A DESIGN FOR A SUBURBAN RETENTION POND

BY

PATRICK WILEY

8 March 2001

A Practicum
Submitted to the Faculty of Graduate Studies
in Partial Fulfillment of the Requirements
for the Degree of

MASTER OF LANDSCAPE ARCHITECTURE

Department of Landscape Architecture
University of Manitoba
Winnipeg, Manitoba

0-612-57593-4

THE UNIVERSITY OF MANITOBA

FACULTY OF GRADUATE STUDIES
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Abstract

This study examines bibliographical research on water quality in Winnipeg's rivers and retention ponds, methods of improving water quality in those retention ponds, and means of accommodating waterfowl that may inhabit the retention ponds. This information is used to create a design for a typical Winnipeg subdivision based around a retention pond which: improves the quality of water in and discharging from the pond; provides better habitat for waterfowl; and provides an aesthetically interesting park and pond, which is easily accessed by the community members.

Acknowledgements

I would like to express my gratitude to the people whose assistance was essential in enabling me to complete this project.

I would like to thank my practicum committee, Carl Nelson, Charlie Thomsen, and Natasha Juck, for their effort, insight and encouragement. I would also like to thank Alf Simon, and Ted McLachlan for their earlier assistance.

I have received valuable information from the City of Winnipeg, and the Province of Manitoba, and I would like to thank the following people: Chris Torpey, Land Development Administrator, Land Development Division; Dave Wardrop, Waste and Water Department; Andy Nagy, City of Winnipeg; Eric Charlson, Manitoba groundwater Department; Randy Gadawski, Entomologist, City of Winnipeg; Ken Nawalsky, Insect Control Branch, City of Winnipeg.

I also owe gratitude to individuals in the private sector such as: Gordon Forsyth, Ken Scott, Rob Sunterland, and Greg Nykiforuk for their assistance.

CONTENTS

This practicum offers an alternative for retention pond design that; would work in conjunction with a stormwater drainage system to provide an attractive landscape, which would provide wildlife habitat, improve water quality, and would be more accessible to people in a community.

Overview of Stormwater Retention Ponds

In order to improve retention ponds it is first necessary to have an idea of what needs these basins satisfy. It is also important to know how these ponds may be lacking.

Many North American cities are expanding their boundaries, developing new subdivisions on their peripheries. Land that was once farmland or forest is being changed due to urban development, and is being covered by, roads, parking lots, and driveways, while the rest is being covered by mown turf and buildings. This change in land usage creates changes in the way precipitation reacts with the landscape. The impermeable surfaces and sparse plant material make water infiltration more difficult, and increase the rates of evaporation and runoff.

At present, ever expanding city development in places like Winnipeg forces the city's stormwater infrastructure to accommodate greater water volumes resulting from stormwater runoff, and move that water increasingly longer distances to the natural water bodies. Existing stormwater sewers cannot deal with the increased higher water volumes. One way to rectify this problem is to impound the excess water in a retention pond, and release it gradually into existing conduits. This method allows water to be emptied into an existing system, or will allow for water to be carried to receiving water bodies by smaller conduits which will yield substantial savings in infrastructure costs. (Chambers and Tottle, 1980)

The decreased cost of a stormwater system that includes a retention pond has caused ponds to become standard in most new subdivisions across the prairies. Since the public seems to find houses adjacent to water landscapes desirable, the potential for developing the retention pond into an attractive and functioning landscape is considerable. Not only are river front and lake front properties popular, but lots adjacent to retention ponds are also desired and can sell for higher prices. This is recognized by the developers, who now include retention ponds in their development even though their construction does not always achieve cost savings (Chambers and Tottle 1980).

In addition to decreasing the intensity of runoff by spreading the volume over a longer time, there are other potential benefits in using retention ponds. These include providing migratory water fowl with temporary refuge or providing permanent homes to a range of aquatic plant and animal species; allowing infiltration and recharge of ground water; cleaning contaminated stormwater runoff before it is returned to ground water or a receiving water body; and acting as a natural amenity providing aesthetic value to increase property values or improve the quality of life for the adjacent residents. The ponds could accommodate a wide range of summer and winter recreational activities, both on the water and on the land that surrounds the ponds.

Although the retention ponds in Winnipeg actually accomplish all of these things to some extent, the way these basins are designed and managed prevents them from realizing their full potential.

Many places in the United States have experienced deforestation and substantial urbanization, which necessitates the use of impoundments for flood protection (Thrasher 1985). Because the landscape of Southern Manitoba has changed from grassland to farm land, the runoff coefficients are not substantially higher now than in pre-agricultural times (Chambers and Tottle 1980). Urban development can drastically increase the amount of water that must drain overland. Since the watersheds of the Red, Assiniboine, and the Seine are not substantially urbanized, the retention ponds do not have to provide substantial flood protection, but they have to accommodate and store excess runoff generated within their own catchment. These needs of flood protection, generated by urbanization of our watershed, are easily met by the impoundments.

Pollution that does not come from a specific source, but rather comes from many diverse atmospheric sources and is carried to water bodies by runoff is called non-point source pollution. Most measures which deal with the pollution control of water deal with point source pollution, but non-point source pollution is a growing problem (Overcash and Davidson 1980). One way in which this polluted stormwater runoff can be treated is through the use of impoundments. In fact, in the United States many impoundments are constructed primarily for the purpose of improving the quality of runoff (UMA 1995). Although smaller population densities in Canada mean pollution poses less of a problem here than in the United States, we should still start dealing with potential pollution problems before we degrade our water and environment further.

Since controlling water quantity and not quality is the primary goal behind the design of the retention ponds in Winnipeg, an important opportunity arising from the use of retention ponds is lost. As a consequence of water being impounded many pollutants precipitate out of the water column and fall to the bottom of pond. In this way many heavy metals and nutrients are removed from the water before it drains into rivers and streams, but there are still pollutants and excess dissolved nutrients remaining in the water (Chambers and Tottle 1980). There are other ways in which nutrients and heavy metals can be removed from the water, and other pollutants can be broken down. Phytoremediation is a process whereby pollutants can be removed from soil and water or even broken down by plant material or associated microbes (Thompson 1998), but, for this to occur the presence of the appropriate vegetation is essential. This is a fundamental weakness in the management practices of retention ponds in Winnipeg, since actions are directed at removing natural vegetation from this system. This policy can not only work against improving water quality, but some of the methods of attaining the 'weed free' environment can also yield other problems.

Management techniques are based on the presumption that, the emergent macrophytes growing on the shores of the ponds are weeds, and should be eliminated (Chambers and Tottle 1980, UMA 1992). Also, a great deal of attention is paid to the algae that grows in the waters. Both the growth of macrophytes and algae is a natural process, which is magnified by the nutritional content of influent waters. A study by UMA Engineering (1992) discussed several solutions designed to both remove aquatic plants and algae. These methods would be typical of the city's traditional approach which deals with plant growth – a symptom of eutrophic waters -- while neglecting the problem of excess nutrients in the water, which is what causes excessive plant growth. When treating the symptoms instead of the problem then the problem of eutrophic water is passed on to the natural water bodies. Additionally, many of the measures proposed such as applying herbicides, algicides or chemical dyes to the water would further pollute waters and sabotage the ability of the retention ponds to act as wildlife habitat. The treatment of contaminated runoff and the provision of better wildlife habitat can be complimentary goals. As a result of agricultural development, and traditional European beliefs that wetlands have little value, many of North America's wetlands have been drained (Hammer, 1992). But wetlands do have value,"[they] provide the vegetative base for many aquatic and terrestrial food chains. Moreover, vegetative production in wetland systems can be considerable because these aquatic environments act as nutrient traps..." (Thrasher 1985). Retention ponds have a good potential if they are to augment environments or habitat that have dwindled.

Unfortunately, the retention ponds are managed in such a way that dubious aesthetic concerns may thwart goals of creating habitat, especially since lack of foresight prevents authorities from recognizing this potential. Decisions to cover the shore with gravel so as to keep the shore free of 'untidy' mud or 'weeds' are made on the basis of an aesthetic that tends to look sterile. Not only are these decisions questionable on the basis of their aesthetic goals, but they can damage the habitat. A muddy shore can provide good habitat for invertebrates, which can be a good food source for birds (Anderson 1992). A gravel edge may also be used so children can more easily extricate themselves from a muddy shore, however, increased emergent vegetation at the shore may provide the same protection. Emergent vegetation can also provide shelter for fish (Allan et al, 1989), as well as other benefits, but if they are not seen as more important than sod by those who design and manage these ponds then the ponds are doomed to be poor natural environments.

Developers have realized that there is a potential in marketing retention ponds as aesthetic amenities, and retention ponds are being developed with more effort and expense focussing on aesthetics. The focus however, seems to be only on a small part of the pond--the small portion of public property adjacent to the road. Little regard seems to be given to the rest of the pond. In fact much of the shore remains adjacent to private lots, and this makes public interaction with a water landscape feature more difficult. If the retention pond is seen as the centre of a public park, then more attention should be paid to developing around the entire pond. Having a retention pond associated with open space will make this more possible, and research by Edwards (1990) suggested that the public would be supportive of this initiative. If the retention pond becomes a more important part of a community, with the public enjoying the scenery and wildlife, then there is also potential to use the retention pond as a means to educate the public about aspects of infrastructure, wildlife habitat, water usage, and how their actions can affect these things.

It seems that storm water retention ponds are an accepted and appreciated part of suburban developments, and they remain so. If they are to be part of our environment then we would be wise to obtain the most value from them. This study proposes that retention ponds can become more attractive landscapes which function as a centre for the community, educate people about environmental issues, provide wildlife habitat, cleanse and filter water, and offer recreational opportunities. In order for this to occur, not only the retention pond, but the area adjacent to the pond, and watershed of the pond must be designed and managed appropriately.

Problem

1) The City of Winnipeg regularly violates established provincial surface water quality objectives for the Red and Assiniboine Rivers in and downstream of Winnipeg. This is caused by treatment plant effluent and contaminated stormwater, which compromises recreational opportunities on the river, degrades water used for drinking and irrigation, threatens aquatic life in the rivers, and contributes to the eutrophication of Lake Winnipeg. Retention ponds are a part of this system and as such can contribute to improving the quality of water discharged into the rivers, when designed properly. Urban stormwater runs off of smooth impermeable surfaces and is delivered directly to retention ponds through underground pipes. This circumvents the natural ability of plants to remove nutrients or pollutants from stormwater that would flow over and through them if stormwater had been allowed to behave as it does in a natural watershed.
2) Although the prairies are a very productive environment for waterfowl, many of the wetlands that once existed have been lost due to agricultural practices, road construction and urban settlement. The urban retention ponds could be used to augment lost wildlife habitat, but in their present state their effectiveness as habitat is limited.
3) A large portion of the shoreline of most retention ponds is privately owned which can fragment the landscape, preventing the public from accessing large portions of the pond and the land surrounding it. This restricts public interaction with the water landscape, and prevents maximum enjoyment of the park. When privately owned houses are on the shoreline then there is a smaller perimeter in which houses can be arranged around the park and pond, which will limit the number of houses adjacent to the park and pond.
4) Public access to the retention pond, and park seems to be oriented towards limited approaches from the busier

vehicular circulation routes and not from pedestrian routes throughout the community.

5) The public takes for granted the infrastructure that exists to allow our cities to function. They remain relatively uneducated about the environmental consequences arising from how we deal with water and how we affect the natural environment. Many people are unaware of how a natural environment such as a marsh can improve water quality for both stormwater and sewage effluent or even that there is a need for this and that viable solutions exist which also provide a variety of other benefits.

Objectives

The objective of this study is to develop principles and procedures for designing improved residential stormwater system based around a permanent water landscape. A successful design would accomplish the following objectives :

1) Improve water quality. The quality of water entering, exiting, and existing in the retention pond can be improved.
2) Provide wildlife habitat which will augment lost natural habitat, such as marshes. The habitat would support fish, invertebrate, and avian species living among native aquatic plants, or the associated upland plant communities. Waterfowl would take priority over other forms of wildlife.
3) Encourage public access to the retention pond, and the park around it. This will increase the public's awareness of that infrastructure, and show how it can be designed in a manner that compliments environmental objectives.

Means of accomplishing the goals of better water quality, and better wildlife habitat will yield a park and retention pond which is different, and has a more interesting configuration than the retention ponds used today in Winnipeg.

Method

The method of achieving the objectives is to conduct bibliographical research to determine the functions of retention ponds in Winnipeg. As retention ponds are ultimately connected to the Rivers which run through Winnipeg, it is important to determine the water quality of those rivers, and to know the origins of quality problems in that water. It is also important to know of pollution issues in the retention ponds. To ascertain this, data from water sampling studies, conducted by the City of Winnipeg laboratory services division, or previously written by Chambers and Tottle is reviewed.

Study of methods of preventing pollution and eutrophication is used to determine feasible strategies of preventing or dealing with contamination through a constructed stormwater management system based around a retention pond.

Study of wetlands provides information on natural precedents that could be modelled in order create wildlife habitat. Since waterfowl currently utilize both retention basins and marshes, waterfowl are also studied, to yield information on how they can be incorporated into a suburban landscape. The issues are considered and applied in a design of a local residential development nearing completion at the time of this study. The intention is to take the design the Southland Park subdivision, and offer a similar, yet alternate design which has improvements in the retention pond and drainage system. Southland Park is used as an example of a typical suburb in Winnipeg.

Scope of Study

This practicum recognizes that techniques of water management have implications far beyond where it is managed, but that the boundary of the 100 acre Southland Park development is the limit of the project. The drainage of the subdivision is of prime importance, and this practicum will deal with the drainage, creating a unique system between the individual lot and the city of Winnipeg outfall. Southland Park is used as an example of a typical community, there is no constriction of exactly duplicating lot size or number imposed on this design. Finally, applying a new system of overland drainage has implications for the nature of the community, but this will be dealt with as it pertains to drainage, the retention pond, and land immediately adjacent to it.

Winnipeg is not a complete watershed, but, is a part of the watersheds of different rivers and creeks. Within Winnipeg the Seine, the La Salle, and the Assiniboine Rivers all drain into the Red River, in addition to three creeks. When the Red River leaves the city it carries with it the accumulated water from an area of approximately 287,000 km^2 of land, and then it empties into Lake Winnipeg, which has a watershed of about 985,000 km^2 (Manitoba Environment 1992). Winnipeg is only a small part of a larger watershed, but since it is a major urban centre, and characteristics such as runoff volumes, nutrient, and oxygen levels tend to be different in an urbanized watershed, it may be useful to look at Winnipeg as a distinct watershed. But, since stormwater management practices have consequences for those in and beyond our own city then we must examine the condition of the water upstream and downstream of Winnipeg, and what happened to it within Winnipeg. Evidence suggests that water quality in our rivers is degraded as it moves through Winnipeg.

The type of infrastructure a city employs to deal with stormwater can affect the quality of natural water bodies that the stormwater eventually drains into. Many pollutants generated by a city's inhabitants find their way into rivers and streams after being discharged from stormwater outfalls, and sewage treatment plants. Even after treating sewage, cities like Winnipeg discharge effluent which negatively affects the water quality of rivers. It is important to minimize any adverse effects to receiving water bodies like the Red and Assiniboine Rivers as they provide habitat for aquatic life, and the water is used to benefit people in several ways.

Uses of Winnipeg's river water

Water from Winnipeg's rivers is used for: domestic consumption, in Selkirk; for industrial consumption; for agricultural consumption, including irrigating local parks; for recreation; and it sustains an abundance of aquatic life. If the quality of water in the rivers degrades, then all of these uses can be put into jeopardy, and this will have negative economic consequences, as well as threatening quality of life, or health.

Aquatic life and oxygen levels

Impressions given from the visual quality of the Red River may lead some to believe that the river is highly contaminated and unproductive. The reality is that the Red and Assiniboine Rivers are important waterbodies which support 55 species and 16 families of fish, making it the third richest waterbody in Canada in terms of fish species diversity (Manitoba Environment 1992). These fish are the basis for an angling industry where many people contribute millions to the local economy. Furthermore, Lake Winnipeg supports a commercial industry worth hundreds of millions (Manitoba Environment 1992), and this could be threatened by poor water quality in and downstream of Winnipeg.

There is reason for concern as the city of Winnipeg does pollute the rivers. A scientist from the University of Winnipeg stated at public hearings on water quality that the fish in the rivers were neither healthy nor abundant, and pointed out that the fingernail clam is found in the Red River upstream of Winnipeg, but not downstream. Stormwater and sewage effluent entering the rivers increases the levels of un-ionized ammonia, biological oxygen demand (BOD), faecal coliform, phosphorus, nitrogen, and heavy metals while reducing the level of dissolved oxygen (DO), that is critical to aquatic life. Andy Lockery (1990) puts necessary DO level for trout at 10mg/L, while the province adopts a minimum level of 5 mg/L for cool water aquatic life. Water entering Winnipeg is well above established criteria for DO, but is degraded as it moves through the city. Wet weather tends to cause violations of 4 and 5 mg/L DO (James F. MacLaren Ltd. 1979) when the river does not have sufficient volume to dilute contaminated effluent. The quality of the Red River can be considered marginal in terms of frequency occurrences of low DO, with oxygen levels that are sometimes insufficient for cool water species, yet upstream of Winnipeg, where the river is not as polluted the DO levels are usually adequate for cold water species.

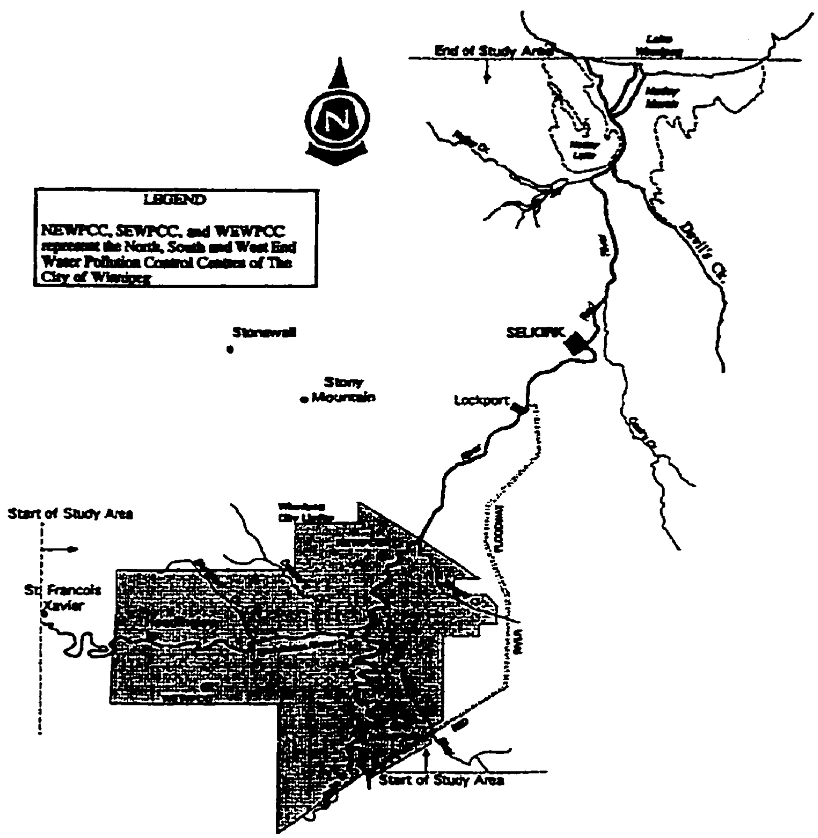


Figure 1.1 Winnipeg Watershed Study Area (Manitoba Environment 1992)

Nitrogen and Phosphorus

The provincial goal for nutrient levels in the rivers is also exceeded. The goal of 0.05 mg/L phosphorus is exceeded 99% of the time upstream, within and downstream of Winnipeg. Although these goals are usually not met upstream of Winnipeg, it is estimated that there is about 30% more phosphorus in the Red River leaving Winnipeg than entering. Excessive nutrient loadings can contribute to excessive plant growth, and, low oxygen levels, but, this may be more important for Lake Winnipeg than for the rivers because the rivers are less conducive to developing excessive algal populations (Manitoba Environment 1992).

Coliform bacteria

Another critical measure of pollution is the number of faecal coliform bacteria (MPN /100mL) present in the water. In this category the Red River is in even poorer condition than it is for its oxygen levels. At Selkirk, after the river has significantly diluted effluent, the coliform levels are well above acceptable levels for most of the year (Lockery 1990). Yet violations of the same standards are rare upstream of Winnipeg in the Assiniboine, but are exceeded 67-96% of the time at the confluence of the Red. On the Red River coliform levels are below objectives almost 100% of the time upstream of Winnipeg, while they are over 96% of the time at the North Perimeter, and 70% of the time at Lockport. The bacteria can endanger the health of individuals participating in recreational activities on the river. Since river water is used for irrigation, bacteria can threaten the health of people using parks or consuming irrigated crops (Manitoba Environment 1992).

Other Pollutants

Some of the more harmful and persistent pollutants are also monitored in Winnipeg's rivers. DDT, PCB's, dioxin and pesticide residues have all been checked, and they were found to be well below international standards (Lockery 1990). In a study between 1973 and 1975 copper, lead, zinc, cadmium, arsenic, nickel, iron, and manganese were all found to be within acceptable limits, although iron and manganese were found to be consistently high in some places (Morelli 1975). There was also a study that looked at skeletal muscle of fish living in Winnipeg's rivers, in order to determine if they were contaminated with heavy metals. Generally the results were good, however, some older, larger specimens were found to have levels of mercury that exceeded acceptable levels for food (Green 1997).

Pollution origins

It is important to know where the pollution entering the river comes from. As human waste is eventually destined for the river one would suspect that this is the source of much contamination. Human waste does cause most of the problems, but, effluent from the pollution control centres is usually not a problem because it is treated before being released into rivers. Rain water causes the most serious violations of water quality standards. This happens, when rain washes off streets, buildings, and vegetation, picking up contaminants, and carrying them to storm sewers where the pipes take the water and contaminants to receiving rivers and streams. The second way, rain water causes poor water quality is by increasing the volume of water heading to the treatment plants to levels that are beyond the capacity of the effluent treatment plants. When this happens some of the sewage and stormwater is diverted past the treatment plant, and into the rivers. This happens, usually in spring and summer, and causes 2% of all waste water to discharge directly into the river without any treatment. This waste water is contaminated with bacteria, and organic material, which will break down in the river, causing oxygen deficiencies (Manitoba Environment 1992). During wet weather the loadings for suspended solids (SS), BOD, and coliform are 72%, 33%, and 60% respectively of annual loadings to the Red River, which is concentrated in 20 - 50 days per year.

Because our rivers receive polluted water from a variety of sources it is helpful to know which sources are the biggest contributors and need to be changed first. The following tables illustrate how much pollution each part of our infrastructure contributes to the rivers' pollution.

Table 1.1 **STORM RESULTS 1975-78**

Concentrations(mg/L or MPN / 100 mL)
(James F. MacLaren Ltd. 1979)

Parameter	Combined sewer overflows (CSOs)	Separate storm sewer overflows (SO's)	Retention pond discharges	NEWPCC * effluent	Limit
SS	370	410	76	53	No limit
BOD	125	20	8	49	5 **
N	9	7	4	24	0.5 ***
P	3	2	0.4	2.9	0.05 +
Coliform	8.5 x10^6	5.6 x 10^5	1.9 x 10^5	1 x 10^6	5.0 x 10^2++

* North end water pollution control centre (processes 70% of the city's waste water)
** See Appendix C
*** See Appendix F
+ See Appendix B
++ See Appendix B

Table 1.2 **AVERAGE ANNUAL LOADINGS 1975-78**

(10^6 kg or 10^{18} MPN)
(James F. MacLaren Ltd. 1979)

Parameter	CSO's	SO's	Retention pond discharges	Wet subtotal	NEWPCC effluent	Total
SS	5.647	6.703	0.266	12.616	5.052	17.688
BOD	2.858	0.508	0.041	3.407	6.955	10.362
N	0.130	0.111	0.007	0.248	2.246	2.494
P	0.041	0.034	0.001	0.077	0.258	0.335
Coliform	1.288	0.092	0.007	1.386	0.045	2.313

These tables show that water from every source is suffering from quality problems. We are completely dependent on the assimilative capabilities of the large quantities of water in the rivers, to reduce the affects of the polluted effluent we discharge. It is evident how polluting

CSO's can be, contributing most of the years load of coliform bacteria, and most of the BOD during wet weather. Year round however, the treatment plant contributes most of the nutrients, and BOD to the rivers. It is not surprising that the treatment plants and combined sewers are the source of much contamination. What is surprising however, is the level of pollution from the separate storm sewers, and the retention ponds, as they are essentially discharging rain water.

In order to improve the water quality of Winnipeg's rivers CSO's and the effluent treatment plants must be improved. The retention ponds are the most efficiently functioning part of our stormwater infrastructure, and they may provide ideas on how to deal with CSO's, but the quality of water emanating from the retention ponds is still below standard. The retention ponds are still contributing to the degradation of river water quality.

Summary

Although there is an abundance of life in Winnipeg's rivers, we can not take for granted their continued good health. The City of Winnipeg continues to pollute waters which flow through their city despite objections from the province, fishermen, the town of Selkirk, and other interested citizens. The city depends on the assimilative capacity of the river to deal with what we dump in them. Federal installations follow guidelines, which recognize "that each polluter has a responsibility to provide practicable treatment regardless of the assimilative capacity of the receiving stream" (James F. MacLaren Ltd. 1979). If we are to follow this guideline, then we must take much more action to improve the quality of river water. Any problems that exist now will only be exacerbated as the population of Winnipeg increases.

The two parameters that need the most improvement in the city of Winnipeg, with regard to river water quality are faecal coliform and dissolved oxygen levels. This city nearly always violates the levels of coliform for the rivers, and it occasionally violates the levels of dissolved oxygen. The goal for dissolved oxygen which has been set is the level sufficient for cool water aquatic life. One of the problems with this goal is that it is arbitrary, since the levels of dissolved oxygen are nearly always sufficient for cold water aquatic life upstream of Winnipeg (Lockery 1990). The objectives for the city should be to closely match the water quality found upstream of Winnipeg, with the quality found downstream. This would be more in keeping with the federal guidelines that require polluters deal with the pollution they cause.

To improve the quality of Winnipeg's water, we must deal with the problems created by contaminated water from the combined sewer overflows, but we must also deal with problems associated with stormwater sewers and retention ponds. The problems associated with what the separate storm sewers may be difficult to deal with, but the retention ponds can be designed better in the future. Retention ponds may be the best part of the stormwater system in terms of water quality, but they still contribute to the pollution of the rivers in Winnipeg. Since retention ponds are being built on the periphery of the city, where the new development is occurring, they do not have to be retrofitted, but, can be built according to designs, which will enable them to function more efficiently in terms of water quality objectives. Since a stormwater system has to be constructed anyway there does not have to be any increased cost associated with better infrastructure in areas yet to be constructed. Essentially, the retention ponds can be designed to deal with polluted stormwater in a manner which contributes to better water quality in the streams and rivers in Winnipeg, instead of the degrading it.

QUALITY

Water quality in Winnipeg's rivers is an important issue because of the uses associated with that water. In order to improve the water quality we must naturally examine the components of the waste and stormwater system -- which brings us to retention ponds. They can play a role in improving the water quality in the rivers, but retention ponds should not only create clean water for discharge, but to function properly in their roles as providers of habitat, aesthetic and recreational amenities, they should have good water quality themselves. The province suggests that standards for water quality should be applied not only to rivers but, also lakes bays and impoundments. Although the priority should be placed on natural water over artificial impoundments, it would seem that the impoundments do not meet the standards quality.

Retention Pond Water Quality

The studies of water discharged from the retention ponds show they must be below standard for Phosphorus levels, coliform, and BOD (see Appendix A). The monitoring of retention ponds has been less rigorous than monitoring of the rivers, but some studies have provided information on their quality.

The Fort Richmond and Southdale impoundment systems were studied from 1975-1977 inclusive, (Chambers and Tottle 1980) and from that study, general conclusions can be made about water quality and aquatic life that may exist in other Winnipeg impoundments. Testing of water quality (Appendix A) revealed that the water entering the impoundments was usually well beyond the 5 mg / L BOD level, which was the threshold of poor quality water (Appendix B). The BOD was often higher than 5 mg / L exiting the retention ponds, as well. The high level of suspended solids (Appendix A) in the retention pond effluent suggests that organic matter was present, and naturally its aerobic decomposition would increase the BOD, and decrease the oxygen levels. Most other water quality parameters were met. Levels of nitrates, were within acceptable limits. Phosphorus, the important nutrient contributing to eutrophication, was found in concentrations higher than acceptable in the effluent from retention ponds (Chambers and Tottle 1980, Manitoba Environment 1992)

Nitrates

Nitrates in the retention ponds were at concentrations which were adequate for drinking water, and the water exiting the ponds was also safe for drinking, based on concentrations of nitrates (Chambers and Tottle 1980).

Faecal coliform

This parameter measures contamination by faeces of warm blooded animals, and the study looked at this parameter for the impoundment systems studied. Total coliform will indicate contamination from human faeces, but may indicate bacteria present from decaying plant material. Although the specific results were not given by Chambers and Tottle (1980) the mean values for both measures were within acceptable limits for primary and secondary recreation. The coliform levels were occasionally exceeded. After rainfalls higher concentrations of bacteria were found at the bottom and mid depths. The findings of James F. MacLaren Ltd. (1979) indicate coliform levels were substantially higher than acceptable levels after a storm event. Tottle and Chambers postulated that possible bacterial contamination could have come from overflows or cross-connections from sanitary sewers, faeces from pets or decaying plant material. Although not mentioned in the study, other animals such as waterfowl may also have contributed to bacterial levels. Coliform levels which can be so high after a storm subside after a short time, and if this is due to sedimentation then increased risk is associated with any activity that stirs-up these sediments.

Heavy Metals

These impoundments were not tested for all heavy metals, and it is unlikely that the more dangerous contaminants such as mercury or cadmium would have been found, usually not detected in the rivers, where water has concentrated toxins, and, where there has been more historic human activity. Tests did reveal high levels of nickel, and levels of lead beyond the maximum acceptable limits in the effluent of the retention ponds. Despite the retention ponds removing 80- 89% of lead levels from water, the Fort Richmond impoundment had effluent lead concentrations that were twice the acceptable level when measured in 1977 (Chambers and Tottle1980). Both Southdale and Fort Richmond had lead levels in the stormwater that was beyond acceptable levels. Because these studies were done before leaded gasoline was banned, they are less relevant today, however, surveys of the sediments showed concentrations of lead from 57 - 212 mg /L. This has implications for these impoundments in the future, but it may also may have implications for future impoundments if construction of a suburb releases any lead or other contaminants that have accumulated in soils. Likely a portion of these soils and their associated contaminants will be washed into a newly constructed pond.

One of the discouraging discoveries was that the retention ponds discharged effluent that was more contaminated with chloride than the influent. The Fort Richmond pond had levels that were unacceptable, and were 830% higher than the chloride levels in the influent. One reason for this may be that the well used to augment water losses due to evaporation had a concentration of 1650 mg/L, (250 mg / L is maximum permissible) and this well was drawn from 16 hours per day in the summer of 1977. Another reason that chloride levels may have increased, is because chloride is present in the herbicide simazine (17.6% Cl) which was used to control algae blooms (Chambers and Tottle 1980).

Dissolved Oxygen

Levels of DO were taken, but the results were not given for this study, save for some levels in winter. The oxygen levels were apparently sufficient to sustain cool water aquatic life, thus one might expect cool water fish in good condition. The oxygen levels, however, ranged from 0.8 mg /L to 2.1 mg /L (Chambers and Tottle 1980) at a depth of 1.5 m with a 0.8 m ice cover on Clear Lake (part of the Southdale system). The oxygen levels were consistently higher in the Southdale ponds than the Fort Richmond ponds, and this may be explained by the fact that the Southdale system has two fountains which would aid in the aeration of the water. Other factors affecting oxygen levels, such as aerobic decomposition or different algal communities may also have been at play.

Algae

As with any aquatic environment, algae was present in the retention ponds, but the type of algae present is the important factor. Studies of the algal communities in 1976-1977 showed that blue-green algae comprised 80% of the population. *Anabaena* and *Aphanizomenan* were the most common, but *Oscillatoria* was also found. The blue-green algae can indicate that the waters are organically enriched. In 1996 readings of chlorophyll-a showed that there is a high level of algae in Southdale and Fort Richmond SRB's but also in most of the others retention ponds as well (see Appendixes F & G). The algae also can thrive in higher water temperatures. When the algae decays it tends to produce offensive odours.

Fish and benthic organisms

The kind of aquatic life that an environment supports can indicate the condition of the water in that body. Animals have naturalized in impoundments, and are exploiting the environment, but the type of animals, and their condition, tell how natural the environment is. Clearwater and Stillwater retention ponds of the Southdale were stocked by the developer with 1000 juvenile and adult yellow perch in 1970. In 1974, when a fish survey was conducted, there were only 12 stunted yellow perch found, which showed no signs of reproduction. This study, however, found 9 northern pike and one white sucker that had not been stocked. Another fish survey, in 1977, looked at both the Southdale and Fort Richmond impoundments (Appendix E). In this study no perch were found, but blackhead, pike, and carp were found. None of these fish were knowingly stocked, but, the Fort Richmond impoundment is fed by a natural creek. The coarse fish in the Fort Richmond impoundment were in average condition, while the pike in the Southdale system were in poor condition. As the fish in Fort Richmond tolerate polluted waters and the pike were in poor condition the conclusion is that these impoundments were inadequate for supporting fish. Whether the fish suffered from poor food supply, low oxygen levels, or some other contaminant is not known. The low oxygen levels in winter would have been deleterious, although there was a 4.3 m hole excavated in Southdale to aid in fish survival through the winter (Chambers and Tottle 1980).

Another fish found in both of these systems was the fathead minnow (*Pimephales promelus*), which is known to live under low oxygen conditions, and can tolerate severely polluted waters (Mason 1991). This minnow was not stocked, but its habitation of the retention ponds should be considered beneficial since these minnows can eat 100 mosquito larvae per day despite being only 50mm long themselves (Chambers and Tottle 1980). During the fish study in 1977 in Clearwater pond several thousand crayfish were caught in gill nets. A preliminary examination showed that they were larger and generally healthier than in other environments in the Winnipeg area (Chambers and Tottle 1980). Both the crayfish and minnows can be a good food source for larger fish, but they are also potential sources of nutrition for birds.

The benthic survey is also telling as benthic organisms are thought to be an excellent indicator of water quality. Surveys in 1975 and 1977 in Fort Richmond and Southdale found that the sensitive mayfly (*Ephemeroptera*) and alderfly larvae (*Megaloptera*) were rare (Appendix D). The invertebrate communities were dominated by organisms believed to be tolerant of extreme pollution, such as the *Diptera* (midges). The dominance of pollution tolerant species living on the bottom of the retention ponds indicates that the sediments are polluted and this is what the chemical surveys of the sediments also found (Chambers and Tottle 1980). The invertebrates do indicate pollution, but their existence will also provide food for fish and fowl.

Conclusion

The studies mentioned earlier showed that the retention ponds were polluted. There are heavy metals, low oxygen levels, high BOD, with animal communities that are dominated by unhealthy, pollution-tolerant coarse fish, pollution-tolerant invertebrates, and pollution-tolerant, toxic blue-green algae. As the retention ponds are often constructed, there isn't a need to preserve their natural state. The priority can be attached to preserving the quality of the natural water bodies, therefore the quality of the water in the retention ponds can be sacrificed in favour of the quality of the rivers and creeks they drain into. But since people, and wildlife do use these retention ponds, there should also be an attempt to keep them as clean as possible, and this is in keeping with the province's suggestion that surface water quality standards also be applied to water bodies such as retention ponds. If the retention ponds have better water quality then the benefits associated with them, such as; recreation, aesthetics, and wildlife habitat, can be more easily realized. To prevent the ponds from becoming contaminated in one way or another, better methods of routing stormwater, as well as better management practices for retention ponds must be used, and these methods will be discussed in the Chapters 3 and 4.

The quality of water in stormwater impoundments is in need of improvement, not only for cleaner effluent, but for the benefit of the pond as an important entity. Some methods such as dredging, or some periodic plant harvest may improve water quality, but the best practice is to have some way of preventing the pollution from entering the ponds. Currently, there is no method employed to deal with pollutants before they enter the ponds. The ponds do some cleansing of water for rivers, but nothing does that for the ponds. The main reason for this is that the retention basins are not seen as an end, but a means to one. They still exist primarily as an engineered solution to the problem of minimizing pipes for stormwater conveyance in order to reduce overall stormwater infrastructure costs. For improved retention ponds, their design must employ a more holistic approach which considers water quality, wildlife,

human use and aesthetics.

TREATMENTS

There are many possible pollutants in the aquatic environment; heavy metals, chemicals, as well as naturally produced substances that can cause damage to plants, animals, and people. Although some toxins may be produced naturally, their abundance in the environment may be due to the disruption of natural systems by human intervention. Under the proper conditions, there are ways that some pollutants can be captured, retrieved and even broken down biologically, if the necessary organisms are in the environment. As we have put contaminants into the environment, we can also design environments that remove or mitigate environmental damage caused by such contaminants.

Heavy Metals

A heavy metal is loosely defined as metallic element with an atomic number higher than iron. But because an element is a heavy metal does not mean that it is particularly toxic in the environment, and some that are toxic can be much more so than others. Some trace elements are necessary for life, but can become toxic if they are present in concentrations that are high enough. To complicate matters further, chemicals or metals often have synergistic effects on other metals or compounds they are found with. For example, zinc increases the toxicity of cadmium as well as increasing its accumulation in plants (Miettinen 1977). Since inorganic heavy metals are in elemental form, they are non-degradable and therefore persistent in the environment. Of the heavy metals mercury, cadmium and lead are considered the most dangerous, based on abundance, persistence in the environment, ability to accumulate in organisms, and, toxicity.

Mercury is a well-known contaminant, and remains in the environment, despite its use being controlled today. Mercury was commonly used in fungicides for grain, which may be an important source of unnaturally high levels of mercury in many environments. In aquatic environments mercury is converted to the highly toxic methyl mercury which is readily absorbed. Some 95% of methyl mercury is absorbed by the gut of fish, and most is retained by the body. Mercury also biomagnifies along the food chain, being found in higher concentrations in fish such as pike, or fish eating birds (Mason 1991).

Most heavy metals do not biomagnify, but, may bioaccumulate, obtaining higher concentrations of heavy metals directly form the water. This happens with cadmium, a dangerous heavy metal which can be extremely toxic to some forms of life in an aquatic environment (Mason 1991).

Lead's historic use and its abundance is longer and greater than mercury or cadmium. Use of lead as a gasoline additive has caused widespread contamination of waters. Lead is however, poorly accumulated in aquatic food chains and, is much less toxic to aquatic organisms than mercury or cadmium (Miettinen 1977), but it can be very dangerous to waterfowl. Lead can be, and usually is rapidly sedimented out of water and becomes bound to the sediments (Miettinen 1977). Because lead drops to the bottom of water bodies with slow-moving water it tends not to pose a threat to phytoplankton, but there are fish such as carp that tend to stir up sediments in order to feed (Weller 1994).

Organochlorines (PCB's)

Polychlorinated biphenyls (PCB's) are a type of organochlorine that have been used for a variety of purposes, for many years, and are still used today. PCB's can be dispersed widely through the environment (Weller 1994). Within the aquatic environment sediments are the greatest potential source of PCB's. Once in the environment these chemicals are dangerous because they are fat soluble, biologically stable and will biomagnify (Mason 1991). PCB concentration among fish is a function of size, lipid concentration and trophic position. Although PCB's can be very toxic, some species are not negatively affected by these chemicals, and this can put other organisms at greater risk if the tolerant species is a food source for an intolerant species (Mason 1991).

Pesticides

Pesticides can be very dangerous and destructive to many environments, but any pesticide that is persistent in the environment has a good chance of ending up in a water body. Runoff is a major source of entry for pesticides into water bodies and, so is atmospheric transport, and precipitation (OECD 1986). Aerosols produced during crop spraying can be dispersed and move vast distances with the wind. But more dangerous than this are the pesticides that are deliberately applied to aquatic environments.

In Winnipeg, Dursban (Chlorpyrifos) is used primarily to control mosquitoes at the larval stage, but the bacteria *Bacillus Thuringensis israelensis* (BTI) is also used as a larvicide (Nawalsky 2000). The organophosphate Melathion is the main insecticide used against mosquitoes. These chemicals are not sprayed directly on retention ponds (Nawalsky 2000), but that does not mean that they will not end-up in the retention ponds.

Chlorpyrifos, for home and garden use, was banned by the United States Environmental Protection Agency because it poses a risk to children because of its potential effects on the nervous system and possibly brain development (Gadawski 2000). Melathion may be toxic for bees or some sensitive fish species but is not supposed to be harmful to humans (Manitoba Clean Environment Commission. 1982).

Some poisons are specific and act only on the target organism, but the majority directly affect organisms that are not the target species. The actual effects of many pesticides on the numerous organism is often unknown. Since insects are an important part of any wetland community, the application of a pesticide and the resultant change in structure of a food web can have serious impacts which may affect many organisms indirectly. Mosquitoes are often the target of pesticides, and any larvicide will be applied to a wet areas. The pesticides may kill the mosquito, but many other organisms may be put at risk, including biological control agents that actually feed on mosquito larvae. The ultimate danger of many pesticides is that they can kill indiscriminately, and that they can remove a crucial link in the food chain, which prevents a natural system from functioning properly.

Herbicides

The application of herbicides is common in agricultural operations, and in the maintenance of park and residential landscapes. Herbicides applied to other areas may inadvertently enter water bodies. It is also not uncommon for herbicides to be applied to plants in an aquatic environment, and this can be much more detrimental to a wetland. When herbicides kill larger plants in a pond, these plants are rapidly replaced by increased algae. The impending aerobic decomposition of plant material will result in de-oxygenation of the water, which can cause fish kills (Mason 1991). The loss of macrophytes may result in the loss of a food source for some animals, but it may also mean the loss of habitat for many invertebrates and microbes which would have served a purpose, or acted as food for higher animals. Macrophytes, for example, provide protection for zooplankton from fish predation. Macrophytes also provide protection for small fish, and without that protection the smaller species or young fry would become depleted through predation. When the plants killed by the herbicide do finally break down the nutrients will be there for new plants or algae to exploit, thus making the original application superfluous.

Oil

With the heavy use of automobiles, petroleum products such as oil and gasoline can leak onto the streets and be washed into waterbodies. In this way water will be subject to contamination by oil. Oil can be toxic to many types of higher plants and animals, but unlike heavy metals or PCB's it can be degraded relatively easily (Mason 1991). Oil can be harmful to aquatic and terrestrial species, but it considered less toxic than other pollutants.

Surprisingly, oil may be beneficial to some species, according to C. F. Mason (1991) "the principle effect of oil on the microbial community is one of stimulation, especially heterotrophic organisms which utilize hydrocarbons" . Oil can benefit some organisms, but since this list of organisms must exclude the vast majority of the earth's biota, Mason's statement should be kept in perspective. The complete degradation of a hydrocarbon can occur if a single strain of a micro organism uses that hydrocarbon for its sole source of carbon and energy. Since crude oil is made of several different hydrocarbons it will take more than one organism to degrade crude, but mixed populations of organisms may degrade the majority of crude oil (Mason 1991). Although eutrophication can sometimes be detrimental to water bodies the opposite may be true for degradation of oil because nitrogen and phosphorus can be limiting to microbial activity in freshwater, and adding these nutrients to lake water samples increased the amount of mineral oil and hexadecane degraded over three weeks (Mason 1991). Encouraging the permanent growth of microorganisms that use oil, may be impractical or impossible for a retention pond, but an environment that is at least favourable to them can be encouraged.

Algae

Many people believe that the presence of algae means the water it lives in is polluted. In some ways this is true. Algae will grow better than many aquatic plants in nutrient rich, poorly oxygenated, warm water, which is often typical of polluted waters. It is important to remember, however, that algae is a necessary primary producer in aquatic environments. Unfortunately, some algae can also be considered toxic. Blue-green algae can produce poisons that can harm fish and mammals. Blue-green algae tend to favour brackish, alkaline water with high temperatures and low CO_2. These conditions are often associated with polluted waters, and this algae is often associated with algal blooms (Vymazal 1995). *Microcystis, Anabaena* and *Aphanizomenan* are algae that produce toxins which can harm or even kill mammals and fish. The poison is neurotoxic and can damage the liver (Mason 1991). Another blue-green algae is *Oscillatoria* and it can cause rashes on people who come in contact with the plant. *Oscillatoria, Anabaena* and *Aphanizomenan* have all been found in Winnipeg impoundments (Chambers and Tottle 1980). The blue-green algal communities will tend to dominate environments where there is excessive phosphorus (when P:N exceeds 1:16 (Mason 1991)) as the algae can fix free nitrogen from the atmosphere. The blue-green algae is also resistant to grazing by zooplankton, which gives it another competitive advantage over other algae. Furthermore, when these communities are established they tend to alter the environment in a manner that puts other algae or submergent plants at a disadvantage, while reducing oxygen saturation in the water below them (Mason 1991).

Coliform

The microbial communities in a water body are of concern to people if the water comes in direct contact with people or is to be used as drinking water. The concentration of organisms such as protozoa, bacteria, viruses, or parasitic worms can be measured to give a level of faecal coliform or total coliform. A source of such contaminants is usually assumed to be faecal matter, from sewage, but not all of these organisms are from sewage, and not all organisms are harmful. Chambers and Tottle (1980) believed that decaying plant material was the source of many coliform bacteria. Water bodies such as impoundments, with no apparent sanitary effluent, may be contaminated by leakage from nearby, sanitary sewers, or they may receive runoff that is contaminated with animal faeces.

Pathogens can harm both man and animal, and can be passed between them. Some animals can be very susceptible to some pathogens. For example, waterfowl are extremely vulnerable to a bacterium called *Clostridium botulinum* (botulism), which grows in the sediments of shallow eutrophic water bodies (Mason 1991). The study of retention ponds illustrated that retention ponds tend to reduce the coliform counts, (Cambers and Tottle 1980) but the mechanism causing this was not explained. There is a possibility that these organisms were killed since many naturally occurring microbial groups are predatory and will feed on pathogenic organisms (Hammer 1992).

Nitrates

Nitrates are naturally occurring molecules, which are one of the main sources of nitrogen for plants. Nitrate is also a key ingredient in fertilizers and it can end up in drinking water which will degrade the quality of the water as can be toxic to many animals. Nitrate concentrations in drinking water has been increasing over the last couple decades, but nitrate levels are not as problematic in Canada (OECD 1986). Nitrates are reduced by bacterial action in low oxygen conditions. Often the denitrifying bacteria in river and lake sediments will reduce nitrates to free nitrogen and nitrogen oxides, which are released into the atmosphere. This process occurs more easily in damp clay soils with high Fe^{++} content and low oxygen (OECD 1986). The clay soils in Winnipeg would be conducive to this process of nitrate degradation.

Deicing salts

Salts, such as NaCl and CaCl, are applied to roads in order to melt ice and snow in many northern cities, and Winnipeg is no exception as we apply CaCl to our roads. Ponds, lakes, and other water bodies can serve as collection points for deicing salts contained in runoff, and if the concentration of salt is too high in waters, it can be harmful to plants animals and people. The maximum concentration for chloride is 250mg/L for domestic consumption (Hanes, Zelazny, and Blaser, 1970), but the level desirable for taste is 25mg/L. Since these chemicals are not particularly harmful, the deleterious effects due to the increased salinity are attributed to osmotic effects of salts rather than the toxicity of the ions. Levels about 1500mg/L are the maximum levels for livestock and wildlife. Yet levels of about 400 mg/L can have negative effects on fish. Other substances have been added to deicing salts to prevent rust, and they can be extremely toxic to humans, animals, and, fish. Luckily most of the harmful additives have been recognized as detrimental and their use has been terminated (Hanes, Zelazny, and Blaser, 1970).

Plants tend to be much more susceptible to the negative effects of deicing salts than animals. Soils adjacent to roadways often accumulate salts which can increase any damage to vegetation that spray from the roadways may cause. Some plants may die from the accumulation of salts over many successive years. Generally, grasses are more tolerant than deciduous trees to road salts, and deciduous trees are less sensitive than evergreens, with exceptions for some plants such as junipers, which are salt-tolerant. Increased water will tend to negate the effects of excess salt in soils, and sufficient nutrient levels are also helpful in reducing the negative effects of salts. Plants that can tolerate drier conditions also tend to tolerate increased soil salinity. (Hanes, Zelazny, and Blaser, 1970).

