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CITY OF NANAIMO

CAT STREAM DRAINAGE

BASIN STUDY

DAYTON & KNIGHT LTD.
Consulting Engineers

See Eric
Re Catstream
@ Quie Place.

DAYTON & KNIGHT LTD.
Consulting Engineers

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December 15, 1981

Mr. A. W. MacDonald
Director of Public Works
City of Nanaimo
455 Wallace Street
Nanaimo, B.C.
V9R 5J6

Dear Mr. MacDonald:

The Cat Stream Basin Study, authorized by your letter of April 16, 1981 has now been completed and we take pleasure in submitting our report.

The Cat Stream Drainage Study of May, 1980 addressed 25 and 200 year storm flows in the Cat Stream, recommended improvements along the Cat Stream and discussed stormwater management policies for the basin.

City wide management policies were subsequently adopted which included the requirement for carrying out studies in each drainage basin of the City.

This report expands upon the 1980 study in conformity with the Stormwater Management Policies. The adequacy of existing facilities in the Cat Stream is evaluated for 100-year storm flows. The adequacy of existing storm drains in the sub-basins tributary to the Cat Stream is also evaluated for both 5-year and 100-year flows.

Recommendations are made to accommodate 100-year flows in the Cat Stream as a major flood route. In the sub-basin areas, storm drains sized for 5-year flows are recommended along with overland routes, where possible, to convey excess runoff up to the 100-year storm.

The recommended improvements are estimated to cost $928,000 for 1982 construction.

The report also delineates the Cat Stream, discusses the regulation of development within the stream management area and provides a drawing showing the proposed extent of the stream management area.

We appreciate the opportunity to have worked on this study and will be pleased to help with its implementation.

Respectfully submitted,

DAYTON & KNIGHT LTD.

B Walker

Brian L. Walker, P.Eng.

REPORT TO

THE

CITY OF NANAIMO

ON

CAT STREAM BASIN STUDY

December 15, 1981

DAYTON & KNIGHT LTD.
Consulting Engineers

CITY OF NANAIMO

CAT STREAM BASIN STUDY

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CITY OF NANAIMO

CAT STREAM BASIN STUDY

1. SUMMARY

1. The May 16, 1980 Cat Stream Drainage Study examined the creek and its ability to handle runoff from future development. Rainfall data were analyzed, design criteria developed, quantities of runoff for 25-year and 200 year storms calculated and four plans were presented for drainage improvements. The study also recommended stormwater management policies be established for the drainage basin.

2. In July, 1980 the City established a Stormwater Management Policy Committee that developed drainage policies applicable on a City wide basis.

3. Policy No. 10 requires the City to undertake drainage basin studies in order to develop conceptual drainage plans to be used for guidance in providing future stormwater facilities within the basin.

4. This study, authorized in May, 1981, is a supplement to the 1980 report. Its purpose is to incorporate requirements arising out of the policies set by the Committee. Specifically the study re-evaluates the adequacy of the Cat Stream culverts and creek sections to handle 100-year flows, both minor flow (5-year) and major flow (100-year) runoff are examined in sub-basin areas tributary to the Cat Stream, and recommendations are made for improvements where existing facilities are inadequate or where storm drainage facilities have not been provided. The study further delineates the stream and establishes a preliminary Stream Management Area wherein all development should be regulated.

5. Coincident with the preparation of this report the City authorized the detailed design of stormwater storage ponds between Bruce Ave. and Third St., culvert improvements at Third St., storm drains in the Howard Ave. area and storm drains along Wakesiah Ave. The preliminary design for storage ponds above Wakesiah Ave. in conjunction with Malaspina College is also being carried out. This work forms a portion of Bylaw 2256 and design is now complete and some work is being constructed. For the purposes of this report, these works are assumed to be existing.

6. Runoff quantities and storage requirements in the Cat Stream were recalculated for the 100-year storm using all year rainfall curves, the ILLUDAS computer model and manual calculations. These runoff quantities and storage requirements are higher than the adopted 1980 Study Plan 2 values which were based on a 25-year event calculated using the winter rainfall curve.

7. The recalculated 100-year values have been used in design of the drainage works authorized under Bylaw 2256.

8. 5-year and 100-year runoff quantities were calculated for all sub-basins tributary to the Cat Stream.

9. Additional storage areas to those established at Bruce and Wakesiah were investigated, but none were found that would be cost effective.

10. The 100-year flow must be accommodated within the Cat Stream without causing flooding to basements or private property outside the Stream Management Area.

11. On this basis, the culvert at Beaconsfield Road should be replaced with an open ditch, the upstream section of the Fifth Ave. culvert must be replaced with a larger pipe, gravel must be removed from four culverts, trash racks are needed ahead of eight culverts, the creek must be regraded and widened near Rosamond St. and at Robins Park, and the creek must be cleared of debris and brambles along its course. The estimated cost of this work within the Cat Stream is $156,000.

12. Existing storm drains in the sub-basins were evaluated for their ability to convey 5-year flows. The drains along Fourth St., Albion St., in the lane between Winchester and Park Ave. just east of Fifth St., and Wakesiah Ave. North were found to be inadequate.

13. The terms of reference require that preliminary designs be done to size storm drains 600 mm (24 in.) and larger that are needed for 5-year minor flows. On this basis, a 600 mm drain is needed along Doric Ave., a 600 mm drain is needed in the lane south of Fifth St., and a 675 mm drain is needed along Park Ave. near Robins Park. Minor system storm drains of a smaller diameter have also been recommended in Fourth St., Albion St. and Wakesiah Ave. North.

14. The terms of reference also require that the major flow (100-year storm) be accommodated in the sub-basin areas. Preference is to be given to conveying the excess flow above the 5-year storm drain capacity overland in order to minimize construction costs. Overland routes in the form of a swale, depressions at driveways and road crossings, and pathways across City owned land appear feasible in conjunction with the 5-year storm drain system on Doric Ave., Wakesiah Ave. Fourth St., Albion St. and in the lane south of Fifth St.

15. Along Park Ave. near Robins Park the difficulty with conveying flow over road crossings makes overland conveyance of major flows more costly than the alternative of increasing the minor pipe system from 675 to 900 mm to accommodate the 100-year flow.

16. The estimated cost of the drainage improvements in the sub-basins is $772,000.

17. The impact from the possible North-South Arterial has not been considered in this report.

18. The Cat Stream was delineated to commence at the 600 mm storm drain discharge from Malaspina College, continue through the storage

ponds above Wakesiah Ave., through the storage pond between Third St. and Bruce Ave. and to terminate at its discharge to the Chase River at Park Ave.

19. A drawing was prepared to define the Stream Management Area along the Cat Stream. Generally the area is a minimum of 18 m wide centered on the stream. Wider sections are needed between Bruce Ave. and Third St., and upstream of Wakesiah Ave. to include the storage ponds and also near Albert St. and in Robins Park to include low lying land.

20. Six recommendations are made in Chapter 6.

- staged construction of $928,000 of drainage improvements.

- for new developments, require a detailed drainage plan as part of the approval process.

- formalize the Stream Management Area by bylaw and regulate development and pollution by bylaw.

- obtain agreement with Malaspina College and the Ministry of Environment for construction, operation and maintenance of storage ponds above Wakesiah.

- carry out regular inspection and at least annual maintenance in the Cat Stream.

2. INTRODUCTION

The Cat Stream Drainage Basin is shown in Figure 1. The total area is about 260 ha. The Cat Stream begins west of Wakesiah Avenue in the area south of Jingle Pot Road and runs to the east and south to discharge into the Chase River near the intersection of Park Avenue and Seventh Street.

Figure 2 shows the drainage area, the sub-area boundaries and existing drainage facilities.

BACKGROUND

The Cat Stream Drainage Study, completed in May 1980, examined the creek and its ability to handle runoff from existing and future development. Rainfall data were studied in detail and the ILLUDAS computer program was used to calculate quantities of runoff and storage requirements. On site measurements of water levels during the December 1979 storm were used to improve the accuracy of the modelling process. Four plans were presented for drainage improvements in the Cat Stream. Watercourse preservation and management were discussed. The study recommended that:

1. The family of rainfall curves based on Vancouver Airport records be adopted for the City of Nanaimo.

2. Use of the Rational Method be continued for storm drainage design, but that preference be given to use of the ILLUDAS Computer Program for basins where retention-detention storage appears possible.

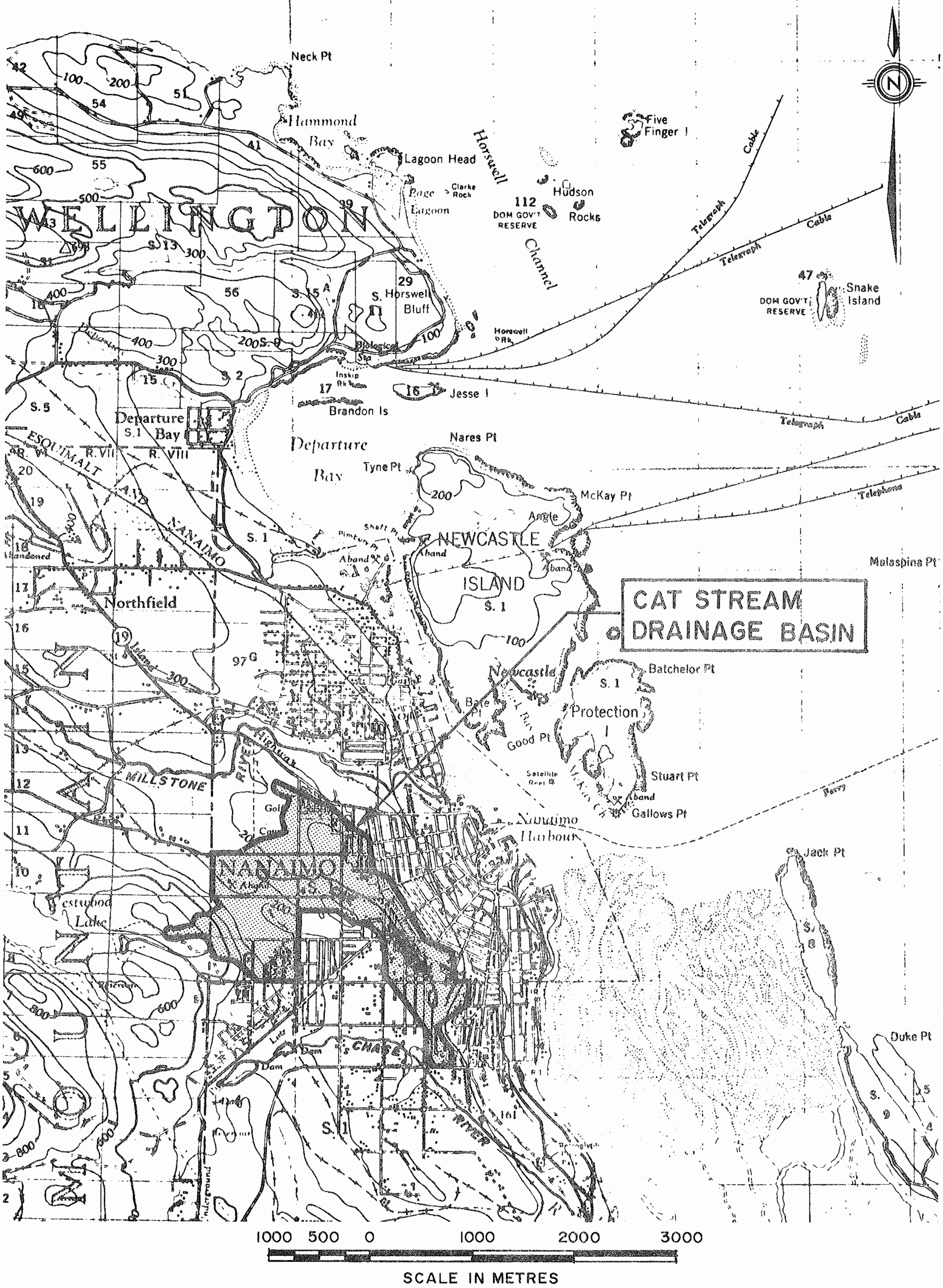
3. The City prepare a bylaw to prohibit the placing of refuse or trash of any kind in its natural watercourses.

4. The design flows and storage requirements for the Cat Stream Drainage Basin be adopted for a 25-year rainfall recurrence interval, with the creek serving as both the minor and major flood route.

5. That Plan 2 of the report, with a 25-year rainfall recurrence interval and comprising storage at both Wakesiah Ave. and Third St. be adopted in principle.

