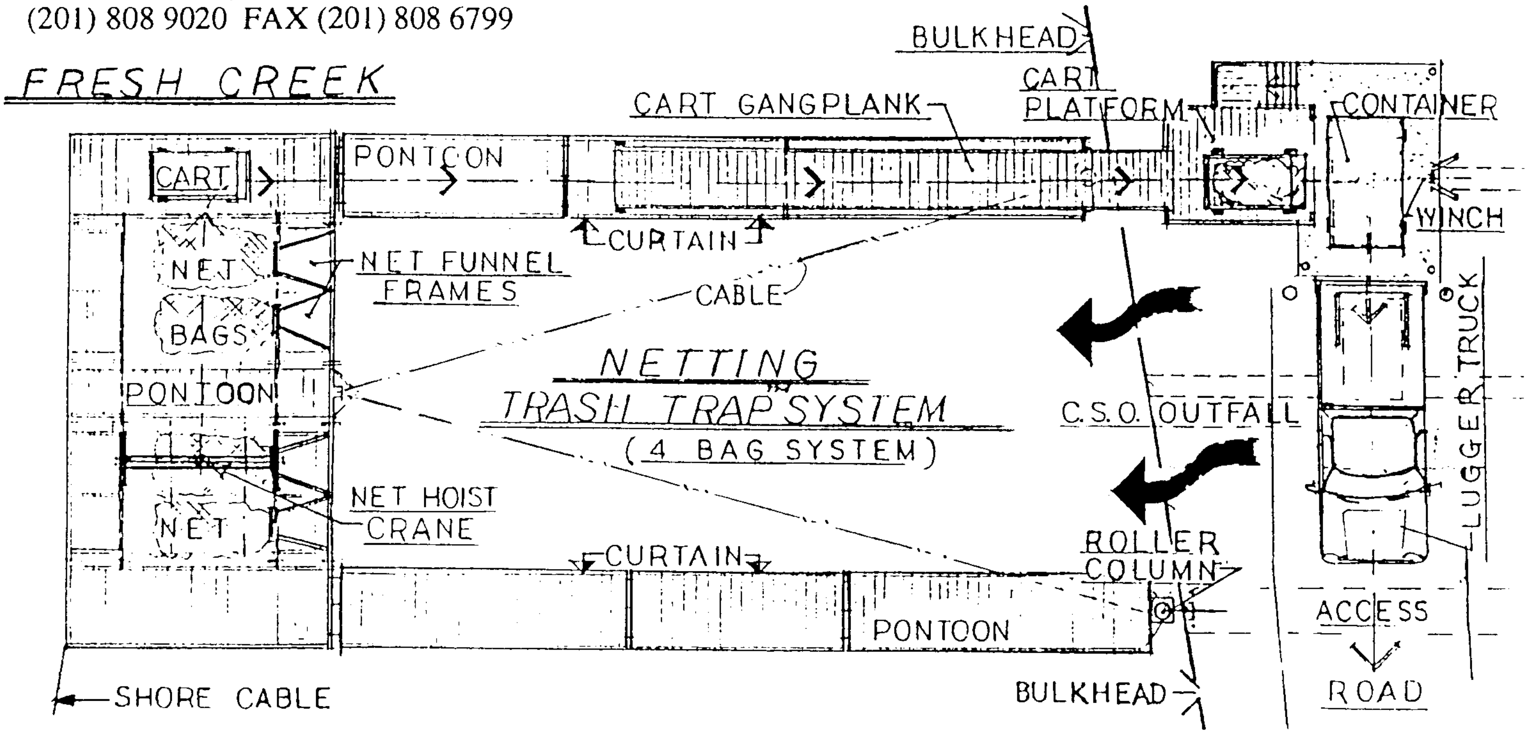
Fresh Creek Technologies
TrashTrap® System

FRESH CREEK TECHNOLOGIES, INC.

P.O. Box 1184
West Caldwell, NJ 07007 - 1184
(201) 808 9020 FAX (201) 808 6799

Netting TrashTrap™

Floatables Collection System



Plan View of Netting TrashTrap™ System at the Fresh Creek Site

Description of System Operation: The standard system consists of a floating pontoon structure that can accommodate two nylon mesh bags that are positioned 18 inches into the water facing the mouth of the outfall. The pontoon structure adjusts to changing water levels by riding on roller columns attached to the face of the outfall. The exact method of attachment and positioning are determined on a site specific basis.

Heavy duty PVC curtains are attached to the pontoons and are weighted to hang down to the bottom of the waterway with enough slack to accommodate changes in water level. The front of the pontoon structure has galvanized steel rectangular funnels that work in conjunction with the curtains to direct the wet weather flow and floatables into the mouth of the bags. The bags are fabricated with a rectangular wood frame at the mouth that slides into a channel in the pontoon structure and are held in the horizontal position by wood supports that lay on cables.

The bags are sized to hold approximately 25 cubic feet of floatables and a weight of 500 pounds. The number of bags needed at a site is determined by the estimated floatables content per volume of discharge and the desired frequency of replacing the bags. The system can be expanded in multiples of two bags.

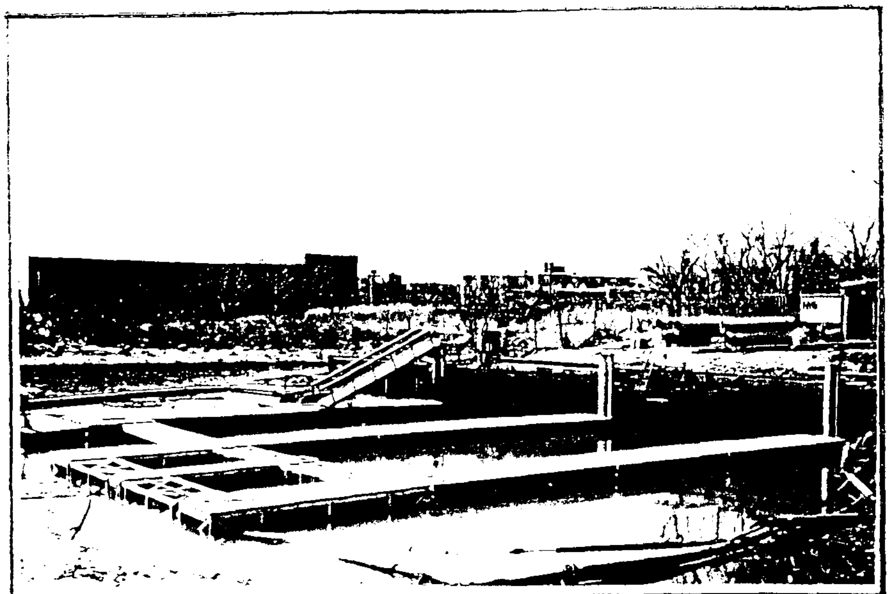
When the bags are full, they are lifted by the rolling hoist and deposited in a cart which is then winched along the pontoon to shore where it is tipped to empty the bag into the standard trash container for disposal. The layout and configuration of the shore side facilities are site specific.

May 26, 1993

FRESH CREEK TECHNOLOGIES, INC.
P.O. Box 1184, West Caldwell, NJ 07007-1184
(201) 808 9020 FAX (201) 808 6799

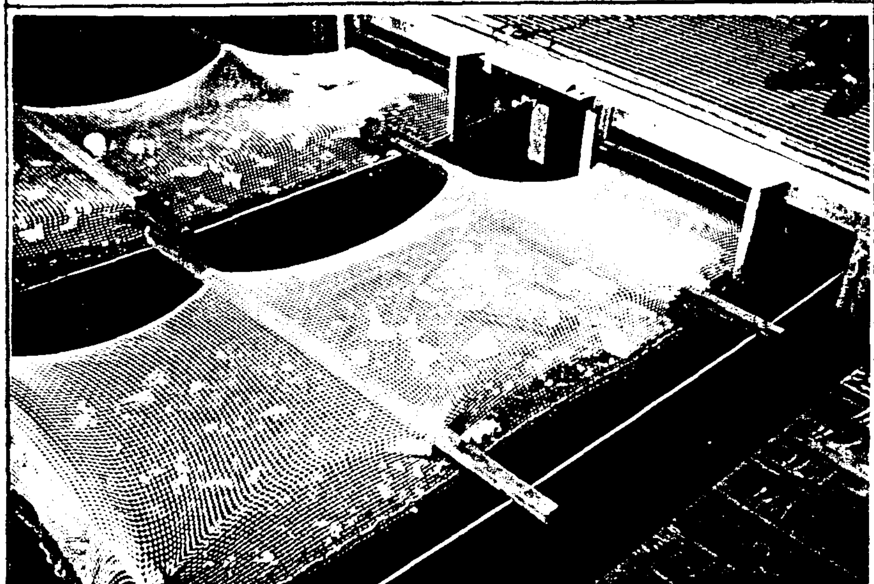
Netting TrashTrap™

Floatables Collection System



1. Pontoon system facing the mouth of outfall with four 10'x15' barrels. Netting **TrashTrap™** is within the **EquiFlow™** system and has capacity of four bags. This site has a 7' tide swing.