Remediation

In a natural environment many organisms can have many ways of dealing with toxic substances. What is toxic to one organism may be benign or even beneficial to another. Some plants and microorganisms can break down and use certain toxic substances. Often microorganisms that aid in the decomposition of waste products or toxic chemicals are associated with plants, and often they exist in a symbiotic relationship with macrophytes. Living organisms have been deliberately used to purify waste water for many years. One such method employed is the activated sludge process, where organisms are in water in which oxygen is continually available. The communities that act on the waste are primarily composed of microscopic plants and animals, and the excess biological growth is mostly removed. Biological filtration is where water is passed through materials that have organisms attached to them. Here it is essential to maximize the surface area that is necessary for the organisms to attach, in order for the process to be successful (Genetelli 1971). These organisms are used to treat coliform and purify sewage water. Often this occurs in very controlled, engineered environments, but the principles can be used to treat water in simpler, natural environments (Hammer 1989). In a natural wetland the aquatic plants provide the necessary surface area for microbial attachment, in addition to furnishing an aerated environment for aerobic microorganisms. Natural and constructed marshes are used to treat sewage (Hammer 1989). The marsh adjacent to

Wasagaming, in Riding Mountain National Park, is a Manatoban example, where this method has been employed. If marshes are sufficient for the coliform existing in sewage effluent, then they should be more than adequate for the lower levels present in urban stormwater.

Using plants to treat contaminated soil or water is referred to as phytoremediation. In the article "Botanical Remedies", (1998) J. W. Johnson lists three categories of phytoremediation, which he describes as follows:

Extraction

> This process uses plants to bring contaminants out of soil or water, and contain them in the plant tissues. The plants can be harvested to remove the contaminants from the site. Sometimes the plants can be composted, or dried and burned, and the heavy metals removed from the ash.

Containment

> This is the use of plants to immobilize contaminants. For example some trees can sequester large quantities of heavy metals in their roots. The contaminants have not disappeared, but are no longer circulating in the environment.

Degradation

> Contaminants, principally hydrocarbons, are broken down so that they are no longer toxic. This degradation may occur in the rhizosphere through microbial or fungal symbiosis with the plant, chemicals effects of the root zone, or enzymes exuded by the roots. Sometimes the plant itself is responsible for degradation. Some plants may take-up organic toxic substances, and in the process of using the chemicals the plant may detoxify the compounds.

This article identifies willows as excellent candidates for the degradation of oil. Other plants may be good phytoaccumulators, Canada bluejoint (*Calamagrostis canadensis)*, which grows in wetland areas, accumulates volatile organic hydrocarbons, while pondweeds (*Potamogeton richardsonii* and *P. graminus*) are supposed to be effective at accumulating heavy metals (Reimer 1989). Many other plants may also degrade or absorb pollutants, but the environment which contains those plants is necessary.

Of the bacteria, fungi, algae and protozoa that inhabit soil and water it is difficult to know which organisms alter toxic substances in order to obtain their nutrients but some do. Microorganisms can break down toxic compounds such as oil, synthetic molecules, detergents, and pesticides (Mason 1991). Bacteria *Alcaligenes, Azotobacter* and *Flavobacterium* use aromatics as a substrate, and the fungus *Trichosporon cutaneum* uses phenols (Mason 1991).

If microbial organisms are primarily responsible for the break-down of toxic substances then it is important to know what is necessary for their survival. The role of macrophytes is crucial because they provide environments for microbial populations, both above and below the substrate. Stems and leaves provide locations for attachment of microbes. Plants also increase the aerobic microbial environment in the substrate which is a result of the unique characteristics of wetland plants. Some hydrophytic plants such as emergents have hollow leaves and stems that allow oxygen to be channelled down to the roots during periods of inundation. The root hairs then can leak oxygen into the rhizosphere, which provides a locally aerated environment which is necessary for so many microbes (Hammer 1992).

Since the possible pollutants, and the potential microbial remedies can be varied, then it may be best to simply construct an environment that will allow a multitude of life forms to exist. Probably one of the best ways to ensure that such an environment exists is to refrain from applying pesticides and herbicides to an environment such as a retention pond. The inadvertent entry of toxic chemicals into an environment is unfortunate, but the deliberate application of such substances is foolish.

One of the important ways that the retention ponds in Winnipeg remove pollutants is through sedimentation. When the water is impounded it slows down and fine particulate drops to the bottom of the pond. In this way heavy metals as well as nutrients can be removed from the water column. This leaves pollution in the pond, where the coarse fish, that tend to inhabit retention ponds can ingest the toxins or bring them back into water column when they stir-up the sediments as they feed. But sedimentation of particulate can be achieved before the water reaches the pond, keeping the water column freer of toxins. One way pollutants are removed from runoff before it enters water bodies, is through the use of vegetative strips, but vegetative strips are redundant if the majority of the water circumvents the strips by entering an impoundment through underground conduits. The current construction method of our retention ponds, means that things such as vegetative strips could not be used, but if a more natural system of overland drainage were used, then nutrients and toxins could be removed before they hit the water, thus protecting the water quality of the retention pond, and treating it more like a natural environment.

Conclusion

The possible list of contaminants that may pollute our water is a long and growing list. Fortunately, in Winnipeg pollution is not severe, and many water pollutants are in concentrations so small that they are not detected. Yet it may be beneficial to have a method of dealing with certain contaminants that enter our water bodies. These methods may deal with the small amount of pollution that is presently in water bodies, or they may be able to deal with the pollution that will enter them in the future.

The chapter on water quality in Winnipeg's rivers indicated that lead, and nickel may be a problem in some of the retention ponds, and mercury may be a problem in the rivers. Sedimentation of particulate matter, before it reaches the retention ponds, can be used to remove some heavy metals that may be in the runoff. After this occurs the sediment must be collected or the pollutants should be absorbed and contained by plants. By encouraging sedimentation possible pollutants can be prevented from entering the water bodies but, there is the possibility that this would merely divert pollution from one place to another. If that is the case then it would be useful to either be able to remove the pollutants or contain them. One way during this is by dredging or scraping the soil, or by allowing plants to absorb and contain the pollutants. If the toxins remain in soils and plants, it may still be better than having the pollutants passed on to the retention ponds, because when they are passed onto water bodies, then they can be absorbed by invertebrates, fish, and fowl. The pollutants can become part of our food, and drinking water, whereas if the pollutants stayed in soil and plants in drainage swales, then they are more isolated from the food chains of wildlife and humans. If such non-degradable pollutants as heavy metals are absorbed by plants, then it may be beneficial to harvest the plant when it dies so the pollutants can be removed from the system. Obviously perennials or trees would be more useful in containing pollution as they do not die annually and return the toxins to the system when they decompose. Harvest of such plants many require careful disposal if they are high in toxins, however, if there is a low concentration of toxicity then plants can be disposed of virtually anywhere, and this would help to disperse all of contaminants which would otherwise be concentrated in water bodies.

Pollutants such as oil or pesticides may be likely to find their way into a water body, and plants may have role in their degradation, however, the amount of such substances is likely too low to warrant specifically designing the retention pond as tool for water purification aimed specifically at such contaminants. It is important to remember that an environment rich in plant material and microorganisms will function better as a water purification system and still be able to function as a natural environment, a habitat for wildlife and an amenity for people.

Although there are methods of remediating contaminants in runoff and methods of removing contaminants from runoff, these are not the most important ways of guaranteeing good water quality. The case where pollutants are prevented from entering the water bodies by slowing the flow of the runoff illustrates the problem. The pollution still exists, the pollutants must be gathered and disposed of. The best method is to stop using such pollutants. This has been done, for the most part, with respect to lead, but things such as pesticides and deicing salts are still used, and can still cause problems. The best method of dealing with many pollutants is to discontinue their use, or more carefully regulate their application.

The majority of pollutants in the suburban environment will be nonpoint source, and any point source contamination should be very small. The retention pond will deal with both of these types of pollution in the same manner, depending upon their means of conveyance. Pollution in the retention pond will be dealt with by sedimentation, absorption, and biological degradation. Water laden with pollution will use the same methods when it is routed overland, assuming it is exposed to plant material, and the runoff is slowed to velocities which allow for sedimentation.

The key to simple improvement of water quality is the use of plants. Plants can increase sedimentation of pollutants from runoff, and absorb heavy metals, where they can be contained, or removed by harvesting the plants. Water from retention ponds can also be used to irrigate trees and other plants, for the purpose of removing more pollutants, or nutrients from the water. Plants and the associated microorganisms can also break down some toxins, suspended sediments, and coliform. But for plants to be useful in these processes, they must first be allowed into the environment of the retention pond. Precise design strategies are:

1) To have an abundance of plant growth in the retention pond, in order to improve water quality of pond effluent. For increased plant growth water levels should be shallow enough to allow for the growth of aquatics. Construction and management procedures should not be directed at preventing macrophyte growth.
2) To create a retention pond which has a length of flow that allows for the aquatics to adequately filter water.
3) To use vegetative buffer strips in order to improve the quality of water entering the pond, by increasing sedimentation, and utilizing phytoremediation.
4) To direct water to plants, slow enough to cause precipitation of sediments which would allow for

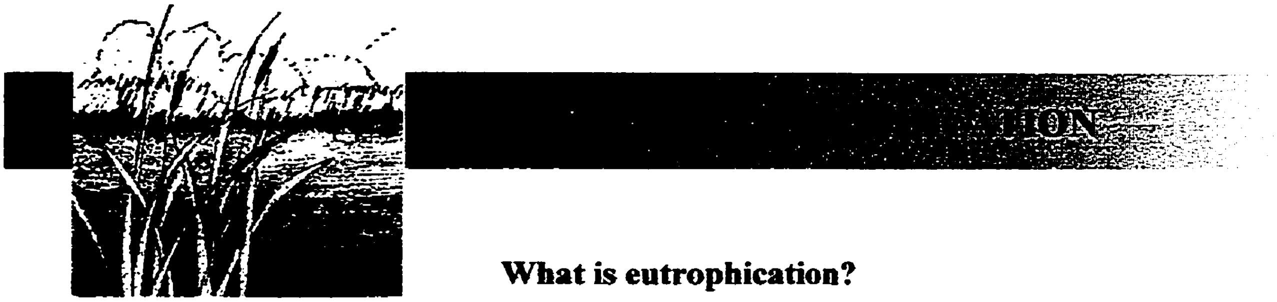
possible absorption and containment of toxins such as heavy metals. Plants which are persistent are the best phytoaccumulators, as they do not die annually and return toxins to the environment. Woody shrubs and trees, therefore, should be used before herbaceous plants, as their life cycles are longer, and they will not have to be harvested annually.

5) To deal with pollution before it enters retention basins, a different method of drainage must be used which will enable sedimentation, and phytoremediation. The natural method is to employ more overland drainage. When this is utilized then plants can be used to degrade some compounds, use some nutrients, and absorb some toxins before entering a pond.

6) To use a forebay when underground pipes are necessary for drainage. This will increase sedimentation in an area which can easily be cleaned, then the aquatic plant material will be relied on for the majority of water quality improvement.

Management Implications

Some contaminants may be non-degradeable, and are not broken down and barely absorbed by plants. They must be removed from the retention pond by dredging, or removed from sedimentation areas outside the pond. This will depend on the toxins, and the concentration of those toxins. Samples after construction of the drainage system, would determine these management actions. Sampling will also determine the uses for, or any disposal methods of harvested plants, or dredged sediments. Macrophytes which are absorbing toxins which cannot be degraded, should be harvested and disposed of as well.



What is eutrophication?

Eutrophication can be seen as the process by which water bodies change over time, to become increasingly filled with living plants and organic matter. The process can be viewed as the natural aging process of a water body. Human settlement, however, has dramatically accelerated the eutrophication process, increasing the runoff, and the nutrients in the runoff, which increases the biological growth within the water body. If humans have not settled in a drainage basin, then the growth of algae and aquatic plants in the associated water bodies is generally more balanced (Ryding and Rast 1989). In order for us to avoid detrimentally altering our environments, we should try to minimize any unnatural changes to the environment as there can be negative consequences.

We can be contributing to eutrophication through the way we deal with stormwater, and we can also help mitigate stormwater conditions with well designed stormwater infrastructure. Stormwater retention basins have several benefits, and one can be to reduce the process of eutrophication in natural water bodies, so that it more closely resembles natural conditions.

Causes of eutrophication

The main causes of eutrophication are the excess nutrients that end-up in the water. The phosphorus and nitrogen are usually the nutrients most limited in the environment, so when levels of these two elements are increased then they contribute to increased plant growth. As nitrogen leaches readily from decaying organic material, and phosphorus tends to bind to soil particles phosphorus is more limited in the environment, so it is the most important nutrient responsible for eutrophication (OECD 1986). The application of fertilizers to agricultural and residential environments, results in excess nutrients which are carried away by precipitation to receiving water bodies. Human wastes, which are high in organic matter are often deposited into rivers. The waste has usually been treated, but it is still high in nutrients. Both of these factors can contribute substantially to eutrophication. Increased runoff may also cause organic debris to be carried to water bodies, which will add to the nutrient levels in water.

The amount of phosphorus in a body of water, and the amount of phosphorus available for plant growth are two different things. The low nutrient oligotrophic lakes are different from the eutrophic lakes. Oligotrophic lakes tend to be deep, cold, with higher acidity, while the eutrophic are shallow, warmer, alkaline and nutrient rich (Mason 1991). In oligotrophic lakes the phosphorus tends to precipitate out of the water and sinks to depths that are beyond where plants can use the phosphorus. Also the deeper water stays cooler, and cool water has a higher solubility for dissolved oxygen (DO) (Lockery 1990). Oxygen levels are related to phosphorus availability, and it is the availability of phosphorus, and not just the presence of phosphorus, that creates eutrophic waters.

Lower DO levels may favour algae, particularly those that float on the water surface, which are not dependent on the water for gaseous exchanges. Floating plants also tend to act as a barrier between the air and the water, which reduces the ability of oxygen to dissolve in the water. In addition to this, floating plants release oxygen they produce to the atmosphere, while submergent species release oxygen to the water, however floating species shade submergent species, thus making their growth more difficult, which limits a source of oxygen to the water. Oxygen levels are important, not only because they allow for fish to survive, but because they determine phosphorus levels. Phosphorus in sediments exists in relatively insoluble salts and ions, that are bound to clay minerals, organic matter and hydroxy gels (Reimer 1984). The release of phosphorus from sediments is dependent upon several factors, but oxygen levels are especially important. Under anaerobic conditions, or when oxygen levels are low, iron is reduced, and the corresponding phosphorus salts that are produced are relatively soluble

(Reimer 1984).

Effects of eutrophication

The process of eutrophication can have many effects on water bodies, some of them are beneficial and some detrimental. Generally increased nutrients mean increased algae and macrophytic growth, as well as the increase in organisms at higher trophic levels, such as fish (Ryding and Rast 1989). The bio-productivity of eutrophic environments are higher than the productivity of oligotrophic or mesotrophic water bodies, but this only occurs to a certain extent. Nutrient levels can become so high that there is a build-up of organic matter. When this organic matter dies and decomposes, the oxygen levels in the water decrease, which limits the type of fish that can survive in the water. Eventually water can become so de-oxygenated that only a few species of fish can survive.

Plant and algae growth

The most prominent effect of eutrophication is a change in the growth of plants – the macrophytes and phytoplankton (Ernst 1977). The increase in biomass can be dramatic, and the species diversity and the dominant biota can also change (Mason 1991). The plant community can often come to be dominated by algae, as opposed to macrophytes. Algae are suited to, warmer, oxygen poor, nutrient rich waters (Allan, Sommerfeldt, and Baglin-Marsh 1989. The growth of algae is also linked to algal die-offs which can cause oxygen deficiencies, and the associated fish kills (Allan, Sommerfeldt, and Baglin-Marsh 1989). The dominance of phytoplankton often occurs in eutrophic waters and this can cause oxygen deficiencies. One way in which algae causes lower DO levels is when bacteria decompose the die-off of an algal bloom, and the other way is by growing prolifically on the water surface and reducing the water-air interaction (Vymazal 1995), as mentioned previously. Of course the oxygen depletion in the hypolimnion will also facilitate the release of more phosphorus from the sediments, which would promote more algal growth and may favour phosphorus loving algae such as the blue-green algae –

which is toxic.

The increased plant growth can contribute to the build-up of organic material and sedimentation, which will help accelerate the aging process of the water body. The volume of the water body will be gradually reduced. The plant growth in moving water bodies will slow the flow velocity an increase sedimentation of particulate matter, which can be good or bad depending upon what the channel is used for.

Wildlife

The increase of nutrients increases organic matter, which can include fish, but when the organic matter decomposes the oxygen levels in a water body drop. The oxygen level determines the type of fish that can survive in the water body. As the oxygen levels drop, the number of viable species is reduced. Eventually only the coarser species are able to live. Often certain fish species are more sought after for food or sport fishing, and these are usually absent in eutrophic waters. For example trout, a fish which anglers eagerly pursue, requires DO levels of 10 mg /L, which is above levels available downstream of Winnipeg (Lockery 1990). The loss of such species from a fishery can have economic impacts for an area, from reduced angling. Any change in the fish community may affect other wildlife species in ways that are yet unknown. Carp are a species that are viable at low oxygen levels, surviving at oxygen concentrations of 1 or 2 mg/ L (Lockery 1990). The feeding habits of carp also tend to stir-up sediments causing turbidity which reduces light availability for submergents, and disturbs waterfowl (see Chapter 5). Since submergent vegetation is reduced then the ability of green plants to oxygenate the water is also reduced.

Pollution

Decaying algae can lead to bacteria, fungus, and invertebrates in pipes transporting drinking water, creating foul odours and taste, or possibly some toxicity (Mason 1991). Eutrophic waters also provide excellent environments for blue-green algae, which are toxic to many animals (see Chapter 3).

Aesthetics

Certain water quality objectives may be beyond notice or concern of the average citizen, but the appearance of a water body is readily apparent to anyone. Algal blooms are a result of eutrophic waters, and they are easily visible as are the growths of the larger macrophytic algae, such as the filamentous algae (eg. *Cladophora, Pitophora,* and *Spirogyra*) commonly referred to as pond scum. The appearance of algae tends to have negative connotations for people and it also reduces the clarity of the water which people associate with purity.

There can often be a foul smell associated with eutrophic waters. Excessive nutrient levels contribute to the excessive vegetative growth, (especially algal blooms) which is often followed by reduced oxygen levels causing fish kills, and often a die-off algae after the nutrients are used up. Blue-green algae are associated with smells, but if the water turns septic the smell is often due to hydrogen sulfide, a compound which is very toxic to aquatic life (Warren 1971). The unpleasant smells associated with eutrophic water, and anaerobic decomposition must be thought of as an unpleasant aesthetic aspect to be avoided.

Responses to eutrophication

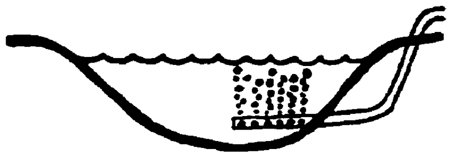
There are many ways of dealing with eutrophic waters, so that the conditions can be improved or possibly prevented from developing in the first place. Another approach to dealing with eutrophication is to benefit from the situation of increased nutrients in the water by growing useful aquatics, pursuing aquiculture, or using the enriched water for irrigating terrestrial crops.

Treatments

The treatments of eutrophic waters involve dealing with the conditions of eutrophication in the water body itself, without the harvest of nutrients from the water. Treatment methods can be through human intervention or by using biological control agents and these methods include:

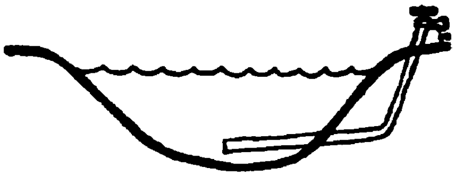
1) Hypolimnetic aeration

The introduction of oxygen to the hypolimnion will help reduce the release of P from the sediments to the water column (Ryding and Rast 1989). In Winnipeg many ponds have fountains to aid in the aeration of the water. Chambers and Tottle (1980) stated that a perforated pipe with forced air was one of the most effective ways of aerating a pond while Allan, Sommerfeldt, and Baglin-Marsh (1989) pointed out that farmers in western Canada have effectively used windmills to power air compressors, which supply air to the bottom of dugouts, ponds and irrigation reservoirs.



2) Selected removal of hypolimnetic waters

This method involves the removal of hypolimnetic waters which tend to be nutrient rich (Ryding and Rast 1989). This method can also be used to yield a possible benefit. If the water from the hypolimnion is used for irrigation, it can supply needed water and fertilization to turf, or other plants. One possible detriment is that any reduction of the water volume can lead to a smaller water body which is less thermally stable, and more subject to solar heating, which may reduce to ability of oxygen to dissolve, and thus reduce the oxygen levels.

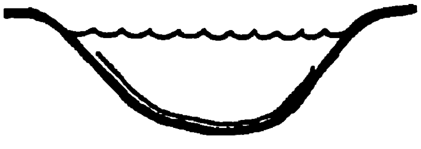


3) Lake level draw down

This method involves exposing the sediments to the atmosphere which can kill macrophytes and algae. Unfortunately this method can kill other biota as well (Ryding and Rast 1989), and when used in a retention pond may create an aesthetic that is unpopular. The nutrient levels do not necessarily decline, but aquatic plants are temporarily killed off. Some plants such as emergents may come back with increased vigour after a draw down (Hammer 1992). The periodic draw-downs or drying-out of natural water bodies, such as marshes, occurs naturally, and would be a good management practice for a retention pond. This is not treatment to do regularly, but it may be done after several years if it coincides with other management objectives such as dredging or servicing the pond.

4) Covering bottom sediments

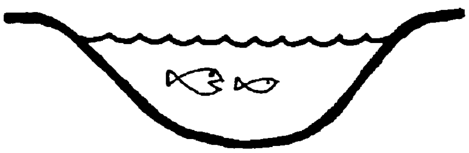
This is accomplished by covering nutrient rich bottom sediments with plastic or particulate materials



such as fly ash. This will prevent nutrient exchange between the sediments and the water. The costs are often prohibitive and there can be negative effects on the biota (Ryding and Rast 1989). There is however, no method by which future nutrients are isolated from the water as they will precipitate over the layer which formally isolated the nutrients from the water. Additionally, if a plastic membrane is placed over organic material will be subject to rising-up as gases from the decaying organic material increase below the membrane (Reimer 1984).

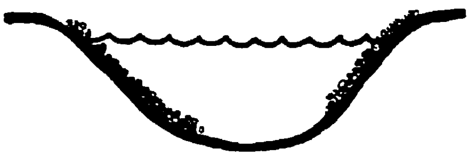
5)Biomanipulation

The feeding activity of zooplankton on phytoplankton increase when the zooplankton community is dominated by *Daphnia,* a larger type of zooplankton. When the fish community is dominated by planktivorus fish, then the zooplankton community will be dominated by small zooplankton which are unable to control phytoplankton communities. When there is sufficient number of piscivorus fish to reduce the number of planktivorous fish then algal blooms can be controlled (Hrbacek 1966, Shapiro 1979, Shapiro et al 1975). This method of control is achieved through the application of retonone which kills the fish so that the desired population of piscivorus can be restocked in the waterbody. This method will not work for an environment which is dominated by larger phytoplankton, since they are too large for zooplankton to graze on (Ryding and Rast 1989). This is another method that deals with the symptoms of eutrophication, and not the cause. The dominance of piscivorous fish may also have the unfortunate consequence of reducing the number of insectivorous fish which can control mosquito populations. The use of such biocides may also have detrimental effects on native fish populations or other wildlife, but the principle of maintaining a more balanced fish community is a worthy objective.

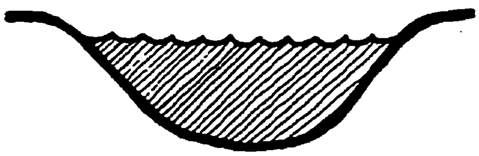


6) Macrophyte prevention

Since the macrophytes grow poorly in gravel (Allan, Sommerfeldt, and Baglin-Marsh 1989), then deep gravel can be put on top of the soil. This method



may slow the growth of some macrophytes, but will not affect the algae. The gravel would also be subject to siltation, which will greatly reduce its effectiveness, over time. This method would only be used to satisfy other design criteria, such as, providing for a portion of bare soil, with may be preferred by some waterfowl (Chapter 5)



7) Aquatic shading

Aquatics cannot tolerate solar shading (Allan, Sommerfeldt, and Baglin-Marsh 1989). It would be possible to shade emergents or aquatics near the shore, with the use of trees or other structures. Some fish can increase the turbidity of water as previously mentioned, but this will not affect floating plants and algae, or emergents, but only limit the oxygenating submergents. Another simple solution is the application of chemical dyes to the water, which will shade submergents, but the nontoxic dye is persistent and ugly (Reimer 1984).

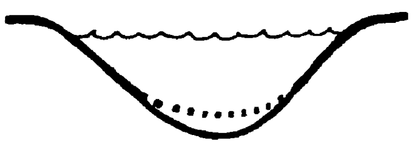
There are several other methods of treating eutrophication, but they are either, ineffective, environmentally dangerous, non-sustainable, or inappropriate for use in a Winnipeg retention pond. The problem with many of the treatments for eutrophication, is they treat the symptom of excessive plant growth and not the cause, which is excessive nutrient levels. Not only is this the wrong treatment because of its likely lack of effectiveness, but also preventing the growth of aquatics has other implications. Aquatics can increase sedimentation of undissolved nutrients, and heavy metals, they act as food for invertebrates, waterfowl and fish, they can oxygenate the water, and they can aid in the decomposition of organic contaminants.

Nutrient removal

The problem with most of the treatments is that they are only dealing with the excess growth of plants. This is a treatment of the symptoms and not the cause of the plant growth which is the excessive nutrient loading. If removing nutrients from a water column is a goal, then logically, plants which use nutrients can absorb nutrients.

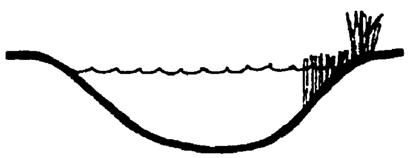
The plants, however, do not use many of the nutrients (Hammer 1992), and when they die the nutrients will be returned to the wetland. The key to nutrient removal must then be harvest, and can involve removing soil, removing plants or even animals.

1) Dredging



The soil on the bottom of the pond is removed along with plants and roots of plants that are in the soil. On smaller ponds, bulldozers can be used (Reimer 1984). This can be an expensive process, but there can be other benefits. The water body is made deeper and thus can stay cooler (if there is sufficient water to fill it), the cooler water temperatures help the water to retain oxygen. In retention ponds there may be natural sedimentation which reduces the capacity of the water body, so after a while, dredging will be a necessary action in order to maintain the stormwater capacity of the pond. Heavy metals in the sediments can also be removed at this time.

2) Plant harvesting



The harvest of plant material can greatly increase the amount of nutrients absorbed by plants. The amount of nutrients will depend on the type of plant and the particular species that is being harvested. The benefit of this method is that nutrients absorbed by the plants will be removed at harvest, and not recycled back into the water body as the nutrients would be if the plants were left to finish their life cycles, die and, decay.

Emergents

These are usually the most conspicuous plants in a marsh, and are often the focus of harvesting in Winnipeg. Usually the tops of these plants are removed, which will enable them to grow back from the roots. Mechanical cutting can have the benefit of not adding any new substances to the system, but the plants can often grow back even more dense. Emergents acquire the majority of their nutrients from the soil and not the water so they are limited in their ability to remove nutrients from the water even when harvested. This means that emergents can act as a pump, retrieving nutrients which were bound to the soil, and returning them to the water after the plant dies (Allan, Sommerfeldt, and Baglin-Marsh 1989). The decomposition of the emergents, however, will deplete the water of oxygen after the plants die and may aid in the release of phosphorus (Allan, Sommerfeldt, and Baglin-Marsh 1989). With this in mind it can still be beneficial to remove emergents.

Submergents

These are difficult to harvest as they are underwater, and equipment is more expensive. The plants will still obtain most of their nutrients from the soil so nutrient removal from the water is still limited, and in addition to this submergents oxygenate the water, so it is wise to ensure there is always a population in the pond.

Free floating plants

These plants are rooted in water, and therefore must obtain all of their nutrients directly from the water column. Plants like water hyacinth and duckweed (*Lemna*) have prodigious growth rates, and can be easily harvested. They are used in biological filtration to treat waste water (Reimer 1984). As hyacinths are non-native plants, duckweeds are more relevant, and are also more easily harvested. One hectare of duckweeds can remove 185 kg of nitrogen, and 60 kg of phosphorus per month from wastewater (Appendix K). Furthermore, the harvest of free-floating species can be accomplished by simply skimming the water. These plants also have the benefit of providing excellent food for waterfowl (see Chapter on waterfowl). A drawback is that the plants may shade submergents, and restrict the oxygen available to the water below, but growth rates in a Winnipeg retention ponds should not be sufficient for the duck weeds to grow in thick mats that would restrict the oxygen interaction.

Animal harvest

It is possible to harvest animals from a waterbody, thus removing some of the nutrients, that are in the ecosystem. Aquiculture, however, would prove relatively impractical in the suburbs, and could not be undertaken without a good knowledge of the water quality of the pond. Other animals such as migratory birds can feed on invertebrates and plants, and thus remove some of the nutrients from the water as well.

Uses for Harvested Nutrients

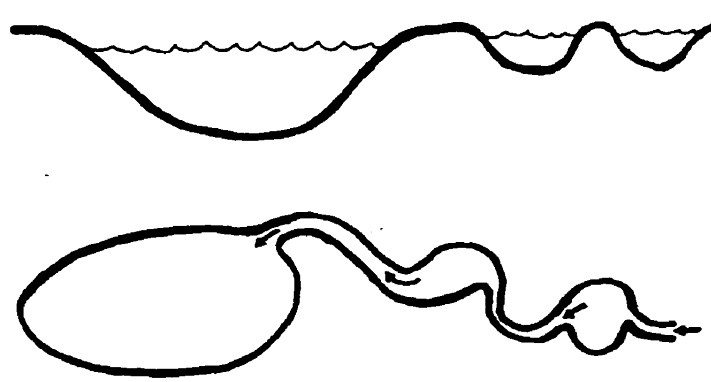
Because the bioproductivity of wetlands is so high, they can benefit us if some we utilize what can be harvested from them, but further discussion is beyond the scope of this practicum.(see Appendix L)

Prevention of eutrophication

Many methods may be used to treat the symptoms of eutrophication, and there also may be several techniques to remove nutrients from a pond, but probably the best strategy is to remove the nutrients from the stormwater before it hits the water body, thus preventing eutrophication. Methods of preventing eutrophication tend to be simple. Some of the methods are:

1) Pre-reservoirs

Smaller reservoirs are used to impound water before it enters a water body. The impoundments or cascade reservoirs prevent the natural water body from becoming filled with silt, and remove phosphorus (Stepanek 1980). The reduction in flow velocity by impoundments, causes phosphorus to settle out of the water column, and the phosphorus will accumulate at the bottom of the water body if there is sufficient oxygen to keep it immobilized (Ryding and Rast 1989). The sedimentation of phytoplankton will also reduce the amount of phosphorus in the water, and this is accomplished by the same means (Ryding and Rast

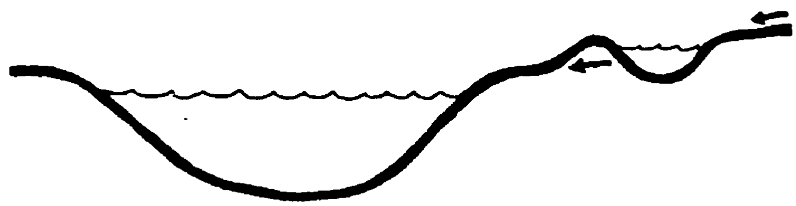


Plan

1989). The neighbourhood retention pond reduces the nutrient content in water before it enters Winnipeg's rivers, and the same mechanism can be applied to the secondary retention ponds if desired. This means that the surface drainage would have to be employed instead of sub-surface conduits. Ponds which are pipe-drained may be possible if they pipes drain the top portion of the pond. There are possible draw backs to using smaller reservoirs to temporarily hold runoff before it enters the retention pond. The scale of these ponds mean that they will likely only be full of water periodically, and empty at other times. The pre-reservoirs will thus be good breeding grounds for mosquitoes because the small depressions will be unable to sustain biological control agents, such as fathead minnows. Since mosquito larva need about ten days to develop (Nawalsky 2000), ponds which hold water for substantially less time could be used. A possible benefit of this system is that these may make excellent ponds for waterfowl in the spring as they would thaw before the larger ponds (see Chapter 5).

2) Seepage pits

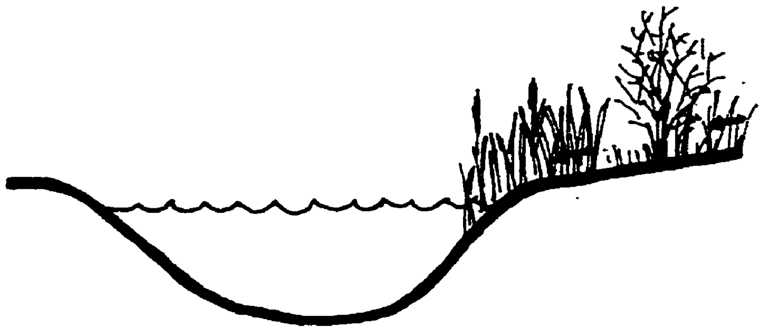
Because phosphorus can be removed when water moves through soil, pits with sandy clay soil can be used to strain stormwater. This method can be used if the tributaries do not have flow exceeding 100 L/ second, and if there is adequate slope and soil that allows seepage (Ryding and Rast 1989). Again the drainage has to be overland, or underground conduits must emerge and let a portion of their flow pass through the seepage pits before the water empties into the retention ponds for this method to be used at retention ponds.



Seepage pits work in a fashion which is similar to infiltration basins, which protect subsurface water, instead of surface water.

3) Vegetative buffer strips

By ensuring that there is adequate vegetation surrounding a water body, sediment and phosphorus can be removed from runoff. The effectiveness of this strip is influenced by the width, height, and vigour of the vegetation, as well as the slope over which the water is passing over (Ryding and Rast 1989). This method works like the retention pond – the flow of the



water is slowed, which causes suspended sediments to fall out of the water. The vegetation will also tend to use the nutrients for their own growth. The current system of drainage in our suburbs enables a great deal of water to bypass any vegetation. The portion of land that drains overland into the retention ponds is small compared to the size of the overall watershed.

Conclusion

The retention ponds in Winnipeg can act to protect the natural water bodies such as the Red and Assiniboine Rivers, by removing nutrients from stormwater. Nutrients can be removed by sedimentation in the ponds, or through absorption of nutrients by plants. The nutrients can be removed from the pond by harvest or dredging. Some approaches can not only reduce the nutrients in the effluent of the ponds, but can reduce nutrients entering the ponds. These are the preventive measures that were discussed, and they are probably the best methods to use. There is no reason that a system can not use all three methods.

The previous methods of dealing with eutrophic waters have the following implications on the character of the retention pond:

1) There should be an abundance of plants in the retention pond for encouraging sedimentation and absorption of nutrients.
2) Coarse plants should be located at the edges of the pond to intercept and use runoff born nutrients.
3) There should be a surface conveyance system which directs runoff through plants before it enters the pond. If this overland system is employed, then there would have to be an allowance of land for the swales or channels to pass through. Not only would the drainage of people's yards be different, but the drainage of the streets would have to be different as well.
4) Where a hybrid system of open and closed drainage is utilized pre-reservoirs can be used. Small reservoirs could be used that hold water before it spills over into pipes that take it to the retention pond.
5) Hypolimnetic aeration can be used to aerate the increase oxygen levels in the water. Additionally, waterfalls, at the end of drainage swales, and fountains can be used to oxygenate water, while acting as sculptural elements in the landscape.
6) Methods of preventing the establishment of macrophytes would not be used as a response to eutrophication. These techniques could be used to keep small portions of the pond or shoreline free of macrophytes, and these methods include; shading aquatics with vegetation, adding gravel, and using membranes to cover sediments.

Management Implications

In a natural environment nutrients are recycled. This means that nutrients absorbed by plants will eventually be returned to the water. It is important to be prepared to occasionally harvest plants. Dredging may also be necessary to remove an accumulation of phosphorus or heavy metals from an impoundment. Although phosphorus binds to soil, the soil can become saturated. Draw-down could be used at the time of dredging, but this would be used to facilitate dredging, and to help ensure viability of the marsh vegetation.

The goals of improving water quality, providing a recreational and aesthetic amenity, and improving wildlife habitat can be used as guidelines to help determine which approaches to management are the best. The management must be responsive to changing condition of the retention pond.

When contemplating constructing a retention pond, which functions like a natural water body, attracts or sustains wildlife, it is important to know something about the wildlife that could exist there. To augment lost habitat, and, obtain maximum benefit from retention ponds one must look at the state of wetlands and the functions they provide. The role of the wetland as a wildlife habitat is one of the most important roles. Although wetlands provide habitat for numerous species of flora and fauna, one the most conspicuous, and appreciated families may be the waterfowl family, (*Anitidae*) whose arrival and passing through the prairies is eagerly awaited by many. As natural wetlands provide habitat for these animals, there is a possibility that the suburban retention pond can also help support this type of wildlife, bringing it into our lives in a tangible way which enables us to benefit from experiencing wildlife, while teaching or reminding us that we must share our world with other species if it is to be complete.

One way to obtain habitat for a species, is to find out what habitats they live in and construct them, but since a retention pond would be a managed environment with other priorities, it may be better to find out what type of wildlife is desired, and what that wildlife needs to be accommodated.

An assessment of wetlands shows that there is a great opportunity for retention ponds to supplement lost wetland habitat. The 1.4 million km^2 of wetlands in Canada and Alaska would seem to be excessive, and indeed it represents 25% of the world's total wetlands (Dugan 1993), but these are very productive environments. Although wetlands are productive, some wetlands are more important than others. There is an area of the North American prairies known as the prairie pothole region, and it is known to be one of the most important wetland zones in the world (Weller 1994). This region, known as 'the duck factory', has many small, medium, and large potholes which hold water on a temporary or permanent basis, providing nesting and feeding habitat for much of North

America's waterfowl.

Obviously this region is very important for waterfowl, but, the same rich soils that make this land productive for waterfowl also make it very productive agriculturally, and this has contributed to changes in the abundance of wetlands. Prairie pothole wetlands have declined significantly since Europeans settled on the prairies. In Canada, wetlands have declined in a dramatic fashion, with losses amounting to as much as 71% of the wetlands which existed just 70 years ago (Dugan 1993). When considering this latter statistic it is also important to consider that wetlands such as bogs lie in more remote locations, with less settlement and little agricultural potential, thus the losses in the prairie pothole region would account for a greater portion of the overall losses. This habitat loss has had effects on waterfowl populations. Data on waterfowl from 1955 to date show major declines in most species that nest in the prairie pothole region (Weller 1994). In order to sustain waterfowl populations there must be an attempt to limit habitat loss, and make existing habitat more productive. There also may be an opportunity to construct new habitat.

Types of waterfowl

The family *Anitidae* includes swans, geese and ducks. Ducks are further grouped into four main tribes: perching ducks, which nest in holes in trees; dabbling ducks, which surface feed on freshwater or on land; pochards, the diving ducks that can dive below the water surface to feed; and sea ducks, which generally nest and winter on coastlines, especially in the Arctic. The dabbling ducks comprise the great majority of the waterfowl, accounting for 64.4% of the waterfowl population that winters in the United States while geese make up 21.6% (Bellrose and Trudeau 1988). Although not all waterfowl that winter in the U.S. migrate into Canada to breed, most do, and we would expect to see somewhat similar numbers for waterfowl on the prairies.

Waterfowl of the Winnipeg Area

Migration

There are numerous species of waterfowl which can be found around the Winnipeg area for at least part of the year. There are many ducks and geese that migrate through Southern Manitoba and even through Winnipeg in spring and fall, on their way to and from their breeding grounds. In addition to migrating to and from nesting and wintering grounds, waterfowl often undertake a migration to and from moulting grounds. Males, failed breeders, and non-breeding females often migrate to moult (Kortright 1962) and some birds may fly through the Winnipeg area on route to their moulting grounds. In terms of migration Winnipeg sits roughly in the middle the Mississippi Flyway, and on the western edge of the Atlantic Flyway (Hanson 1997).

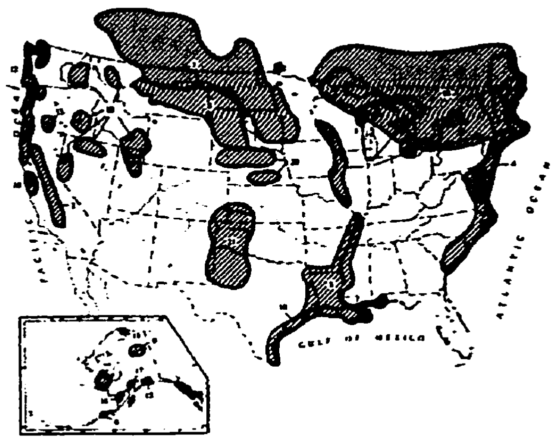


Figure 5.1 Duck breeding grounds
Bolen and Baldessare p.378

Breeding

The viability of any animal species is dependent on a successful breeding season. Since many ducks breed in the prairie pothole region this is an extremely important area for ducks. Ducks and geese find the prairies ideal for breeding, and raising a brood. According to Paul Johnsgard (1975) there are seventeen species of ducks that may have breeding grounds in the vicinity of Winnipeg (See Appendix I), although there are probably only twelve species that are common to the prairie pothole region. In addition to ducks, Canada Geese (*Branta Canadensis*) will breed in the area. As with most animals, food, water, and shelter are of utmost importance for waterfowl. Waterfowl have the ability to fly which can keep them relatively free of predation from most animals, but additional security from terrestrial predation can be gained by taking to the water. There are certain times, however, when waterfowl are particularly vulnerable to predation. These times are during and shortly after the nesting season when the eggs make an easy meal or when ducklings and goslings are too young to fly. The other time is during a moult when adults or juveniles have lost enough feathers to make them incapable of flight. During both of these periods adequate cover is important to protect the birds from predation. It is also at this time when the nutritional demands for the waterfowl are high, yet very specific (Swanson 1988). An adequate habitat must therefore, provide water, material for nest construction and cover, and enough of the right types of foods which meet the particular nutritional demands of the birds.

Nesting Requirements

There are different nesting requirements for ducks, depending upon the tribe to which they belong. Wood ducks (*Aix sponsa),* for example, nest in cavities found in old trees, but since old trees cannot be made available for years, then artificial nests associated with forest can be used. The dabbling ducks such as the Mallard (*Anas platyrynchos),* the Pintail (*Anas acuta),* the Gadwell (*A. strepera*), and the Blue-winged Teal (*A. discors*) are much more numerous. The pochards are also an important group, which include such species as Canvasback (*Aythya valisineria*)and the Redhead (*A. americana).* The pochards are specially adapted for swimming underwater, while the dabblers are more suited to a terrestrial existence (Johnsgard 1975). This fact is also represented in where waterfowl tend to build their nests.

Location of nests

The location of nests is determined by the type of waterfowl that is nesting. The dabbling ducks, such as the Mallard, the Pintail, and Gadwell nest farther away from a water body than Pochards like Northern Shovelers or Blue-winged Teals, but, 70% of all ducks were found nesting within 90 metres of the marshes at Delta (Sowls 1955). Mallards probably nest at the longest distance from water. In Florida they nested an average of 179 metres away from the water (Figley and Vandruff 1982). The Mallard generally builds its nests near prairie ponds where the ground is dry or only slightly moist (Kortright 1962), while Canvasbacks and Redheads preferred nesting among cattails, bull rushes and sedges (Bellrose and Trudeau1988). Obviously the uplands associated with the wetlands are very important especially for the dabbling ducks. Unfortunately, often when farmers have not drained the wetlands, they have often cultivated crops in the uplands leaving little natural vegetation for nesting. The vegetation that remains will often only be the vegetation that can grow in standing water, such as emergent vegetation.

The type of vegetation that ducks build their nests in, may of course depend upon the species, Sowls (1955) studied 683 nests at Delta Marsh, and found that Whitetop was the most important nesting cover, with 41% (278 nests) of all nests found there. Chord grass accounted for 17% of nests, while bluegrass was 12%, and quack grass was used by less than 5% (see Appendix J). Dense stands of phragmites accounted for 41% of the cover, yet was only used by 11% of the Mallards, and the nests that were in the Phragmites tended to be in small isolated clumps of the plant, which suggests that the plants normally grew too densely to allow nesting. In areas where cattails and phragmites were trampled by grazing cattle the habitat was improved. Trees and shrubs also proved to be poor nesting habitat, possibly because they were too dense or too shaded. Hine and Schoenfeld (1968) found that tag alder reduced visibility and collected great drifts of snow that failed to clear in time for nesting of Canada Geese, perhaps similar factors could be involved for ducks. According to Sowls (1955) ungrazed marsh meadows made the most productive nesting cover at Delta. It is evident that since ducks favour ungrazed meadow, and that many may nest a considerable distance from a wetland, the uplands have to be protected in addition to the wetlands. Natural grasslands with some brush are believed to be the best nesting habitat for ducks in the Canadian prairies (Galatowitsch and van der Valk 1994). Unfortunately, in major duck producing areas, in Canada, much of the tall grass prairie, the short grass prairie, the mixed grass prairie, and the Aspen parkland had been lost to cultivation (Baldassare and Bolen 1994). Ducks may be adaptable in their nesting behaviour, but nests too close to water could be more subject to flooding or easier predation, and nests farther away may be subject to being destroyed by farming. A portion of protected upland, supporting appropriate cover would be highly beneficial to nesting success.

Since the waterfowl often arrive a month before there is sufficient time for new plant growth it is understandable that most of the nesting material consists of dead plant material from the previous year (Sowls 1955). Usually ducks and geese will nest on the ground in rudimentary nests. Kortright (1962) described geese nests saying "... the nest is a depression in the ground, lined with material from the vicinity, sticks, flags, or grasses, and soft grey down." The nests are simple and their construction material seems to be less important than the cover the nest is found in.

Another important aspect of the nesting of both ducks and geese was a noticeable preference for islands. Hine and Schoenfeld (1968) noticed that Canada Geese preferred islands with grass and sparse brush 6 -20 inches (15 -50 cm) high. Johnson's (1981) study of *Branta canadensis maxima* at Reykjavik, Manitoba found that although most of the nesting was on mainland as opposed to islands the density of nesting was 0.05 nests / ha for mainland and 0.32 nests / ha for islands. The reason for this security can be easily explained by the fact that terrestrial predators are separated from the nests by water. Geese, however, show that the barrier of water is not the only important factor. If islands were closer than 45m and occupied by one goose then the other island would either not be occupied or if it was, one goose would often abandon her nest. If an island was more than 75m long it could be occupied by more than one breeding pair (Hine and Schoenfeld 1968). This territoriality may be only intraspecific, as geese and mallards have been spotted nesting on the same round hay bale (Johnson, Lee and Messmer 1986).

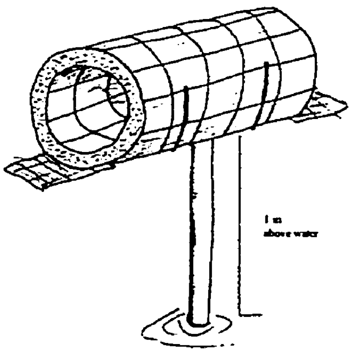


Figure 5.2 Tunnel Nest

Artificial Nests

Artificial means of constructing nests have been successful for Wood ducks (Stanley 1984). Platform nesting has been used for Mallards and Canada Geese (Johnson, Lee and Messmer 1986), but it may be preferable to simply provide the habitat, and let the ducks take care of the nests. From an aesthetic point of view, natural nests will have less visual impact than artificial nests, and will more easily blend in with the environment. The artificial nests can be very cost effective method of ensuring a higher nesting success rate than allowing the birds to build nests in an environment that can be easily disturbed by humans. The cost of constructing islands for waterfowl nesting sites would likely be very expensive, especially given the small potential number of nesting pairs that would use them, but constructing a retention pond with an island may be considered as part of the overall construction of the retention pond. Another option is to carefully include artificial nest sites that are part of a deliberate aesthetic.

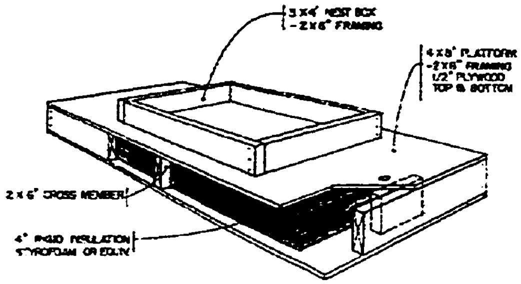


Figure 5.3 Nest Raft
Johnson, Lee, Messmer 1986

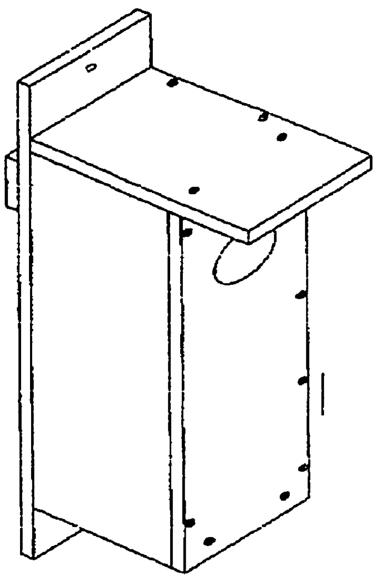


Figure 5.4 Wood Duck Nest Box
Stanley 1984

Arrival

If cover and food is important for nesting waterfowl which reside in a managed pond, then it is important to know when this season begins and ends. Delta Marsh can be used as an example of when nesting ducks arrive. Sowls (1955) found that on average Mallards arrive on April 2, Pintails April 5, Gadwells April 21, Northen Shovellers April 15, and Blue-winged Teals April 23. The temperature in any given year is crucial, the Mallards and Pintails move north as fas as open water in available (Sowls 1955). Despite having a longer distance to travel, the migrants arrived at Delta after the breeding pairs (Sowls 1955). The birds are feeding from the ponds as they thaw out, and perhaps the birds that breed in the area are trying to select a nesting spot.