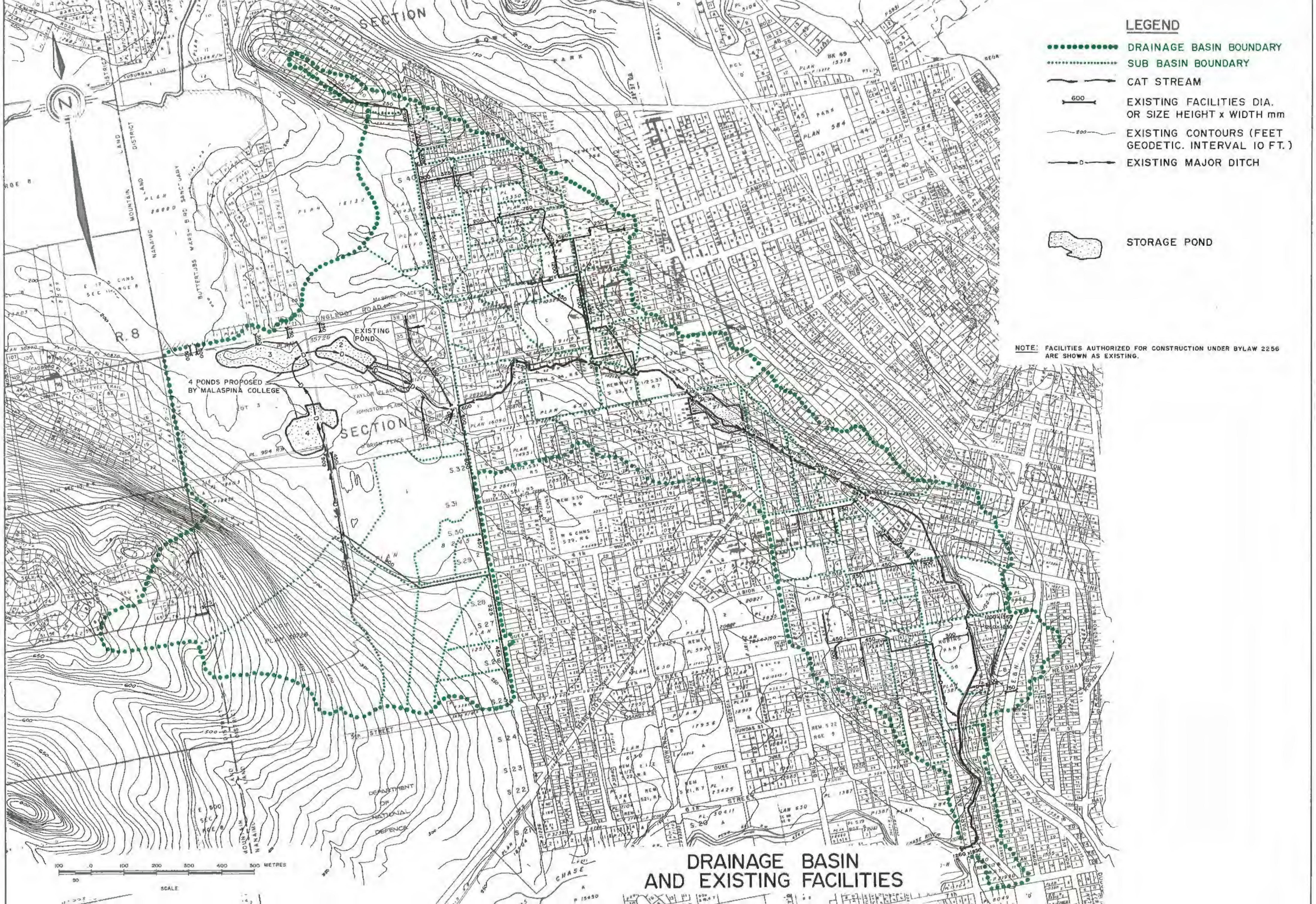
6. That culverts crosssing Jingle Pot Road be blocked off to prevent Millstone River flow from entering the Cat Stream Basin.

7. The City prepare a bylaw to regulate construction of any kind in or near its natural watercourses.



LOCATION PLAN

FIGURE I



DRAINAGE BASIN AND EXISTING FACILITIES

8. The City petition the Provincial Government for legislation to place storm drainage on the same basis as water and sewerage for Senior Government approvals and financial assistance.

9. The City prepare a Development Cost Charge Bylaw for the Cat Stream Drainage Basin, and

10. The City proceed with applications to control authorities for approval to implement Plan 2 of the report.

A Stormwater Management Policy Committee was formed by the City in July 1980 and included representatives from four engineering consulting firms practising in Nanaimo. Submissions were invited from government agencies and from the Vancouver Island Real Estate Board. After a series of meetings the committee produced a number of policies and objectives as shown in Appendix I. In summary, the Policies are as follows:

1. Natural watercourses shall be protected and managed as open streams except under special circumstances.

2. Creek Management Areas shall be established along natural watercourses within which all development will be restricted.

3. Regulations shall be enacted that will place all alterations which affect flow capacity or stream environment within Creek Management Areas under Municipal control consistent with the Water Act.

4. Natural watercourses shall remain as private property except at utility crossings or under special circumstances.

5. Both minor and major flow routings shall be investigated and included in all drainage systems in the City.

6. Rainfall and runoff design criteria shall be established on a City-wide basis.

7. Increase in runoff due to new developments shall be limited according to the capacity and sensitivity of the downstream drainage system.

8. Storm sewers with individual parcel connections shall be required for all new developments, except in special circumstances.

9. Minimum water quality standards for storm water contributions from agricultural, industrial, commercial, residential and institutional developments shall be considered.

10. Natural drainage areas shall be established for watercourses and individual analyses of major and minor flow routing, and of retention/detention works for watercourses in each area shall be instituted.

The present basin study is a supplement to the Cat Stream Drainage Study of 1980. Its purpose is to incorporate requirements arising from the policies and objectives of the Stormwater Management Policy Committee, specifically, Policy No. 10 in which the City is to carry out Basin Studies in order to develop conceptual drainage plans for stormwater management. In addition to the Cat Stream Basin Study, the City has authorized two other basin studies that are being carried out by other consultants.

Plan 2 in the Cat Stream Study comprising storage at both Wakesiah and Bruce and protection for winter runoff up to a 25-year recurrence interval has been adopted by the City. In addition, the City has authorized the design of storm drains in the area of Howard Avenue and along Wakesiah Avenue, which are respectively Item CH 1-1 and CH 1-2 that were recommended in the 1977 Storm Sewer Study. These works were authorized in January 1981 and are presently under design or are being constructed under Drainage Bylaw 2256.

TERMS OF REFERENCE

A meeting of consultants and the City was held on March 9, 1981 to coordinate terms of reference for basin studies. Following the meeting terms of reference for the Cat Stream Basin Study were outlined in a letter to the City dated March 18, 1981, as follows:

- Calculation of the major flow (100 year return period).
- Delineation of the Stream Management Area.
- Review of bridge locations and erosion areas.
- Review of storage areas.
- Review of drainage areas for major/minor flows for basin sizes of 15 ha in existing areas and 25 ha in undeveloped areas and for minor pipe sizes 600 mm and larger.

The City Utilities Committee report dated April 3, 1981 sets out the following requirements for Basin Studies:

- Update legal information on base plans.
- Check and update drainage boundaries and sub-catchment areas (15 ha urban, 25 ha rural), soils permeability classes and future land use based on the existing Community Plan.
- Determine locations for minor system trunk mains (600 mm and greater), regional detention areas and major flow paths. Comment on other retention/detention areas.
- Model minor and major flows using ILLUDAS.
- Establish the adequacy of the existing system and recommend improvements.
- Delineate stream management area for creeks with 100 year post development flows in excess of 1 cms. Also identify creeks that are sensitive to minor or major flows and remedial works required (erosion control, flood control, etc.).

- Identify where bridges would be required.

- The guidelines will allow for individual basin characteristics and conditions and will be flexible enough to allow for a system to be designed which will work under reasonable conditions.

- Investigation of major and minor systems and ILLUDAS modelling for developed or subdivided areas. Undeveloped areas will be analysed in conjunction with future subdivisions at developer's cost.

CONDUCT OF STUDY

The study commenced in May, 1981.

After some correspondence, a meeting was held at the City offices on June 2, 1981 to determine ILLUDAS parameters for basin studies. All consultants were present to agree on the parameters, so that uniformity would prevail in the various basin studies.

Progress was discussed at a consultants meeting with the City on August 14, 1981.

A second meeting was held on September 9, 1981 to report on progress and to discuss report presentation and uniformity of drawings. Draft reports were requested by October 31, 1981.

The draft report was submitted on October 30, 1981. The draft report was discussed with Fish and Wildlife Branch officials on November 4, 1981 and with City Staff on November 17, 1981.

The draft report was presented to City Staff on November 26, 1981.

The report was prepared by D.J. Palmer, P.Eng. with general direction by B.L. Walker, P.Eng.

ACKNOWLEDGMENTS

The assistance of the Director of Public Works, Mr. A. W. MacDonald and his staff, particularly Mr. Waugh and Mr. Bangah, has been most valuable.

ABBREVIATIONS

The following abbreviations have been used in this report:

ILLUDAS	- Illinois Urban Drainage Area Simulator (a computer program)
ha	- hectares
ac.	- acres
m	- metres
ft.	- feet
mm	- millimetres
cms	- cubic metres per second
m^3	- cubic metres
cfs	- cubic feet per second
CSP	- corrugated steel pipe

RC	- reinforced concrete
WS	- woodstave
AMC	- antecedent moisture content
n	- Manning's roughness coefficient
dia.	- diameter
HGL	- hydraulic grade line
R/W	- right-of-way

CONVERSION FACTORS

1 hectare	= 2.471 acres
1 metre	= 3.28 feet
1 millimetre	= 0.03937 inches
1 cubic metre	= 35.3 cubic feet
1 cubic metre per second	= 35.3 cubic feet per second

3. DESIGN CRITERIA AND FLOWS

Much of the design criteria developed and presented in the 1980 Cat Stream Study is applicable in this basin study. These data include rainfall analysis, soil classifications, land use assumptions, fisheries considerations, runoff coefficients and pipe roughness coefficients. These criteria are not repeated herein.

The 1980 study calculated quantities of runoff and storage requirements at various points in the Cat Stream, and these quantities were based on either a 25-year or 200-year recurrence interval storm using winter rainfall curves.

The terms of reference expand the requirements for the basin study to include minor and major flow quantities in the sub-basins (maximum 15 ha urban and 25 ha rural) as well as in the stream. A 5-year storm is to be used for minor flows and a 100-year storm for major flows. All year rainfall curves are to be used, which will increase the quantity of runoff over that calculated using winter curves.

One exception to the sub-basin size criteria is in the area of the ponds proposed by Malaspina College west of Wakesiah Avenue. The area used for this sub-basin is 68 ha. This area is a special case because of the proposed ponds and no advantage could be seen in dividing the area into smaller units. The aim was to establish an overall storage requirement which can be built into the pond system.

In this chapter, accordingly, runoff and storage requirements are re-calculated for the Cat Stream. In the sub-basins tributary to the Cat Stream, the minor and major flows are calculated and the use of additional off-stream storage is investigated.

During the conduct of this study, design of four items of work under Drainage Bylaw No. 2256 was underway. This work includes the storage pond between Bruce Avenue and Third Street, the storage ponds above Wakesiah Avenue, the Howard Avenue Area storm drains and the Wakesiah Avenue storm drains. Various alternatives and design quantities of run-off were investigated with use of the ILLUDAS model and recommended designs have now been accepted by the City. These items of work are assumed to be existing facilities in the analysis of stormwater quantities carried out in this chapter.

DRAINAGE BYLAW 2256

The following is a brief description of the final designs for the four items of work that will be built under the current drainage bylaw. The facilities are illustrated on Figure 2 as existing pipelines and on Figure 3 the branch and reach numbers used in the ILLUDAS analysis are shown.

Storage between Bruce and Third. Detailed design has been completed for detention storage upstream of Bruce Avenue. This work will provide for the 100-year storage requirement of 15,000 m^3 between Bruce and Third and replacement of undersized culverts at Third Street with a 1200 x 1800 R.C. box section having capacity for the 100-year flow. The City has purchased 1.2 ha to accommodate the storage. Dyking will be constructed to protect two private properties.

Storage at Wakesiah. Preliminary design is continuing for retention ponds above Wakesiah Avenue. These will also provide for 100-year flows. At this time it is proposed that Malaspina College or the Fish and Wildlife Branch construct four ponds to include the City's storage requirements of approximately 40,000 m^3 with their needs for a wildfowl sanctuary. The City will design and construct the restricted pond discharge at the Wakesiah Avenue culvert crossing.

Howard Avenue Area Storm Drains. Storm drains are being installed in this area as shown on Figure 2. Pipe of 900 and 1200 mm diameter from Thora Place to Second Avenue, along Howard Avenue to Gail Place and discharging to the Cat Stream has capacity to handle the 100-year flows. The upstream section from Thora Place to Kerr Street and Doric Avenue comprises 750 mm diameter pipe designed to handle 5-year flows with excess up to 100-year flows being conveyed in a swale. The pipe is smoothflow CSP.

