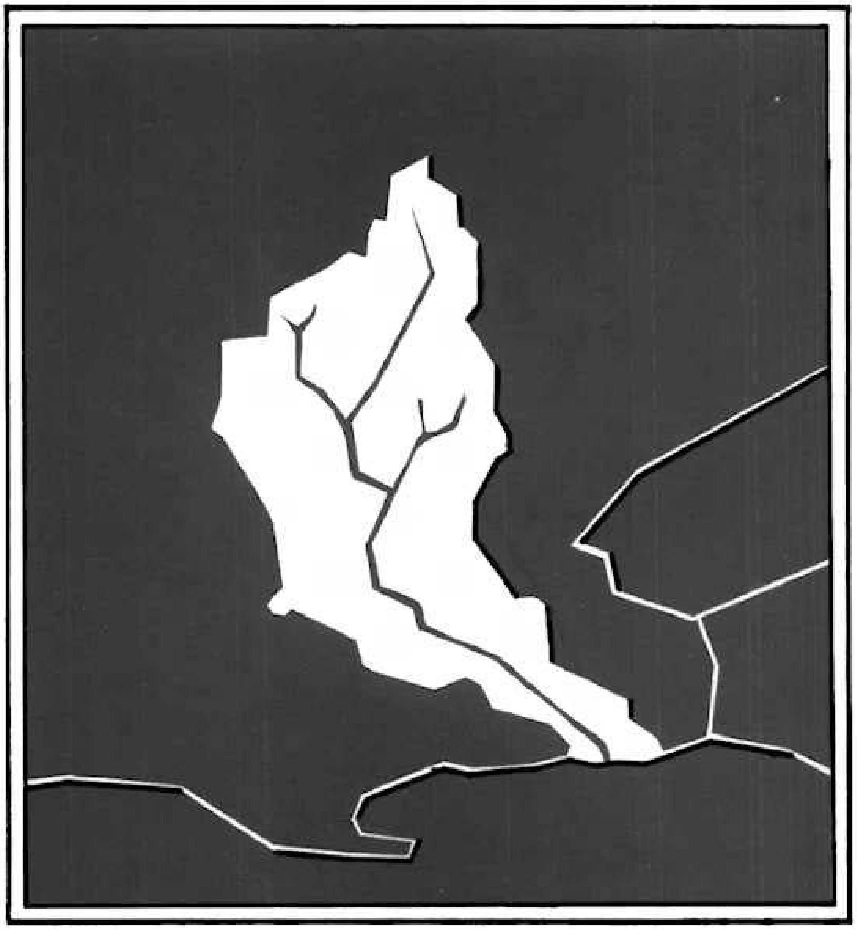
GRAND RIVER BASIN
WATER MANAGEMENT STUDY



APPENDICES

GRAND RIVER IMPLEMENTATION COMMITTEE

1982

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WATER MANAGEMENT STUDY

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Ontario

GRAND RIVER IMPLEMENTATION COMMITTEE

1982

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A. GRIC MEMBERS AND STUDY ORGANIZATION

A.1 Members

Present and former members of the Grand River Implementation Committee (GRIC) and their affiliated agencies are listed below. While GRIC was formed in 1972, only persons who were members since September 1977, the start of the basin study, have been listed.

Grand River Implementation Committee

Chairman	D. N. Jeffs, Director, Water Resources Branch, Ministry of the Environment	
Vice-Chairman	G. M. Coutts, General Manager, Grand River Conservation Authority	
Present Members	P. Burns, Policy Advisor, Functions Policy Section, Local Government Organization Branch, Ministry of Municipal Affairs and Housing	J. Darrell, Planning Co-ordinator, Office of the Assistant Deputy Minister of Community Planning, Ministry of Municipal Affairs and Housing
	J. Johnston, Drainage Co-ordinator, Drainage Section, Foodland Development Branch, Ontario Ministry of Agriculture and Food	T. M. Kurtz, Asst. Director Services, Conservation Authorities and Water Management Branch, Ministry of Natural Resources
	J. McFadden, Regional Conservation Authorities Program Supervisor, Central Region, Ministry of Natural Resources	S. Salbach, Supervisor, Quality Protection Section, Water Resources Branch, Ministry of the Environment
	I. G. Simmonds, Manager, Municipal and Private Abatement, West Central Region, Ministry of the Environment	A. F. Smith, Co-ordinator, Grand River Basin Water Management Study
Former Members	N. Harris, represented Management Board of Cabinet Secretariat	R. Hunter, Supervisor, Land Management and Program Evaluation, Conservation Authorities and Water Management Branch, Ministry of Natural Resources
	C. Lonero, Economist, Economic Development Branch, Ministry of Treasury and Economics	

G. Pearce,
West Central Region,
Ministry of the Environment,
now with Envirosearch Ltd.

F. Shaw, Deputy Regional Director,
Central Region,
Ministry of Natural Resources

T. Spearin, Manager,
Program Planning and Budgeting Group,
Ministry of Industry and Tourism

R. Stewart, Manager,
Technical Support,
West Central Region,
Ministry of the Environment

P. Wormwell, represented Management Board of Cabinet Secretariat,
now with Land and Waters Group,
Ministry of Natural Resources

A.2 Study Organization

The work of the basin study was guided by a steering and co-ordinating committee called the Grand River Implementation Committee (GRIC) made up of members from five participating ministries and agencies. Present member agencies of GRIC include:

Ontario Ministry of Agriculture and Food
Ontario Ministry of the Environment
Ontario Ministry of Municipal Affairs and Housing
Ontario Ministry of Natural Resources
Grand River Conservation Authority

The functions of GRIC involve:

a) planning and directing the Grand River Basin Water Management study
b) co-ordinating the implementation of the recommendations of the 1971 report, Review of Planning for the Grand River Watershed
c) providing a forum for the exchange of information among provincial and municipal representatives and area residents.

The technical work of the basin study was carried out by five sub-committees:

a) Hydrologic Sub-Committee
b) Water Quality Sub-Committee
c) Facilities and Operations Sub-Committee
d) Public Consultation Sub-Committee
e) Water and Related Land Use Sub-Committee

Members of these sub-committees were from agencies represented on GRIC and from local municipalities.

The technical sub-committees' activities were, in turn, co-ordinated by the Grand River Basin Study Team who reported directly to GRIC. The basin study team was made up of the technical sub-committee chairmen plus one additional representative from the Ministry of the Environment and the Ministry of Natural Resources, a representative from the Ontario Ministry of Agriculture and Food and a representative from the municipal water managers in the basin.

In addition to the five main sub-committees, several advisory groups were formed to carry out more detailed investigation for the main sub-committee. The organization is illustrated in Figure A.1 and the members are listed in Appendix G.

Two important advisory groups were the Public Involvement Program Advisory Group (PIPAG) and the four Public Consultation Working Groups, both of whom provided advice to GRIC and the study team through the Public Consultation Sub-Committee. Basin residents with diverse backgrounds and interests served on these groups.

The municipalities were kept informed of the study's progress through the efforts of the municipal involvement group. This group, composed of GRIC members, arranged several information meetings with the basin's municipal representatives.

As a multi-agency committee, GRIC is responsible through the Ministry of the Environment directly to the Cabinet Committee on Resources Development. Throughout the study, GRIC has kept the committee informed by submitting progress reports and results of basin study investigations.

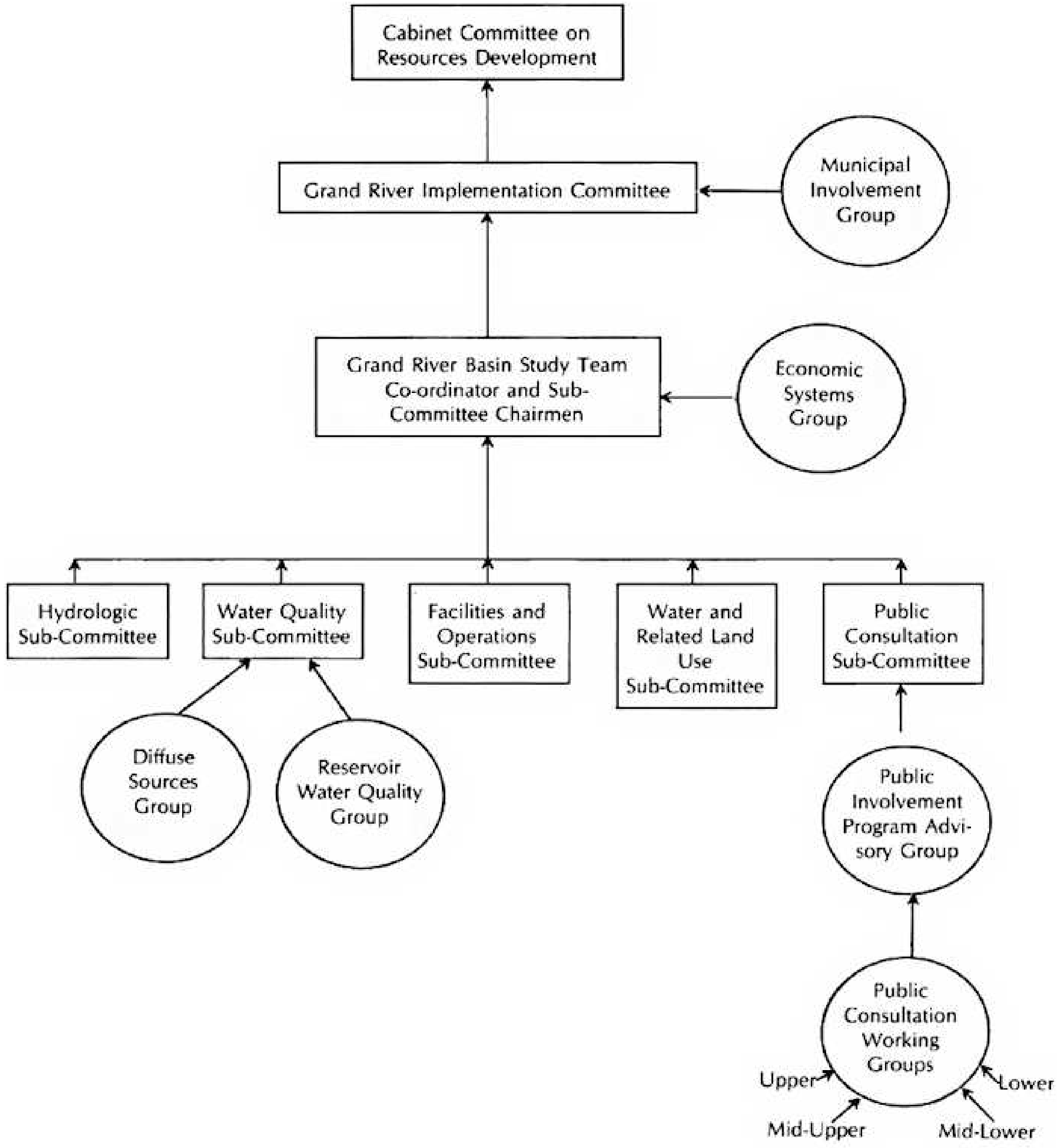


Figure A.1 Organization of the Grand River Basin Water Management Study.

B. EVALUATION PROCESS TO SELECT THE MAIN WATER MANAGEMENT PLANS

B.1 Formulation of Water Management Plans

Water management plans were formed by combining various projects such as dams, dykes, sewage treatment plants, and well fields in different ways which would satisfy the basin objectives to varying degrees. Numerous projects identified in Table B.1 were investigated by the basin study and combined to form twenty-six plans.

B.1.1 Plan Generation

Preliminary plans were generated through the use of optimization or screening models. Deviations in plans resulted by varying input parameters such as population and flows or constraints such as maximum day municipal water demands and dissolved oxygen levels.

Two screening models were formulated for the study. One model, a linear programming screening model, incorporated an optimization algorithm to formulate management plans. However, it did not allow for population growth. The second model was an interactive project staging model which incorporated population growth (Ref. Tech. Report No. 22). Rather than using an optimization routine, projects were selected for input into the model. Both models imposed water quality and water consumption constraints and included measures of flood benefits and project costs. The results of the screening models were supplemented by more accurate water quantity and quality simulation results.

Flood Damages

Flood damages were included in the screening models in the form of reductions in average annual flood damages resulting from the specified projects. Only the damage centres which are affected by more than one project solution were considered in the preliminary economic analysis.

The projects considered for reducing flood damages were: dams; channelization and dyking in Cambridge (Galt and Preston), Paris, Brantford, Caledonia, Dunnville and New Hamburg; flood proofing of existing floodplain structures in all flood damage centres; and floodplain land acquisition in Cambridge (Galt), Paris and Brantford.

Water Quality

The screening models incorporated the results of a steady state water quality assimilation model to assess the impact of wastes discharged from major urban centres upon the dissolved oxygen levels of the river system.

Sewage treatment plants having potential major effects on basin watercourses were selected for preliminary analysis. These included plants located in the urban centres of Waterloo, Kitchener, Cambridge (Galt and Hespeler) and Brantford. Other sewage treatment plants were excluded from this analysis because of their relatively minor impact on downstream dissolved oxygen levels. However, some of the excluded plants can cause local water quality problems and are examined in separate water quality studies as described in Chapter 7.

The effects of urban and rural non-point sources were considered independently in detailed water quality simulation models and are discussed in Chapters 9 and 10. Simulation results indicate that urban sources have a negligible effect upon dissolved oxygen levels in the main river system. Rural non-point sources have a negligible effect on the dissolved oxygen levels in the Speed river below Guelph, but have some effect on the middle Grand river system.

Two levels of sewage treatment for each plant were identified: (1) conventional treatment; and (2) conventional treatment + advanced treatment. Effluent quality improves with the level of treatment.

Conventional treatment refers to the standard biological treatment (activated sludge) with chemical treatment for phosphorus removal presently practiced at all of the basin's major sewage treatment plants. This type of treatment removes approximately 90 to 95 percent of the carbonaceous oxygen-demanding wastes and suspended solids and removes phosphorus to about 1 mg/L (80 percent reduction).

Advanced sewage treatment in this report refers to any new treatment process beyond conventional treatment. Advanced treatment is designed to remove pollutants which are not adequately removed by conventional processes. The advanced in-plant treatment processes considered at Waterloo and Kitchener were:

- nitrification to convert toxic ammonia to nitrates (which are relatively harmless at concentrations less than 10 mg/L)
- dual-media filtration to remove organics, suspended solids and phosphorus
- carbon adsorption to remove organics, suspended solids and toxic substances.

Two advanced treatment processes were considered at Guelph to provide additional phosphorus removal. The first process considered chemical treatment of the RBC effluent and modification of the existing filters. The second, more expensive process considered chemical treatment of the RBC effluent, followed by filtration in a new deep-bed multi-media filter installed before the existing filter.

Table 8.1 Water Projects Investigated in the Grand River Basin Water Management Study.

Structural Projects.

Project	Reduce Flood Damages	Provide Adequate Water Supply	Improve Water Quality	Reference	Comment
1. Reservoirs					
Montrose (multi-purpose)	X	X	X	Plan B, Chapter 9	
Montrose (single-purpose)	x			Plan C2, C3, Chapter 9	
Ayr	X	X	X	Plan 5, Appendix B	
Nithburg	X		X	Chapter 7	
Everton			X	Plan A3, Chapter 9	
St. Jacobs	X			Plan C1, Chapter 9	
Wallenstein	X		X	Appendix B, Plan 3,11	
Salem	X			Appendix B, Plan 38	
Freeport	X			Appendix B, Plan 11	
Hespeler	X			Tech. Report 32	
2. Dyking & Channel Improvements					
a) Grand Valley	X			Chapter 7	
b) New Hamburg	X			Chapter 7	
c) Hespeler	X			Chapter 7	
d) Preston	X			Chapter 7	
e) Galt	X			Chapter 9, Plan A	
f) Paris	X			Chapter 9, Plan A	
g) Brantford	X			Chapter 9, Plan A	
h) Caledonia	X			Chapter 9, Plan A	
I) Dunnville	X			Chapter 9, Plan A	
3. Flood Proofing	X			Appendix B, Plan 1C	effective for flood fringe areas
4. Point Source Controls					
a) conventional treatment			X	Chapter 9, Plan A1	
b) advanced treatment					
i) nitrification			X	Chapter 9, Plan A1	recommended for Kitchener-Waterloo STP
ii) dual-media filtration			X	Chapter 9, Plan A1	recommended for Kitchener-Waterloo STP
iii) chemical treatment and multi-media filtration			X	Chapter 9, Plan A1	recommended as one option to remove additional phosphorus at Guelph STP
iv) activated carbon			X	Tech. Report 41	not cost-effective
v) land treatment			X	Tech. Report 41 File Reports MOE- 1974, 1975	requires extensive amounts of land, may be viable for small communities, still under investigation

Table B.1 Water Projects Investigated in the Grand River Basin Water Management Study (Continued)

Structural Projects.

Project	Reduce Flood Damages	Provide Adequate Water Supply	Improve Water Quality	Reference	Comment
5. Non-Point Source Controls					
a) Urban				Chapter 9	
I) storage	X		X	Tech. Report 28	
treatment			X		
b) Agriculture				Chapter 9	
I) waterway stabilization	X		X	Tech. Report 27	
ii) bank stabilization	X		X		
iii) fencing for livestock			X		
iv) buffer strips	X		X		
v) manure storage			X		
In stream Controls					a) to be studied further
a) weirs			X		b) insufficient depth
b) aerators			X		c) high environmental
c) cropping			X	File Report 1980	impact to stream
d) oxygen injection			X		d) possible on Speed river
6. Short pipeline for sewage treatment - Guelph to Glen Morris			X	File Report 1980	▸ costs over $10 million ▸ may affect raw water quality for Brantford water supply
7. Great Lakes Pipeline		X		Chapter 9	▸ most expensive water supply option
8. Recharge of ground- water		X		Chapter 9 Tech. Report 10, 32	Mannheim recharge scheme
9. Induced infiltration		X		Tech. Report 10. 32	
10. New Groundwater Supplies		X		Chapter 9, 11 Tech. Report 10, 32	
11. De-mineralization of groundwater high in sulphates, chlorides		X			expensive, useful for small communities like Plattsville, when demand is less than 2,631 m^3/d (0.5 mgd)

Table B.1. Water Projects Investigated in the Grand River Basin Water Management Study (Cont'd)

Non-Structural Projects

Project	Reduce Flood Damages	Provide Adequate Water Supply	Improve Water Quality	Reference	Comment
1. Floodplain Management					
a) flood plain regulation	X			Chapter 9	
b) flood plain acquisition	X			Chapter 9 Appendix B, Plan 1E	
2. Flood Forecasting & Warning	X			Chapter 8	
3. Wetland Preservation	X	only locally	X	Chapter 9	‣ 7% of watershed in wetlands ‣ approx. 3.5% recharge ‣ approx. 3.5% discharge ‣ important to preserve on Eramosa for flood reduction ‣ important locally not basin wide for water supply
4. Reforestation	X		X		‣ only 17% of water shed in forest ‣ effective locally not basin wide
5. Water Conservation		X		Chapter 9,Tech. Report No. 26	‣ defers need for new water supply projects 5 to 10 years ‣ defers need for sewage treatment expansions by approx. 5 years

The level of treatment required at each plant depends upon several factors including the volume of sewage, the capacity of the river to absorb wastes, river flows, and water quality objectives.

Water Supply

In constructing the screening models, only the water demands of the major urban areas of Guelph, Kitchener, Waterloo, Cambridge and Brantford were considered, since most smaller communities have adequate water supplies to meet future demands to the year 2031.

The projects considered to maintain adequate water supplies include:

(1) maintaining river flow through the existing reservoir operation to provide supply for: (i) Mannheim recharge scheme (Kitchener-Waterloo); (ii) infiltration wells (Kitchener-Waterloo); and (iii) direct river takings (Brantford)

(2) ground water extraction (Cambridge, Guelph, Kitchener-Waterloo)

(3) construction of a Lake Erie pipeline (Brantford, Cambridge, Kitchener-Waterloo)

(4) construction of a reservoir pipeline from Montrose or Ayr reservoir sites (Kitchener-Waterloo)

(5) implementation of a water conservation program in major urban areas where warranted.

B.1.2 Water Management Plans

Twenty-six preliminary water management plans were assembled using the projects simulated in the screening models. These plans are described briefly in the following sections. All references with respect to the staging of various plan components are based on a medium population projection.

Plan 1

There are nine versions to plan 1 (plan 1A to 1i). The same water quality projects are incorporated into all component plans except for one version, 1G. Attempts to meet water quality objectives for dissolved oxygen and ammonia nitrogen involve expansion of conventional sewage treatment plants to meet growing population needs plus advanced treatment at Kitchener immediately and at Waterloo in the year 2001. Future treatment on the Speed river will depend to a large extent upon the effectiveness of the recently installed nitrification and filtration facilities at Guelph. However, for estimating plan costs, it has been assumed that additional treatment will be required immediately and these costs have been incorporated into plan 1A. As well as improving water quality by additional sewage treatment, plan 1G incorporates a reservoir at Everton on the Eramosa river to improve water quality in the Speed river below Guelph by augmenting low, summer streamflows.

With the exception of plan 1F, water supply projects for 1 series plans are the same. Additional water supply for Kitchener-Waterloo will be provided by induced infiltration from the Grand river initiated in 1980, and recharge to the Mannheim aquifer from the Grand river in 1991. In the years 1986 and 2001, Cambridge is supplied by additional ground water extracted from Puslinch Township and North and South Dumfries Townships, respectively. Additional supplies are required from the Mannheim recharge system in 2001 Guelph water requirements will be met through further extraction of local ground water in 2011 and expansion of the Arkell recharge system in 2021. An expansion of the Brantford water treatment plant with additional extraction from the Grand river will be required by 1996. Plan 1F differs from other plans since it reduces demands through water conservation methods, thereby postponing the introduction of new water supply projects.

