The University of Manitoba

A Holistic Approach to Dike Design:
St Norbert Manitoba, A Case Study and Application

A Practicum submitted to the Faculty of Graduate Studies
in partial fulfillment of the requirements for the degree
of Master of Landscape Architecture

by Andrew M. Jones

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THE UNIVERSITY OF MANITOBA

FACULTY OF GRADUATE STUDIES
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A HOLISTIC APPROACH TO DIKE DESIGN: ST NORBERT MANITOBA, A CASE STUDY AND APPLICATION

BY

ANDREW M. JONES

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of

MASTER OF LANDSCAPE ARCHITECTURE

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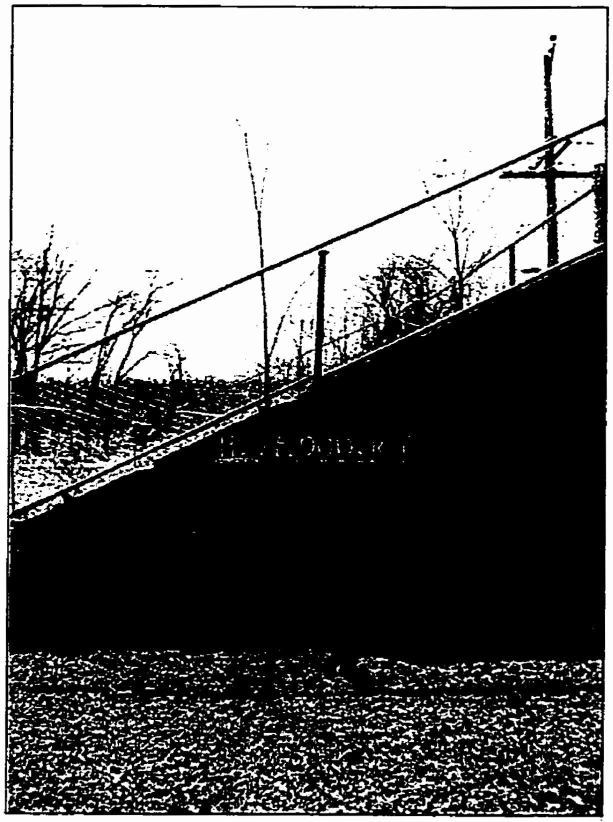
PART I: FLOOD CONTROL AND DIKING

1.0 INTRODUCTION



> "It is futile to assume that the Red River shall never again overflow its banks. Man is utterly powerless to prevent its occurring periodically, and whenever it occurs the disastrous consequences will be intensified in proportion to the increased number of inhabitants within the submerged district"
>
> Sir Lord Fleming,1879

1.0 INTRODUCTION

> Disregard of natural processes in the city is, always has been, and always will be both costly and dangerous. Many cities have suffered from a failure to take account of nature (Spirn 1984).

The stark truth of this statement was realized by the people of Manitoba in the spring of 1997 when the Red River rose to a height of 24.5 feet, threatening to inundate hundreds of homes and businesses, and displacing some 28,000 residents from southern Manitoba, including 4,000 from the Winnipeg suburb of St Norbert. Periodic, sometimes annual, springtime flooding has been a feature of the Red and Assiniboine Rivers for centuries.

In this century, attempts to control the Red River, and other rivers world-wide, have involved the extensive use of diking systems. As historian of Red River floods, J.M. Bumsted, has noted, "Most flood related research is very engineering-oriented, but engineering isn't everything" (Novum 1998:1). Diking systems consist essentially of utilitarian structures with a single temporally-limited purpose. While they fulfill their primary purpose of keeping flood waters away from homes, businesses, and agricultural land, they are typically lacking in visual appeal and often act as intrusive obstacles to the social lives of the communities they protect. Despite the widespread occurrence of dikes, particularly in North America, the role of the landscape architect in reconciling the community's need for protective structures with its social needs is only just beginning to be recognized. The landscape architect, as environmental steward and designer, is trained to seek holistic solutions that are both environmentally appropriate and culturally responsive. The multidisciplinary approach of the landscape architect can productively provide for both human and ecological needs, satisfying social needs within the human community while preserving healthy environments for wildlife and vegetation. With proper attention to detail, context, and alternative uses, the negative visual impact of diking on the landscape can be reduced, and necessary utilitarian structures can be integrated into their immediate physical and social environments.

1.1 Study Objectives

The objective of this study is to identify a set of principles to guide the landscape architect in integrating a diking system into community life, to suggest how these principles may be used within different local situations, and to provide examples of how the principles may be applied in a specific community. The principles will attempt to combine the utilitarian function of diking with visually appealing form and sensitivity to ecological processes, and incorporate possibilities for alternative use by human communities wherever possible. The guiding principles must be general and flexible enough to meet the needs and philosophies of different societies, and capable of being adapted by the landscape architect to fit pre-existing factors within particular local contexts, such as topography, vegetation, architecture, sociology, ecology, and history.

To show how the principles might be used in a specific situation, the study will focus on the small suburban community of St Norbert, on the southern boundary of Winnipeg, Manitoba. A series of drawings will suggest how imposed structures can be woven into the social fabric of this particular community, while at the same time, preserving animal and plant habitats. St Norbert was selected as a test area for the study because it possesses a number of design situations characteristic of flood protection planning. The design plan suggested for St Norbert will incorporate native vegetation suitable to the utilitarian purpose of the dikes; it will provide ecological opportunities for species movement; and it will include possibilities for social and recreational use by the community. Some emphasis will be placed on the connective nature of dikes by creating an integrated green belt joining various aspects of the community, such as historic sites, recreational facilities, existing trail systems, and econiches.

A major theme of the study is that a more holistic solution than has typically been sought can enhance life within the community while at the same time providing for maximum flood protection. As Grant Jones has pointed out, landscape architects must find "new tools and new language to understand how to live without losing nature. The solutions will be at the landscape scale - working with the larger pattern, understanding how it works, and designing in harmony with the structure of the natural system that sustains us all" (Jones 1996). Jones's comment, intended as a general statement for the enhancement of social environments, is equally applicable to landscapes on a smaller scale, such as those in which diking systems are present.

1.2 Methodology

The actual creation of diking systems is the business of the hydrological or civil engineer, whose task it is to come up with a functional solution to a functional problem. The landscape architect is not required to question or endorse basic engineering decisions relating to size, materials, placement, or construction of dikes. The landscape architect's role is to find appropriate ways to integrate a system of existing dikes into the social fabric of the community. Because specific elements of dikes and diking systems, such as dimensions, slope, materials, and surface treatment, inform decisions on design modifications to create more user friendly spaces for both wildlife and people, the landscape architect needs to understand the various components of flooding and flood control, as well as the basics of dike construction. These elements of the diking process will, therefore, be dealt with, but only to the point of enabling a discussion of how utilitarian engineered structures necessary to river control can be adapted so as to respond to the needs of wildlife and human communities.

Sections 2 to 6 provide the necessary background by examining factors in flooding and flood control systems which need to be taken into account by the landscape architect in designing socially and environmentally appropriate systems. Section 7 will examine the Red River's geologic history, its flooding history and how flood events of the past have affected its human populations, as well as describing local diking conditions. The material in these Sections is based, for the most part, on evidence from documentary sources, including diking case studies from The Netherlands and North America. The former will assist in the design process as it relates to the placement and location of future dikes, while the latter present design possibilities.