Nesting period

The nesting period for most ducks is from mid-May to June. The incubation period is usually about 21 days, which will determine the end of nesting for a particular hen, if the hen had a successful clutch. An unsuccessful clutch, will mean that the nesting season can vary dramatically, being greatly extended if necessary. If the first clutch is not successful, then a hen will have a second, and possibly a third in the case of some Mallards. The nesting season can go into July, but, not August, as it is too late for the young to mature enough to make the flight to the wintering grounds (Sowls 1955).

Food Requirements

The most important thing about habitat is that it provides the necessary food for waterfowl. Ducks and geese can obtain their food from aquatics, invertebrates in ponds, upland plants, and agricultural crops or the waste from them.

Agricultural crops have become an important source of nutrition for many wildfowl, Canada Geese and Mallards have adapted well to grazing in stubble fields (Kortright 1962). Some fowl can obtain the necessary carbohydrates and calories after a short time spent grazing, however, they cannot obtain all of their necessary nutrition from agricultural crops (Loesch and Kaminski 1989). Agricultural crops are insufficient for waterfowl, but, another problem, is that the waterfowl consume part of the crops before they are harvested.. Although waterfowl may opportunistically feed on agricultural crops, the degree to which they do so, is dependent on the availability of natural food sources (Belrose and Trudeau 1988). New wetlands may reduce the pressure of waterfowl to feed on agricultural crops.

In order to adequately support ducks and geese, it is important to know which plants they feed on. Waterfowl feed on seeds, tubers, bulbs, rhizomes, and leafy vegetation. Among plant foods *Potamogeton* (pondweed) ranked first in terms of volume consumed by 18 species of ducks. Pondweeds were consumed twice as much, by volume, as the next ranked plant food. *Scirpu maritimus* (bulrush) is good food, and *S. validus* produces desirable nutlets (Bolen and Baldassare 1994). Cattails, with its fibrous leaves provide a poor food source, while wild rice is excellent for ducks (Bolen and Baldassarre 1994). Plants such as filamentous algae, and duckweed (*Lemna spp.*) make good food sources (Swanson 1988), but some plants such as duckweed may be even more valuable for the other types of life they support.

Although plants comprise an important part of the diet of waterfowl, macroinvertebrates that live in the wetlands also comprise a crucial portion of their diet (Murkin and Wrubeski 1988). This is particularly true for laying hens in nesting season. The extra protein contained by invertebrates makes their consumption critical for laying hens (Swanson 1988). Invertebrate consumption for laying females in the prairie pothole region in North Dakota accounts for a substantial portion of the diets of several species of waterfowl (Swanson, Meyer and Adomaitis1985). Not only are the invertebrates important to the hens, but, also to juveniles as they were the dominant part of the diet for a group studied in Manitoba (Swanson 1988). Waterfowl could be considered biological control agents for mosquitoes, when they consume *Diptera,* the group which mosquito larvae belong to.

As invertebrates are so important to waterfowl it is essential that there is an environment to sustain them. Sowls provides a list of the submergent plant species that seems to provide the best food for these bugs (see Appendix H). Some invertebrates are insectivorous, some break down dead organic material, some may feed on algae, or plants, so there are may ways to support these populations, but, they may be very susceptible to pesticides or insecticides used to kill mosquitos, so it is important not to contaminate wetlands, and kill crucial fish and fowl food sources.

Plants are important as a food source for waterfowl. Beyond the specific nutritional value of aquatics their existence is generally beneficial. There should be an abundance of hydrophytes since a marsh with a 50 : 50 water-to-vegetation ratio supports the most bird species (Baldassare and Bolen 1994). Aquatics tend to be intolerant of shade, and they can be shaded by trees and shrubs or other aquatics. Similarly the activities of coarse fish such as carp can stir-up sediments, shading submergent vegetation, which is particularly likely with the clay soils in the Red River Valley area (Bolen and Baldassare 1994).

Predators

Predators can be a very significant factor in the success of the clutches. Eggs are susceptible to both predation from birds and mammals. At the Delta Marsh the Franklin ground squirrel was a significant predator of duck eggs (Sowls 1955). A study in the prairie pothole region identified the striped skunk, the racoon, Franklin's ground squirrel and the red fox as being important mammalian predators, while ring-billed gulls and American crows were the leading avian predators. Mammalian predation, however was the most important cause of nest failure, accounting for up to 85% of failures, while interference from farming was the next greatest change for waterfowl nests (Klett, Shaffer and Johnson 1988). The use of islands, or artificial nests become more important as a means to ensure increased safety from predation.

Artificial ponds as habitat

Since a retention pond is usually constructed and not a natural water body it may be useful to look at constructed water bodies to see how ducks and geese use them. Since many small bodies of water have been constructed there are pertinent studies. There are also studies relating human habitation with duck habitat. As the prairie pothole region is associated with agriculture, there are numerous dugouts, stock ponds, and even sewage lagoons. Sewage ponds tend to lack vegetation, but, their high nutrient content causes them to have midges and invertebrates in abundance, which attracts waterfowl (Belanger and Couture 1988). Water bodies with an abundance of macroinvertebrates would logically be beneficial to breeding pairs, developing fowl, and migrants. In fact, the brood density for sewage lagoons was higher than that of natural wetlands nearby (Flake, Gates, and Ruwald, 1979). Sewage lagoons have been specifically managed for waterfowl, yielding both high nesting density and high hatching success, but the drawback is that the conditions in sewage lagoons may be more conducive to the existence of microbial diseases which can cause mortality in waterfowl (Belanger and Couture 1988).

Stock ponds and dugouts can also provide habitat, although stock ponds probably more closely resemble the natural environments used by waterfowl. The size of the ponds and the type of vegetation in them influence their use by breeding pairs and their brood. In Montana, brood size was highest for ponds of intermediate size, 0.51 - 1.5 ha, an irregular shoreline, a water depth of <61 cm, > 30% cover of emergent vegetation, > 20% cover of submergent vegetation, and < 10% bare shoreline (Belanger and Couture 1988), but, the desired vegetation did not develop for at least five years after construction (Galatowitsch and van der Valk 1994). Artificial ponds greater than 0.4 ha constituted 29% of all ponds studied, yet accounted for 65% of all pairs and 87% of all broods. Stock ponds were well used (Belanger and Couture 1988), but they are also in a more natural setting, and close to agricultural food sources, which may make them more desirable for waterfowl than stormwater retention ponds.

Studies of storm water retention basins shows that ducks, especially Mallards, will use these and they will adapt to human habitation. In Florida, there was actually a correlation between high Mallard use and shores that were highly developed (Figley and Vandruff 1982), signifying that Mallards tolerate close association with humans.

Mallards were not only feeding at urban waterbodies, but nesting as well. In urban areas Mallards used different nesting sites, using evergreens, ornamental shrubs, and artificial structures (Figley and Vandruff 1982). Not only did the ducks nest in peoples' yards but the highest nesting success for Mallards was for ducks that nested in peoples' yards (Figley and Vandruff 1982). Due to lack of egg eating predators, urban lagoon Mallards had a very high nesting success compared to birds nesting in wild habitats, however, the nesting success in public parks was low due to disturbance by people and pets (Figley and Vandruff 1982). There was actually another adverse consequence to urbanization, which was high water temperatures, stagnant water, and excessive build-up of organic material which helped produce anaerobic conditions conducive to the growth of *Clostridium* bacteria, or botulism which is a major killer of waterfowl.

Since laying hens tend to home to the same meadow every year, it would be expected that newly constructed environments might not be adopted. Some urban basins may have existed previous to development, which may explain the presence of ducks. There is evidence to suggest that newly constructed ponds will be adopted by ducks. Ducks will differ in their propensity to adopt new environments, juveniles are more likely to colonize new areas than adults, and dabblers are more likely to be pioneers than pochards. Mallards and Pintails are good pioneers, while Redheads and Canvasbacks are poor pioneers (Sowls 1955).

Opinions about waterfowl

One reason to allow waterfowl to nest in urban settings, is to try and help replace habitat that has been destroyed through agricultural practices or habitat that may have been displaced by the suburbs themselves. Another reason is to try to improve the quality of our lives by including wildlife that may reduce our dissociation from the natural environment and help add beauty to our surroundings. But do people actually want this? A survey performed in Beach Haven West, Florida, a community which is closely associated with ducks, showed that 95% of residents considered ducks a benefit and a pleasure (Figley 1974), and this benefit would not have been for the perceived value of hunting since only 6% of respondents had family members that engaged in hunting. In Columbia, Maryland 94% of residents responding to a survey favoured including wildlife habitat in the design of retention basins (Livingston 1989).

Fully 98% of respondents enjoyed viewing wildlife associated with neighbourhood retention basins and 92% considered seeing ducks as outweighing any nuisance the birds might cause (Livingston 1989). There is also evidence that Winnipeg residents would accept waterfowl in an urban setting, as a survey distributed to residents for Heather Edwards' practicum (1990) found that 85.6% of respondents favoured the inclusion of wildlife such as ducks and geese around retention ponds, or on the islands. It seems that many people would favour seeing waterfowl at retention ponds, even if there are some who would not. If the habitat of retention ponds is improved, there would not be a large increase in the use of the ponds by waterfowl, as the nesting density is low. The suburban ponds would not have the numbers of nesting pairs associated with the migrations, but the retention ponds would become more useful and beneficial to some waterfowl.

Conclusion

There are important factors about waterfowl that may have a bearing on the design of suburban retention ponds: waterfowl habitat has decreased, there has been a corresponding decline in the populations of several species, many people would favour having waterfowl associated with retention ponds, waterfowl will nest or use artificial water bodies even if humans are closely associated with those water bodies, and the best water body for fowl will have adequate vegetation in and around the pond and have the associated invertebrate population.

With these factors in mind it is difficult to overlook the opportunity to create wildlife, when constructing stormwater infrastructure. Trying to use our stormwater system to accommodate other species is a good way of alleviating the harmful effects of habitat loss, but it does not negate the value of preserving the original habitat. The goal of habitat creation is also conducive to creating infrastructure that more efficiently removes impurities and excess nutrients from stormwater. Not only will creating habitat benefit wildlife in a direct way, but if people are aware of how our infrastructure can be part of the natural environment, then more people can see how we are part of ecosystems, and that our actions will have ramifications on natural environments.

A retention pond that is designed to be beneficial for waterfowl will have several characteristics:

1) The pond should be substantially vegetated, with a significant emergent cover.
2) There should be naturally vegetated uplands. One of the problems with wetland preservation, it does not focus enough on the uplands, and many waterfowl, not only need the wetlands, but they need substantial upland prairie for nesting, and food.
3) Islands with upland vegetation should be in the pond because they accommodate the highest density of fowl, and offer them the best protection from disturbance, or predation. This is especially important since space is limited in the residential context, and the amount of natural upland is limited. The islands also provide an interesting visual element.
4) The pond should be greater than 0.5 ha to ensure adequate waterfowl use.
5) Smaller water bodies should be associated with the larger pond since fowl use many sizes of wetlands, and the early arrivals in the region depend on small temporary ponds which thaw-out before the larger ponds.
6) Open shoreline should be maintained on at least a portion of the pond as some fowl prefer it.
7) The use of trees or tall shrubs near the water will be limited since they can prevent the necessary aquatics from growing. Trees can be used in places where aquatics are unsustainable or where open water is desired.

Management Implications

Management practices should be planned to coincide with waterfowl behaviour associated with wetlands. The early arrival of waterfowl to areas near our city, coupled with their nesting habits, mean that actions such as cutting of emergents, or upland vegetation, should take place later in the summer, when there is a low probability of disturbing a hen and her clutch. The application of pesticides is detrimental, but, if it is to be done, then it should be a non-persistent chemical.

Since ducks and geese already use the ponds for loafing, and nesting densities are low, then improving habitat for nesting should not unduly increase fowl populations on retention ponds, but would tend to increase the benefit the pond provides them. Increasing the plant and invertebrate populations of the retention ponds, would likely also have benefits for nearby farmers. If there is sufficient nutrition available in the wetlands, then the birds will be less dependant on grain from farms, and this should help minimize any damage they inflict on crops. There may also be some benefit of fowl harvesting some of the nutritional yield from eutrophic waters which will minimize the plant and animal matter that is returned to the water body seasonally.

Although waterfowl are by no means the only species to use wetlands, they may be some of the most valued. Providing a more natural retention pond will also attract other avian species, as noted earlier, a 50% vegetation cover on the pond will attract the most bird species. Maintaining a healthy environment for fowl is likely to benefit other generalists, and specialists alike, not the least of which may be ourselves.

In order to design a retention pond that functions like a natural water body, existing natural precedents must first be examined. Suburban developers, who have stormwater retention basins constructed in their developments, often equate these basins with lakes. The sale of lots is often tied to the image of a freshwater lake existing in the community. These basins, however, do not tend to resemble lakes, but are often more akin to wetlands. In order to construct a pond that has more potential for supporting wildlife it would be wise to emulate natural wetlands. First it is necessary to know which wetlands are relevant to stormwater retention ponds and how their condition can help retention pond design.

What is a wetland ?

A wetland is a shallow water body often having large percentage of vegetative cover, unlike a lake which is deeper, having large areas of open water. Wetlands can be, and are often found at the edge of water bodies such lakes, rivers, and oceans. Although this generalization is frequently untrue, it may be useful as wetlands do tend to function like edge communities. One useful definition of a wetland is an area of land where the water level is at or slightly above the level of the mineral soil for the entire year (Johnson, Kershaw, MacKinnon, and Pojar, 1995). Some marshes may not fit this classification as they can dry-out during the year.

Wetlands relevant to retention ponds

There are several types of wetlands, bogs and swamps are not relevant to retention ponds in Winnipeg, but definitions of marshes and fens are useful (Hammer, 1992; Johnson, Kershaw, MacKinnon, Pojar, 1992).

Fens

Have more water flow and higher water levels with slightly more nutrients than bogs. These environments are dominated by sedges and mosses.

Marshes

These are often inundated with water, which is rich in nutrients, and slightly alkaline. The soils are mostly mineral soils. The dominant plants tend to be emergents such as reeds, rushes, sedges or grasses.

In addition to these categories Johnson et al have a classification of open water as a wetland type, while Hammer uses a classification for wet meadows. Each of these classifications can be associated with marshes simultaneously. A classification based on depth of a marsh may be more useful. Since Winnipeg is at the edge of the prairie pothole region, we can look at the classification of prairie potholes. A prairie pothole is a shallow depression that has been left behind by the glaciers. Usually these depressions are hydrologically isolated from other water bodies, which makes them basins. In the prairie pothole region there is a collection of potholes numbering over one million. Prairie potholes can be marshes, so a classification of potholes is useful, and (Galatowich and Van der Valk (1994) have provided a useful method of classification. This system looks at the depth and duration of standing water in the deepest part of a particular wetland, which determines the vegetation of that wetland. The deeper wetlands will have the characteristics of the shallower wetlands on their edges. The classifications are:

Class I - ephemeral ponds - wet prairie
- dominated by grasses, ie. *Andropogon gerardii* (big bluestem), *Poa* (bluegrass), and, *Panicum vergatum* (switchgrass).

Class II - temporary ponds - sedge meadow
- dominated by sedges, ie. *Carex lanigiosa* (woody sedge), *C. praegacilis* (graceful sedge), *Calamagrostis canadensis* (bluejoint), and *Spartina pectinata* (cordgrass).

Class III - seasonal ponds - shallow marsh
- dominated by coarse sedges, ie. *Scirpus fluviatilis, Typha latifolia* (cattail) etc.

Class IV - semi-permanent ponds, with a central deep zone.

- has previous plants, plus a deep marsh zone with *Scirpus acutus, S. validis,*(common bulrush) and *Typha glauca*

Class V - permanent ponds or lakes with a central deep zone.

An urban retention pond in Winnipeg would sit in rich prairie soil, similar to the rich soils the prairie potholes are found in. Not only is the soil similar, but most of the basin's are similarly isolated from natural water bodies, with the exception of underground pipes. This makes a large prairie pothole the natural model for a stormwater retention basin. Since the retention ponds are inevitably linked to natural water bodies the ponds can play a role in filtering water, just like the larger marshes.

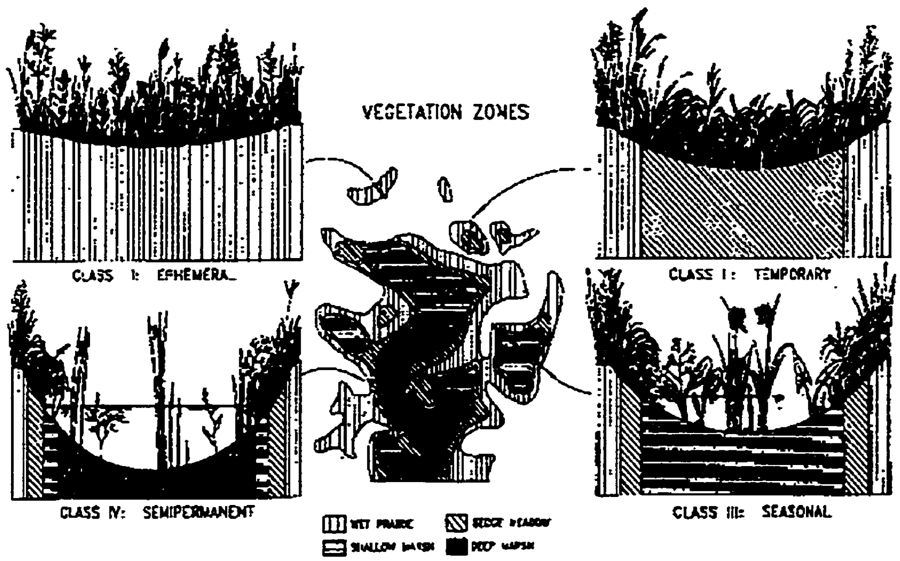


Figure 6.1 Wetland Classes and their associated wetland zones. (Galatowitsch and van der Valk 1994)

Characteristics

Functions

As mentioned in the introduction, wetlands can have several functions, both for the natural environment and for people. Wetlands provide habitat for many species of plants, animals and microbes. Several organisms are only found in wetlands, while many organisms are dependent on wetlands for a part of their life, and some will use wetlands where convenient. Wetlands play an important role in hydrology, slowing water, and preventing erosion, removing sediments, and toxins from water, and recharging or discharging ground water (Mitsch and Gosselink, 1986).

Humans can use wetlands for recreation, or can obtain food derived from them, like wild rice, or ducks. One of the greatest benefits we may obtain, in an urban environment, is from the way wetlands naturally repair what we have done to the water. In our altered watersheds, there is an abundance of runoff, which is contaminated by excess nutrients, heavy metals, pesticides, and grease. Marshes can take this runoff, slow it down, use some nutrients, break down some contaminants, allow heavy metals and silt to drop from the water column before the water enters other water bodies.

Soil

Typically, wetlands have gradually sloping shorelines for basins, which is to be expected as their shores are comprised of soil and not gravel or rocks. The soils in wetlands are hydric soils. The hydric soils can be further classified into two categories: mineral soils, which have <12-20% organic matter; and organic soils, which have >12-20% (Hammer 1992). Marshes will have primarily mineral soils. Often wetland soils will only have the top 1-5mm of soil that is aerobic -- with the exception of the rhyzosphere (Hammer 1992). The development of organic soils is related to anaerobic conditions, because organic material will not completely break down in an anaerobic environment. Marshes, which have more aerobic conditions and periodic draw-downs, will not have as much accumulation of organic matter as other wetlands.

Hydrology

The hydrology of a wetland is dependent on numerous variables. Evapo-transpiration, precipitation, surface inflows, and outflows, and groundwater recharge and discharge. Each of these factors is also dependent on other conditions. Evapo-transpiration depends on vegetative cover, solar radiation levels, humidity, temperature, and air pressure. Water losses or gains vary with soil permeability, and ground water depth and slope (Hammer 1992).

Some of these factors are variable because of the unpredictability of natural processes, but some factors can be controlled through deliberate design if we understand how structure influences marsh function. Evaporation accounts for 35- 55% of the water loss from semi-permanent and permanent ponds, and the evaporation in a water body varies inversely with the water depth, thus shallower wetlands warm faster (National Working Group, Canada Committee on Ecological Classification 1988). Larger water bodies are also more stable, with wetlands of about 2 hectares, or more, usually being permanent water bodies. Vegetated wetlands also have reduced water losses – not just from evaporation – but less total losses from evapo-transpiration than un-vegetated ponds. There are, however, more losses from seepage in a pond with more vegetation, but those will be more than compensated for by the reduced evapo-transpiration losses (National Working Group, Canada Committee on Ecological Classification 1988).

Inflows and outflows of water can be variable in a natural wetland, but run-off rates tend to be much more stable in a natural watershed than in an urban watershed. Design techniques can be used which create more stable water levels. A control structure can be used that reduce rapid outflows, and could also be used to regulate pond levels to produce periodic flooding and draw-down that it necessary for a natural water body (Weller 1994). Disturbance is necessary for proper functioning of any natural marsh (Hammer 1992), and a static water level will result in an unhealthy marsh. It is important allow for some variation which will allow a pond to undergo natural vegetation cycles.

Vegetation

The vegetation of a pothole provides food and shelter for invertebrates, amphibians, mammals and birds, changing a water basin into habitat. In the southern prairie pothole region there are some 350 wetland species, but, only one third to one sixth of those species are present in any particular wetland (Galatowitsch and van der Valk 1994).

Some woody species are sometimes associated with marshes, but, the majority of the species are herbaceous. Although not all classifications of wetland plants are the same, the categories are simple, and can give useful generalizations about the members in each category. Aquatic macrophytes can be divided into two categories, free-floating and rooted macrophytes which can be further divided into three categories.

Free-floating - Examples of these are the duckweeds (*Lemna*). These plants float freely on the top of the water surface, or are neutrally buoyant and can float beneath the surface of the water. Species that float below the water surface may be sometimes classified as submergents. These plants have root hairs or roots that draw their nutrition directly from the water column. The productivity of these plants is equal to or greater than that of emergents. Sometimes if these plants form dense mats they can shade emergent vegetation, and reduce the amount of oxygen that enters the water column (Hammer 1992).

Rooted macrophytes

Emergents - Examples include *Juncus* (rushes), *Scirpus* (bulrushes), *Typha* (cattails), and *Carex* (sedges) These are often the most conspicuous plants in a marsh, growing in the shallow water at the margins. The water is often 5 - 30 cm in depth, although the plants will often spend part of the season out of the water, when the wetland dries-up. Emergents have high light saturation levels, which may account for their great productivity (Hammer 1992). Emergents obtain almost all of their nutrients from the soil, and obtain oxygen from the air which is transported to the roots through hollow leaves or stems (Hammer 1992).

Floating leaved plants - *Nuphar* (water lilies) are an example.

These plants are rooted in the soil, where they obtain most of their nutrients, and their leaves float on the water surface and obtain oxygen and CO_2 from the air.

Submergent - *Potamogeton* (pondweed) is an excellent example

Submergents typically occur at water depths of 0.5m to 1m. These plants experience low light levels and low CO_2 levels, which limits their productivity. Submergents can obtain their nutrients from both the soil and the water column. Oxygenation, is an important benefit that these plants provide for the water. They do a better job of this than the other macrophytes (Hammer 1992).

Algae

Algae are a group of very simple yet important photosynthesizing plants that are found in most water bodies. These plants range in size from the microscopic phytoplankton to the larger branching algae or the filamentous algae, known as 'pond scum'. The algae is a primary producer which efficiently converts nutrients and solar energy into plant mass, which is used as food for zooplankton, invertebrates or small fish, and its energy is thus transferred up the food chain to the higher organisms. In this respect algae is a critical necessity for any wetland environment to be a successful habitat for other organisms. It can however, come to dominate some environments, if the water is too eutrophic (Vymazal 1995).

Seed banks and restoration

Increasing awareness about wetland loss has prompted the protection of many wetlands, and encouraged others to be restored. Construction of wetlands may be somewhat possible, but, restoration holds more promise. When a former wetland is restored, there is already typical wetland soil, and there can be a store of seeds from wetland plants. Another obvious reason is that even if drained and partially filled, the site of the former wetland will still be the lowest point in the area, which allows for easier construction or restoration. After a basin is constructed reestablishing vegetation is necessary. As mentioned earlier a store of aquatic seeds, referred to as a seed bank, may already exist on site. The aquatic plants have evolved to produce seeds that can survive for several years, even decades, through prolonged drought or inundation (Galatowich and van der Valk 1994). Seed banks surveyed in prairie potholes in Iowa contained more than 25 species of plants and contained as many as 21,445 - 42,615 seeds/ m^2 in the upper 5 cm of soil (Galatowich and van der Valk 1994). These seeds are distributed equally throughout all zones of a wetland. There are also many species that can establish themselves through wind dispersal, or animal dispersal. A problem with simply allowing a restored or constructed wetland to establish itself on its own is that the wetland can come to be quickly dominated by some plants. Cattails for example tend to establish easily and prevent other plants from establishing themselves, leading to an almost monotypic wetland (Galatowitsch and van der Valk 1994).

A more active effort to restore wetland vegetation may be faster and more successful, and Susan Galatowitsch and Arnold van der Valk (1994) discussed such methods. The five methods they discuss are:

1) Using donor soil

This method involves taking donor soil from an existing wetland, and spreading it over the wetland being restored. Most of the seeds are in the first 5 cm, and most roots within the first 10 - 15 cm, thus soil should not be scrapped below that level in the donor wetland. The new plants can germinate from the seeds or can generate vegetatively from root or stem fragments. This method involves considerable labour and expense, and can potentially damage a natural wetland if it is used as a donor.

2) Inoculating with donor soil

This is the same method as above except small amounts of soil are spread over one or two small areas, and natural seeding or vegetative reproduction will allow those plants to spread out from those areas. A few cubic feet of soil would be sufficient. Inoculation is a cheaper version of spreading donor soil.

3) Spreading seeds

This involves spreading out collected seeds. Often some aggressive species will not allow slower growing species to establish, so less aggressive species can be planted in a separate application. It is best to seed in stages and remove unwanted weeds along the way. This method is an effective way of establishing sedge meadows, or wet prairie.

4) Using wild hay

Wild hay is collected from wetlands in fall and from sedge meadows in mid-summer and spread over appropriate portions of a recipient wetland. Hay can be collected from different wetlands to ensure adequate representation of a particular species. This method works best for sedge meadows, and wet prairies, but is cheaper than the previous method.

5) Transplanting seedlings

Plants that are difficult to establish can be grown from seedling, rootstocks or the whole plant. Plants can be obtained from wetlands, and grown in a green house until they attain a sufficient size, and then they can be planted in a new area.

Establishing new wetland vegetation can take several years, can involve finding a source of plant material, and possibly obtaining organic matter or fertilizers. Planting aquatics, removing undesirable species and altering water levels may all be necessary. Pondweeds, bladderworts, and duckweeds establish rapidly on most sites, as do emergents such as cattails and bulrushes. Sedge meadow species and wet prairie species do not colonize easily and may need help being established. Sedges should probably be planted before cattails are established and take-over (Galatowitsch and van der Valk 1994).

Conclusion

Retention ponds in the Winnipeg area most closely resemble marshes. The marshes are much like prairie pothole marshes, but some exceptions such as the connectivity of water through underground conduits makes stormwater retention basins different from prairie potholes. An important difference between our constructed basins and natural wetlands, is the amount of vegetation that is encouraged to grow in and around them. Many retention ponds in Winnipeg are sterilized during construction. A long way from the 50% vegetation cover that is recommended for fish and waterfowl. The naturalization of retention ponds is often discouraged by applying herbicide, and sterilization, which will also prevent a more natural habitat. Establishing vegetation is not necessarily difficult. There can be several types of plants to exploit different levels of inundation. An interesting water environment can be created in a retention pond, which can benefit people and animals.

An effective method of constructing wildlife habitat, is to emulate a natural environment. For a retention pond, a marsh is the logical natural model to be emulated. Methods of constructing retention basins result in structures which are not entirely dissimilar from natural marshes. The 7:1 safety slope employed around retention ponds in the city would be similar to a natural marsh. To ensure that the retention pond is more natural a design must ensure the following:

1) A vegetated pond, which will be allowed and encouraged by refraining from techniques which prevent plant growth, and by using methods of plant establishment which were discussed previously. This will provide an abundance of habitat and food for different species.
2) A gently sloping shoreline, which will allow for different aquatic communities to establish along distinct depth gradients.
3) A water depth deeper than 1.5m for a portion of the pond, which will allow for submergents.
4) Pond depths of 5-30cm for 20-50% of the water surface area. This will allow for the emergent cover discussed in previous chapters.
5) Surface area of 2ha, which will allow for a water body which is permanent under most conditions.
6) More natural hydrology, which will include more overland drainage.

If the previous conditions were met then it is more probable that the retention pond will resemble a natural marsh. It may take years to establish the vegetation, but to help, the retention pond should be constructed in the lowest part of the site, and if there was natural aquatic vegetation before grading and excavation was carried out then soil should be saved to apply after construction is complete. Many plant and even animal species will arrive without human assistance, but monitoring the development will reveal if intervention is needed.

The site chosen for the proposed project is a site on the eastern edge of Winnipeg, east of Rue Lagimodiere and South of Fermor Avenue. On the present site a stormwater retention pond exists, which acts as a reservoir for an uncompleted development which consists primarily of single, detached family dwellings. Here a different plan will be proposed which will demonstrate better principles of stormwater management, by using more sustainable methods to control pollution and eutrophication, while also considering the pond as habitat for waterfowl. This will happen in a similar context of a development dominated by single, detached family houses.

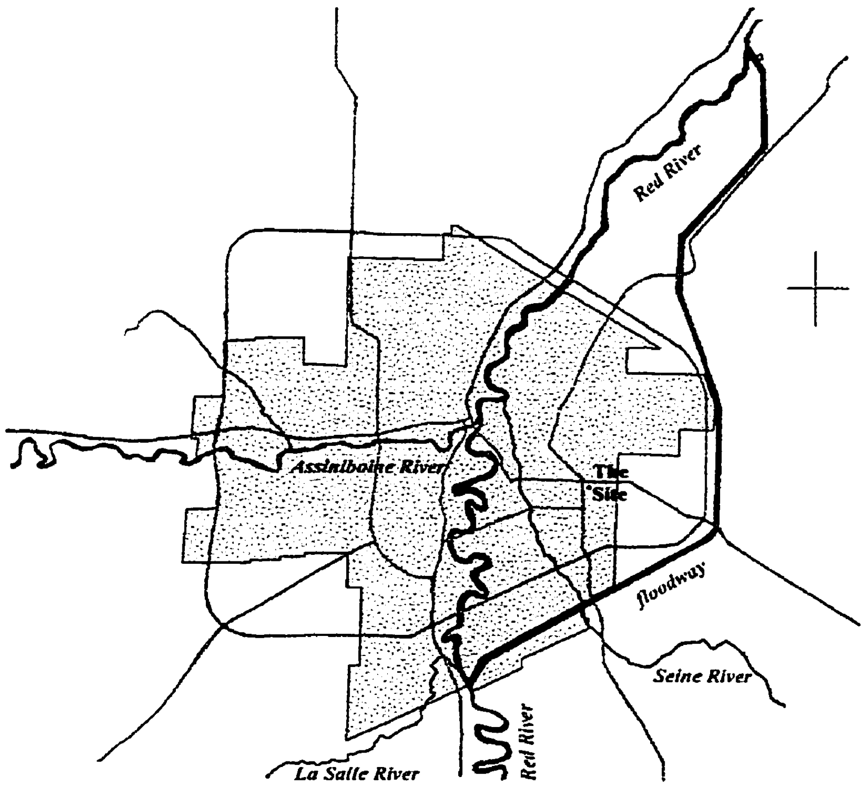


Figure 7.1 The Site in the Winnipeg context

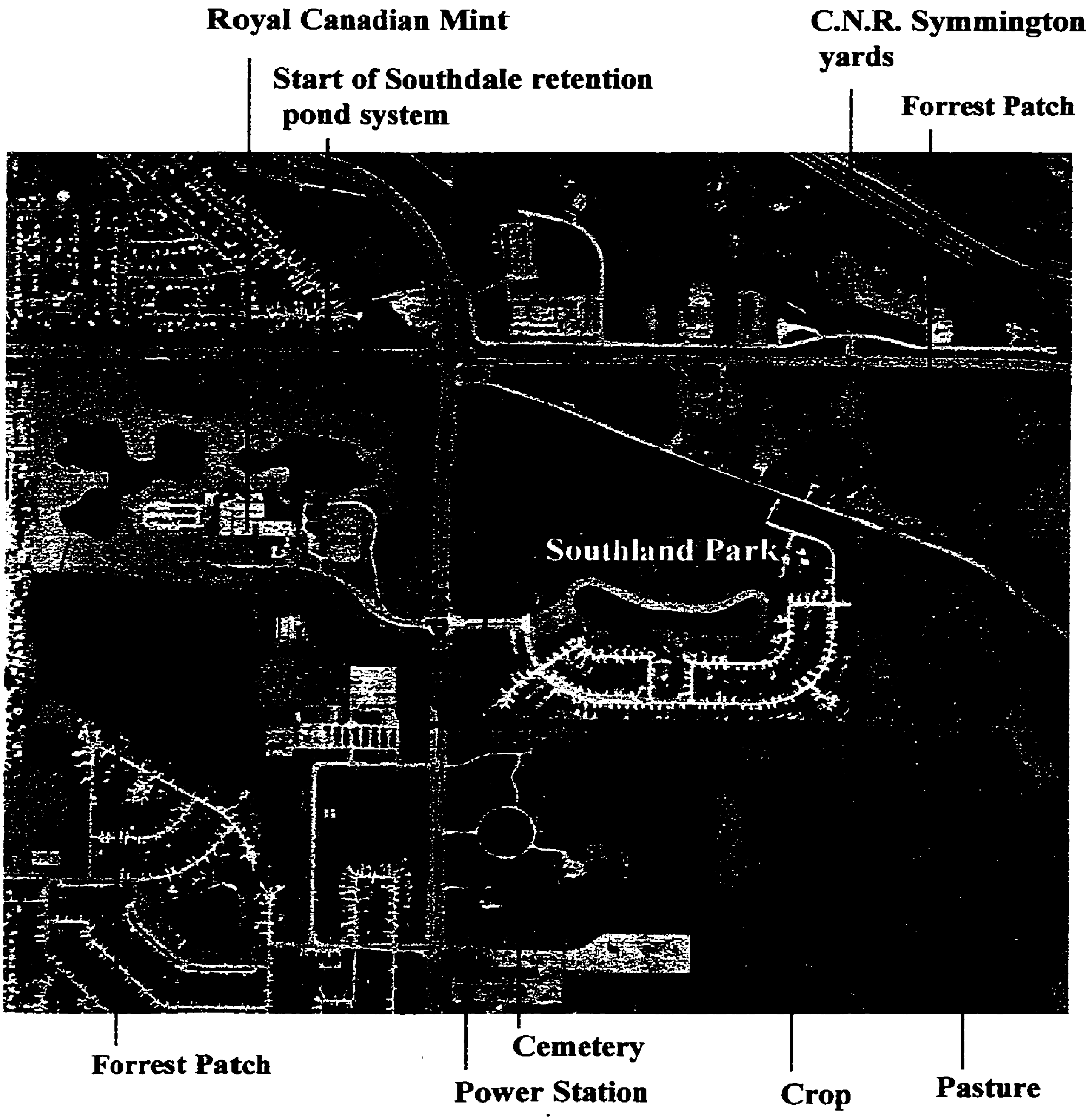


Figure 7.2 Site context
Manitoba Natural Resources

Context

Presently, the development of Southland Park is bound on two sides by major roads. Highway #1 is on the north and Rue Lagimodiere is to the west. A farm with grazing cattle presently exists to the east, and a cemetery lies directly to the south, with a power substation directly beyond that. To the north lies a house, which was associated with the land on which the site has been developed, and a patch of Aspen forest. Beyond Lagimodiere picturesque Royal Canadian Mint, breaks the skyline.

The Mint, in its park setting is probably the only notable item which a view could exploit. The pasture may be a desired scene for some, but, it provides no landmark from a distance and will likely be developed at a later date. To the north, the commercial nature of the highway, along with noise, does not provide opportunities for view or linkage. The northwestern corner provides an opportunity for some linkage to land which is in a fairly natural state.

The roadways which surround this site have implications for the possibilities of development. They bisect the landscape and hinder pedestrian and wildlife movement from the site to nearby areas. The roads naturally lack aesthetic appeal, but, the traffic creates noise. Currently, the access point of Southland Park is also the access point of the Mint.

Figure 7.3 Pasture

Figure 7.4 Cemetery

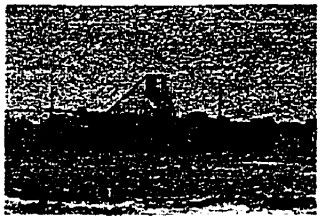


Figure 7.5 View of Canadian Mint

Soil

The construction of a retention pond is dependent on the soil in which it is constructed. The permeability of soils will affect the water holding capacity of the basin. Sandy soils will allow rapid infiltration of accumulated runoff, while clays tend to hold water. The soil in the area tends to be primarily Osborne clay, which is described as being slightly saline, with poor to very poor drainage. The permeability is <.05 in/hr and the native vegetation typically supported on this soil is meadow grasses, sedge, reeds, cattails, and some willow (Michalyna 1975).

To ascertain the ground water and soil depth one must extrapolate from information gathered from wells drilled adjacent to the site. The depth of clay extends down 39ft.on the northern side of Fermor, and 48ft. on the western side of Lagimodiere, on the Mint's property

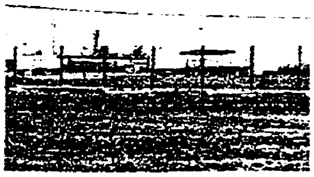


Figure 7.6 View of Fermor Ave.

Figure 7.7 View of Fermor

(All photos by author)

(Charlson 2000).

Topography

The topography of the site is typical of the Winnipeg area - flat. The existing terrain does not particularly present obvious choices for locating a retention pond, but nor does it restrict the placement of such an excavation.

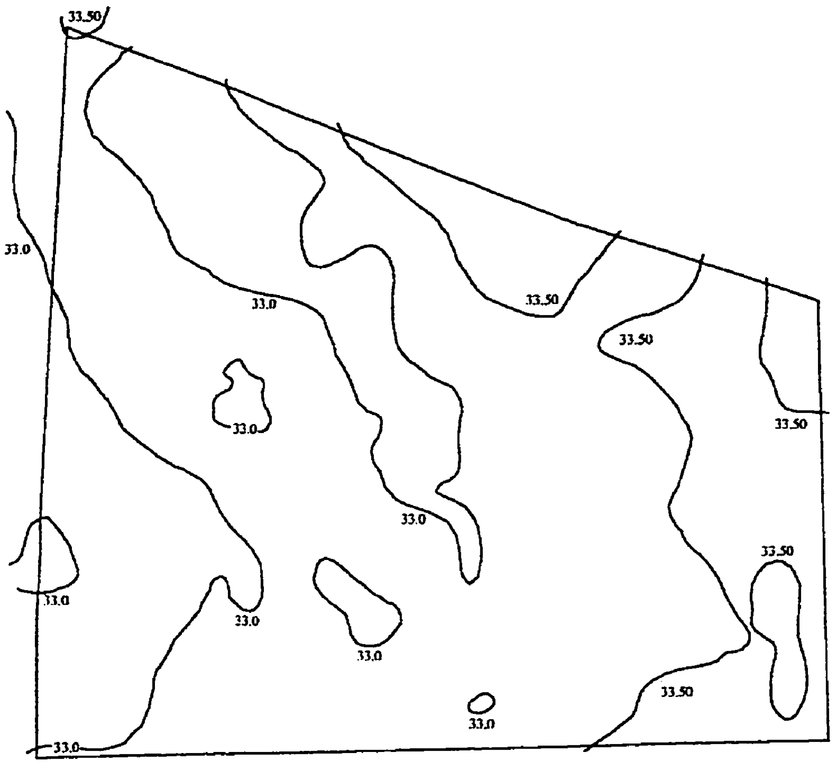


Figure 7.8 Topography (Wardrop Engineering 1987)

Vegetation

As the site has already been completely disturbed, and mostly developed it is difficult to ascertain the vegetation. Adjacent to the site there is a small patch of aspen forest, and pasture which has small parts of sedge meadow. The site would thus be typical of aspen parkland which has been disturbed for agriculture. If that is the case then the vegetation does not present important issues such as preservation.

Water

It is important to know the level of ground water as it will influence the hydrology of the pond. A natural wetland can recharge groundwater, or groundwater can recharge the retention pond. In certain cases the groundwater is under pressure, and an excavation could cause flooding, and a reduction of ground water levels. This depends on the depth of the wetland. The stormwater could also contaminate the aquifer, if the stormwater is contaminated, and it seeps into the groundwater without sufficient filtration as it passes through the soil. This will not be the case since the groundwater is so deep. At the mint limestone bedrock is 50 feet down, and the water is below that. The well is drilled to a depth of 300 feet (Charlson 2000).

Another issue which may be of importance, is where the site drains to. The current retention pond drains into a conduit that heads south along Lagimodiere, and then west beside Bishop Grandin Boulevard until it empties in the Seine River. The forcemain for the site runs out along East Mint Place, and originates from the west end of the basin (Wardrop 2000).

Water quality

The water quality of the retention pond being constructed at Southland Park has not been adequately assessed since it has just been completed, and the subdivision is still yet to be finished. One can, however, expect it to be similar to other retention ponds in Winnipeg, having problems with BOD, DO, and phosphorus. Chambers and Tottle's (1980) study of stormwater retention ponds dealt primarily with two systems. The Southdale system, is just across Lagimodiere, starting on the property of the Mint, and one could presume that a retention pond in Southland Park would yield similar water as the Southdale system. If the retention pond were designed in a similar manner, then it would likely discharge water of similar quality.

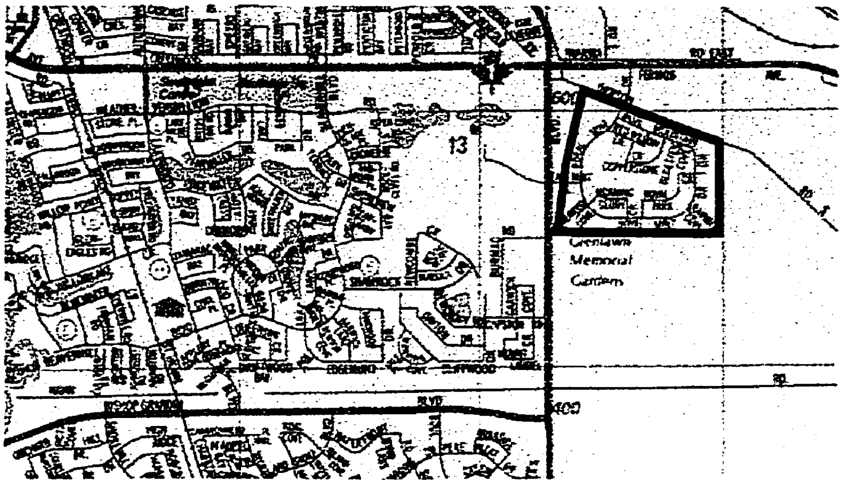


Figure 7.9 Southdale drainage pond system
Rand McNally

Since Southland Park lies outside the area of Winnipeg which relies on combined sewers for stormwater drainage (Manitoba Environment 1992), then its drainage will have no effect on CSO's. The water, taken from the site, will eventually make its way into the Red River, and if its quality is poor it will only exacerbate any water quality problems already caused by water from combined sewers, separate sewers, pollution control plants, and other retention ponds. The water from the site drains into the Seine River, which is much smaller than the Assiniboine and Red Rivers. This means that the Seine River has even less ability to dilute contaminated runoff, and it is even more important that it receives water of adequate quality.

Existing Development

As Southland Park has been constructed it is similar to other recent developments in Winnipeg. There is a simply shaped retention pond, which is fed by underground pipes, except for a small piece of land around the perimeter of the water body, which drains directly into the pond. There is a fairly substantial sodded portion adjacent to the reservoir which comprises the public reserve. Another substantial section is comprised of large private lots, with their sizeable houses, which run up to the edge of the water.

Figure 7.10 Existing plan

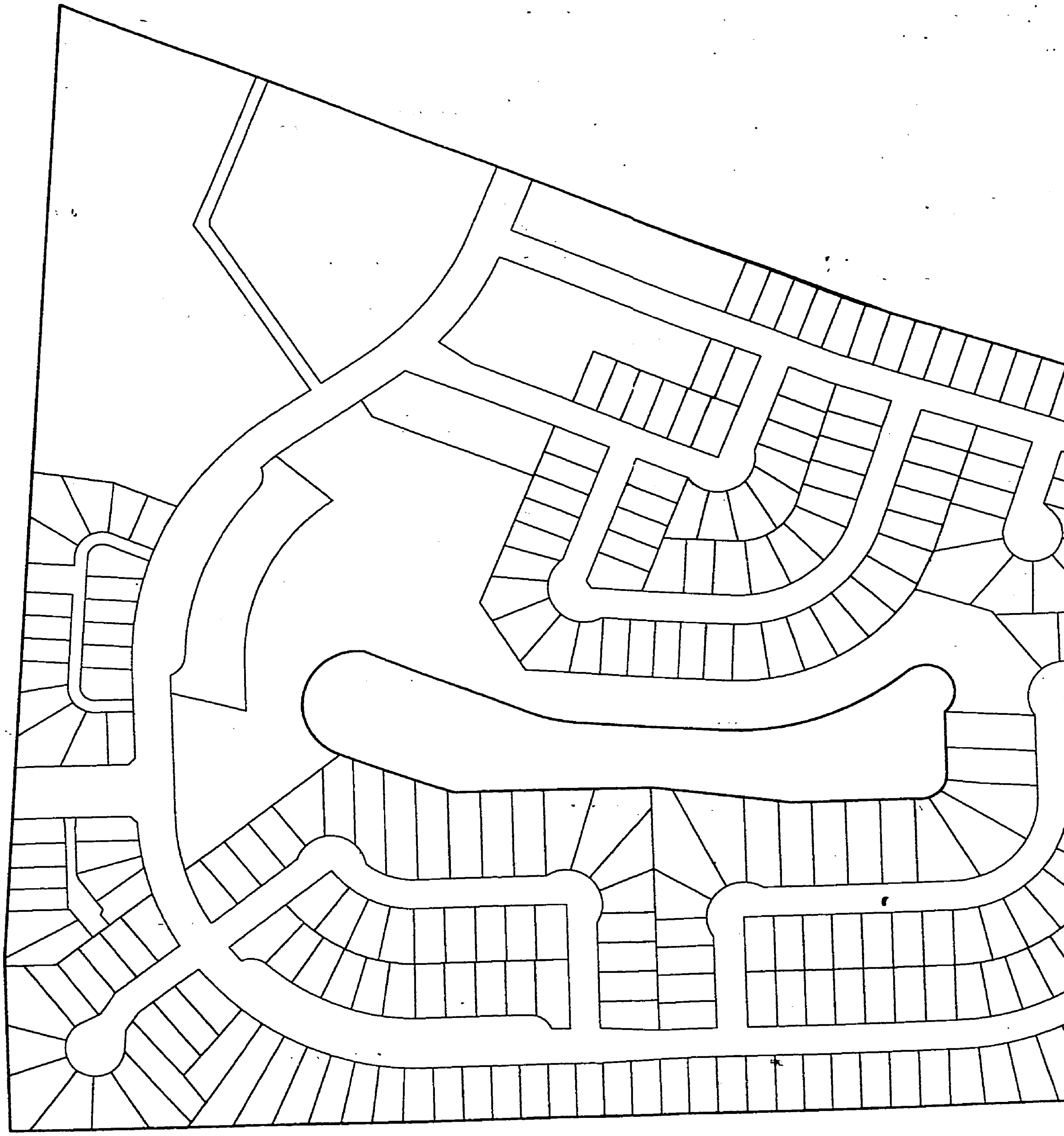
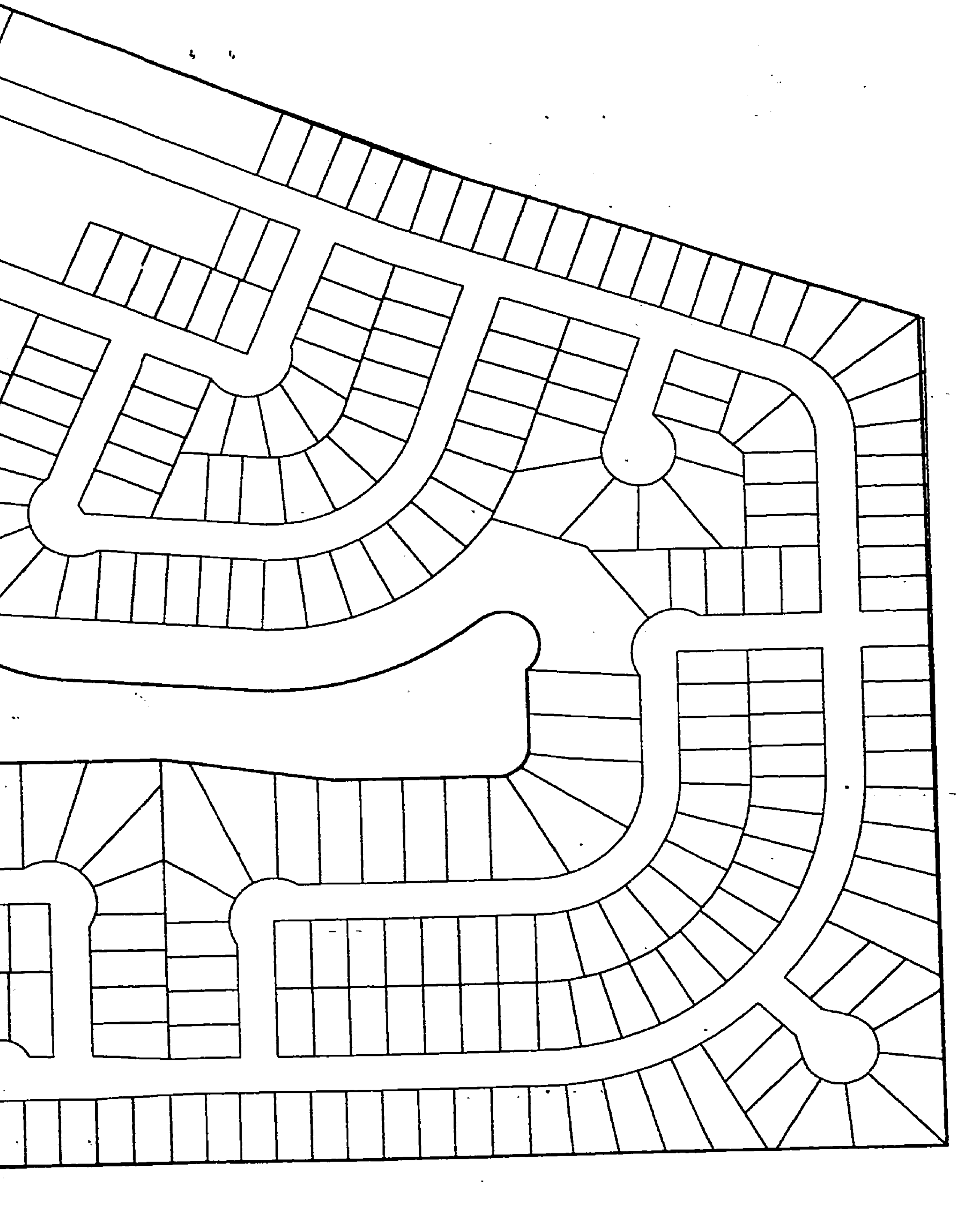
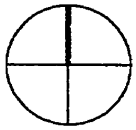


Figure 7.10





Southland Park
Existing Plan

Access

The public access originates from the two areas on either end of the basin. For the lots that are not contiguous with the pond, the access routes to the retention pond are not clearly delineated. People from houses which are near the edges of the development have a long and circuitous route if they want to walk to the pond. Pedestrian movement around the pond is limited by the privately owned lots. There are no landscape elements such as bridges, boardwalks, or other viewing areas which provide closer association and views of the pond.