(Saybrook CSO)



2. Disposable nylon 1/2" mesh bags with 2 1/2' square wood frame that is part of the bag slides into support channel with 18" below water level. Bag is held in horizontal position by wood supports laying on cables.

3. Each bag is sized for 500 lb and 25 cu. ft. capacity. When full (or as needed), the bag is removed by hoist system, placed in the cart which is then winched along the pontoon to shore where it is tipped into a standard trash container for hauling. (see diagram)

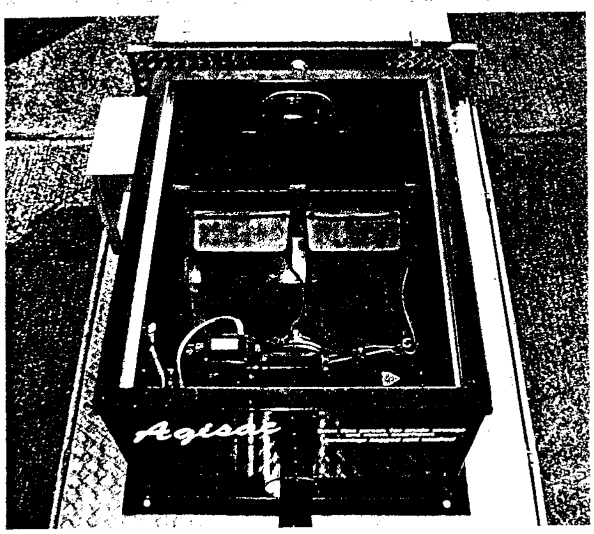
May 26, 1993

FIGURE A13

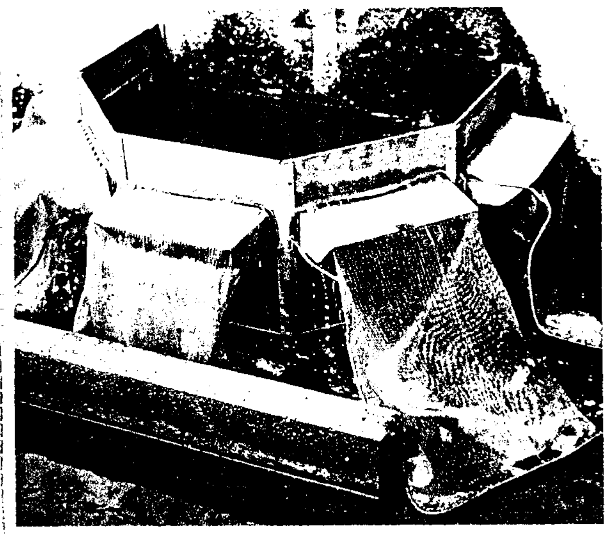
Copa Products Sac Screens Including Copatrawls

sacology

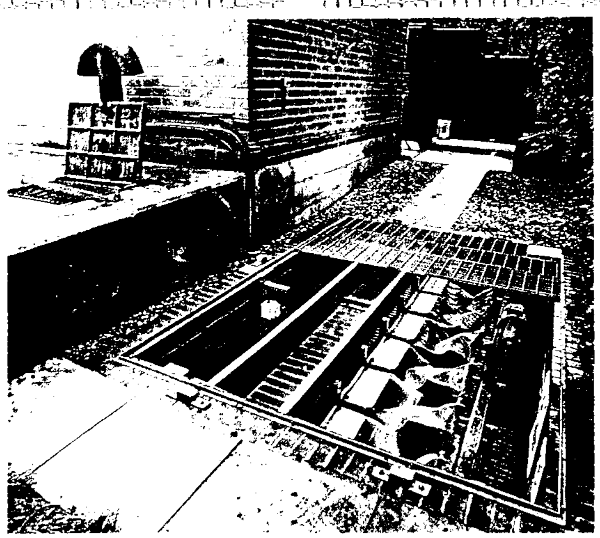
CRUDE SEWAGE



SETTLED SEWAGE



STORM OVERFLOWS



FINAL EFFLUENT

Copa

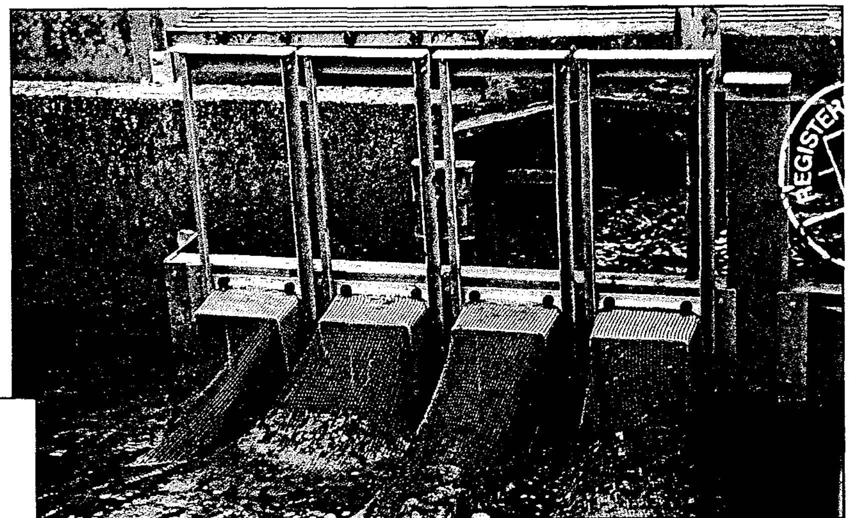
pioneers of sac screening technology

A FIRST IN SACOLOGY

;OPASACS

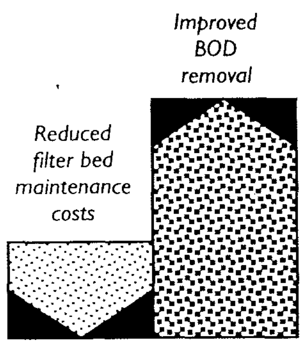
he screening of settled ewage and final effluent

pasacs provide inter-stage screening for l types of sewage treatment works and rotect final effluent discharge from ivated sludge plants, removing floating astics, debris, etc.

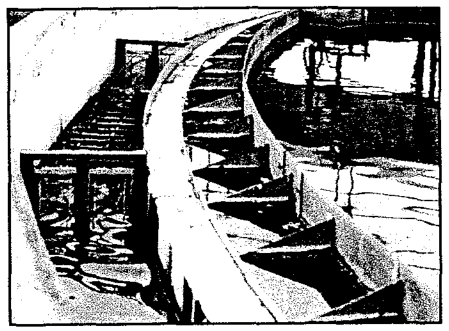


- ✓ 3 mm, 6 mm or 12 mm disposable sac
- ✓ Protects filter arm sparge holes
- ✓ Reduces labour spent on pricking out filter arms
- ✓ Improves distribution across filter bed, improving BOD removal
- ✓ Low capital cost
- ✓ Low revenue cost
- ✓ Installed at more than 2,000 sewage treatment works in the last three years
- ✓ Used by all ten UK water companies

COPASACS SCREENING AT A PERCOLATING FILTER WORKS

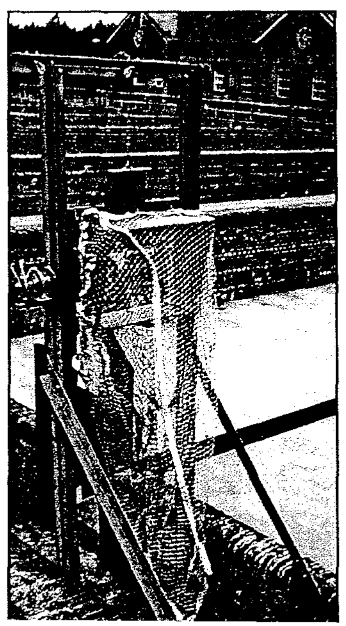


COPASACS REMOVING VISIBLE POLLUTANTS FROM FINAL EFFLUENT AT AN ACTIVATED SLUDGE PLANT



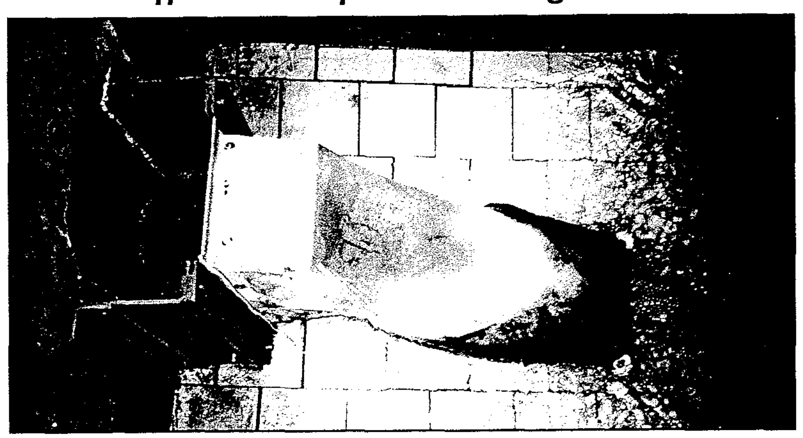
;OPATRAWL

Copatrawls are used in larger flow applications and generally installed in channels, protecting ctangular filter eds, discharges from storm tanks, or even the removal of snails from filter bed effluent!