Section 8 will introduce the design phase of the study with a statement of principles, both philosophical and practical, which address the problems of integrating diking systems into human communities. The design component of this practicum will emphasize "smart designs." Smart designs are concerned with "fit" between structure and context. The term originated in a study, *Investigating Basic Principles of River Dike Improvement*, which defines smart designs as "tactics that enable dikes to provide the same level of safety as standard dikes but have less impact on the landscape, natural, and cultural (LNC) values around the dikes" (Walker et al 1993). Landscape values are defined as natural features such as forests, lakes, and curves in the river. Cultural-historical values refer to ruins or old buildings, monuments, and heritage sites which have cultural value and must be preserved. Natural values refer to changes in ecological infrastructure or quantities or types of vegetation. The philosophical basis of "smart designs" and LNC theory will be discussed, adapted, and used as major analytical tool of this practicum.

In order to create an appropriate design which puts the principles into practice, the landscape architect must be familiar with the social fabric of the particular community. St Norbert, on the southern boundary of Winnipeg, has been chosen as the community where the principles will be applied to specific situations. A community profile of St Norbert and site analysis, consisting of a brief discussion of its history, its evolving demography, and the requirements of its residents, constitutes Section 9 of this study. Sources of evidence for the community profile and site analysis include maps, aerial photographs, digital data, census information, local histories, and personal familiarity with the community.

The final Section of the study will be a series of designs showing how the principles of diking system design can be put into practice in the specific case of St Norbert.

1.3 Vocabulary of the Study

Because flooding is a universal phenomenon, it follows that all languages have a word or words to describe the means by which floodwaters are constrained. The origins of the word "dike" in all the Germanic languages, ranging from Old English and Old Norse to Frisian, German, Dutch, Swedish, Danish, Icelandic, and Modern English, is *dîc*. Its meaning at various times and places has been both "ditch" (which is clearly a form of the original *dîc*) and "embankment, wall, or causeway." According to the Oxford English Dictionary, the word appeared in print with the former meaning for the first time in the year 847 of the Common Era. Exactly when and why it also came to mean "embankment" is unclear, but the first appearance of the word with the latter meaning was in 1497. Throughout the millennium of use, variations have included *ditch, dijk, dîk, dick, teich, deîch, dige, diki*. A fairly recent spelling variant is *dyke*. However, this usage is etymologically incorrect.

In French, an embankment or earth-bank is described as a *levée*, from the root *lever*, to raise or lift. This word entered the English language with several different meanings, one of which was *levy*, referring to the raising of taxes or an army. In the 19th century, "levy" appeared in American usage with the meaning of "dike" or "embankment," and later reverted to the original French spelling of levee, but without the accent. In the United States, the word is still quite commonly used in popular culture, and has appeared in songs such as "American Pie" (Don McLean), "Working on the Levee" (Raymond Bazemore), and "When the Levee Breaks" (Led Zeppelin). The present text uses the etymologically correct variant "dike," in preference to "dyke" or the Americanized "levee."

2.0 FLOODING

"Floods increase in magnitude and destructiveness with each increment of urban growth; urbanization can increase the mean annual flood by as much as six times"

Anne Whiston Spirn

2.0 FLOODING

2.1 Factors Influencing Flooding

The original source of rivers is rainfall and snowmelt; simply put, precipitation is what feeds rivers. Factors that contribute to flooding are, on the other hand, not as simple; they can be inherent in the natural physical environment or they can be the result of human activities. Most often they are the consequence of a combination of both. Factors in the physical environment which affect the hydrologic cycle include amounts of precipitation, soil quality, porosity, and percolation rate, slope, drainage area, vegetation, climatic fluctuation, temperature, and aquifer extent. Human activities also affect the hydrologic cycle by altering one or more aspects of the physical environment. Human induced factors include structures, such as buildings, paved areas, roads, and railway embankments; practices, such as livestock overgrazing, forest denudation, and wastewater management; and topographical modification, such as wetland drainage, damming, and river diversion. Flooding has been greatly exacerbated by human activities ranging from draining of rivers, natural reservoirs, and marshes for agriculture, and residential purposes, to the increased runoff and decreased evaporation caused by modern agricultural practices (Figure 2.1a).

The phenomenon of flooding is not limited in its occurrence to any particular area or region. It occurs whenever and wherever the necessary conditions coincide. In nearly every watershed in the world, and in nearly every river system from the Arno to the Zambezi, flooding occurs without prejudice and without justice. The financial burden of flooding can be enormous. "In some years floods alone account for more property damage in the United States than any other single natural hazard" (Whiston Spirn). Other countries have repeatedly faced similar financial burdens resulting from flooding losses, and to this must be added the often catastrophic psychological and emotional damage resulting from flooding.

Because of the inter-relatedness of factors in the physical environment, none can be discussed in isolation from the others. Similarly no aspect of human behavior or activity in relation to the river valley, floodplain, and hydrologic cycle operates independently. L.B. Leopold suggested that "of all the land use changes affecting the hydrology of an area, urbanization is by far the most forceful" (1968:1). More than a century earlier, Charles Ellett identified the extension of agriculture as the major cause of increased flooding in the

Mississippi Valley.

> Floods are attributed primarily, to the extension of cultivation throughout the Mississippi Valley, by which the evaporation is thought to be, in the aggregate, diminished, the drainage obviously increased, and the floods hurried forward more rapidly into the country below (Ellett 1853: 17).

2.1.1 Soil Profile, Percolation Rate, and Runoff

Soil characteristics have a significant impact on incidence of flooding. Floodplains, which are the product of river deposits, often have characteristics distinctly different from those of neighboring uplands. Soil profile, percolation rate, and runoff are determined by the physical characteristics of the particular type of soil (Figure 2.1b). There are four basic categories of soils - sand, silt, clay, and loam - each of which appears in varying mixtures and proportions. What is of concern for flooding is particulate size of the respective soils. Soils with larger particles, such as sand, have good permeability, while soils with smaller particles, such as clays, have poor permeability due to the cohesion of the small particles.

The amount of runoff water that reaches creeks, streams, and rivers, is, generally speaking, greater when the underlying soil is less permeable, or, to put it another way, when the percolation rate is relatively slow. An inverse relationship exists between runoff and percolation rate, largely as a result of underlying soil type. The amount of runoff is determined by the drainage factor of a particular soil. The drainage of a soil is a product of three characteristic variables: infiltration capacity, permeability, and percolation rate. The infiltration capacity of a soil refers to the rate at which water penetrates the soil surface. The permeability of a soil refers to the rate at which water within the soil moves through the volume of that soil. The percolation rate is the rate at which a given amount of water is absorbed into the soil.

There is a direct relationship between the percolation rate of a soil, and the amount of surface runoff. Also called infiltration rate, the maximum rate at which water can penetrate into a soil, is determined primarily by two variables, soil porosity and existing soil moisture conditions. The grain size, pore size, density of soil particles, and molecular shape together determine the soil percolation rate. If the soil has a high percolation rate the probability of large amounts of runoff is greatly reduced.

The Red River basin is characterized by soils that have a high clay-silt composition and therefore poor permeability and considerable runoff.