The capacity of the new storm drains along with the design flows are as follows:

Pipe Details						Design Flow	
Diameter (mm)	Length (m)	Slope (%)	Design HGL(%)	Capacity (cms)	Branch Reach	5 Year (cms)	100 Year (cms)
750	166	0.95	0.95	1.13	1-5	0.95	1.84
750	47	2.97	2.97	1.98	1-6	1.01	1.98
900	43	2.97	2.97	2.61			
1200	106	0.20	0.28	2.15	1-7	1.08	2.15
1200	61	0.20	0.32	2.27	1-8	1.11	2.27
1200	171	0.23	0.32	2.27	1-9	1.12	2.26
1200	95	0.51	0.51	2.89	1-10	1.33	2.75
1200	119	0.53	0.78	3.60	1-11	1.31	2.75
1200	70	0.10	0.48	2.81	1-12	1.33	2.81
525	12	0.80	1.20	0.49	6-2	0.25	0.49

The existing storm drain along Howard Avenue and north of Elizabeth Street will remain in service for 5-year flows and discharge to the new system at Elizabeth Street. The 450 mm drain that crosses the School property and continues across private property to the Cat Stream will also remain in service to accommodate the 100-year flows from the area tributary to it. Capacities and design flows for these pipes are listed below.

Location	Existing Pipe Details Diameter (mm)	Length (m)	Slope (%)	Design HGL(%)	Capacity (cms)	Branch Reach	Design Flow 5 Year (cms)	100 Year (cms)
Howard	450	108	0.40	0.40	0.19	6-0	0.16	0.30
Howard	450	154	0.28	0.45	0.20	6-1	0.20	0.39
School	450	150	0.23	0.23	0.15	-	0.08	0.13
Elizabeth St. to Cat Stream	450	200	0.4	0.4	0.20	-	0.05	0.10

Wakesiah Avenue Storm Drains. The existing 450 and 600 mm storm drains on Wakesiah Avenue are inadequate to convey 100-year flows. An overland route is not feasible and a diversion at Fourth Street and across part of the High School property has been selected as the final design after investigating several alternatives. An open ditch will then convey the flow to the upstream end of the storage ponds. The existing drain on Wakesiah Avenue will continue to carry the residual flow downstream of Fourth Street. Some surcharging is needed in the downstream section of the existing drain for 100-year flows.

The capacity of the diversion storm drain and ditch with design flows are as follows:

Location	Existing Pipe or Ditch Diameter (mm) or Height x Width (mm x mm)	Length (m)	Slope (%)	Design HGL(%)	Capacity (cms)	Branch Reach	Design Flow 5 Year (cms)	100 Year (cms)
Fourth St.	900	220	0.6	0.6	1.5	7-3	0.66	1.26
High School	900	300	0.6&2.0	1.2	2.1	7-4	0.95	1.07
Ditch	700x3000	300	0.3	0.3	3.2	7-5	1.33	2.66

The capacity of the existing drains on Wakesiah Avenue and the required design flows are as follows:

Existing Pipe Details						Design Flow	
Diameter (mm)	Type	Length (m)	Slope (%)	Capacity (cms)	Branch Reach	5-year (cms)	100-Year (cms)
450	WS	21	1.8	0.40			
450	RC	9	1.8	0.40			
450	RC	61	4.6	0.65		0.04	0.08
450	CSP	31	4.6	0.40		0.06	0.10
600	CSP	39	1.29	0.42	8-0	0.06	0.13
600	WS	45	1.29	0.71			
600	RC	53	1.29	0.71	8-1	0.22	0.42
600	RC	184	1.29	0.71	8-2	0.45	0.92

ILLUDAS COMPUTER MODEL

The ILLUDAS model has been utilized to calculate quantities of runoff and to estimate storage requirements.

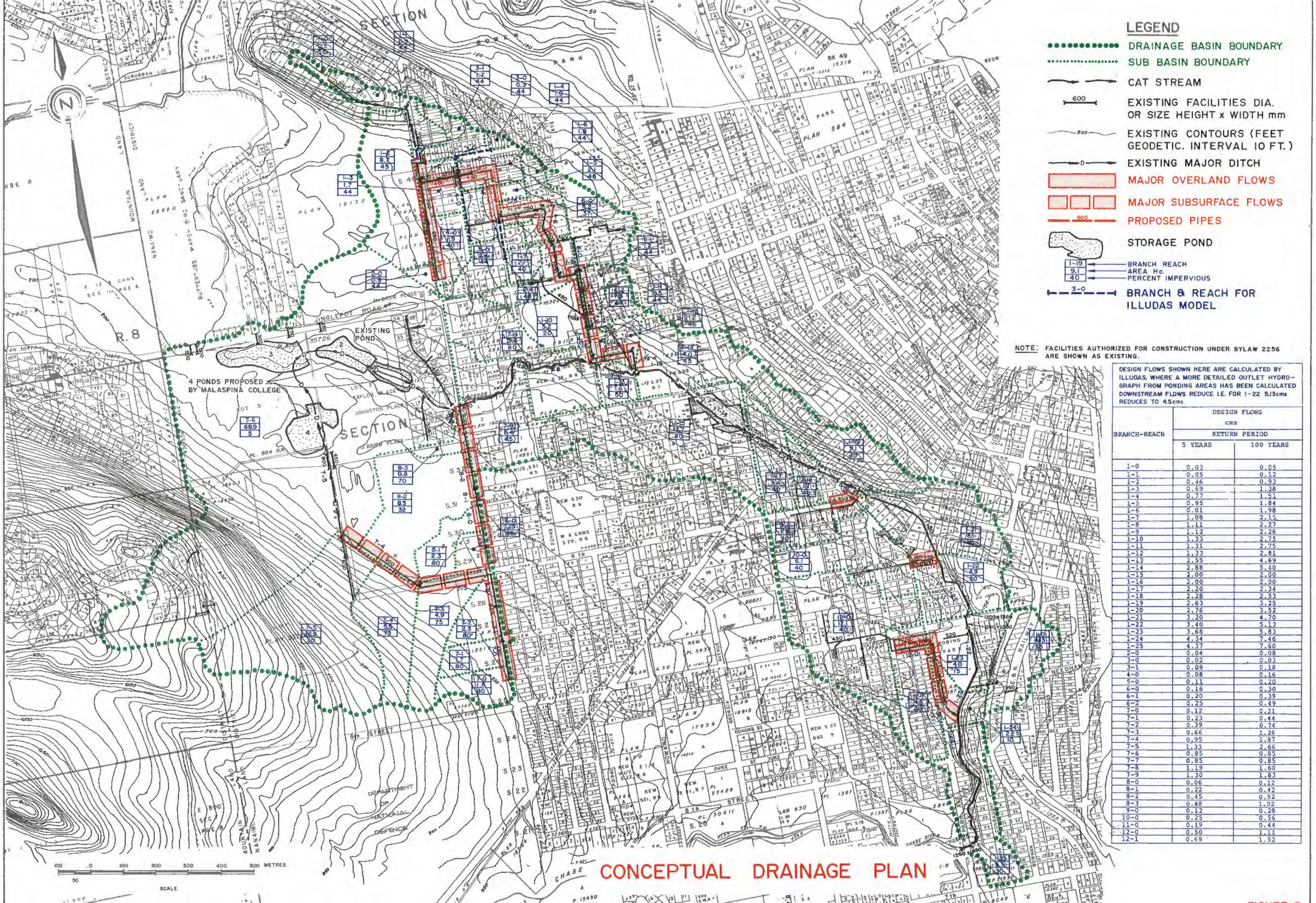
ILLUDAS was developed by the Illinois State Water Survey and was based on a design method used by the British Road Research Laboratory. The program accepts rainfall data in the form of rainfall amounts over specific time steps making up a "design storm". Infiltration is accounted for and allowance is made for depression storage. The balance of the rainfall becomes runoff and a runoff hydrograph is calculated separately for paved areas, grassed areas and "indirectly connected paved areas" where a paved area is separated from other paved areas by a grassed area.

The catchment area is divided into sub-basins with a system of pipes or channels being specified to convey water. The runoff is routed through this system with a simple storage routing procedure.

The principal parameters used in the ILLUDAS model are summarized in Part A of Appendix II.

Part B of Appendix II shows the Input data used in ILLUDAS for this study. Figure 3 shows the branch and reach numbers used.

The major culverts on the Cat Stream have not been modelled in ILLUDAS except where a restricted outflow is required, i.e., at Wakesiah Avenue and Bruce Avenue. At these locations a pipe size and slope has been chosen which limits the flow to that required. Once the pipe flow has reached capacity, the surplus inflow is calculated as a storage requirement. Typical cross-sections and slopes have been assumed for each section of the creek and design flows calculated using ILLUDAS.



DESIGN FLOWS SHOWN HERE ARE CALCULATED BY ILLUDAS. WHERE A MORE DETAILED OUTLET HYDROGRAPH FROM PONDING AREAS HAS BEEN CALCULATED DOWNSTREAM FLOWS REDUCE I.E. FOR 1-22 5.13cms REDUCES TO 4.5cms

BRANCH-REACH	DESIGN FLOWS cms RETURN PERIOD 5 YEARS	100 YEARS
1-0	0.03	0.05
1-1	0.05	0.12
1-2	0.46	0.93
1-3	0.69	1.38
1-4	0.77	1.51
1-5	0.95	1.84
1-6	0.01	1.98
1-7	1.08	2.15
1-8	1.11	2.27
1-9	1.12	2.26
1-10	1.33	2.75
1-11	1.31	2.75
1-12	1.33	2.81
1-13	2.55	4.69
1-14	2.88	5.40
1-15	2.00	2.00
1-16	2.00	2.00
1-17	2.20	2.34
1-18	2.28	2.53
1-19	2.63	3.25
1-20	2.76	3.52
1-21	3.20	4.70
1-22	3.40	5.13
1-23	3.68	5.83
1-24	4.34	7.46
1-25	4.37	7.60
2-0	0.04	0.08
3-0	0.02	0.03
3-1	0.09	0.18
4-0	0.08	0.16
5-0	0.11	0.20
6-0	0.16	0.30
6-1	0.20	0.39
6-2	0.25	0.49
7-0	0.12	0.21
7-1	0.23	0.44
7-2	0.39	0.74
7-3	0.66	1.26
7-4	0.95	1.87
7-5	1.33	2.66
7-6	0.85	0.85
7-7	0.85	0.85
7-8	1.19	1.60
7-9	1.30	1.83
8-0	0.06	0.12
8-1	0.22	0.42
8-2	0.45	0.92
8-3	0.48	1.02
9-0	0.12	0.28
10-0	0.25	0.56
11-0	0.19	0.44
12-0	0.50	1.11
12-1	0.69	1.52

CONCEPTUAL DRAINAGE PLAN

DESIGN FLOWS AND STORAGE REQUIREMENTS

Figure 3 and Table 3-1 show the design flows for 5 and 100 year return periods calculated using ILLUDAS. The underlined figures in Table 3-1 are the maximums for each reach.

In order to minimize the need for downstream improvements in the Cat Stream, flows have been restricted to 0.85 cms at Wakesiah Avenue and 2.0 cms at Bruce Avenue. The latter release rate differs from Plan 2 of the Cat Stream Drainage Study which recommended a limit of 2.4 cms at Bruce Avenue. With the increased rainfall used for this study the limit has been reduced to 2.0 cms in order to reduce downstream flows to acceptable limits. The restriction to 0.85 cms at Wakesiah Avenue is the same as assumed for the Cat Stream Drainage Study and represents the approximate capacity of the existing culvert in its present condition with gravel deposits.

The design flows calculated by ILLUDAS have been used to determine the required headwater depth and capacity of the Cat Stream culverts. The ILLUDAS program gives a higher discharge downstream from storage than actually occurs, because the maximum release rate is assumed constant in the program. Where culvert capacities are found to be close to design flows, the design flows have been reduced through use of a hand calculated outlet hydrograph for the upstream storage. This applied at Fifth Avenue where the ILLUDAS design flow was reduced from 5.13 cms to 4.5 cms.

Table 3-2 shows the storage requirements upstream of Wakesiah Avenue and upstream of Bruce Avenue calculated using ILLUDAS. The maximum storage requirements are underlined for 5 and 100 year return periods. When an outlet hydrograph is used, the storage requirement at Bruce Avenue increases from 11,000 m^3 to 15,000 m^3 and from 33,000 m^3 to 40,000 m^3 at Wakesiah Avenue.

NORTH-SOUTH ARTERIAL

The original route recommended for the North-South Arterial crosses the basin to the west of the storage ponds proposed by Malaspina College.

The publication "Issues and Options" on this arterial dated October, 1981 lists 5 other options. The second option is to use Jingle Pot Road and Wakesiah Avenue. The third option would upgrade Bruce Avenue, Howard Avenue, Pine Street, Second Street and Fifth Street. The fifth option would involve construction in the area of Pine Street.

All of these options would have a major impact on the basin.

The design flows calculated for this Study do not take into account the proposed North-South Arterial. If and when a route is selected, its impact must be reviewed and the design flows adjusted if required.

COST DATA

The following unit prices have been used in cost estimates in the next Chapter. These costs are based on unit prices tendered for 1981 drainage work in the City, increased 15% for 1982 work.

These costs are preliminary in that detailed surveys have not been carried out. Cost must be refined and updated for bylaw purposes.