COPASOCKS

Protect effluent compliance during maintenance



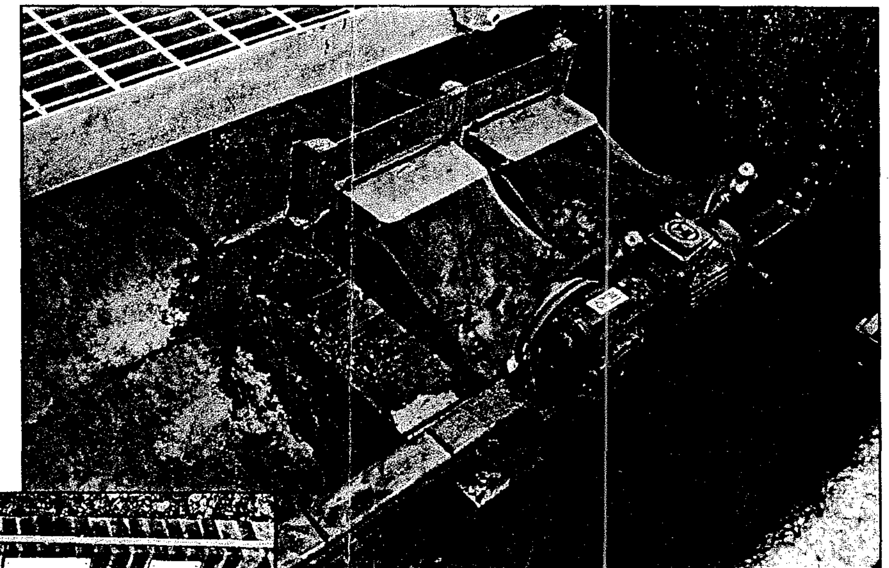
Copasock is a maintenance tool with a site specific monafilament mesh fitted to a standard Copasac framework and nose box, upstream of the consented sampling point.

When channel cleaning takes place, the Copasock is slid into

AGISAC

Fine screen for crude sewage and storm overflows

AgiSac uses a reinforced version of the Copasac. Crude sewage is screened down to 3 mm particle size. AgiSac is ideal for populations ranging from 50 to 6,000 people. And in the population range up to 2,000 people the clean screenings produced by AgiSac cannot be matched by any other system.



WORKS INLET, 3mm SCREEN, 1500 PE

AGISAC ON EMERGENCY OVERFLOW AT A PUMPING STATION

AgiSac is prefabricated and pre-wired for rapid installation with minimal civil works requirement.

AgiSac's washing action leaves you with bagged, washed screenings for easier disposal. Faecal matter is broken down and passes through the AgiSac leading to improved primary settlement.

For discharges at sensitive locations on storm/emergency overflows and small sea outfalls, AgiSac offers 3 mm screening, preventing the discharge of visible pollutants.

AgiSac offers an ideal low-cost solution to what can be an intermittent problem.

- ✓ 3 mm fine screen
- ✓ Bagged and washed screenings
- ✓ Ideal for small populations
- ✓ 50 to 6,000 people
- ✓ Low capital cost
- ✓ Low revenue cost

TECHNICAL SPECIFICATIONS

COPASACS

Settled sewage and final effluent

Maximum flow rate per sac
12.5 Lit/sec per nosebox

Mesh sizes
3 mm, 6 mm, 12 mm – disposable sacs

Configuration
Site specific, with three nosebox sizes:
400 wide × 100 high
300 wide × 200 high
200 wide × 300 high

Sac sizes (laid flat)
500 × 800, 500 × 600

Sac change frequency
2–4 weeks

COPATRAWL

Maximum flow rate per sac
150 Lit/sec per unit

Common mesh sizes
6 mm, 12 mm, 18 mm and 25 mm

Sac size

Circumferences:	1.9 m, 3 m, 3.4 m
Taper to flat end seam:	200 mm long
Sac length:	2 m

COPASOCKS

Design criteria as per Copasacs

Mesh size
Site specific from 100 micron to 1,000 micron

AGISAC/TRAWL DESIGN SELECTION CHART

System	Sewage flows DWF Lit/sec	Sewage flows MAX Lit/sec	Mesh size mm	Dimensions L × W × H	Motor *kW/HP*	Start up current *amps*	Running current *amps*
AgiSac							
2-sac	9	15	3 × 3	1.59 × 1.29 × 0.78	1.1/1.5	10	2.5
4-sac	18	30	3 × 3	1.59 × 2.22 × 0.78	1.1/1.5	10	2.5
AgiTrawl							
2-trawl	60	120	5 × 5	2.32 × 2.1 × 1.17	1.1/1.5	10	2.5
4-trawl	120	240	5 × 5	2.32 × 3.98 × 1.17	1.1/1.5	10	2.5

Average AgiSac/Trawl change frequency every 3 days

Copa

Copa Products Ltd
Copa House, Crest Industrial Estate, Marden,
Tonbridge, Kent TN12 9QJ, England.
elephone: (44) 0622-832444 Fax: (44) 0622-831466

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APPENDIX C

City of Winnipeg

Combined Sewer Overflow
Management Study

Technical Memorandum

Real Time Control

July, 1995

1 Real Time Combined Sewer Overflow Control

Introduction

This technical memorandum describes a strategy for implementing real time control to reduce or eliminate combined sewer overflows. The combined sewer overflow strategy is described from a systems viewpoint; first by defining a combined sewer system model and second by identifying real time control system approaches that will support the model.

The City of Winnipeg has embarked upon a major effort to reduce pollution from combined sewer overflows. Since the final recommendations are being developed at this time, this memorandum is more conceptual than detailed. Final recommendations may include combinations of in-system and off-line storage as well as treatment and disinfection. All of these scenarios will require some degree of real time control.

Section 2 describes two combined sewer overflow system models. The first model -- typical of most CSO systems -- shows the major subsystems associated with the flow of water from the sources, traveling through the combined sewers, and finally discharging into the receiving water. The second model describes the combined sewer overflow ***abatement*** system that is more complex due to the additional subsystems needed to reduce overflows. This section is most beneficial for the non-technical reader.

Section 3 describes an evolutionary path for real time control systems. It begins with a basic, entry level real time control system. It progresses to a "smart" real time control system that can support more complex applications, and finally to an advanced real time control systems that more fully exploit model-based control.

Section 4 describes implementation scenarios. It includes discussion of a pilot project as well as longer term solutions. Several decisions need to be made relative to timing of pilot and full scale projects.

Basis of Memorandum

Urban runoff pollution sources, including storm water, combined sewer overflows, and non point sources of water pollution, are formidable obstacles to achieving water resource quality goals. Urban runoff pollution problems are rarely clear cut and the pollution characteristics are difficult to quantify.

During storm events, overflows from combined sewers result in the discharge to receiving waters of untreated domestic sewage, commercial and industrial wastewaters, and untreated stormwater. Combined sewer overflows often contain high levels of suspended solids, pathogenic microorganisms, toxic pollutants, floatables, nutrients, oxygen-demanding organic compounds, oil and grease, and other pollutants. Combined sewer overflows can represent a large portion of the urban runoff pollution.

Real time control, in conjunction with overflow storage and treatment facilities, will minimize the urban runoff pollution. There is an orderly progression to achieve real time control in support of the goal. This progression is affected by time and resource constraints in the areas of system monitoring, system modeling, and system control.

System Monitoring

Ideally, measuring actual rainfall, wastewater flows and pollutant loading throughout system in real time over a long period of time provides the most accurate picture of the system behavior. However, it is a very complex, costly and time consuming undertaking to acquire sufficient data to ensure statistical validity and significance.

1. Real-time ***quality*** data is very difficult to obtain. To obtain the data requires complex, maintenance intensive sensors. It is often difficult to get good, representative samples to the instrument. Some items, such as floatables, can't be measured.

2. Flow sensors to obtain ***quantity*** data require careful installation, calibration and maintenance.

3. Although long term rainfall data at the airport has been available for many years, it has limited spatial distribution. Many years of data collection from the rain gauge network would be necessary to develop statistically valid spatial distributions.

System Modeling

Because of the limitations in acquiring real time data, computer models are used to predict water source volumes such as precipitation or snow melt; runoff quality and quantity; infiltration quantity; transport dynamics; overflow loading; and water quality impacts.

Models need to be accurate for the purpose intended -- planning, design, or operation. Models developed for planning purposes require much less calibration data than models developed for design. Real time models are considerably more complex than those used for design and development costs may become prohibitive.

System Control

CSO discharges occur when the flow in the combined sewer system exceeds the capacity of the interceptor system or the treatment plant. Controls must route excess flow to local storage or treatment facilities. Disinfection of treatment facility effluent may be required.