2.1.2 Slope

The topography of a particular drainage basin or watershed can have a significant effect on the amount, degree, and type of flooding that occurs. On steep slopes the duration of the surface contact between the molecules of water and the soil particles is greatly reduced resulting in a reduced rate of infiltration. This time is increased or decreased depending on soil, vegetative cover, leaf litter, and temperature.

2.1.3 Drainage Area

The size of a drainage basin and the number and order of streams can also affect the amount of water that is concentrated in a specific space. The particular characteristics of a drainage area can also help determine the likelihood of a flood, given certain criteria. To determine this likelihood, a particular river can be examined for its flow capacities based on a number of variables. The total discharge of a rain shower with a given duration can be determined using infiltration rate, discharge, and slope. Based on measured results from empirical data, each of these variables provides information on the probability, extent, and severity of flooding, relative to established baselines. However, it is important to note that one of the major difficulties for flood forecasting, particularly for the Red River, in addition to the large area of the basin, are the sub basins within that area, each with different topography soil conditions, and drainage characteristics.

2.1.4 Vegetation

Evapotranspiration rates and ground litter both affect the amount of moisture that is available for runoff. Different plants have different water needs, which affect the quantities of water available for aquifer recharge and runoff. Plants which absorb relatively large amounts of water through root uptake and evapotranspiration reduce the amount of water available for aquifer recharge and runoff. Similarly, ground litter tends to hold moisture and reduces the amount of water that needs to be shed by the land in one way or another.

2.1.5 Climatic Fluctuation

Rapid changes in day to day weather systems can trigger flash floods, which are often unpredictable. Flash flooding, usually a fairly local phenomenon, frequently occurs when the ground is quickly saturated as a result of soil inability to absorb water.

The temperature gradient of a river valley can also have significant effects on the availability of stored precipitation. Fluctuations in temperature directly affect rates of plant transpiration, which removes water from the soil, and evaporation, which may prevent water from reaching the ground at all or may remove it from ground surfaces after it has fallen. Water is also stored as frost or ice in the soil in regions which experience below-freezing winter temperatures. This water source is particularly important in this study because spring flooding in a flat valley such as the Red River valley is nearly always the result of runoff due to spring thaw, possibly exacerbated by heavy spring rains.

Flooding that occurs as a result of spring thaw is a function of a number of factors. When a number of these factors coincide in sufficient proportions they provide flood conditions. For example, when large amounts of precipitation during the winter months are stored as ice, snow, or frost, a rapid rise in temperature before the ground has had a chance to thaw will result in overland and riverine flooding. Another situation that occurs frequently is an early spring temperature rise while the soil is only partially thawed. In this situation, soil which is no longer frozen acts as an impermeable barrier, pooling of surface water, excessive runoff, and flooding. In a less direct way, large amounts of precipitation in the form of snow can delay flooding, or accelerate it if temperatures rise suddenly above freezing, so that runoff flows over still frozen ground, with little or no chance for infiltration.

2.2 Urbanization

> Floods increase in magnitude and destructiveness with each increment of urban growth; urbanization can increase the mean annual flood by as much as six times (Spirn).

The effects of urbanization (Figure 2.2) on flood hazard are manifold. As impermeable materials are used in the construction of our urban centers, they upset the natural hydrological processes. The natural percolation of surface runoff is prevented from entering the water table slowly and is redirected through a series of constructed pathways such as roofs, roads, parking lots, storm water drains, and culverts. The result is a rapid overload of the hydrological system which, without human interference, has a natural self-regulating equilibrium. During times of flooding the amount of runoff exceeds the natural flow capacity of the river or stream, causing it to back up into wetlands such as sloughs and marshes, and tributary streams that typically lie adjacent to its course. With high river water, these adjacent and tributary waterways may themselves overflow. When these natural retention basins have been drained for agriculture or residential development, as they often are, the possibility of flooding is increased, and floods are likely to be more severe and frequent.

2.3 Types of Flooding

There are two basic types of riverine flooding. The first is flash flooding, typical of watersheds that are characterized by steep slopes, and short, intense bursts of precipitation. Flash floods are most often associated with watersheds in mountainous regions, or foothills such as the foothills of the Rocky Mountains, and the deserts of the southwestern United States. The second type of flooding is due to seasonal snowmelt and heavy rainfall associated with impervious soils, such as those with high amounts of silt and clay, or with man-made impervious ground covers such as asphalt. Clay and silt soils are most often found in ancient lake beds and sea bottoms, while asphalt, and concrete are common in urban and suburban areas. Both naturally occurring and man-made impervious ground covers typically increase runoff potential or even produce excess runoff in catchments basins.