- Supply and installation of pipelines (includes catchbasins, connections, manholes and all associated work) .... \$0.70 per metre per mm of diameter.
- Supply and place fill .... \$20/m^3.
- Concrete for headwalls .... \$700/m^3.
- Swales ......\$10/m.
- Ditching ....\$15/m^3.
- Regrade driveways \$1,000/each
- Trash Racks ......\$2,000/each.

To the estimated cost of construction are added 25 percent for engineering and contingencies and 15 percent for interim financing, bylaw costs and administration.

TABLE 3-1

DESIGN FLOWS (cms)

Branch Reach	5-Year Return Period Duration (hours)					100-Year Return Period Duration (hours)				
	0.5	1	2	6	12	0.5	1	2	6	12
1-0	0.03	0.02	0.01	0.01	0.01	0.05	0.04	0.03	0.02	0.01
1-1	0.05	0.05	0.04	0.03	0.02	0.12	0.09	0.07	0.06	0.04
1-2	0.46	0.40	0.29	0.23	0.18	0.93	0.74	0.59	0.43	0.33
1-3	0.69	0.60	0.43	0.35	0.27	1.38	1.10	0.87	0.66	0.50
1-4	0.77	0.65	0.48	0.38	0.30	1.51	1.20	0.96	0.73	0.55
1-5	0.95	0.77	0.57	0.45	0.37	1.84	1.46	1.16	0.87	0.67
1-6	1.01	0.82	0.61	0.49	0.40	1.98	1.54	1.25	0.93	0.73
1-7	1.08	0.88	0.65	0.52	0.43	2.15	1.65	1.34	1.00	0.79
1-8	1.11	0.93	0.70	0.56	0.46	2.27	1.78	1.43	1.07	0.85
1-9	1.12	0.93	0.71	0.56	0.46	2.26	1.77	1.43	1.07	0.85
1-10	1.33	1.14	0.87	0.70	0.58	2.75	2.17	1.77	1.32	1.09
1-11	1.31	1.15	0.88	0.71	0.59	2.75	2.20	1.80	1.33	1.10
1-12	1.33	1.20	0.91	0.72	0.61	2.81	2.25	1.86	1.36	1.13
1-13	2.46	2.55	2.23	1.89	1.63	4.69	4.21	3.70	2.77	2.39
1-14	2.61	2.88	2.47	2.06	1.74	5.40	4.91	4.23	3.07	2.61
1-15	2.00	2.00	2.00	2.00	1.95	2.00	2.00	2.00	2.00	2.00
1-16	2.00	2.00	2.00	2.00	1.95	2.00	2.00	2.00	2.00	2.00
1-17	2.03	2.20	2.19	2.11	2.01	2.30	2.34	2.26	2.17	2.12
1-18	2.06	2.24	2.28	2.17	2.04	2.46	2.53	2.39	2.25	2.18
1-19	2.29	2.63	2.55	2.40	2.19	2.23	3.25	3.06	2.65	2.47
1-20	2.35	2.76	2.65	2.48	2.24	3.48	3.52	3.28	2.78	2.56
1-21	2.44	3.18	3.20	2.85	2.49	4.33	4.70	4.33	3.38	3.00
1-22	2.46	3.38	3.40	2.95	2.56	4.66	5.13	4.71	3.57	3.15
1-23	2.50	3.61	3.68	3.14	2.69	5.05	5.83	5.31	3.89	3.39
1-24	2.75	4.28	4.34	3.59	2.99	6.38	7.46	6.72	4.70	3.96
1-25	2.68	4.24	4.37	3.72	3.10	6.24	7.60	7.17	4.85	4.12
2-0	0.04	0.03	0.02	0.02	0.02	0.08	0.06	0.05	0.04	0.03
3-0	0.02	0.01	0.01	0.01	0.01	0.03	0.02	0.02	0.01	0.01
3-1	0.09	0.07	0.05	0.04	0.03	0.18	0.14	0.11	0.08	0.06
4-0	0.08	0.06	0.05	0.04	0.03	0.16	0.12	0.10	0.08	0.06
5-0	0.11	0.08	0.06	0.04	0.03	0.20	0.15	0.11	0.07	0.07
6-0	0.16	0.12	0.09	0.06	0.06	0.30	0.22	0.17	0.12	0.11
6-1	0.20	0.17	0.11	0.08	0.07	0.39	0.29	0.22	0.16	0.15
6-2	0.25	0.20	0.14	0.11	0.09	0.49	0.37	0.29	0.21	0.18
7-0	0.12	0.09				0.21	0.17		0.07	0.05
7-1	0.23	0.19				0.44	0.36		0.14	0.10
7-2	0.39	0.32				0.74	0.59		0.24	0.17
7-3	0.66	0.57				1.26	1.06		0.44	0.31
7-4	0.95	0.86				1.87	1.59		0.67	0.47
7-5	1.33	1.24				2.66	2.35		1.26	0.92
7-6	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
7-7	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
7-8	1.10	1.19	1.15	1.06	1.01	1.60	1.59	1.50	1.21	1.11
7-9	1.15	1.30	1.27	1.13	1.07	1.82	1.83	1.72	1.34	1.21
8-0	0.06	0.05				0.13	0.12		0.05	0.03
8-1	0.22	0.19				0.42	0.36		0.14	0.10
8-2	0.45	0.42				0.92	0.88		0.46	0.33
8-3	0.48	0.47				1.02	0.95		0.49	0.35
9-0	0.12	0.12	0.11	0.07	0.05	0.28	0.26	0.23	0.13	0.09
10-0	0.23	0.25	0.23	0.15	0.10	0.56	0.54	0.47	0.26	0.18
11-0	0.17	0.19	0.17	0.10	0.07	0.44	0.44	0.34	0.18	0.12
12-0	0.46	0.50	0.45	0.30	0.20	1.11	1.07	0.94	0.52	0.37
12-1	0.60	0.69	0.62	0.41	0.27	1.52	1.50	1.29	0.72	0.50

Note: - Max. flow underlined.

TABLE 3-2

STORAGE REQUIREMENTS

(m^3)

Storage Upstream of	5-Year Return Period Duration (hours)					100-Year Return Period Duration (hours)					
	0.5	1	2	6	12	0.5	1	2	6	12	24
Wakesiah Ave.	500	1,650				5,430	11,030		26,150	32,310	25,800
Bruce Ave.	340	1,460	1,660	1,070		3,780	6,350	9,200	10,720	9,930	3,290

NOTE: Maximum storage requirement underlined, calculated using ILLUDAS.

When outlet hydrograph is applied, maximum storage at Bruce Avenue increases to 15,000 m^3 and at Wakesiah Avenue increases to 40,000 m^3.

4. CONCEPTUAL DRAINAGE PLAN

In this Chapter, the capacity of existing drainage facilities is compared with the stormwater quantities calculated in Chapter 3 in order to determine their adequacy. Where existing facilities are found inadequate, recommendations are made for upgrading.

In areas not serviced with storm drains, preliminary pipe sizes are calculated for minor system (600 mm and larger) flows.

Major flow pathways are also selected with emphasis on overland routing where possible. Otherwise, pipelines sized for 100-year flows are recommended.

The existing facilities are shown on Figure 2. Included as existing facilities are the four items of work included in Drainage Bylaw No. 2256, namely storage between Bruce Avenue and Third Street, storage above Wakesiah Avenue, Howard Ave. area storm drains and the Wakesiah Ave. storm drain.

ADEQUACY OF EXISTING FACILITIES

1. Cat Stream Culverts. There are 10 culverted road crossings of the Cat Stream and these are described in detail in the 1980 Study. The 1980 Study determined that the Cat Stream was the only practical flood relief route and therefore the culverts must be capable of handling 100-year flows. Details of these culverts and their capacities together with design flows are as follows:

Culvert Location	Branch Reach	Size Diameter or Height x Width mm	Type	Top Water Level at Entrance m	Capacity cms	Design Flow 5 Year cms	Design Flow 100 Year cms
Wakesiah Avenue	7-6	600(1)	CSP	54.50	0.85	0.85	0.85
Beaconsfield Road	7-8	1220	CSP	52.87	1.20	1.19	1.60
Howard Avenue	7-9	910	CSP	50.30	1.80	1.30	1.83
Third Street	1-14	1200x1800(1)	RC box	46.70	5.40	2.88	5.40
Bruce Avenue	1-15	1240x1520(1)	RC box	46.70	2.00	2.00	2.00
Chesterlea Avenue	1-17	940x1670	RC Box	45.00	2.60	2.20	2.34
Pine Street	1-18	1000x1520	RC box	43.50	2.80	2.28	2.53
Albert Street	1-19	965x1520	RC box	42.20	3.25	2.63	3.25
Fifth Street	1-22	1200x1360 1260x1850	Conc.Blk. RC box	38.10 38.10	3.60 5.13	3.40	5.13
Park Avenue	1-25	1260x1850	RC box	33.10	9.60	4.37	7.60

Note (1) assumes new work constructed under Bylaw 2256.

The capacities shown are for water levels at culvert entrances which will not flood adjacent basements or private property more than 7.5 m away from the top of the stream bank. One exception is the culvert at Beaconsfield Road where low lying ground upstream of the culvert entrance governs the permissible top water level. The 7.5 m setback was selected to keep flooding within the minimum Stream Management Area width requirements of 18 m that will be discussed in Chapter 5.

The drainage bylaw will provide a new 600 mm diameter CSP pipe through the existing Wakesiah 1130 mm woodstave culvert to restrict the release rate to 0.85 cms and dyking will be constructed upstream to prevent flooding of private property. The 1200 x 1800 RC box culvert will replace the existing 610 and 910 mm culverts at Third Street and a restricted entrance will be provided at the Bruce Ave. culvert to limit the release rate to 2.0 cms.

Culverts which are inadequate to handle the 100-year flow include the Beaconsfield Road culvert and the upstream section of the Fifth Street culvert.

The culvert at Fifth Street includes a 1260 x 1850 mm RC box section across the road which appears structurally sound. A private property owner has extended the culvert upstream for approximately 16 m. This section terminates in a 1200 x 1360 mm section which controls hydraulic capacity of the combined culvert section. Overall, the capacity of the Fifth Street culvert is governed by the maximum headwater depth of 38.1 m to prevent flooding upstream to Albert Street. The upstream section has concrete block walls and what appears to be a reinforced concrete roof. There is no bottom slab. When inspected the walls and culvert roof were stable. The culvert is covered in lawn.

The entrance to the Albert Street culvert needs cleaning out. Vegetation also affects culverts at Howard Avenue, Bruce Avenue, Pine Street, Albert Street and Fifth Street.

Culverts affected by deposition of gravel are those at Beaconsfield Road, Pine Street, Albert Street and Fifth Street.

The culvert at Chesterlea Avenue is partly blocked by debris, vegetation and a fence.

2. <u>Cat Stream Between Culverts</u>

Apparent critical sections of the stream channel were surveyed and have been analyzed using average slopes between culverts. The results are summarized below. The criteria for permissible top water levels are the same as for culverts.

Location	Branch Reach	Top Water Level m	Capacity cms	Design Flows 5-yr. cms	Design Flows 100-yr. cms
Downstream of Wakesiah Avenue	7-7	53.8	1.0	0.85	0.85
Downstream of Beaconsfield Rd.	7-8	53.0	3.8	1.19	1.60
Downstream of Bruce Avenue	1-16	45.1	2.1	2.00	2.00
Downstream of Chesterlea Avenue	1-17	43.9	5.0	2.20	2.34
Downstream of Pine Street	1-18	42.2	4.8	2.28	2.53
Sanitary Pumping Station at Albert Street R/W	1-20	39.1	1.4	2.76	3.52
Albion Street	1-21	38.5	2.25	3.20	4.70
Upstream of Fifth Street	1-21	38.3	3.2	3.20	4.70

The Cat Stream was inspected for evidence of stream bed erosion, bank instability, debris and encroachment of vegetation.

Between Wakesiah Avenue and Albert Street, the stream is adequate for 100-year flows. There is some debris in the stream through this section. The stream bed needs regrading at Wakesiah Avenue, Pine Street and Beaconsfield Road in conjunction with removal of gravel deposits in these culverts. Some brambles encroach on the stream channel and should be removed.

Between the pumping station at the Albert Street R/W and Fifth Street the channel is inadequate for 100-year flows. There is a high point in the stream channel near Rosamond Street that limits capacity. Some debris exists upstream of Rosamond Street. Some vegetation impairs the hydraulic capacity of the stream between Albert and Rosamond. Generally, this area is flat and subject to flooding if the Cat Stream overflows its banks.

Between Fifth St. and the end of Robins Park the channel comprises a steep bank on one side and on the other side low lying flat ground in the downstream two-thirds of the Park. In this section water frequently overflows into the Park because the channel is inadequate. This condition is made worse by beaver dams at the downstream end of the Park. There is considerable debris, brush and brambles in this section of the stream.

Downstream from Robins Park to Chase River, the stream is in a well defined channel which has adequate capacity for 100-year flows. There is debris and brush, particularly in the lower sections, that need removal.