Shoreline ownership

Figure 7.11 Public Reserve

Private lots directly adjacent to the pond tend to have the same type of plants that exist on the public shore: mown turf, and occasional trees. If vegetative buffer strips were to be used then coarser plant material such as willows, tall grasses, and emergents would work best. The coarse plant material, that would help filter and remove contaminants from runoff, is lacking.

Park

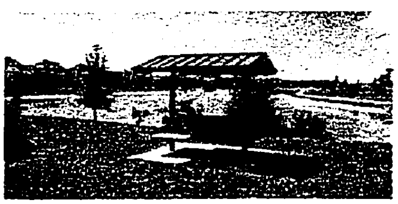


Figure 7.12 Sheltered Bench

The park around the pond is sodded with non-native grass, which offers little resistance to runoff. There are no clearly defined spaces in the park, and park elements are not arranged relative to plant material. There are no transitions between park and pond, and plant communities do not recognize topographic gradients as they would in a natural environment. The plant diversity does not exist, and there is little cover to provide habitat. There are trees in the park, but no forest. Again typical vegetation structure with herb, shrub, and tree canopy does not exist, and there is no typical plant communities. If native vegetation is used then a richer environment should result.

Edge

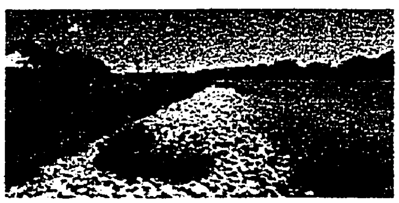


Figure 7.13 Gravel Edge

The edge of the water is where one would expect to find emergents. Instead there is a consistent edge of gravel. Chambers and Tottle (1980) said the city desired a gravel shore to slow the growth of emergents, and to prevent erosion. The addition of crushed rock represents an unnecessary expense since aquatic plant growth should be encouraged and because emergents themselves will prevent erosion.

Aesthetic

The aesthetic of the pond and park seems to be simple and bland. The shape of the pond is simple, and the vegetative structure is simple. The most dominant item in the landscape are the houses especially the larger ones with private shoreline. In an attempt to exploit the proximity of the neighbouring houses to the park, the park has been crowded by the houses, and the park's value has been diminished.

Figure 7.14 Dominant Houses

House Placement

The houses in this subdivision are typical of other locations in Winnipeg, where the house is placed halfway between the street and the end of the lot. This creates a front yard as big as a back yard, despite the fact that people never actually use their front yards except for approaching their houses.

If the typical approach was not used then there would be more room in the back yard. There would be more room for activities where outdoor activities actually occur, and backyards would take on a more park-like quality. If more overland drainage was used then there would have to be more space allotted to that purpose. This would create a more urban feel to the front of the street, which would more closely resemble the higher-density housing already on one part of the site.

Figure 7.15 Higher Density Housing

Cul-de-sacs

The cul-de-sacs have paving-stone islands, which lack interest. Not only do they lack interest, but the pavers provide no function. These islands tend to have a bleak look, they increase runoff, and will tend to thermally contaminate runoff when it washes over the islands.

Figure 7.16 Cul-de-sac

Conclusion

The site lacks exceptional characteristics, in architecture, topography, hydrology, soil, and, as far as is evident, vegetation. Conversely, the site also lacks factors which will prohibit construction. The soil is well suited to holding the water that would be channeled into it. The ground water is deep enough to prevent it from being contaminated by stormwater. The till and bedrock are also deep enough so as not to interfere with excavation, but, it is not close enough to provide any rock or gravel which could be used in the landscape. The original site is much like a blank slate.

The site that was developed also seems to lack interesting characteristics. The pond shape, and structure, the vegetation of the park and pond is bland, and the streets are typical. The drainage system is typical of other subdivisions, and this system will yield poor water quality as do the others.

The subdivision can be improved starting from the retention pond and working out. The pond can be designed to:

1) Incorporate more plant material.
2) Have a more interesting shape. A more complex form will be more interesting, and can increase the length of the pond which helps the plants to filter the water.
3) Have pedestrian circulation which has a more dynamic interaction with the water. Using bridges and boardwalks can bring people in closer proximity with the water landscape.

The area around the park can be developed differently. The perimeter around the pond should have:

1) Coarse vegetation such as emergents and shrubs. The vegetation would give a more interesting and natural aesthetic, while it more efficiently cleanses runoff.
2) A more diverse, plant population which is comprised of more native species. More native plant material can be used to provide better food sources for birds, or other animals. The native plants, when established, will require less management, and provide more benefit.
3) There should be an adequate buffer between the private lots and the pond, where the general public is allowed to pass.

Overland drainage provides an opportunity to use swales or channels which create interest. If a right-of-way is necessary for the swales, then that same corridor can also act as a pedestrian circulation route. This level of narrow public spaces would separate pedestrians from vehicles and lead people gently towards the retention pond at the centre of the community.

Because the site is flat it would be difficult to channel all the water above ground. Some underground pipes could be used. Also some smaller temporary ponds could be used, especially in the northwest corner of the site, which is the farthest away from the centre of the site. Sedimentation and plant filtration could be used on a small scale at the intake of some conduits. This will provide smaller more dynamic wetlands.

Remediation of water, interesting aesthetics can be part of wildlife habitat which people could also enjoy. It could all occur simultaneously in a suburb based around a retention pond drainage system.

The neighbourhood of Southland Park and its accompanying retention pond are composed of a series of elements. Each of which has characteristics that affect their performance. The design of these elements, is based on a compromise which shall accomplish the best mix of the goals of improving water quality, providing habitat, and producing a more interesting park and pond which is more accessible to the people of the neighbourhood.

Pond Shape

The shape of the pond will have determinant effects on stormwater decontamination, and pond hydrology. Simple shapes tend to have geometries that conserve water, because of reduced edge. The shape of a simple water body will have reduced perimeter which will increase the absorption of water, since it occurs more rapidly at the edge of a waterbody (see Chapter 6). Simple shapes are therefore, generally, more stable than complex, sinuous shapes. This is important at Southland Park since, in Winnipeg, a typical suburban watershed will yield a water 89body which is about 5% of the catchment area (UMA 1992), and, that would amount to 2 ha (see Chapter 6), which is about the minimum size of a permanent marsh on the prairies.

A pond of more complexity will increase the length of flow from where water enters the pond, to where it drains. This will increase the ponds ability to remove contaminants, as it extends the distance the water travels through cleansing aquatics. A more linear or more complex shape will also favour increased length of recreational circulation paths that surround a pond.

Another aspect of pond shape that is important is how various parts or channels come together. Channels should open up to larger parts of the pond to ensure that entering water is spread evenly throughout the waterbody,

Figure 8.1 Planting Plan

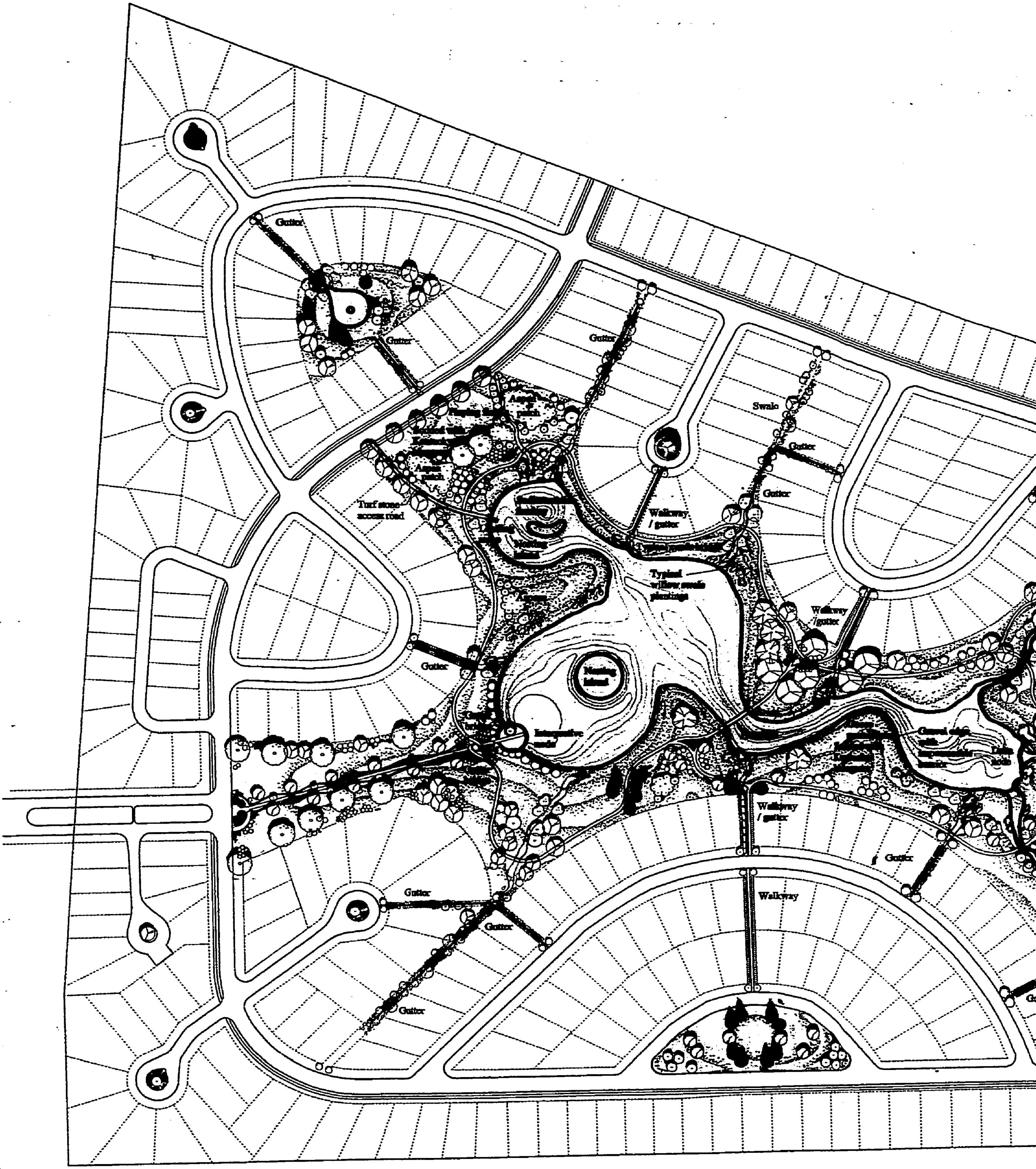
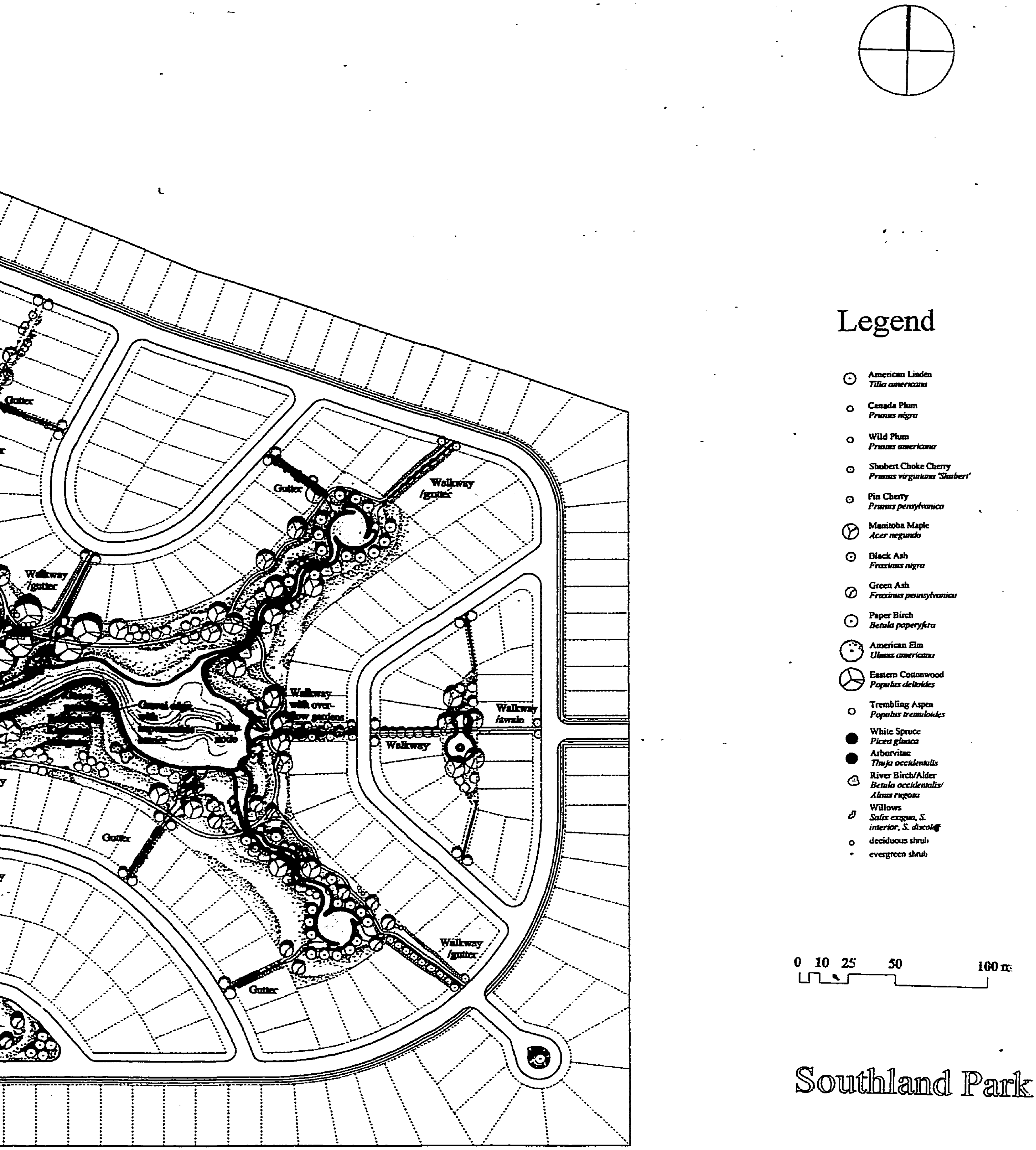


Figure 8.1 Planting Plan



Gutter
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Legend
American Linden
Tilia americana
Canada Plum
Prunus nigra
Wild Plum
Prunus americana
Shubert Choke Cherry
Prunus virginiana 'Shubert'
Pin Cherry
Prunus pensylvanica
Manitoba Maple
Acer negundo
Black Ash
Fraxinus nigra
Green Ash
Fraxinus pennsylvanica
Paper Birch
Betula papyrifera
American Elm
Ulmus americana
Eastern Cottonwood
Populus deltoides
Trembling Aspen
Populus tremuloides
White Spruce
Picea glauca
Arborvitae
Thuja occidentalis
River Birch/Alder
Betula occidentalis/
Alnus rugosa
Willows
Salix exigua, S.
interior, S. discolor
deciduous shrub
evergreen shrub
0 10 25 50 100 m
Southland Park

Figure 8.2 Wetland Classification

33.5
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31.5

Figure 8.2

Deep zone
(open water)

Semipermanent Zone
(submergents and
tall emergents)

Shallow Zone
(seasonally
flooded emergents)

Temporary pond
(sedge meadow)

Ephemeral pond

0 10 25 50 100 m

Southland Park

Wetland Classifications

thus preventing 'dead zones' of stagnant water.

The design of the retention pond will have to consider the factors of water permanence, as well as cleansing ability, aesthetics, and recreational objectives when determining the shape of a pond. This pond was laid out, to create a longer length of flow, without unduly compromising water volume through increased absorption.

Proposed Existing

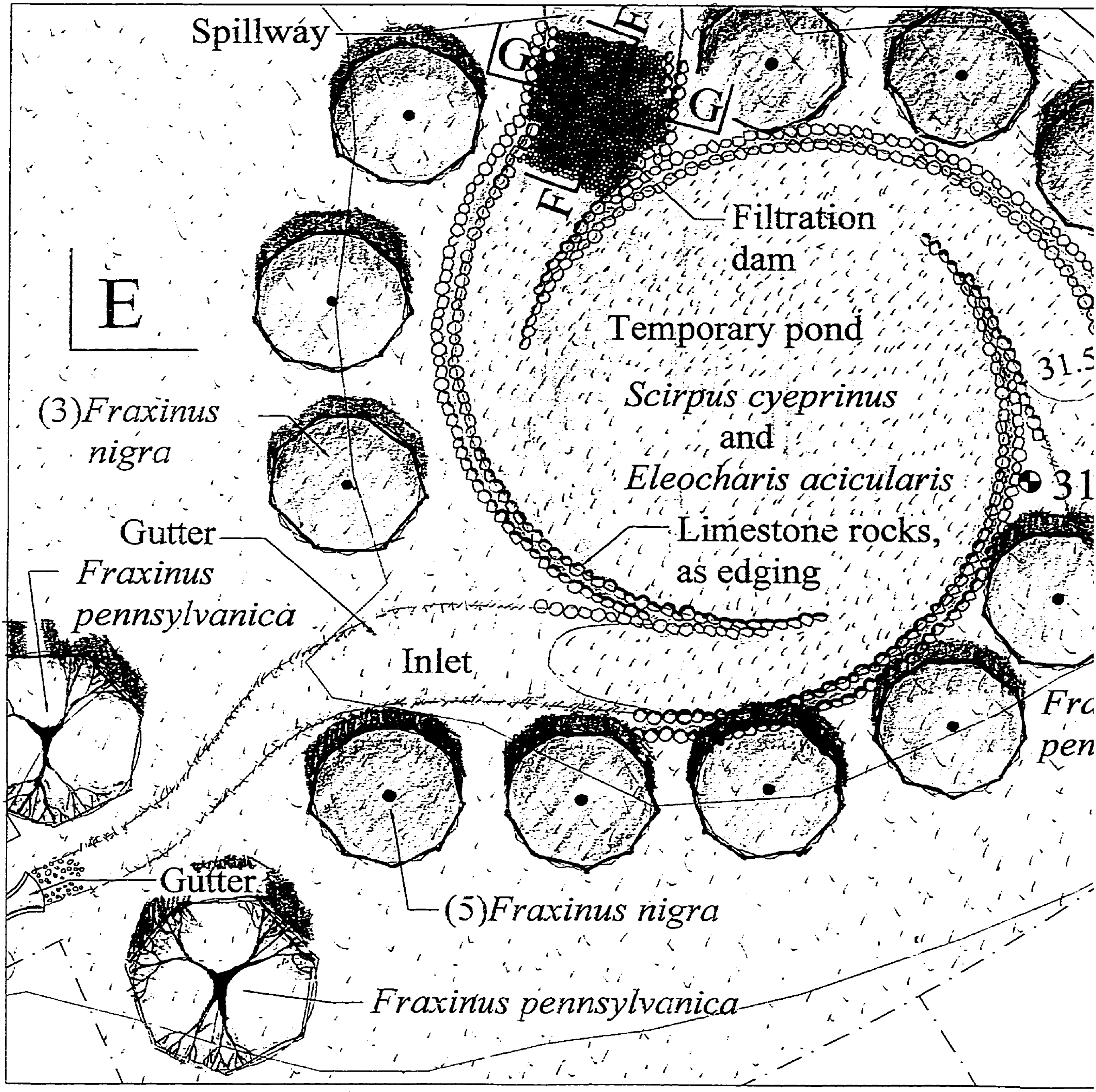
Figure 8.3 Shape comparison

Pond Depth

The water depth will help determine aspects of vegetation, water temperature, and viability of animals such as fish. Water depths should be such that desired plants, and animals can be accommodated. Since both fish and waterfowl need a substantial emergent cover for success, then appropriate water levels should be used to encourage this. The 5-30cm water depth will encourage the growth of emergents (see Chapter 6). Water depths approaching 1.5m are adequate for submergents species, and water over 2m should remain open, which will provide visual appeal. At approximately 2m depth, the water is deep enough to allow fish to survive the winter under the ice.

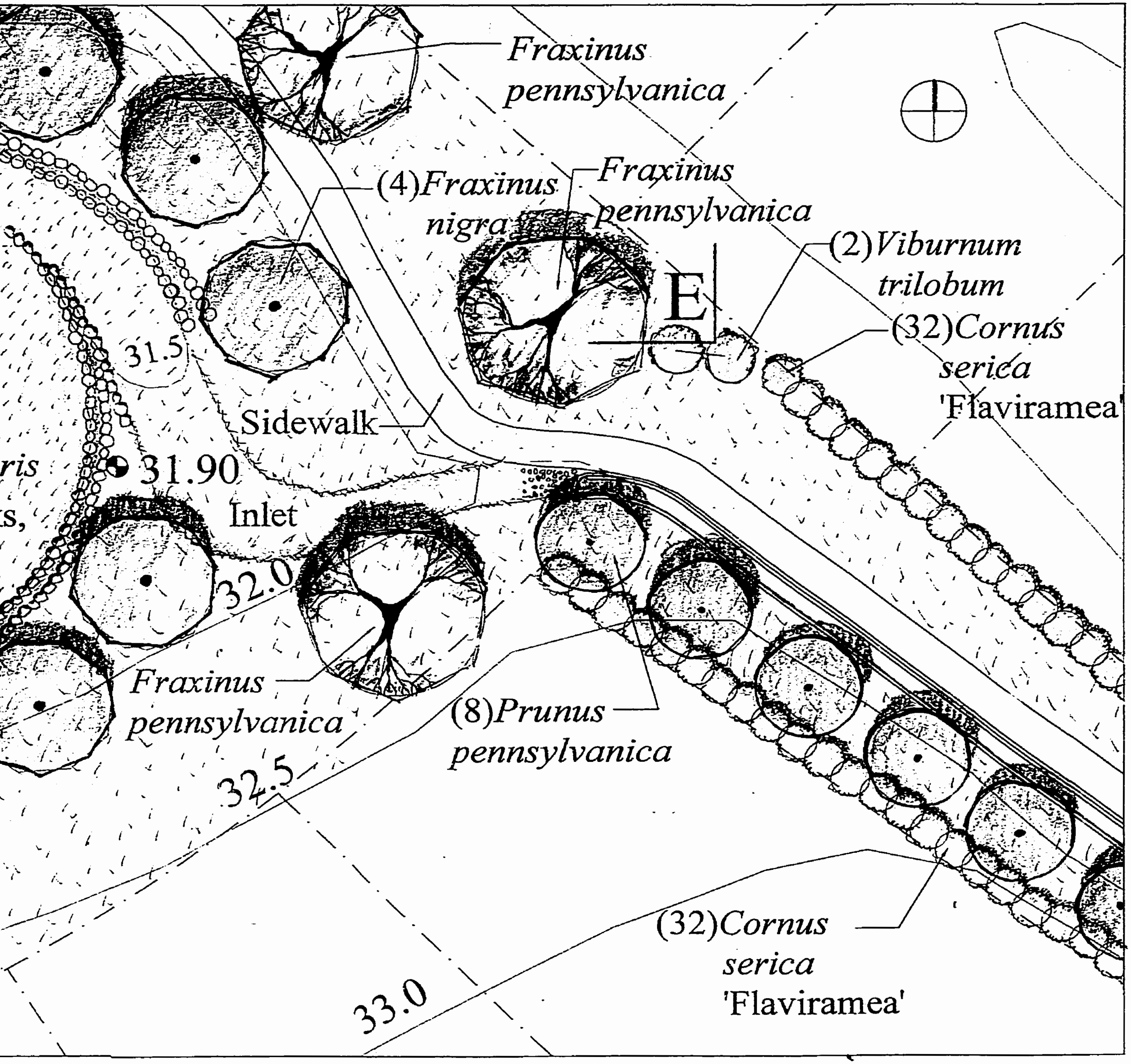
If the water is too deep, however, then more of it can flow over the aquatics, during a storm when the retention pond is draining. This means that more of the water bypasses the cleansing vegetative filter of the marsh.

Figure 8.4 Temporary pond and filtration dam



Plan: temporary pond and filtration dam

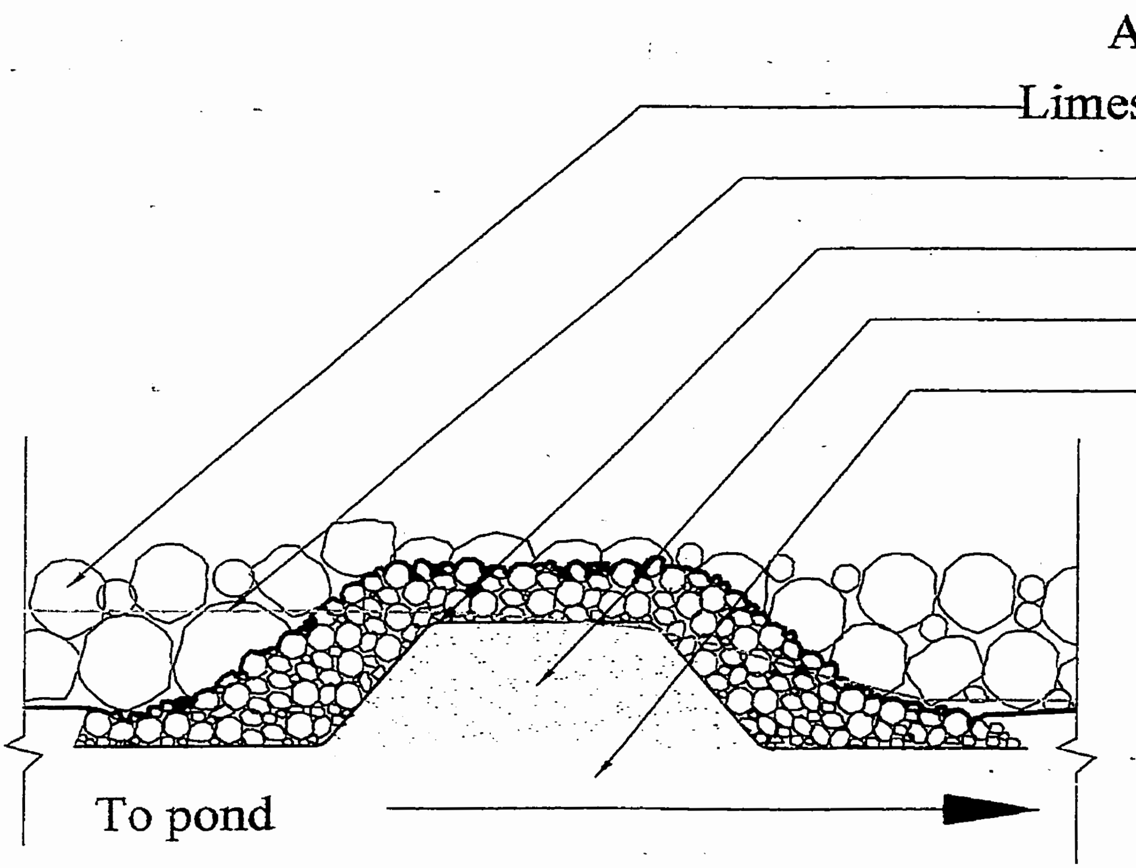
Figure 8.4


Fraxinus pennsylvanica
(4)Fraxinus nigra
Fraxinus pennsylvanica
(2)Viburnum trilobum
E
(32)Cornus serica 'Flaviramea'
31.5
Sidewalk
31.90
Inlet
ris
s,
32.0
Fraxinus pennsylvanica
(8)Prunus pennsylvanica
32.5
33.0
(32)Cornus serica 'Flaviramea'

m

Scale 1:200

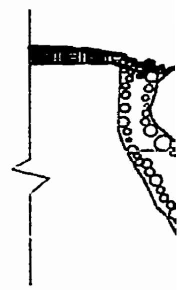
Figure 8.5 Section of filtration dam
Figure 8.6 Section of filtration dam and spillway
Figure 8.7 Temporary pond with filtration dam



F

Section of filtration dam   Scale 1:50

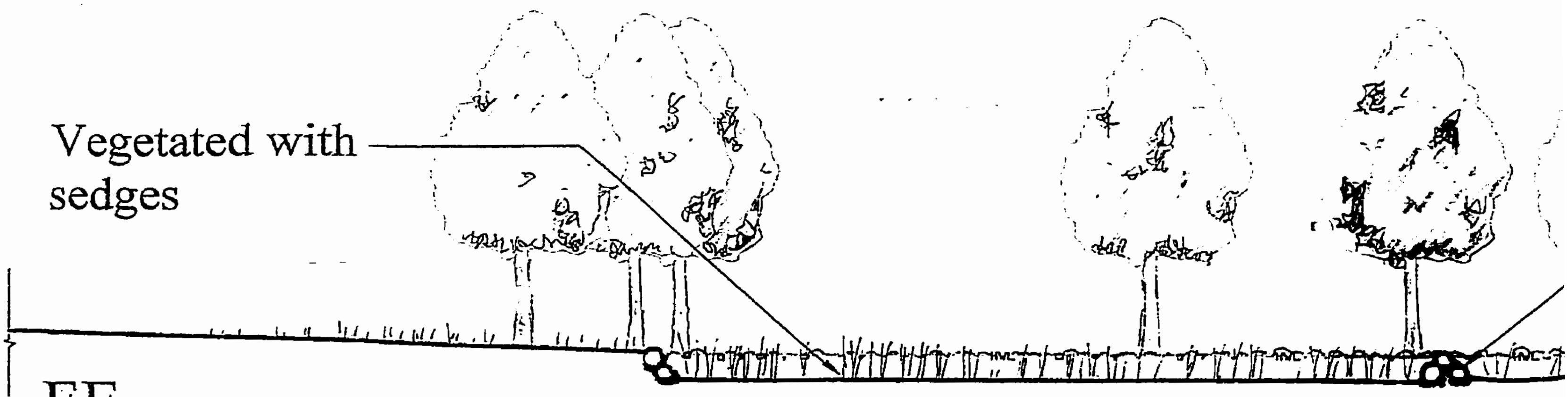
Figure 8.5 Section of filtration dam



G

Sect
dam

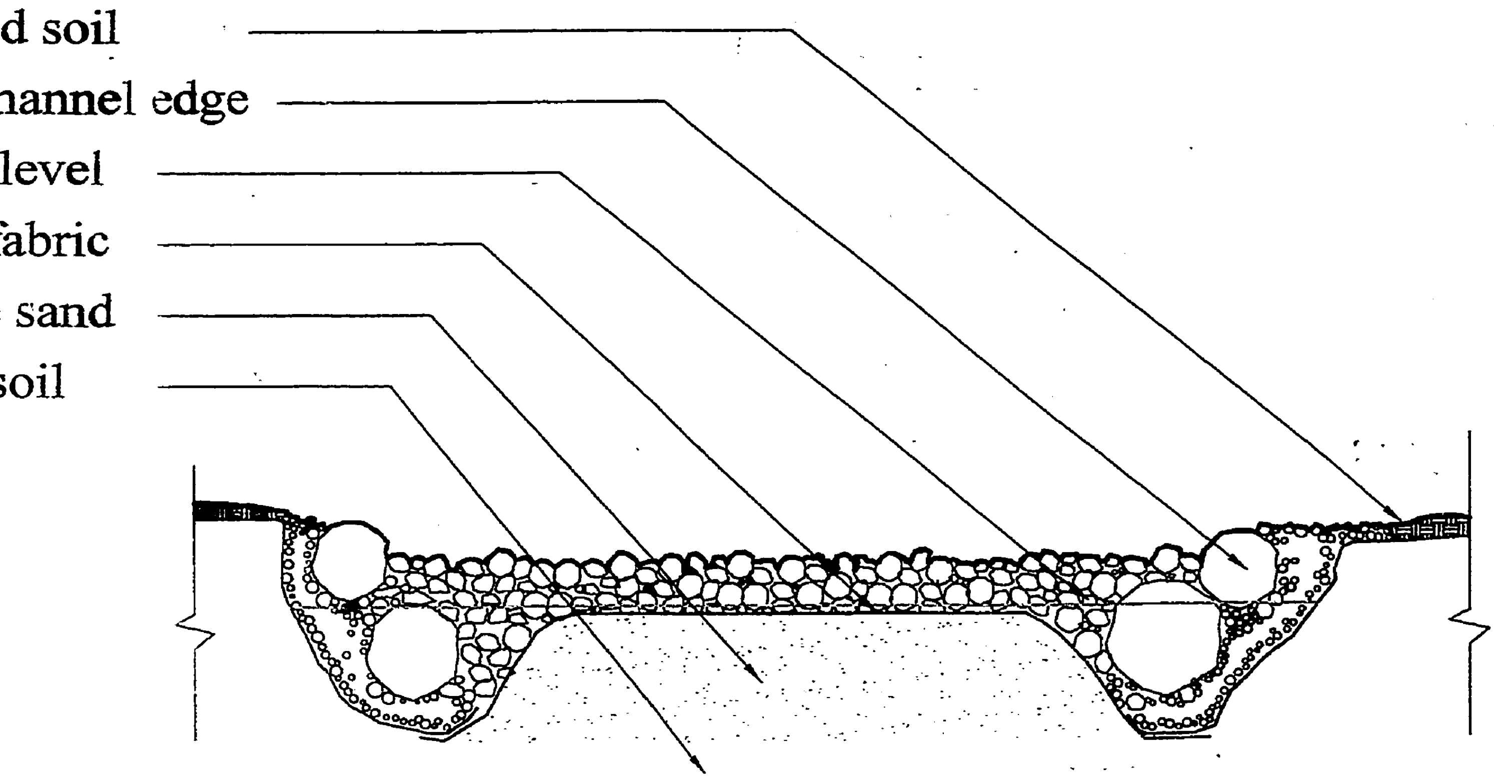
Figure 8



EE

Elevation of temporary pond with filtration dam

Figure 8.7

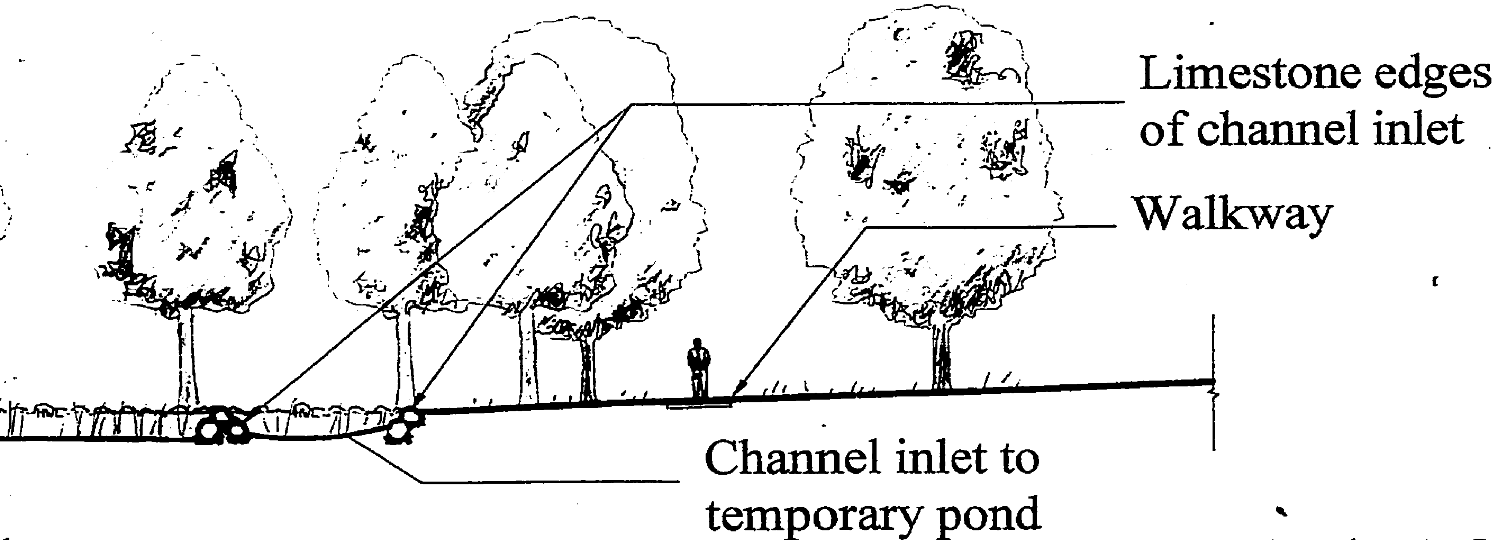


G

Section of filtration dam and spillway

Scale 1:50

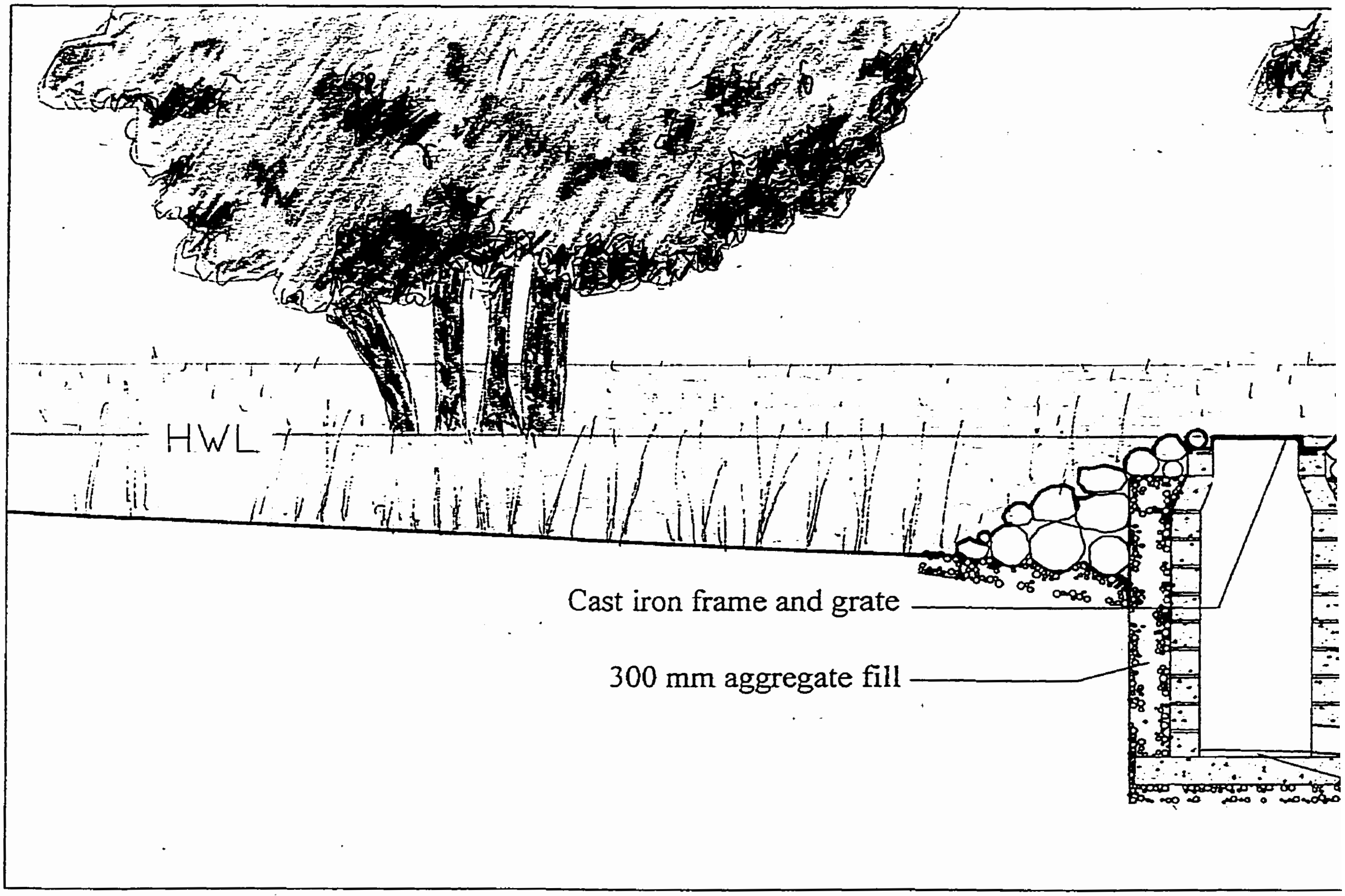
Figure 8.6



dam

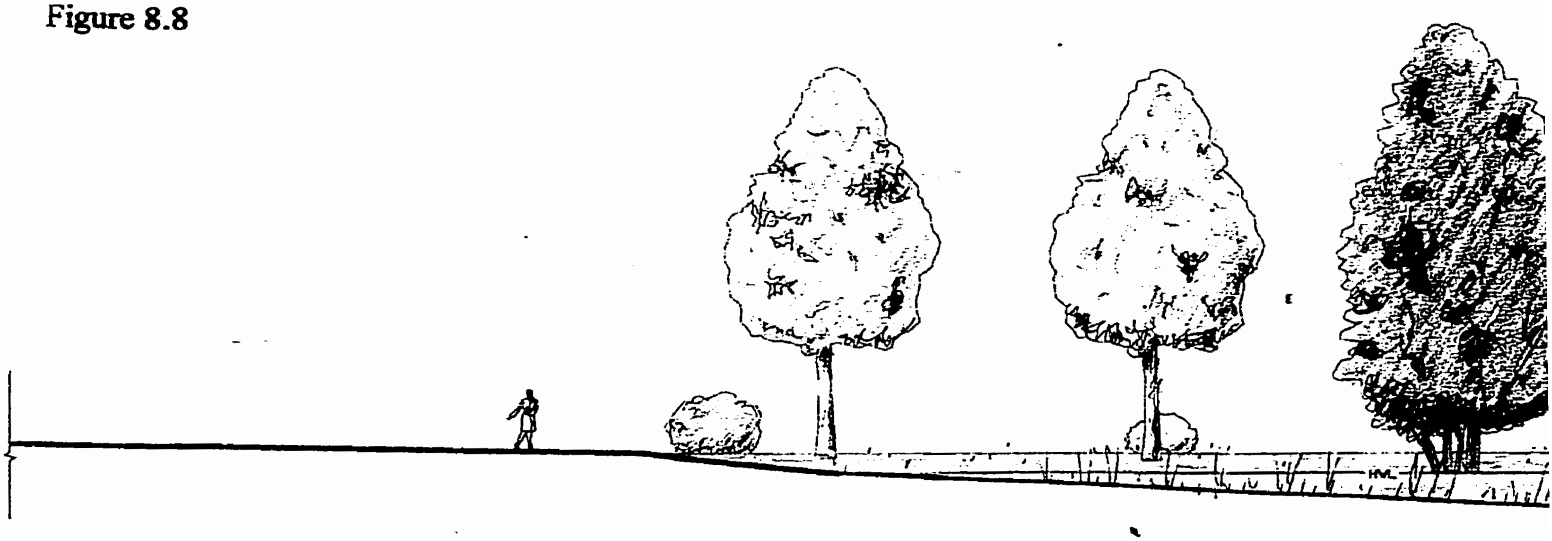
Scale 1:200

Figure 8.8 Temporary pond with filtered drainage, 1:50
Figure 8.9 Temporary pond with filtered drainage, 1: 200



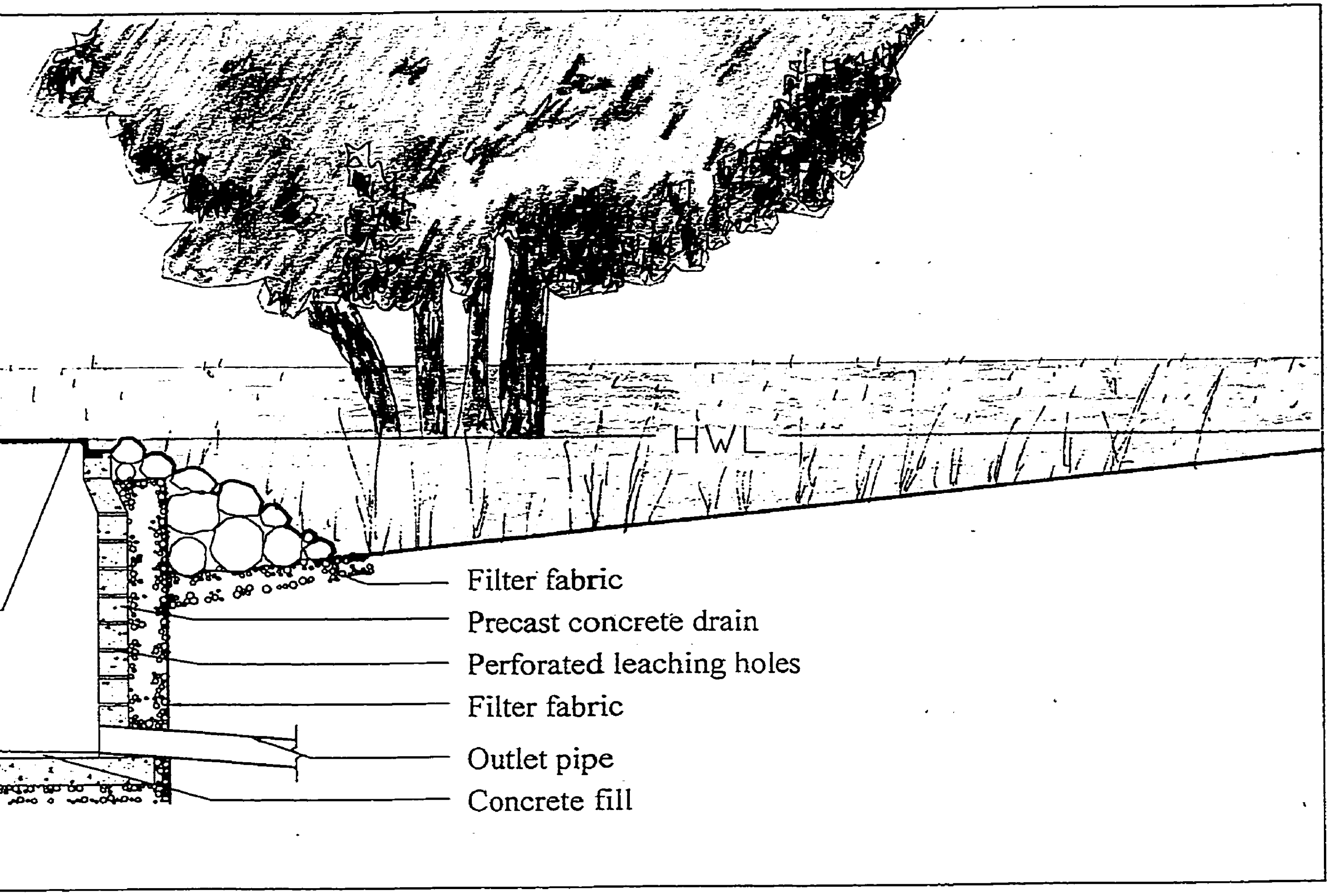
Detail: Temporary pond with filtered drainage (from

Figure 8.8



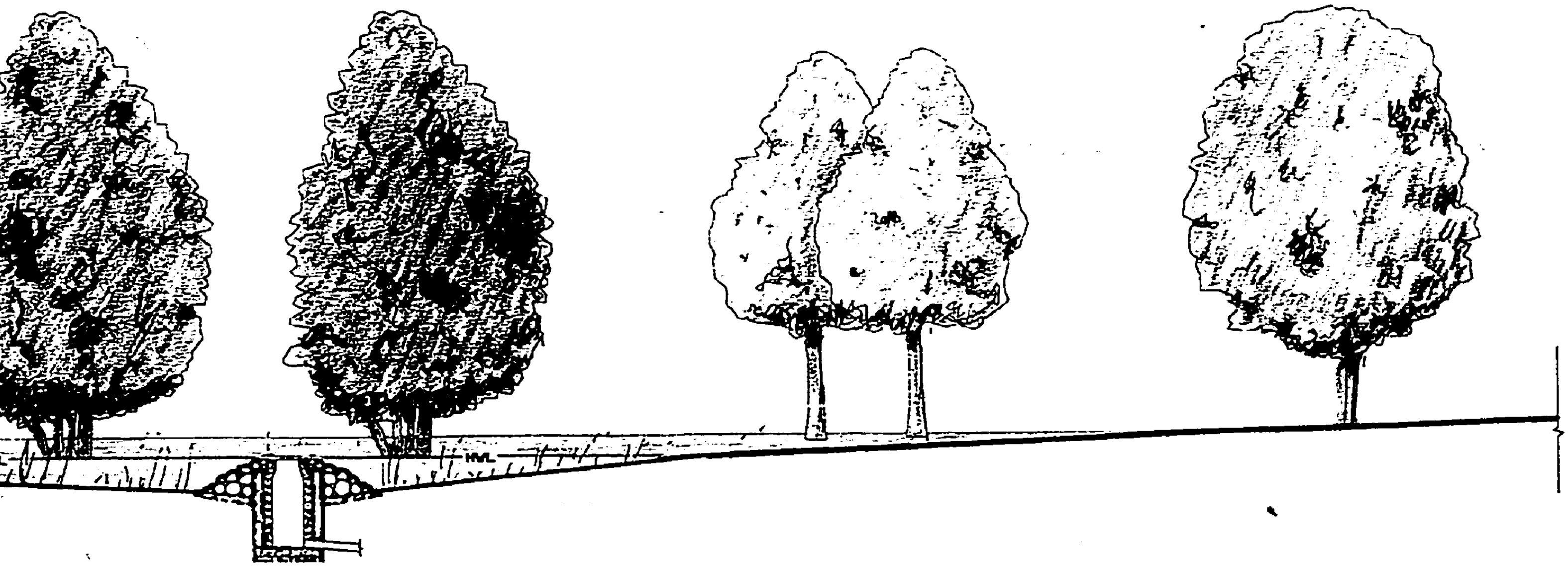
Elevation: Temporary pond with filtered drainage

Figure 8.9



from below)

Scale 1:50



ge

Scale 1:200

Shallow water can be less thermally stable, being susceptible to solar heating. However, this can be offset by the shade provided by emergents. A balanced approach is probably the best method, providing shallow, medium, and deep water, in the pond, ensuring more heterogeneous habitat, and aesthetic.