Methods for reducing flood damage vary among the versions of plan 1. For example, plans 1A, 1F and 1G incorporate dyking and channelization projects, whereas plan 1B utilizes a dry or single-purpose reservoir at Salem on the Irvine river. Plan 1C includes flood proofing of existing floodplain structures; plan 1E suggests floodplain land acquisition, and plan 1D provides no flood damage protection. Plan 1H includes the effect of the Nithburg reservoir.

Plan 1i is similar to plan 1A except that land required for the construction of the Montrose reservoir on the Grand river is acquired at market prices as the land becomes available. This plan allows for flexibility in the future. If future water management uncertainties are resolved and the Montrose reservoir is not required, the land can be sold on the market place.

Plan 2

There are 5 versions to plan 2 (plans 2A to 2E). Methods for flood damage reduction incorporate a reservoir at West Montrose for all plans. In plans 2A, 2B, 2C and 2D the reservoir would be multi-purpose. In plan 2E, the reservoir is used strictly for flood reduction. Additional flood control measures include dyking and channelization in plans 2B and 2C.

With the option of flow augmentation in plans 2A, 2B, 2C and 2D, recommended sewage treatment improvements outlined in the 1 series plans apply. However, advanced treatment is delayed at Kitchener and Waterloo to the years 2001 and 2021, respectively. Since no flow augmentation is available in plan 2E, all sewage treatment improvements suggested for 1 series plans are required.

The water supply options for plans 2A, 2B, 2C and 2E are the same as those outlined for plan 1A. Plan 2D differs from the others since water is supplied directly from the Montrose reservoir by pipeline. This option would be considered if water quality conditions prevented extraction from the Grand River at Kitchener.

Plan 3

Plan 3 provides flood damage reduction through the implementation of a multi-purpose dam near Wallenstein on the Conestogo river. Improvement of water quality involves the expansion or upgrading of sewage facilities in accordance with plan 1A plus flow augmentation from the Wallenstein reservoir. Water supply options are the same as plan 1A.

Plan 4

Plan 4 is a combination of plans 1B and 3. Flood damage reduction is achieved by the implementation of a dry or single-purpose reservoir at Salem. Water quality projects include improved sewage treatment as outlined for plan 1A and flow augmentation from the Wallenstein reservoir. Water supply options are the same as plan 1A.

Plan 5

Plan 5 differs from plan 1A through the utilization of the Ayr reservoir on the Nith river for a limited amount of flood damage reduction (9 to 10 percent at Paris and Brantford) and for water supply to Kitchener, Waterloo and Cambridge.

Plan 6

Plan 6 requires the same flood damage reduction and water quality projects as plan 1A. However, additional water supply for Kitchener, Waterloo, Cambridge and Brantford is provided by a pipeline from Lake Erie. Other great lakes sources considered in the past were Georgian Bay and Lake Huron. However, pipeline schemes from these sources proved considerably more expensive than the Lake Erie option.

Plan 7

There are two versions to plan 7 (plans 7A and 7B). In both plans existing conventional sewage treatment plants are expanded but no advanced treatment is installed at the Waterloo, Kitchener and Guelph sewage treatment plants. In addition, no new flood protection is provided. While these plans are the cheapest, it would be necessary to curtail population growth because of water quality or water supply constraints.

Plan 7A immediately limits growth at Kitchener, Waterloo and Guelph because of violations in provincial water quality objectives for dissolved oxygen.

Plan 7B neglects deteriorating water quality and allows for population growth. However, water shortages become a problem, limiting growth in Kitchener and Waterloo by 1991, in Cambridge by 2021 and in Brantford and Guelph by 2031. These dates could be prolonged 5 to 10 years if water conservation measures are implemented.

Plan 8

Plan 8 consists of the same water quality and water conservation projects as plan 1A. However, the effects of water conservation on the cost and staging of these projects are considered in two versions of the plan (plans 8A and 8B).

Plan 8A reduces the average and maximum day demand by 7 and 15 percent respectively, and delays the time at which water supply projects are required by 5 to 10 years. Sewage treatment expansions are also delayed by approximately 5 years.

Plan 8B reduces the average and maximum day demand by 20 and 23 percent respectively, and defers the requirement for water supply projects by an additional 5 to 15 years and sewage treatment projects by an additional 2 years. These reductions are applicable to the supply portions of any of the other plans should water conservation measures be implemented.

Reductions in flood damages for both plans are achieved by flood proofing existing floodplain structures.

Plan 9

There are two versions to plan 9 (plans 9A and 9B).

Plan 9A is the same as plan 1A with the exception of the water quality projects. Sewage treatment plants are allowed to expand. However, advanced treatment at the Waterloo, Kitchener and Guelph sewage treatment plants is not installed. Under these circumstances water quality conditions will gradually deteriorate.

Plan 9B utilizes the same water supply projects as plan 1A, but examines the case for achieving the highest water quality possible on the Grand and Speed rivers. With advanced sewage treatment at Kitchener, Waterloo and Guelph, plus flow augmentation from the Montrose and Everton reservoirs, 69 percent of the provincial water quality objective for dissolved oxygen is achieved on the Speed river and about 94 percent is achieved on the Grand river. Reductions in flood damages are provided by the Montrose dam.

Plan 10

Plan 10 is the same as plan 1A except it utilizes a single-purpose reservoir at St. Jacobs to reduce flood damages rather than dyking and channelization.

Plan 11

Plan 11 utilizes single-purpose reservoirs at Salem, St. Jacobs and Freeport and one multi-purpose reservoir at Wallenstein. The projects used for water quality and water quantity are the same as plan 1A. In addition, the Wallenstein reservoir provides flow augmentation which would improve water quality.

B.1.3 Summary of Water Management Plans

The twenty-six water management plans are summarized in Table B.2. For each plan the project components are described relative to the water management objectives, and the project costs and benefits are summarized for various discount rates. Table B.3 describes the objectives and measurements used to calculate the percentage of objective completion.

An explanation of how cost and benefits were derived in Table B.2 is discussed in Chapter 10 and an explanation of the discount rate and how it pertains to the study is given in Appendix C.1. The plans of Table B.2 have been prepared for a medium population projection. In order to determine the consequences of varying basin population growth, the basin study analyzed each plan in terms of the other population projections: the low low projection, the low projection and the high projection. The effects of these projections upon costs and benefits are described in Chapter 10 and Appendix B.2 for the four main plans.

Table B.2 Summary of Preliminary Water Management Plans For A Medium Population Projection.

(Costs and Benefits are in Millions of 1979 Dollars)

PLAN	PLAN DESCRIPTION:			PRESENT VALUE OF BENEFITS & COSTS				NOTES.
	WATER QUALITY	WATER SUPPLY	FLOOD PREVENTION	ITEM	DISCOUNT RATE			
					0%	6%	10%	
1A	Sewage Treatment:	Ground Water:	Dykes & Channel Works:	1) STP-CAS+Guelph RBC	379	94	54	
	Kitchener - Nitrification,	Guelph, Cambridge	Preston, Galt,	2) STP-New Facilities	77	30	23	
	Filtration, 1981	Surface Water:	Paris, Brantford,	3) Water Supply	38	14	9	
	Waterloo - Nitrification,	Kitchener-Waterloo	Caledonia, Dunnville,	4) Reservoirs	0	0	0	
	Filtration, 2001	1991	New Hamburg	5) Other Flood Prot.	25	24	23	
	Guelph - Chemical Treatment	Cambridge connect to		6) Water Sup. Benefits	1078	107	26	
	and Multi-Media	Kitchener-Waterloo		7) Flood Prot. Benefits	46	14	9	
	Filtration, 1981	2021		8) Net Benefits =				
				(6+7) - (2+3+4+5)	984	53	-20	
	28% - Speed	100%	91%					
	23% - Grand							
1B	Same as Plan 1A	Same as Plan 1A	Salem Single-Purpose	1) STP-CAS + Guelph RBC	379	94	54	Reservoir is used for flood control only. Reservoir remains dry during non-flood periods.
			Reservoir	2) STP-New Facilities	77	30	23	
				3) Water Supply	38	14	9	
				4) Reservoirs	24	22	21	
				5) Other Flood Prot.	0	0	0	
				6) Water Sup. Benefits	1078	107	26	
	28% - Speed			7) Flood Prot. Benefits	10	3	2	
	23% - Grand	100%	20%	8) Net Benefits =				
				(6+7) - (2+3+4+5)	949	44	-25	
1C	Same as Plan 1A	Same as Plan 1A	Flood Proofing	1) STP-CAS+Guelph RBC	379	94	54	Flood proofing is carried out only where economically justified (i.e. Benefits >=Costs)
				2) STP-New Facilities	77	30	23	
				3) Water Supply	88	14	9	
				4) Reservoirs	0	0	0	
				5) Other Flood Prot.	2	2	2	
				6) Water Sup. Benefits	1078	107	26	
	28% - Speed			7) Flood Prot. Benefits	10	3	2	
	23% - Grand	100%	20%	8) Net Benefits =				
				(6+7) - (2+3+4+5)	971	64	-6	
1D	Same as Plan 1A	Same as Plan 1A	None	1) STP-CAS+Guelph RBC	379	94	54	
				2) STP-New Facilities	77	30	23	
				3) Water Supply	38	14	9	
				4) Reservoirs	0	0	0	
				5) Other Flood Prot.	0	0	0	
				6) Water Sup. Benefits	1078	107	26	
	28% - Speed			7) Flood Prot. Benefits	0	0	0	
	23% - Grand	100%	0%	8) Net Benefits =				
				(6+7) - (2+3+4+5)	963	63	-6	

Note: Percent figures refer to % of objective achieved; except where noted the objectives are: Water Quality - meet a water quality index of 0.0 on the Grand river and on the Speed river; Water Supply = Max. *Day* Demand; Flood Damage Reduction - zero average annual damages.

Table B.2 Summary of Preliminary Water Management Plans For A Medium Population Projection (Cont'd)

(Costs and Benefits are in Millions of 1979 Dollars)

PLAN	PLAN DESCRIPTION:			PRESENT VALUE OF BENEFITS & COSTS				NOTES
	WATER QUALITY	WATER SUPPLY	FLOOD PREVENTION	ITEM	DISCOUNT RATE			
					0%	16%I	10%	
1 E	Same as Plan 1A	Same as Plan 1A	Land Acquisition in Paris, Galt and Brantford to Regional Storm Flood Line	1) STP-CAS+Guelph RBC	379	94	54	
				2) STP-New Facilities	77	30	23	
				3) Water Supply	38	14	9	
				4) Reservoirs	0	0	0	
				5) Other Flood Prot.	515	486	468	
				6) Water Sup. Benefits	1078	107	26	
	28% - Speed			7) Flood Prot. Benefits	43	13	8	
	23% - Grand	100%	93%	8) Net Benefits =				
				(6+7) - (2+3+4+5)	491	-410	-466	
1F	Same as Plan IA	Ground Water and Surface Water Projects same as Plan 1A	Same as Plan 1A	1) STP-CAS+Guelph RBC	339	87	50	Implementation date for most water supply projects deferred by 5-10 years using moderate conservation measures. STP costs in Item 1) are also reduced by water conservation.
				2) STP-New Facilities	70	28	22	
				3) Water Supply	35	10	5	
				4) Reservoirs	0	0	0	
		Water Conservation:		5) Other Flood Prot.	25	24	23	
		Ave. Day reduced 7%		6) Water Sup. Benefits	734	66	13	
	28% - Speed	Max. Day reduced 15%		Flood Prot. Benefits Net Benefits =	46	14	9	
	23% - Grand	100%	91%	(6+7) - (2+3+4+5)	650	18	-22	
1G	Same as Plan 1A	Same as Plan 1A	Same as Plan 1A	STP-CAS+Guelph RBC	379	94	54	
				STP-New Facilities	77	30	23	
	Flow Augmentation on Speed River from Everton Reservoir			Water Supply	38	14	9	
				Reservoirs	17	16	15	
				5) Other Flood Prot.	25	24	23	
				6) Water Sup. Benefits	1078	107	26	
	69% - Speed			7) Flood Prot. Benefits	46	14	9	
	23% - Grand	100%	91%	8) Net Benefits =				
				(6+7) - (2+3+4+5)	967	37	-35	
1H	Same as Plan 1A	Same as Plan 1A	Nithburg Reservoir	1) STP-CAS+Guelph RBC	379	94	54	
				2) STP-New Facilities	77	30	23	
				3) Water Supply	38	14	9	
				4) Reservoirs	26	24	23	
				5) Other Flood Prot.	0	0	0	
				6) Water Sup. Benefits	1078	107	26	
	28% - Speed			7) Flood Prot. Benefits	1	0.3	0.2	
	23% - Grand		2%	8) Net Benefits =				
				(6+7)- (2+3+4+5)	938	39	29	

Note: Percent figures refer to % of objective achieved; except where noted the objectives are: Water Quality — meet a water quality index of 0.0 on the Grand river and on the Speed river; Water Supply = Max. Day Demand; Flood Damage Reduction = zero average annual damages.

Table B.2 Summary of Preliminary water management Plans for A Medium Population Projection (Cont'd).

(Costs and Benefits are in Millions of 1979 Dollars)

PLAN	PLAN DESCRIPTION:			PRESENT VALUE OF BENEFITS & COSTS				NOTES
	WATER QUALITY	WATER SUPPLY	FLOOD PREVENTION	ITEM	DISCOUNT RATE			
					0%	6%	10%	
1i	Same as Plan 1A	Same as Plan 1A	Dykes & Channel	1) STP-CAS+Guelph RBC	379	94	54	This version of plan assumes: ▸ land acquisition is completed by 2001; ▸ reservoir is not built; ▸ land is resold in 2031.
			Works same as Plan 1A	2) STP-New Facilities	77	30	23	
				3) Water Supply	38	14	9	
			Acquire Montrose	4) Reservoir Land	0*	4*	5*	
			Reservoir Land for	5) Other Flood Prot.	25	24	23	
			possible future use	6) Water Sup. Benefits	1078	107	26	
				7) Flood Prot. Benefits	46	14	9	
	28% - Speed			8) Net Benefits =				
	23% - Grand	100%	91%	(6+7)- (2+3+4+5)	984	49	-25	
2A	Sewage Treatment:	Same as Plan 1A	Montrose Reservoir	1) STP-CAS+Guelph RBC	379	94	54	
	Kitchener - Nitrification,		Dykes in New Hamburg	2) STP-New Facilities	68	17	10	
	Filtration, 2001			3) Water Supply	38	14	9	
	Waterloo - Nitrification,			4) Reservoirs	46	42	41	
	Filtration, 2021			5) Other Flood Prot.	1	1	1	
	Guelph - Chemical Treatment			6) Water Sup. Benefits	1078	107	26	
	and Multi-Media			7) Flood Prot. Benefits	27/28**	9	5	
	Filtration, 1981			8) Net Benefits =	952/			
	Flow Augmentation:			(6+7) - (2+3+4+5)	953	42	-30	
	Montrose Reservoir							
	40% - Speed / 58% - Grand	100%	54% / 56%					
2B	Same as Plan 2A	Same as Plan 1A	Montrose Reservoir	1) STP-CAS+Guelph RBC	379	94	54	
			Dykes and Channel	2) STP-New Facilities	68	17	10	
	Flow Augmentation:		Works same as	3) Water Supply	38	14	9	
	Montrose Reservoir		Plan 1A	4) Reservoirs	46	42	41	
				5) Other Flood Prot.	25	24	23	
				6) Water Sup. Benefits	1078	107	26	
	28% - Speed			7) Flood Prot. Benefits	48	15	9	
	58% - Grand	100%	96%	8) Net Benefits =				
				(6+7) - (2+3+4+5)	949	25	-48	
2C	Same as Plan 2A	Same as Plan 1A	Montrose Reservoir	1) STP-CAS+Guelph RBC	379	94	54	
			Dykes and Channel	2) STP-New Facilities	68	17	10	
	Flow Augmentation:		Works (lower elevation than	3) Water Supply	38	14	9	
	Montrose Reservoir		Plan 2B)	4) Reservoirs	46	42	41	
				5) Other Flood Prot.	20	19	18	
				6) Water Sup. Benefits	1078	107	26	
	28% - Speed			7) Flood Prot. Benefits	38	12	7	
	58% - Grand	100%	76%	8) Net Benefits =				
				(6+7) - (2+3+4+5)	944	27	-45	

Note: Percent figures refer to % of objective achieved; except where noted the objectives are: Water Quality - meet a water quality index of 0.0 on the Grand river and on the Speed river; Water Supply = Max. Day Demand; Flood Damage Reduction = zero average annual damages.

* It was assumed that the land acquired for the Montrose reservoir would be sold in the year 2001.

** A range of flood damage benefits is given for multi-purpose reservoirs. This range reflects variations in the assumed storage volume available in the spring to retain flood flows. Storage volumes will vary with the time of year and the operating rules used for each reservoir.

Table B.2 Summary of Preliminary Water Management Plans For A Medium Population Projection (Cont'd)

(Costs and Benefits are in Millions of 1979 Dollars).

PLAN	PLAN DESCRIPTION:			PRESENT VALUE OF BENEFITS & COSTS				NOTES
	WATER QUALITY	WATER SUPPLY	FLOOD PREVENTION	ITEM	DISCOUNT RATE			
					0%	6%	10%	
	Same as Plan 2A	Reservoir Pipeline:	Montrose Reservoir	1) STP-CAS+Guelph RBC	367	90	53	
		Kitchener, Waterloo,	Dykes in New Hamburg	2) STP-New Facilities	77	30	23	Net benefits include savings in cost Item 1). Lower costs result from reduced hydraulic STP load caused by water demand falling in response to a higher water price.
	Flow Augmentation:	Cambridge		3) Water Supply	111	69	62	
2D	Montrose Reservoir	Ground Water:		4) Reservoirs	46	42	41	
		Guelph		5) Other Flood Prot.	0	0	0	
		Surface Water:		6) Water Sup. Benefits	918	80	15	
		Brantford		7) Flood Prot. Benefits	27/28*	9	5	
	28% - Speed			8) Net Benefits =	711/			
	58% - Grand	100%	54% / 56%	(6+7) - (2+3+4+5)	712	-52	-106	
	Same as Plan 2A	Same as Plan 1A	Montrose Single-Purpose	1) STP-CAS+Guelph RBC	379	94	54	
			Reservoir	2) STP-New Facilities	77	30	23	
			24.7 million cubic metres	3) Water Supply	38	14	9	
2E			(20,000 acre feet)	4) Reservoirs	46	42	41	
				5) Other Flood Prot.	1	1	1	
			Dykes in New Hamburg	6) Water Sup. Benefits	1078	107	26	
	28% - Speed		8)	7) Flood Prot. Benefits	27/28*	9	5	
	58% - Grand	100%	54% / 56%	8) Net Benefits =	943/			
				(6+7) - (2+3+4+5)	944	29	-43	
	Same as Plan 1A	Same as Plan 1A	Wallenstein Reservoir	1) STP-CAS + Guelph RBC	379	94	54	
				2) STP-New Facilities	77	30	23	
	Flow Augmentation:		Dykes in New Hamburg	3) Water Supply	38	14	9	
3	Wallenstein Reservoir			4) Reservoirs	36	33	31	
				5) Other Flood Prot.	1	1	1	
				6) Water Sup. Benefits	1078	107	26	
	28% - Speed			7) Flood Prot. Benefits	10	3	2	
	32% - Grand	100%	20%	8) Net Benefits =				
				(6+7) - (2+3+4+5)	936	32	-36	
	Same as Plan 1A	Same as Plan 1A	Wallenstein Reservoir	1) STP-CAS+Guelph RBC	379	94	54	
			Salem Single-Purpose	2) STP-New Facilities	77	30	23	
	Flow Augmentation:		Reservoir	3) Water Supply	38	14	9	
4	Wallenstein Reservoir			4) Reservoirs	60	55	53	
				5) Other Flood Prot,	1	1	1	
				6) Water Sup. Benefits	1078	107	26	
	28% - Speed			7) Flood Prot. Benefits	23	7	4	
	32% - Grand	100%	46%	8) Net Benefits =				
				(6+7) - (2+3+4+5)	925	14	-56	

Note: Percent figures refer to % of objective achieved; except where noted the objectives are: Water Quality - meet a water quality index of 0.0 on the Grand river and on the Speed river; Water Supply = Max. Day Demand; Flood Damage Reduction = zero average annual damages.

* A range of flood damage benefits is given for multi-purpose reservoirs, This range reflects variations in the assumed storage volume available in the spring to retain flood flows. Storage volumes will vary with the time of year and the operating rules used for each reservoir.

Table B.2 Summary of Preliminary Water Management Plans For A Medium Population Projection (Cont'd).