3. Malaspina College. The campus area is served by storm sewers terminating in a 600 mm diameter RC pipe west of the High School. This pipe is adequate for the 100 year design flow of 0.8 cms from this area. The rest of the system has not been analysed. As it is on private property this system should not become the responsibility of the City.

4. Subdivision West of Wakesiah Avenue. The recently constructed subdivision west of Wakesiah Avenue between Jingle Pot Road and Third Street provides residential lots on both sides of the Cat Stream with a strip of City owned property along the Cat Stream. The storm sewers in this subdivision have a maximum size of 450 mm diameter.

From the northern part of the development, stormwater flows to the Cat Stream through a single 450 mm diameter pipe. The 5 and 100 year flows are 0.30 cms and 0.53 cms.

From the southern part, there are two 300 mm diameter pipes discharging to the Cat Stream. The 5 and 100 year flows are 0.07 and 0.12 cms, respectively.

The storm drains installed are capable of handling 100 year flows.

5. Fourth Street to Cat Stream. The design flows for this pipe where it crosses Pine Street are 0.12 cms for a 5-year return period and 0.28 cms for a

100-year return period as shown for 9-0 on the ILLUDAS model. The 250 mm drain has a capacity of about 0.06 cms. The end of the pipe is partially blocked and ditching is needed from the end of the pipe to the Cat Stream.

6. Albion Street to Cat Stream. The existing 450 mm diameter along Albion Street from Hamilton Avenue continues across Park Avenue and discharges to a ditch. Downstream there is a 300 mm drain which leads to the Cat Stream. The design flows are 0.25 cms and 0.56 cms for 5-year and 100-year return periods, respectively, as shown for 10-0 on the ILLUDAS model. The 450 mm has a capacity of about 0.6 cms overall although the section across Park Avenue is flatter and can carry only 0.3 cms without surcharge. This drain is considered adequate. The downstream 300 mm drain has a capacity of about 0.1 cms and is inadequate.

7. Fifth Street from Winchester Avenue to Park Avenue. The existing 450 mm drains in this area terminate in a ditch on the east side of Park Avenue. The design flows are represented by ILLUDAS 12-0 and are 0.50 cms and 1.11 cms for 5 and 100 year return periods, respectively. The pipe capacity is estimated to be 0.3 cms and is inadequate. The Park Avenue ditch capacity is about 1.0 cms, and is adequate for 5 year flows but not for 100-year flows.

8. Railway Avenue. The existing 900 mm diameter culvert across Railway Avenue is represented by 11-0 in the ILLUDAS model. The 5 and 100 year design flows are 0.19 cms and 0.44 cms, respectively. The existing culvert has a capacity of 1.1 cms and is adequate.

9. Wakesiah Ave. North and Garner Crescent. The 250, 300 and 375 mm drains along Wakesiah Avenue and in the lane running to Doric Ave. are represented by 1-1, 2-0, 1-2 and 1-3 in the ILLUDAS model. The respective design flows and pipe capacities are as follows:

	Branch Reach	Design Flow 5-year	Design Flow 100-year	Pipe Size (mm)	Pipe Capacity (cms)
Garner & Wakesiah	1-0	0.03	0.05	300	0.15
Wakesiah Ave.	1-1(1)	0.23	0.49	300	0.16
Wakesiah Ave.	2.0(1)	0.22	0.45	300	0.16
Lane	1-2	0.46	0.93	300 375	0.17 0.31
Lane	1-3	0.69	1.38	375	0.31

(1) One half of flow from sub-area 1-2 has been added to allow for runoff into the 300 mm diameter pipeline along Wakesiah Ave.

The 300 mm storm drains on Wakesiah near the lane, the 300 mm crossing of Wakesiah, and the 375 mm storm drain in the lane are inadequate for 5-year design flows.

It is reported that the drains on Wakesiah Ave. are root infested.

PROPOSED MINOR SYSTEM

By the terms of reference, this study is limited to minor system pipelines 600 mm diameter and greater. Depending on the slope, the pipe capacities vary. For example, a 600 mm diameter pipeline at 0.5 percent will carry a flow of 0.46 cms while at 5 percent the capacity increases to 1.47 cms.

The proposed minor system, illustrated on Figure 3, follows. Approximate grades were established in the field to calculate pipe sizes. Where existing storm drains are shown to be inadequate, the pipe size needed for the 5-year flow is determined. The use of capacity in the existing pipe is not allowed for, but should be considered in detail design.

1. Doric Avenue to Wakesiah Avenue. The storm drains should be continued north on Doric Avenue and then west in the lane just south of First Street to Wakesiah Avenue. A 600 mm drain is needed along Doric Avenue to convey 5-year flows while through the lane 450 and 525 mm diameter will suffice. The existing 375 mm drain is too shallow and should be abandoned. The section through the lane has been included in the proposed work in order to complete the piped system up to Wakesiah Avenue, because a ditch in the lane is not practical.

2. Fourth St. to Cat Stream. The existing 250 mm drain is too small for 5-year flows. A 375 mm drain is needed across Pine Street and to Sterling Avenue.

3. Albion St. to Cat Stream. In order to convey 5-year flow, the ditch and short section of 300 mm drain from Park Ave. to the Cat Stream should be replaced with a 600 mm storm drain.

4. Fifth St. from Winchester Ave. to Park Ave. The 450 mm drain in the lane between Winchester and Park is inadequate for 5-year flows. The pipe is reported to be in poor condition. A 600 mm is needed to convey the 5-year flow. This storm drain system should be continued as a 675 mm pipeline along Park Ave. to the downstream end of Robins Park.

5. Wakesiah Ave. North. The 300 mm drains near the lane leading to Doric Ave. are inadequate for 5-year flows. A 450 mm drain is needed.

6. Other Sub-Basin Areas. The storm drain sizes needed in the other sub-basins that are tributary to the Cat Stream are all less than 600 mm diameter and are therefore not considered herein.

PROPOSED MAJOR SYSTEM

The major system must have the ability to convey the 100-year flow, either by itself or in conjunction with the 5-year minor system capacity. When a minor system exists, it is generally desirable, because of capital cost savings, to develop an overland route to carry the excess flow. Such an overland system will normally comprise a swale, ditch or paved roadway between curbs. If terrain or acquisition of easements on private property prohibit the use of an overland route, then a relief storm drain will be needed in conjunction with the existing minor pipe system to handle the major flow. In unserviced areas where a minor system does not exist, then it will be necessary to increase the size of the pipeline to handle the 100-year design flow.

As an illustration of overland flow, a swale, paved roadway and roadway plus right-of-way have the following carrying capacities at the given grades:

Grade	Approximate Carrying Capacity (cms)		
	Swale	Roadway	Road R/W
0.5%	0.2	0.9	2.8
1.0%	0.3	1.3	3.7
2.0%	0.5	1.9	5.4
4.0%	0.7	2.7	7.3

In the foregoing table a swale 3 m wide at the top by 0.20 m deep is assumed, a roadway 8 m wide with an average of 100 mm water depth between curbs is assumed and for the roadway plus right-of-way, a 20 m right-of-way with 8 m wide roadway, 150 mm curbs and 2% boulevard sloping down to the curb is assumed. In the latter example, water is assumed to flood up to the edge of right-of-way.

In new developments, with proper planning, roadways can be designed to accommodate overland flow and provide a cost saving in the drainage system. In existing unserviced developments, however, frequently the cost of regrading driveways and road intersections and the need to acquire easements across private property make an overland flow route a more expensive alternative than increasing the minor pipe size to handle major flow.

As a second illustration, typical minor and major flows for the Cat Stream basin along with required pipe sizes are as follows:

Design Flow (cms)		Req'd. Pipe Size (mm)	
5-Year	100-Year	5-Year	100-Year
0.25	0.29	450	600
0.46	0.93	600	750
0.80	1.54	675	900

The pipe sizes shown assume a grade of 1%.

Major systems recommended hereafter apply to the Cat Stream and to the sub-basin areas tributary to the Cat Stream. The major system is illustrated on Figure 3.

Cat Stream

The Cat Stream must be able to convey 100-year flows.

The storage areas above Wakesiah and Bruce are designed to retain 100-year flows and the release rates therefrom have been restricted to minimize downstream upgrading.

The remaining eight culvert crossings of roads are judged adequate, with minor improvements, to convey the 100-year flows. No overtopping of the roadways is recommended. Bridges are not justified in place of culverts because of the relatively minor nature of improvements needed to make the culvert crossings suitable.

1. Culvert at Beaconsfield. To increase the capacity of this facility to handle the 100-year flow of 1.60 cms, dyking is needed upstream from the culvert. This work would be approximately 0.7 m high in the form of an earthern berm. The culvert and a short section of creek downstream from the culvert must be cleaned of gravel and a small dam and a fence must be removed.

Alternatively, the culvert should be removed in favour of an open channel. Some bank protection will be needed at the bend in the channel unless the City can obtain permission to realign the stream. The downstream dam and fence should be removed.

2. Culvert at Fifth Ave. The capacity of the upstream section of culvert must be increased from 3.6 cms to 4.5 cms. The existing upstream section must be replaced with a 1200 x 1800 RC Box, or equivalent CSP section.

3. General. All major culverts should be protected with a trash rack located upstream of the culvert entrance and incorporating an overflow into the culvert. Access for maintenance by machinery must be considered in siting the trash racks. Gravel should be removed from the culverts at Pine Street and at Albert Street. Debris should be removed from the Chesterlea Avenue culvert.

4. Sections of the Cat Stream. The stream bed needs regrading in the vicinity of the Wakesiah Avenue, Beaconsfield Road and Pine Street culverts and near Rosamond Street. Throughout the length of the stream, debris should be removed along with vegetation which limits hydraulic capacity.

In the Robins Park Area the beaver should be removed and relocated elsewhere. To prevent flooding of the Park fields the creek should be deepened and widened.

Where regrading or widening of the Stream is necessary, gravel should be placed in the Stream bed to assist the fisheries resource.

Upstream of Jinglepot Road, the 1980 Study recommended that culvert crossings of the road be blocked off to prevent runoff from the Millstone River basin entering the Cat Stream. This recommendation remains valid.

Sub-Basin Areas

Detailed survey has not been carried out and so the judgements made with respect to the feasibility of conveying major flow overland in a swale are preliminary. Detailed design is needed to confirm the most cost effective means for accommodating the major flow. Of particular concern is the feasibility and cost of creating a swale across existing driveways and at road intersections.

1. Doric Avenue to Wakesiah Avenue. It is not practical or desirable to provide overland flow from the lower part of the area around Second Street to the Cat Stream. The major flow was therefore designed to be carried in the pipe from the end of Thora Place to the Cat Stream as part of Bylaw 2256.

Through the lane from Wakesiah Avenue, along Doric Avenue, Kerr Street and Thora Place, overland flow appears feasible and can be initially provided by swales above the pipe. If these streets are improved and curbs installed, the road design must provide for those overland flows, including entry of the water into the major pipe system at the end of Thora Place.

For both swales and curbs, driveways must be designed or reconstructed to prevent flow from the street entering into private property.

2. Wakesiah Avenue Storm Drain. The portion of pipeline along Wakesiah Avenue south of Fourth Street has been designed to carry the minor flow with major flows being carried in a swale above the pipe. Three driveways need regrading in order to do this. In the future, if Wakesiah Ave. is provided with curb and gutter, accommodation must be made for the major flows and their entry into the storm drain at Fourth Street. A boulevard swale should be retained for this purpose. This work will be carried out as part of Bylaw 2256.

3. Fourth Street to Cat Stream. A swale is feasible for conveying major flow from Chesterlea Avenue to the Cat Stream. Pine Street will need regrading as will driveways.

4. Albion Street to Cat Stream. A swale is feasible for conveying major flow between Park Avenue and the Cat Stream. Upstream from Park Avenue the existing 450 mm drain, if surcharged, is adequate for 100-year flows. Driveways will need regrading.

5. Fifth Street from Winchester Avenue to Park Avenue. A swale appears feasible in the lane between Winchester Avenue and Park Avenue. Regrading in the lane is needed to form the swale. The proposed minor system drain crosses Park Avenue and continues along Park Avenue in the ditch to discharge to the Cat Stream at the south end of Robins Park. It does not appear feasible to route flow over Park Avenue. Major flow should be piped across Park Avenue to the Cat Stream. This requires that the minor system pipe size be increased from 675 mm to 900 mm.

6. Wakesiah Avenue North. It appears feasible to allow major flow to be contained in a swale along Wakesiah Avenue and to cross Wakesiah Avenue at the low point opposite the lane in conjunction with the minor system storm drain.

STORAGE FACILITIES

The possibility for providing additional storage facilities along the Cat Stream has been investigated but no addition would be beneficial. It has been possible to minimize work needed in the Cat Stream by making use of the storage areas at Bruce and Wakesiah. These two areas provide adequate storage for the future full development of the catchment area.

The use of storage areas off the Cat Stream has also been investigated. The characteristics of the basin, being narrow and essentially fully developed downstream of Wakesiah Avenue makes the development of offstream storage ineffective and it is not recommended.

COST OF IMPROVEMENTS

The following cost estimates illustrate the approximate value of the work described in previous sections. Work in the Cat Stream and in the sub basin areas is shown separately.