Controls must be fail safe and respond in real time to local conditions. As a minimum, level sensing equipment ensures that control actions do not create flooding upstream. For in-system storage, level sensing is needed at the storage device and several minutes upstream. For dewatering, interceptor levels are important.

Over time, heuristic operations rules and model outputs can be used to optimize operation.

2 Combined Sewer Overflow "Systems"

This section describes two holistic (whole system) models, one for a combined sewer overflow system and one for a combined sewer overflow **abatement** system. These models are to help in understanding combined sewer systems. This section lays the foundation for develop of real time control strategies as described in the following section.

Combined Sewer Overflow System

Combined sewer overflow systems were designed to convey wet weather flow (and sometimes dry weather flow) to the receiving water as effectively as possible. Design flows were based on heuristic runoff formulas. Basement flooding complaints helped to identify under-designed sewers or areas where capacity is insufficient due to changed land use since the original design. The systems were designed for simple, fail-safe operation with little or no human intervention required for proper operation.

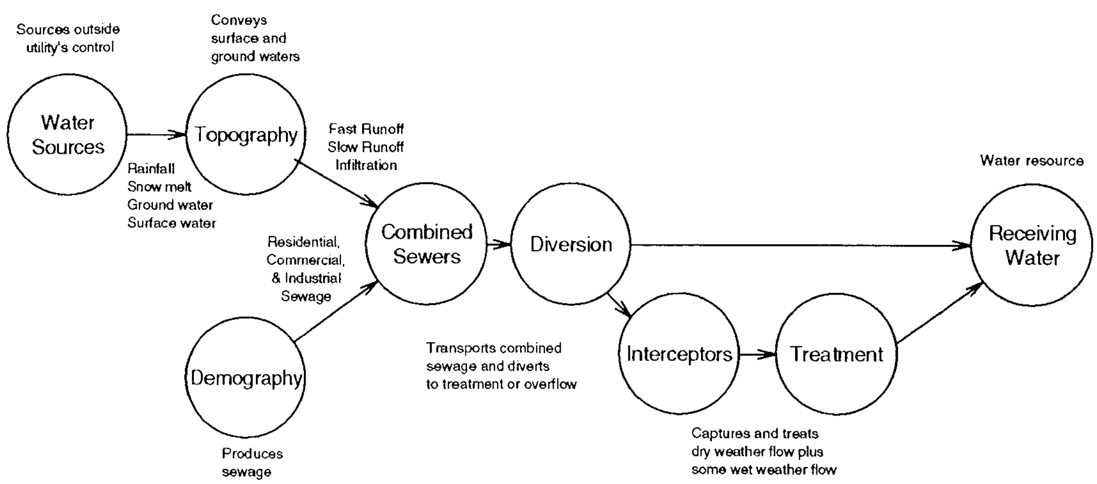

Figure 2-1 CSO System

The combined sewer overflow system model shows the major subsystems and how they relate to each other. The model generally follows the flow of stormwater from the source to the receiving water. A brief description of each subsystem follows.

Water Sources

Rainfall and snow melt are the major sources of water that can enter the combined sewer system. Depending on the soil characteristics, water table and sewer condition, ground water or water from rivers, creeks and ditches can also be a major source of water entering the system. Minor water sources include leaking water mains, fire fighting operations, and similar non-natural events.

These sources vary in volume and quality characteristics as well as location and time. The natural sources of water are generally beyond the utility's control. The CSO system is designed to respond to these events.

Topography

The service area topography influences how the source water flows to the combined sewer system and how its quality may change. Rainfall and snow melt may travel overland on impervious or frozen surfaces and reach the sewer system fairly quickly. Street, parking lot, and roof drainage are good examples of fast runoff. Rainfall or snow melt may also percolate into the soil and reach the sewer system more slowly through foundation drains or by infiltration through joints and cracks in the sewer system.

As the water travels to the combined sewer system, it conveys debris, sediments, oils and dissolved chemicals to the combined sewer. The pollution loading will depend on sediments on the catchment area surface and dissolved pollutants.

Demography

Wastewater that enters the combined sewer system comes from domestic, commercial and industrial sources within the service area. These sources vary in volume and quality, but the temporal distribution is somewhat easier to predict. The spatial distribution is relatively fixed, although regional population and industrial shifts will alter the wastewater patterns over time.

Combined Sewers

The combined sewers transport dry and wet weather wastewater from the entry points in each catchment area to diversion structures. For most CSO systems, few interconnections exist between catchment areas. For systems with many interconnections, operational complexity increases exponentially.

The sewers may also store limited amount of combined sewage by using excess volumetric capacity available during smaller rain events.

Diversion

Regulators in the diversion structures divert flow to interceptors during normal dry weather operations. During wet weather, the diversion structures control the amount of combined sewage to interceptors and provide relief of wet weather flow to outfalls -- or in some cases to other sewers.

Static regulators -- such as weirs, restricted outlets, high level relief ports, and vortex valves common in combined sewers -- restrict the amount of flow entering the interceptor. They require minimal maintenance, but do not usually allow easy adjustments to the regulated flow.

Mechanical regulators such as tilting plates, float controlled gates, and lift stations can vary the amount of flow to the interceptor based on level in the combined sewer or interceptor at that location. The regulated flow is easier to adjust than static regulators, but these regulators typically require more maintenance.

In most combined sewer systems, these regulators are self-contained and self-regulating. They are usually near outfalls. Conservative designs protect the interceptor and prevent upstream flooding.

Interceptors

Interceptors convey diverted wastewater to the treatment works. In properly designed and operated systems, all intercepted flow is conveyed to the treatment plant. Lack of regulation or poor regulator maintenance can cause the interceptor to surcharge and intercepted flow to divert out of the interceptor and back to the receiving water.

The interceptor capacity has major impact on how much wet weather flow is intercepted or stored. Interceptor capacity may limit dewatering rates and thus limit potential storage volumes. Capacity must be available to empty the system before the next rain event.

Treatment

The treatment works are the facilities that treat all dry weather flow and some wet weather flow. The capacity of the works restricts the amount of wet weather flow that can be captured similar to the interceptor. The works must be able to treat all stored wastewater before the next rain event to make maximum use of storage facilities.

Receiving Water

The receiving water may be a river, stream, lake, ocean, or ground water. The water quality requirements drive the CSO control efforts. The purpose of the RTC is to operate the CSO abatement system in a manner that minimizes overall water quality impacts.

Combined Sewer Overflow Abatement System

Combined sewer overflow abatement systems have a different goal -- to minimize impact of overflows on the receiving water. These systems can be very complex. Hydraulic conditions are highly variable due to the intermittent and variable characteristics of rainfall and other water sources. The quality can vary significantly from location to location, from storm to storm, and from beginning to end of storm (first flush phenomena).

The combined sewer overflow abatement system model builds on the combined sewer system model by adding three subsystems: storage, treatment, and disinfection. It may also include routing to and from other subcatchments. This added functionality increases the complexity of the diversion subsystem.

Catchment Area Interconnections

To take full advantage of underutilized in-system storage potential or to route flows to shared storage or CSO treatment facilities, catchment areas may be interconnected. Interconnections may allow bi-directional flow routing and in-system storage.

These interconnections increase the flow routing options.