(Costs and Benefits are in Millions of 1979 Dollars)

PLAN	PLAN DESCRIPTION:			PRESENT VALUE OF BENEFITS & COSTS				NOTES
					DISCOUNT RATE			
PLAN	WATER QUALITY	WATER SUPPLY	FLOOD PREVENTION	ITEM	0%	6%	10%	
5	Same as Plan 1A	Ayr Reservoir	Ayr Reservoir on	1) STP-CAS + Guelph RBC	379	94	54	
		Pipeline:	Nith River	2) STP-New Facilities	77	30	23	
		Kitchener, Waterloo		3) Water Supply	131	72	63	
		Cambridge	Dykes in New Hamburg	4) Reservoirs	40	36	35	
		Ground Water:		5) Other Flood Prot.	0	0	0	
		Guelph		6) Water Sup. Benefits	894	76	14	
	28% - Speed			7) Flood Prot. Benefits	1	0.4	0.3	
	23% - Grand	100%	3%	8) Net Benefits =				
				(6+7) - (2+3+4+5)	647	-62	-107	
6	Same as Plan 1A	Lake Erie Pipeline:	Same as Plan 1A	1) STP-CAS+Guelph RBC	348	89	52	
		Brantford, Cambridge,		2) STP-New Facilities	75	29	22	
		Kitchener, Waterloo		3) Water Supply	553	278	230	
		Ground Water:		4) Reservoirs	0	0	0	
		Guelph		5) Other Flood Prot.	25	24	23	
				6) Water Sup. Benefits	825	66	9	
	28% - Speed			7) Flood Prot. Benefits	46	14	9	
	23% - Grand	100%	91%	8) Net Benefits =				
				(6+7) - (2+3+4+5)	218	-251	-257	
7A	No new sewage treatment	Ground Water:	None	1) STP-CAS + Guelph RBC	231	67	40	Population growth is stopped if water quality criteria are violated or if water supply capacities from conventional sources are exceeded.
	methods	Cambridge		2) STP-New Facilities	0	0	0	
		Surface Water:		3) Water Supply	15	4	2	
		Brantford		4) Reservoirs	0	0	0	
		100% up to:		5) Other Flood Prot.	0	0	0	
		1981 - Kitchener		6) Water Sup. Benefits	127	7	-2	
		Waterloo, Guelph		7) Flood Prot. Benefits	0	0	0	
	0%	2021 - Cambridge	0%	8) Net Benefits =				
		2031 - Brantford		(6+7) - (2+3+4+5)	112	3	-4	
7B	No new sewage treatment	Ground Water:	None	1) STP-CAS+Guelph RBC	310	82	47	Population growth is stopped if water supply capacities from conventional sources are exceeded. Water quality is not impaired.
	methods	Kitchener, Waterloo,		2) STP-New Facilities	0	0	0	
		Cambridge, Guelph		3) Water Supply	26	8	4	
		Surface Water:		4) Reservoirs	0	0	0	
		Brantford		5) Other Flood Prot.	0	0	0	
		100% up to:		6) Water Sup. Benefits	399	33	5	
		1991 - Kitchener, Waterloo		7) Flood Prot. Benefits 8) Net Benefits =	0	0	0	
	0%	2021 - Cambridge	0%	(6+7) - (2+3+4+5)	373	25	1	
		2031 - Brantford, Guelph						

Note: Percent figures refer to % of objective achieved; except where noted the objectives are: Water Quality - meet a water quality index of 0.0 on the Grand river and on the Speed river; Water Supply = Max. Day Demand; Flood Damage Reduction = zero average annual damages.

Table B.2 Summary of Preliminary Water Management Plans For A Medium Population Protection (Cont'd).

(Costs and Benefits are in Millions of 1979 Dollars)

PLAN	PLAN DESCRIPTION:			PRESENT VALUE OF BENEFITS & COSTS				NOTES
	WATER QUALITY	WATER SUPPLY	FLOOD PREVENTION	ITEM	DISCOUNT RATE			
					0%	6%	10%	
8A	Same as Plan 1A	Same as Plan 1A except demand is reduced by moderate water conservation as in Plan 1F	Flood Proofing	1) STP-CAS+Guelph RBC	339	87	50	Refer to notes for Plan 1F.
				2) STP-New Facilities	70	28	22	
				3) Water Supply	35	10	5	
				4) Reservoirs	0	0	0	
				5) Other Flood Prot.	2	2	2	
				6) Water Sup. Benefits	734	66	13	
	28% - Speed			7) Flood Prot, Benefits	10	3	2	
	23% - Grand	100%	20%	8) Net Benefits =				
				(6+71 - (2+3+4+5)	637	29	-14	
8B	Same as Plan 1A	Ground Water:	Flood Proofing	1) STP-CAS+Guelph RBC	298	79	46	Implementation date for water supply projects deferred by 10- 30 years using extreme conservation measures. STP costs in Item 1) are also reduced.
		Cambridge, Guelph		2) STP-New Facilities	63	27	21	
		Surface Water:		3) Water Supply	30	7	3	
		Kitchener, Waterloo		4) Reservoirs	0	0	0	
		Brantford		5) Other Flood Prot.	2	2	2	
		Water Conservation:		6) Water Sup. Benefits	287	18	1	
	28% - Speed	Ave. Day reduced 20%		7) Flood Prot. Benefits	10	3	2	
	23% - Grand	Max. Day reduced 23%		8) Net Benefits =				
		100%	20%	(6+7) - (2+3+4+5)	202	-15	-23	
9A	No new sewage treatment methods	Same as Plan 1A	Same as Plan 1A	1) STP-CAS+Guelph RBC	379	94	54	Water quality deteriorates with growing population.
				2) STP-New Facilities	0	0	0	
				3) Water Supply	38	14	9	
				4) Reservoirs	0	0	0	
				5) Other Flood Prot.	25	24	23	
				6) Water Sup. Benefits	1078	107	26	
	0% - Speed			7) Flood Prot. Benefits	46	14	9	
	0% - Grand	100%	91%	8) Net Benefits =				
				(6+7) - (2+3+4+5)	1061	83	3	
9B	Sewage Treatment:	Same as Plan 1A	Montrose Reservoir	1) STP-CAS + Guelph RBC	379	94	54	Best water quality on the Grand River and Speed River is achieved by this plan.
	Kitchener - ACA, 1981			2) STP-New Facilities	227	90	70	
	Waterloo - Filter, 1981			3) Water Supply	38	14	9	
	Guelph - Chemical Filter, 1981			4) Reservoirs	65	59	57	
	Flow Augmentation:			5) Other Flood Prot.	1	1	1	
	Montrose, Everton			6) Water Sup. Benefits	1078	107	26	
	Reservoirs			7) Flood Prot. Benefits	27/28*	9	5	
	69% - Speed			8) Net Benefits =	774/			
	90% - Grand	100%	51% / 57%	(6+7) - (2+3+4+5)	775	-48	-106	

Note: Percent figures refer to % of objective achieved; except where noted the objectives are: Water Quality = meet a water quality index of 0.0 on the Grand river and on the Speed river; Water Supply = Max. Day Demand; Flood Damage Reduction = zero average annual damages.
A range of flood damage benefits is given for multi-purpose reservoirs. This range reflects variations in the assumed storage volume available in the spring to retain flood flows. Storage volumes will vary with the time of year and the operating rules used for each reservoir.

Table B.2 Summary of Preliminary Water Management Plans For A Medium Population Projection (Cont'd).

(Costs and Benefits are in Millions of 1979 Dollars)

PLAN	PLAN DESCRIPTION:			PRESENT VALUE OF BENEFITS & COSTS				NOTES
	WATER QUALITY	WATER SUPPLY	FLOOD PREVENTION	ITEM	DISCOUNT RATE			
					0%	6%	10%	
10	Same as Plan 1A	Same as Plan 1A	St. Jacobs Single-Purpose Reservoir	1) STP-CAS+Guelph RBC	379	94	54	
				2) STP-New Facilities	77	30	23	
			Dykes in New Hamburg	3) Water Supply	38	14	9	
				4) Reservoirs	26	25	24	
				5) Other Flood Prot.	1	1	1	
				6) Water Sup. Benefits	1078	107	26	
	28% - Speed			7) Flood Prot. Benefits	25/26*	8	5	
	23% - Grand	100%	49% / 50%	8) Net Benefits = (6+7) - (2+3+4+5)	961/ 962	45	-26	
11	Same as Plan 1A	Same as Plan 1A	Wallenstein Reservoir	1) STP-CAS+Guelph RBC	379	94	54	Single-purpose or dry reservoirs are used for flood control only. Reservoirs remain dry during non-flood periods.
			Single-Purpose Reservoirs at:	2) STP-New Facilities	77	30	23	
			Salem	3) Water Supply	38	14	9	
			St. Jacobs	4) Reservoirs	126	116	111	
			Freeport	5) Other Flood Prot.	1	1	1	
			Dykes in New Hamburg	6) Water Sup. Benefits	1078	107	26	
	28% - Speed			7) Flood Prot. Benefits	30	9	6	
	32% - Grand	100%	61%	8) Net Benefits = (6+7) - (2+3+4+5)	866	49	-112	

Note: Percent figures refer to % of objective achieved; except where noted the objectives are: Water Quality = meet a water quality index of 0.0 on the Grand river and on the Speed river; Water Supply = Max. Day Demand; Flood Damage Reduction = zero average annual damages.

* A range of flood damage benefits is given for multi-purpose reservoirs. This range reflects variations in the assumed storage volume available in the spring to retain flood flows. Storage volumes will vary with the time of year and the operating rules used for each reservoir.

Table B.3 Description of Water Management Objectives

OBJECTIVE	WATER QUALITY	WATER SUPPLY	FLOODING
DESCRIPTION	Maintain adequate dissolved oxygen levels with minimum values never falling below 4.0 mg/L.	Satisfy average and maximum day demand.	Eliminate or reduce average annual flood damages.
MEASUREMENT OF % CHANGE	% Reduction in water quality D.O. index. This index is a function of non-compliance with the provincial water quality objectives, frequency of violation in any one month and length of stream in violation.	% Satisfaction of water demand.	% Reduction in average annual damages.

B.2 Evaluation and Selection of Water Management Plans

The next step after creating the twenty-six water management plans was the selection of the preferred plans. This was done in two stages: the first stage consisted of a preliminary screening of the plans to reduce the twenty-six plans to a more manageable number and the second stage consisted of selecting from this reduced number of plans, one or more preferred plans.

The preliminary screening process involved a series of evaluations which eliminated less optimal plans from further consideration. Each plan was evaluated in terms of how well it achieved the study objectives, costs and environmental and social impacts. This evaluation process reduced the number of plans to four main plans.

In the second stage, evaluations for the selection of the preferred plan were first carried out by the technical members of the basin study team and the public consultation working groups (Appendix A). The study team narrowed the plan selection from four to two preferred plans by a voting and discussion process. Similarly, each of the four public consultation working groups selected a preferred plan.

The results from the study team and the public consultation working groups were then submitted to the Grand River Implementation Committee for a final selection. After a detailed review of the four main plans and their various options, the committee identified a single plan as the preferred plan to meet the water management needs of the basin.

The following sections describe the preliminary screening and final selection process in more detail. A flow diagram, Figure B.1 describes the evaluation process and the interaction among the various groups.

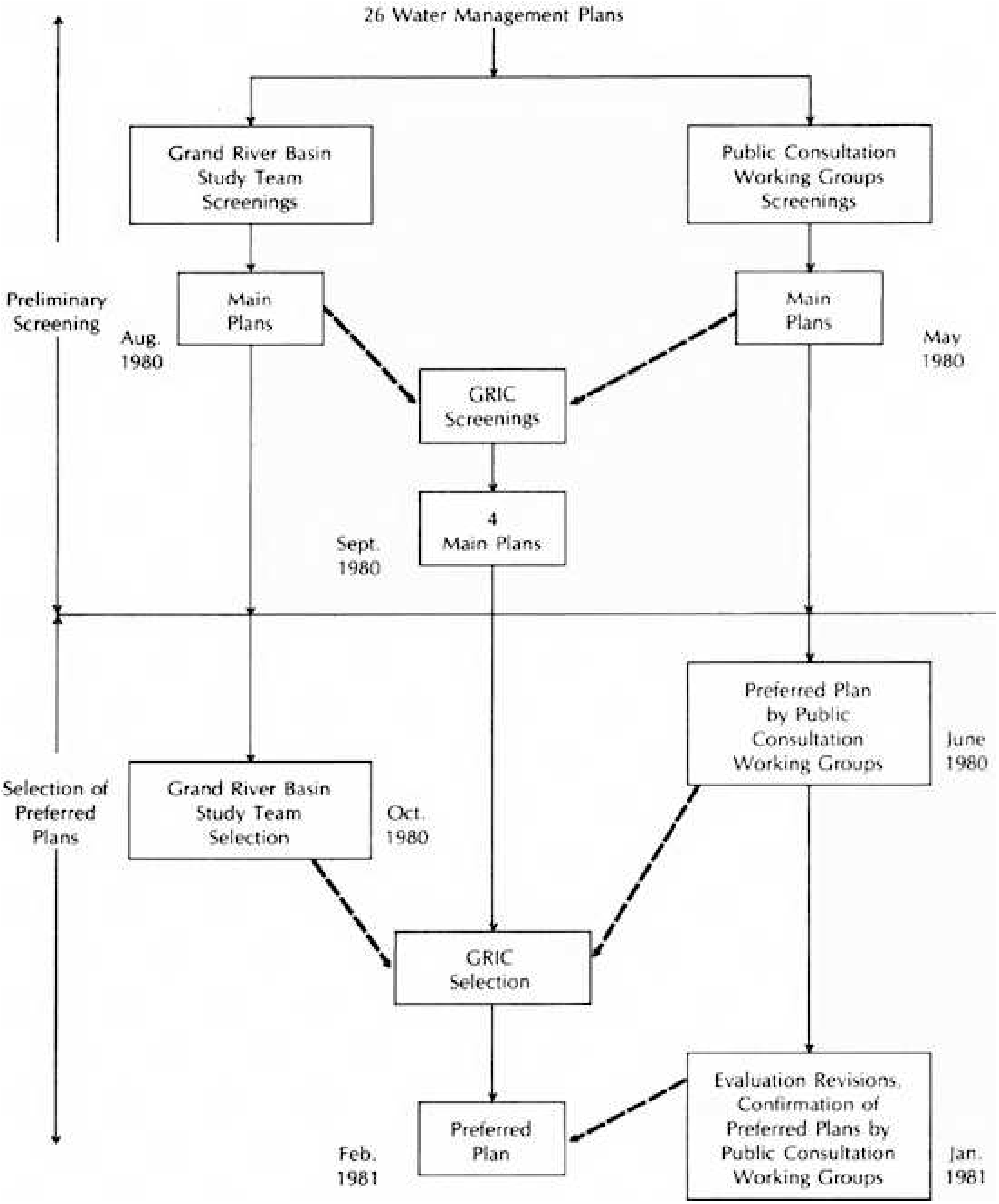


Fig. B.1 A flow diagram describing the evaluation process used in the selection of the preferred plan.

B.2.1 Preliminary Screening

Study Team Evaluation

The initial preliminary screening was carried out using an evaluation matrix which compared plan costs, environmental and social impacts and how satisfactorily each plan fulfilled the objectives. The details of this process are described in Appendix B.3 and the results are summarized on Table B.4. The matrix process eliminated seven plans, reducing the viable number of plans from twenty-six to eighteen plans. In a series of meetings, the basin study team evaluated the matrix results and weighed the pros and cons of each plan.

As a result of these meetings, an additional four plans were eliminated (plans 8B, 9A, 2D and 2C) and two plans (plans 1C and 1F) were incorporated into plan IA. The reasons for eliminating the four plans are summarized in Table B.4.

Table B.4 Summary of Preliminary Screening by the Basin Study Team and GRIC.

Plan	Accepted	Rejected	Incorp. With 1A	Reasons
1A	X			Meets all objectives with minimum social and environmental impacts.
1B		X		Salem reservoir only reduces flood damages 28 to 36% — rates only fair in meeting objective.
1C			X	Flood proofing by itself only offers limited flood reduction. However, flood proofing will be included in general flood reduction package to be applied to all plans.
1D		X		No flood damage reduction.
1E		O		Cost of land acquisition by itself is too expensive. However, land acquisition will be included in general flood reduction package to be applied in specific instances where it is the most economic solution.
1F			X	Water conservation will be included in plan 1A.
1G	X			The Everton reservoir can provide the highest water quality in the Speed river below Guelph. It will also augment the Arkell recharge water supply system for the City of Guelph.

O Rejected by evaluation matrix results
X Decision of study team and GRIC

Table 8.4 (Continued)

Plan	Accepted	Rejected	Incorp. With 1A	Reasons
1H		O		Ranks poor in meeting flood reduction objective. The Nithburg reservoir is not effective in reducing flood damage on the Grand river. The Nithburg reservoir will he reviewed for its effect on the Nith river.
1i			X	The concept of Montrose reservoir land purchase has been expanded to include the optimum (Montrose or other) reservoir. Also, it reservoir is not needed in the future, the land can be sold.
2A	X			Meets all objectives — incorporated with plan 2B.
2B	X			
2C		X		Inefficient in flood protection.
2D		X		The Mannheim recharge scheme will provide water to Kitchener-Waterloo area at a cheaper rate than this plan (pipeline from Montrose reservoir). However, this scheme provides an alternative if the Mannheim scheme does not prove feasible.
2E	X			Will be considered as a single-purpose reservoir if it is more effective than the St. Jacobs single-purpose reservoir.
3		O		Poor flood reduction.
4		X		Less flood protection at a greater cost than the Montrose reservoir.
5		O		Poor flood damage reduction, high environmental and social impact.

O Rejected by evaluation matrix results
X Decision of study team and GRC

Table 8.4 (Continued)

Plan	Accepted	Rejected	Incorp. With 1A	Reasons
6	X			While the pipeline is extremely expensive, it has a minimum environmental and social impact. In addition, it has been a historical alternative.
7A		O		Water quality constraints limit urban growth
7B		O		Allows water quality to degrade, water supply constraints limit urban growth.
8A			X	No flood damage reduction; water conservation incorporated in plan 1A.
8B		X		Water conservation objectives unrealistic.
9A			X	The option of maintaining existing water quality conditions but allowing no degradation will be examined in Plan 1.
9B		X		The effect of increasing water quality in the Grand river and the Speed rivers will be examined in plans 1 and 2.
10	X			St. Jacobs as a single-purpose reservoir is almost as efficient as a Montrose reservoir in reducing flood damages.
11		O		High social and environmental impacts — costly.

O Rejected by Evaluation Matrix Results
X Decision of study team and GRIC

Public Consultation Working Groups' Preliminary Screenings

In a series of meetings, the four public consultation working groups selected ten plans (1A, 1C, 1E, 2A, 2B, 2C, 2D, 6, 8, and 9B) for further study and suggested eight additional options to be included with the preferred plans. The plans and additional variations required are shown in Table B.5. This was an informal screening held prior to the screening by the study team. Several of the suggestions made by the working groups to the study team were incorporated into the preliminary plans prior to screening by the study team.

For the preliminary screening, the protection of Montrose reservoir lands, plan 1I was not an option and therefore, the working groups did not react to it. Plan 11 (later called plan A4), was formulated after the identification of preferred plans by the working groups. However, they were given an opportunity to confirm their original selections in a later meeting held in January, 1981 prior to GRIC's final selection.

Table B.5 Preliminary Screening by Public Consultation Working Groups.

Upper:	**Preferred Plans** Plan 1A with Salem reservoir Plan 1A — calculate cost benefit of various flow augmentation management techniques using the existing reservoir system **Additions to Plans** flood damage — combine channelization and dyking, flood proofing, reduction: floodplain and wetland acquisition water quality:— improve sewage treatment, provide urban and rural runoff controls water supply:— increase supply by using groundwater aquifers rather than reservoirs or pipelines
Mid-Upper:	**Preferred Plans** Plans 1A, 8, 1E, 6, 2B, 1C **Additions to Plans** Plan 1A with water conservation Plan 1A with sewage treatment as in plan 8
Mid-Lower:	**Preferred Plans** Plan 1A Plan 1E — investigate social and environmental benefits gained from flood- plain acquisition Plans 2B and 2C — with some reservations concerning social impacts re: Montrose reservoir **Additions to Plans** Plan 1E with Nithburg reservoir and water conservation reservoirs at Salem and Everton Reservoir at Ayr with pipeline to Kitchener-Waterloo Enlarge Shand dam Plan 1A with floodplain acquisition and water conservation Incorporate flood proofing with preferred plans
Lower:	**Preferred Plans** Plans 1A, 2A, 2B, 2C, 2E, 6, 8 and 9B **Additions to Plans** Plan 1A — add channelization and dyking or flood proofing at Cayuga

GRIC Preliminary Screenings

The Grand River Implementation Committee then reviewed the plans recommended for further evaluation by the study team and the four public consultation working groups. In discussion sessions, GRIC eliminated three additional plans (1B, 1D and 9B). Two plans (8A and 9A) were incorporated with plan 1A. Plan 9A had been previously rejected by the study team.

Summary of Preliminary Screening

Based on the preliminary screening results from the basin study team and public consultation working groups, four main plans evolved. Selected features of the previous twenty-six plans were combined as options of the four plans. A brief description of each plan and its reference to the previous twenty-six plans is given in the following table.

Main Plan	Description	Incorporates Features of the Following Plans
A	Dykes and channelization, advanced sewage treatment, local sources of water supply.	1A, 1C, 1F,1I, 1G, 8A
B	Montrose reservoir, advanced sewage treatment, local sources of water supply.	2A, 2B, 1G,1F, 8A
C	Dry reservoir for flood control advanced sewage treatment, local sources of water supply.	2E, 10
D	Lake Erie pipeline, advanced sewage treatment, dykes and channelization.	6

A summary of the plans and their options illustrating costs and benefits for a low low, low and high population projection is shown in Tables B.6, 8.7 and B.8. Chapter 10 describes plan costs and benefits for a medium population projection.

Table B.6 Summary Table of Costs and Benefits For Main Plans — Low Low Population Projection.