These costs represent preliminary 1982 estimates for the work. The costs must be refined for bylaw purposes.

Cat Stream

1.	Beaconsfield Culvert	
	- dyking or removal of culvert	$ 5,000
2.	Fifth Street Culvert	
	- 1200 x 1800 culvert	$ 25,000
	- landscaping	$ 5,000
	- headwall	$ 10,000
3.	Trash Racks	
	- 8 culverts	$ 16,000
4.	Clean out Culverts	
	- Chesterlea	$ 1,000
	- Pine	$ 1,000
	- Albert	$ 1,000
	- Wakesiah	$ 1,000
5.	Regrade and Widen Stream Bed	
	- Rosamond	$ 20,000
	- Robins Park	$ 11,000
6.	Remove Debris from Creek and Block culverts at Jinglepot Road	$ 15,000
		$ 111,000
	25% engineering and contingencies	28,000
	15% bylaw and administration	17,000
TOTAL		$ 156,000

Sub Basin Areas

7.	Doric to Wakesiah	
	- 600 mm x 150 m	$ 65,000
	- 525 mm x 105 m	$ 40,000
	- 450 mm x 90 m	$ 30,000
	- swales & driveways	$ 14,000
8.	Fourth Street	
	- 375 mm x 90 m	$ 25,000
	- swales & driveways	$ 7,000
9.	Albion Street	
	- 600 mm x 60 m	$ 30,000
	- swales & driveways	$ 5,000
10.	Fifth - Winchester to Park	
	- 600 x 110 m	$ 55,000
	- 900 mm x 210 m	$ 135,000
	- ditching	$ 5,000
	- regrade lane	$ 10,000
11.	Wakesiah Avenue North	
	- 450 mm x 380 m	$ 120,000
	- swale and driveways	$ 10,000
		$ 551,000
	25% engineering and contingencies	138,000
	15% bylaw and administration	83,000
TOTAL		$ 772,000

DETAILED DRAINAGE PLAN

The foregoing improvements form a conceptual drainage plan for the basin within limitations of the terms of reference which consider minor system pipe sizes 600 mm and larger.

A requirement of all new development should be the preparation of a detailed drainage plan for the land in question. A drawing should be required to show the location of the development within the drainage basin. The developer should be required to accommodate flow from upstream land and to convey all flow to the Cat Stream or recommended minor-major system proposed in this study. Within the developers property a detailed layout of the minor-major system should be provided. Of particular importance would be the grading of roadways and swales to accommodate overland flow and the relative elevation of basements and the major system hydraulic grade line.

5. STREAM MANAGEMENT AREA

This Chapter delineates the Cat Stream, discusses a proposed Stream Management Area bylaw, summarizes criteria used in defining the Stream Management Area and defines in a preliminary way the proposed Stream Management Area.

DELINEATION OF WATERCOURSES

Policy No. 1 requires the City to delineate watercourses in consultation with Federal Fisheries and Provincial Fish and Wildlife authorities.

The terms of reference refine the delineation process to include streams having a 100-year post development flow in excess of 1 cms and to the identification of streams sensitive to erosion and bank stability.

The Cat Stream, commencing at the 600 mm piped discharge from Malaspina College and continuing through the Wakesiah Avenue storage ponds, the Bruce Avenue storage pond and discharging to the Chase River is the delineated watercourse to be protected and managed by creation of a Stream Management Area. This watercourse is illustrated on Figure 5.

There are no other watercourses in the Cat Stream basin that qualify under the Stream Management Area criteria.

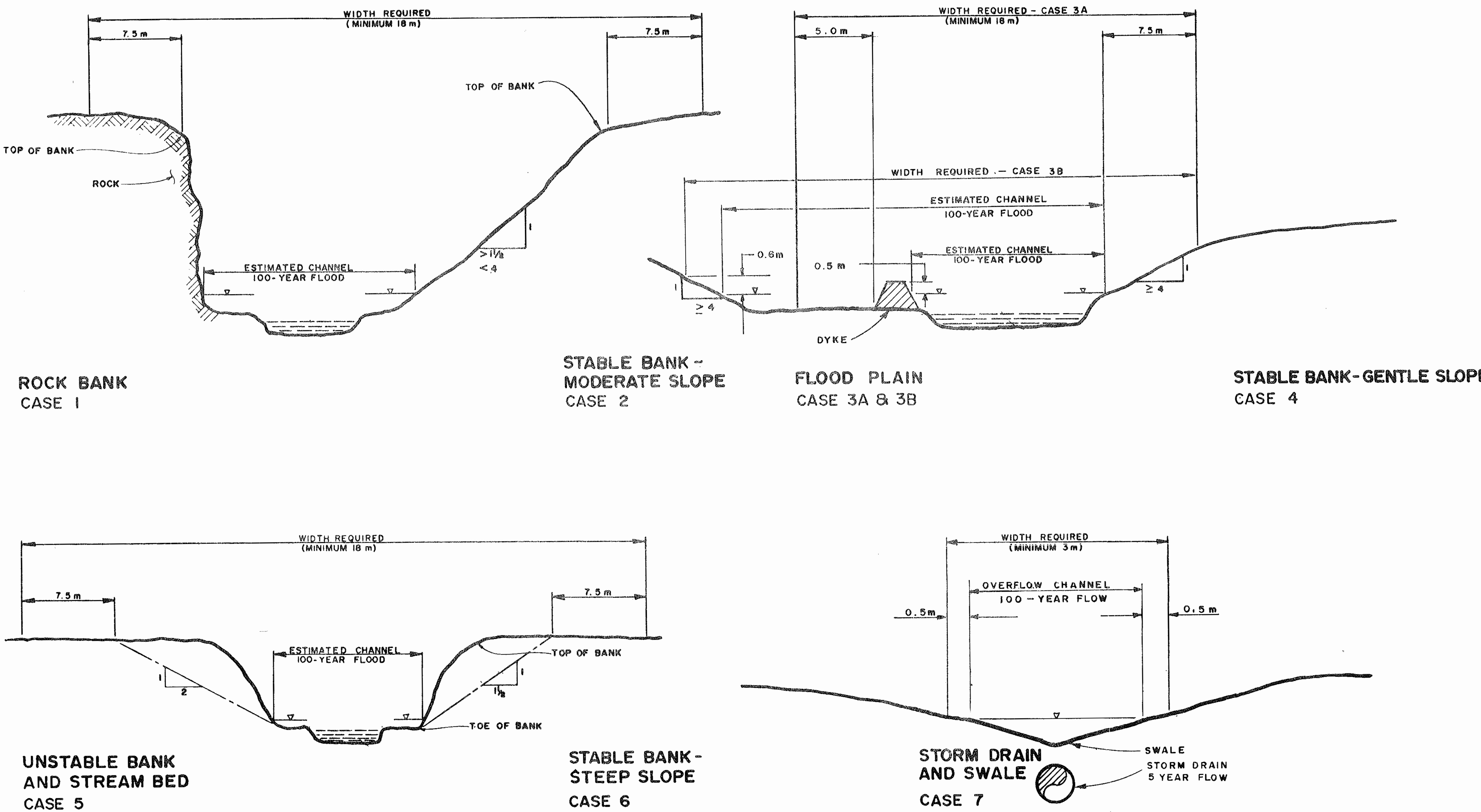
MANAGEMENT AREA BYLAW

In a subsequent section, the proposed Stream Management Area will be defined on a drawing. The intent is that the proposed Stream Management Area drawing would serve as a guide to identify property that would be regulated under a Stream Management Area bylaw(s).

The bylaw(s) should define the stream and should regulate the disposal of debris, construction of new works, alteration of existing structures, soil and tree removal and the discharge of pollutants within the Management Area. The bylaw(s) should also establish a permit system and a system for approval and inspection.

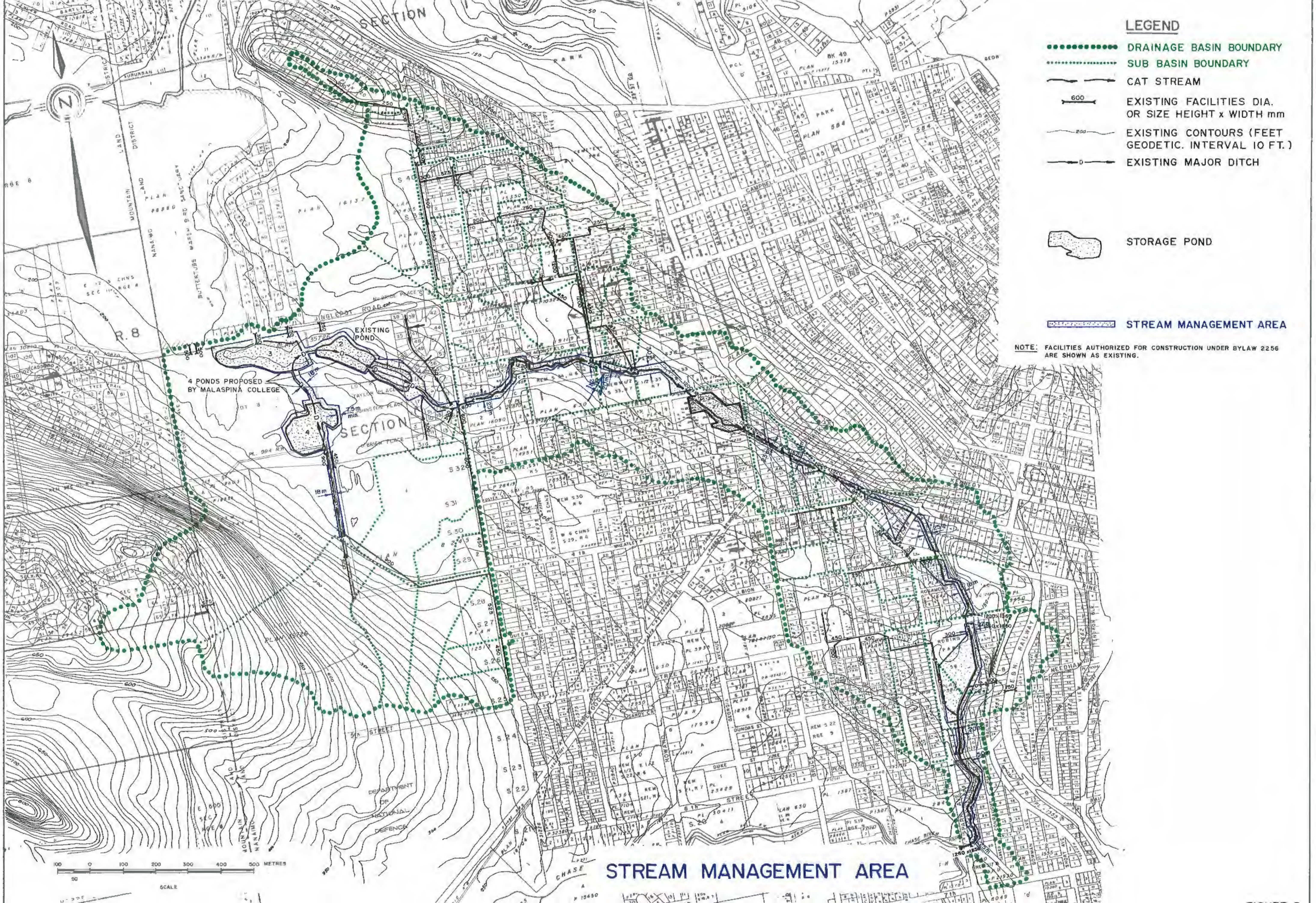
Existing developments and new subdivisions or building revisions would be subject to the Stream Management Area regulations.

The Stream Management Area drawing forming part of this study would be incorporated into the bylaw. As new development occurred, either subdivision or building permit or development permit, a legal survey should be required to formalize the Management Area on the land in question. In time, most of the Stream Management Area would be defined in a precise way by legal survey.



GUIDELINES FOR STREAM MANAGEMENT AREA WIDTH REQUIREMENTS

FIGURE 4



STREAM MANAGEMENT AREA

MANAGEMENT AREA CRITERIA

Policy No. 2 requires that the minimum width of the Management Area shall be 18 metres with the maximum width to be defined by topography and 100 year flood flow requirements. Disturbance of natural vegetation is to be minimized.

Riparian rights are to be respected when possible and factors affecting flow or environmental regimes are to be identified and regulated in consultation with environmental agencies.

Figure 4 shows Management Area width requirements for seven typical cases and these have been used as a guide.

Each section of the creek was inspected and survey carried out to establish a "typical" cross-section. From this cross section a determination of the required width for the Stream Management Area was made, based on required channel capacity to accommodate the 100-year flow, bank stability, potential for stream bed erosion, prevention of basement flooding, prevention of flooding private property outside the minimum 18 m width requirement and the preservation of fisheries and wildlife habitat.

The widths shown on Figure 5 are approximate and may be refined in individual cases with further survey.

During inspection of the stream no areas of unstable banks or severe erosion were found.

Erosion is not expected to be a problem and no measures are proposed for protection from erosion.