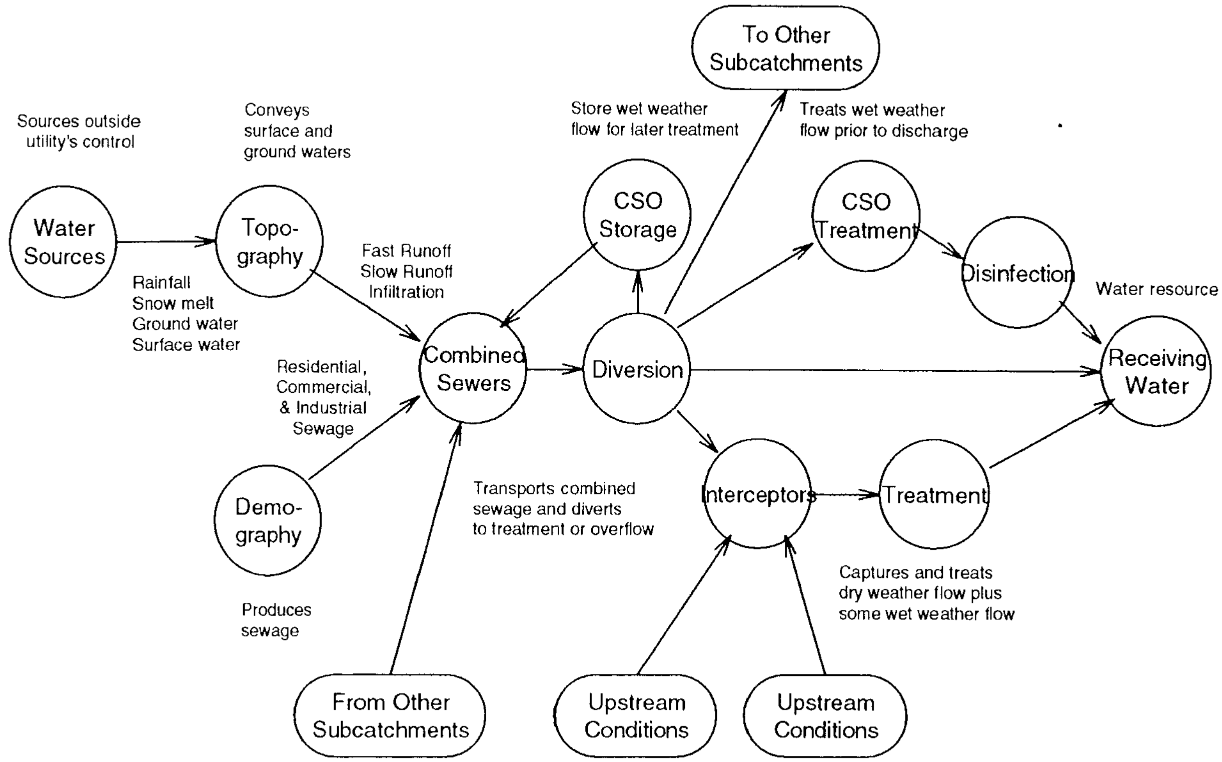

Figure 2-2 CSO Abatement System

Diversion

Diversion becomes more complex and critical to operation in the CSO abatement system. In addition to diversion to interception or outfall, the model shows four additional diversion functions: diversion to storage, diversion to treatment, diversion to disinfection, and diversion to other subcatchments.

The diversion operation becomes more dependent on upstream and downstream conditions in the interceptors, upstream conditions in the sewer system, as well as rainfall and runoff characteristics.

The diversion typically adds inflatable dams, and motor or hydraulic operated gates that must be self-contained and self-regulating to ensure continued safe operation under abnormal or emergency conditions.

CSO Storage

Storage options include in-line storage and off-line storage. In-line storage uses the existing capacity in major combined sewers to store flow. Off-line storage consists of constructed near surface or deep tunnel detention facilities. Off-line storage may be located near existing diversion structures or upstream within the collection system.

CSO Treatment

Treatment options may include screening, vortex solids separators, dissolved air floatation, filtration, sedimentation, chemical precipitation, or biological treatment. Treatment is difficult to design and operate because of the varying nature of the wastewater flow rate and volume.

Treatment may be on line and may occur for every storm event. It may occur only when the runoff volume exceeds in-line or off-line storage capacity.

CSO Disinfection

Disinfection options may include ultraviolet radiation or chlorination. Disinfection generally follows treatment. It may be needed when storage capacity is exceeded. Variations in flow rates make disinfection operation and control complex.

Complexity of CSO Abatement Controls

Control systems must respond to the actual dynamic behavior of the system to prevent upstream flooding and to effectively operate CSO abatement facilities. While relying on models to establish design parameters, the installed equipment and controls must be capable of proper operation no matter what happens.

To help understand the system, we can use models to look at a series of events and how these events affect the state of the system. An event is something that happens at a point in time external to a system or subsystem. For example, a rainfall event logically precedes a second rainfall event, even though in some cases it is difficult to determine when one event stops and another event starts..

A rain event or series of rain events causes each catchment area to assume a certain state. State examples for the combined sewer system catchment areas might include:

- dry weather flow or wet weather flow state
- filling or emptying state
- intercepting, storing, treating, or overflowing state.

Another example of possible system states is shown in the following table.

Table 2-1 Possible CSO Abatement System States

Storm Event Type	System State
Very small	Intercept
Small	In-line storage
Medium	Off line storage
Large	Treatment
Very large	Overflow

Each catchment area can be in a different state as the storm moves across the CSO system. Additionally, large storms may closely follow small storms or vice versa before the CSO abatement system has returned to an empty state. Thus, the system state may take on several scenarios, requiring the control systems to respond accordingly.

Response to Unpredictable Inputs Increases Complexity

At any point in time during a storm event, it is difficult to understand how the current rainfall is affecting runoff, how runoff is affecting transport, what overflows, if any, are likely to occur, and how overflows may affect receiving water quality. It is even more difficult to predict how future changes in rainfall may affect the system.

Current rainfall may be easy to monitor, but hard to project into the near future. Runoff may be easier to predict, but difficult to actually measure due to the number of inlets, i.e., catchbasins, and the number of pipes in the system.

The amount of uncontrollable in-line storage is difficult to predict during the course of a storm event.

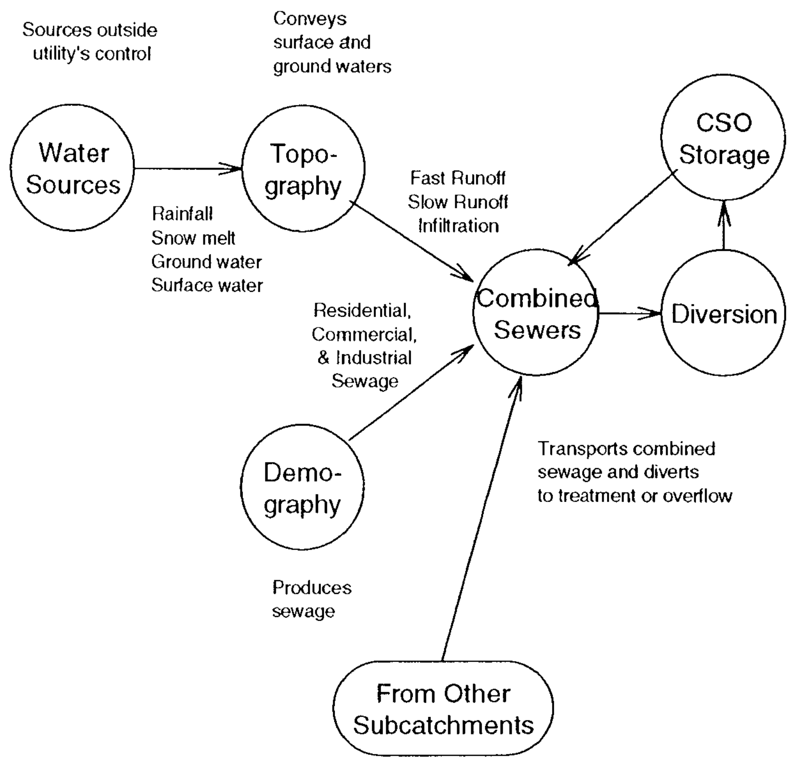

Figure 2-3 Unpredictable Inputs Increase Complexity

Water Sources

Rainfall volume, intensity, and duration vary considerably from storm event to storm event. Inflow from surface waters may depend on the flood stage of rivers, creek, or storm drains. Infiltration depends on water table level, soil moisture and permeability, and sewer condition -- all of which may be difficult to predict.

Runoff (Topography)

The volume and quality of runoff vary considerably from storm event to storm event, even for similar storm events. Sediment buildup between storms, sediment moisture, and particle size, density and settling velocity all affect the runoff quality.

Sewage (Demography)

Illegal or unknown connections from industrial, commercial, or residential sources affect the quantity of wastewater. Illegal dumping can significantly affect quality.

Transport (Combined Sewers)

Sewer condition, unknown interconnections, and unknown water sources affect the hydrograph at the diversion structure. Sediment deposition and re-suspension, sewer wall biofilm kinetics, advection and dispersion of dissolved substances, and organic matter degradation during transport affect quality and are difficult to predict.

Rapid Responses at Diversion Increases Complexity

The diversion subsystem facilities are the most difficult to control because: inputs are difficult to predict; diversion must occur rapidly (if needed) and safely as the state of the system changes; and diversion strategies must achieve water quality goals.

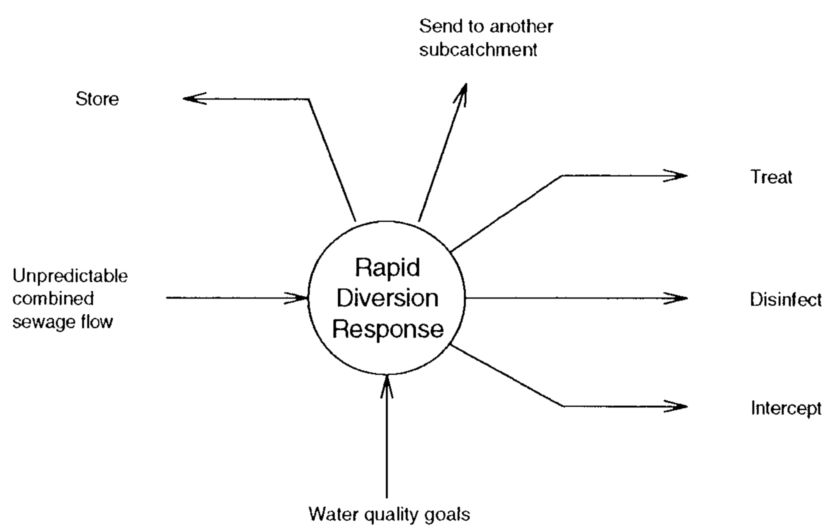

Figure 2-4 Rapid Diversion Response Required

In order to minimize the very large costs associated with CSO abatement, facility design is often less conservative than other wastewater facility designs. Thus, there is less margin for error in the control system design. In addition, since temporal rainfall and runoff relationships are often difficult to predict, abatement facility designs are based on assumed events that may or may not represent actual dynamic behavior during wet weather.