(Millions of 1979 Dollars)

	PLAN DESCRIPTION			PRESENT VALUE OF BENEFITS & COSTS			
PLAN	WATER QUALITY	WATER SUPPLY	FLOOD DAMAGE REDUCTION	ITEM	DISCOUNT RATE		
					0%	6%	10%
A Option 1	Sewage Treatment: Kitchener - Nitrification, Filtration 1981 Guelph - Chemical Treatment and Multi-Media Filtration 1981	Ground Water: Cambridge, Guelph Surface Water: Kitchener-Waterloo 2001 Cambridge connect to Kitchener-Waterloo 2021	Dykes and Channelization: Preston, Galt, Paris, Brantford, Dunnville, Caledonia, New Hamburg	1) STP-CAS+ Guelph RBC	260	75	46
				2) STP-New Facilities	45	24	20
				3) Water Supply	26	8	4
				4) Reservoirs	0	0	0
				5) Other Flood Prot.	25	24	23
				6) Water Sup. Benefits	130	5	-4
				7) Flood Prot. Benefits	46	14	9
	28% - Speed 23% - Grand	100%	91%	8) Net Benefits = (6+7) - (2+3+4+5)	80	- 37	-42
A Option 2	Same as Plan A, Option 1	Ground Water: Guelph Surface Water: Kitchener-Waterloo 1996 Cambridge connects to Kitchener-Waterloo, 1991	Same as Plan A. Option I	1) STP-CAS+Guelph RBC	260	75	46
				2) STP-New Facilities	45	24	20
				3) Water Supply	27	8	4
				4) Reservoirs	0	0	0
				5) Other Flood Prot.	25	24	23
				6) Water Sup. Benefits	127	4	-4
	28% - Speed			7) Flood Prot. Benefits	46	14	9
	23% - Grand	100%	91%	8) Net Benefits = (6+7)- (2+3+4+5)	76	-38	-42
A Option 3	Same as Plan A. Option 1 Flow Augmentation on Speed River from Everton Reservoir	Same as Plan A. Option 1	Same as Plan A. Option I	1) STP-CAS + Guelph RBC	260	75	46
				2) STP-New Facilities	45	24	20
				3) Water Supply	26	8	4
				4) Reservoirs	17	6	15
				5) Other Flood Prot.	25	24	23
				6) Water Sup. Benefits	130	5	-4
	69% - Speed			7) Flood Prot. Benefits	46	14	9
	23% - Grand	100%	91%	8) Net Benefits = (6+7) - (2+3+4+5)	63	-53	-57
A Option 4	Same as Plan A. Option 1 Possible future augmentation on Grand River from Montrose Reservoir	Same as Plan A Option	same as Plan A, Option 1 Acquire Montrose Reservoir land for possible future use	1) STP-CAS+Guelph RBC	260	75	46
				2) STP-New Facilities	45	24	20
				3) Water Supply	26	8	4
				4) Reservoir Land	0*	4*	5*
				5) Other Flood Prot.	25	24	23
				6) Water Sup. Benefits	130	5	-4
	28% - Speed			7) Flood Prot, Benefits	46	14	9
	23% - Grand	100%	91%	8) Net Benefits = (6+7)-(2+3+4+5)	80	-41	-47

Note: Percent figures refer to % of objectives achieved, except where noted the objectives are: Water Quality = meet a water quality index of 0.0 on the Grand over and on (he Speed river:
Water Supply = Max. Day Demand. Flood Damage Reduction = zero average annual damages.

* For purposes of economic analysis t was assumed that the land acquired for the Montrose reservoir would be sold in the year 2001.

Table B.6 Summary Table of Costs and Benefits For Main Plans — Low Low Population Projection. (Cont'd)
(Millions of 1979 Dollars)

	PLAN DESCRIPTION:			PRESENT VALUE OF BENEFITS & COSTS			
					DISCOUNT RATE		
PLAN	WATER QUALITY	WATER SUPPLY	FLOOD DAMAGE REDUCTION	ITEM	0%	6%	10%
	Sewage Treatment:			1) STP-CAS+Guelph ROC	260	75	46
	Kitchener - Nitri-	Same as Plan A,	Montrose Reservoir	2) STP-New Facilities	41	13	9
	fication, Filtration	Option 1	Dykes in New Hamburg	3) Water Supply	26	8	4
B	2001			4) Reservoirs	46	42	41
	Guelph - Chemical			5) Other Flood Prot.	1	1	1
Option	Treatment and Multi-			6) Water Sup. Benefits	130	5	-4
1	Media Filtration			7) Flood Prot. Benefits	27/28*	9	5
	1981	100%	54% / 36%	8) Net Benefits =			
	Flow Augmentation:			(6+7) - (2+3+4+5)	43/44	-50	-54
	Montrose Reservoir						
	28% - Speed; 58% Grand						
	Same as Plan B,	Same as Plan A.	Montrose Reservoir	1) STP-CAS+Guelph RBC	260	75	46
	Option 1	Option 1	Dykes and Channel	2) STP-New Facilities	41	13	9
			Works same as Plan	3) Water Supply	26	8	4
B			A, Option 1	4) Reservoirs	46	42	41
				5) Other Flood Prot.	25	24	23
Option				6) Water Sup. Benefits	130	5	-4
2	28% - Speed			7) Flood Prot. Benefits	48	15	9
	58% - Grand	100%	96%	8) Net Benefits =			
				(6+71 - (2+3+4+5)	40	-67	-72
	Same as Plan A.	Same as Plan A.	St. Jacobs Single- Purpose	1) STP-CAS+Guelph RBC	260	75	46
	Option 1	Option 1	Reservoir	2) STP-New Facilities	45	24	20
			Dykes in New Hamburg	3) Water Supply	26	8	4
C				4) Reservoirs	26	25	24
				5) Other Flood Prot.	1	1	1
Option				6) Water Sup. Benefits	130	5	-4
1	28% - Speed			7) Flood Prot. Benefits	46	14	9
	23% - Grand	100%	49% / 50%	8) Net Benefits =			
				(6+7) - (2+3+4+5)	78	-39	-44
	Same as Plan A,	Same as Plan A.	Montrose Single- Purpose	1) STP-CAS+Guelph RBC	260	75	46
	Option 1	Option 1	Reservoir	2) STP-New Facilities	45	24	20
			24.7 million cu. metres	3) Water Supply	26	8	4
C			(20,000 acre feet)	4) Reservoirs	30	28	27
			Dykes in New Hamburg	5) Other Flood Prot.	1	1	1
Option				6) Water Sup. Benefits	130	5	-4
2	28% - Speed			7) Flood Prot, Benefits	27/28*	9	5
	23% - Grand	100%	54%! 56%	8) Net Benefits =			
				(6+7)- (2+3+4+5)	55/56	-47	-51
	Same as Plan A,	Same as Plan A,	Montrose Single- Purpose	1) STP-CAS+Guelph RBC	260	75	46
	Option 1	Option 1	Reservoir	2) STP-New Facilities	45	24	20
C			77.7 million cu. metres	3) Water Supply	26	8	4
				4) Reservoirs	46	42	41
Option			(63,000 acre feet)	5} Other Flood Prot.	1	1	1
3	28% - Speed		Dykes in New Hamburg	6} Water Sup. Benefits	130	5	-4
	23% - Grand	100%	56% / 57%	7} Flood Prot. Benefits	27/28*	9	5
				8) Net Benefits =			
				(6+7) - (2+3+4+5)	39/40	-61	-65
	Same as Plan A.	Lake Erie Pipeline	Same as Plan A,	1) STP-CAS+Guelph RBC	250	73	45
	Option 1	Kitchener-Waterloo	Option 1	2) STP-New Facilities	40	13	8
		Cambridge,		3) Water Supply	455	234	194
D		Brantford		4) Reservoirs	0	0	0
		Ground Water:		5) Other Flood Prot.	25	24	23
		Guelph		6) Water Sup. Benefits	2	-15	-11
	28% - Speed		91%	7) Flood Prot. Benefits	46	14	9
	23% - Grand	100%		8) Net Benefits =			
				(6+7) - (2+3+4+5)**	-472	-272	-227

Note: Percent figures refer to % of objective achieved; except where noted the objectives are: Water Quality = meet a water quality index of 0.0 on the Grand river and on the Speed river; Water Supply = Max. Day Demand; Flood Damage Reduction = zero average annual damages.

* A range of flood damage benefits is given for multi-purpose reservoirs. This range reflects variations in the assumed storage volume available in the spring to retain flood flows. Storage volumes will vary with the time of year and the operating rules used for each reservoir.

** Net benefits include savings in cost Item 1 over Plan A. These savings arise due to a reduced STP hydraulic load brought about by price induced reductions in water demand.

Table 8.7 Summary Table of Costs and Benefits For Main Plans — Low Population Projection.

(Millions of 1979 Dollars)

	PLAN DESCRIPTION:			PRESENT VALUE OF BENEFITS & Costs			
PLAN	WATER QUALITY	WATER SUPPLY	FLOOD DAMAGE REDUCTION	ITEM	DISCOUNT RAIL		
					0%	6%	10%
	Sewage Treatment:						
	Kitchener - Nitrification.	Ground Water:	Dykes and Channel Works	1) STP-CAS+Guelph RBC	269	77	47
	Filtration	Cambridge. Guelph	Preston, Galt,	2) STP-New Facilities	55	26	20
	2006	Surface Water:	Paris, Brantford,	3) Water Supply	32	12	8
A	Waterloo - Nitrification	Kitchener-Waterloo	Caledonia, Dunnville,	4) Reservoirs	0	0	0
	Filtration	1991	New Hamburg	5) Other Flood Prot.	25	24	23
	1981			6) Water Sup. Benefits	210	20	2
Option 1	Guelph - Chemical Treatment and Multi-			7) Flood Prot. Benefits	46	14	9
				8) Net Benefits =			
	Media Filtration			(6+7) - (2+3+4+5)	144	-28	-40
	1981	100%	91%				
	28% - Speed						
	23% - Grand						
	Same as Plan A,	Ground Water:	Same as Plan A	1) STP-CAS+ Guelph RBC	269	77	47
	Option I	Guelph	Option 1	2) SIP-New Facilities	55	26	20
		Surface Water.		3) Water Supply	28	11	7
A		Kitchener-Waterloo		4) Reservoirs	0	0	0
		1991		5) Other Flood Prot.	25	24	21
Option 2		Cambridge connects		6) Water Sup. Benefits	208	19	2
	28% - Speed	to Kitchener-		7) Flood Prot. Benefits	46	14	9
	23% - Grand	Waterloo 1986	91%	8) Net Benefits =			
				(6+7) - (2+3+4+5)	146	-28	30
		100%					
	Same as Plan A,	Same as Plan A.	Same as Plan A.	1) STP-CAS+Guelph RBC	269	77	47
	Option I	Option 1	Option I	2) STP-New Facilities	55	26	20
	Flow Augmentation			3) Water Supply	32	12	8
A	on Speed River from			4) Reservoirs	17	16	15
	Everton Reservoir			5) Other Flood Prot.	25	24	23
Option 3				6) Water Sup. Benefits	210	20	2
	69%. Speed			7) Flood Prot. Benefits	46	14	9
	23% - Grand	100%	91%	8) Net Benefits =			
				(6+7) - (2+3+4+5)	127	-44	-55
	Same as Plan A,	Same as Plan A.	Same as Plan A.	1) STP-CAS + Guelph RBC	269	77	47
	Option 1	Option 1	Option 1	2) STP-New facilities	55	26	20
	Possible future augmen-		Acquire Montrose	3) Water Supply	32	12	8
A	ration on Grand River		Reservoir land for	4) Reservoir Land	0*	4*	5*
	from Montrose Reservoir		possible future use	5) Other Flood Prot.	25	24	21
Option 4				6) Water Sup. Benefits	210	20	2
	28% - Speed			7) Flood Prot. Benefits	46	14	4
	23% - Grand			8) Net Benefits =			
				(6+7) - (2+3+4+5)	144	-32	-45

Note: Percent figures refer to % of objective achieved; except where noted the objectives are: Water Quality = meet a water quality index of 0.0 on the Grand river and on the Speed river;
Water Supply = Max. Day Demand; Flood Damage Reduction = zero average annual damages.

* For purposes of economic analysis it was assumed that the land acquired for the Montrose reservoir would be sold in the year 2001.

Table B.7 Summary Table of Costs and Benefits For Main Plans — Low Population Projection (Cont'd).

(Millions of 1979 Dollars)

	PLAN DESCRIPTION:			PRESENT VALUE OF BENEFITS & COSTS			
PLAN	WATER QUALITY	WATER SUPPLY	FLOOD DAMAGE REDUCTION	ITEM	DISCOUNT RATE		
					0%	6%,	10%
	Sewage Treatment:			1) STP-CAS+Guelph RBC	379	94	54
	Kitchener -	Same as Plan A.	Montrose Reservoir	2) STP-New Facilities	68	17	10
	Nitrification, Filtration	Option 1	Dykes in Ness Hamburg	3) Water Supply	38	14	9
B	Waterloo - Nitrification			4) Reservoirs	46	42	41
	Filtration, 2021			5) Other Flood Prot,	1	1	1
Option	Guelph - Chemical			6) Water Sup. Benefits	1078	107	26
1	Treatment and Multi-			7) Flood Prot. Benefits	27/28*	9	5
	Media Filtration 1981	100%	54% / 56%	8) Net Benefits -	952/		
	Flow Augmentation: Montrose Reservoir			(6+7) - (2+3+4+5)	953	42	- 40
	28% -Speed; 58% -Grand						
	Same as Plan B.	Same as Plan A.	Montrose Reservoir	1)I STP-CAS + Guelph RBC	379	94	54
	Option 1	Option 1	Dykes and Channel	2) STP New Facilities	68	17	10
			Works same as in	3) Water Supply	38	14	9
B			Plan A. Option 1	4) Reservoirs	46	42	41
				5) Other Flood Prot.	25	24	23
				6) Water Sup. Benefits	1078	107	26
Option	28% - Speed			7) Flood Prot. Benefits	48	15	9
2	58% - Grand	100%	96%	81 Net Benefits - (6+7) - (2+3+4+5)	949	25	48
	same as Plan A.	Same as Plan A	St. Jacobs Single-Purpose	11 STP-CAS ''Guelph RBC	379	94	54
	Option 1	Option I	Reservoir	2) STP-New Facilities	77	30	23
			Dykes in Now Hamburg	3) Water Supply	38	14	9
				4) Reservoirs	26	25	24
				5) Other Flood Prot.	1	1	1
Option				6) Water Sup. Benefits	1078	107	26
1	28% - Speed			7) Flood Pro(. Benefits	25/26*	8	5
	23%- Grand	100%	49% 50%	8) Net Benefits =	961/		
				(6+7) - (2+3+4+5)	962	45	-26
	Same as Plan A,	Same as Plan A	Montrose Single Purpose	1) STP-CAS - Guelph RBC	379	94	54
	Option 1	Option 1	Reservoir	2) STP-New Facilities	77	30	23
			24.7 million cu. metres	3) Water Supply	38	14	9
C			120.000 acre feet	4) Reservoirs	30	28	27
Option			Dykes in Ness Hamburg	5) Other Flood Prot.	1	1	1
2				6) Water Sup. Benefits	1078	107	26
	28% - Speed			7) Floor) Prot. Benefits	27/28*	9	5
	23%- Grand	100%	54% 56%	8) Net Benefits =	959/		
				(6+7) - (2+3+4+5)	960	43	-29
	Same as Plan A,	Same as Plan A.	Montros$_e$ Single Purpose	1) STP-CAS+Guelph RBC	269	77	47
	Option 1	Option I	Reservoir	2) STP-New Facilities	55	26	20
		C3)	27.7 million cu. metres	3) Water Supply	32	12	8
				4) Reservoirs	46	42	41
Option			(63,00 acre feet)	5) Other Flood Prot.	1	1	1
3	28% - Speed		Dykes in New Hamburg	6) Water Sup. Benefits	210	20	2
	23% - Grand	100%	56% 57%	7) Flood Prot. Benefits	27/28*	9	5
				8) Net Benefits =	103/		
				(6+7) - (2+3+4+5)	104	-52	-63
	same as Plan A.	Lake Erie Pipeline	Same as Plan A,	1) STP-CAS+Guelph RBC	252	74	45
	Option I	Kitchener-Waterloo,	Option I	2) STP-New Facilities	55	26	20
		Cambridge,		3) Water Supply	471	238	196
D		Brantford		4) Reservoirs	0	0	0
		Ground Water		5) Other Flood Prot.	25	24	23
		Guelph		6) Water Sup. Benefits	47	-9	-10
	28% - Speed		91%	7) Flood Prot. Benefits	46	14	9
	23% - Grand	100%		8) Net Benefits -			
				(6+7) - (2+3+4+5)**	454	-283	-240

Note: Percent figures refer to % of objective achieved: except where noted the objectives are: Water Quality - meet a water quality index of 0.0 on the Grand river and on the Speed river; Water Supply - Max. Day Demand; Flood Damage Reduction - zero average annual damages.

* A range of flood damage benefits is given for multi-purpose reservoirs. This range reflects variations in the assumed storage volume available in the spring to retain flood flows. Storage volumes will vary with the time of year and the operating rules used for each reservoir.

** Net benefits include savings in cost item 1 over Plan A. These savings arise due (o a reduced STP hydraulic load brought about by price induced reductions in water demand.

Table 8.8 Summary Table of Costs and Benefits Far Main Plans — High Population Projection.

(Millions of 1979 Dollars)

PLAN	PLAN DESCRIPTION:			PRESENT VALUE OF BENEFITS & COSTS			
	WATER QUALITY	WATER SUPPLY	FLOOD DAMAGE REDUCTION	ITEM	DISCOUNT RATE		
					0%	6%	10%
	Sewage Treatment:						
	Waterloo - Nitrification, Filtration 2001	Ground Water: Cambridge, Guelph	Dykes and Channel Works	1) STP-CAS+Guelph RBC	449	115	66
				2) STP-New Facilities	85	32	24
		Surface Water: Kitchener-Waterloo 1991	Preston, Galt, Paris. Brantford, Caledonia, Dunnville, New Hamburg	3) Water Supply	47	17	10
A	Kitchener - Nitrification, Filtration 1981			4) Reservoirs	0	0	0
		Cambridge connects to Kitchener- Waterloo 2016		5) Other Flood Prot,	25	24	23
				6) Water Sup. Benefits	2125	205	52
Option 1	Guelph - Chemical Treatment and Multi-Media Filtration			7) Flood Prot. Benefits	46	14	9
				8) Net Benefits =			
				(6+7) - (2+3+4+5)	2014	146	4
	1981	100%	91%				
	2B% - Speed						
	23% - Grand						
	Same as Plan A. Option 1	Ground Water: Cambridge, Guelph	Same as Plan A, Option 1	1) STP-CAS+Guelph RBC	449	115	66
				2) STP-New Facilities	85	32	24
		Surface Water: Kitchener-Waterloo 1991		3) Water Supply	42	15	9
A				4) Reservoirs	0	0	0
		Cambridge Connects to Kitchener-Waterloo		5) Other Flood Prot.	25	24	23
Option 2				6) Water Sup. Benefits	2121	205	52
	28% - Speed			7) Flood Prot, Benefits	46	14	4
	23% - Grand	1986	91%	8) Net Benefits =			
				(6+7) - (2+3+4+5)	2015	148	5
			100%				
	Same as Plan A. Option 1	Same as Plan A, Option 1	Same as Plan A, Option 1	1) STP-CAS+Guelph RBC	449	115	66
				2) STP-New Facilities	85	32	24
	Flow Augmentation on Speed River From Everton Reservoir			3) Water Supply	47	17	10
A				4) Reservoirs	17	16	IS
				5) Other Flood Prot.	25	24	23
Option 3				6) Water Sup. Benefits	2125	205	52
	69% - Speed			7) Flood Prot. Benefits	46	14	9
	23% - Grand	100%	91%	8) Net Benefits =			
		.		(6+7) - (2+ 3+ 4+ 5)	1997	130	7
	Same as Plan A. Option 1	Same as Plan A, Option 1	Same as Plan A, Option 1	1) STP-CAS+Guelph RBC	449	115	66
				2) STP-New Facilities	85	12	24
	Possible future augmentation on Grand River from Montrose Reservoir		Acquire Montrose Reservoir land for possible future use	3) Water Supply	47	17	10
A				4)Reservoir Land	0*	4*	5*
				5) Other Flood Prot.	25	24	23
Option 4				6) Water Sup. Benefits	2125	105	51
	28% - Speed			7) Flood Prot. Benefits	46	14	4
	23% - Grand	100%	91%	8) Net Benefits =			
				(6+7)- (2+3+4+5)	1014	141	1

Note: Percent figures refer to % of objective achieved: except where noted the objectives are: Water Quality = meet a water quality index of 0.0 on the Grand river and on the Speed river;
Water Supply = Max. Day Demand; Flood Damage Reduction = zero average annual damages.

* For purposes of economic analysis it was assumed that the land acquired for the Montrose reservoir would be sold in the year 2001.