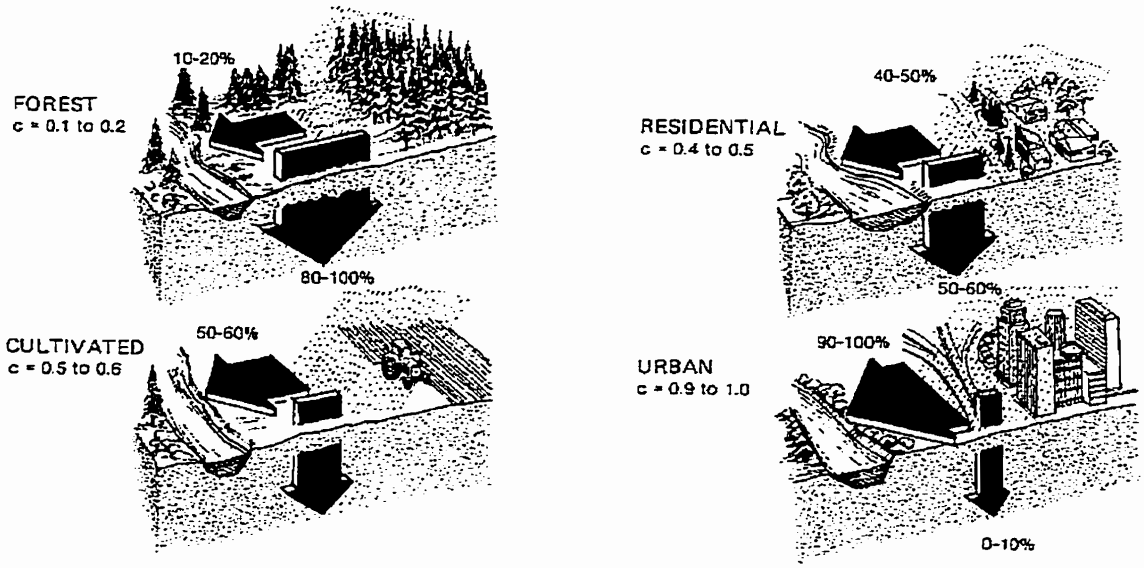


Figure 2.1a Runoff based on soils type Source: Marsh

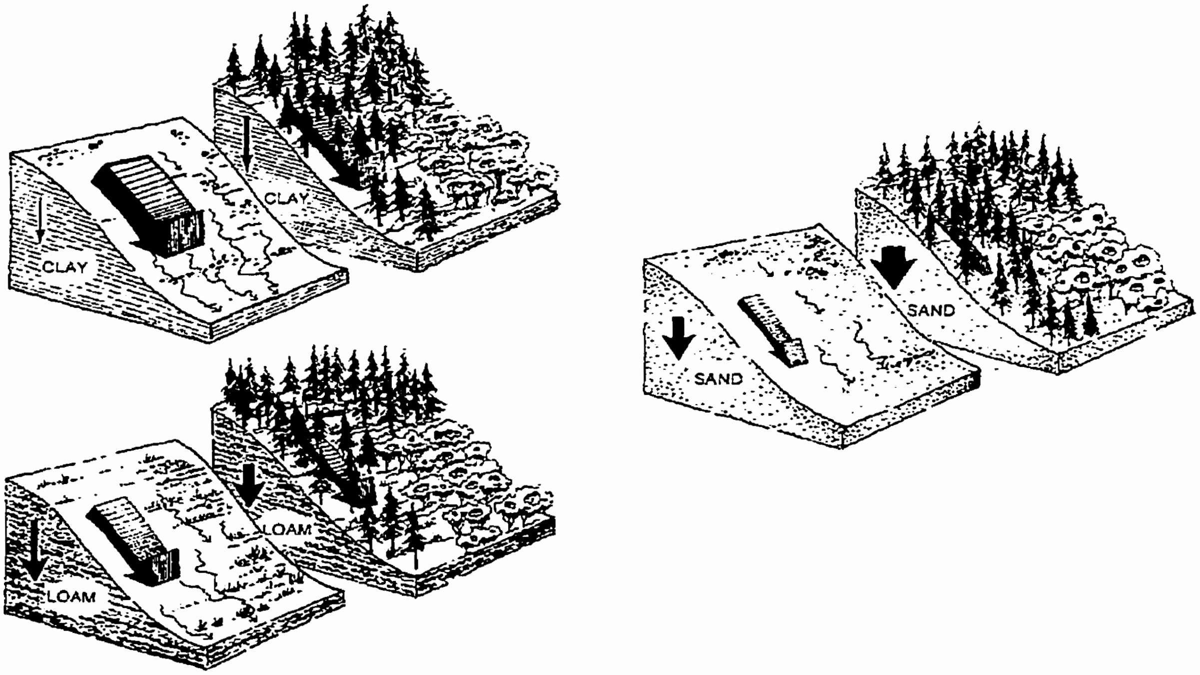


Figure 2.1b Runoff based on soils type Source: Marsh

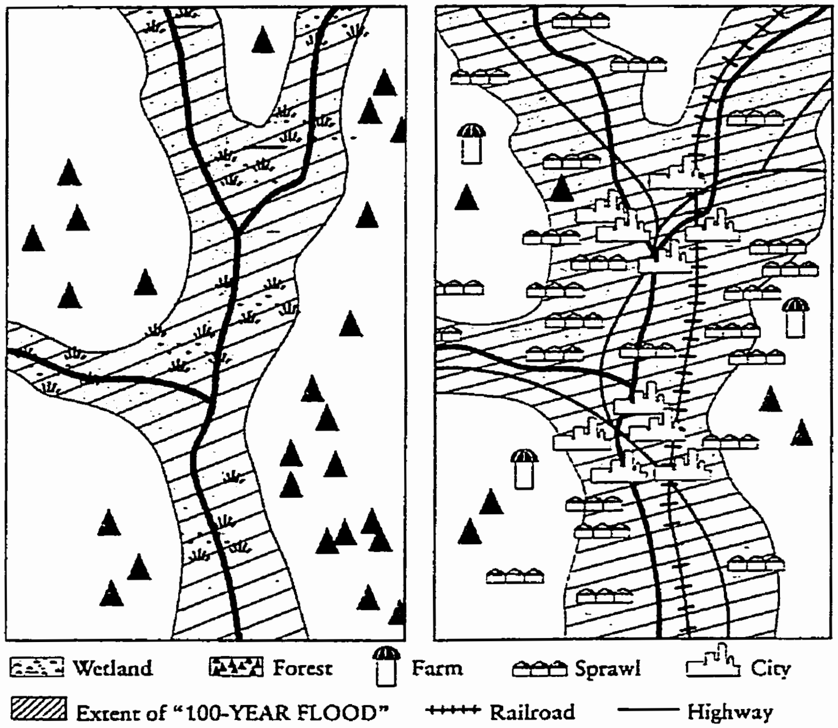
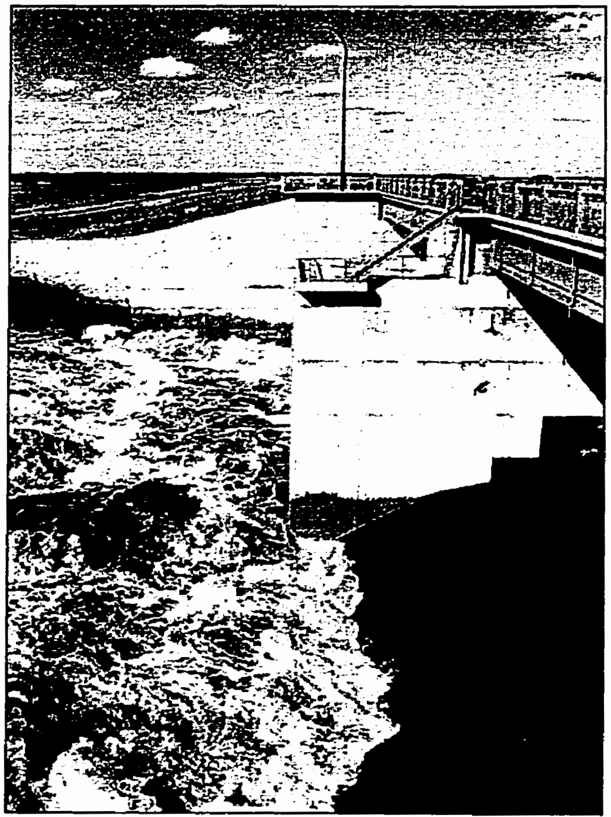


Figure 2.2 Effects of Urbanization on Floodplains Source: Lincoln Institute of Land Policy

SECTION 3 FLOOD CONTROL STRUCTURES



"Nature is blamed for failings that are Man's, And well-run rivers have to change their plans"

(From the poem 'Water' by Sir Alan P. Herbert) - In Preface to Ward, 1978

3.0 FLOOD CONTROL STRUCTURES

There is no preferred flood control mechanism which is universally effective. Type of flooding, available resources for protective structures, and local soil profiles are among the factors which must be evaluated in choosing control methods.

3.1 Polders

Polders are the result of a landforming technique used for the intentional drainage of low lying areas such as marshes and lakes often for agricultural purposes (Figure 3.1a,b), or for protecting flood prone areas. A polder is basically a system of networked surround dikes which subdivide land into manageable and easily protected plots, rather than a single structure. Some of the most famous polders are those produced in the development of the Zuider Zee (Figure 3.1c). There are typically three types of polders: the bedijkingen, which is intended to protect land from incoming waters; the droogmakerij, which drains and controls water from marshes and lakes; and a combination of the first two, which is particularly suited to controlling inundations which originate in the ocean. The combination technique was used in the creation of the Zuider Zee. The polder type most relevant to the present study is the bedijkingen. The bedijkingen or "land dike" is used to divide and protect large areas of agricultural lands from riverene flooding. The country itself has been divided into large polders for the purpose of controlling through isolation of damage due to breaches in the diking system.