STREAM MANAGEMENT AREA

The Stream Management Area is shown on Figure 5 and described hereafter.

1. Upstream of Wakesiah Avenue. Commencing at the upstream end of the Cat Stream where the 600 mm storm drain discharges to the ditch, the minimum 18 m width is adequate for the management area until the storage ponds are reached.

At this time it is understood that the Department of Environment or Malaspina College will own and operate the four ponds which will also provide the City's storage needs. The City should establish a minimum 7.5 m width around the outside edge of the ponds as the Management Area.

From the ponds to Wakesiah Avenue, the City owns a strip of land centered on the stream. One section of this land is only 15.24 m wide in which dyking is needed to prevent flooding of private property. This strip of land is wide enough to incorporate the dykes to be built under Bylaw 2256 and so there is no need to increase the width to 18 m.

2. Wakesiah Avenue to Howard Avenue. Immediately downstream of Wakesiah Avenue, the north bank has a moderate slope (2.7 to 1) and the south bank has a gentle slope. A width of 25 metres is required at a section surveyed 18 m from Wakesiah Avenue. The corner of an apartment building is 4 m from the bank of the creek, compared with 7.5 m required for the Stream Management Area.

A greater width is needed in ponding areas near Beaconsfield Road and between Wakesiah Avenue and Beaconsfield Road. At Beaconsfield Road a dyke has been proposed to eliminate flooding. If development occurs in this area, a realignment of the Cat Stream would be preferable.

In the area downstream of Beaconsfield Road, the City owns a strip of land along the creek. This strip is too narrow to meet the Stream Management Area criteria. There is also an easement for a sanitary sewer line in this area. Rather than defining a new boundary the edge of the sanitary sewer easement should be used as one edge of the Stream Management Area.

At Howard Avenue, the 100-year flood channel will extend 7.5 metres onto the grassed field on the south side of the creek.

3. Howard Avenue to Third Street. Case 4, Stable Bank - Gentle Slope applies for most of this section. In the area upstream of Third Street a flood plain condition exists. Agreement has been reached with one developer to provide a 30 m easement and fill the flood plain to retain the 100-year flow within this easement. The Stream Management Area should coincide with this easement.

4. Third Street to Bruce Avenue. The City has purchased 1.2 ha of property to accommodate the storage pond. The Stream Management Area should coincide with the City-owned property, as shown on Figure 5.

5. Bruce Avenue to Fifth Street. Between Bruce Avenue and Chesterlea Avenue about 23 metres is needed.

Between Chesterlea Avenue and Pine Street two houses are within 4 m of the top of the bank. Between Pine Street and Albert Street the steps of a house are only 1 m from the bank. The City owns some property along the creek, especially between Albert Street and Albion Street. Much of this area is a flood plain and has been included in the Stream Mangement Area. If steps are taken to reduce flooding such as creek regrading or filling of low lying land, the Stream Management Area could be reduced. Between Rosamond Street and Fifth Street, most of the Stream Management Area is road right-of-way.

6. Fifth Street to the Chase River. Downstream of Fifth Street Case 2 (Stable Bank - Moderate Slope) applies to the east bank with some Case 1 (Rock Bank) and some Case 6 (Stable Bank - Steep Slope).

Case 4 applies for both banks of the stream for about 200 m upstream from the Chase River.

For the west side of the stream, downstream from Fifth Street, after a short section of Case 4 a flood plain condition exists at Robins Park. If the City is able to regrade the creek bed the Stream Management Area can be reduced.

From Duke Street to Sixth Street Case 4 applies. Downstream of Sixth Street Cases 1, 2 and 6 occur until the section of Case 4 is reached near the Chase River.

6. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are based on a review of the 1980 Cat Stream Drainage Study and on the findings of this Basin Study.

CONCLUSIONS

1. The Cat Stream is the major drainage pathway in the Basin and it should be made capable of conveying runoff from a 100-year storm without causing flooding to buildings.

2. Additional storage areas to those being constructed under Bylaw 2256 are not beneficial.

3. The basin study criteria of calculating 100-year flows using all year rainfall intensities result in about 25 percent greater runoff than would be the case if winter rainfall intensities were used, as in the 1980 Cat Stream Drainage Study.

4. Improvements are needed in the Cat Stream to accommodate the 100-year flows.

5. In the sub-basins some existing storm drains are undersized to handle 5-year minor system flows.

6. Overland routes in the form of swales combined with the minor system storm drains appear feasible as a means of conveying 100-year major system flows in most of the sub-basin areas. An exception is along Park Ave. when a major system storm drain should be used.

7. Within the basin, the Cat Stream is the only watercourse that requires regulation under a Stream Management Area bylaw.

8. The Stream Management Area should extend from the Chase River upstream to the 600 mm diameter storm drain discharge from Malaspina College.

RECOMMENDATIONS

1. Within the Cat Stream, $156,000 of improvements should be undertaken to accommodate 100-year flows. This work can be staged.

2. Within the sub-basins that are tributary to the Cat Stream, $772,000 of work is needed to provide the minor - major system for conveyance of 100-year runoff. This work can also be staged.

3. A detailed drainage plan should be a requirement of all new development.

4. Bylaws should be implemented to establish a Stream Management Area for the Cat Stream, to regulate all development within the Management Area and to control debris and pollution in the stream.

5. The City should obtain an agreement with Malaspina College and/or the Fish and Wildlife Branch which sets out responsibility for construction, operation and maintenance of the Wakesiah Avenue storage facility.

6. The City should inspect the Cat Stream on a regular basis. A yearly maintenance program, or more frequently if inspection dictates, should be undertaken to clear the stream of debris.

CITY OF NANAIMO

CAT STREAM BASIN STUDY

APPENDIX I

STORM WATER MANAGEMENT
POLICY ORGANIZATIONAL COMMITTEE

BROAD OBJECTIVE

To prepare recommendations for the City of Nanaimo which achieve effective Storm Water Management as a balanced compromise between environmental, social and economic considerations.

DETAILED OBJECTIVES

(1) To convey surface run-off to the sea, or other point of disposal, without causing unacceptable flooding.

(2) To limit environmental damage and improve upon existing conditions where possible, including consideration of slope stability, erosion, sedimentation, water quality, peak flows and maintenance of minimum flows.

(3) To recognize Federal and Provincial requirements.

(4) To build major and minor Municipal drainage systems which can be constructed and maintained at reasonable cost.

(5) To limit interference with private lands for drainage purposes.

(6) To limit liability for flooding.

(7) To encourage economic designs of drainage systems and effective land use on private developments.

(8) To set enforceable constraints on private drainage systems, which remain under private maintenance.

(9) To design a total system which enhances general public convenience, safety and esthetics and allows development to proceed according to Community Plans.

(10) To produce a set of design standards which are technically acceptable, workable and enforceable within the Community.

(11) To develop storm water systems with due consideration to energy conservation.

POLICIES

POLICY NO. 1

Natural watercourses shall be protected and managed as open streams except under special circumstances.

(a) Watercourses shall be delineated by the City of Nanaimo in consultation with the Federal Department of Fisheries and Oceans and the Provincial Fish and Wildlife Branch.

(b) Watercourses shall not be conduited if practical.

(c) Location of bridges shall be established by the City of Nanaimo.

(d) Culverts shall be approved by City of Nanaimo with consideration to backwater, fisheries and trash.

(e) Utility crossings shall not obstruct waterways.

(f) Animal fencing shall be erected where required.

(g) On-stream detention shall be acceptable except where it would adversely affect fish or other assets.

(h) Streams shall be protected and stabilized through control of soil erosion, stream bank erosion, and sedimentation.

(i) Consideration shall be given to fisheries resources, for maintaining minimum flows and the protection of fish habitat.

POLICY NO. 2

Creek Management Areas shall be established along natural watercourses within which all development will be restricted.

(a) Creek Management Area shall follow all natural watercourses as defined by bylaw.

(b) Minimum width shall be 60 feet with maximum width to be defined by the City of Nanaimo giving consideration to topography and flood flow requirements.

(c) Riparian Rights shall be respected wherever possible.

(d) Factors affecting flow or environmental regimes shall be identified and regulated in consultation with environmental agencies. Disturbance of natural vegetation shall be minimized in Creek Management Areas.

POLICY NO. 3

Regulations shall be enacted that will place all alterations which affect flow capacity or stream environment within Creek Management Areas under Municipal control consistent with the Water Act.

(a) Subdivision control bylaws shall include drainage control regulations.

(b) Development permit areas shall be established where necessary.

(c) Drainage control bylaws shall be passed (Sections 588, 589 and 590).

(d) Other regulations and referrals shall be implemented where and as required.

(e) Minor encroachment shall not be permitted except under a covenant and indemnity agreement (Section 215 Land Titles Act).

(f) Excavation, filling and debris disposal shall be regulated by bylaw.

POLICY NO. 4

Natural watercourses shall remain as private property except at utility crossings or under special circumstances.

(a) Section 588.2 of the Municipal Act provides us means to obtain access through private property.

(b) If necessary, the City shall exercise its rights as provided in the Municipal Act to maintain the proper flow of water.

(c) Existing developments, subdivisions or building revisions shall be subject to Creek Management Area regulations.

(d) Restrict liability and costs to City of Nanaimo.

POLICY NO. 5

Both minor and major flow routings shall be investigated and included in all drainage systems in the City.

(a) Minor systems consist of underground conduits, open channels and watercourses to handle peak flows (5-25 year storms).

(b) Major systems consist of overland flood paths, roadways and watercourses to handle design flows above minor systems (up to 100 year storm could cause inconvenience but no major damage). In special conditions where adequate overland flood paths cannot be established, pipes and culverts of the minor system may be enlarged to accommodate the major flow.

(c) For each drainage basin, conceptual plans be developed by the City to define the generalized flow pattern including the H.G.L. and the flood plain for minor and major flows.

(d) Both minor and major systems shall be located in private and public rights-of-way where possible, except within Creek Management Areas.

POLICY NO. 6

Rainfall and runoff design criteria shall be established on a City-wide basis.

(a) Minor routings shall be designed for a minimum 5 year recurrence interval.

(b) Major routings shall be designed for 100 year recurrence interval.

(c) The Modified Rational Formula shall be used for system analysis with computer modelling (Illudas) optional.

(d) Inlet times shall be a minimum of 5 minutes.

(e) Time of concentration shall be derived from the Kirby Formula or equivalent.

(f) "All Year" rainfall curves shall be used on City-wide basis.

(g) Runnoff co-efficients from existing City standards shall apply.

(h) The City of Nanaimo will initiate data gathering for design hydrographs.

POLICY NO. 7

Increase in runoff due to new developments shall be limited according to the capacity and sensitivity of the downstream drainage system.

(a) Limit expenditures in existing downstream areas.

(b) Limit increase in peak storm flows and volumes to the receiving waters. Consideration shall be given to fish bearing streams to restrict the post-development peak runoff to the pre-development condition for all storms up to and including the 10 year storm.

(c) The number of storage facilities shall be minimized.

(d) Groundwater infiltration is to be encouraged where appropriate, but no allowance shall be made for it in hydraulic design.

I. Residential (single family dwellings) developments.

(a) Permanent storage to be surface or underground storage.

(b) Permanent storage facilities shall be maintained by the municipality.

(c) Basin studies shall determine location, number and size of ponds and the release rate (flood routing) for trunk routes.

(d) Where land developments occur in advance of completed basin facilities, the municipality will consider temporary storage facilities on an individual basis.

(Note: Maintenance charges for temporary storage facilities to be reviewed on an individual basis.)

II. Commercial, Industrial and Other Corporate Entities

(a) Storage facilities may be open ponds or underground either private or community. Rooftop or parking lot storage shall be considered, where appropriate.

(b) The owner shall maintain private systems. The City shall require an enforcement bylaw (penalties, bonding, additional fee for bi-annual inspections) to allow City to do regular inspections and to do maintenance, and charge back costs, if facilities are not being maintained.

(c) Private property owners shall indemnify the City from liability arising out of private facilities.

POLICY NO. 8

Storm sewers with individual parcel connections shall be required for all new developments, except in special circumstances.

(a) Splash Pad concept may be permitted in conjunction with lot drainage plans.

(b) Foundation drains shall be connected to storm sewer connections except under special circumstances.

(c) A gravity connection to the municipal storm drainage system may be made only where the habitable portion of a dwelling is above the major system hydraulic grade line. Otherwise, only a pumped connection will be permitted.

(d) Special cases where there is no storm sewer connection to every lot shall be reviewed on an individual basis.

POLICY NO. 9

Minimum water quality standards for storm water contributions from agricultural, industrial, commercial, residential and institutional developments shall be considered with respect to the following:

- control of temperatures
- control of B.O.D.
- control of sedimentation during construction using temporary storage facilities (settling chambers, ponds).

POLICY NO. 10

Natural drainage areas shall be established for watercourses and individual analyses of major and minor flow routing, and of retention/detention works for watercourses in each area shall be instituted.

(a) The City shall carry out basin studies, as soon as possible, looking at existing City systems, study of rivers capacity, regional ponding systems, study of collection systems in existing developments and major routings through developments.