Table B.8 Summary Table of Costs and Benefits For Main Plans — High Population Projection (Continued) (Millions of 1979 Dollars)

	PLAN DESCRIPTION:			PRESENT VALUE Of BENEFITS & COSTS			
PLAN	WATER QUALITY	WATER SUPPLY	FLOOD DAMAGE REDUCTION	ITEM	DISCOUNT RATE		
					0%	6%	10%
	Sewage Treatment:			1) STP-CAS + Guelph R8C	449	115	66
	Waterloo - Nitrification.	Same as Plan A,	Montrose Reservoir	2) STP-New Facilities	76	20	12
	Filtration 2021	Option 1		3) Water Supply	47	17	10
B	Kitchener - Nitrification,		Dykes in New Hamburg	4) Reservoirs	46	42	41
	Filtration. 2001			5) Other Flood Prot.	1	1	1
Option	Guelph - Chemical			6) Water Sup. Benefits	2125	205	52
1	Treatment and Multi-			7) Flood Prot. Benefits	27/28*	9	5
	Media Filtration1981	100%	54% / 56%	8) Net Benefits -	1982/		
	Flow Augmentation:			(6+7) - (2+3+4+5)	1983	134	-7
	Montrose Reservoir						
	28% - Speed; 58% - Grand						
	Same as Plan B.	Same as Plan A.	Montrose Reservoir	1) STP-CAS+Guelph RBC	449	115	66
	Option 1	Option I	Dykes and Channel	2) STP-New Facilities	76	20	12
			Works same as in	3) Water Supply	47	17	10
B			Plan A, Option I	4) Reservoirs	46	42	41
				5) Other Flood Prot.	25	24	23
Option				6) Water Sup. Benefits	2125	205	52
2	28% - Speed			7) Flood Prot. Benefits	27/28*	9	5
	58% - Grand	100%	96%	8) Net Benefits =	1958/		
				(6+7) -(2+3+4+5)	1959	111	-29
	Same as Plan A.	Same as Plan A.	St. Jacobs Single-	1) STP-CAS+Guelph RBC	449	115	66
	Option 1	Option I	Purpose Reservoir	2) STP-New Facilities	85	32	24
			Dykes in	3) Water Supply	47	17	10
C			New Hamburg	4) Reservoirs	26	25	24
				5) Other Flood Prot.	1	1	1
Option				6) Water Sup. Benefits	2125	205	52
1	28% - Speed			7) Flood Prot. Benefits	25/26*	8	5
	23% - Grand	100%	49% / 50%	8) Net Benefits =	1991/		
				(6+7) - (2+3+4+5)	1992	138	-2
	Same as Plan A,	Same as Plan A.	Montrose Single- Purpose	1) STP-CAS + Guelph RBC	449	115	66
	Option 1	Option 1	Reservoir	2) STP-New Facilities	85	32	24
			24.7 million cu. m.	3) Water Supply	47	17	10
C			(20,000 acre feet)	4) Reservoirs	30	28	27
			Dykes in	5) Other Flood Prot.	1	1	1
Option			New Hamburg	6) Water Sup. Benefits	2125	205	52
2	28% - Speed			7) Flood Prot. Benefits	27/28*	9	5
	23% - Grand	100%	54% / 56%	8) Net Benefits =	1989/		
				(6+7) - (2+3+4+5)	1990	136	-5
	Same as Plan A.	Same as Plan A,	Montrose Single- Purpose	1) STP-CAS+Guelph RBC	449	115	66
	Option 1	Option I	Reservoir	2) STP-New Facilities	85	32	24
C			77.7 million cu. m.	3) Water Supply	47	17	10
				4) Reservoirs	46	42	41
Option			(63,000 acre feet)	5) Other Flood Prot.	1	1	1
3	28% - Speed	100%	Dykes in New Hamburg	6) Water Sup. Benefits	2125	205	52
	23% - Grand		56% / 57%	7) Flood Prot. Benefits	27/28*	9	5
				8) Net Benefits -	1973/		
				(6+7)- (2+3+4+5)	1974	122	-19
	Same as Plan A.	Lake Erie Pipeline	Same as Plan A,	1) STP-CAS+Guelph RBC	409	108	63
	Option 1	Kitchener-Waterloo,	Option 1	2) STP-New Facilities	80	32	4
		Cambridge.		3) Water Supply	576	279	230
D		Brantford		4) Reservoirs	0	0	0
		Ground Water:		5) Other flood Prot.	25	24	23
		Guelph		6) Water Sup. Benefits	1870	165	35
	28% - Speed		91%	7) Flood Prot. Benefits	46	14	9
	23% - Grand	100%		8) Net Benefits -			
				(6+71- (2+3+4+5)**	1235	-156	-233

Note: Percent figures refer to % of objective achieved: except where noted the objectives are: Water Quality = meet a water quality index of 0.0 on the Grand river and on the Speed river: Water Supply = Max. Day Demand; Flood Damage Reduction = zero average annual damages.

* A range of flood damage benefits is given for multi-purpose reservoirs. This range reflects variations in the assumed storage volume available in the spring to retain flood flows. Storage volumes will vary with the time of year and the operating rules used for each reservoir,

** Net benefits include savings in cost Item I over Plan A. These savings arise due to a reduced STP hydraulic load brought about by price induced reductions in water demand.

B.2.3 Selection of Preferred Plan

Utilizing the results of the prior evaluations, the Grand River Implementation Committee, through a series of discussions and voting procedures, identified a preferred plan.

The study team plus invited technical experts from other basin sub-committees, reviewed the four main plans and submitted formal written responses ranking the plans and their four variations. The voting results were analyzed on the basis of two groupings:

- Grand River Basin Study Team (Appendix A and G)
- Grand River Basin Study Team plus invited technical experts from other committees (members listed in Table B.9).

The technical experts were familiar with the basin study and had served on one or more of the study's technical sub-committees. The voting results listed in Table B.10 were analysed using four different voting procedures; the Simple Plurality scheme, the Borda Count, Pair Wise Wins and the Copeland Score (Ref. Tech. Report No. 25).

The voting analysis narrowed the selection to two main plans; A and B, and four variations of these plans; A1, A2, A4 and B2. For both groups, plans A1, A2, A4 and B2 were almost equally ranked. The study team by itself appeared to prefer plan A4 over plan B2, while the larger group's preference shifted slightly from plan A4 to plan B2. The voting indicated that the basin water managers tended to favour the Montrose dam option, plan B2, because it offered a more reliable and secure water management system. Other members more removed from the immediate management of the river generally opted for plan A (1, 2 or 4) with its lower cost and reduced social and environmental impacts.

Table B.9 Enlarged Study Team

Members of basin study team plus the following invited members:

M. Fortin,
Systems Economist (Basin Study),
Water Resources Branch,
Ministry of the Environment

B. Mitchell,
Faculty of Environmental Studies,
Dept. of Geography,
University of Waterloo

U. Sibul, Head,
Resource Assessment Group,
Water Resources Branch,
Ministry of the Environment

R. Wilson,
General Manager,
Brantford Public Utilities Commission,
City of Brantford

E. McBean,
Faculty of Engineering,
Dept. of Civil Engineering,
University of Waterloo

J. Sanvido,
Superintendent of Water
Pollution and Water Works,
City of Guelph

D. Weatherbe, Head,
River Systems Unit,
Water Resources Branch,
Ministry of the Environment

Note: Members of the basin study team are listed in Appendix A.

Table B.10 Selection of the Preferred Plans by The Basin Study Team using Various Voting Techniques.

Voting Results From Study Team Only

Voting Scores

Voting Method	**A1.2**	**A4**	**B1**	**B2**	**C1**	**C2**	**C3**	**D**
Plurality	3	5	1	4				
Borda	56	59	23	51	12	11	0	0
Pair Wise Wins	6	7	4	5	3	2	0	0
Copeland	5	7	1	3	-1	-3	-6	-6
Overall ranking	2	1		3				

Voting Results From Enlarged Study Team

Voting Scores

Voting Method	**A1.2**	**A4**	**B1**	**B2**	**C1**	**C2**	**C3**	**D**
Plurality	5	6	1	6				
Borda	93	88	42	94	15	22	4	0
Pair Wise Wins*	6	6	4	5	2	3	1	0
Copeland	5	5	1	3	-3	-1	-5	-7
Overall ranking		1		1				

* If a clear majority is not indicated in pair wise voting (as in this case) then the Borda Count results are recommended for use in place of Pair Wise Wins.

Public Consultation Working Group Selections

In June, 1980, the public consultation working groups made their final plan selections. These plans were chosen from the plans which appeared viable after the preliminary screening exercise undertaken by them and prior to the study team's selection. Three of the four working groups selected plan A as their final choice. The fourth group, representing the lower region of the basin, selected plan B as its first choice. Table B.11 summarizes the plan selections and Technical Report Nos. 25 and 43 discuss their choices in more detail. The plan numbers are given in their original numerical classification as well as their equivalent main plan alphabetical classification.

After the plan selection of June, 1980, a new plan 1i (later called Plan A4) was added and evaluated by GRIC. In addition, several technical revisions altered the effectiveness of various plans.

The changes occurring principally in the water quality area, were due to corrections and improvements in the simulation models. A meeting with the public consultation working groups was held in January, 1981 to inform them of the changes. The original plan selections were reconfirmed. However, two of the three groups favouring plan A1 (upper and mid-upper groups) did not favour plan A4's preservation of the Montrose reservoir lands.

Table B.11 Preferred Plan Selections by Public Consultation Working Groups

Public Consultation Working Groups	Preferred Plan		Comments
	Original Classification	Main Plan Classification	
Upper	1F	A1	‣ incorporate planned floodplain acquisition with plan
Mid-Upper	1A	A1	‣ incorporate urban and rural stormwater management ‣ improve surface water quality monitoring, particularly with respect to toxic substances ‣ improve ground water quality monitoring network ‣ introduce water conservation ‣ review assumptions on a regular basis ‣ need a co-ordinating body for plan implementation
Mid-Lower	1A, 1F 1G	A1, A2, A3	
Lower	2B 2A 2C (in order of preference)	B2 B1	‣ Montrose Reservoir required to augment flows for water quality and recreational purposes

GRIC Selection

GRIC reviewed the results of the study team and the public consultation working groups and then carried out a lengthy examination of the pros and cons of each plan (Chapters 9 and 10). An initial voting analysis was carried out to provide a basis for further discussion (Table B.12). Following further evaluations of the merits and disadvantages of each plan, the Grand River Implementation Committee identified plan A4 as the preferred plan to guide water management discussions in the basin.

The reasons for this selection are discussed in detail in Chapter 12.

Table B.12 GRIC Voting Results of February, 1981.

Voting Procedure	Water Management Plans			
	A1	A4	B2	C, D
Plurality	3	2	4	0
Borda	16	19	19	0
Pair Wise Wins	1	2	3	0
Copeland	1	1	3	-3

Wins and ties are underlined

B.3 Evaluation Matrix

An evaluation matrix was used by the basin study team in carrying out an initial screening of the twenty-six water management plans (Appendix B.2). This matrix, shown on Table B.18, was derived by assessing each plan in terms of:

a) achievement of the study objectives
b) costs
c) environmental impacts
d) social impacts.

The objectives and costs were assessed using quantitative data related to a common grading system. The intangible parameters (environmental and social impacts) were graded based on the results of a questionnaire which was analyzed using a multi-criteria method called fuzzy set analysis (Ref. Tech. Report No. 25).

Each plan's parameters were then compared to the corresponding parameters of other plans through the same multi-criteria method. This method enabled the plans to be classified as very good, good, fair or poor. A description of the grading system, formation of the matrix and evaluation of the plans is provided in the following section.

B.3.1 Grading of Objectives

Flood Damage Reduction

The effectiveness of each plan in reducing flood damages was measured using the average annual flood damages calculated for each plan (Appendix F.1). The grading system was established by dividing the total average annual damages of approximately $1,000,000 equally among four grades; very good, good, fair and poor. This assumes, for example, that any plan that does not reduce average annual flood damages by 25 percent should be considered poor in terms of meeting the flood damage reduction objective.

The grading system and corresponding plan groupings are shown in Table B.13.

Water Duality improvement

The effectiveness of each plan for improving water quality was measured by the dissolved oxygen water quality severity index (Appendix E.1). The grading of the water quality achieved by each plan was based on available fish toxicity information (Ref. Tech. Report No. 13) and is presented in Table B.14.

Table B.13 Evaluation Grading System for Flood Damage Reduction.

Grading	Average Annual Flood Damages (in thousands of dollars)	Plan Ranking
Very Good	0 - 250	1A, 1E, 1F,1G,1i 2B, 2C, 6, 9A
Good	250 - 500	2A, 2D, 2E, 4, 9B, 10, 11
Fair	500 - 750	
Poor	750 - 1,000	1B,1C,1D,1H 3, 5,7A, 7B, 8A, 8B

Table B.14 Evaluation Grading System for Water Quality.

Grading	Description	Dissolved Oxygen Water Quality Index - Grand River	Plan Ranking for Water Quality on the Grand River	Dissolved Oxygen Water Quality Index - Speed River	Plan Ranking for Water Quality on the Speed River
Very Good	Meets dissolved oxygen criteria for warm-water fish 100 percent of the time.	0+		0+	
Good	Meets existing dissolved oxygen criteria 95 per cent of the time. Dissolved oxygen does not fall below 3.5 mg/L. Conditions equal to background conditions upstream of Waterloo or Guelph.	0 - 17	2A, 2B, 2C, 2D, 9B	0 - 9	1G, 11, 9B
Fair	Improves existing dis-solved oxygen level.	17 - 40	1A, 1B, 1C, 1D, 1E, 1F,1G, 1H,1i, 2E, 3, 6, 8A, 8B, 10, 5, 11, 4		1A, 1B, 1C, 1D, 1E,1F,1H,1i,2A, 2B, 2C, 2D,2E, 3, 4, 5, 6,8A, 88, 9, 10
Poor	Existing conditions.	40 - 63	7A, 7B, 9A	20 - 49	7A, 7B, 9A

Water Supply Benefits

Since the water supply objective is met 100 percent of the time for all plans, an evaluation of how well each plan meets the objectives is measured by the water supply benefits accrued. Benefits are measured using the consumer surplus technique outlined in Appendix C.2.

As with grading of each for flood damage reduction, the grading system for water supply benefits was established by dividing the highest water supply benefit achieved by a plan equally among the four gradations of very good, good, fair and poor. The gradings and plan evaluations are shown in Table B.15.

Water Management Plan Costs

Total plan costs were used to evaluate the adequacy of each plan in achieving the objectives at a minimum cost. Total costs include advanced sewage treatment costs, water supply costs, and reservoir and channelization costs.

The grading system was established by dividing the highest total cost for a plan equally among four gradations. This assumes, for example, that those plans with less than 25 percent of the highest total cost should be considered very good. The grading and evaluations are given in Table 8.16.

Table B.15 Evaluation Grading System for Water Supply Benefits.

Grading	Water Supply Benefits (Present value in millions of 1979 dollars at 6% Discount)	Plan Ranking
Very Good	75 - 100	1A, 1B, 1C, 1D, 1E, 1G, 1H, 1i, 2A, 2B, 2C, 2E, 3, 4, 9A, 9B, 10, 11
Good	50 - 75	1F, 2D, 5, 6, 8A
Fair	25 - 50	7B, 8B
Poor	0 - 25	7A

Table B.16 Evaluation Grading System For Plan Costs.

Grading	Total Cost (Present value in millions of 1979 dollars at 6% Discount)	Plan Ranking
Very Good	0 - 133	1A, 1B, 1C, 1D, 1F,1G,1H,1i, 2A, 2B, 2C, 2E, 3, 4, 7A, 7B, 8A, 8B, 9A, 10
Good	133 - 266	2D, 5, 9B, 11
Fair	266 - 399	6
Poor	399 - 532	1E

Environmental and Social Impacts

Since many environmental and social impacts are non-quantitative, they are difficult to grade objectively. To overcome this problem, the basin study designed a questionnaire which was completed by the basin study team (Appendix B.2). The responses of the questionnaire were compared using a fuzzy set analysis. The social and environmental impacts of each plan were then ranked (Ref. Tech. Report No. 25).

Eight parameters were used to evaluate environmental and social impacts. The parameters used in the environmental evaluation were:

a) land habitat (animals and plants)
b) aesthetics (land based).

The parameters used in the social impact analysis were:

a) agricultural land permanently removed
b) agricultural land with reduced flood damage
c) households permanently relocated
d) community ties
e) transportation
f) recreation.

The results of the analysis and plan grading are shown in Table B.17. For comparison purposes, the grading of the plans by the basin study team are presented with the grading of the plans by the public consultation working groups (Appendix B.2). The results from these two groups were similar, since their ranking of each plan did not differ by more than one gradation.

Table B.17 Plan Ranking for Environmental and Social Impacts.

Grading	Plan Ranking for Environmental Impacts		Plan Ranking for Social Impacts	
	Basin Study Team	Public Consultation Working Groups*	Basin Study Team	Public Consultation Working Groups*
Very Good	1C (1A,1F,1D, 1i, 6, 7A, 7B, 8A, 8B, 9A)	1A, 1F, 8A, 8B 1C, 6	1 F 1 A	1A, 1F 6 1C 8A, 8B
Good	1B 1E 2E 10	18 1D, 1E, 7A, 78, 9A	1B,1H,1i, 6 3, 2E 8A, 1C, 8B	9A 1D 7A, 7B 2E
Fair		2E	7B, 7A, 9A 4 1G 1D 2C, 2B 2D, 2A 9B 10	1B 1E 1G 3 2C, 2B, 4, 9B 2A, 2B
Poor	1G, 1H, 2A, 2B, 2C, 2D, 3, 4, 5, 9B, 11	1G 2A, 2B, 2C, 2D, 9B 3, 4, 5	1E 11 5	5

* Plans 10, 11, 1i and 1H were not evaluated by the public consultation working groups at the time of the questionnaire.

Table B.18 Plan Evaluation Matrix.

	Effectiveness in Meeting Plan Objectives			Plan impact				Preliminary Plan Screening **	
Plan*	Flood Damage Reduction (1)	Maintain an Adequate Water Quality (2)	Provide an Adequate Water Supply (3)	Costs (4)	Environmental Impact (5)	Social Impact (6)	Plan Evaluation by Fuzzy Set Analysis (7)	In (8)	Out (9)
1A	Very Good	Fair-Speed R. Fair-Grand R.	Very Good	Very Good	Very Good	Very Good	Very Good	X	
1B	Poor	Fair-Speed R. Fair-Grand R.	Very Good	Very Good	Good	Good	Good	X	
1C	Poor	Fair-Speed R. Fair-Grand R.	Very Good	Very Good	Very Good	Good	Good	X	
1D	Poor	Fair-Speed R. Fair-Grand R.	Very Good	Very Good	Very Good	Fair	Good	X	
1E	Very Good	Fair-Speed R. Fair-Grand R.	Very Good	Poor	Good	Good	Fair		X
1F	Very Good	Fair-Speed R. Fair-Grand R.	Good	Very Good	Very Good	Very Good	Very Good	X	
1G	Very Good	Good-Speed R. Fair-Grand R.	Very Good	Very Good	Poor	Fair	Good	X	
1H	Poor	Fair-Speed R. Fair-Grand R.	Very Good	Very Good	Poor	Good	Fair		X
1I	Very Good	Fair-Speed R. Fair-Grand R.	Very Good	Very Good	Very Good	Good	Very Good	X	
2A	Good	Fair-Speed R. Good-Grand R.	Very Good	Very Good	Poor	Fair	Good	X	
2B	Very Good	Fair-Speed R. Good-Grand R.	Very Good	Very Good	Poor	Fair	Good	X	
2C	Very Good	Fair-Speed R. Good-Grand R.	Very Good	Very Good	Poor	Fair	Good	X	
2D	Good	Fair-Speed R. Good-Grand R.	Very Good	Good	Poor	Fair	Good	X	
2E	Good	Fair-Speed R. Fair-Grand R.	Very Good	Very Good	Good	Good	Very Good	X	
3	Poor	Fair-Speed R. Fair-Grand R.	Very Good	Very Good	Poor	Good	Fair		X
4	Good	Fair-Speed R. Fair-Grand R.	Very Good	Very Good	Poor	Fair	Good	X	
5	Poor	Fair-Speed R. Fair-Grand R.	Good	Good	Poor	Poor	Poor		X
6	Very Good	Fair-Speed R. Fair-Grand R.	Good	Fair	Very Good	Good	Very Good	X	
7A	Poor	Poor-Speed R. Poor-Grand R.	Poor	Very Good	Very Good	Fair	Poor		X
7B	Poor	Poor-Speed R. Poor-Grand R.	Fair	Very Good	Very Good	Fair	Poor		X
8A	Poor	Fair-Speed R. Fair-Grand R.	Good	Very Good	Very Good	Good	Good	X	
8B	Poor	Fair-Speed R. Fair-Grand R.	Fair	Very Good	Very Good	Good	Good	X	
9A	Very Good	Poor-Speed R. Poor-Grand R.	Very Good	Very Good	Very Good	Good	Very Good	X	
9B	Good	Good-Speed R. Good-Grand R.	Very Good	Good	Poor	Fair	Good	X	
10	Good	Fair-Speed R. Fair-Grand R.	Very Good	Very Good	Good	Fair	Very Good	X	
11	Good	Fair-Speed R. Fair-Grand R.	Very Good	Good	Poor	Poor	Fair		X

* Refer to Table B.2 for pan descriptions.

** Plans considered for further analysis are labelled 'In', those that were not studied further are labelled 'Out'.

B.3.2 The Evaluation Matrix and Plan Screening

The gradings for each plan which resulted from analysis of the basin study team responses are summarized in Table B.18 (Columns 1 to 6). Each plan is described by its objective completion, costs, and social and environmental impacts.

Each column parameter was ranked using the following numerical rankings for a descriptive evaluation.

Descriptive Evaluation	**Numerical Ranking**
Very Good	4
Good	3
Fair	2
Poor	1

Since some of the parameters may be considered more important than others, they were weighted for the purpose of fuzzy set analyses according to the preferences expressed by the basin study team. The preference weightings as a fraction of 1 for the evaluation parameters were:

Parameter	**Weighting by Basin Study Team**
1) Objectives	
Flood Damage Reduction	0.70
Adequate Water Quality	0.66
Adequate Water Supply	0.89
2) Costs	0.68
3) Impacts	
Environmental	0.54
Social	0.56

The preference weighting of the evaluation parameters by the study team was similar to that of the public consultation working groups. However, the study team put slightly more emphasis on cost as a means of evaluating the plans.

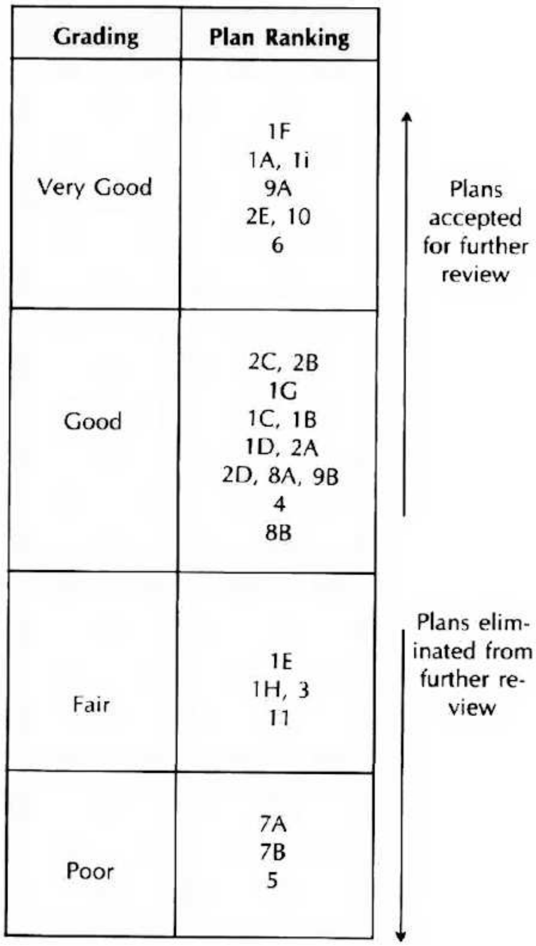
Fuzzy set analysis was then used to compare one plan with another. This was done by comparing a particular weighted parameter for a given plan with the corresponding weighted parameter of the other plans (Table B.19).