Controls need to be "adaptive" -- able to respond to the changing dynamics and response time constraints imposed by different types of storm events. Upstream levels, widely dispersed rain gauge networks and weather radar are necessary to provide predictive control capability.

Complex Water Quality Goals Increase Complexity

It is difficult to accurately simulate short term fluctuations in flow and water quality caused by combined sewer overflows and to distinguish these effects from those caused by non-point sources or other point sources such as land drainage sewers.

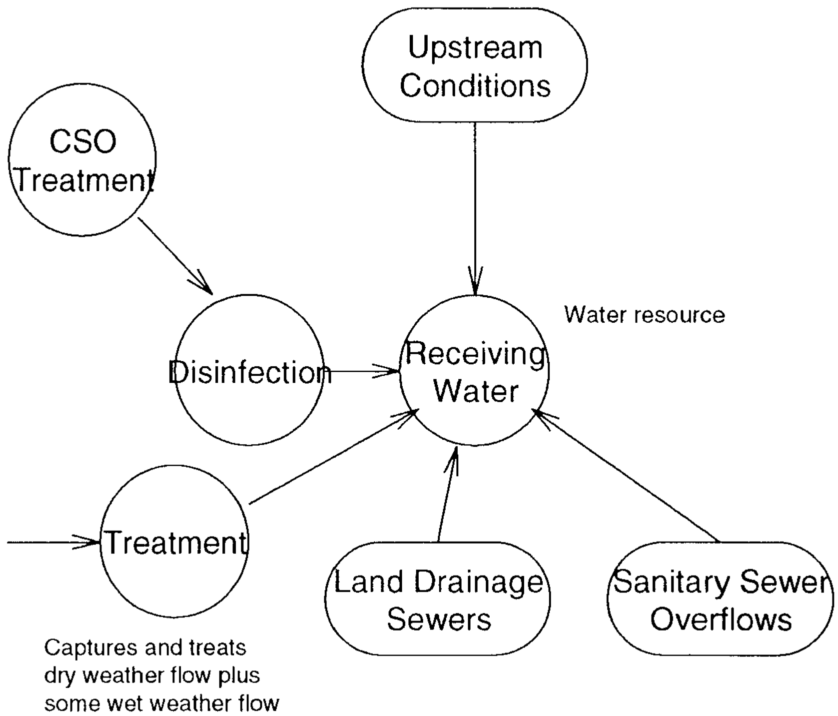

Figure 2-5 Complex Water Quality Goals

To apply water quality criteria to the operation and control of the diversion structures poses additional difficulties. To optimize water quality, CSO abatement facilities must be operated to give preference to the worst locations. Identifying the worst locations given the unpredictability of the inputs may be difficult. In addition, the effect of other sources such as land drainage sewers and sanitary sewer overflows adds complexity.

Using Computer Models to Understand the System

Because of the complex interaction of the subsystems in the CSO abatement system, computer models help to understand the behavior of the system under various conditions. The City of Winnipeg has 44 CSO catchment areas and 54 land drainage catchment areas.

Deterministic models attempt to define the fundamental relationships defining the combined sewer system. Stochastic models attempt to forecast near future events from some initial state conditions.

Water Source Models

Most models for planning and design use either a "design storm" concept or "continuous simulation" of actual storms. For continuous simulation, a "representative" year is selected for screening alternatives in the planning or design phase of a project. The representative year reflects an average year or season of rain events.

Runoff Models

Runoff models generate wet weather inflow hydrograph for each catchment area or for the system as a whole. The models use rain gauge data, design storm events, or continuous simulations and route the rain over the catchment area. Flow data is a function of spatial and temporal variation in rainfall amount and intensity.

Land use, population, temperature, humidity, soil moisture and permeability, erosion factors, wind speed and direction, antecedent rainfall or wetness index, ground water tables, catchment surface sediment build-up rates, sediment moisture, dissolved pollutants are some of the variables that need to be included in the model.

Transport Models

A number of good transport models exist. Some can model the effect of control devices on the outflow hydrographs and pollutographs.

Inflow, sewer system network topology, sediment erosion, transport and deposition, advection/dispersion of dissolved substance, pipe wall biofilm kinetics, invert sediments, first flush phenomena, are typical model variables.

Water Quality Models

Most water quality models attempt to describe organic matter degradation, bacterial fate, and exchange of oxygen. They do not account for floatables or toxicity.

For accurate modeling, all pollutant loading sources must be incorporated. The sources include not only the combined sewer system, but also land drainage sewers, sanitary sewer overflows, and upstream conditions.

Using Computer Models to Control the System

Using computer models to control the system is much different than using them to understand the system. Models used for real time control strategy development need to be more accurate than those for planning and design. Traditional model calibration, such as adjusting impervious area to match limited flow survey data, may not reflect reality. Similar storms may produce different runoff and flow data may be inaccurate. Similar flows can produce different levels in the sewer depending on the previous state of the sewer, i.e., filling or emptying.

Each subsystem affects the other. Errors in a rainfall model affect runoff. Errors in runoff affect transport. Errors in transport affect diversion and water quality models. With a good model, reasonable errors with respect to peaks, total volume, depths and timings are +/-20% to +/-40%.

The literature reports that in a 245 square kilometer catchment with 400 kilometers of sewers, model run times to simulate flow for a 72 hour event can vary from 30 minutes to over 3 days, far too slow for real time control.

3 Real Time Control

One of the more readily implemented and cost-effective approaches to achieving immediate reductions in CSO volumes is to use the available storage and conveyance capacity of existing collection systems and the available treatment works capacity. Longer term abatement will require the design and installation of additional storage, treatment, and disinfection facilities.

To effectively operate and optimize these facilities will require real time control (RTC) systems. This section describes a practical approach to implementing RTC.

Basic Real Time Control

The first step is to install a basic RTC system to observe the system operation, collect data, and provide limited operator directed control. The system could act as a pilot system to train operators and gain knowledge of the CSO system operation under various conditions. A few control sites would provide initial experience with CSO abatement system operation.

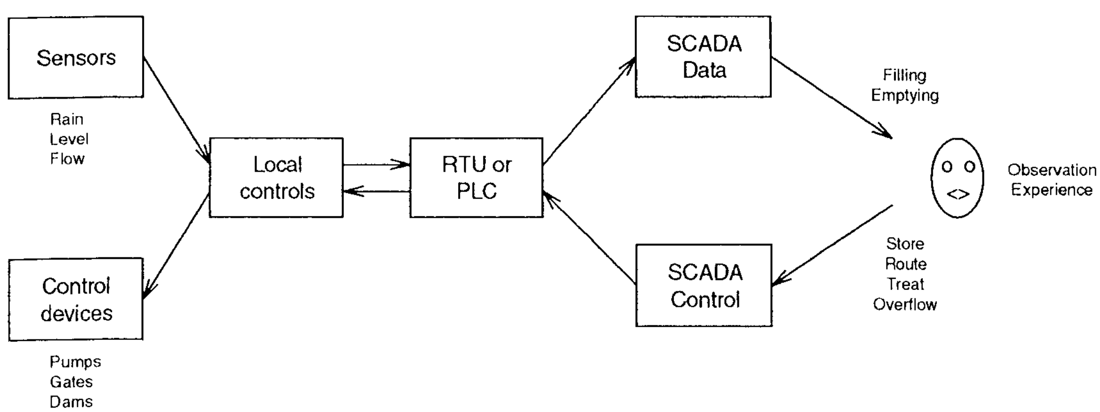

Figure 3-1 Basic Real Time Control

The RTC system would include limited monitoring and control capability as follows:

1. Sensors to measure rain, level, and CSO occurrence;

2. Control devices such as sluice gates or inflatable dams to restrict discharges and cause in-system storage;

3. Control devices such as mechanical regulators or lift stations to regulate the flow of stored wastewater back into the interceptor;

4. Local control systems to operate control devices in a fail-safe manner;

5. Remote terminal units (RTUs), SCADA computer(s) and communication systems to acquire and display operating information from sensors and control devices and to permit control commands to be sent from central location.

As more facilities are added, a more proactive control approach may be needed. The weather service radar, Nexrad, can be added to display rainfall distribution and relative intensity. Nexrad stands for next generation radar. It is an improved Doppler radar that shows rainfall intensity in much greater detail than previous versions. Tie-ins to local radar images are available throughout North America. Nexrad will allow operators to more proactively prepare the system for rain events.

Smart Real Time Control

Computer models that are used to plan and design the CSO abatement facilities can help predict runoff, transport through the sewers, and impact of abatement measures on the receiving water. As the models are calibrated with real time data, they can be used to develop and test real time operating rules.