Pond Slope

The slope of retention pond desired by the city is 7:1 for the first thirty feet (Chambers and Tottle 1980). This is to provide a region of safety, allow for easier cutting of emergents, and to make banks more immune from failure. A gentle slope would likely occur in a real pothole, so this is not an objectionable goal. The use of emergent vegetation, or using coarse materials for the basin are other ways of allowing easy extrication from anyone deliberately or inadvertently entering the pond. Railings, and vegetative barriers, as well as stepped shorelines are also ways of achieving safety around the pond, while allowing a more variable shoreline geometry. A steeper pond edge can also bring open water closer to the shoreline – closer to a specific designed vantage point which could take advantage of the view of open water.

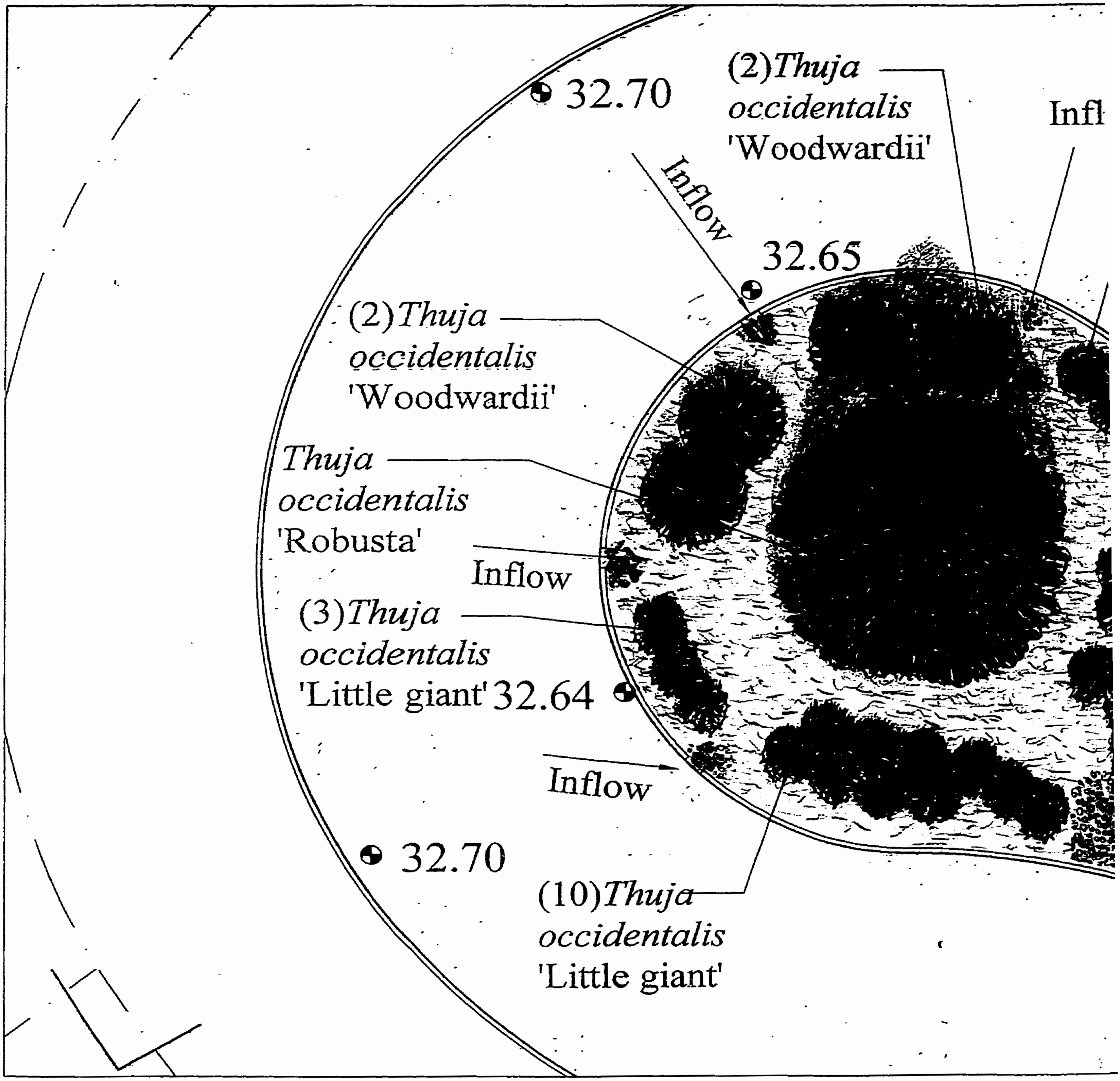
Pond Edge

The gravel laden shoreline so typical of Winnipeg's retention ponds, serves to reduce the affects of erosion, and to prevent the growth of macrophytes. The problem with this, is that macrophytes are desired for purposes of aesthetics, wildlife habitat, and water quality improvement. The shoreline could be more natural looking, and more natural functioning. Gravel used in conjunction with filter fabric, can be used strategically to provide some open shoreline, which is recommended for waterfowl (see Chapter 5)

Temporary Ponds

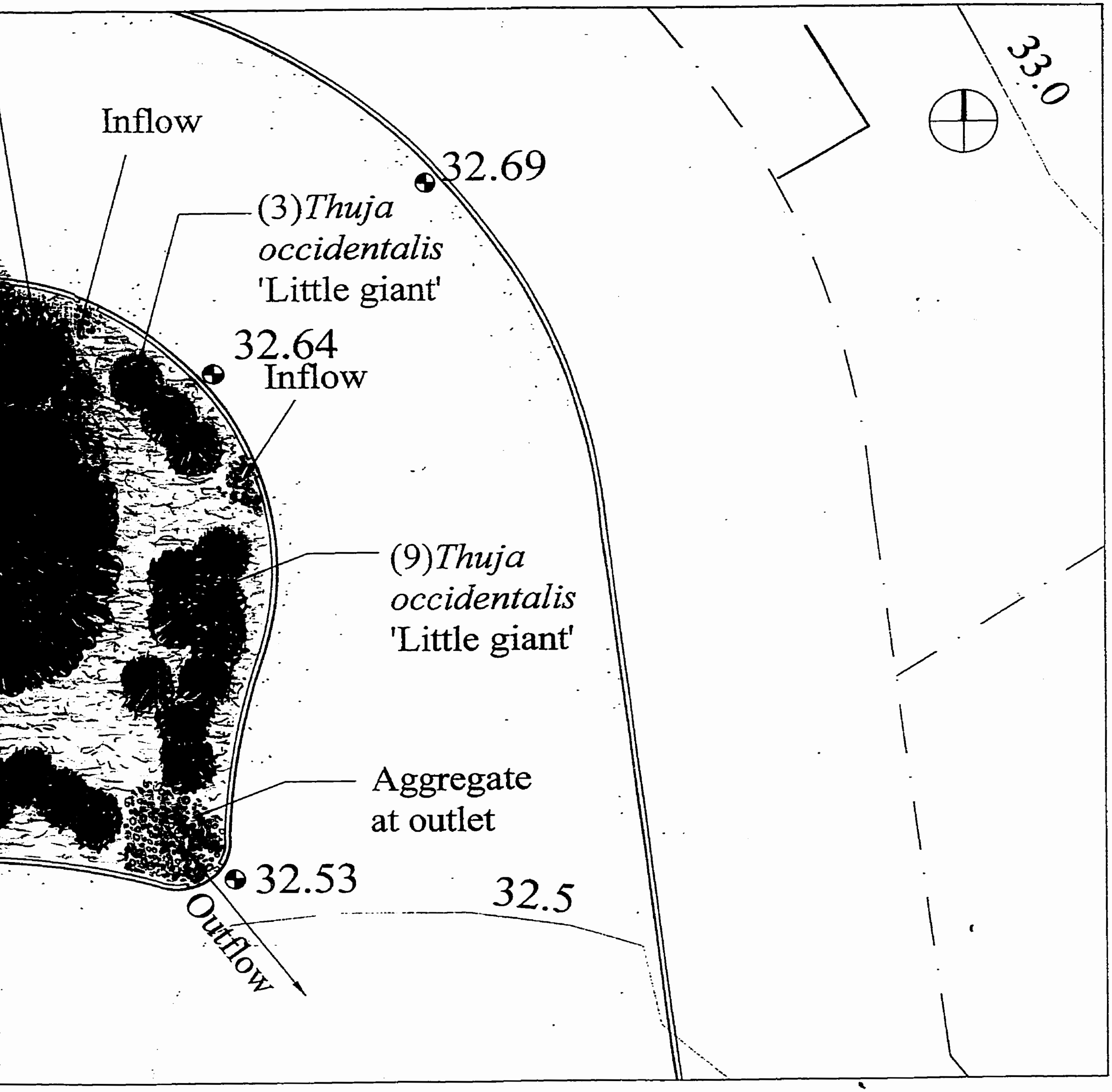
The temporary ponds use the principles of cascade ponds to aid in water quality enhancement. While

Figure 8.10 Plan of cul-de-sac



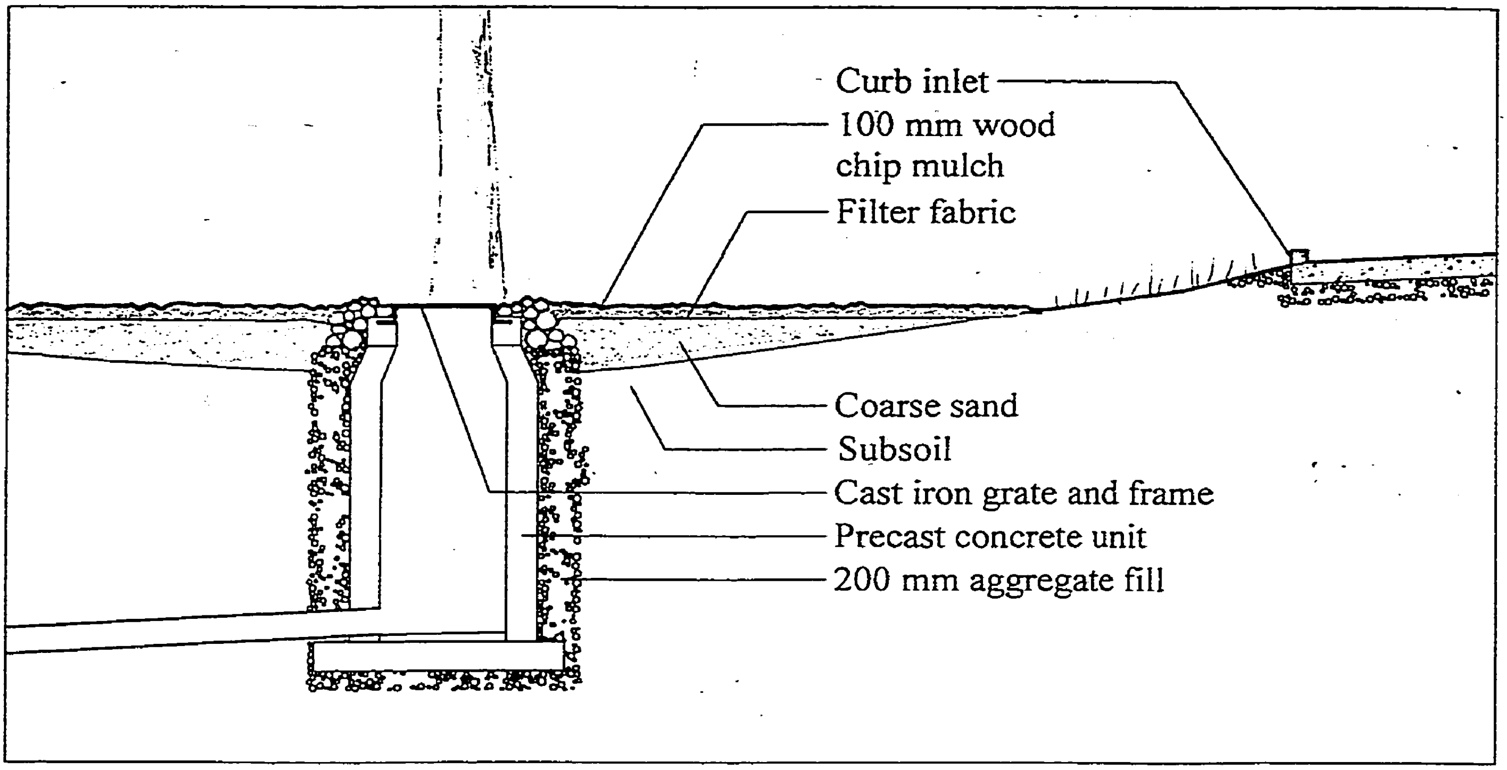
Plan of cul-de-sac infiltration island

Figure 8.10

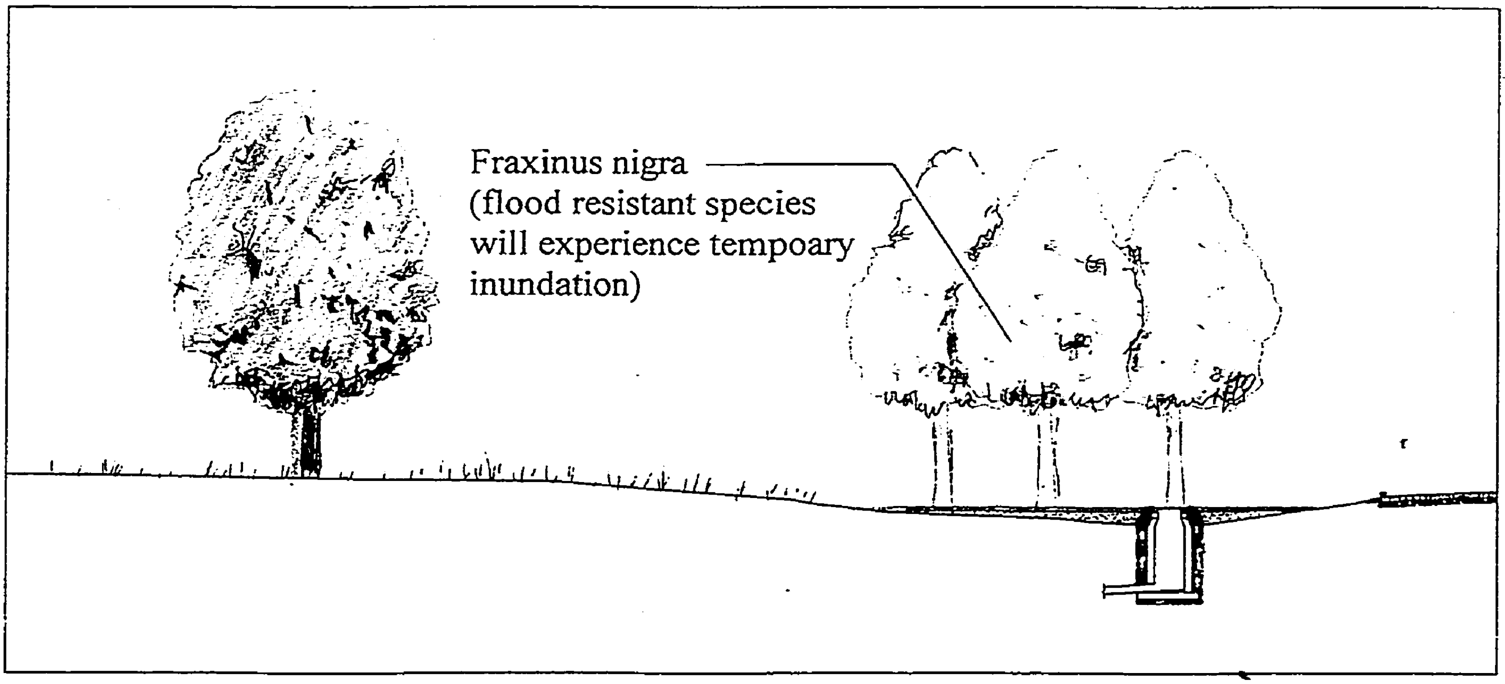

Inflow
32.69
(3)*Thuja occidentalis* 'Little giant'
33.0
32.64
Inflow
(9)*Thuja occidentalis* 'Little giant'
Aggregate at outlet
32.53
32.5
Outflow

Scale 1:100

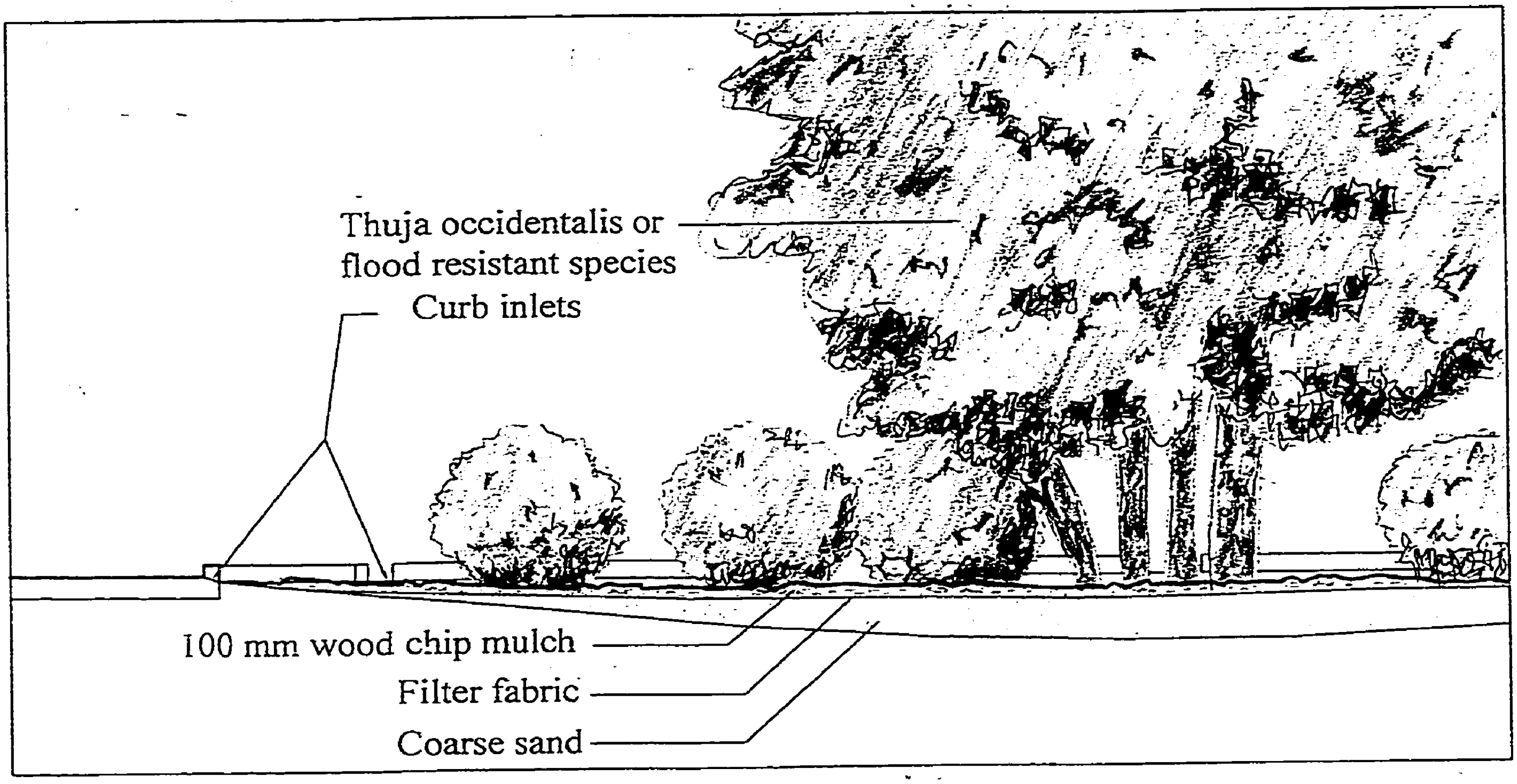
Figure 8.11 Absorption basin, 1: 50
Figure 8.12 Absorption basin, 1: 200
Figure 8.13 Cul-de-sac infiltration island, 1:50
Figure 8.14 Cul-de-sac infiltration island, 1:200



Absorption basin Scale 1:50
Figure 8.11

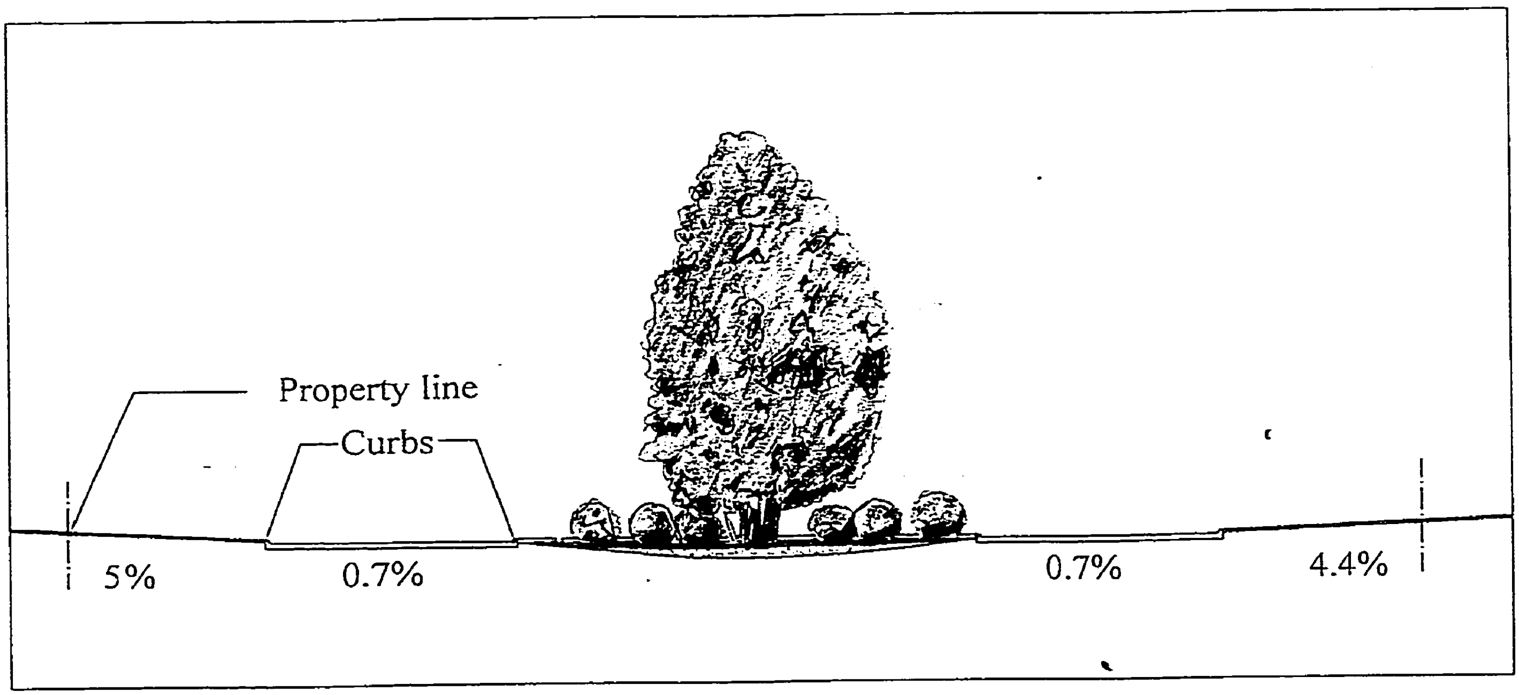


Absorption basin (detail above) Scale 1:200
Figure 8.12



Cul-de-sac infiltration island Scale 1:50

Figure 8.13



Cul-de-sac infiltration island Scale 1:200

Figure 8.14

sedimentation, filtration, and absorption are used for water quality, a new landscape element is created. An ephemeral pond, which benefits waterfowl. The pond can support different plants such as sedges, and grasses which only tolerate temporary inundation. The ponds should not hold water long enough for mosquito larvae to develop.

Lookout Node

The lookout provides a place for relaxing, which is conveniently overlooking open water. It provides a location for interpretive signs which explain goals for the retention pond in terms of pollution control, and habitat creation. Trees provide shade which prevents excessive algae from accumulating in an area immediately adjacent to people.

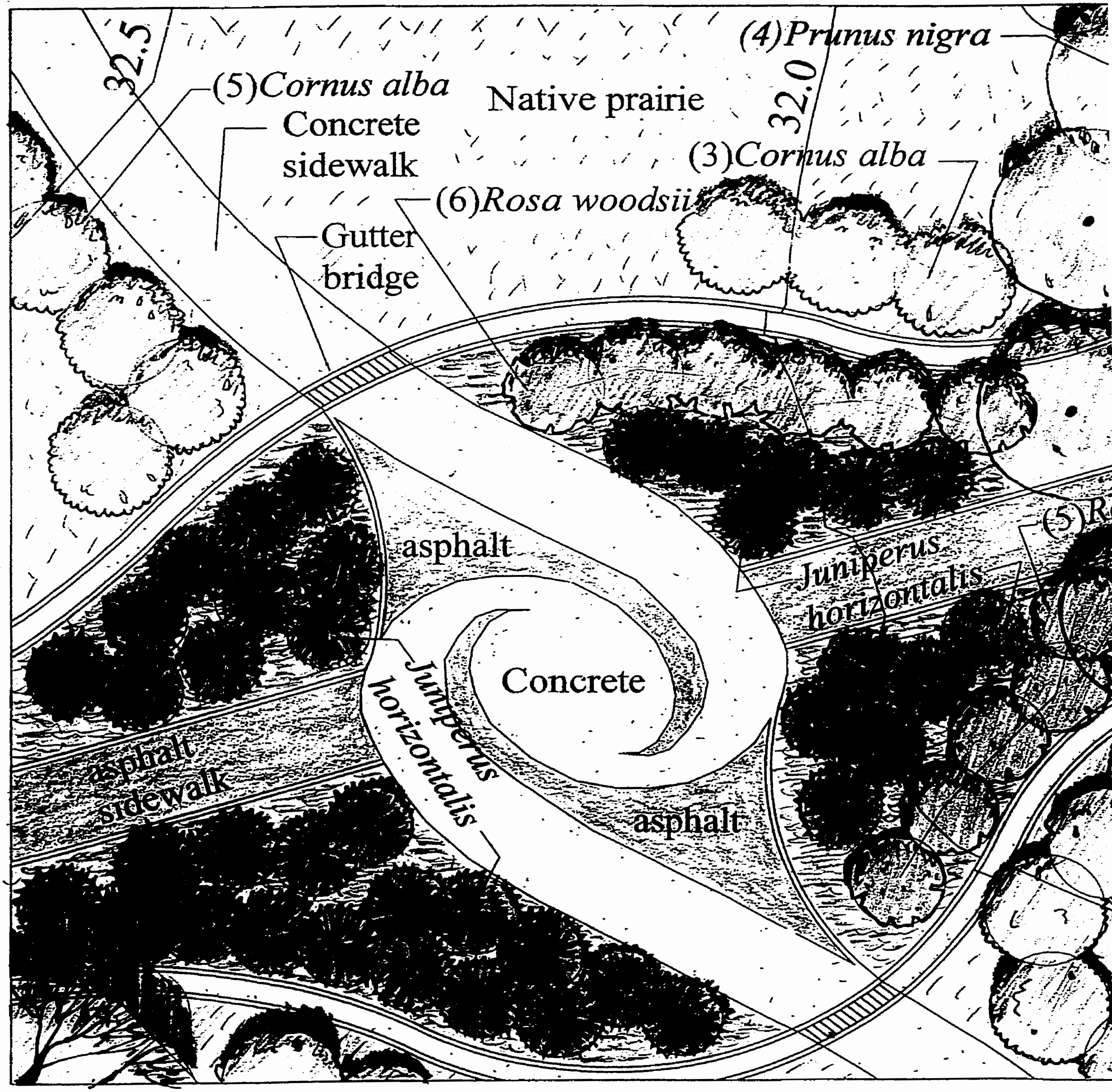
Cul-de-sac islands

In order to help control runoff quality and quantity the islands in a cul-de-sac could be changed. Instead of having a hard surface, they should have a soft vegetated surface. Stormwater should drain off of the road, onto the vegetation instead of the other way around. In this way some runoff can be absorbed, by the soil, and plant life, and, some of the nutrients as well. Excess water will flow out of the islands, and gradually make its way to the retention pond.

Forest

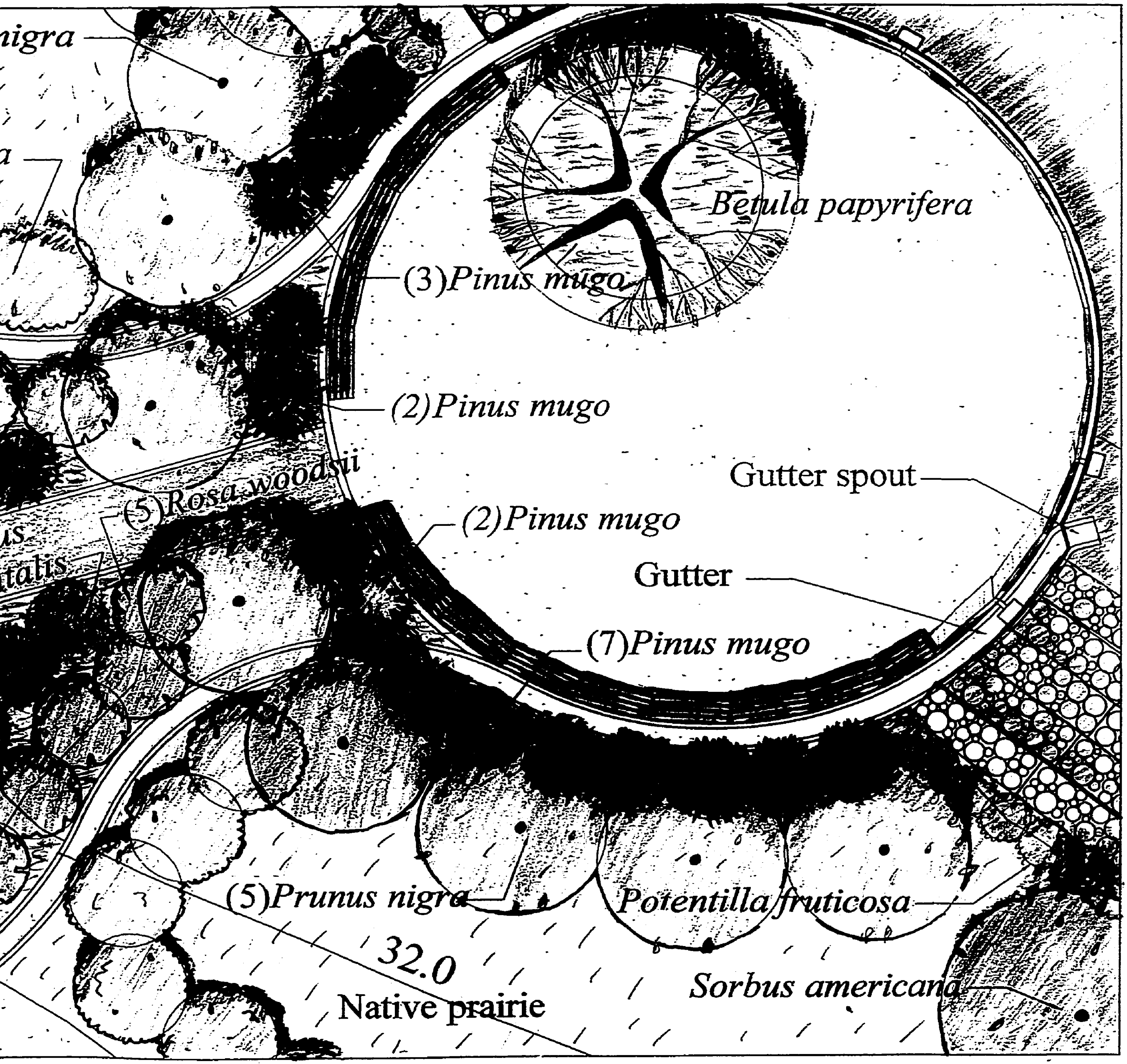
The aspen forest provides a physical boundary for the retention pond area. The forest will provide upland vegetation that is typical of the Winnipeg area. In addition, the forest provides, another habitat, for flora and fauna. The existence of the forest will increase the heterogeneity of the landscape, which will increase the number of species that could live in the area, and increase the interest in the park. Some of the potential species will use both the pond, and the forest. The wood duck (*Aix sponsa*) is a prime example, however, since they tend to use tree cavities, present in old growth forests, so they will need artificial

Figure 8.15 Plan of interpretive node and walkway



Plan of interpretive node and walkway

Figure 8.15

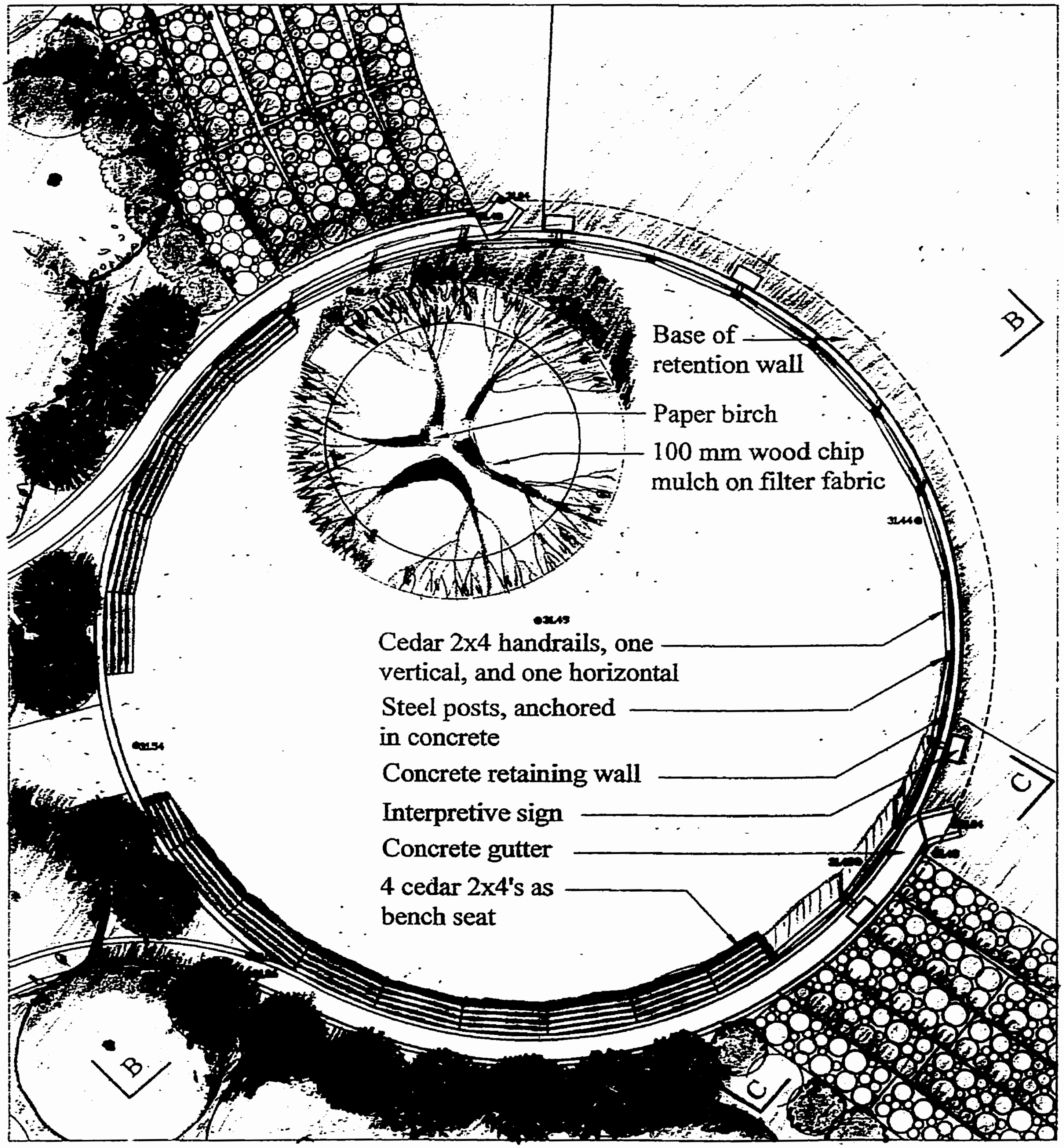


nigra
Betula papyrifera
(3)Pinus mugo
(2)Pinus mugo
(5)Rosa woodsii
Gutter spout
(2)Pinus mugo
Gutter
(7)Pinus mugo
(5)Prunus nigra
Potentilla fruticosa
32.0
Sorbus americana
Native prairie

y

Scale 1:100

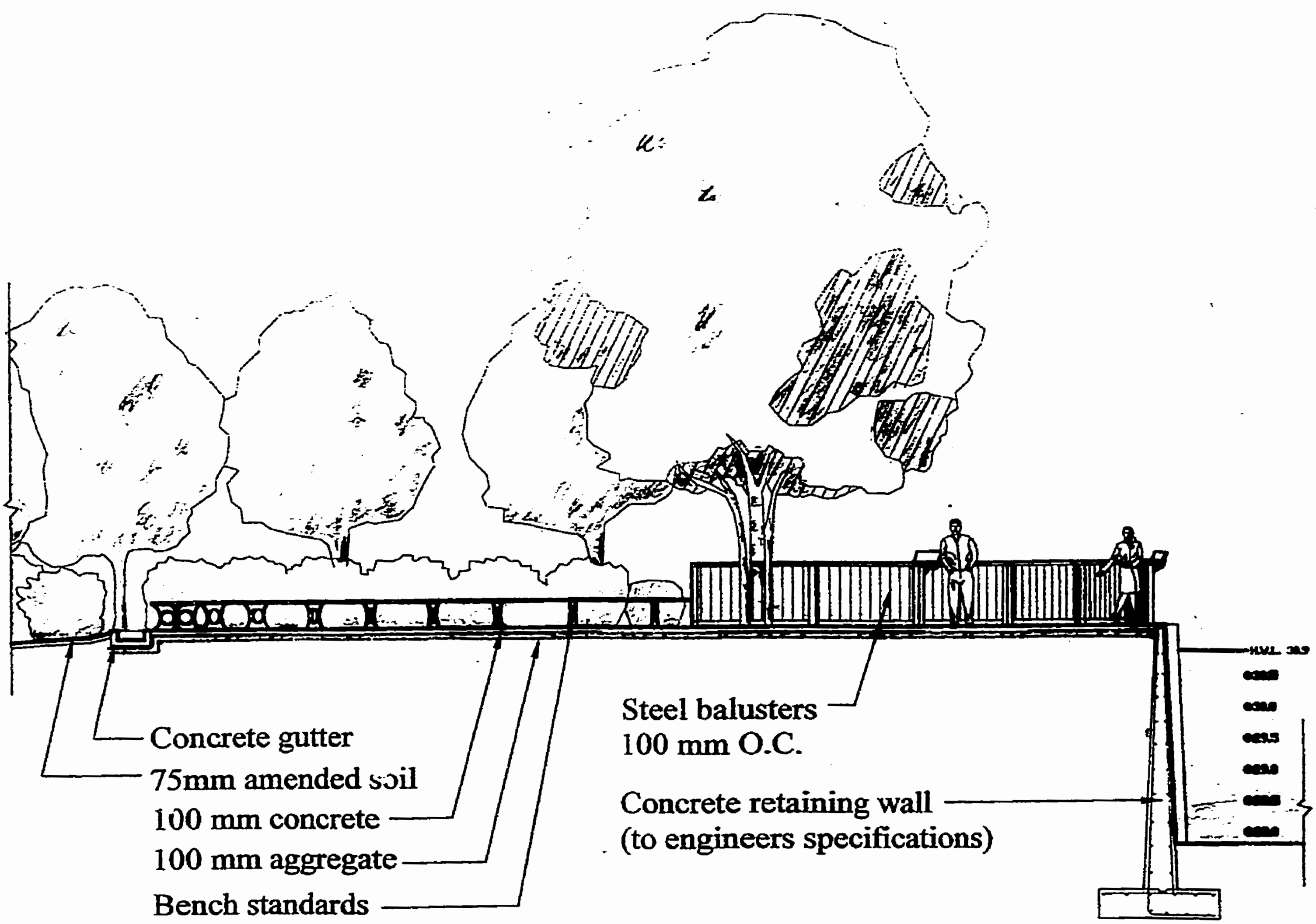
Figure 8.16 Plan of interpretive node
Figure 8.17 Section of interpretive node



Plan of interpretive node

Scale 1 : 100

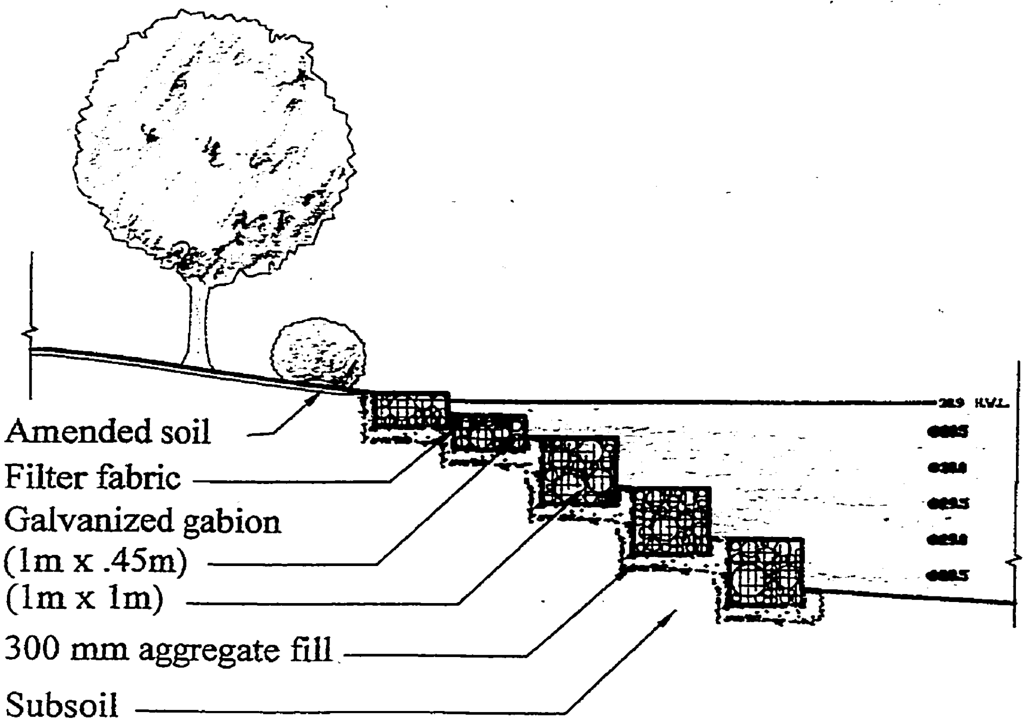
Figure 8.16



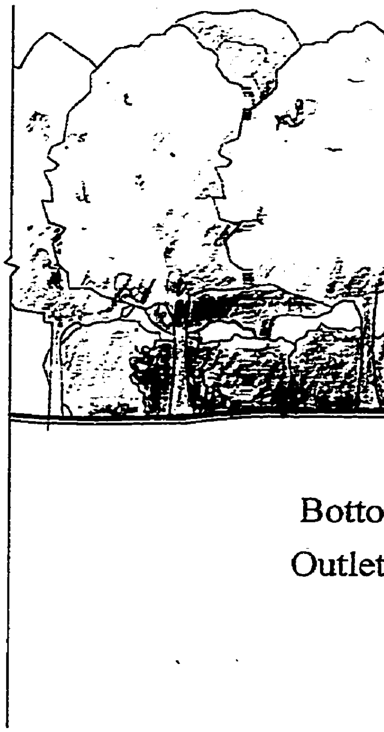
Interpretive node
Section B
Figure 8.17

Scale 1 : 100

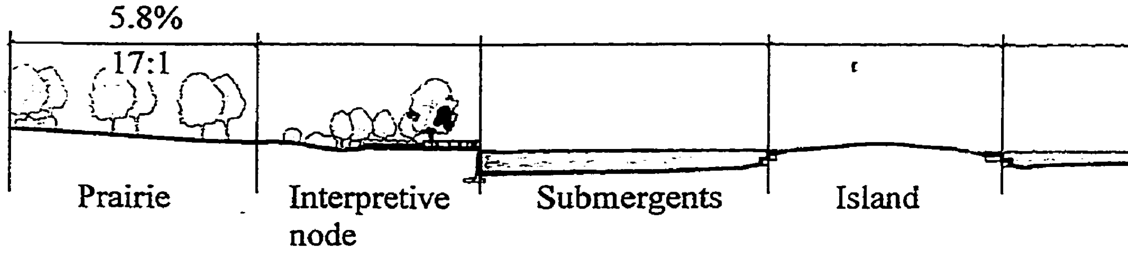
Figure 8.18 Section of gabion edge
Figure 8.19 Section of gabions and interpretive node
Figure 8.20 Section BB (pond section)