This comparison was then used to grade the individual plans from very good to poor as shown in the evaluation matrix (Table B.18, Column 7). The plans that were ranked very good to good were included for further study, while those ranked fair or poor were removed from further consideration (Table B.18, Columns 8 and 9; Table B.19).

The preliminary screening of the twenty-six water management plans using a multi-criteria method for evaluation eliminated seven plans from further consideration, reducing the number of plans to be studied to nineteen.

This screening process was only one of several screening techniques used by the basin study to evaluate the various water management plans. The entire evaluation process is described in Appendix B.2.

Table B.19. Screening of Water Management Plans Using Fuzzy Set Analysis.



Grading	Plan Ranking
Very Good	1F 1A, 1i 9A 2E, 10 6
Good	2C, 2B 1G 1C, 1B 1D, 2A 2D, 8A, 9B 4 8B
Fair	1E 1H, 3 11
Poor	7A 7B 5

Plans accepted for further review

Plans eliminated from further review

Plans are listed in order of their ranking.

C. TECHNIQUES USED IN ECONOMIC ANALYSES

C.1 Discount Rates

Projects have a lifetime, usually extending over several decades. Generally, they yield benefits at least intermittently over that lifetime, and usually they incur some costs during that period. If the costs per year and the benefits per year were constant over the lifetime, to compare a year's benefits to a year's costs would suffice to determine whether the project was worthwhile. Such a situation is depicted by the benefit and cost lines B, and C, in Figure C.1. However, project costs and benefits are usually very unevenly distributed. Costs are heavy during an initial construction period, then taper off to operating costs alone, and increasing maintenance costs follow. Benefits may be accrued uniformly from the start of a project but usually increase to a maximum over time.

For example, benefits stemming from reduced flood damages occur over the life of a flood control project such as a dam or dyke. However, construction costs occur over a short period of time at the beginning of the project. Because of the very different time-frames of the benefits and the major costs, the two cannot be compared directly. Such situations are depicted as benefit and cost lines B, and C, in Figure C.1.

The question then is: how do we compare benefit and cost values that are anticipated to occur at different points in time? One scheme might be simply to add up the benefit and cost values over the life of the project. Yet it requires little emphasis in a world filled with interest rates, bond issues, loans, and financial institutions to realize that a dollar in the hand is considered more desirable than a dollar one or ten years hence. People, corporations, and governments appear very willing to pay a premium (i.e. interest) to have money available for use today rather than in the future.

Many people are willing to pay interest for immediate acquisition of consumer durables: homes, cars, televisions, and so on. They frequently exhibit this preference for satisfaction today over satisfaction tomorrow, usually referred to in technical jargon as 'a positive (rate of) time preference.' Corporations are willing to pay interest or share profits to get money today because they have profit opportunities that predictively will return more on their use of funds (resources) than what they will have to pay in interest or dividends. Provincial and local governments borrow to expedite capital expenditures. (This borrowing also makes it possible to spread the cost of common public facilities out over time).

Due to the premium society places on immediate satisfaction of its needs, the time factor emerges as an important element in assessing the value of benefits which will occur in the long-term. In fact

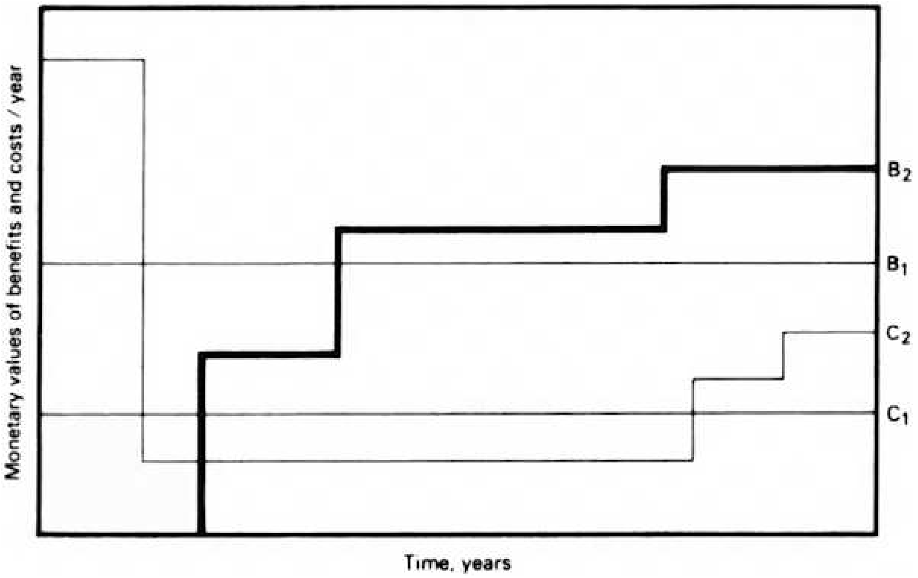


Figure C.1. Project benefit and cost streams over time.

all the benefits and costs predicted to occur at different points in time over the life of a project should be weighted differently according to their time of occurrence. Only then can the benefits and costs be considered as comparable units of social value.

Generally, the relative valuation of sums available at different points in time is a matter that society or at least the public sector must decide for itself. To establish a relative scale of values for benefits and costs, i.e. to weight benefits and costs, so that they can be compared realistically, a weighting function called a discount rate can be used. A discount rate is the measurement of the premium one is willing to pay at the present time in order to start enjoying the benefit of a commodity now, rather than later in the future. Conversely, that same premium (i.e. rate) must be subtracted (discounted) from future benefits in order to give them their present day value.

In order to calculate the present value of costs and benefits, the following mathematical equations are used:

If d, represents a discount weight for year 1, then we could add the weighted future values to get a present value equivalent:

$$PV = d_oV_o + d_1V_1 + d_2V_2 + \ldots + d_nV_n$$

where V_n is the value coming due or falling in year n.

How are the weights $d_o, \ldots\ldots d_n$ determined? Granting that they should decrease over time and that d_o (the weight given to immediate values) should be 1, we usually assume (generally for lack of better foresight) that the weights should decrease into the future in a geometric fashion akin to compound interest. If the rate of decrease is r, then

$$d_{n-1} = (1 + r)d_n$$
$$d_{n-2} = (1 + r)d_{n-1} = (1 + r)^2 d_n$$
$$d_1 = (1 + r)d_2 = (1 + r)^{n-1} d_n$$
$$d_o = (1 + r)d_1 = (1 + r)^n d_n$$

Since we have assumed that $d_o = 1$, then $d_n = [1/(1 + r)^n]$, and from the above equations we can reason that

$$d_{n-1} = 1/(1 + r)^{n-1}$$
$$d_{n-2} = 1/(1 + r)^{n-2}$$
$$. \qquad\qquad .$$
$$. \qquad\qquad .$$
$$d_1 = 1/(1 + r)$$

The parameter r is the discount rate.

The selection of a discount rate "r" is critical as it may have a profound influence on plan selection. The present value of future impacts is lower the higher the discount rate. The opposite is also true. High discount rates therefore "favour" projects with little initial investment, while low discount rates "favour" capital intensive projects.

Inflation

Two approaches to discounting are often used. One approach, the one used by the basin study, assumes that future costs and benefits are constant throughout the fifty-year planning period and the discount rate (called the real discount rate) is free of any inflationary premium. An alternative to constant prices is to incorporate inflation into future prices. If this is done, the discount rate (called the nominal discount rate) must include the corresponding inflation component.

For example, with an inflation rate of 10 percent per year, the study's real discount rate of 6 percent is equivalent to a nominal discount rate of 16 percent (10 percent + 6 percent).

Regardless of which approach is selected, the results of the analysis are the same and are based on constant dollar measures of value. The impact of inflating prices in the second approach is fully and exactly offset by the inflationary component of the discount rate.

For the basin study, costs and benefits were assumed to accrue over a fifty-year planning period. At the end of this period, future costs and benefits become insignificant due to the effects of discounting.

To examine the sensitivity of the plans to various discount rates, all water management plan costs and benefits were discounted using rates of 4, 6, 8 and 10 percent. These rates were chosen since it was indicated in a study that a discount rate of 6 percent with a range of 4 to 8 percent was a practical choice (Ref. Tech. Report No. 23). A higher rate of 10 percent was also examined since the Federal Treasury Board recommended it as a suitable rate.

A more detailed explanation of discount rates and their appropriateness for determining plan costs and benefits is presented in Technical Report No. 23.

C.2 An Economic Measure of Water Supply Benefits

This appendix describes a dollar measure of project benefits that has been used to quantify water supply benefits in the Grand River Basin Water Management Study. This measure, called consumer's surplus, was developed by economists using information contained in demand curves for goods and services. Municipal water supply is used here to illustrate the concept.

In Ontario, municipal water supply systems generally charge less than $2.00 for a thousand gallons of water. Water consumption patterns reflect the fact that this price is low; widespread efforts to conserve water are uncommon. Economists argue that the use of water will be reduced if prices increase. They use a demand curve, shown in Figure C.2, to describe this inverse response of consumption to price. Each point on the demand curve indicates how much a consumer would be inclined to consume at the corresponding price. The demand curve therefore reveals how much consumption would change as prices are raised or lowered.

Demand curves also reveal the value attributed to water by consumers. To understand this, consider the point A in Figure C.2. At this point, Qa water is consumed at price Pa. This quantity likely includes drinking, washing, cooking and some outdoor uses. At a zero price, new uses are added that push consumption to Qo. These uses are not, however, warranted at the price Pa; i.e. their value is too low. Looking at the demand curve, this judgement of value is obvious from the fact that the consumer is not willing to pay a price of Pa for consumption beyond Qa. Moving in the other direction, it is equally clear that he would pay more than Pa for most uses between a zero consumption level and Qa. Basic consumption needs are very important. These might amount to Qb in Figure C.2 and would be given a value of at least Pb as shown. The price Pb therefore measures the value of water consumed at the level Qb.

This information about value translates directly into a measure of benefit. At point B on the demand curve, the consumer uses water valued at Pb but on the basis of current pricing practices pays only Pa for the water. He receives a surplus of value measured by the amount "C". Likewise, a similar surplus of value is enjoyed for most of his consumption up to the level, Qa, at which point value equals price and consumption stops. Consumer's surplus is simply the sum of these surplus values. It measures the net benefit a consumer receives when he can purchase water at the price Pa. Mathematically, it is derived as the area under the demand curve up to the point A minus the total expenditure measured as (Pa x Qa).

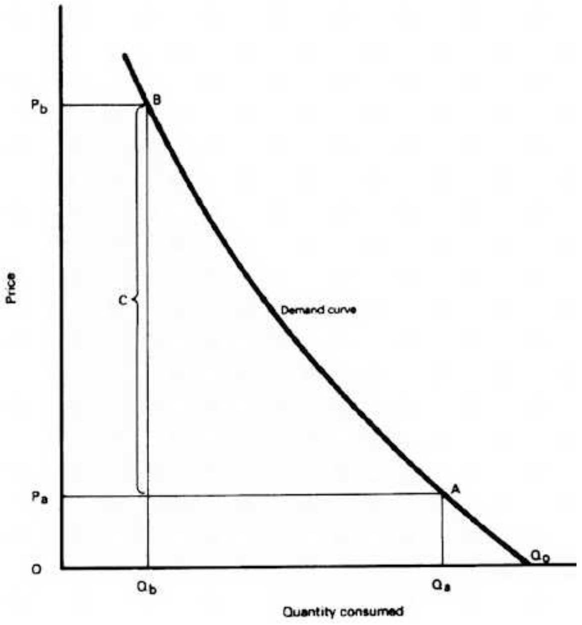


Figure C2. Demand curve for water.

C.3 Cost Allocation for Multi-Purpose Reservoirs

Certain reservoir projects considered by the Grand River Basin Water Management Study help meet more than one objective while other reservoir and non-reservoir projects have only a single purpose. In the evaluation process it is useful to compare project costs to the performance of projects in meeting the various planning objectives. This comparison must be made for each objective separately since no satisfactory summary measure of performance combining all three objectives is available. This need to separate objectives is problematic because the multi-purpose reservoirs have costs which can be attributed to more than one objective. A comparison for a single objective based on total costs for all projects would be misleading since it would not account for the attainment of the other objectives. The multipurpose projects would be given an overly pessimistic rating as a result. To overcome this, total costs for multipurpose projects can be apportioned to various objectives. The comparisons can then be conducted on the basis of allocated costs. Such a procedure, however, is also misleading, since, for the multi-purpose project, the rated performance for one objective cannot actually be achieved for the allocated costs alone. The total project must be built in order to obtain any of the benefit. Therefore, using allocated costs, multi-purpose projects are unduly favoured in a comparison.

In this basin study, the performance-cost comparisons are considered to be a useful means of displaying project data and are not intended to form the basis for overall evaluations of management plans. For this reason, allocated costs seemed more to the point and the associated problems of favouring multi-purpose projects did not seem serious since the eventual project selection is based on a comparison of comprehensive management plans that included groups of projects. At this level, total costs formed the basis for evaluation and selection.

The procedure used here to allocate project costs is called the "separable costs — remaining benefits" method (Ref. A1).

This method distinguishes between separable costs and joint costs. Separable costs are those costs that can be attributed to specific uses. They are determined by sub-trading from total project costs the total costs that result when the project is redesigned to exclude a particular use. Defined in this manner, the separable cost is the incremental co:t incurred in order to include a use in the project design. A separable cost can be estimated for each objective fulfilled by the project.

Joint costs are defined as total multi-purpose project costs minus the sum of all estimated separable costs. They are the residual costs that cannot be allocated to individual uses on the basis of project design. Joint costs are allocated to each use in proportion to net or "remaining" benefits associated with each use. Remaining benefits are estimated as total benefits related to a use minus the separable costs for that use. Where there is an alternative single-purpose project that can produce equivalent benefits for that use, then the cost of the alternative project must be compared to total benefits for the, use. If the single-purpose project costs are less than the value of the total benefits then remaining benefits are calculated as the alternative project costs minus separable costs. The lesser of total benefits and alternative project costs are called justifiable costs.

The total allocated cost for an objective is its separable cost plus the allocated joint cost for that objective. In summary, we have for a project with two uses —flood protection (FP) and flow augmentation (FA):

1. Total Cost of Project.

2. Purpose.
   a) description of uses
   b) storage required for single use, FP or FA
   c) storage cost is a direct function of the amount of water required in storage to serve a single use, FP or FA, (i.e. the higher the dam, the larger the storage, and the greater the cost)

3. Separable cost for FP = (total project cost including FP) - (total project cost without FP).

4. Total Joint Cost = (total project cost) - (separable cost for FP and FA).

5. Total benefits are obtained from economic analyses in Appendix B and Chapter 10 of the main report. For the Montrose reservoir, Table C.1, the reduction in flood damages is $8.6 million and the reduction in costs for advanced sewage treatment facilities as a result of flow augmentation is $13 million.

6. Alternative projects are other projects that could achieve similar results as the proposed project.

7. Justifiable costs for FP = minimum of (benefits from FP use, alternative cost to fulfill FP use).

8. Remaining benefits for FP = (justifiable cost for FP) - (separable cost for FP).

9. Allocated Cost.
   a) Joint costs allocated to FP = (total joint costs) x [remaining benefit for FP/(remaining benefit for FP + remaining benefit for FA)].
   b) Total costs allocated for FP = (separable costs for FP) + (joint costs allocated to FP).

Tables C.1 and C.2 outline the cost allocation according to the above calculations for the Montrose and Wallenstein reservoirs relative to flood protection and flow augmentation.

In this study, separable costs for multi-purpose reservoirs have been defined strictly on the basis of storage requirements needed to allow for each use. It was assumed therefore that overall project design would not change but the scaling would change for the different uses. This assumption is justified because no uses considered here involve radical design changes such as would be required to accommodate hydro-electric generation for instance.

Cost allocation was required for two reservoirs — Montrose and Wallenstein. The data and calculations used to allocate their total costs are given in Tables C1 and C2. Data problems necessitated some assumptions about benefits and alternative costs in this work. These assumptions are approximate and result in an analysis that is quite crude. The resulting values are generally reasonable but must be used with caution. In particular, this analysis is not considered robust enough to support conclusions about cost-sharing arrangements that could arise once these projects were implemented (even though this type of cost allocation exercise is generally undertaken to determine cost-sharing).

Table C.1 Cost Allocation for Montrose Reservoir.

(Present Value of Costs and Benefits in Millions of 1979 Dollars at 6% Discount)

1. Total Cost	$42.4	
2. Purpose:	Use 1	Use 2
a) description	Flood Protection	Flow Augmentation
b) storage - million m^3 required	24.67	54.27
storage - (acre-feet)	(20,000)	(44,000)
c) storage cost	$31.4	$36.6
3. Separable Cost	$ 5.8	$11.0
4. Total Joint Cost	$25.6	
5. Total Benefits	$8.6	$13.0
6. Alternative Project:		
a) description	Salem (single-purpose), Wallenstein and St. Jacobs (single-purpose) Reservoirs	Everton, Wallenstein and St. Jacobs (multi-purpose) Reservoirs
b) cost	$79.9	$74.3
7. Justifiable Cost	$8.6	$13.0
8. Remaining Benefit	$2.8	$2.0
9. Allocated Costs:		
a) Joint Costs	$14.9	$10.7
b) Total Costs	$20.7	$21.7

Table C.2 Cost Allocation for Wallenstein Reservoir*.

(Present Value of Costs and Benefits in Millions of 1979 Dollars at 6% Discount)

1. Total Cost	$32.8	
2. Purpose:	Use 1	Use 2
a) description	Flood Protection	Flow Augmentation
b) storage - million m^3 required	17.27	17.27
storage - (acre-feet)	(14,000)	(14,000)
c) storage cost*	$31.4	$31.8
3. Separable Cost	$1.0	$1.4
4. Total Joint Cost	$30.4	
5. Total Benefits	$2.7	assumed $0.0 to $2.7
6. Alternative Project:		
a) description	Salem (single-purpose)	St. Jacobs Reservoir (multi-purpose)
b) cost	$22.0	$24.9
7. Justifiable Cost	$2.7	$0.0 to $2.7
8. Remaining Benefit	$1.7	$0.0 to $1.3
9. Allocated Costs:		
a) Joint Costs**	$30.4 - $17.3	$0.0 - $13.1
b) Total Costs	$31.4 - $18.3	$1.4 - $14.5

* The cost difference arises because of O&M costs.

** A range is given because of uncertainty in estimating benefits from flow augmentation. Further studies would be required to determine flow augmentation benefits.

D. SIMULATION MODELS

D.1 Hydrologic Models

The Grand River Basin Water Management Study used three major models in simulating the effect each water management plan had upon the streamflow regime of the basin. This appendix briefly describes the following three major models:

Flood 2 Model — used to model high flow events
Reservoir Yield Model — used to model the effects of existing and proposed reservoir operations on the low flow regime
HEC 5 Model — used to model the effects of existing and proposed reservoirs upon flood events

Further details of the individual models are described in Technical Report Nos. 36, 37 and 38.

FLOOD 2 Model

Flood 2 was developed by the Conservation Authorities Branch, Ministry of Natural Resources for computing synthetic storm hydrographs for a river system where many sub-watersheds must be considered. The 1975 version of FLOOD 2 was modified by the Grand River Conservation Authority (1980) in order to add flexibility for use in the Grand River Basin Water Management Study. The program develops synthetic hydrographs in accordance with the Soil Conservation Service procedure for sub-watersheds in a river system. It combines and then routes these hydrographs through the basin.

For each sub-basin watershed, a synthetic hydrograph is developed. This hydrograph is then combined with adjacent or upstream hydrographs and routed through the basin using one of three available channel routing techniques. Runoff volumes are computed using the Soil Conservation Services curve number method and the synthetic hydrographs are constructed using the SCS triangular unit hydrograph approach (Ref. A2). Available channel routing techniques are:

1) Muskingum
2) Storage-indication
3) Variable storage coefficient.

Flows can also be routed through small reservoirs by using the storage indication method.

The FLOOD 2 model was calibrated for the entire Grand River watershed and verified on the April, 1975 flood event. FLOOD 2 was used to simulate the 5, 10, 25, 50, and 100-year flood events on the Grand river. These simulated flood events were then used to compute average annual damages due to flooding. The regional storm, centred at several locations, was also investigated.

Reservoir Yield Model

The Reservoir Yield program was developed by the U.S. Army Corps of Engineers, Hydrologic Engineering Centre, California, for the testing, sizing and operating policies of conservation reservoirs. The program simulated monthly reservoir operation for a single reservoir operated to meet downstream flow targets.

With reservoir storage areas defined in Figure D.1, reservoir operation is simulated as follows:

If, at any given time the water level is within the		Then, the reservoir discharge is determined by:
flood pool	_____	discharge necessary to lower reservoir level to conservation pool, down-stream channel capacity not to be exceeded.
conservation pool	_____	required discharge from reservoir or discharge required to meet down stream target flow, whichever is greater.
buffer pool	_____	discharge required to meet downstream flow target, reduced by % storage deficit.
dead storage	_____	discharge equal to or less than inflow.

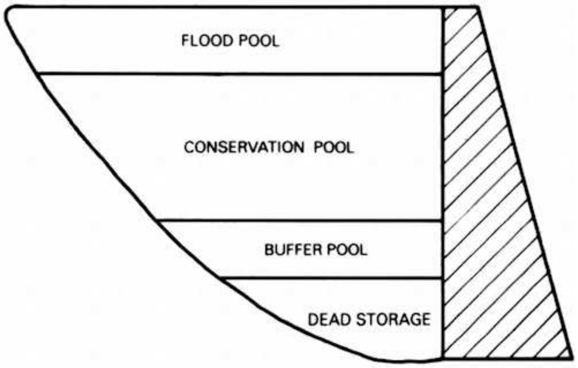


Figure D.1. Reservoir storage areas as defined in reservoir yield and HEC 5 simulation models.