As operational experience is gained, operational rules can be developed and incorporated into the SCADA computers. The rules may be based on observation and experience initially. Examples could include such rules as:

1. Empty in-system storage so that all facilities have the same percent full
   or
   Empty in-system storage from West to East.

2. Regulate diversion structures equally to keep the interceptor at 5 times dry weather flow
   or
   Regulate diversion structures with higher pollutant loads to intercept a large percentage of flow.

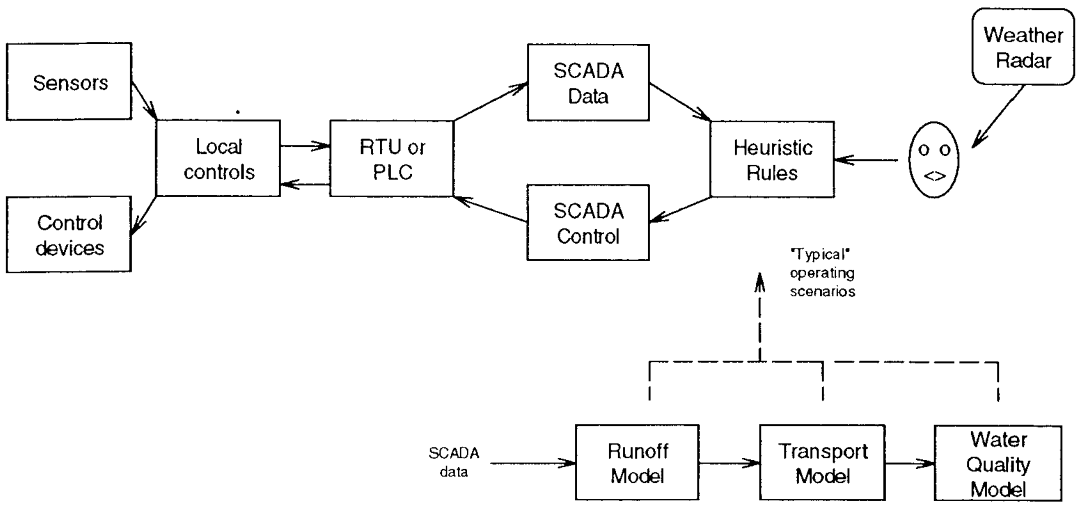

Figure 3-2 Smart Real Time Control

Off-line computer models can simulate various operating scenarios to further refine and enhance the rules. These models could include:

1. Runoff estimation to generate combined sewer system inflow hydrographs.

2. Transport estimation to generate hydrographs (and pollutant loadings) at the diversion subsystems.

3. Water quality models to identify critical operating goals when overflows are likely to occur.

Additional sensors could measure flow in sewers and in the overflow and pollutant concentration in the overflow and in the receiving water.

Modeling efforts need to be balanced -- an accurate transport model will be useful in developing operating rules only if the runoff model is good. Similarly, good runoff and transport models require accurate rainfall estimates. Rainfall models must be supplemented to account for excessive infiltration and other sources of water entering the system.

With enough sophistication, it may be possible to use model output directly for real time control in a more advanced real time control applications.

Advanced Real Time Control

Advanced RTC attempts to control the CSO abatement system in real time to maximize use of storage facilities and treatment plant capacity, and to optimize CSO storage, treatment and disinfection. It does so by linking models to the real time operation. Models may be deterministic, stochastic, or combinations of both. Advanced real time control attempts to replace heuristic rules and human intervention with computer control.

Advanced real time control is most applicable when there are multiple control options that require rapid response or long lead time in relation to the system response time. It is a more proactive approach to real time control, whereas smart real time control is more reactive.

For example, the decision to begin chlorination of stored combined sewage in the smart real time control system might be based on a rule that looks at the current level in the storage basin, whether the level is increasing or decreasing, the present rate of increase, and a projection of when an overflow might occur. Without a good knowledge of upstream conditions and current runoff and transport state, the projection may be inaccurate resulting in starting chlorination too soon or too late.

In an advanced real time control system, the decision to begin chlorination might be based on the current level and the projected inflow based on rainfall, runoff and transport models. If the models are correct, chlorination should begin right on time.

Runoff models, transport models, water quality models and heuristic operating rules developed in the smart real time control phase must be supplemented with a rainfall predictor model such as Calamar, a sewage model to predict sanitary and industrial flow components, sensor state estimators, comparators, and diversion models. GIS may also be used to update land use for the runoff model.

Electric Industry Experiences with Advanced RTC

Advanced RTC implementation in CSO abatement systems parallels the electric utility approach linking models and real time control of the power distribution system. When electric utilities first implemented advanced RTC, they found that two additional computer models were required, a sensor state estimator and a comparator.

These models are very expensive to develop and it would be unreasonable for Winnipeg to develop them alone. The electric utility industry combined resources to develop the base models through the Electric Power Research Institute.

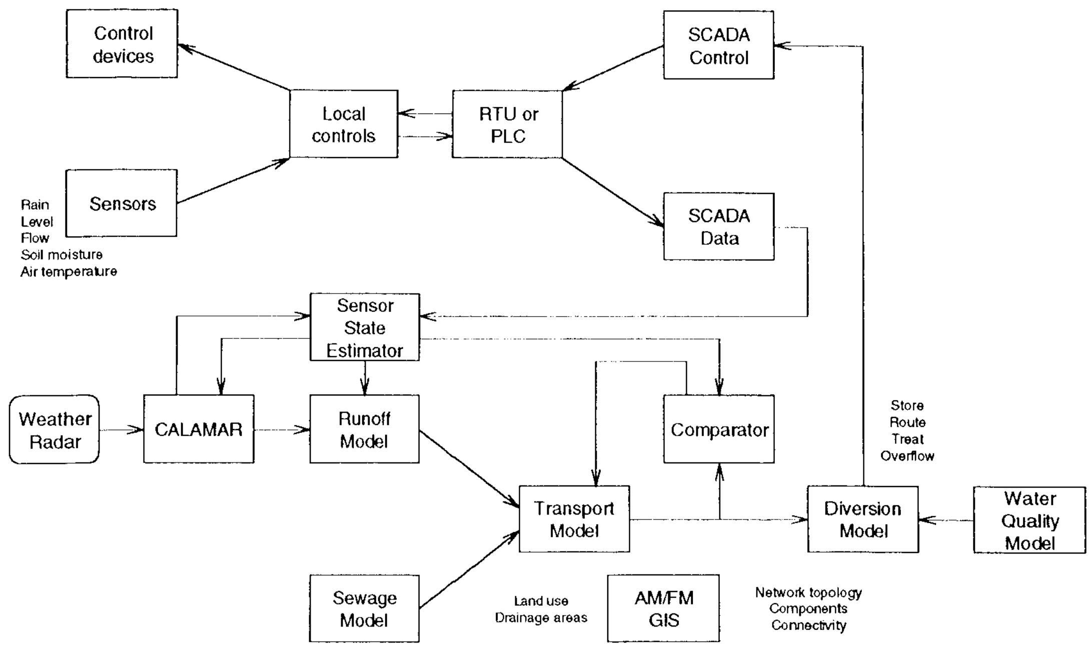

Figure 3-3 Advanced Real Time Control

Sensor State Estimator

The purpose of a sensor state estimator is to provide reliable inputs to real time models. It would receive data from the SCADA system and detect anomalies. It would reject bad data and estimate replacement values. The sensor state estimator would include limit checking and data consistency analysis.

Comparator

The purpose of a comparator is to check the model output against real time data and to dynamically adjust tuning parameters in the rainfall, runoff and transport models -- a self-learning type approach.

Advanced RTC Has Limited Application

The cost effectiveness of a single utility developing advanced real time control is questionable.

1. It will be very costly and time consuming to model the system in the detail required and, more importantly, to verify the accuracy of the model in real time. Errors compound and it is unlikely that the predicted inflow hydrograph at the diversion structures would be any more accurate than +/-20% to +/-40%.

2. It will be very costly to develop state estimators and comparators. Combined sewer system are more complex than electric distribution systems. Therefore, more sophisticated algorithms to determine sensor state or provide feedback corrections to runoff and transport models will be required.

3. Current computing power still limits application in terms of response speed.

4. A key variable in optimizing the system is the amount of rainfall that has fallen in the near past, the current intensity, and predicted rainfall for the near future.

   Calamar is a hardware and software system that processes Nexrad images from weather information providers and rain gauge data from SCADA systems to transform radar images in geographically precise rainfall intensity images. It has the following features:

Table 3-1 Calamar Features

Resolution:	1 km^2 (230 acres)
Update rate:	5 to 6 minutes
Rainfall depth resolution:	+/-10% 90% statistical confidence interval
Accuracy:	+/-4% to +/-380% when compared to rain gauge networks Most accurate when rainfall intensity > 3 mm/hour (0.1 inches/hour)
Prediction capability:	1 hour in the future

As indicated in the above table, Calamar has a relatively slow update rate and can be highly inaccurate at times. Its use in real time control without a state estimator and comparator could introduce significant error into the optimizing strategies.