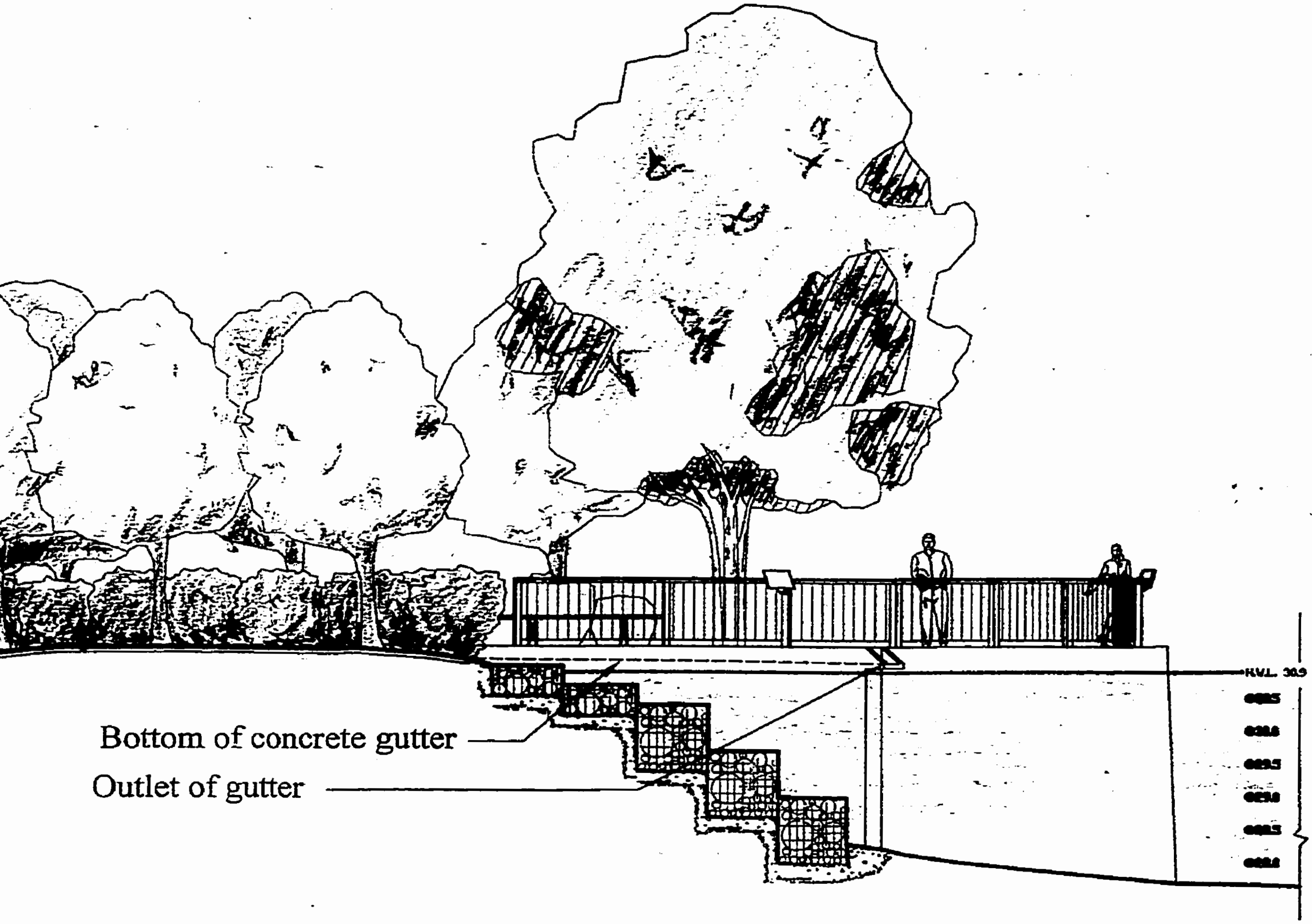
Section of gabion edge Scale 1 : 100
Section MM
Figure 8.18



Section of ga
Section CC
Figure 8.19

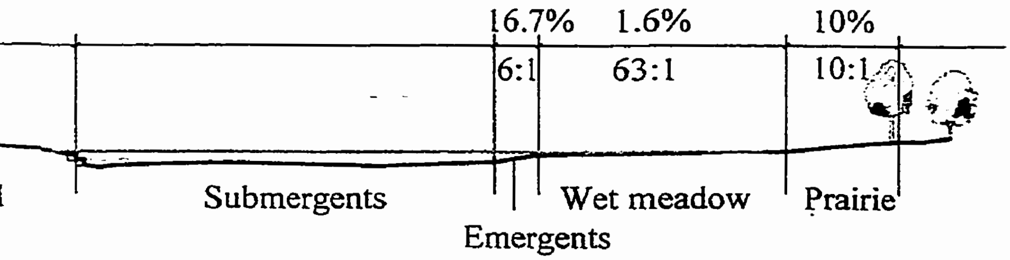


Section BB
Figure 8.20



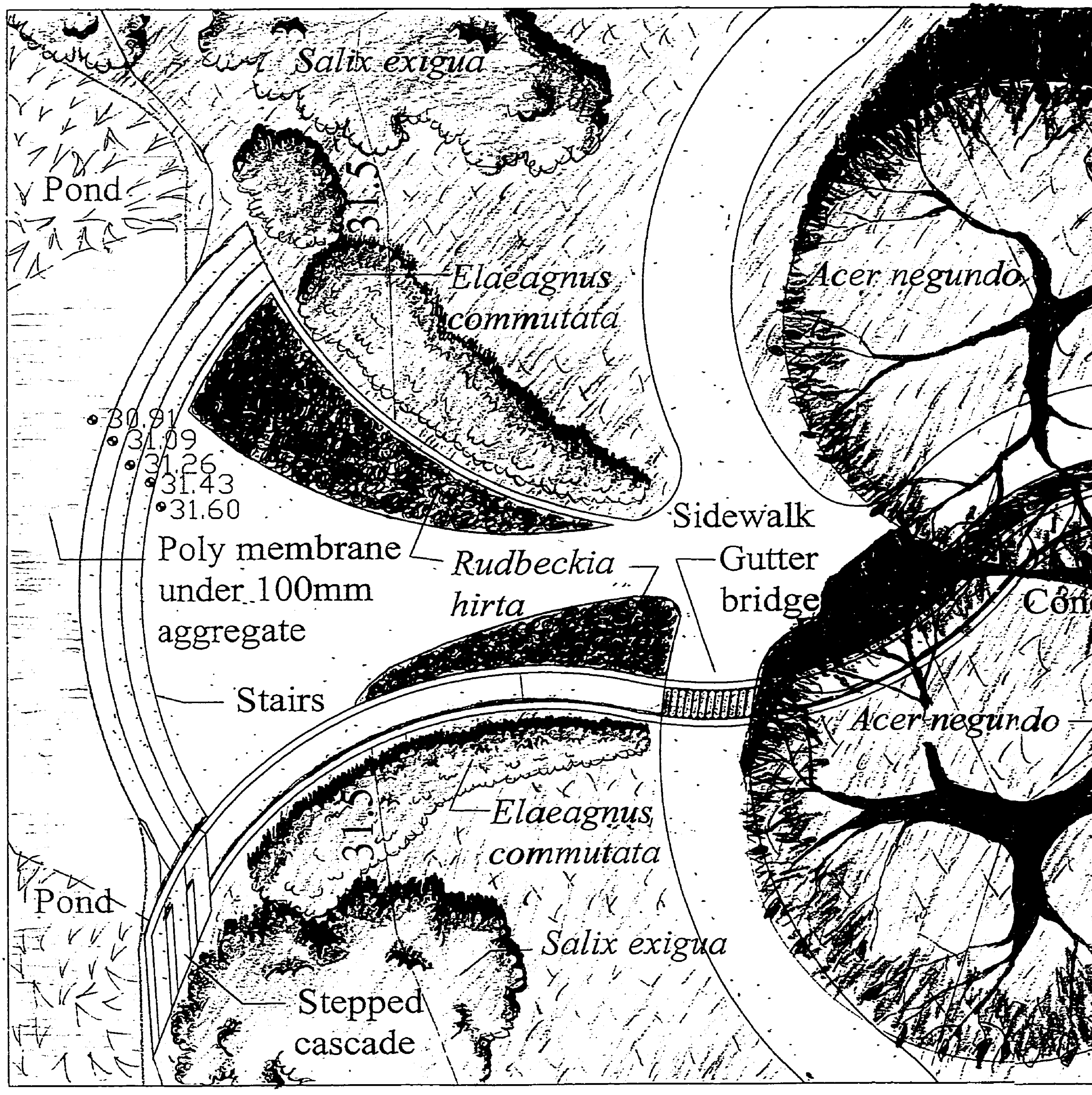
on of gabions and elevation of interpretive node
on CC

Scale 1 : 100



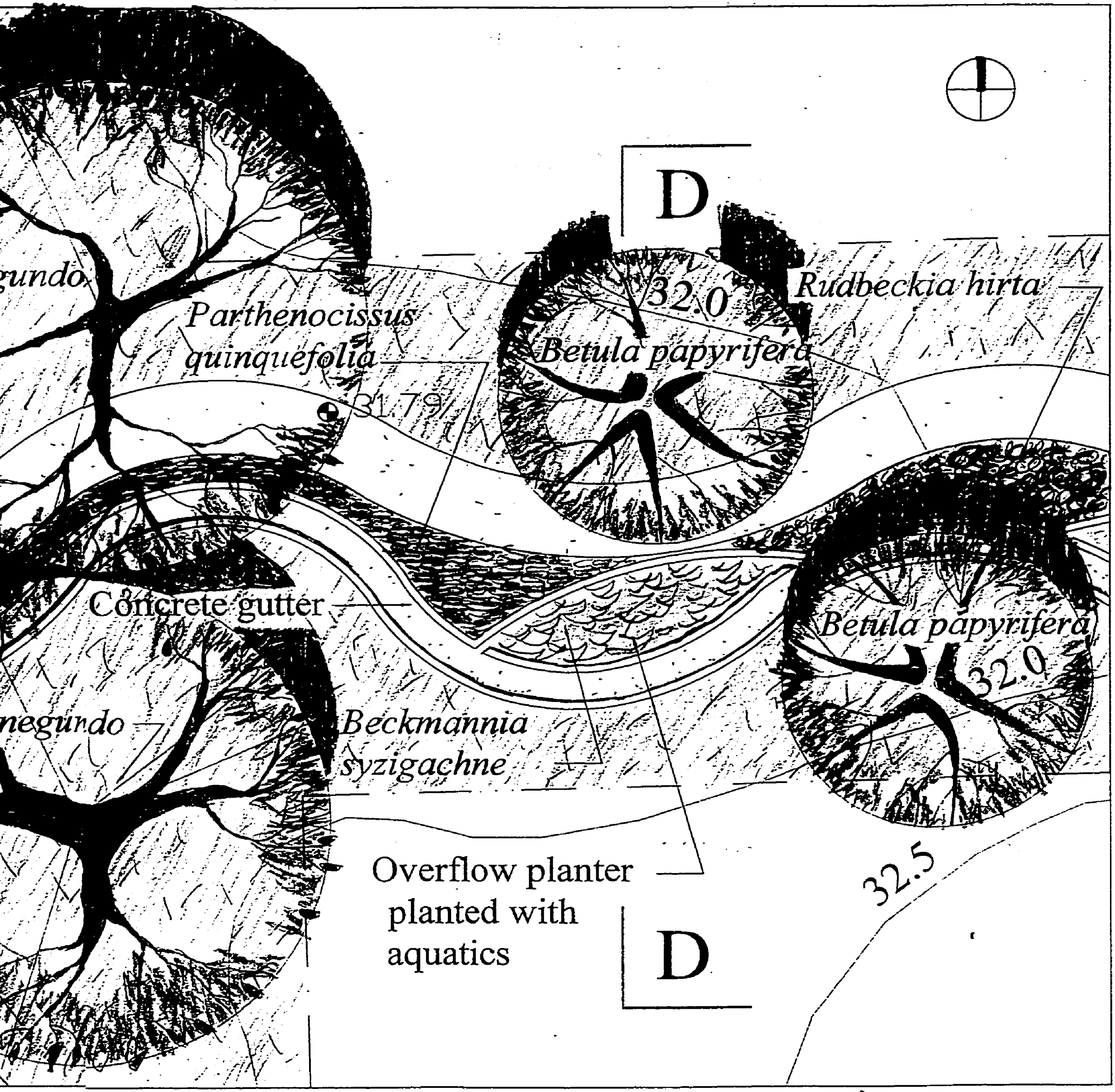
Scale 1 : 1000

Figure 8.21 Plan of delta node



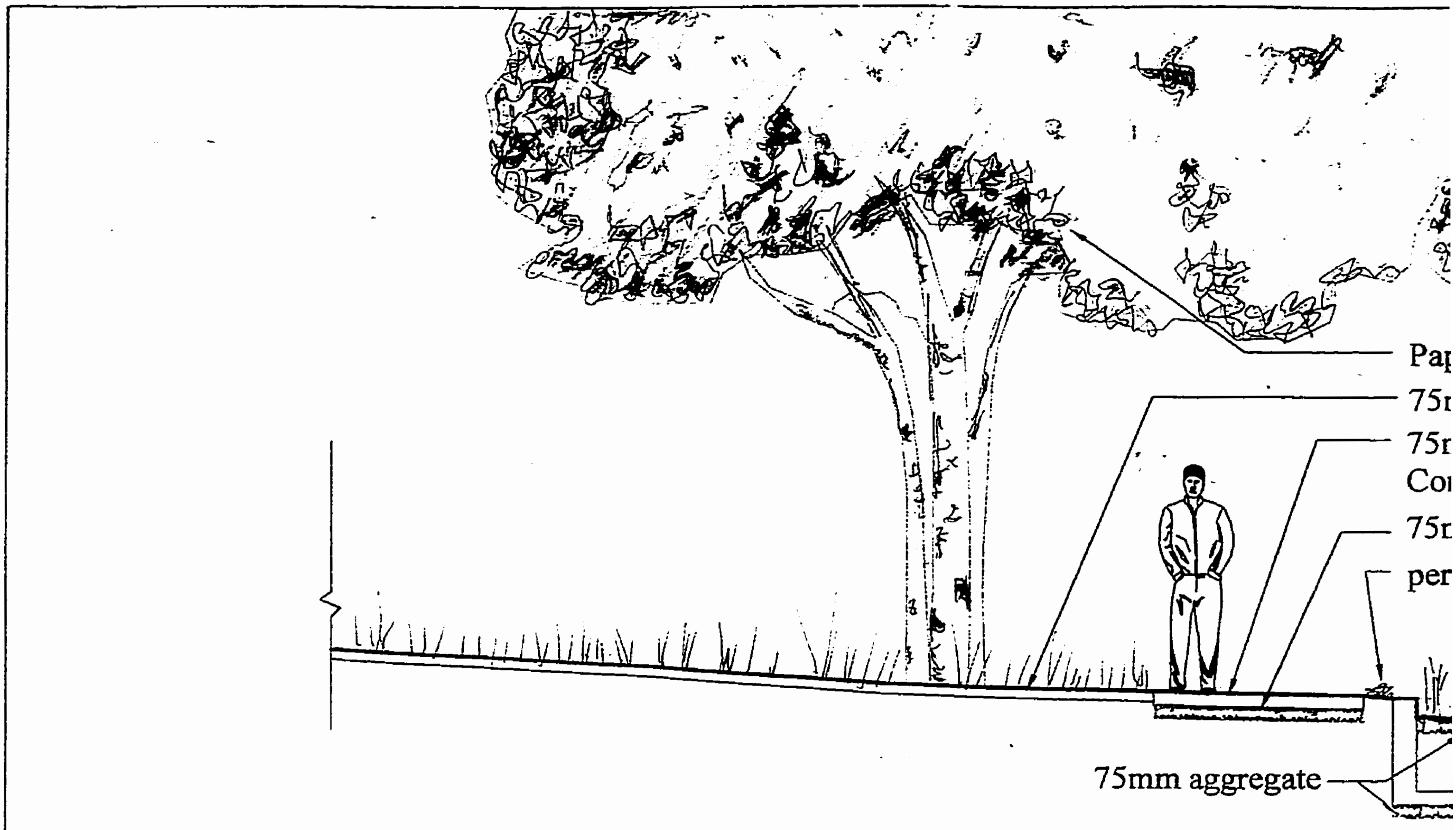
Plan of delta node and overflow gutter

Figure 8.21


gundo
Parthenocissus quinquefolia
31.79
D
32.0
Rudbeckia hirta
Betula papyrifera
Concrete gutter
negundo
Beckmannia syzigachne
Betula papyrifera
32.0
Overflow planter planted with aquatics
D
32.5

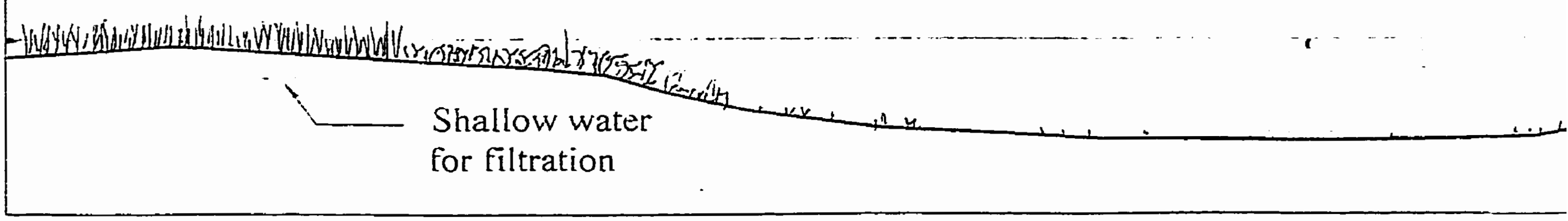
Scale 1:100

Figure 8.22 Section of walkway, gutter and overflow planter
Figure 8.23 Section of pond and delta node



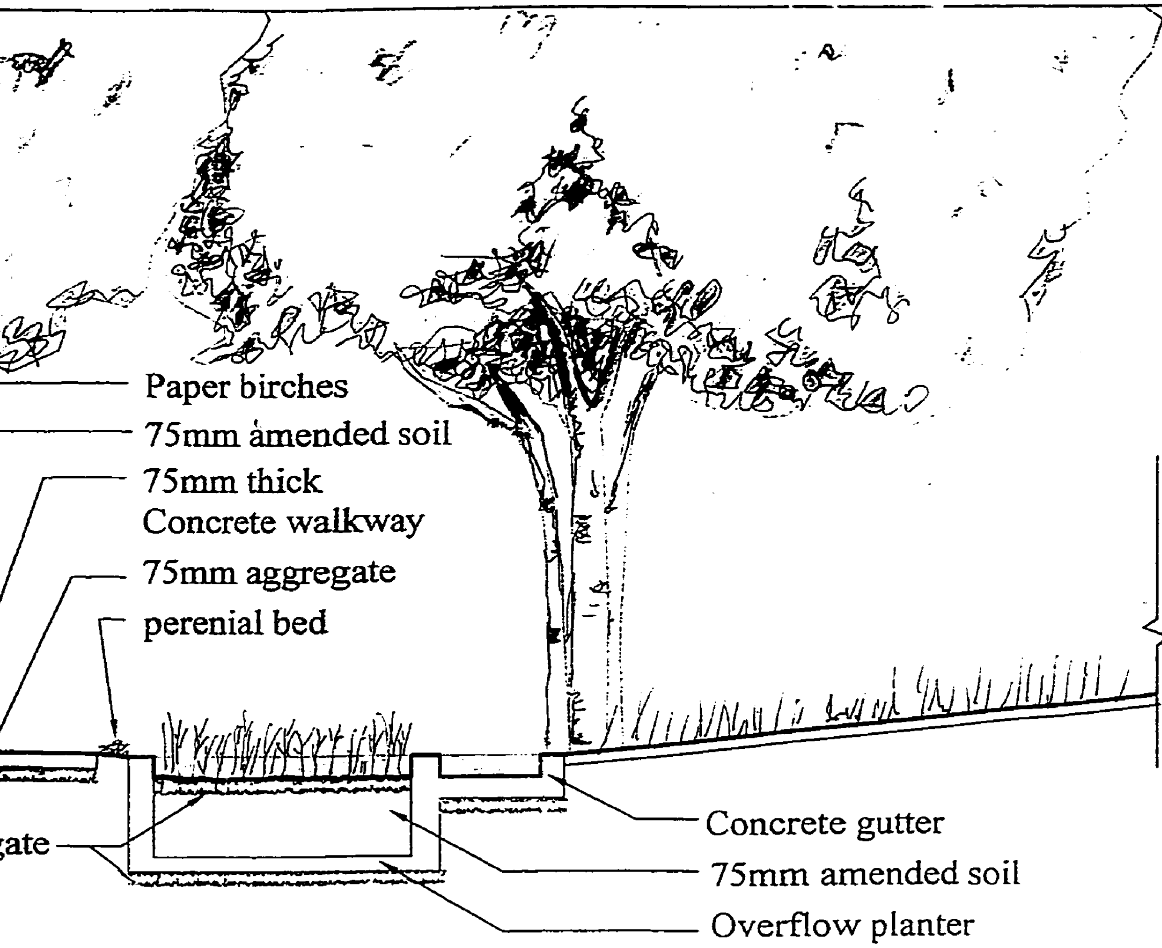
Section of walkway, gutter and overflow plante

Figure 8.22 **D D**



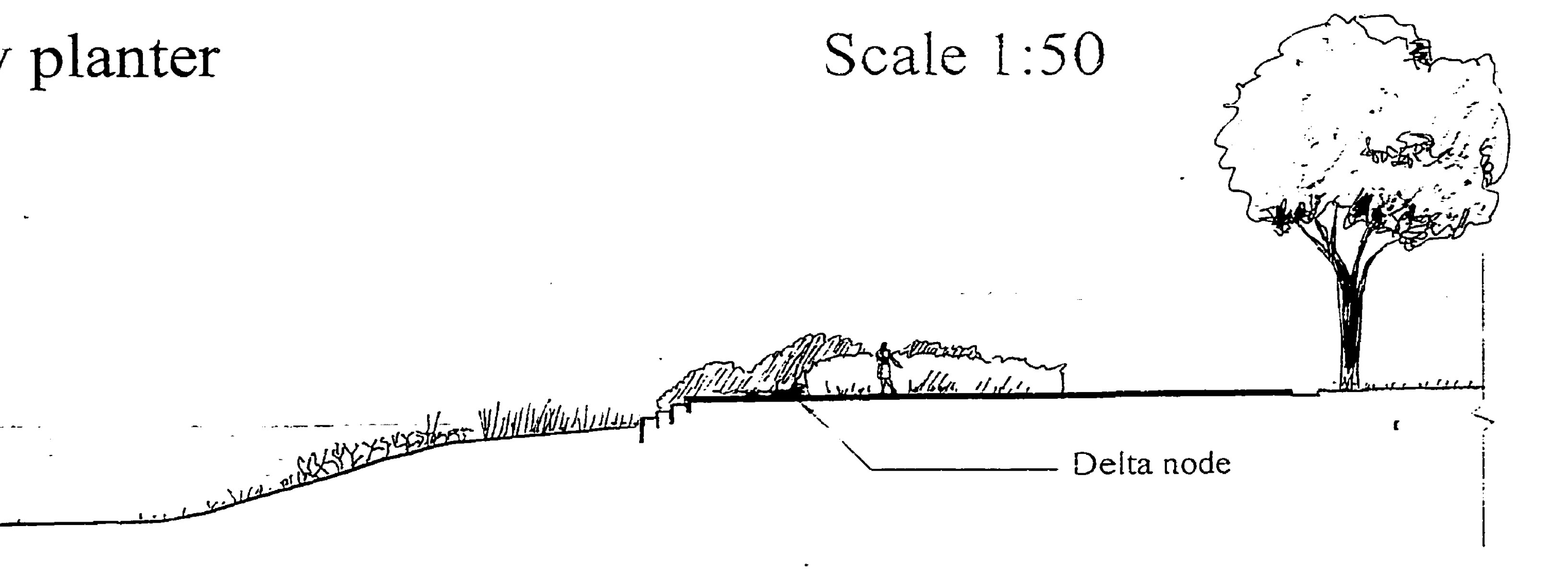
Section of pond and delta node

Figure 8.23



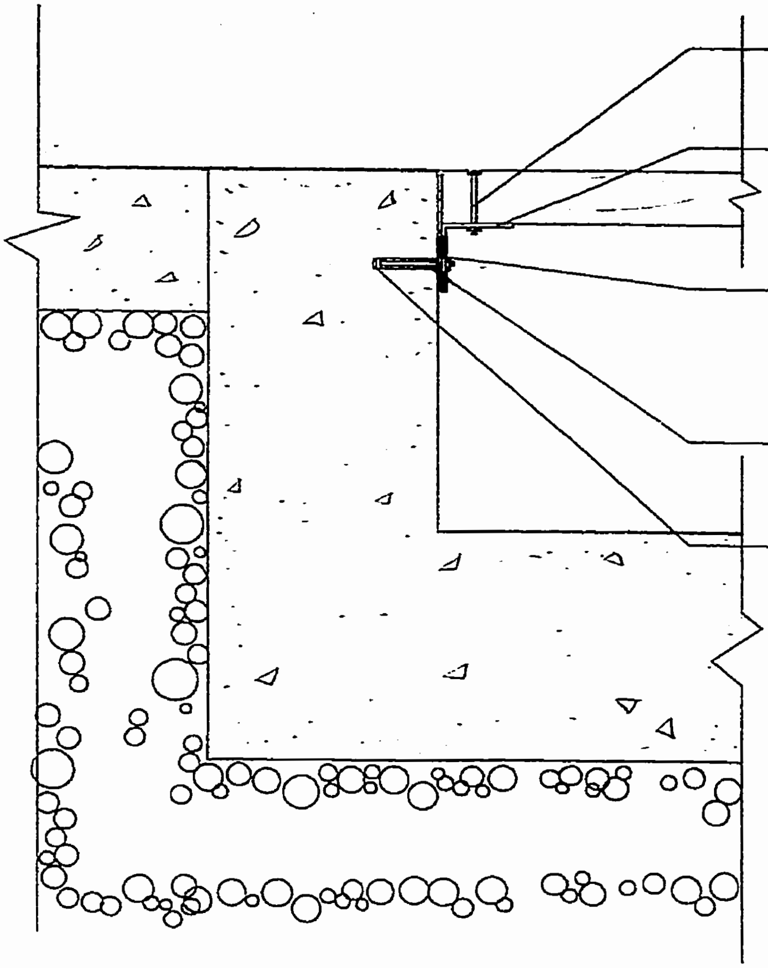
y planter

Scale 1:50



Scale 1:200

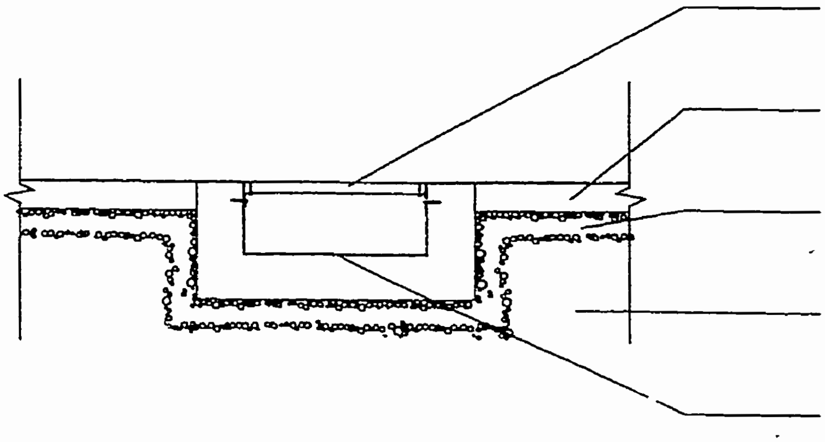
Figure 8.24 Detail of gutter bridge
Figure 8.25 Section of gutter bridge
Figure 8.26 Plan of gutter bridge



Scale 1:5

Detail of gutter bridge

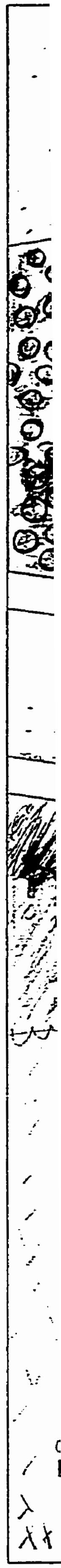
Figure 8.24



Section of gutter bridge

Figure 8.25

Scale 1:25



Figu

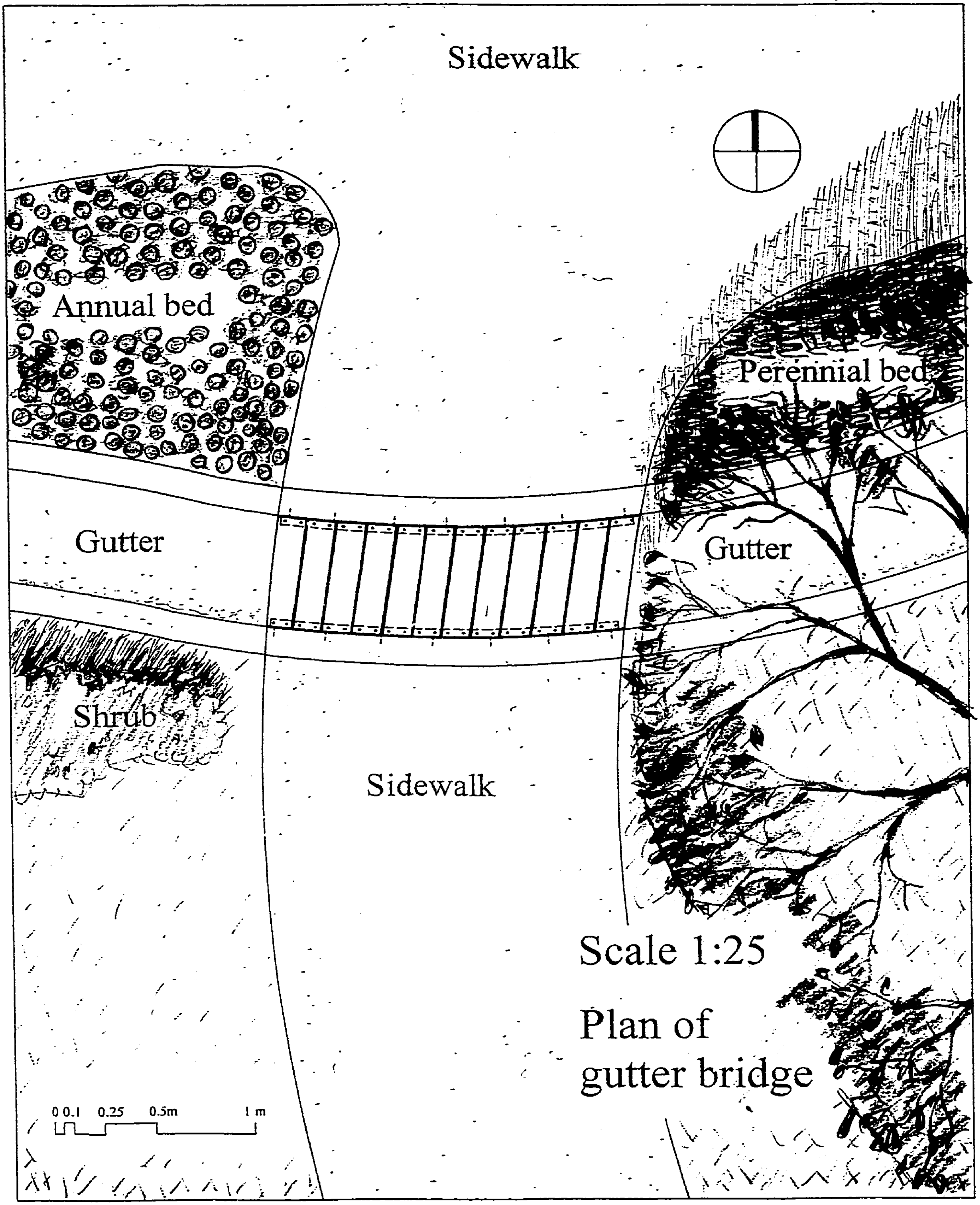

Sidewalk
Annual bed
Perennial bed
Gutter
Gutter
Shrub
Sidewalk
0 0.1 0.25 0.5m 1 m
Scale 1:25
Plan of gutter bridge

Figure 8.26

nest boxes. The forest will also provide shelter from north west winds in winter, that can blow across the park and pond.

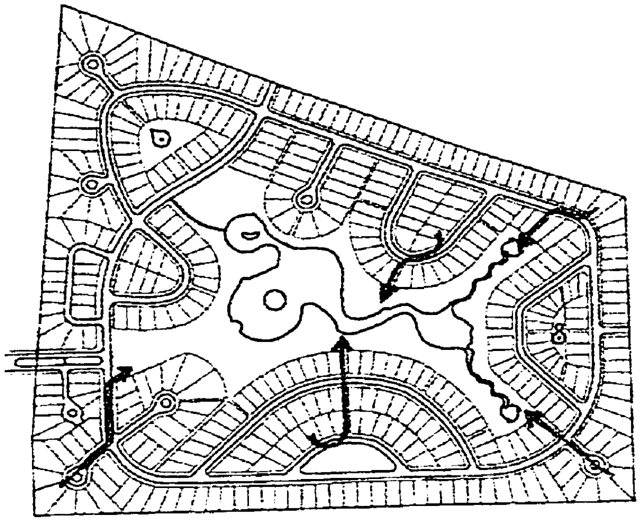
The forest would be planted with trees in the centre, and smaller seedlings, on the outside, which would simulate the concentric growth typical, of aspen bluffs. Oak acorns could also be used to seed oaks, that could eventually surpass the aspens in size, taking advantage of natural succession.

Access

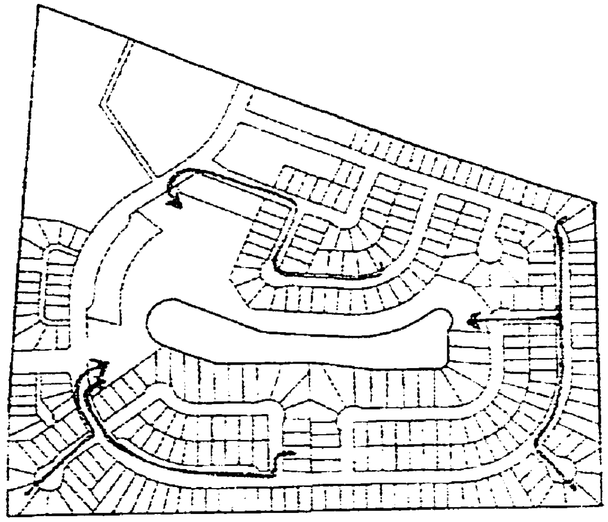
When houses or other real estate is adjacent to water, or a park its actual or perceived value tends to go up. The distance to the nearest park can also be important for home-owners or potential buyers. A traditional neighbourhood arranged around a retention pond has a limited number of houses associated with the pond, and the park around it. If more houses in the neighbourhood could have a closer association with the park and pond then this would benefit their inhabitants.

There are means of strengthening the relationship of a house to a park. One way is to place that house adjacent to the park, and another method is to locate that house closer to the park. This can be done by extending fingers of public open space into the neighbourhood. In this manner a park can take on a more complex shape, with a vastly greater perimeter. The increased perimeter means that more houses will fit on the edge of the park. If an open drainage system is used, then the swales can remain public property and become an extension of the park. In this way the park moves to the houses.

Distances of pedestrian travel from houses on the subdivision's periphery to the park should be reduced. This can be accomplished by ensuring more direct pedestrian access to the park through the use of pedestrian thoroughfares in the community, and by ensuring that where the park meets the road there is public access to the park. Drainage swales could act as thoroughfares, but also allowing more public space around the retention pond can ensure pedestrians are not kept out of the park, or forced to travel long indirect routes to the park.



Proposed plan with easier access to park



Existing

Figure 8.27 Accessability Comparison

Conclusion

There are several approaches to dealing with stormwater in a suburban setting, but retention ponds can carry with them several benefits. The benefits of water quality improvement, and habitat replacement are very important. The aesthetic benefits of the ponds has been appreciated by developers, although not fully realized in the many designs. The problem with many retention ponds is that they are just wet basins, where they could be much more. Using marshes as natural precedent to model retention ponds after will help a retention pond accomplish more in terms of stormwater remediation, and habitat creation. The idea that the growth of plants and microbes in the water is something that must be counteracted is an idea that must be changed within the city. Even the manufactured chemicals that we have created and used in the landscape, to the detriment of our own water, can be degraded by natural processes which we may barely understand. We must allow the plants which support the important microbes to grow if they are to provide benefit.

A problem with using the retention pond as the sole means of improving water quality, is that the pond itself becomes polluted. The excessive nutrients can lead to eutrophic conditions which will result in the pond becoming anoxic. The anaerobic conditions will promote the growth of algae, which will further reduce oxygen levels in the water, which inhibits the existence of fish which in turn control mosquitoes.

A solution to this problem is to partially cleanse the stormwater before it reaches the pond. The use of pre-reservoirs, and vegetative buffers cleanse water if surface drainage is used. These methods are not ones which are generally employed in Winnipeg. Unfortunately, there are some local conditions which hinder the implementation of an overland drainage system. The main challenges, in Winnipeg, are the flat terrain, and the mosquito problem.

The flat terrain in the Winnipeg area makes it impossible to deal with drainage completely above ground, for a site this size. If there are a number of smaller ponds spread out around the neighbourhood or a sinuous linear drainage channel then it is feasible to have an overland drainage system. The problem with this is that the size of the site currently would yield a pond just of about 5.5 acres. This size is about the minimum size for a permanent pond on the Canadian prairies. If all the water were contained in smaller bodies, or if there were excessive edge in a waterbody, then the bodies would cease to be permanent. Temporary ponds are perfectly natural, and would normally be a suitable technique of dealing with stormwater, however, there are reasons why this is not a good approach. Firstly, when the ponds are not water-filled they can lose some of their aesthetic value. Most importantly, they will tend to be warmer, with lower oxygen levels, or perhaps dry-up entirely. In either case, they cannot sustain the permanent biological control agents which feed on mosquitoes and keep their populations in check.

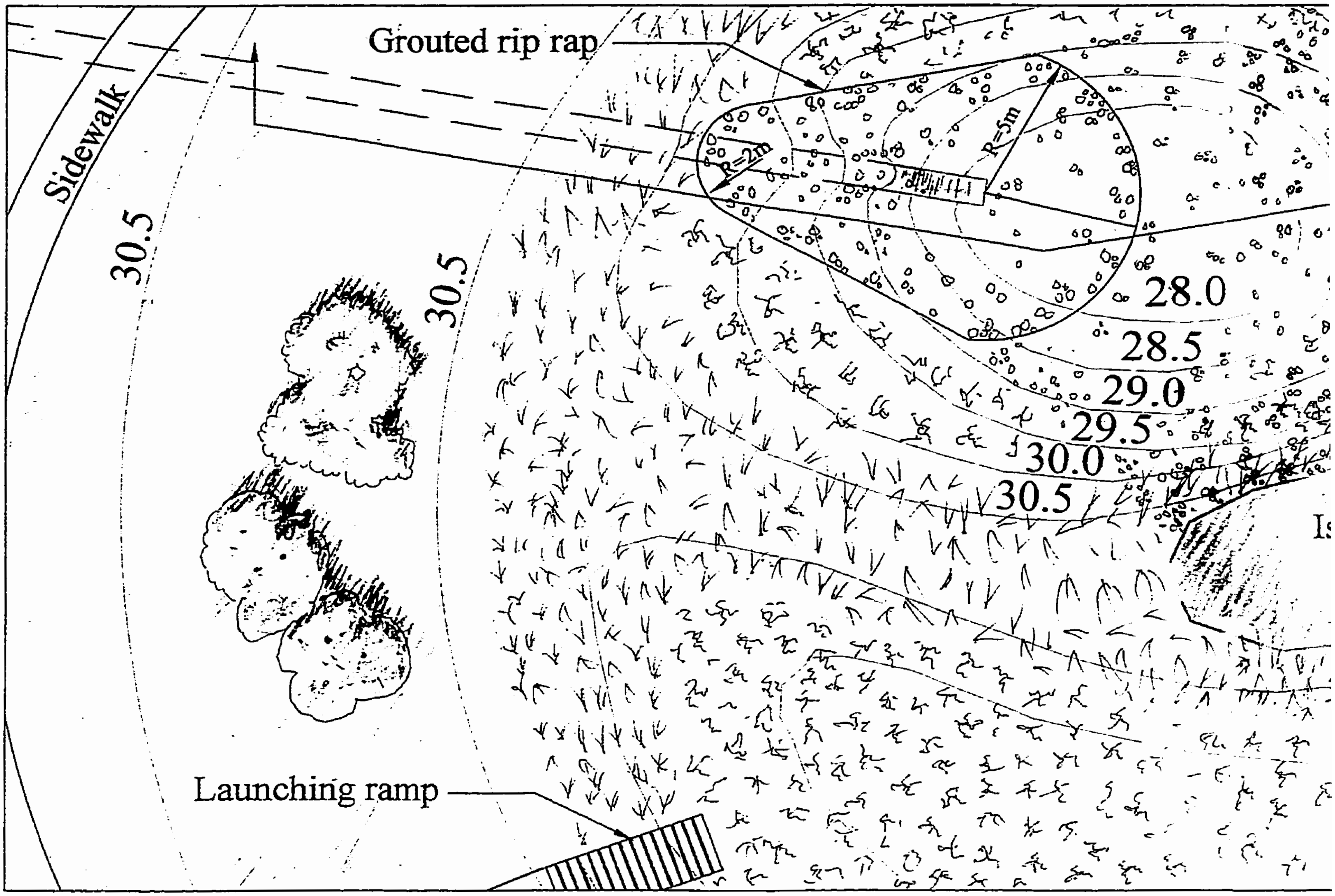
Winnipeg's harsh winter climate and the salt used on the roads to melt snow and ice present another potential problem with a surface drainage system. The salt causes damage to plants and alters aquatic ecosystems. Although the heavy salt use is primarily on highways and major city arteries, there is also some salt and sand spread on the roads of typical subdivisions. When this is done the salt can be absorbed by plants that are used to filter stormwater as in this practicum. The saline runoff can affect plant growth, and even threaten the long term viability of the plant if plants cannot absorb water, or if salt is absorbed into plant tissues. Plant harvest can remove some salt from the environment, but harvesting trees would prove too expensive. Salt should therefore be limited to ensure health of plants in a surface based drainage system.

Another problem, is that snow clearing from the gutters would like likely be necessary. Although this is not difficult, it is a factor that the City of Winnipeg may consider before using such a system of stormwater management.

Although it may be difficult to complete a total surface drainage system for most Winnipeg subdivisions, a hybrid system can be utilized. Such a system is proposed in this practicum, and it can be constructed using techniques discussed, and designed here. Because of the techniques employed, if implemented, this design would improve stormwater quality in the pond and the quality of water discharged to the Winnipeg rivers. The park and pond provide more diverse habitat and essential habitat for waterfowl. The park and pond as designed here provide a more aesthetically interesting landscape which can be more easily enjoyed by the residents of the community.

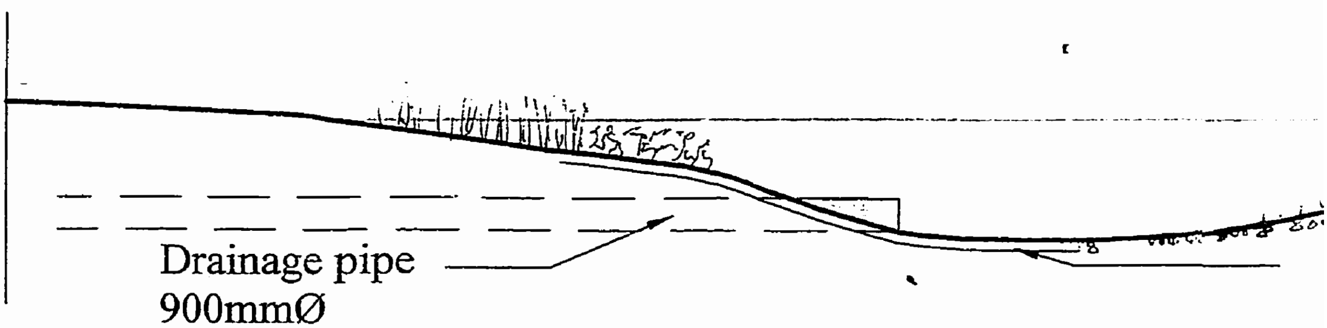
The city may be hesitant to adopt a new stromwater system such as this as it means employing management techniques to ensure the proper functioning of the system. The landscape proposed here is very different than most parks, and may cause some hesitancy from developers, or city officials. There is great potential, and need in exploring improved stormwater management methods, but economics and a lack of vision will hinder such progress. A feasibility study which demonstrates that a new type of subdivision can be profitable may convince developers to be more adventurous. A prototype can be built in which economic, environmental, and public acceptance factors can be assessed. Such a proto-type will illustrate better methods of managing our stormwater, and our environments in order to gain better environments for plants, animals and humans.