> Quite apart from pure technique, this work of civilization marks man's victory over the natural order. There can be no limit to our admiration for those who, down the ages, have dared to undertake this task and determined to carry it through, these 'makers of farmland', as Jean Brunhes called them, the creators of the polders. (Wagret 1968: 280)

3.2 Dams

One of the oldest means by which rivers have been controlled is the dam, which holds back the river in its course, permitting only limited amounts of water to flow down river. Binnie (1987) traces the origins of dams in Britain back to the Roman occupation. Dams near Hadrian's Wall dating from this period indicate that Roman garrisons impeded stream flow by damming, and stored water in reservoirs behind the dams for use at a later time. In the late eighteenth century, storage dams were created to provide water power for cotton milling, hydraulic mining, ore processing and separating, and to supply the canal network which was expanding rapidly in the last quarter of the century.

3.3 Floodways

One of the most ambitious and expensive forms of flood control is the floodway. There are several modern examples of floodways including those on Manitoba's Red River Floodway (Figure 3.3) and much larger constructions on the Mississippi River. The basic principle of a floodway is to divert excess water around populated areas in times of high water, thereby reducing the likliehood of inundation. The monumental task of constructing such structures is costly, but if the urban centre that it protects is sufficiently large, the substantial costs are easily rationalized in terms of safety factors, as well as associated future potential costs and losses.

3.4 Diking

The most common, and probably the oldest, means of controlling the extent and location of flooding is a system of dikes which divert floodwaters away from populated areas. Dikes come in a variety of types ranging from additions to natural river banks (called canal embankments) to engineered obstacles to constrain the movement of water. The distinction between diking and canal embankments is primarily related to purpose. Although dikes and canal embankments are similar in construction, the latter are intended to contain or divert water for transportation, hydro electrical power, or irrigation. The former is concerned with the containment of existing water courses for the protection of land and development. The present study is concerned only with the containment type of diking, also known as anti-flood diking, anti-inundation dikes, or control dikes.

The various forms a dike can take are as diverse as their use is widespread. Although they have many different manifestations, and applications, control dikes are designed to accomplish the same specific goals, the prevention of inundation. For example, the Dutch use dikes in a variety of situations; as sea walls and diking embankments for protecting against coastal waves; as perimeter dikes around reclaimed land for improving land use conditions; as perimeter dikes for the protection of housing, towns and land from both oceanic and riverene flooding; and as regulating mechanisms to direct water flow and limit quantities of flow.

3.5 Flood Walls

Often when space is confined, or a substantial barrier is needed, often for an urban area, or where there are already substantial amounts of infrastructure present.

3.5.1 Prefabricated

The most recent expansion in this area of flood control has been in the area of ready-made walls or partitions that can be used as a seasonal solution to flood control (Figure 3.5.1a). One such system is called the "Invisible Floodwall". This method uses reinforced concrete that is poured in place, to anchor the foundation and supports of the structure (Figure 3.5.1b), which appear only as low posts (Figure 3.5.1c), which are easily integrated into an urban context, and into which the stacking components of the wall are locked when needed (Figure 3.5.1d). The benefit of this modular system is its flexibility, and the ability to provide an approved method of protection, yet be easily disassembled when the threat has passed. The temporally limited visual impact of this method (Figure 3.5.1e,f,g) of flood wall makes it a highly favourable choice in situations where the desire to preserve views are as great as the need for flood protection. Another advantage of this system is its ease of assembly, once the structural components have been constructed, the individual stacking wall components are light enough and easy enough for the average person to assemble. The only major drawback of this system is its high installation cost.

Since the flood of 1997, the City of Grand forks North Dakota, has commissioned the use and installation of this type of flood barrier to protect its downtown area (Figure 3.5.1h,i,j).

3.5.2 Self-Inflating

In recent years new methods and technologies have emerged to help combat the problem of flooding, but perhaps one of the most recent and innovative is inflatable flood walls. These portable PVC dikes (Figure 3.5.2) use the pressure of the flood water itself to fill and expand to form low walls that block the passage of water. These simple and portable solutions, are limited in their use as they are generally low, usually around 4', but are effective at controlling minor overland flooding. The application of these barriers in extreme riverene flood situations is questionable, as the forces exerted can be enormous, and the floating debris and ice could possibly puncture the PVC membrane, thereby compromising the entire system.

3.5.3 Fixed

Fixed flood walls come in a large variety of shapes and sizes, but perhaps the most common form utilizes sheet piling (Figure 3.5.3a). Driven deep into the ground, the piling is used to provide a mold for concrete, which gives the structure its mass, while the piling itself provides a backbone giving strength to the elongated barrier.

This form of flood wall usually requires a substantial amount of labour and associated high construction costs. Flood walls are commonly used where subsoil conditions are unfavourable or unstable, and where flood conditions are frequent and extreme.

A second common type of fixed flood wall uses precast concrete blocks (Figure 3.5.3b). Often used in retaining walls, this product has been recently adapted to the problem of flood control. Flood-bloc is an example of these modified interlocking blocks that is designed specifically for this application. Although limited by its generic appearance, this form of flood wall can be effective in certain situations. Advantages of this system are its moderate cost and flexibility in form making.