The program was modified by the Grand River Conservation Authority to:

1) simulate operation of a system of reservoirs

2) allow simulation of weekly or daily reservoir operation.

The major difference in the operating logic between the Reservoir Yield program and the HEC-5 program lies in the handling of discharge when the water level is in the buffer pool. The buffer pool is storage required for augmentation later in the year. Reservoir Yield decreases augmentation by a small amount, causing the downstream flows to drop slightly below the target flow. This logic is very realistic. HEC-5 makes discharge equal to minimum required discharge; operation is not determined by the degree of shortage. Results from HEC-5 are not as realistic. This difference in logic is important when testing a reservoir system barely capable of meeting its demands. The Reservoir Yield program was used to:

1) test various operating policies for the existing reservoir system

2) determine the effects of proposed reservoirs on summer low flows.

Reservoir Operation Model HEC-5

The computer program HEC-5 (June, 1979) was developed by the U.S. Army Corps of Engineers at the Hydrologic Engineering Center, California, for evaluation of proposed flood control and conservation systems. The Grand River Basin Water Management Study used the flood control portion of the program to assess the flood damage reduction potential of the existing system plus nine alternative systems (the conservation portion was not used — see Reservoir Yield Model, Figure D.1).

HEC-5 defines a basin's river system in terms of control points, flows and routing coefficients. The control points include reservoirs and flood damage centres as shown in Figure D.2. Flows can be observed, natural or local and routing coefficients are used to route reservoir discharges and local flows.

Reservoir operations for flood control use the following basic rules:

1) when reservoir level is in flood pool the program attempts to draw down to top of conservation pool without exceeding channel capacity of downstream control points

2) when reservoir level is at top of flood pool, discharge is set equal to inflow

3) desired flow at downstream control points is released when reservoir level is in conservation pool; required flow at downstream control points is released when reservoir level is in buffer pool.

One typical HEC-5 computer run consisted of a reservoir system operating on each of five natural flood events (FLOOD 2) to produce corresponding regulated flows at downstream control points. At each control point, the regulated peak flow was associated with a damage and frequency. The resultant damage-frequency curve for the 5 events was integrated by the program to produce average annual flood damages for the control point. Damages for all control points within a reservoir system were summarized to produce an average annual flood damage for the system.

The potential flood damage reduction for a proposed reservoir system was found by comparing its average annual flood damages with that of the existing system.

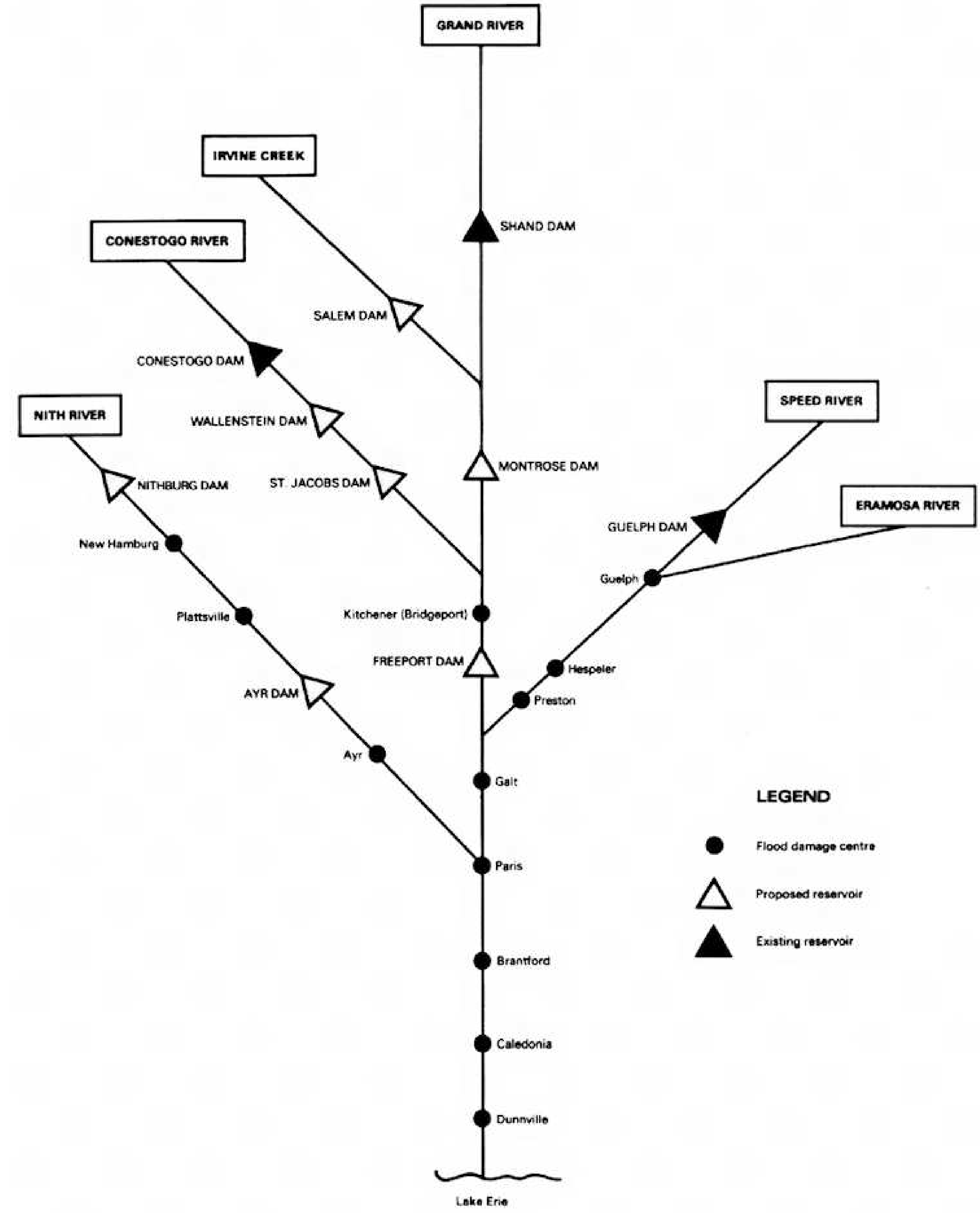


Figure D.2. Flood damage centres and reservoirs modelled in HEC 5.

D.2 Water Quality Simulation Models

The water quality simulation procedure for the Grand River Basin Water Management Study consisted of a package of three major models, which are described in this appendix. For further details about the models and the many supporting programs the reader should refer to Grand River Technical Report No. 30, "Water Quality Simulation Models and Modelling Strategy for the Grand River Basin."

The three models described herein are: (1) the aquatic plant model, ECOL1; (2) the steady state model, DOMOD7; and (3) the dynamic simulation model, GRSM.

ECOL1

The aquatic plant model, ECOL I , is an independent, continuous simulation model which is capable of simulating the seasonal and daily growth of three aquatic plant types, specifically *Cladophora glomerata, Potamageton pectinatus* and *periphyton*. In simulating the growth of these aquatic plants, the model accounts for a variety of processes, including: the release of oxygen from photosynthesis and the uptake of dissolved oxygen by respiration of the plants; the uptake and release of soluble nitrogen and phosphorus, including luxurious uptake of phosphorus; advective transport of soluble nutrients and dissolved oxygen into and out of each simulated reach; loss of standing biomass through death and washout; and the effects on growth of incident light variations, turbidity, self-shading and temperature. Various physical processes such as aeration-de-aeration and changes in river depth, width and velocity associated with changing hydrologic conditions are also simulated.

DOMOD7

The DOMOD7 model is a steady state water quality simulation model which simulates a twenty-four hour period on a two-hour time step. The model accounts for such instream processes as carbonaceous and nitrogenous oxygen demand, re-aeration from weirs and dams, and all processes included in ECOL 1 . A version of ECOL1 was modified and incorporated into DOMOD7 as a subroutine. This provides for estimates of dissolved oxygen and nutrient fluxes which are corrected for the plant biomass within each simulated reach. DOMOD7 predicts instream concentrations of dissolved oxygen, biochemical oxygen demand, nitrogenous oxygen demand, nitrite plus nitrate, suspended solids, and total phosphorus.

DOMOD7 also has the capability to account for the input of up to two point sources, such as sewage treatment plants, or tributaries into each reach. DOMOD7 is useful for examining the effects of point source remedial measures and upstream flow changes upon instream pollutant concentrations.

GRSM

The Grand River Simulation Model, GRSM, is a dynamic (continuous simulation) water quality model which is capable of long-term simulations (up to twenty years) on a two-hour time step. The model incorporates all the features of ECOL1 and DOMOD7, and includes the same processes. The model simulates instream levels of dissolved oxygen, biochemical oxygen demand, nitrogenous oxygen demand, nitrite plus nitrate, unionized ammonia, suspended solids, total phosphorus; and also predicts daily and seasonal biomass growth along with the associated fluxes of soluble nutrients and dissolved oxygen in each simulation reach.

Upstream water quality and non-point source quality are input to GRSM in the form of cumulative probability distributions, derived from historical data collected during routine monitoring and special field surveys. Flow data were generated using various hydrologic models, such as HEC-5, allowing evaluation of hydrologic conditions associated with various reservoirs and operational policies. The use of the STORM model to generate both quality and quantity of urban runoff for input to GRSM allowed for the testing of the effects of changing populations and land use patterns as well as various control options affecting this source.

Continuous water quality monitoring data were collected and extensive field surveys were mounted during 1975, 1976 and 1977 to provide a sufficient data base for calibration and verification of all three models. Each calibration run on the 1976 data was subjected to rigorous statistical and time series analysis and adjustments of model parameters were made until good agreement with observed data was achieved. Further refinement of the model parameters, such as the statistical testing of results of verification runs on 1977 data, was performed until acceptable results for both calibration and verification were achieved.

Modelling Strategy

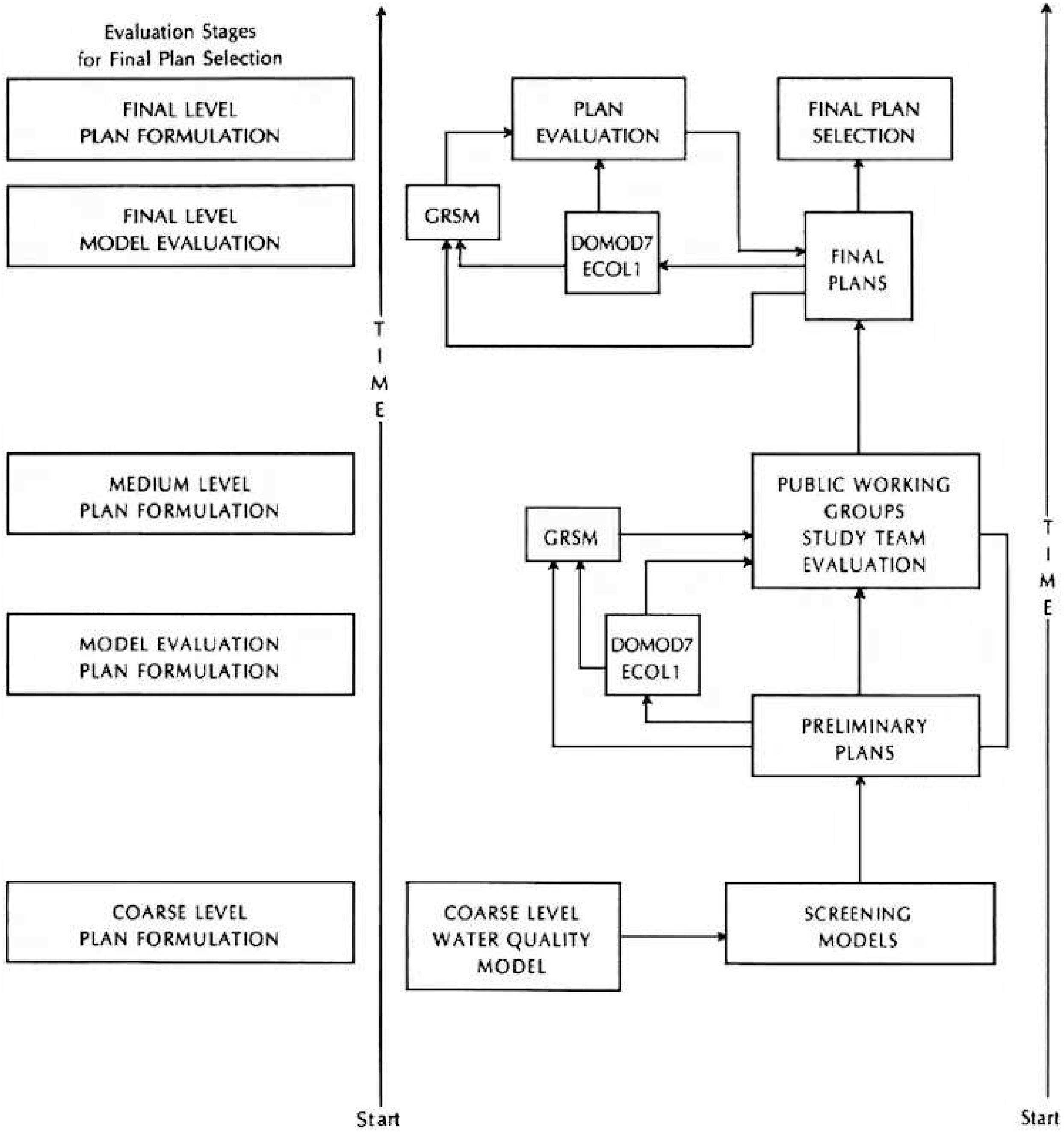
GRSM is expensive in terms of computer costs and requires large and accurate data sets as input for long-term simulation runs. This model provides the best simulation results for long-term statistical evaluation of specific basin management scenarios. In order to reduce computer costs and to provide a quick method of screening many management plans, the three models were used in combination.

DOMOD7 and ECOL1 were used together to provide a relatively quick and inexpensive tool for plan screening. Predicted changes in nutrient concentrations were used as input data for the ECOL1 model. ECOL1 was then run to provide necessary information about impacts on biomass growth which in turn were used in DOMOD7 runs. DOMOD7's role was to assess the improvements in instream dissolved oxygen levels associated with remedial measures for reduction of oxygen-demanding substances at the major sewage treatment plants in the basin.

From the many scenarios tested with DOMOD7 and ECOL1, a few basin management strategies were formulated for evaluation with GRSM. Modifications to these strategies were evaluated using the DOMOD7-ECOL1 package. The most feasible plans based on this screening were then evaluated in detail with GRSM to provide input for the final plan screening process.

Figure D.3 is a simple flow chart illustrating the interrelationships of the working groups, and the roles of the various water quality models in evaluation of management strategies for the Grand river basin.

Figure D.3 Use of Water Quality Models in Evaluation of Management Plans for the Grand River Basin.



E. WATER QUALITY

E.1 Calculation of the Dissolved Oxygen Water Quality Severity Index

A water quality severity index was used in Chapter 10 to compare the effectiveness of each plan in improving water quality on the central Grand and Speed rivers. The index incorporated time, magnitude (concentration), and spatial extent of non-compliance with the dissolved oxygen objective. The index was developed solely for comparing the various water management plans. it was not intended and is not suitable for more general use.

A zero water quality index indicates that the provincial water quality objective for dissolved oxygen is met 100 percent of the time. Table E.1 illustrates an example of calculating the severity index. For a given reach, the water quality model (GRSM) indicated the percentage of time (Column 2) dissolved oxygen in the stream was within a specified class interval or range (Column 1). The deficit (Column 4) is the amount by which the mean of the class interval lies below 4.0 mg/L of dissolved oxygen, the provincial water quality objective for warm water fish at 20°C.

The severity index for a particular reach is then:

Deficit (mg/L) x % time x total length of reach (km)
in class
interval

An example of calculating a water quality index for a river reach, two kilometres in length, is shown in Table E.1.

For n reaches the water quality index is:

$$\sum_1^n \frac{\text{water quality indices}}{\text{number of reaches}}$$

For 3 months (June, July and August) the water quality index is:

$$\sum_1^3 \sum_1^n \frac{\text{water quality indices}}{n \times 3}$$

For each main plan the water quality severity indices have been calculated for existing and future conditions and are described in Chapter 10.

While the ultimate goal is to maintain dissolved oxygen at or above 4 mg/L at all times, the practical or "target" water quality index, given natural or uncontrollable upstream influences on the dissolved oxygen regime, was defined for any reach as being not more than 5 percent of the time below 4.0 mg/L and not lower than 3.5 mg/L at any time. These values representing background conditions in the stream were based upon actual measurements of dissolved oxygen made upstream of Waterloo on the Grand river and upstream of the Guelph sewage treatment plant on the Speed river. The desired water quality index was then calculated in a manner as outlined previously (Table E.1). For the same two kilometre reach the desired index is:

Deficit x of time x length of reach

(4 mg/L - 3.5 mg/L) x 5% x 2 km = desired water quality index

0.5 x 5% x 2 = 5.0

or for n reaches: $\sum_1^n \frac{\text{desired water quality index}}{n}$

and for 3 months:

$$\sum_1^3 \sum_1^n \frac{\text{desired water quality indices}}{n}$$

For the basin study, the desired water quality index was 16.7 on the Grand river and 8.7 on the Speed river.

Table E.1 Calculation of the Dissolved Oxygen Water Quality Severity Index

(1) D.O. Concentration (mg/L)	(2) % Time in D.O. Interval For One Month	(3) Mean of D.O. Interval (mg/L)	(4) Deficit 4 mg/L - value from (3)	(5) Length of Reach (km)	(6) Index Values (4) x (2) x (5)
0-2	10	1	3	2	60
2-4	20	3	1	2	40
			Total For Reach = Water Quality Index for month		100

E.2 Water Quality Monitoring

Provincial Water Quality Monitoring Network

Since 1964, the Ministry of the Environment and its predecessor, the Ontario Water Resources Commission, working in co-operation with the Grand River Conservation Authority, has maintained a routine surface water quality monitoring program throughout the Grand river basin. Samples are collected approximately monthly at 40 locations on the main stem and tributary streams. Analysis includes dissolved oxygen and temperature, bacteriological organisms, 5-day biochemical oxygen demand, nitrogen and phosphorus compounds, solids and, at some locations, other physical parameters, salts and metals. Data from this program have been used extensively in the basin study for modelling and general water quality assessments. Complete records of this surveillance program are published annually by the Ministry of the Environment in "Water Quality Data — Ontario Lakes and Streams."

Continuous Dissolved Oxygen Monitoring

Since 1975, the Ministry of the Environment, working in co-operation with the Grand River Conservation Authority, has maintained a network of automated stations which measure and record, continuously, dissolved oxygen and temperature. Stations are located at the following sites:

Grand river at Bridgeport — upstream of the major population centres
Grand river at Woolner's Flats — downstream of the Waterloo sewage treatment plant
Grand river at Blair — downstream of the Kitchener sewage treatment plant
Speed river at Guelph — upstream of the Guelph sewage treatment plant
Speed river at Glen Christie — downstream of the Guelph sewage treatment plant
Speed river at Preston — near confluence with the Grand river
Grand river at Glen Morris — downstream of the megalopolis area

In 1979, automatic stations were added on the Grand river at Brantford. One station was located near the city's water works intake. The other was sited downstream from the sewage treatment plant outfall.

Data from all stations were used for the development and verification of water quality models and for general water quality assessments. Detailed information about these automated stations and summarized data results for the period 1975-1979 are provided in Technical Reports 11 and 11 a.

Automated dissolved oxygen/temperature monitoring stations are being maintained jointly by the Ministry of the Environment and the Grand River Conservation Authority at Bridgeport, Woolner's Flats, Blair, Guelph, Glen Christie and Glen Morris so that the effects of remedial measures to improve water quality can be adequately measured.

Proposed Organic Chemical Monitoring Program

During the basin study, samples for trace organic chemical analyses were collected from the main stem of the Grand river, the Speed river, Canagagigue creek and the Elmira sewage treatment plant. A variety of organic compounds were measured at very low concentrations. While there have been very few objectives or guidelines set for these organic compounds, a review of literature indicates that the concentrations measured to date in the river pose no threat to aquatic life or use of the river for water supply.