(b) A conceptual plan incorporating policies 1 to 9 inclusive will be developed.

(c) The storm water management policy shall be consistent with the Zoning Bylaw and the Community Plan.

(d) City staff shall provide detailed Terms of Reference for each study area.

1981-JAN-23

CITY OF NANAIMO

CAT STREAM BASIN STUDY

APPENDIX II

ILLUDAS DATA

PART A - DETERMINATION OF PARAMETERS

The following parameters were discussed at a meeting at the City of Nanaimo on June 2, 1981 and agreement was reached that these should be used for the basin studies.

Card III:	Paved Abstraction	- 0.1 inches
	Grassed Abstraction	- 0.2 inches
	Soil Group	- generally 4 but 3 permissible where particularly absorbtive area exists.
	Minimum diameter	- 10 inches
	New pipe 'n'	- 0.013
Card IV:	Rainfall increments	- minimum of one twelfth of rainfall duration.
	Time increment	- from above up to a maximum of 15 minutes.
	Duration	- full range of appropriate durations to be tested for each catchment to determine peak flows and storage (if applicable).
	Total Rainfall	- intensity based on Vancouver Airport records.
	Antecedent Moisture Content (AMC)	- 4 for winter, 3 for summer or all-year.
Card V:	Rainfall pattern	- Based on Table II-1.
Card VI:	No set parameters	

Card VII: Areas - maximum area to be used for basin studies:

Developed	- 15 ha
Rural	- 25 ha

Smaller areas to be used where necessary and appropriate.

Directly Connected Paved Area -

Residential:	between 30% and 50%
Commerical	80%
Industrial:	from 80% (light) to 40% (heavy)
ALR:	5% (no development beyond existing level to be assumed for ALR)

Supplemental Paved Area -

Average value	5%

Paved Area entry time -
use Illudas for detailed design, for basin studies use:

slope over 5%	0.03 min/m.
slope 1% to 5%	0.04 min/m.
slope less than 1%	0.05 min/m.

Contributing Grassed Area -
100% of remaining sub-basin area

Grassed Area entry time -
use Illudas for detailed design, for basin studies use:

slope over 5%	0.20 min/m.
slope 1% to 5%	0.25 min/m.
slope less than 1%	0.30 min/m.

Soil Group -
as noted for Card III

TABLE II - 1

TABULATION OF RAINFALL FOR DESIGN STORM

Total Rain = 1.00 (inches or mm)

Number of increments = 60

Units shown are rain in each increment. In this example, the values are numerically equal to inches/min. or mm/min.

Time	Units	Time	Units	Time	Units	Time	Units
0	0.000	16	0.012	32	0.027	48	0.016
1	0.003	17	0.014	33	0.029	49	0.016
2	0.005	18	0.016	34	0.031	50	0.015
3	0.005	19	0.020	35	0.032	51	0.014
4	0.005	20	0.022	36	0.032	52	0.014
5	0.005	21	0.023	37	0.033	53	0.013
6	0.005	22	0.023	38	0.032	54	0.013
7	0.005	23	0.023	39	0.031	55	0.011
8	0.005	24	0.023	40	0.029	56	0.009
9	0.005	25	0.023	41	0.028	57	0.007
10	0.005	26	0.023	42	0.027	58	0.005
11	0.006	27	0.023	43	0.024	59	0.003
12	0.006	28	0.023	44	0.022	60	0.000
13	0.007	29	0.023	45	0.020		
14	0.008	30	0.024	46	0.019		
15	0.009	31	0.024	47	0.017		

For ILLUDAS, the rainfall is input as inches per increment with the design storm period being divided into a number of equal increments.

PART B - DATA USED FOR STUDY

Card I: Title CITY OF NANAIMO CAT STREAM BASIN STUDY

Card II: Basin Parameters

Basin Area	641 acres
Paved Area Abstraction	0.10 inches
Grassed Area Abstraction	0.20 inches
Predominant Soil	Group 4
Minimum Diameter	
New Pipe "n"	0.013

Cards IV & V: Rainfall Data

AMC = 3 was used for all cases. Table II-2 shows the design storm used for a 5 year return period, while Table I-3 shows the 100 year design storm.

The 12 hour design storm has a time increment of 60 minutes which exceeds the 15 minutes maximum specified in Part A. In order to check the accuracy of the longer durations, the design storm shown in Table II-4 for a 12 hour design storm was used for the basin. The results were within 4 percent of those calculated with 60 minute increments.

The results show that increments of up to one hour may be safely used.

Table II-4 also shows the 24 hour design storm used for a 100 year return period.

Cards VI: Reach Data

Note that "n" is 0.013 unless shown otherwise. Where an open channel has been assumed, the height (H), width (W) and slope (LS) are shown. For a 1:1 slope LS = 1. Where only H and W are shown, i.e., for 1-25, the section is rectangular.

Table II-5 shows the reach data used.

Cards VII: Sub-Basin Data
Note that the area of indirectly connected paved area is 5 percent for each sub-basin, except for 7-0 to 7-6 and 8-0 to 8-3 where the indirectly connected paved area is zero. The grassed area is assumed to be the balance after deducting the paved area and indirectly connected paved area.

Table II-6 shows the sub-basin data.

TABLE II - 2

DESIGN STORM DATA

5-YEAR RETURN PERIOD

Duration (Hours)	0.5	1	2	6	12
Time Increment (Minutes)	2.5	5	10	30	60
Total Rainfall (Inches)	0.39	0.58	0.75	1.30	1.83
Increments					
1	0.000	0.000	0.000	0.000	0.000
2	0.009	0.013	0.017	0.030	0.043
3	0.010	0.015	0.019	0.033	0.046
4	0.014	0.021	0.027	0.047	0.067
5	0.033	0.049	0.064	0.110	0.155
6	0.046	0.067	0.087	0.151	0.213
7	0.046	0.068	0.088	0.152	0.215
8	0.057	0.083	0.109	0.187	0.265
9	0.062	0.092	0.119	0.206	0.290
10	0.048	0.071	0.092	0.159	0.224
11	0.033	0.048	0.063	0.109	0.154
12	0.026	0.038	0.049	0.085	0.120
13	0.010	0.014	0.018	0.031	0.044

TABLE II - 3
DESIGN STORM DATA
100-YEAR RETURN PERIOD

Duration (Hours)	0.5	1	2	6	12
Time Increment (Minutes)	2.5	5	10	30	60
Total Rainfall (Inches)	0.72	0.99	1.36	2.12	3.07
Increment					
1	0.000	0.000	0.000	0.000	0.000
2	0.017	0.025	0.032	0.049	0.071
3	0.018	0.025	0.034	0.054	0.077
4	0.026	0.036	0.049	0.077	0.111
5	0.061	0.084	0.115	0.180	0.260
6	0.084	0.115	0.158	0.246	0.350
7	0.085	0.116	0.159	0.248	0.358
8	0.104	0.143	0.196	0.306	0.442
9	0.115	0.157	0.216	0.336	0.485
10	0.088	0.121	0.166	0.259	0.374
11	0.061	0.083	0.114	0.178	0.257
12	0.047	0.065	0.089	0.139	0.201
13	0.017	0.024	0.033	0.051	0.074

Increments of rainfall are in inches.

TABLE II - 4

DESIGN STORM DATA

100-YEAR RETURN PERIOD

Duration (Hours)	12	24			
Time Increment (Minutes)	12	24			
Total Rainfall (Inches)	3.04	4.20			
Increment	12 hour	24 hour	Increment	12 hour	24 hour
1	0.000	0.000	31	0.074	0.102
2	0.009	0.013	32	0.074	0.115
3	0.015	0.021	33	0.083	0.123
4	0.015	0.021	34	0.089	0.132
5	0.015	0.021	35	0.095	0.136
6	0.015	0.021	36	0.098	0.136
7	0.015	0.021	37	0.098	0.140
8	0.015	0.021	38	0.101	0.136
9	0.015	0.021	39	0.098	0.132
10	0.015	0.021	40	0.095	0.123
11	0.015	0.026	41	0.089	0.119
12	0.018	0.026	42	0.086	0.115
13	0.018	0.030	43	0.083	0.102
14	0.022	0.034	44	0.074	0.094
15	0.025	0.038	45	0.068	0.085
16	0.028	0.051	46	0.061	0.081
17	0.037	0.060	47	0.058	0.072
18	0.043	0.068	48	0.052	0.068
19	0.049	0.085	49	0.049	0.068
20	0.061	0.094	50	0.049	0.064
21	0.068	0.098	51	0.046	0.060
22	0.071	0.098	52	0.043	0.060
23	0.071	0.098	53	0.043	0.055
24	0.071	0.098	54	0.040	0.055
25	0.071	0.098	55	0.040	0.047
26	0.071	0.098	56	0.034	0.038
27	0.071	0.098	57	0.028	0.030
28	0.071	0.098	58	0.021	0.021
29	0.071	0.098	59	0.015	0.013
30	0.071	0.102	60	0.009	0.000

Increments of rainfall are in inches.

TABLE II - 5

REACH DATA

Branch-Reach	Length (ft.)	Slope (%)	'n'	Dia. in.	H (ft.)	W (Ft.)	LS
1-0	906	.5					
1-1	732	.5					
2-0	827	.5					
1-2	323	.5					
3-0	386	.5					
3-1	180	.5					
4-0	693	.5					
1-3	323	.5					
1-4	457	.5					
5-0	464	.5					
1-5	489	.67					
1-6	387	2.5					
1-7	348	.32					
1-8	233	.37					
1-9	561	.22					
6-0	354	.5					
6-1	504	.5					
6-2	40	.4					
1-10	312	.45					
1-11	390	.61					
1-12	203	.1					
7-0	360	.4					
7-1	330	.4					
7-2	350	4.0					
7-3	720	.4					
7-4	980	.6					
7-5	3300	.1	.020		5	5	1
8-0	272	1.23					
8-1	174	1.29					
8-2	594	1.29					
8-3	308	3.3					
7-6	57	.2	.013	36			
7-7	920	.3	.035		3	4	1
7-8	920	1.18	.035		3	4	1
7-9	440	1.1	.035		4	4	1
1-13	610	.75	.035		4	4	1
1-14	740	.16	.035		4	4	1
1-15	10	2.92	.013	30			
1-16	460	.3	.035		4	4	1
1-17	460	1.0	.035		4	4	1
1-18	460	.7	.035		4	5	1
1-19	70	.7	.035		4	6	1
9-0	180	1.0					
1-20	1090	1.0	.035		4	6	1
10-0	200	1.0					
1-21	600	.5	.035		5	6	1
1-22	850	.7	.035		5	6	1
11-0	200	2.0					
1-23	240	.3	.035		5	6	1
12-0	720	.7					
12-1	280	.5					
1-24	1640	.9	.035		5	6	1
1-25	46	3.2			4.13	6	

TABLE II - 6

SUB-BASIN DATA

Branch-Reach	Area (ac)	% Paved Area	Entry Time (min.)	Paved Area Length (ft.)	Paved Area Slope (%)	Entry Time (min.)	Grassed Area Length (ft.)	Grassed Area Slope (%)
1-0	1.2	50		350	3		80	3
1-1	2.2	44		500	4		100	3
2-0	2.3	44		380	2		100	2
1-2	21.5	45		800	4		100	3
3-0	0.8	44		200	3		120	3
3-1	4.3	44		600	3		100	3
4-0	4.8	40		470	3		100	3
1-3	4.2	44		600	3		100	3
1-4	4.7	44		330	3		100	3
5-0	5.9	44		350	3		200	3
1-5	5.2	46		275	3		270	3
1-6	4.8	44		550	3		150	3
1-7	5.3	40		780	4		200	5
1-8	5.9	40		150	3		150	3
1-9								
6-0	10.3	37		520	3		200	3
6-1	2.9	44		780	3		200	3
6-2	3.2	44		590	3		120	3
1-10	7.9	20		510	3		400	3
1-11	1.2	44		340	3		120	3
1-12	3.0	46		230	3		270	3
7-0	3.9	80	8			7		
7-1	4.3	80	8			7		
7-2	5.8	80	8			8		
7-3	12.1	75	13			14		
7-4	13.7	75	8			9		
7-5	41.8	30	13			70		
8-0	2.8	65	8			7		
8-1	5.8	80	11			7		
8-2	20.9	32	15			30		
8-3	2.1	70	8			3		
7-6	170.2	5	20			132		
7-7								
7-8	20.8	45	13			19		
7-9	7.8	40	11			19		
1-13	4.0	50	5			14		
1-14	17.3	45	8			10		
1-15	31.4	40	16			18		
1-16								
1-17	8.4	40	7			15		
1-18	4.2	40	4			15		
1-19	22.5	40	18			19		
9-0	7.3	40	11			19		
1-20								
10-0	15.1	40	16			15		
1-21	20.0	40	4			25		
1-22	12.0	30	6			12		
11-0	10.2	35	8			12		
1-23	9.9	15	5			30		
12-0	30.0	40	16			15		
12-1	11.0	40	8			15		
1-24	5.5	10	3			38		
1-25	14.6	30	8			38		