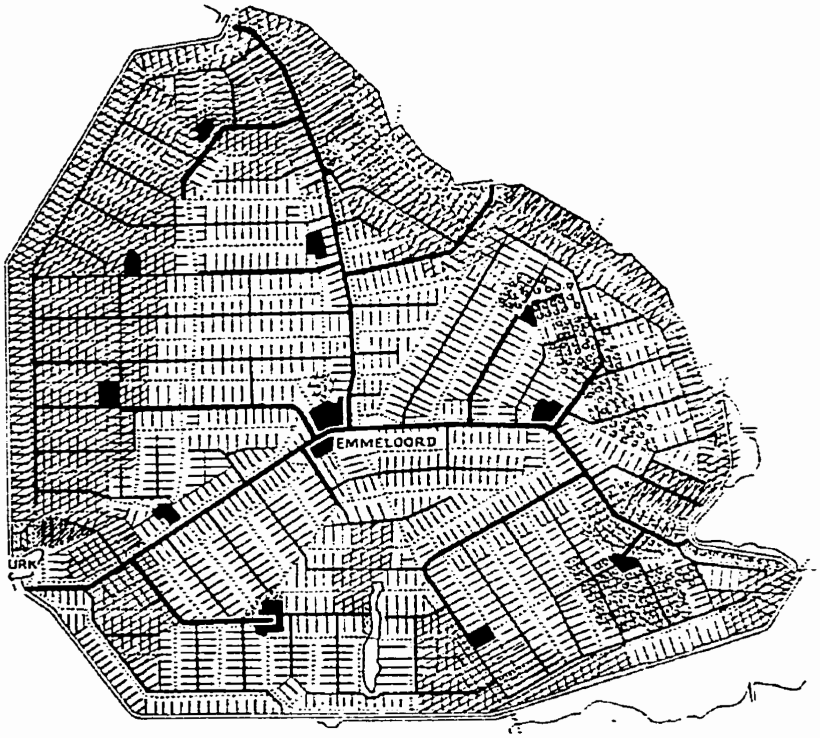


Figure 3.1a Plan of the North-East Polder Netherlands Source: Lambert

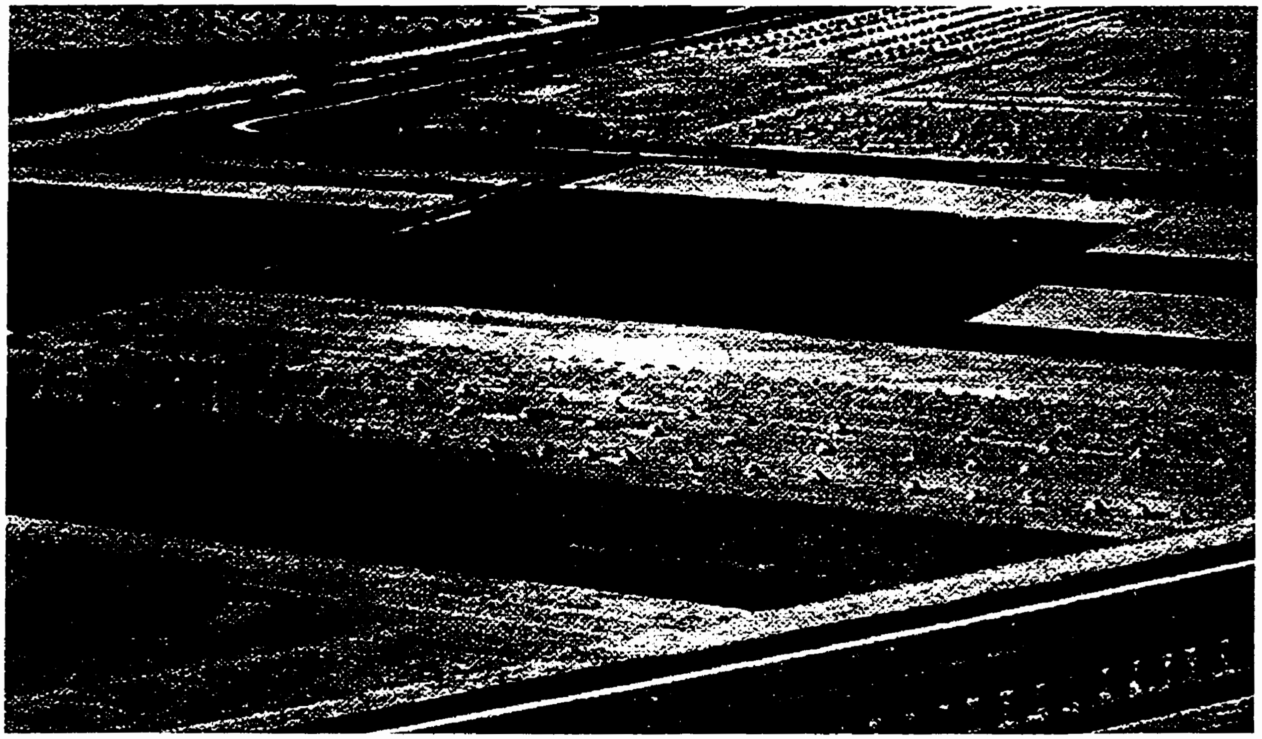


Figure 3.1b Aerial View of Agricultural Polder Source: Wagret

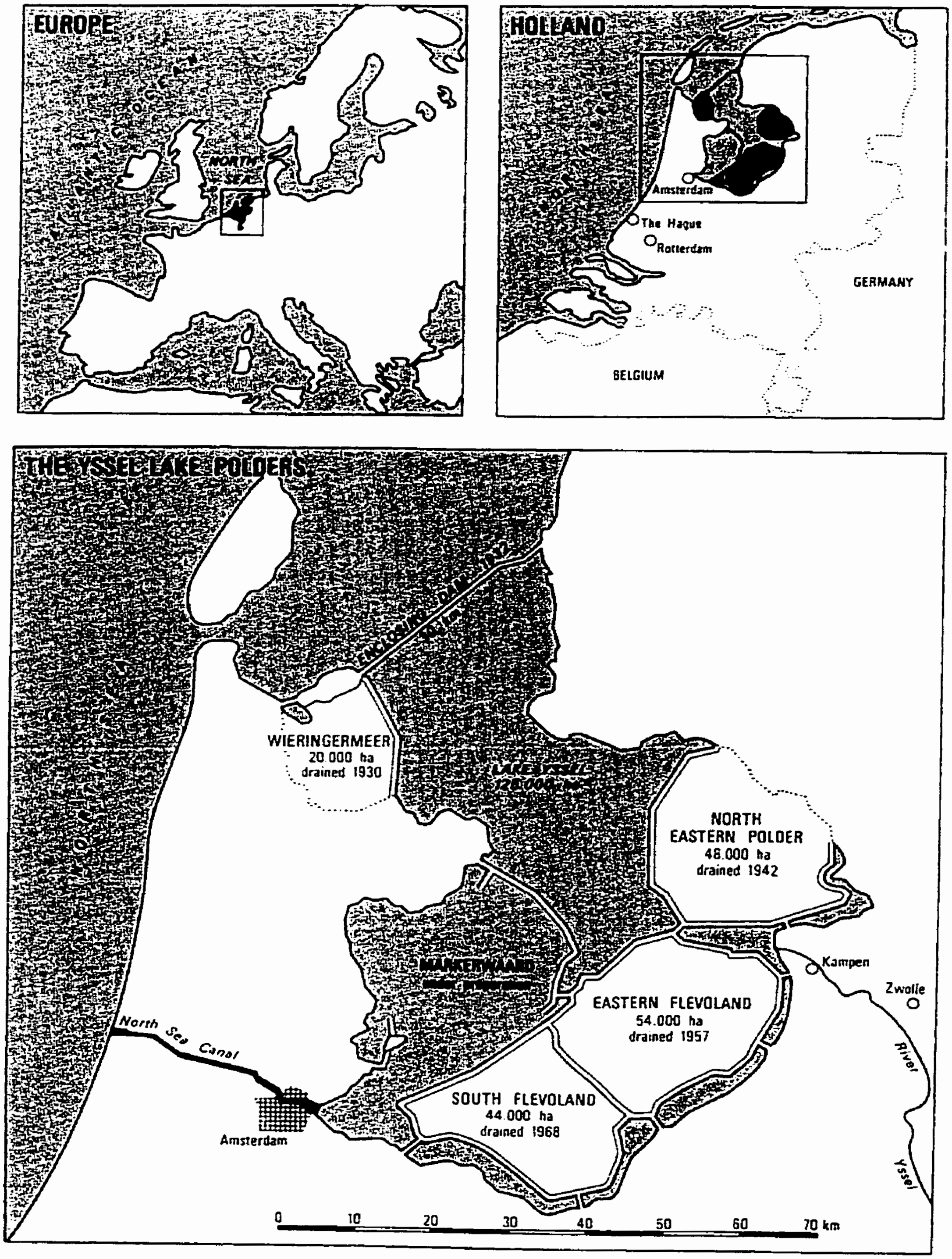


Figure 3.1c The Zuider Zee Polders Source: Steiner

Figure 3.3 Aerial Photograph of Winnipeg's Floodway. Source: Manitoba Department of Natural Resources