5. Changes in land use, illegal or unknown connections, changes in user habits will force continuing reevaluation of models and optimizing strategies, making long term support costly.

4 Implementation

CSO abatement projects will be planned, designed, and implemented over several years and some form of real time control is inevitable. Since sensors and control devices will be required sooner or later, early installation of some equipment may be desirable. This allows the City to acquire data used in planning studies, to learn more about their system operation during wet weather events, and to gain experience with sensor and control device operation and maintenance.

Pilot Testing

Use desk-top or model-based analysis to identify subcatchments in which to place in-system controls at minimal engineering and installation cost. In system controls are generally most effective where upstream drainage systems consist of large-diameter pipes laid on shallow gradients.

The design and operation of the control devices and control algorithms, that regulate flow and water levels without increasing the risk of basement or street flooding or overloading the interceptor and treatment works, can be verified during pilot testing.

The Clifton District is ideal for a pilot test. The District was modeled in a relief study conducted in the late 1970's and verified against City monitoring program data. This District ranked number 12 of 41 in terms of pollutant load per unit area. The study indicated that substantial reduction in overflow pollution could be achieved by in-line storage. An increase in equivalent storage from 0.7 to 1.5 mm is as effective as an increase in the interception rate from 2.75 to 7.75 times dry weather flow.

The study indicated that storage depths up to an elevation of 225.4 will not inhibit sewer system capacity to discharge a 5-year design event and the overflow of BOD to the river could be reduced 40% - 50%. At this level, the storage volume is about 6,000 cubic meters.

An inflatable dam at the Strathcona Street Relief Sewer Outfall and a control gate at the Clifton St. Sewer outfall should provide an excellent pilot for in-line storage implementation. Control gate design parameters were defined in the study. Several level sensors upstream of the facilities would provide advance warning of severe storm conditions. With these upstream sensors, higher storage elevations are possible. Further model studies will be required to review the system dynamics to determine optimal locations for these level sensors. Tie-in to the existing rain gauge network is optional.

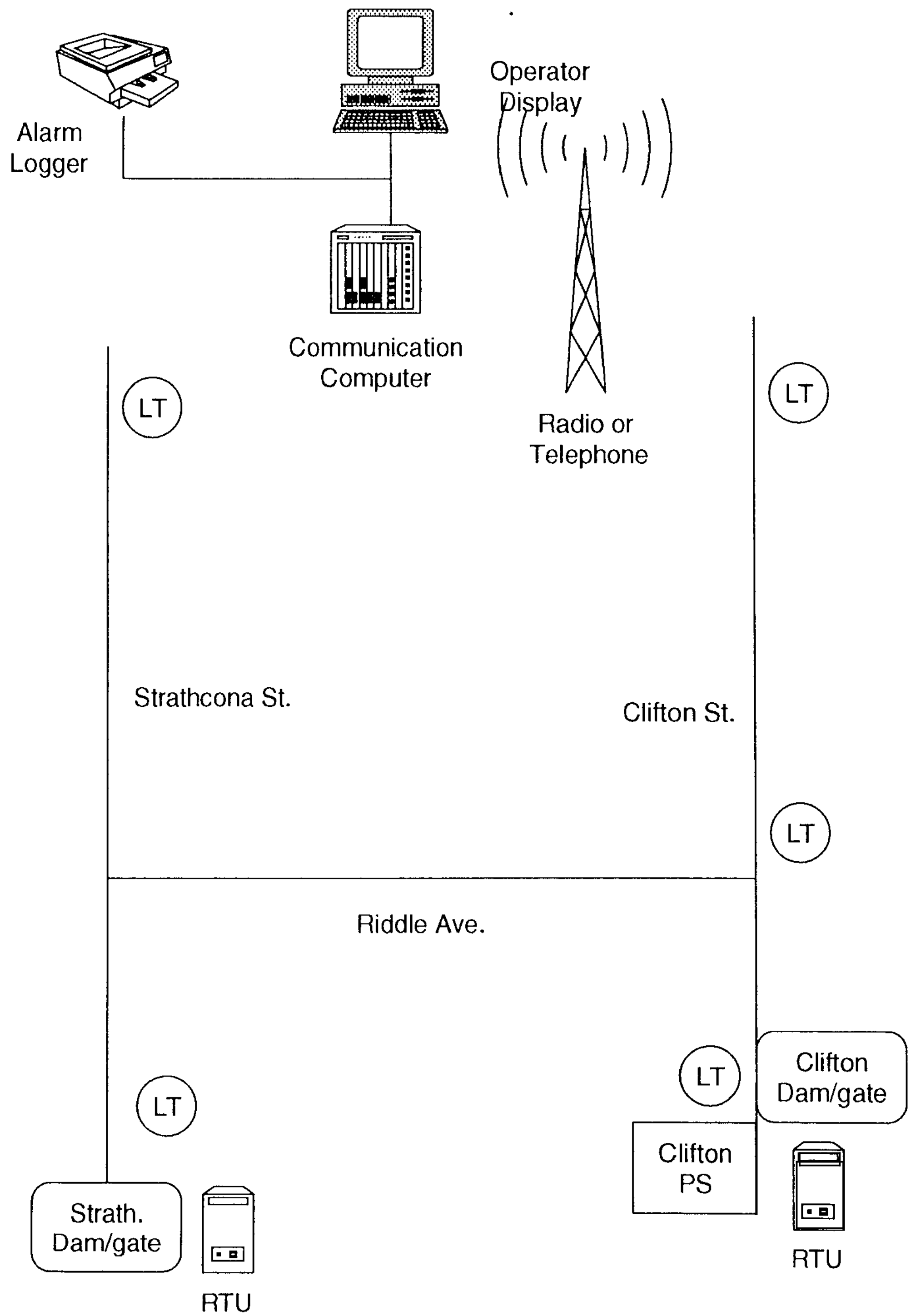

Figure 4-1 Pilot Real Time Control System

System-Wide Monitoring

- The City has a dial up rain gauge network in place and the FAST system that monitors overflows and lift station status. The rain gauge network and FAST system should be incorporated into a City-wide monitoring system. Level sensors at key points around the combined sewer system should be added.

  Data collected by this system will provide basic information on the dynamics of the drainage area. The monitoring system design must include expansion capability to permit monitoring and control of all combined sewer overflow abatement works.

Operator Directed Supervisory Control

As in-line storage and overflow storage/treatment facilities are constructed, implement reactive ***operator directed control***. Over time, operators learn what works and what doesn't work in controlling various devices in the system.

The initial operating rules could be developed and tested using models. Experiences gained and observations made during this phase can help further refine the operating rules.

Nexrad may be installed to give operators advanced warning of approaching storms so they can prepare the CSO abatement system for maximum capture or treatment of wet weather flows.

Computer Directed Smart Supervisory Control

Automatic, ***computer directed control*** of CSO abatement system facilities will be needed as more facilities come on line. Operators will experience increasing difficulty in handling the complex system operation.

Based on rain gauge readings and upstream sewer levels, the real time control system will select an appropriate operating state. The operator may choose to change the state based on Nexrad images.

Model refinement for rainfall, runoff, transport, and water quality prediction should continue.

Advanced Real Time Control

Automatic, ***model-based control*** would be the final development effort needed to optimize the operation of the CSO abatement facilities. Several years of operating data will be used to fine tune models and verify their prediction accuracy.

Calamar may be purchased to better predict rainfall patterns and to help define operating rules. Joint applications development of state estimators and comparators with other utilities may have progressed to make these tools cost-effective.

Time Frame For Advanced RTC is Extensive

Real time controls will be implemented as the CSO abatement system facilities are placed into operation over the next several years. One possible scenario is shown below, assuming construction of the various works will begin in 1997 or 1998.

In this scenario, the monitoring system is designed in late 1996 and in operation by the end of 1998. Pilot systems are not shown.

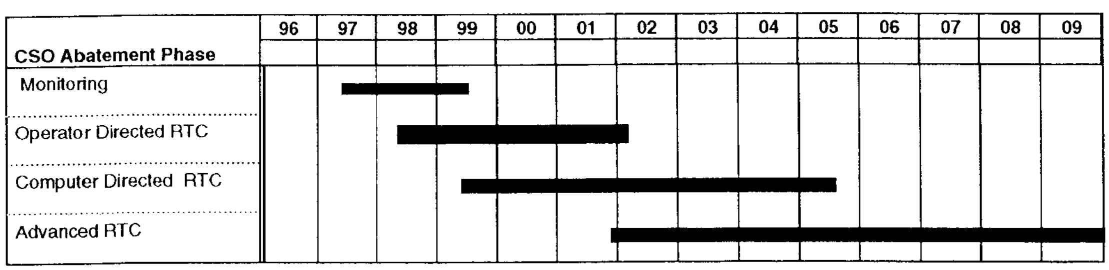

Figure 4-2 Real Time Control Implementation Scenario

The limiter in the above scenario is the time of construction of the physical facilities and the time to acquire statistically valid system operational data. Computer and control system technology will easily keep pace with the increased computational demands to implement advanced real time control.