Figure 8.28 Pond with sedimentation forebay
Figure 8.29 Sedimentation forebay with planted bench



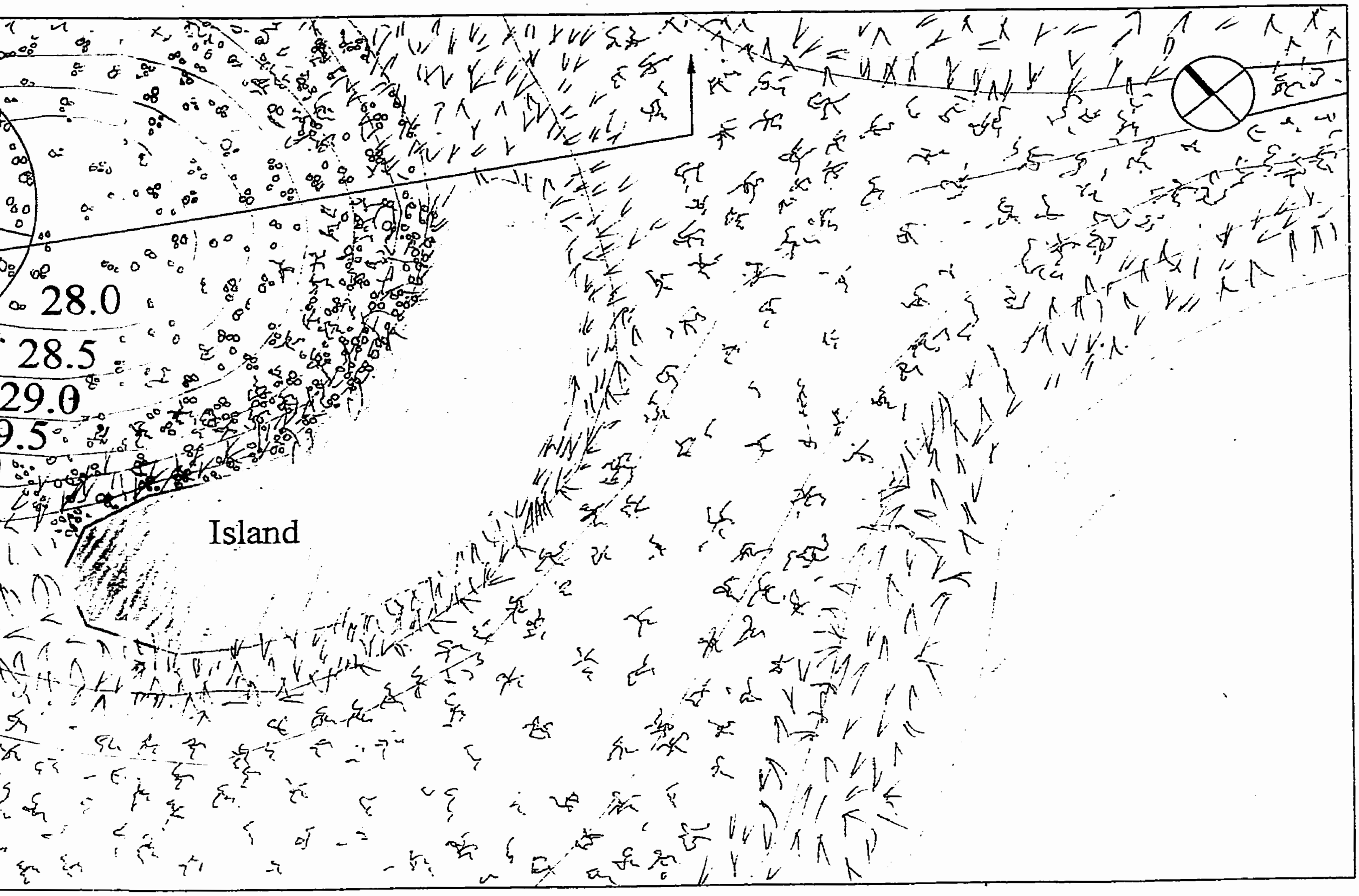
Pond with sedimentation forebay

Figure 8.28

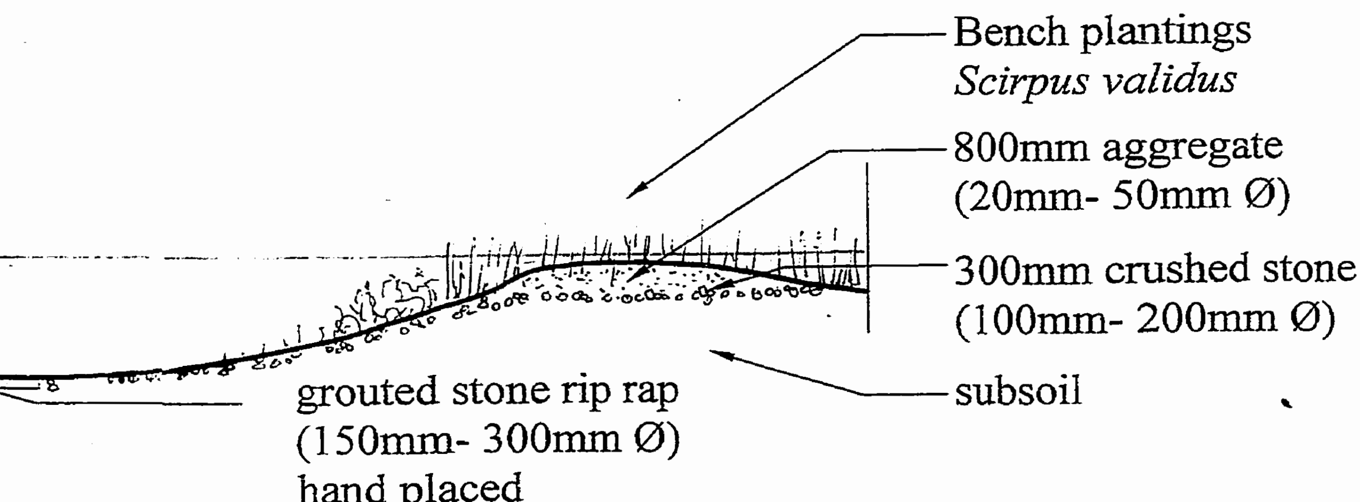


Sedimentation forebay, with planting bench

Figure 8.29

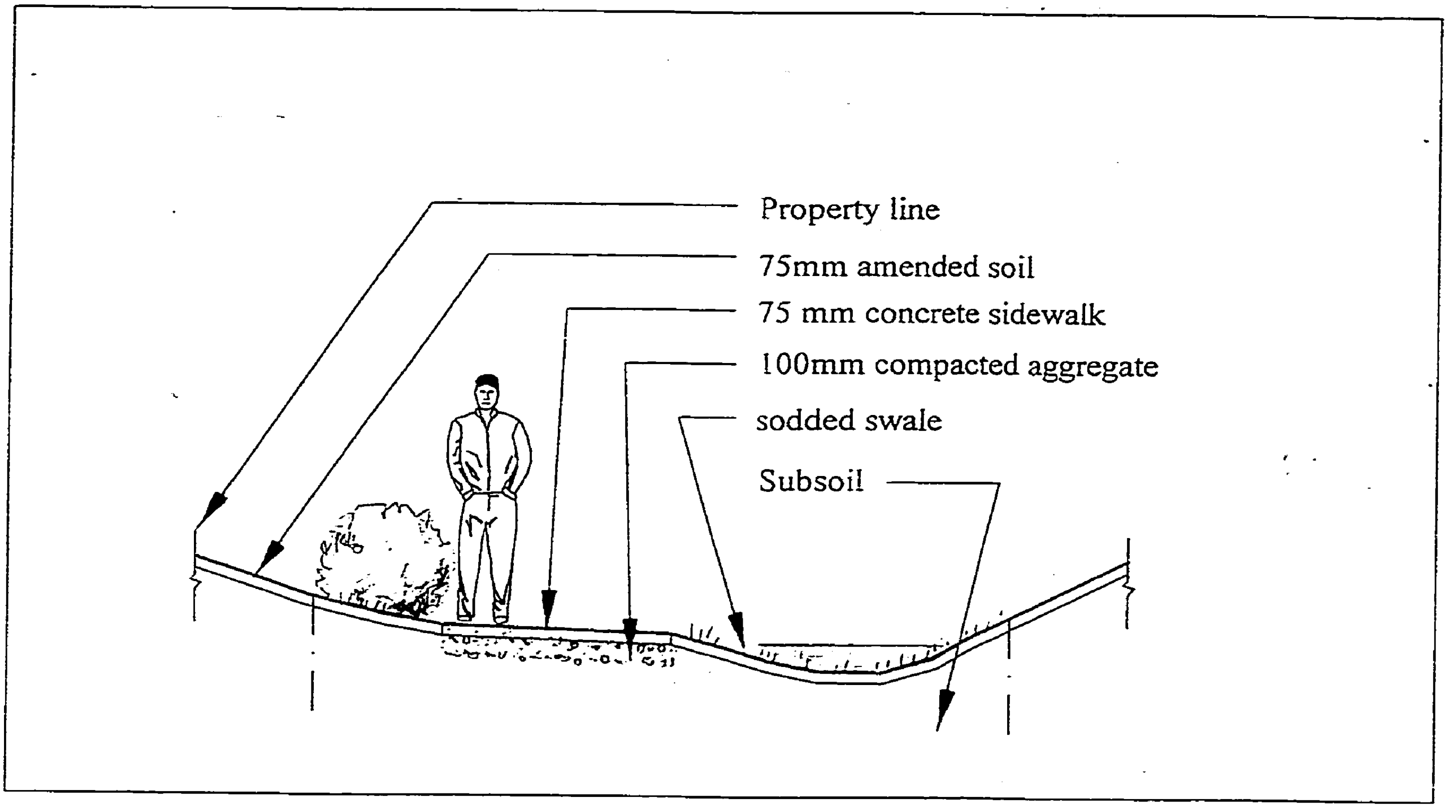


Scale 1:200



Scale 1:200

Figure 8.30 Walkway / swale
Figure 8.31 Swale
Figure 8.32 Spillway
Figure 8.33 Walkway / gutter



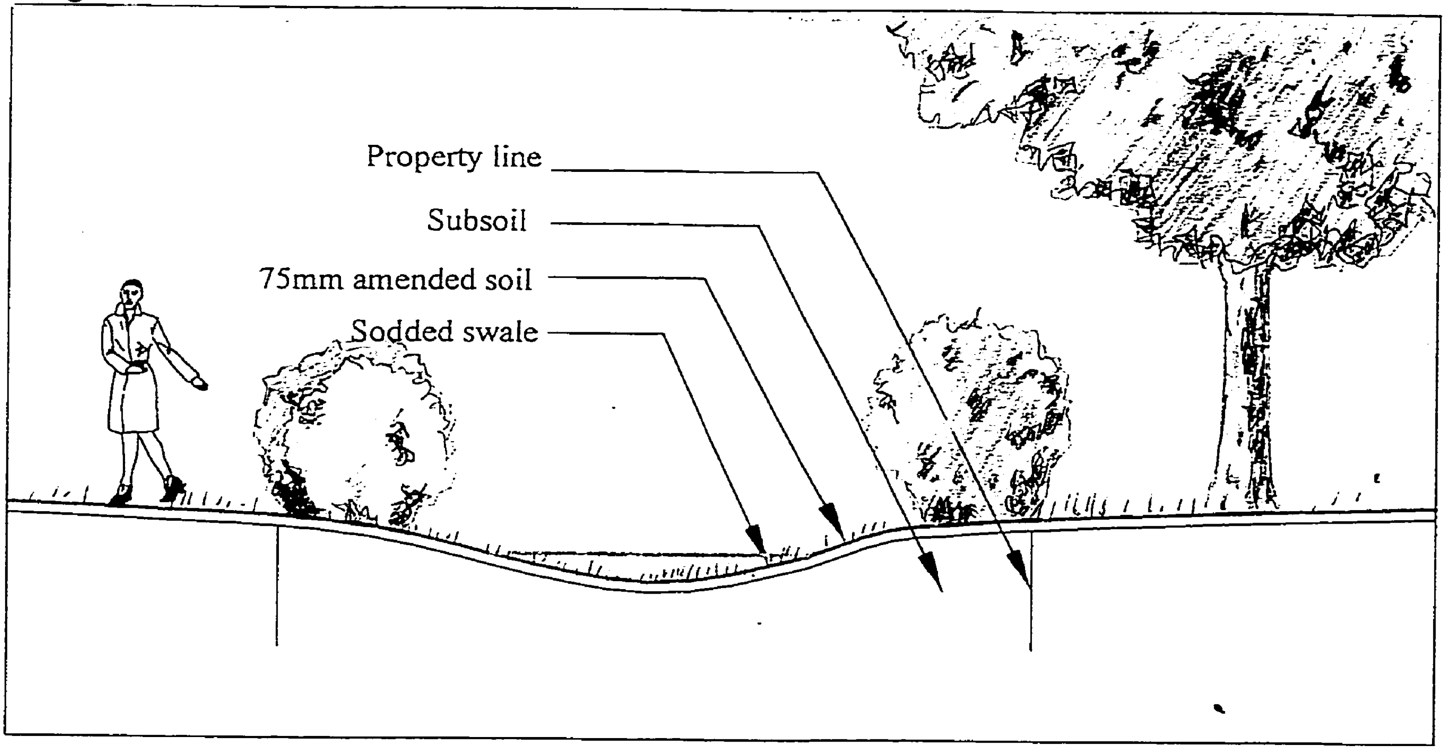
Walkway /swale

Scale 1:50

Figure 8.30

Spil

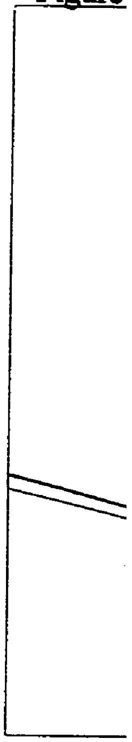
Figure



Swale

Scale 1:50

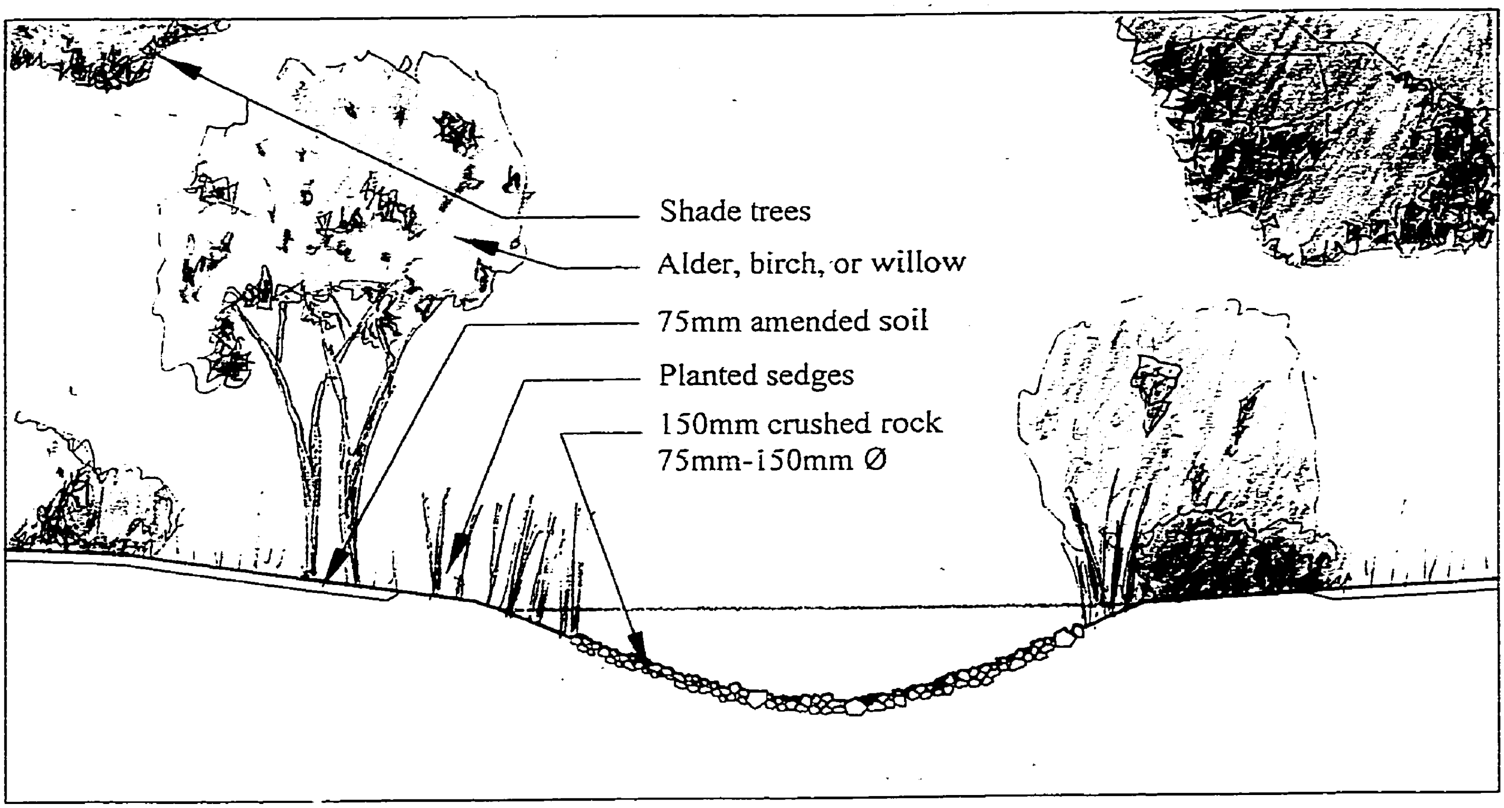
Figure 8.31



Wal

Figure

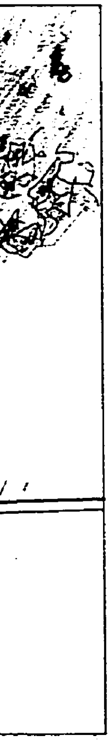
:50



Spillway

Scale 1:50

Figure 8.32



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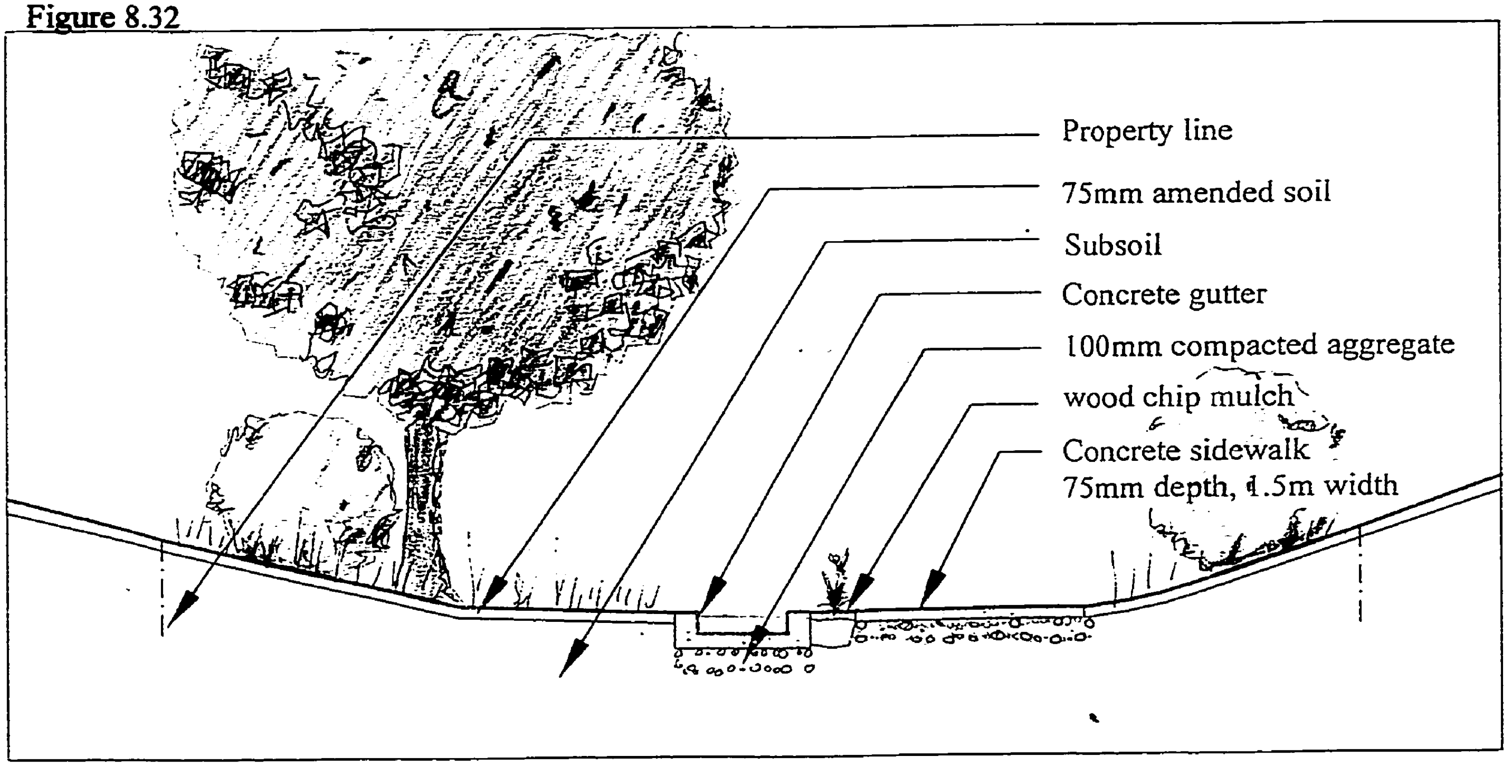
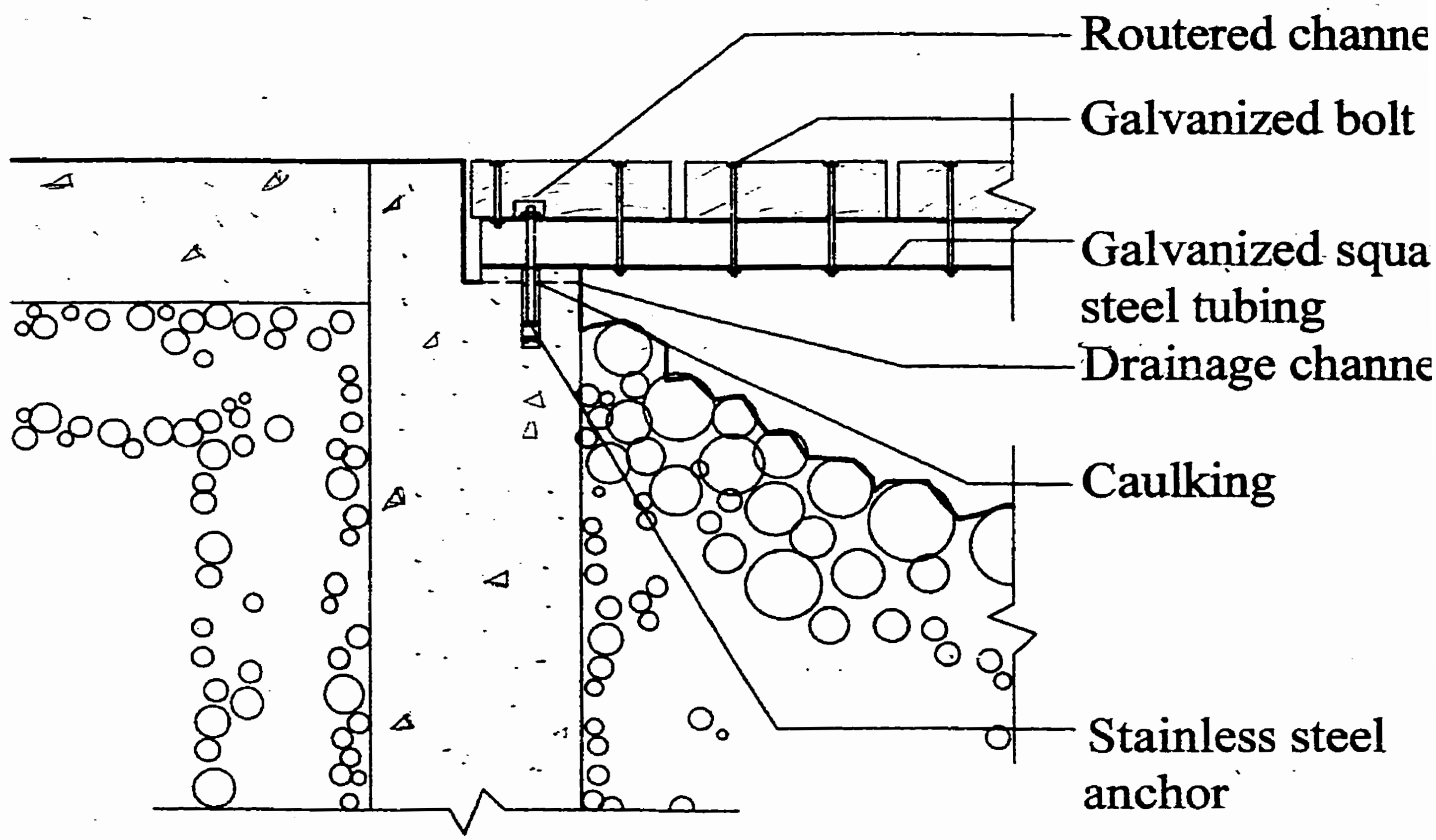


Walkway/ gutter

Scale 1:50

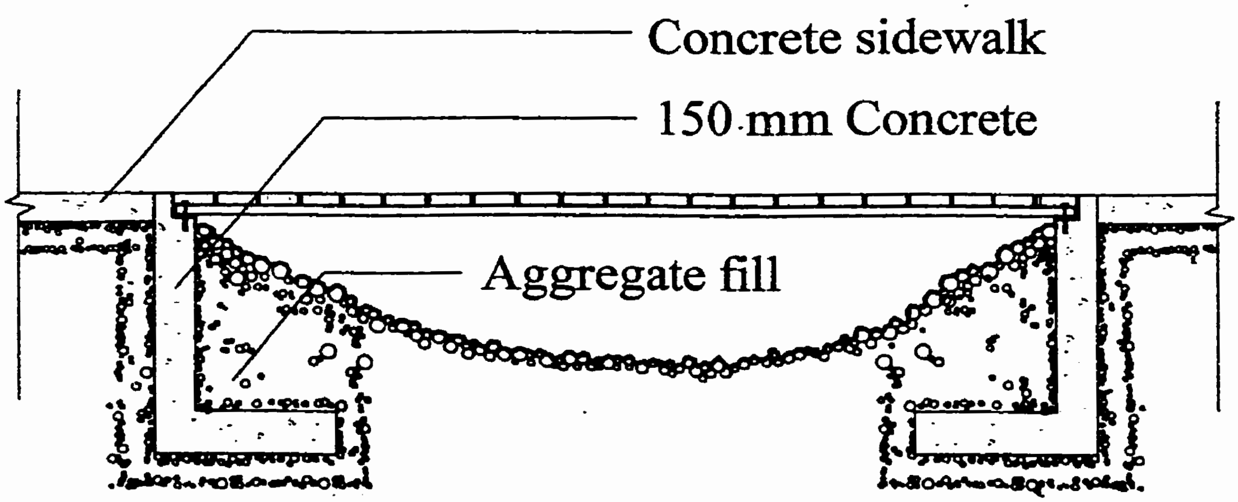
Figure 8.33

Figure 8.34 Section of swale bridge, 1:5
Figure 8.35 Section of swale bridge, 1:25
Figure 8.36 Plan of swale bridge



Section of swale bridge Scale 1:5

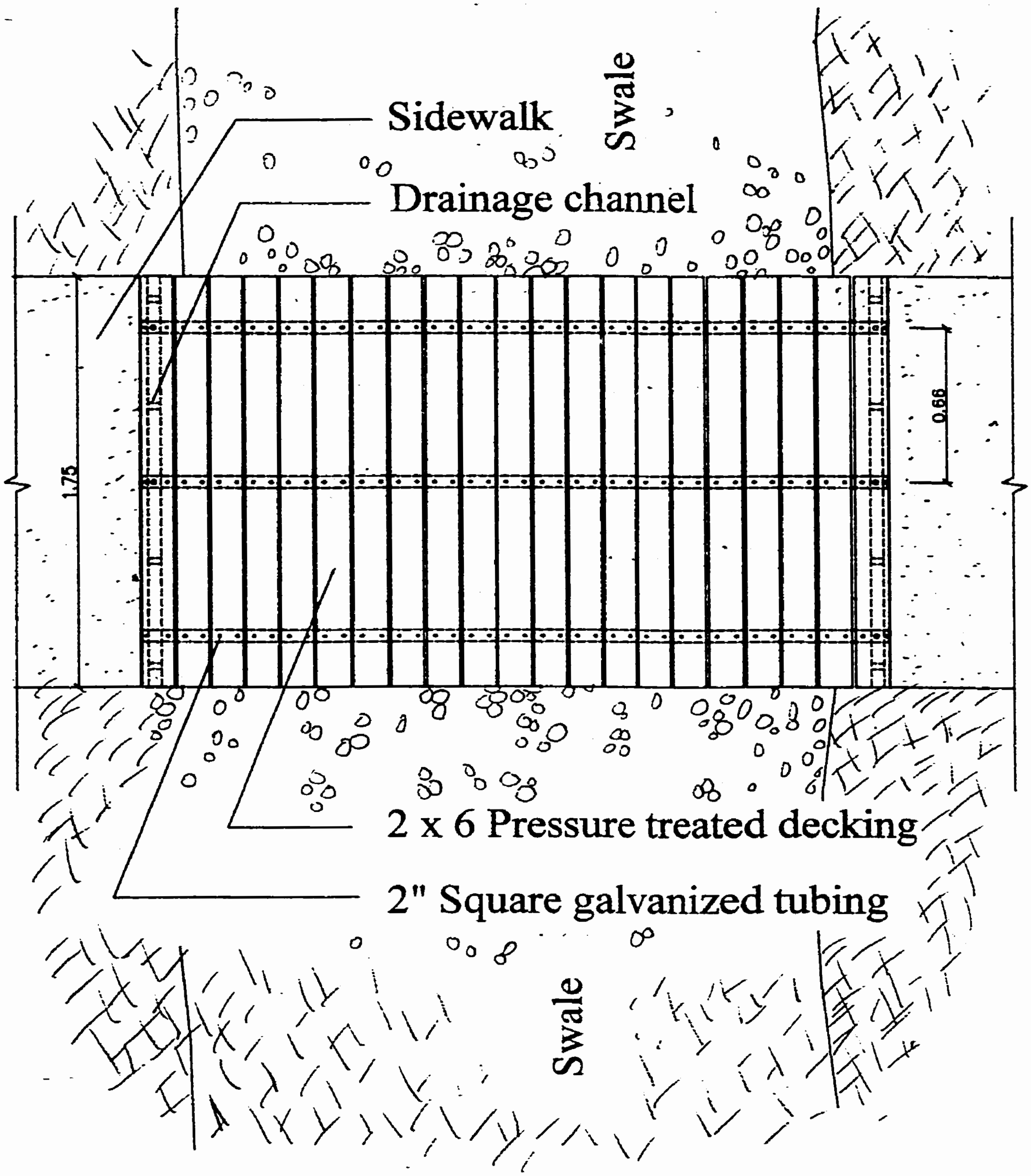
Figure 8.34



Section of swale bridge Scale 1:25

Figure 8.35

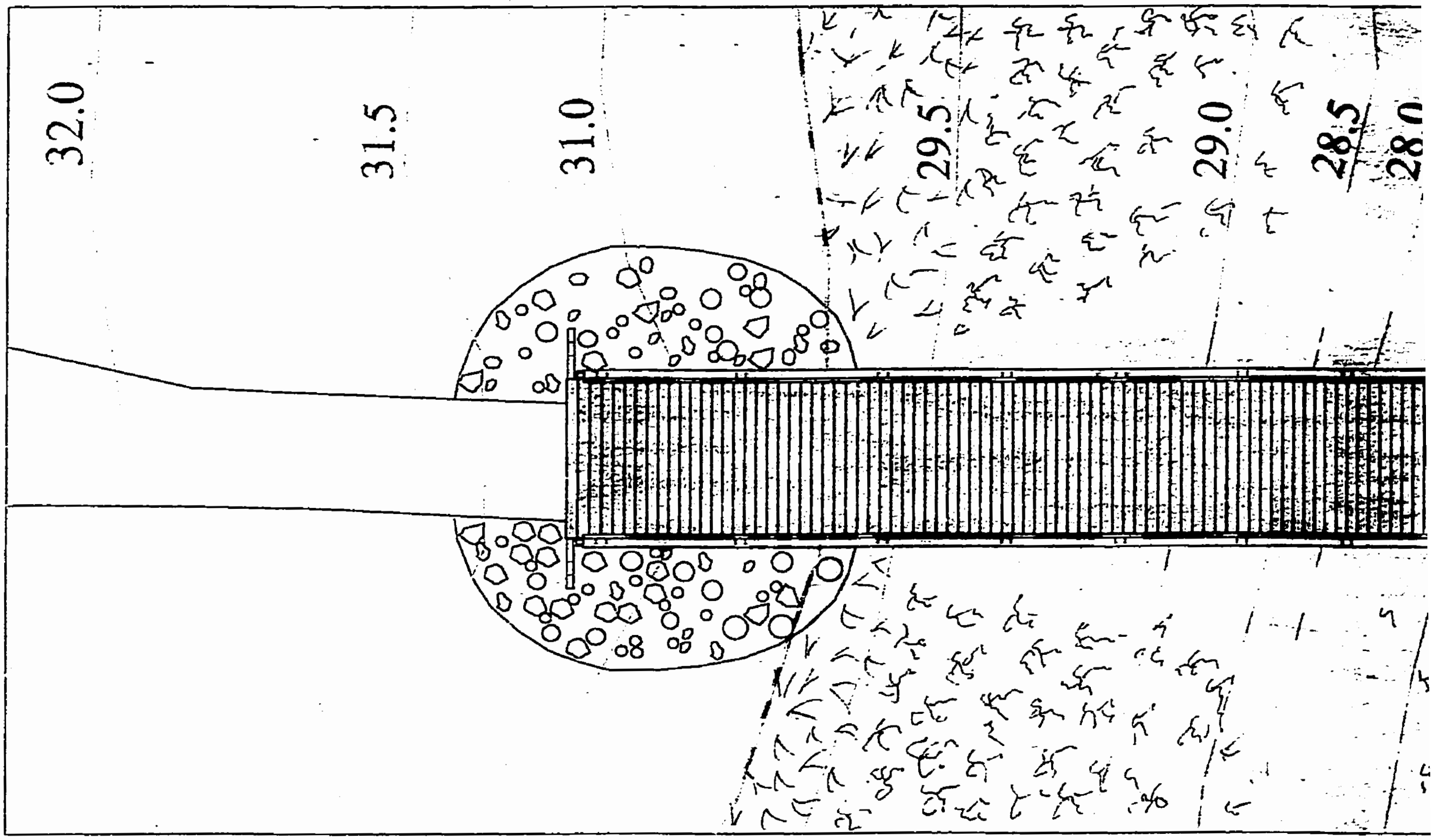
ed channel
ized bolt
ized square
bing
ge channel
ng
ss steel