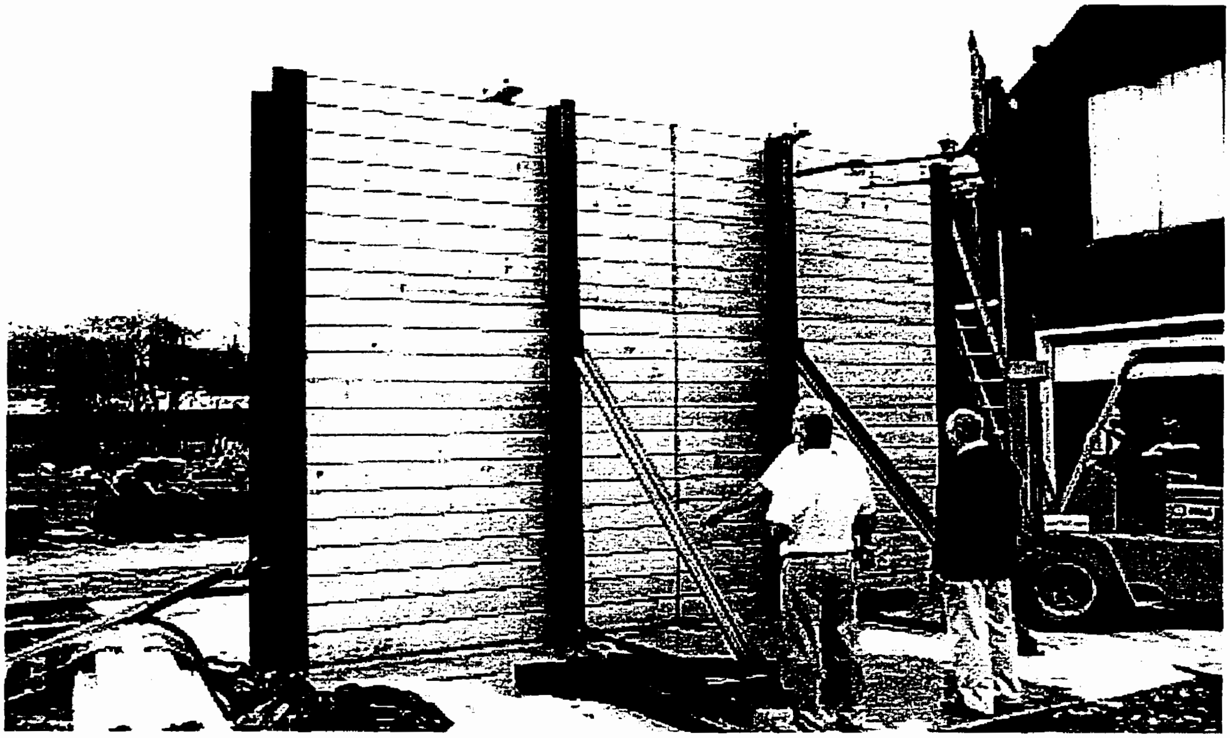


Figure 3.5.1a Flood Control of America's "Invisible Floodwall" Source: Flood Control of America

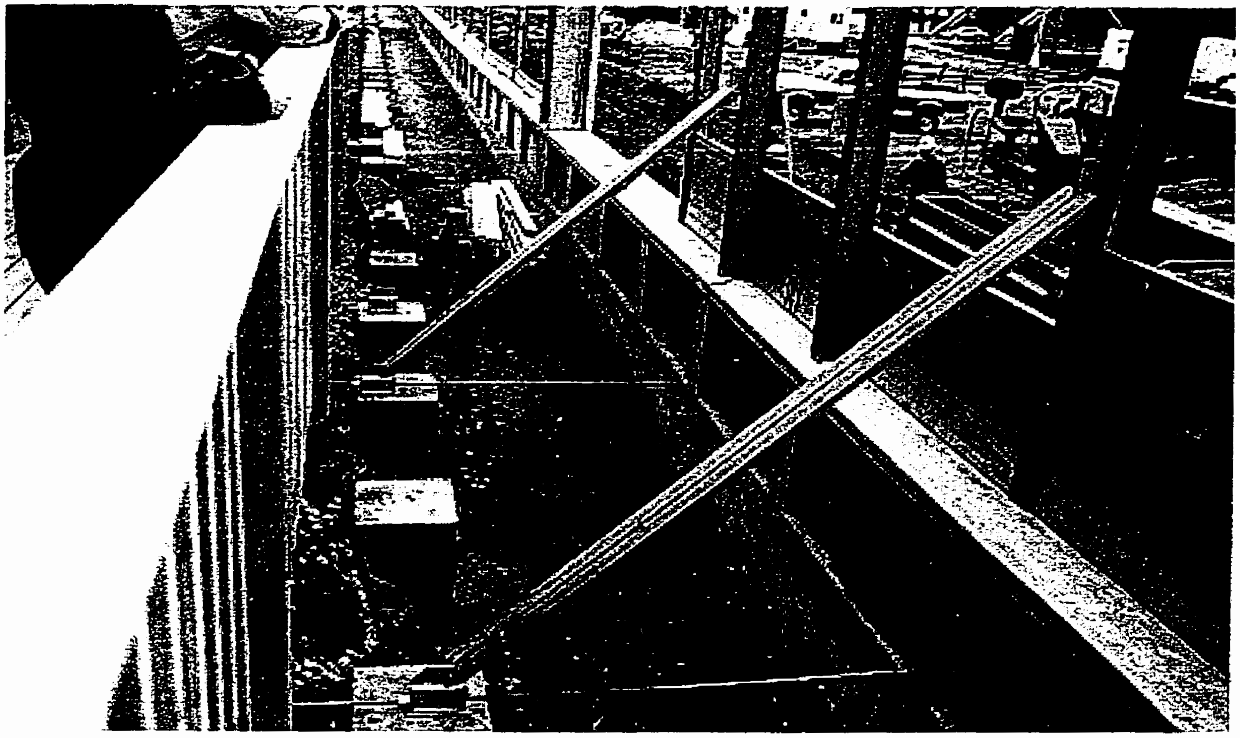


Figure 3.5.1b Foundation and supports of floodwall Source: Flood Control of America

Figure 3.5.1c Minimal visual impact of permanent components of this floodwall
Source: Flood Control of America