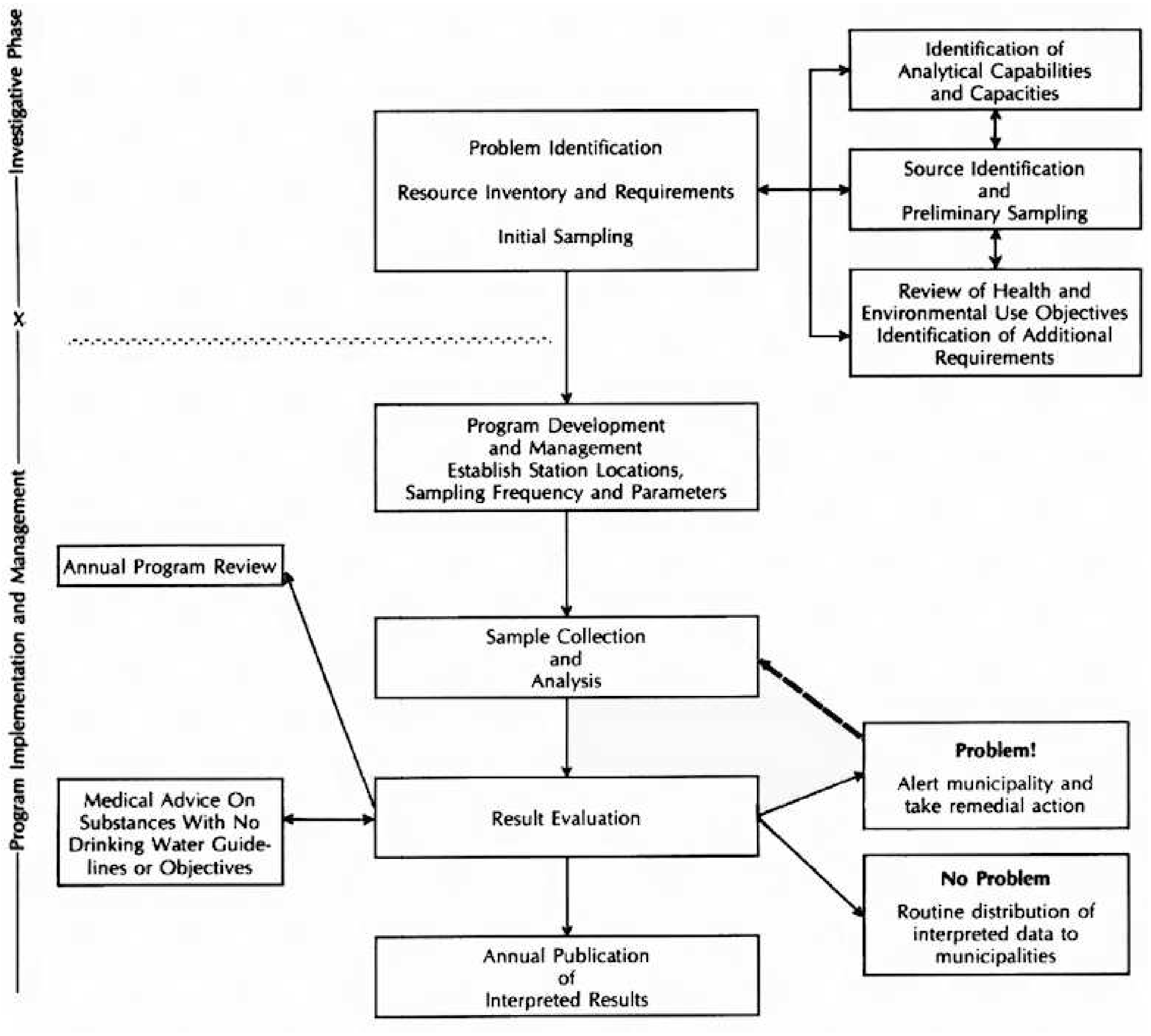
It must be pointed out, however, that the trace organic substance analyses carried out during the basin study were limited in scope. With the existing and growing use of the river for municipal drinking water supply, a more comprehensive program is warranted. To this end, a tentative framework for a trace organic contaminant monitoring program has been prepared and is presented in Figure E.1. The proposed program has two parts: an initial problem identification/resource requirement investigative phase followed by the implementation and management of a routine monitoring program.

The lead agency in the overall program would be the Ministry of the Environment. This agency would, essentially, be responsible for carrying out the investigative phase of the study, organizing the program management team, collecting and analysing samples and reporting results. Medical authorities of the Provincial Government would be asked to provide advice on any required, new drinking water objectives or consumption guidelines and comment upon analytical results as required. Municipalities using the river as a source of water supply could participate in the planning of the program and would receive the interpreted results of analysis routinely. The interpreted results of the program could be published annually.

The precise location of sampling stations can be set only after the investigative phase; however, such stations should include major municipal and industrial point sources, urban drainage sites, the river at municipal water supply extraction points, treated water from these municipalities and control samples from headwater areas of the basin unaffected by municipal or industrial inputs. Lists of substances for routine analysis should be set only after the initial sampling and problem identification activities of the investigative phase are complete.

The entire project should be managed by a team composed of representatives from the Ministry of the Environment, the major municipalities, provincial health authorities, and the basin co-ordinating committee.

Figure E.1. Structure of A Proposed Trace Organic Pollutant Monitoring Program.



E.3 Sewage Treatment Plants

This appendix briefly describes the sewage treatment facilities used to treat the municipal, private and industrial wastes of the Grand river basin.

Municipal and Private Sewage Treatment Plants

All of the municipal treatment facilities in the Grand river basin are listed in Table E.2, with private facilities listed in Table E.3. Also included in these tables are the type of treatment, the capacity, and the general effluent quality of each plant. The locations of municipal sewage treatment plants are shown on Figure 4.5 in Chapter 4.

Industrial Discharges

The vast majority of industries or commercial operations in the Grand river basin with waste discharges are connected to a municipal sewage system and their wastes are adequately treated and discharged along with the municipality's sanitary wastes. There are a number of industries discharging treated wastewater directly to the river. These industries are listed in Table E.4 and are described briefly in the following paragraphs.

Silknit Ltd (formerly Dominion Woolens) — Cambridge (Hespeler)

This textile plant located in Cambridge(Hespeler) treats its wastes in an aerated lagoon which discharges continuously to the Speed river, upstream from the Hespeler sewage treatment plant, at a rate of 2400 m^3/d (0.528 mgd). Effluent quality is marginally above the Ministry of the Environment's criteria and remedial action is not justified at this time. However, an increase in the size of the aeration basin is planned which will result in lower organic loads and less dyes being released to the river. The sanitary wastes from the plant are directed to the municipal sewage treatment plant.

J. M. Schneider — Ayr

Wastes from this meat processing plant, located in Ayr, are treated in a conventional activated sludge type plant before being discharged to the Nith river. Organic and phosphorus levels are unacceptably high. Plant flows are 300 m^3/d (0.066 mgd). The problem is under consideration by the Ministry of the Environment. Sanitary wastes are treated in the municipal sewage treatment plant.

Solar Ware — Cambridge (Hespeler)

Metals are cleaned, etched with a nickel solution, and porcelainized in this plant located in Cambridge (Hespeler). Wastes from these processes are neutralized and subjected to flocculation and precipitation for metals removal. Although nickel levels were high in 1979 (1.7 mg/L), adjustments have been made to the treatment system with acceptable levels resulting. Flows in 1979 averaged 180 m^3/d (0.04 mgd). Sanitary wastes are directed to the municipal system.

Stanley Works — New Hamburg

This electroplating plant, located in New Hamburg, treats its wastes by various methods including cyanide destruction, chromium conversion, neutralization, flocculation and precipitation. Approximately 270 m^3/d (0.059 mgd) of treated wastes are discharged to the Nith river. Although zinc levels were high in 1979, they have been controlled and the discharge is acceptable to the Ministry of the Environment.

Tend-R-Fresh — Petersburg

This poultry processing and rendering plant located in Petersburg, discharges 2700 m^3/d (0.594 mgd) of treated wastes to the head waters of Alder creek. Treatment includes pretreatment for large solids removal (including feathers) followed by biological treatment with a polishing lagoon being utilized if necessary. Although the aqueous discharges ae generally acceptable to the Ministry of the Environment, the company has been asked to provide phosphorus removal to 1 mg/L to reduce aquatic growths in Alder creek. Sanitary wastes are treated in the industrial treatment plant.

The company has had a history of odour problems. Local residents have objected to a recent request to increase rendering operations by accepting outside wastes, as odour problems may extend into nightime periods. Sanitary wastes are treated in the industrial treatment plant.

Industries Discharging to Municipal Sewage Systems

There are a great many industries in the Grand river basin which discharge processed wastes directly to the sanitary sewers. In the Kitchener-Waterloo area alone about 300 industries dispose of their wastes in this manner. In most cases no problems result. However, problems have been encountered with the industries discussed below.

St. Jacobs

The St. Jacobs Canning Company discharges high BOD wastes to the sanitary sewer in the fall which interferes with normal operation of the sewage treatment plant. Methods to minimize sewage treatment plant disruption are under investigation.

Fergus

Canada Wire and Cable and Noranda Metals discharge wastes which are high in heavy metals to the town's sanitary sewer. Although operation of the sewage treatment plant is not affected adversely, sewage sludge is above the Ministry of the Environment's guidelines as a result of these inputs.

Elmira

Uniroyal Chemicals Ltd. provide pretreatment of their wastes before discharging to the sanitary sewer. Pretreatment includes aeration and pH and temperature stabilization, followed by carbon filtration. Because of the nature of the Uniroyal wastes, solid setting is inhibited in the sewage treatment plant resulting in a high level of suspended solids in the effluent. As part of the expansion of the Elmira sewage treatment plant, flow proportioning between Uniroyal and the town's wastes will be provided and thus result in less shock loads to the sewage treatment plant. As well, the company is installing a "wet-ox" system to reduce the toxicity of their effluent and treat some waste streams currently being disposed of off-site. Wastes from Borg Textiles are also suspected of placing shock loads on the sewage treatment plant at times.

Paris

Approximately one-half of the hydraulic loading to the sewage treatment plant is provided by Penmans Limited Textile plant. Colours and a high organic load from the dyes used at Penmans interfered with normal operation of the sewage treatment plant and resulted in a poor quality effluent on many occasions. The company is in the process of removing its dying operations from this plant, thereby eliminating this industrial discharge to the sewage treatment plant.

Table E.2 Municipal Sewage Treatment Plants In The Grand River Basin.

Municipality	Type of Treatment	Sewage Flows - 1979		Mean 1979 Effluent Quality(mg/L)			Receiving Watercourse	Comments
		Plant Capacity	1979					
		x10 ^{3} m^3/d lagoon size in hectares	Average Daisy Flow x 10^{3}m^3/d	BOD$_5$	Suspended Solids	Total Kjeldahl Nitrogen		
Arthur	Seasonal Discharge Lagoons	11.6 ha		15.0	25.0	15.0	Conestogo River	
Ayr	Extended Aeration	1.05	---	5(e)	15(e)	8.0(e)	Nith River	Completed January, 1980.
Baden	Extended Aeration	0.92	0.5	3.2	7.6	4.4	Baden Creek	
Brantford	Conv. Activated Sludge	57.0	40.9	7.3	13.0	8.9	Grand River	Expansion to 84 x 10^{3}m^3/d virtually completed.
Caledonia	Conv. Activated Sludge	2.3	1.9	8.0	20.0	8.0	Grand River	
Cayuga	Extended Aeration	0.9	---	2.0	8.0	1.6	Grand River	
Dundalk	Seasonal Discharge Lagoons	6.5 ha	---	10.0	18.0	5.0	Grand River	Expansion planned.
Dunnville	Conv. Activated Sludge	7.7	4.4	8.0	12.0	3.8	Grand River	
Elmira	Conv. Activated Sludge	3.1	3.3	17.0	40.0	32.0	Grand River	Expansion planned to 4.6 x 10^{3}m^3/d with filters and nitrification.
Elora	Extended Aeration	0.38	0.92	14.0	40.0	24.0	Grand River	Recently expanded to 3 x 10^{3}m^3/d (1980)
Fergus	Conv. Activated Sludge	5.0	3.0	11.0	14.0	9.0	Grand River	
Galt	Conv. Activated Sludge	38.6	29.3	8.2	9.4	9.9	Grand River	
Grand Valley	Extended Aeration	0.6	0.32	6.0	12.0	12.0	Grand River	
Guelph	Conv. Activated Sludge	45.5	41.4	20.0	22.0	19.0	Speed River	Expanded in 1980 to 55 x 10^{3}m^3/d with nitrification and filters.
Hespeler	High Rate Activated Sludge	9.3	5.0	35.0	46.0	17.0	Speed River	
Kitchener	Conv. Activated Sludge	123.0	61.2	13.0	8.0	4.0	Grand River	
New Hamburg	Seasonal Discharge Lagoons	11.1 ha	---	7.0	15.0	12.0	Nith River	Expansion under construction. Discharge will be proportional to streamflow.
Paris	Extended Aeration	2.3	1.9	33.0	40.0	22.0	Grand River	Plant presently being expanded to 6.9 x 10^3/m^3/d.
Preston	Conv. Activated Sludge	19.1	7.9	32.0	53.0	8.0	Grand River	
St. George	Extended Aeration	1.1	---	7.5(e)	7.5(e)	8.0(e)	Fairchild Creek	Under construction - effluent storage, if necessary.
St. Jacobs	Extended Aeration	0.95	1.0 - 0.78*	5.0	16.0	2.5	Conestogo River	Effluent affected by industry.
Waterloo	Conv. Activated Sludge	45.5	30.7	9.0	12.0	9.0	Grand River	
Wellesley	Extended Aeration	0.55	0.39	4.0	13.0	1.9	Nith River	

* High flows recorded in 1979 may be due to faulty meter and/or infiltration.

Table E.3 Private Sewage Treatment Plants In The Grand River Basin.

Facility	Type of Treatment	Sewage Flows		Mean 1979 Effluent Quality (mg/L)			Receiving Watercourse
		Plant Capacity	1979				
		10^3 m^3/d or lagoon size in hectares	Average Daily Flow x 10^3 m^3/d	BOD_5	Suspended Solids	Total Kjeldahl Nitrogen	
Breslau Hotel	Seasonal Discharge Lagoons	0.81 ha	--	30.0	23.0	0.4	Hopewell Creek
Burtch Correctional Centre	Conventional Activated Sludge	0.2	0.09	9.5	24.0	13.0	Mt. Pleasant Creek
Cainsville Industrial Park	Seasonal Discharge Lagoon	2.4ha	---	8.0	10.0	--	Fairchild Creek
Ontario Hydro	Seasonal Discharge Lagoons	0.17 ha	---	5.5	11.0	4.6	Big Creek
Oshweken Reserve	Seasonal Discharge Lagoons	1.3ha	---	15.0	9.0	4.0	McKenzie Creek

Table E.4 Industrial Waste Treatment Plants In The Grand River Basin.

Industry	Location	Type of Treatment	1979 Flows x 10^3 m^3/d	Receiving Watercourse	Major Effluent Constituents
Silknit Ltd. (formerly Dominion Woolens	Cambridge (Hespeler)	Aerated lagoons with continuous discharge	2.4	Speed River	BOD_5 - 34. mg/L, Phenols 68 mg/L, S.S. 35 mg/L, Total P - 0.1 mg/L, Dyes, Detergents
Electric Reduction (Erco) Industries Ltd.	Port Maitland	Recycling	8.5	Grand River	Total P - 5 mg/L, S.S. - 16.3 mg/L
International Minerals and Chemical Corp. (Canada) Ltd. (I.M.C.)	Port Maitland	Recycling and/or lime neutralization	29.4	Grand River	Total P - 17.2 mg/L, Fluorides - 16.3 mg/L, S.S. - 19.4 mg/L
J.M. Schneider Ltd.	Ayr	Biological treatment	0.30	Nith River	BOD_5 - 44 mg/L, S.S. - 69 mg/L, Total P - 18 mg/L, NO - 15.2 mg/L
Solar Ware	Cambridge (Hespeler)	Primary (metal removal)	0.18	Speed River	Ni - 1.7 mg/L, S.S. - 50.3 mg/L
Stanley Works	New Hamburg	Metals removal	0.27	Nith River	Zn - 2.9 mg/L, Cr - 0.3 mg/L, Ni - 0.2 mg/L, Cu - 0.5 mg/L
Tend-R-Fresh	Petersburg	Biological treatment and polishing lagoon	2.7	Alder Creek	BOD_5 - 20 mg/L, S.S. - 36 mg/L, Total P - 3.3 mg/L

KEY
BOD_5 - 5-Day Biochemical Oxygen Demand
S.S. - Suspended Solids
Total P - Total Phosphorus
NO_3 - Nitrate Nitrogen

Ni — Nickel
Zn — Zinc
Cr — Chrome
Cu — Copper

F. WATER QUANTITY

F.1 Average Annual Flood Damages

This appendix briefly describes how the average annual flood damages are calculated for a particular site.

First, an elevation-discharge curve, which shows the relationship between discharge and river water levels is derived for the area subject to flooding (Fig. F.1.a).

Flood damages are then calculated with the use of unit flood damage curves or tables for various types of residential, commercial or industrial structures. These tables represent the total structural and content damage for various depths of submergence.

For each flood elevation in a flood centre, the individual residential, commercial and industrial damages are accumulated and plotted to form an elevation-damage curve as shown on Figure F.1.b.

For each area subject to flooding, a flood frequency curve is developed (Fig. F.1.c). This curve is based upon a statistical analysis of the maximum river discharges.

A damage frequency curve is developed from Figure F.1.a, the elevation-discharge curve; Figure F.1.b, the elevation-damage curve; and Figure F.1.c, the flood-frequency curve.

A damage-frequency curve is shown in Figure F.1.d and in Figure 6.1 in Chapter 6. The shaded area under the curve represents the average annual flood damages.

The average annual benefits as a result of the construction of a dyking system are shown in Figure F.1.e. If it is assumed that the dykes are designed for a flow of 2 m^3/s corresponding to a frequency of exceedance of 2 percent, then benefits are only obtained for flows less than 2 m^3/s.

If a reservoir is designed to offer the same protection as the dyking system in the previous example, the average annual flood damages will generally be lower than those sustained by the dyking system (Fig. F.1.f). This is because the reservoir, with its ability to store flood volumes will often continue to reduce flood flows even when the design flow is exceeded.

In contrast, the dyking system offers protection up to the design flow or elevation. When this elevation is exceeded, the dyking system is assumed to fail and the damage is as large as if there had been no dyking system.

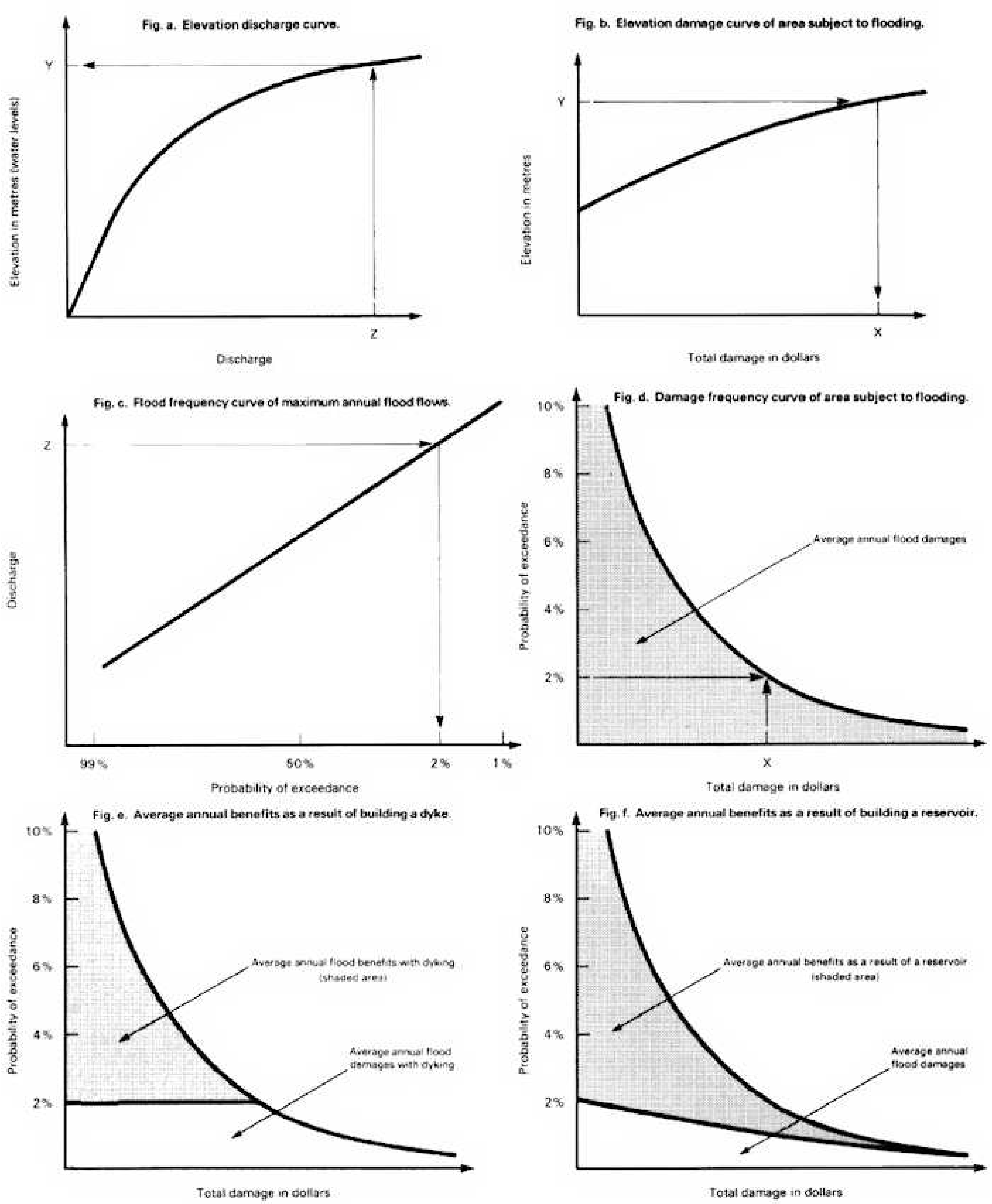


Figure F.1. Average annual flood damages.

F.2 Variation of Average Annual Flood Damages With Floodplain Development

The basin study has assumed that the floodplain regulations, as presently administered and enforced, would control future floodplain development. Therefore, existing average annual flood damages are not expected to increase significantly during the 50-year planning period due to floodplain development.

This assumption was based on a review of past floodplain development (Table F.1). For example, the total number of structures in Cambridge (Galt) and Brantford has increased only 5 percent between 1954 and 1976. Since over 85 percent of the average annual flood damages occur in these two cities, the total average annual flood damages should not change materially in the future due to floodplain development.

Table F.1 Floodplain Development for Selected Communities within the Grand River Basin (1954-1976).

Community	Number of Structures Within the Floodplain*	New Structures Erected in the Floodplain**	
		1954-1966	1966-1976
Cambridge (Galt)	746	3 (0.4%)	13 (2%)
Brantford	2694	112 (4%)	48 (2%)
New Hamburg	115	6 (5%)	7 (6%)
Bridgeport	130	19 (15%)	32 (25%)

* Floodplain for this review is defined as the land within the Regional Storm Floodline

** Net result = new structures — structures removed

( ) percentage increase in structures within the floodplain

Source: Ref. A3.

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