Plan of swale bridge Scale 1:25

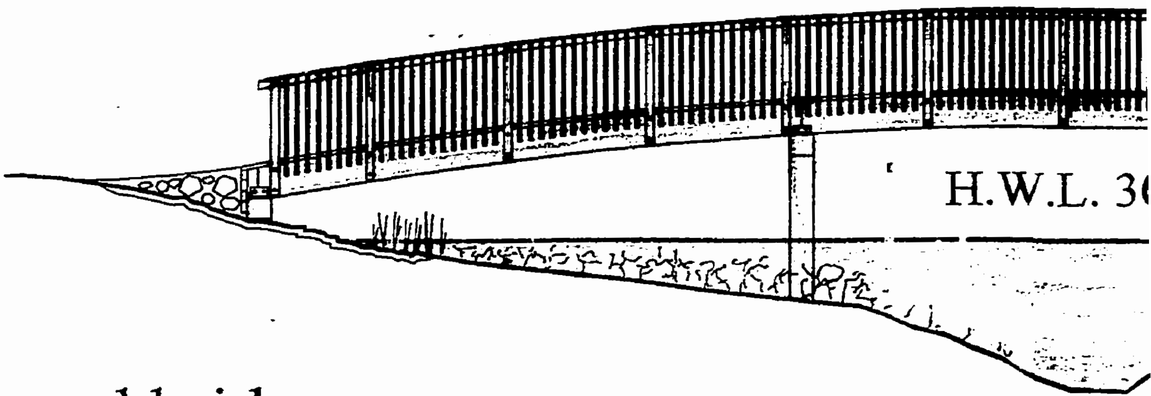
Figure 8.36

Figure 8.37 Plan of pond bridge
Figure 8.38 Elevation of pond bridge, 1: 100



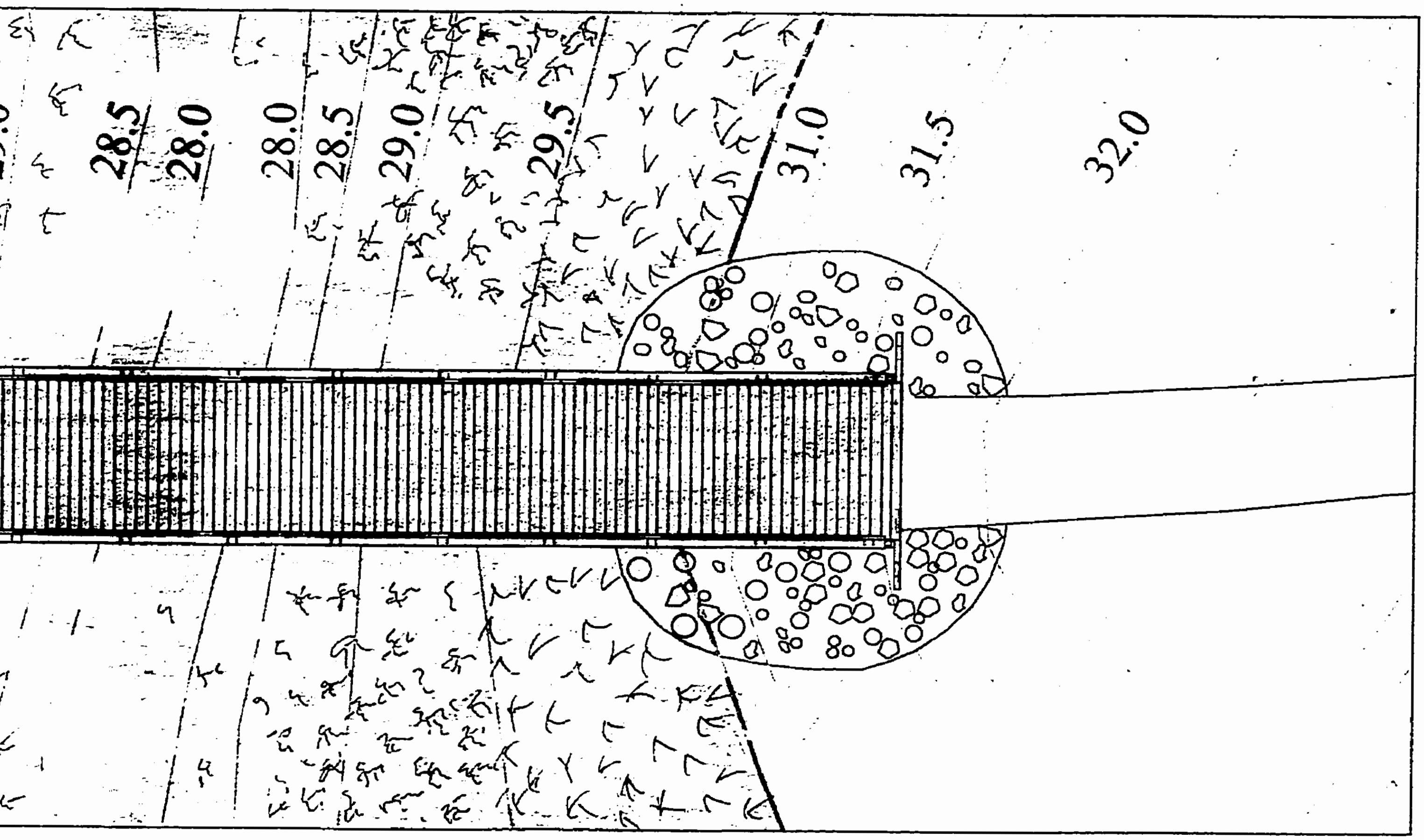
Plan pond bridge

Figure 8.37

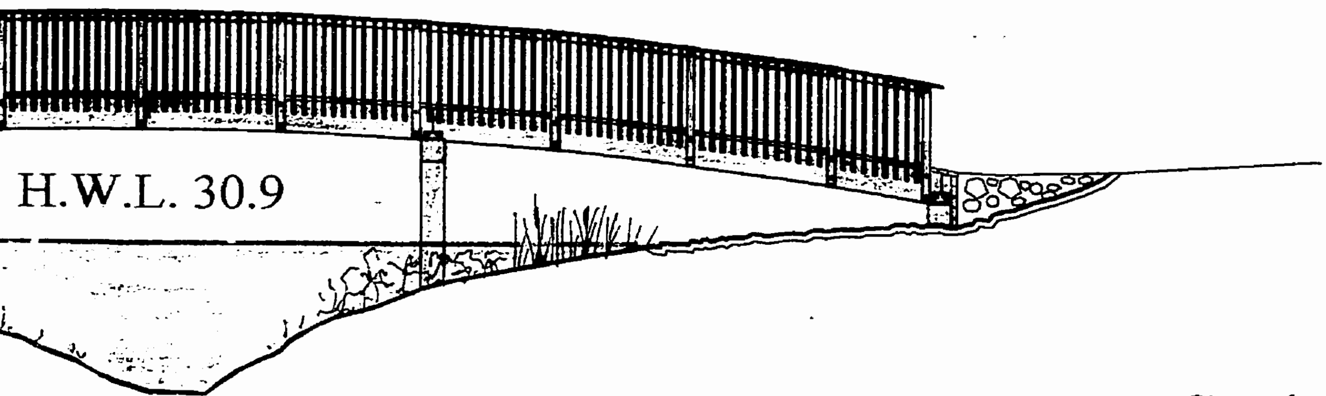


Elevation of pond bridge

Figure 8.38

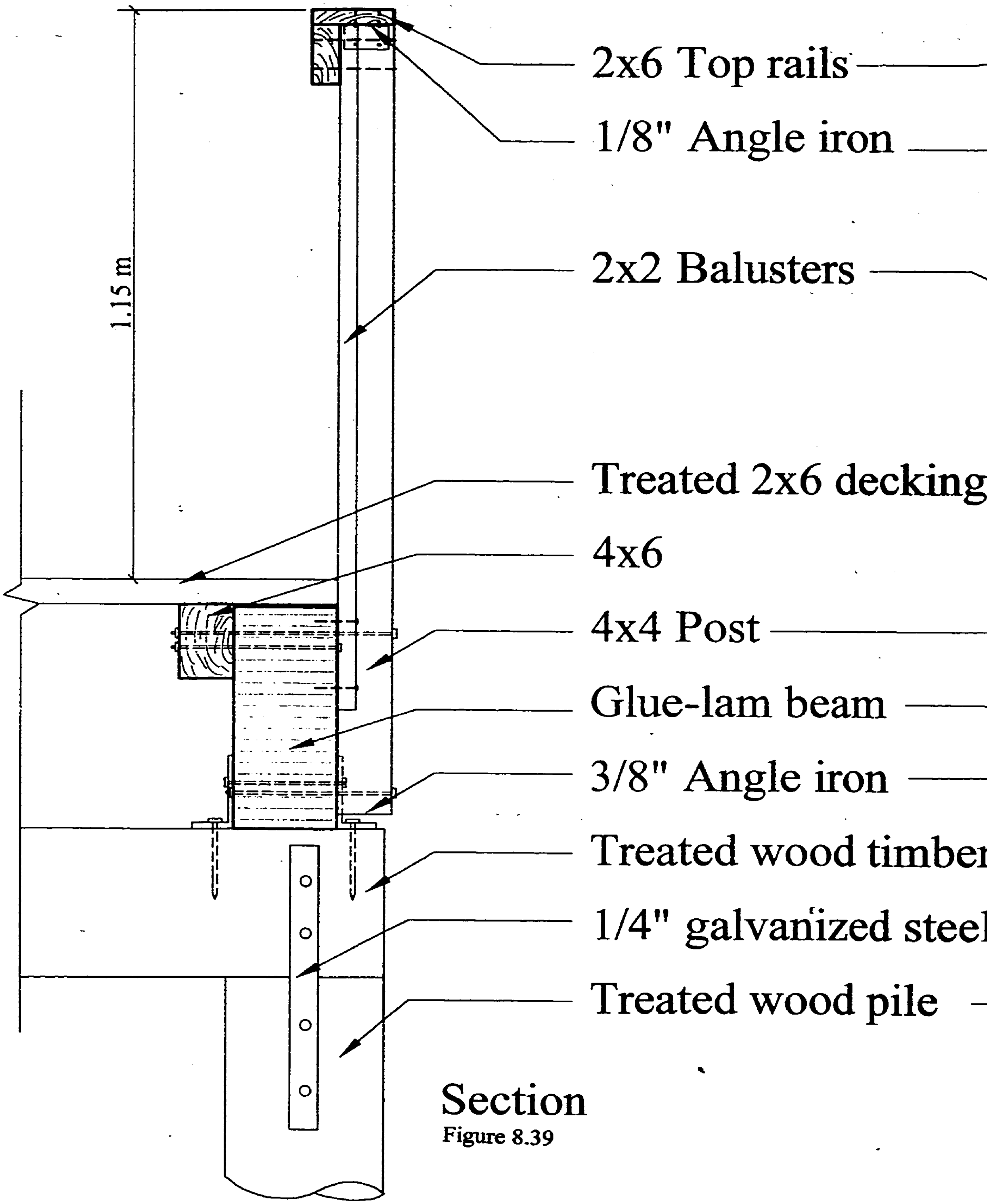


Scale 1:100

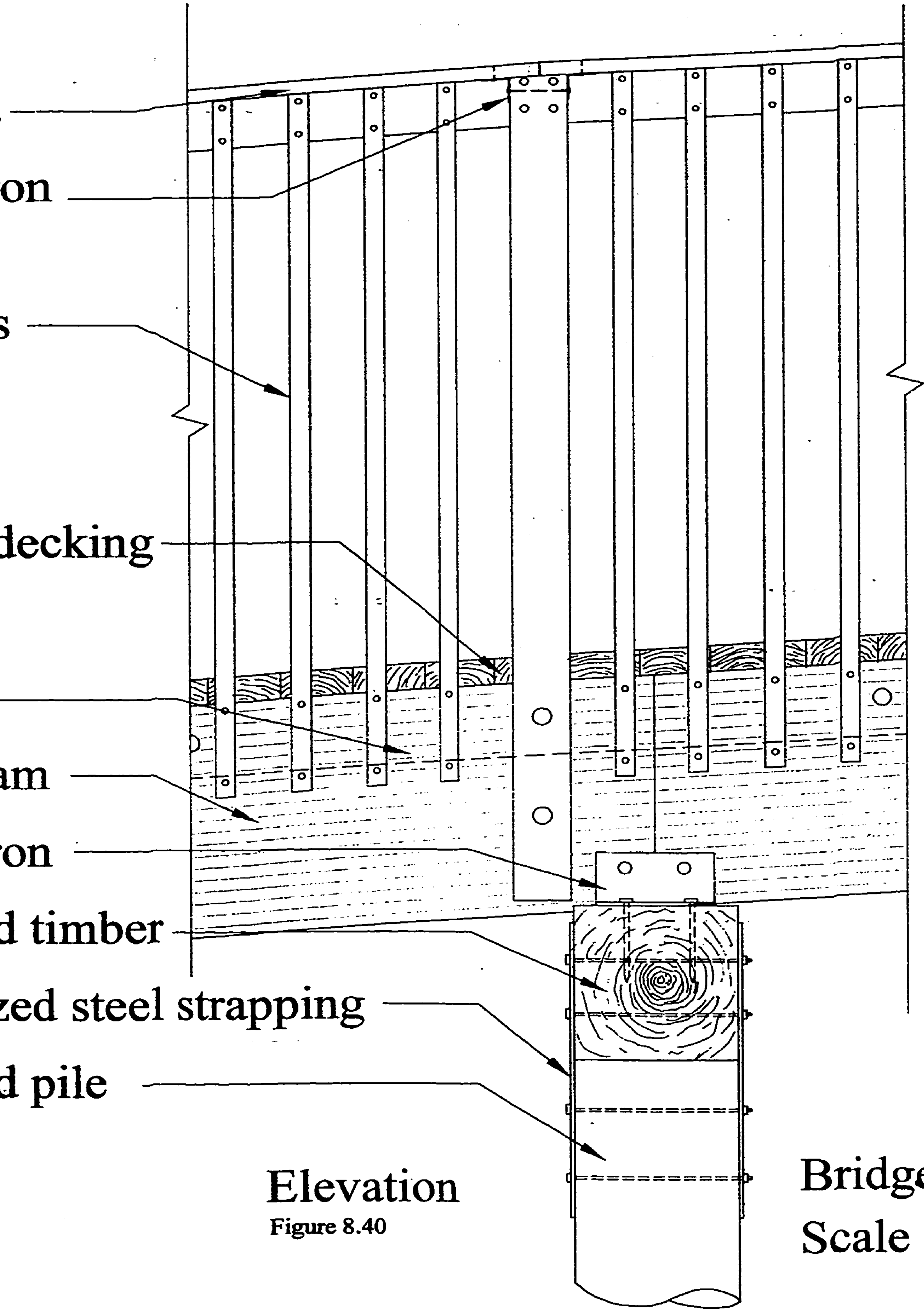


Scale 1:100

Figure 8.39 Section of pond bridge
Figure 8.40 Elevation of pond bridge, 1:10



Section
Figure 8.39



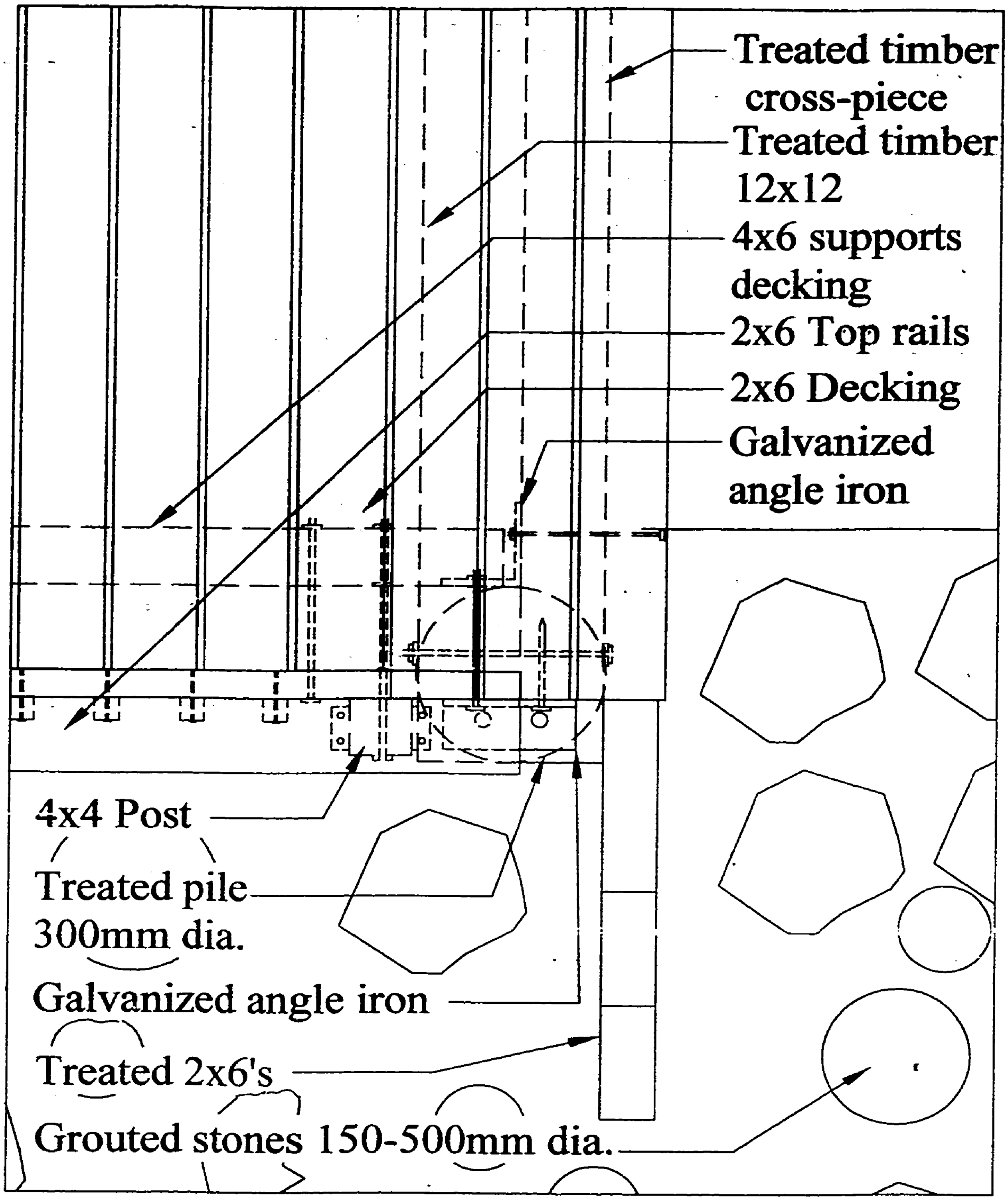
Elevation

Figure 8.40

Bridge over pond

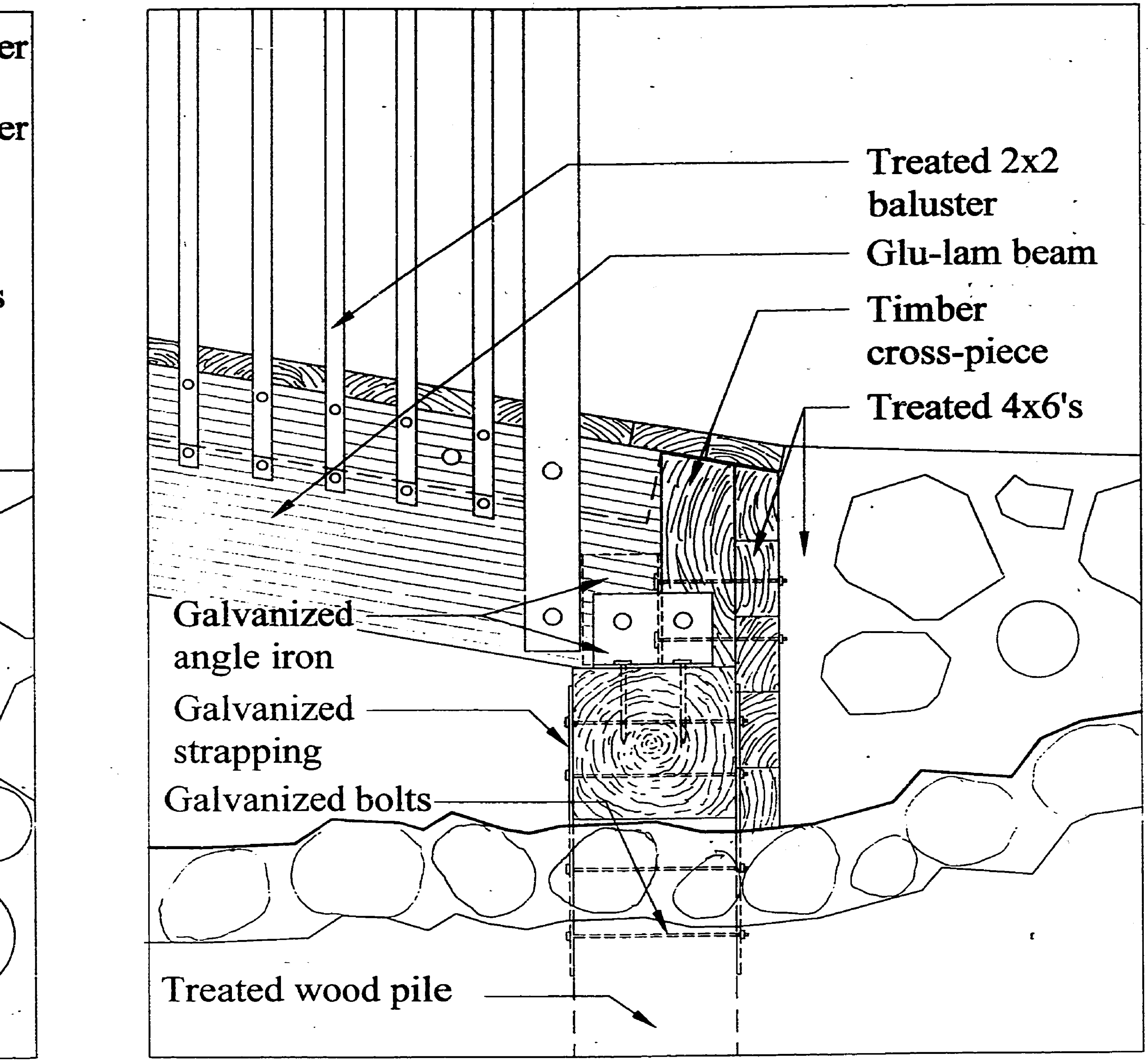
Scale 1 : 10

Figure 8.41 Plan of corner of bridge
Figure 8.42 Elevation of corner of bridge



Plan of corner of bridge Scale 1:10

Figure 8.41



Elevation of corner of bridge

Scale 1:10

Figure 8.42

Figure 8.43 Drainage plan

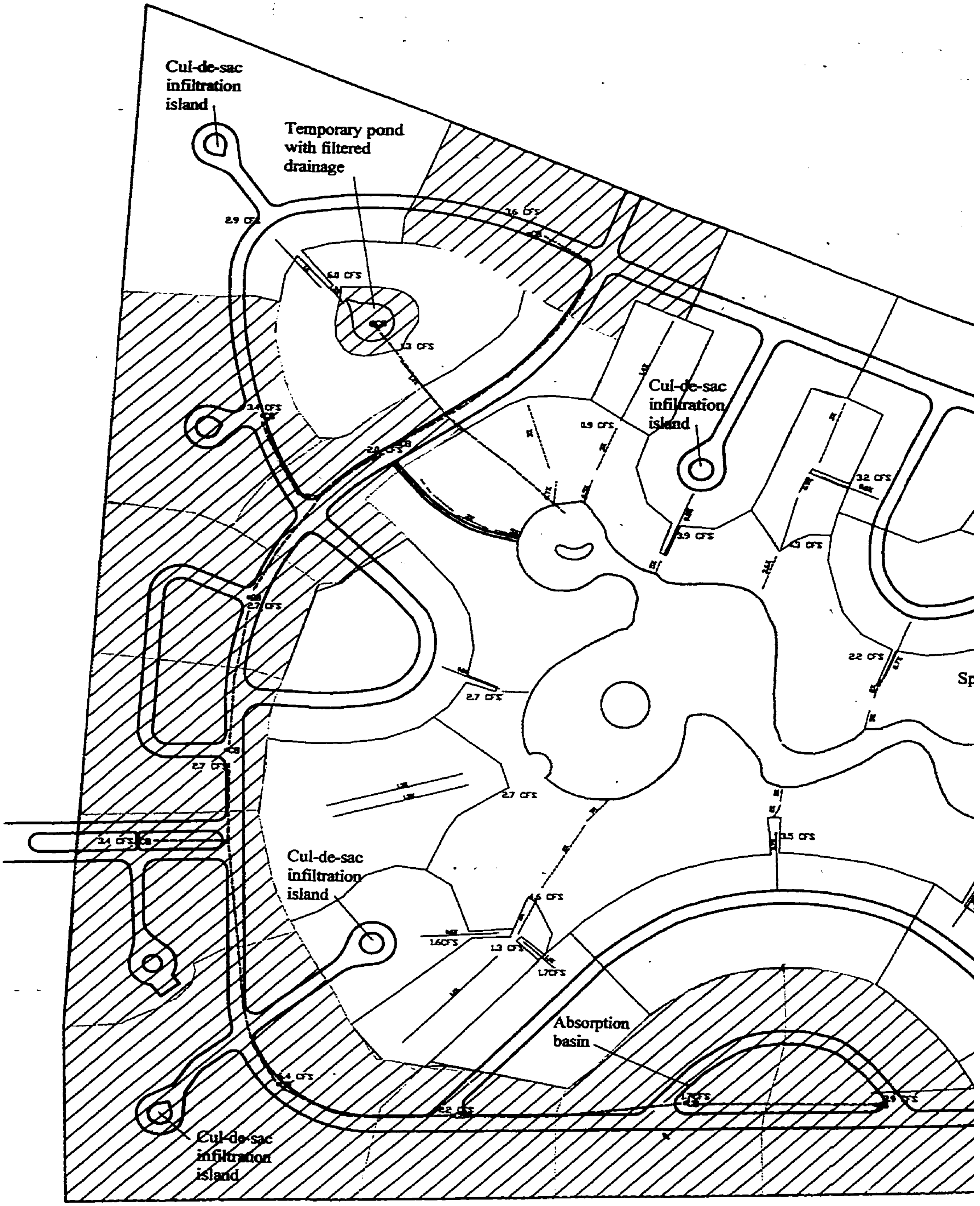
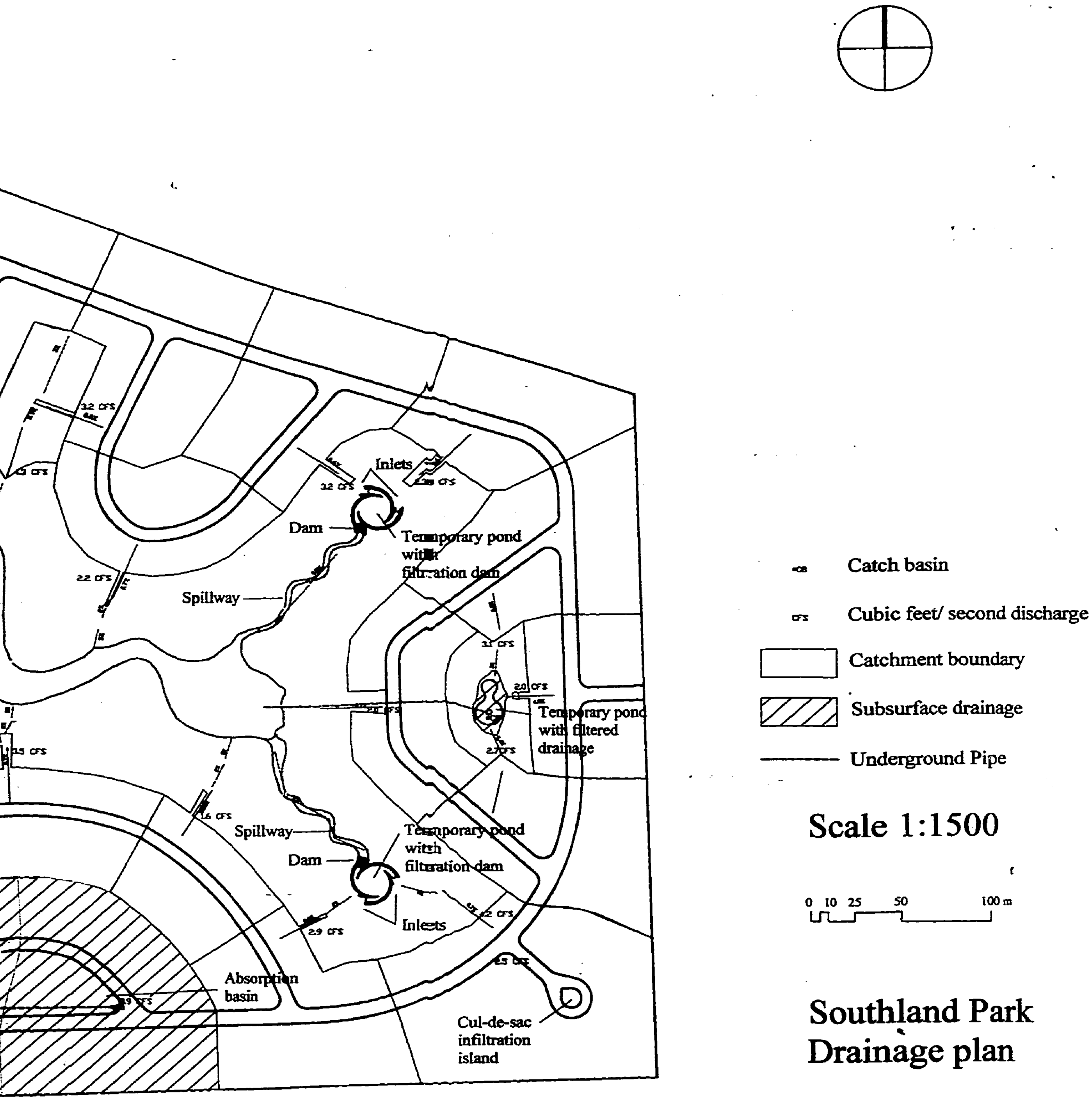

Cul-de-sac
infiltration
island
Temporary pond
with filtered
drainage
Cul-de-sac
infiltration
island
Cul-de-sac
infiltration
island
Absorption
basin
Cul-de-sac
infiltration
island
2.9 CFS
6.8 CFS
1.3 CFS
3.4 CFS
2.0 CFS
0.9 CFS
3.9 CFS
3.2 CFS
2.7 CFS
2.7 CFS
2.7 CFS
2.2 CFS
3.4 CFS
2.7 CFS
3.5 CFS
1.6 CFS
1.60CFS
1.3 CFS
1.7CFS
2.4 CFS
2.2 CFS
3.9 CFS

Figure 8.43



Southland Park Drainage plan

Figure 8.44 Grading plan

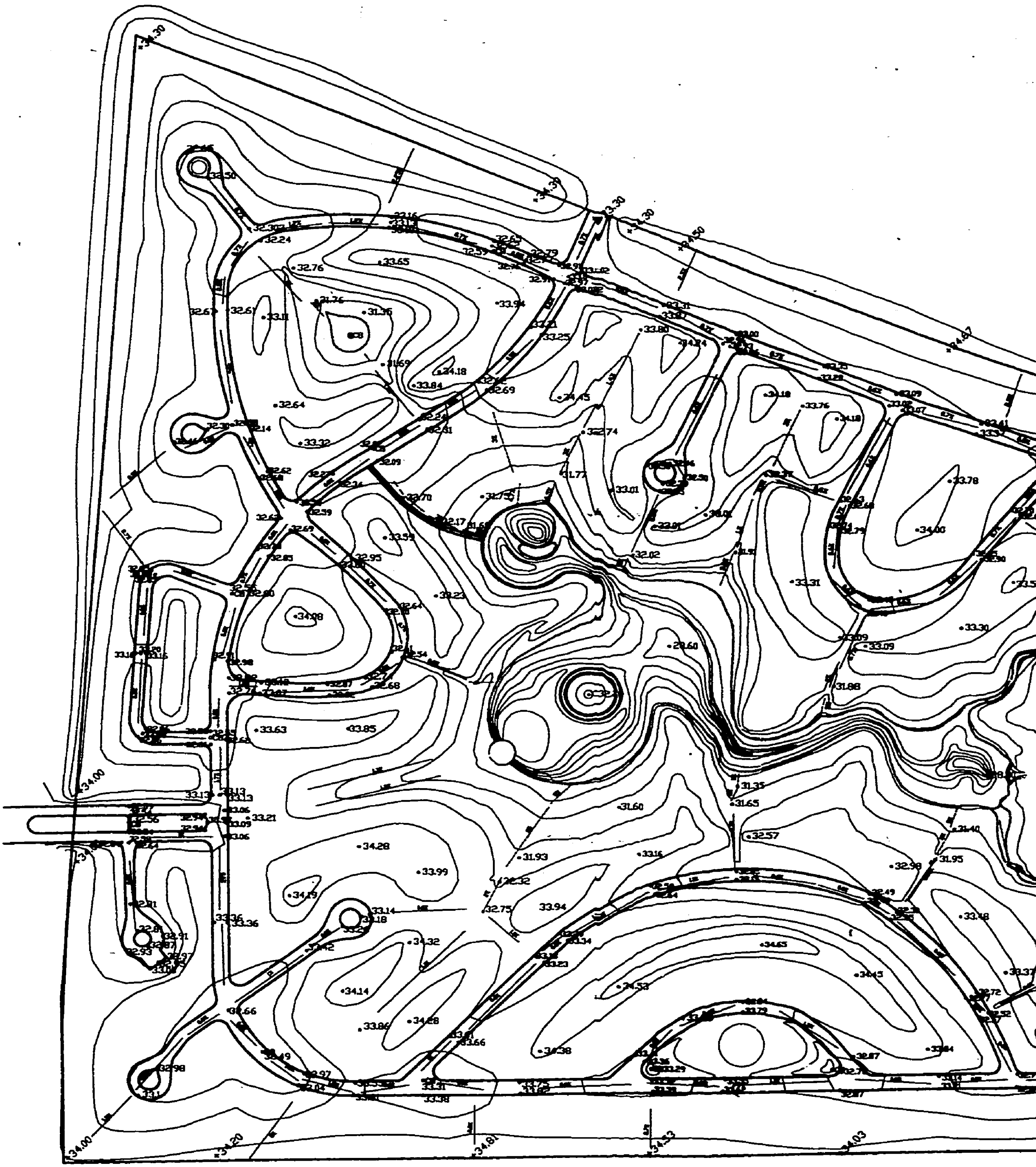
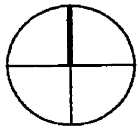
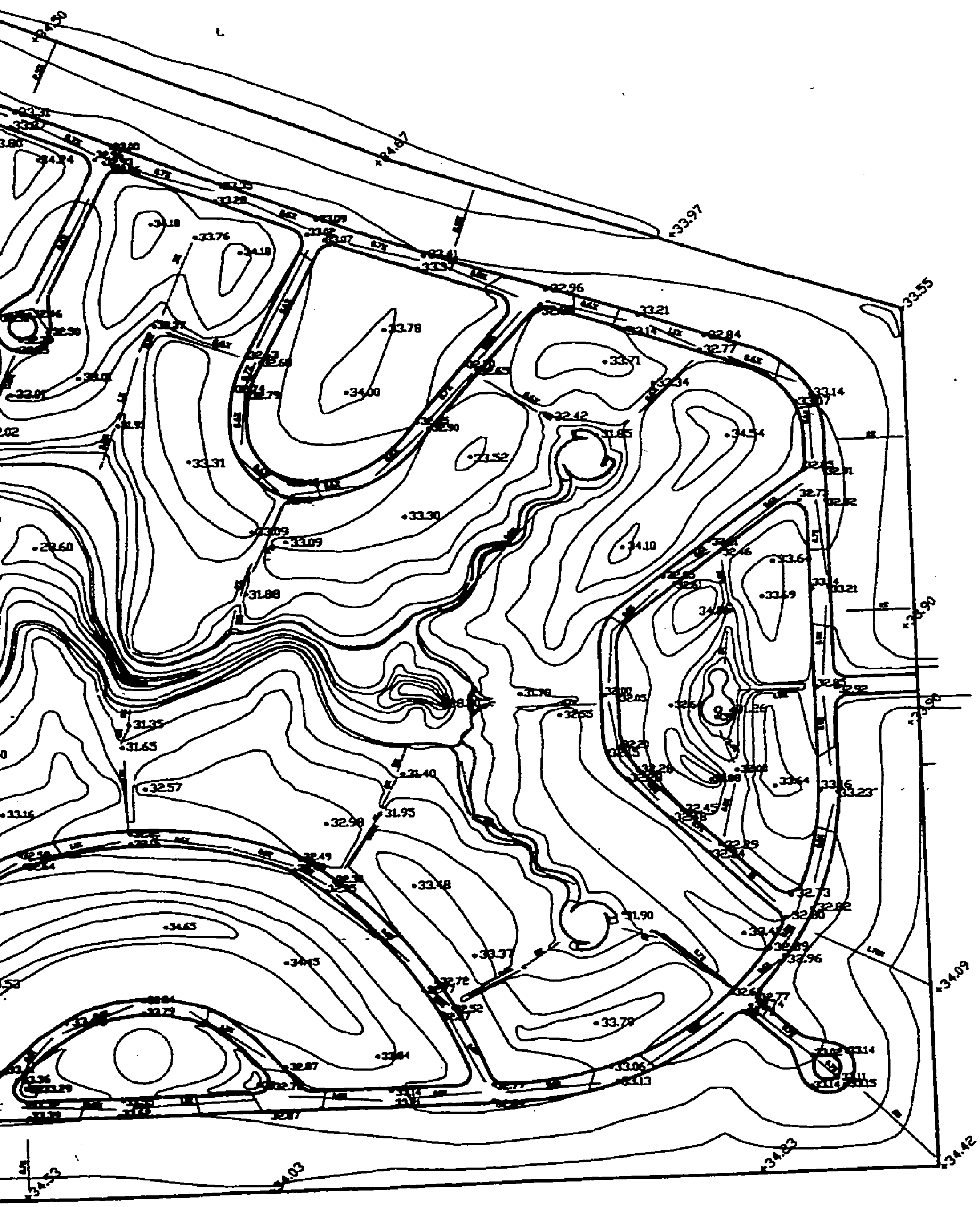


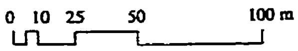
Figure 8.44





- Proposed catch basin
- Proposed swale
- Proposed elevation
- Original elevation

Contour interval 0.5m



Southland Park Grading Plan

APPENDIX A

TYPICAL STORMWATER QUALITY FOR SOUTHDALE AND FORT RICHMOND: 1975 - 1977

TABLE 5-1

TYPICAL STORMWATER QUALITY 1976 (Average Concentrations in mg/L)
(Chambers and Tottle 1980)

Parameter	Influent	Effluent	Percent reduction
Southdale			
BOD_5	12	8	33
SS	206	43	79
N*	1.9	1.9	0
P*	0.4	0.3	28
Fort Richmond			
BOD_5	11	4.5	59
SS	950	87	91
N*	8.8	1.7	72
P*	1.0	0.2	80

* Total
BOD_5 – Measure of biological oxygen demand over a five day period.

TYPICAL STORMWATER QUALITY SOUTHDALE 1977 (Average Concentrations in mg/L)
(Chambers and Tottle 1980)

Parameter	Influent Site 1	Influent Site 2	Average Influent	Effluent Site	Percent Reduction
SS	308. 5	307.9	308.2	19.0	94
TOC	17.8	33.4	25.6	11.9	54
BOD5	6.6	8.4	7.5	4.7	37
TKN	4.3	2.5	3.4	1.7	50
NO3	0.4	0.4	0.4	0.04	90
p*	0.6	0.6	0.6	0.2	67
Cl	8.7	12.4	10.6	18.3	-73
Pb	0.2	0.5	0.4	0.04	90

* Total

TYPICAL STORMWATER QUALITY FORT RICHMOND 1977
(Average Concentrations in mg/L)
(Chambers and Tottle 1980)

Parameter	Influent Site 1	Influent Site 2	Average Influent	Effluent Site	Percent Reduction
SS	1 791.1	574.4	1 182.8	87.1	93
TOC	90.6	37.1	63.9	14.3	78
BOD_5	10.0	7.4	8.7	7.3	16
TKN	4.4	6.3	5.4	3.7	31
NO_3	7.0	2.3	4.7	1.4	69
P*	0.9	1.7	1.3	0.4	69
Cl	39.6	24.9	32.3	300.4	-830
Pb	1.5	0.4	1.0	0.1	90

* Total

STORMWATER EFFLUENT QUALITY 1975
(Average concentration in mg/L)
(Chambers and Tottle 1980)

Parameter	Southdale	Fort Richmond
BOD_5	8	9
SS	26	84
P	0.20	0.24

RESULTS OF BOTTOM SEDIMENT ANALYSIS (Average values)

Impoundment and Date	Total Solids (%)	Volatile Solids (%)	Pb (mg/kg*)	TKN (mg/kg**)	Cl (mg/kg*)	P (mg/kg)
Clearwater L. Southdale 1975	N	11.4	N	N	N	N
Clearwater L. 1976	39.8	7.2	80	1 646	185	N
Clearwater L. 1977	34.8	6.5	212	10 000	N	2 075
North Lake Fort Richmond 1977	49.2	5.1	65	4 500	N	2 050
South Lake Fort Richmond 1977	43.4	5.3	57	6 300	N	1 713

* using dry weight
** adjusted to dry weight
N no analysis was done for this parameter

APPENDIX B

SOME SURFACE WATER QUALITY OBJECTIVES FOR MANITOBA
(Manitoba Environment 1992)

Item	Aquatic life	Primary recreation	Secondary recreation
ammonia (un-ionized)	0.02 mg/l		
Clarity (secchi disc)		1.2 metres	
DO	47% (5mg/l) cool water 60 % cold water	maintain aerobic conditions	
faecal coliform bacteria		mean 200org./ 100ml or individual maximum of 400/ 100 ml	mean 1000/ 100ml or maximum 2000 org/ 100ml
iron	1.0 mg/l		
lead	0.05 mg/l		
mercury	0.00057 ug/l		
nickel*	56 ug/l @ 50 mg/l $CaCO_3$ mg/l 96 ug/l @ 50 mg/l $CaCO_3$ mg/l 160 ug/l @ 50 mg/l $CaCO_3$ mg/l		
nitrate (NO_3)	only important for domestic consumption (10mg/L)		
nitrite (NO_2)	only important for domestic consumption (10mg/L)		
pH	6.5 - 9.0 pH units		
phosphorus	0.05 mg / L		
total coliform		only for domestic consumption	
zinc	**47 ug /l**		

* ug/l = micrograms / litre

APPENDIX C

ACCEPTABLE BOD LEVELS
(Lockery 1990)

1 mg / L	Very Clean
2 mg / L	Clean
3 mg / L	Moderately Clean
4 mg / L	Doubtful Cleanliness
5 mg / L	Poor

BOD LEVELS
James F. MacLaren Ltd.1979

1 mg / L	Very Clean Stream
2 mg / L	Clean Stream
5 mg / L	Doubtful Quality
10 mg / L	Bad – (will likely result in significant O depletion)

APPENDIX D

BENTHIC SURVEY RESULTS 1975 AND 1977
(Chambers and Tottle 1980)

	Sensitive to pollution		Tolerant to intermediate pollution	Tolerant to extreme pollution	
Impoundment	Mayfly Nymph*	Alderfly larvae	Univalve snail	Diptera (midge fly larvae)**	Tubificidae (Sludgeworm)
Southdale					
spring 1975					
fall 1975					
1977					
Fort Richmond					
spring 1975					
fall 1975					
1977					

* Mayfly nymph (Ephemeroptera)
** Midge Fly Larvae (Chironomid Larvae or Bloodworm)

APPENDIX E

1977 FISH SURVEY RESULTS
(Chambers and Tottle 1980)

Impoundment	Number & type of fish	Mean weight (grams)	Condition
North Lake	40 Black Bullheads	99	Average
Fort Richmond	1 Carp	500	Poor
Clearwater Lake Southdale	10 Northern Pike	1053	Poor
Stillwater Lake Southdale	3 Northern Pike	1587	Poor

APPENDIX F

EUTROPHICATION SURVEY FOR LAKES AND RESERVOIRS
(Mason 1991)

PARAMETER	CLASSIFICATION		
	Oligotrophic	Mesotrophic	Eutrophic
Total Phosphorus (ugL^{-1})	< 10	10- 20	> 20
Total Nitrogen (ugL^{-1})	< 200	200-500	> 500
Secchi depth (m)	> 3.7	3.7-2.0	< 2.0
Hypolimnetic dissolved O (% saturation)	> 80	10-80	< 10
Chlorophyll-a (ugL^{-1})	< 4	4-10	> 10
Phytoplankton production ($gCm^{-2}d^{-1}$)	7-25	75-250	350-700

APPENDIX G

1996 STORMWATER RETENTION BASIN MONITORING PROGRAM: BASELINE ANALYSIS VALUES

(City of Winnipeg Laboratory Services Division)

Hydraulic System:

St. James Drainage Network: SRB's 2-2, 2-3 (dry basin), 2-4

Week #	SRB 2-2 Chlorophyll a (ug/L)	SRB 2-3 Chlorophyll a (ug/L)	SRB 2-4 Chlorophyll a (ug/L)	Baseline Value (SRB 2-2)
1	8	N/A	6	8.0
2	3	N/A	3	3.0
3	<3	N/A	4	2.5
4	9	N/A	3	9.0
5	<3	N/A	3	2.5
6	5	N/A	4	5.0

East Kildonan Drainage Network: SRB's 4-2, 4-4, 4-8, 4-9, 4-10, 4-11

Week #	SRB 4-2 Chlorophyll a (ug/L)	SRB 4-4 Chlorophyll a (ug/L)	SRB 4-8 Chlorophyll a (ug/L)	SRB 4-9 Chlorophyll a (ug/L)
1	24	17	8	31
2	<3	26	5	30
3	18	50	10	60
4	14	59	20	82
5	36	86	30	177
6	96	133	23	99

Week #	SRB 4-10 Chlorophyll a (ug/L)	SRB 4-11 Chlorophyll a (ug/L)	Baseline(Untreated) Mean of SRB's4-4,4-8,4-9	Baseline Value (Mean of SRB's4-2,4-4,4-8,4-9)
1	24	N / A	18.7	20.0
2	<3	N / A	20.3	15.3
3	18	N / A	40.0	34.5
4	14	N / A	53.7	43.8
5	36	N / A	97.7	82.3
6	96	N / A	85.0	87.8

River Park South Drainage Network: SRB's 5-16, 5-17, 5-18

Week #	SRB 5-16 Chlorophyll a (ug/L)	SRB 5-17 Chlorophyll a (ug/L)	SRB 5-18 Chlorophyll a (ug/L)	Baseline Value (Mean of SRB's 5-16 & 5-17)
1	18	16	20	17
2	8	25	11	17
3	9	6	12	8

4	10	35	18	23
5	5	45	24	25
6	24	121	27	73

Southdale Drainage Network: SRB's 5-5, 5-6, 5-7, 5-8, 5-9, 5-10, 5-21

Week #	SRB 5-5 Chlorophyll a (ug/L)	SRB 5-6 Chlorophyll a (ug/L)	SRB 5-7 Chlorophyll a (ug/L)	SRB 5-8 Chlorophyll a (ug/L)
1	24	53	21	63
2	86	106	69	136
3	143	177	127	199
4	132	164	124	149
5	184	99	78	237
6	425	509	192	380

Week #	SRB 5-9 Chlorophyll a (ug/L)	SRB 5-10 Chlorophyll a (ug/L)	SRB 5-21 Chlorophyll a (ug/L)	Baseline Value Mean of 5-5, 5-6, 5-7, 5-8, 5-9, 5-10
1	38	32	9	39
2	84	94	16	96
3	54	48	28	125
4	43	97	38	118
5	53	178	39	138
6	343	242	74	349

Fort Richmond Drainage Network SRB's 6-10, 6-11

Week #	SRB 6-10 Chlorophyll a (ug/L)	SRB 6-11 Chlorophyll a (ug/L)	Baseline Value (ug/l) (Mean of SRB's 6-10 & 6-11)
1	22	17	20
2	22	31	27
3	58	36	47
4	114	64	89
5	55	59	57
6	46	53	50

St. Norbert Drainage Network SRB's 6-12 & 6-13

Week #	SRB 6-12 Chlorophyll a (ug/L)	SRB 6-13 Chlorophyll a (ug/L)	Baseline Value (ug/L) (Mean of SRB's 6-12 & 6-13)
154	20	24	22
	14	11	13
183	16	21	19
	104	31	68
210	11	3	7
	11	15	13

Turbidity:

Week #	SRB 6-10 Turbidity (ntu)	SRB 6-11 Turbidity (ntu)	Baseline Value (ntu) (Mean of SRB's 6-10 & 6-11)
154	12.5	17	15
183	14	9.9	12
210	18	26	22

Week #	SRB 6-12 Turbidity (ntu)	SRB 6-13 Turbidity (ntu)	Baseline Value (ntu) (Mean of SRB's 6-12 & 6-13)
154	7.6	8.2	7.9
183	8.3	10.0	9.2
210	3.3	2.8	3.1

Week #	SRB 6-7 Turbidity (ntu)	SRB 6-8 Turbidity (ntu)	SRB 6-9 Turbidity (ntu)
154	2.6	2.9	2.8
183	6.5	1.8	11
210	8.3	27	7.0

Transparency

Week #	SRB 6-10 Transparency (m)	SRB 6-11 Transparency (m)	Baseline Value (m) (Mean of SRB's 6-10 & 6-11)	SRB 6-12 Transparency (m)
154	0.2	0.2	0.2	0.3
169	0.3	0.2	0.3	0.2
183	0.1	0.2	0.2	0.2
196	0.2	0.2	0.2	0.2
210	0.1	0.1	0.1	0.8
233	0.7	0.1	0.4	0.8

Week #	SRB 6-13 Transparency (m)	Baseline Value (m) Mean of 6-12, 6-13	SRB 6-7 Transparency (m)
154	0.2	0.3	0.6
169	0.2	0.2	0.4
183	0.2	0.2	0.2
196	0.2	0.2	0.4
210	0.7	0.8	0.2
233	0.8	0.8	0.3

pH

Week #	SRB 6-10 pH	SRB 6-11 pH	Baseline Value (pH) (Mean of SRB's 6-10 & 6-11) pH	SRB 6-12
154	8.8	8.9	8.9	7.6
183	8.4	8.2	8.3	9.0
210	8.7	8.9	8.8	9.5

pH

Week #	SRB 6-12 pH	SRB 6-13 pH	Baseline Value (pH) (Mean of SRB's 6-12 & 6-13)	SRB 6-7 pH
154	7.6	7.7	7.7	9.4
183	9.0	9.3	9.2	10.4
210	9.5	9.7	9.6	9.3

APPENDIX H

RELATIONSHIPS BETWEEN SUBMERGENT PLANTS
AND MACROINVERTEBRATE ABUNDANCE
(Sowls 1955)

Plant species	Food value (as Plants)	Taxa / Species supported	Mass / 100g plant (animal / Plant)	Overall rank
Lemna trisulca	6	46	2 059	1
Heteranthera dubia	29	30	1 530	2
Ceratophyllum demersum	20	18	1 510	3
Elodea canadensis	37	45	1 117	4
Chara vulgaris & Najas flexis	10	30	795	7
Potamegeton spp.	1	30	660	9
Algae	18	32	306	11
Myriophyllum spicatum	27	18	71	12

APPENDIX I

LIST OF DUCK SPECIES BREEDING IN THE WINNIPEG AREA
(Johnsgard, 1975)

Tribe	**Common Name**	**Species Name**
Perching ducks	Wood duck	*Aix sponsa*
Dabbling ducks	American Widgeon	*Anas americana*
	Gadwell	*A. strepera*
	Green-winged Teal	*A. creeca*
	Mallard	*A. platyrynchos*
	Pintail	*A. acuta*
	Blue-winged Teal	*A. discors*
	Northern Shoveler	*A. clypeata*
Pochards	Canvasback	*Aythya valisineria*
	Redhead	*A. americana*
	Ring-necked duck	*A. collaris*
	Lesser Scaup	*A. affinis*
Sea Ducks	White-winged Scot	*Bucephala* ***
	Bufflehead	*B. albeolo*
	Common Goldeneye	*B. clangula*
	Hooded Merganser	*Mergus cucullatus*
Stiff Tailed Ducks	Ruddy ducks	*Oxyura jamaisensis*

APPENDIX J

COVER PLANT SPECIES FOR 683 DUCK NESTS
OF FIVE SPECIES AT DELTA, MANITOBA
(Sowls 1955)

Duck species >	Mallard	Pintail	Gadwell	Shoveller	B-w Teal
Size of sample >	143	222	38	65	215
Cover species V	Percentage of nests in each type				
Whitetop *Scolochload~ stucacea* ???	58	51	58	28	24
Cord grass *Spartina pectinata*	12	8	18	26	27
Blue grass (*Poa sp.)*	5	10	8	18	19
Quack grass (*Agropyron spp.)*	0	2	0	20	17
annual weeds	5	6	15	3	2
phragmites *(Phragmites australis*)	11	3	0	0	1
skunk grass	1	4	0	1	4
grain stubble	1	6	0	0	0
Brome grass *Broma spp.*	0	0	0	0	5
Sedges *(Carex spp.)*	0	4	0	4	0
Goldenrod/ Aster	3	2	0	0	1
Bulrush *(Juncus spp.)*	34	1	1	0	0
Snowberry *(Symphoricarpos Spp.)*	0	1	0	0	0
Willow *Salix spp.*	0	1	0	0	0

on Muskrat house	0	1	0	0	0

APPENDIX K

REMOVAL OF NUTRIENTS FROM WASTEWATER BY DUCKWEEDS

(Culley and Epps 1973)

	Kg/ month/ ha
Duckweed (dry weight)	2800
Crude protien	1120
Total N	185
Total P	60
Total K	65

APPENDIX L
USES FOR HARVESTED NUTRIENTS

Uses for removed nutrients

The bioproductivity of wetlands is very high, and this can be used to our benefit. As with the example of aquiculture, where fish are raised in ponds for human consumption, there can be other benefits. Another Asian example, is the use of emergents such as rice for food. Here, wild rice may have potential, and there are other plants such as water chestnuts, watercress, and water lilies that can be used for food. The potential for human food may be somewhat limited when compared to the potential for animal feed.

Free floating plants tend to have production rates that outstrip any terrestrial crops, and they can also be good sources of nutrition. Duckweeds have as much as 44.7% crude protein, which is more than many cultivated crops (Hillman et al 1978), but since the production of duckweeds is so high, then the relative protein production per year is much higher than many agricultural crops (Truax et al 1972). *Lemna minor* and *Spirodela polyrhyza*, when used as a food supplement for pigs produced 20% additional growth (Sperling 1962). Emergents such as cattails, on the other hand, tend to be mostly fibrous, having lower nutritional content in the part of the plant that is harvested. Cattle may also refuse to eat such plants, possibly because they contain tannins (Varshne and Roska 1976).

The same fibrous nature of emergents, that make it a poor feed, also make it suitable for other uses. The fibre from the plants can be used by pulp mills to make paper, cellophane or cardboard. It can also be made into insulation, fibre board, compressed into building blocks or used in straw bale construction (Reimer 1984).

Macrophytes, and algae are nutrient-rich, and therefore would make excellent compost. The algae must be of sufficient size or diameter to enable harvesting if it is to be harvested and used. Digesting is a process similar to composting, but here the decomposing organic material yields methane, which can be used as an energy source.

Soil that is removed through dredging may be nutrient rich, but it may not make good topsoil. It may be useful as potting soil if it is mixed with peat sand and vermiculite (Reimer 1984). Chambers and Tottle (1980) suggest that the sediment dredged from our retention ponds would make suitable fill.

Practicality

Although the previous uses for aquatic plants represent a great opportunity for maximizing the potential benefits of wetlands they may not be practical, or at least not practical at a neighbourhood retention pond. The levels of any potential contaminants in plants and soil should be known before they are used for food, feed or compost. The possibility of using aquatic plants as feed may also be limited because the moisture content in the plants makes the transport of them more expensive unless they are dried. Using retention ponds for the raising of fish may also prove unsuccessful if the fish are not a species that are desired by local people. Uses for the fibre of emergents may also prove unrealistic if there are not adequate facilities nearby to process the material, and there would not be the facilities in Winnipeg. If there were the facilities then there might not be enough material the make the venture feasible financially. If there is to be a harvest, then it is possible to find a use for the vegetation, even if it is just to avoid disposing the plants in a landfill, but if the harvested plants prove to be too contaminated then that is where they should go.

Appendix M

Species Lists

Aspen forest

Aster laevis	smooth aster
Aster codifolius	blue wood aster
Cornus alba	red osier dogwood
Populus tremuloides	trembling aspen
Populus balsamifera	balsam poplar
Quercus macrocarpa	bur oak
Ribes glandulosum	skunk current
Ribes oxycanthoides	gooseberry
Rubus pubescens	dewberry
Rubus strigosus	raspberry
Symphoricarpus occidentalis	western snowberry
Viburnun lentago	nannyberry

Spillway border

Acer negundo	Manitoba maple
Alnus rugosa	river alder
Betula papyifera var.*papyifera*	paper birch
Fraxinus nigra	black ash
Fraxinus pennsylvanica var. *subintegerrima*	green ash
Ribes americanum	wild black current
Salix planifolia	flat-leaved willow

Gutter border

Pinus mugo	mugo pine
Potentilla fruticosa	shrubby cinquefoil
Prunus americana	wild plum
Prunus pennsylvanica	pincherry
Prunus pumila	sandcherry
Prunus virginiana var. *melanocarpa*	chokecherry
Ribes americanum	wild black current
Rosa acicularis	prickly rose
Rubus idaeus	wild red raspberry
Viburnum lentago	nannyberry
Viburnum trilobum	high bush cranberry
Solidago	goldenrod

Marsh

Emergents

Beckmannia syzigachne	slough grass
Hippuris vulgaris	Mare's Tail
Iris versicolor	wild iris
Juncus balticus	Baltic rush
Phragmites communis	reed grass
Typha latifolia	cattail
Scirpus validus	common bulrush
Scolochoa festucacea	splangle top

Submergents

Callitriche autumnalis	water starwort
Catabrosa aquatica	water grass
Ceratophyllum demersium	hornwort
Elodea canadensis	waterweed
Lemna trisulca	ivy-leaved duckweed
Myriophyllum exalberscens	water milfoil
Potamogeton zosteriformis	eel grass
Potamogeton richarsonii	Richardson's Pondweed
Polygonum coccineum	swamp persicaria
Sagittaria cuneata	arrowhead

Edge

Alopecurus aequalis	foxtail
Catabrosa aquatica	water grass
Glyceria borealis	manna grass
Potentilla palustris	marsh five-finger
Potentilla aserina	silverweed
Rorippa islandica	marsh cress
Alisma triviale	water plantain

Others

Lemna minor	duckweed
Limosella aquatica	mudwort
Nymphaea odorata	scented water lily

Appendix N

Tall Grass Prairie Plants
(Morgan, Collicutt, Thompson, 1995)

Grasses

Scientific name	**common name**
Agropyron subsecundum	awned wheatgrass
Agrostis scabra	hair grass
Andropogon gerardii	big bluestem
Andropogon scoparius	little bluestem
Elymus canadensis	Canada wild rye
Muhlenbergia racemosa	marsh muhly
Muhlenbergia richardsonis	mat muhly
Panicum virgatum	switch grass
Spartina pectinata	prairie cord grass

Wildflowers

Scientific name	**common name**
Achillea millefolium	yarrow
Allium stellatum	pink flowered onion
Anemone canadensis	Canada anemone
Anemone cylindrica	long fruited anemone
Asclepias ovalifolia	dwarf milkweed
Aster ericoides	many-flowered aster
Aster laevis	smooth aster
Astragalus canadensis	Canada milk vetch
Campanula rotundifolia	harebell
Gaillardia aristada	gaillardia
Gallium boreal	northern bedstraw
Helianthus maximilliani	narrow leaved sunflower
Heuchera richardsonii	alum root
Liatrus ligulistylus	meadow blazingstar
Lillium philidelphicum	prairie lily
Monarda fistulosa	bergamot
Petalostemon candidum	white prairie clover
Petalostemon purpureum	purple prairie clover
Potentilla arguta	white cinquefoil
Potentilla pensylvanica	prairie cinquefoil
Ratibida columnifera	yellow coneflower
Rudbeckia hurta	black-eyed Susan

Solidago canadensis	Canada goldenrod
Solidago rigida	stiff goldenrod
Solidago uliginosa	marsh goldenrod
Zigadenus elegans	smooth camas
Zizia aptera	heart-leaved alexander

Shrubs

Scientific name	**common name**
Elaeagnus commutata	silverberry, wolfwillow
Potentilla fruticosa	shrubby cinquefoil
Rosa acicularis	prickly rose
Rosa arkansana	prairie rose
Rosa woodsii	Wood's rose
Spirea alba	meadow sweet
Symphoricarpus occidentalis	western snowberry

Appendix O

Issue Checklist

Pollution

Aquatics
- Slows water flow and increases sedimentation.
- Absorb and contain some toxins.
- Absorb and metabolize some toxins.
- Provide surfaces for attachment of some microbes which degrade toxic substances.
- Aerate rhizosphere, providing aerobic habitat for microbes which degrade toxins.

Upland vegetation
- Coarser vegetation increases sedimentation of heavy metals, or other toxins.
- Absorb and contain toxins.
- Absorb and degrade toxins, along with associated microbes.
- Habitat for microbes.

Temporary ponds
- Increased sedimentation.
- Reduces runoff quantities, and velocities to main pond.
- Sediments can be collected easily.

Eutrophication

Aquatics
- Increase sedimentation of undissolved nutrients.
- Absorb nutrients.
- Submergents oxygenate water increasing the ability of soil to hold phosphorus.

Upland vegetation
- Increases sedimentation of undissolved nutrients outside of waterbody.
- Absorbs an uses nutrients.
- Nutrients in vegetation can be easily harvested.

Shallow water depths
- Increases amount of water that must flow through vegetation.

More complex pond shape
- Increases length of flow for water.

Islands
- Increase length of flow for water.

Temporary ponds
- Increases sedimentation of phosphorus.
- Self-draining allows for easy plant/nutrient harvest.

Waterfowl

Aquatics
- Provide shelter for fowl.
- Act as a food source for waterfowl.
- Provide nesting material for waterfowl.
- Provides food and habitat for invertebrates, which act as food for fowl.
- Can act as perches for some birds.

Upland vegetation
- Provides shelter for nests.
- Provides material for nest construction.
- Provides food.

Islands
- Provides nesting site safe from terrestrial predation, and public disturbance.

Temporary ponds
- Thaw early in spring, giving for waterfowl early ponds for feeding on invertebrates.

Forrest
- Provides habitat for perching birds.
- Provides food for birds.

Shoreline
- shoreline has more vegetation, but has some open areas in to improve access for waterfowl.

Access

Swales
- Provide right-of-ways which can be used by pedestrians.

Bridges
- Provides unique viewpoint of pond.
- Provide easier pedestrian passage over pond, and through park area.

Lookouts
- Provides better viewpoints near water landscape.

Continuous public space
- Allows continuous pedestrian movement, which facilitates maximum length of paths for pedestrians.

Aesthetics

Pond shape
- Complex pond shape adds to interest of pond.

Landscape heterogeneity
- More interest through the amalgamation of forest, grassland and pond.

Upland vegetation
- More plant species, and mix of plant heights, textures, and

colours increase interest.

Trees

- Define spaces, reinforce axis, and designate entrances to public areas.

Islands

- Add interest to pond, creating more complex interaction between land and water.

GLOSSARY

Anoxic -	Condition where there is a lack of oxygen.
Autotrophic -	Self nourishing, able to feed on simple substances, and obtain its chemical constituents from simple inorganic compounds.
Benthic -	Living at the soil water interface, at the bottom of a water body.
Bioaccumulation-	Process whereby organisms accumulate a significantly higher concentration of toxins than the water they obtained them from.
Biomagnification-	Process whereby increasingly higher concentrations of toxins are found in organisms relative to their positions on the food chain.
Bloom -	An aggregation of phytoplankton sufficiently dense to be readily visible
BOD -	Biological oxygen demand. The amount of oxygen required to break down effluent. (Usually a high BOD means that organic material is being broken down by aerobic bacteria, which is using up oxygen).
CEC -	Cation exchange capacity
Chelators -	Chemical which bonds with unwanted metal ions (heavy metals)
Chlorophyll-a -	Can be a measure of density of green algae
CSO's -	Combined sewer overflows
Cyanobacteria -	Blue-green algae (name recognizes similarities between bacteria and algae, however, the name has fallen out of use).
Dabbling duck -	Duck that feeds on the surface of freshwater, or on land.
DO -	Dissolved oxygen, measure of oxygen available in water (mg/L)
Eutrophic -	Condition where water has a high amount of nutrients.
Epilimnion -	The upper layer of warm water in a body of water.
Faecal cloliform -	Provides a measure of possible pathogens in the water (MPN / 100mL (MPN -most probable number))
Flocculation-	The coalescence of finely divided precipitate into larger particles.

Histosols - Organic soils.

Hydrophilic - Having an affinity for water.

Hydrophyte - Plant having an affinity for water. Leaves are partly or wholly submerged, or buds exist in water.

Hypertrophic - Excessively rich in nutrients (more than eutrophic waters) .

Hypolimnion - Lower level of water in stratified lakes.

Isotherm - A line drawn on a map joining points of equal temperature.

Lentic - Pertaining to standing water.

Mesotrophic - Condition where water has a medium amount of nutrients.

Oligotrophic - Condition where water is nutrient poor, usually a characteristic of cold deep lakes.

Phytobenthos - Plants living at the water soil interface, at the bottom of a waterbody.

Phytoplankton - Algae, that is small or often microscopic.

Phytoremediation - Using plants to heal the environment by the absorption and containment or degradation of pollutants.

pH- value - A logarithmic unit for measuring hydrogen ion (H+) concentration (values below 7 are acidic, and values above are alkaline).

Pochard - Diving duck that feeds below the surface of a freshwater body.

Redox-potential - The reduction-oxidisation potential

Rhizosphere- The zone of soil immediately adjacent to the active root.

SO's - Stormwater overflows

SS - Suspended solids (organic matter in water)

Synergism - Combined effect of drugs, organs, pollutants, etc.

Thermocline - In lakes, a region of rapidly changing temperature, found between the hypolimnion and the epilimnion.

Zooplankton - Small aquatic animal that grazes on plankton.

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