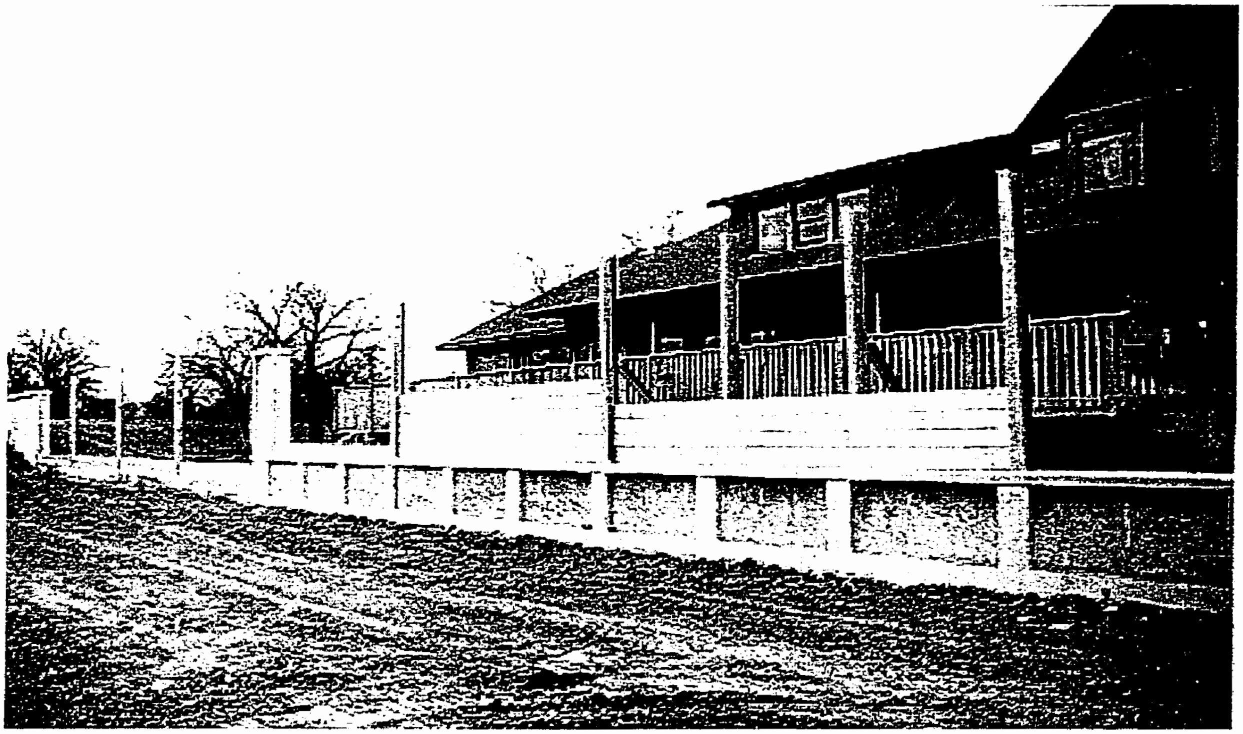


Figure 3.5.1d Partial assembly of floodwall's residential application
Source: Flood Control of America

Figure 3.5.1e Permitting desirable views, while protecting property Source: Flood Control of America

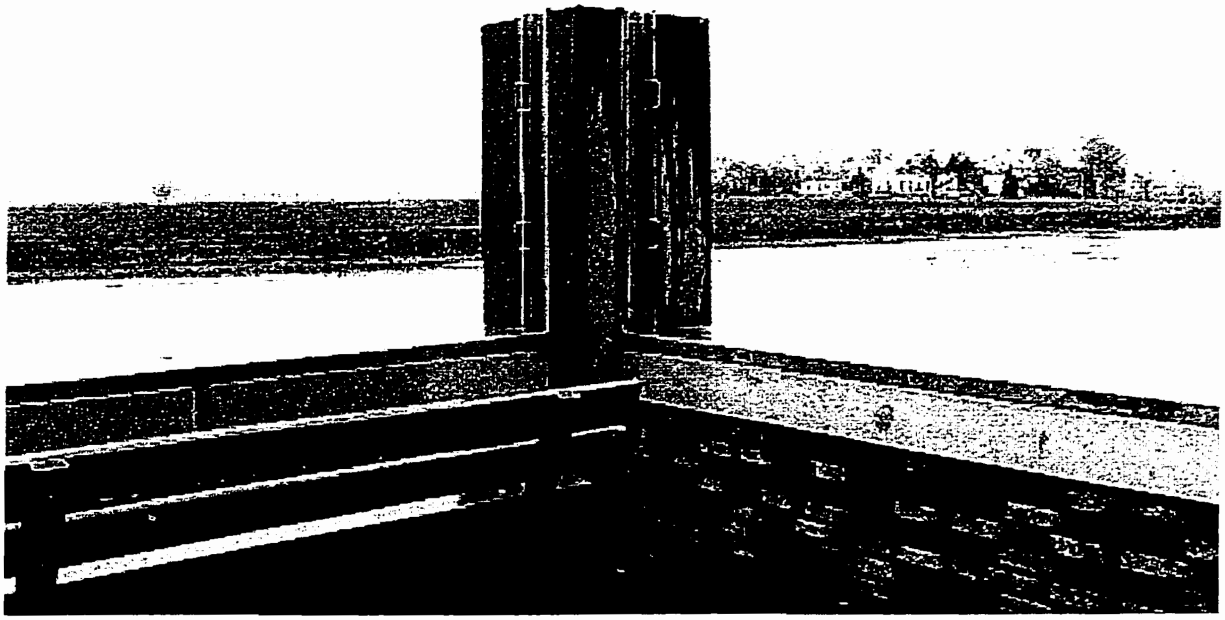


Figure 3.5.1f Permitting desirable views, while protecting property Source: Flood Control of America

Figure 3.5.1g Permitting desirable views, while protecting property Source: Flood Control of America

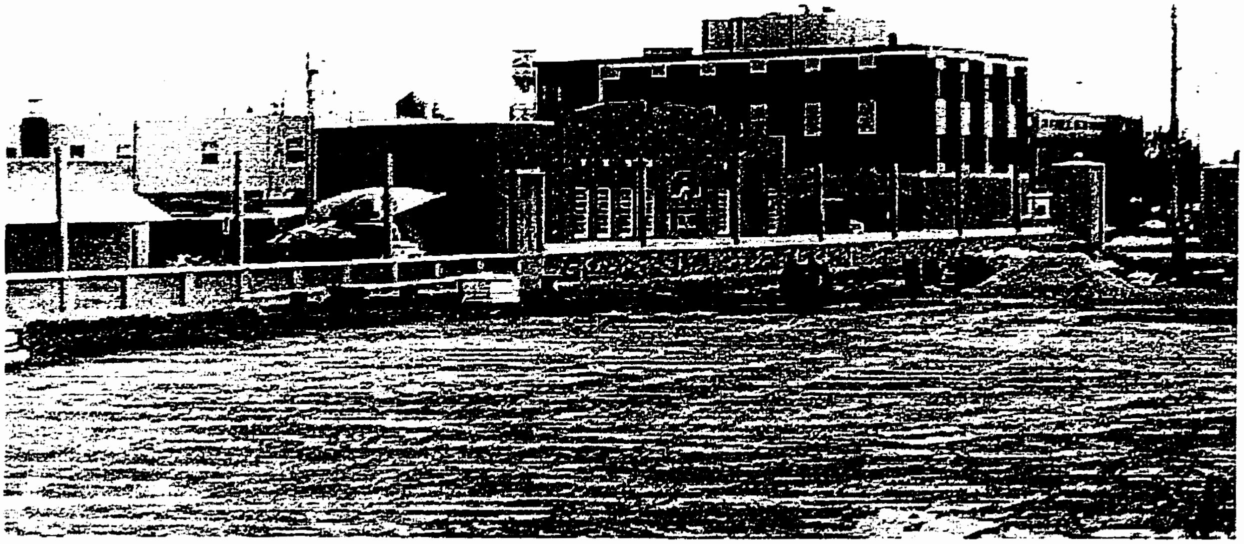


Figure 3.5.1h A new flood wall for the City of Grand Forks, North Dakota Source: Flood Control of America

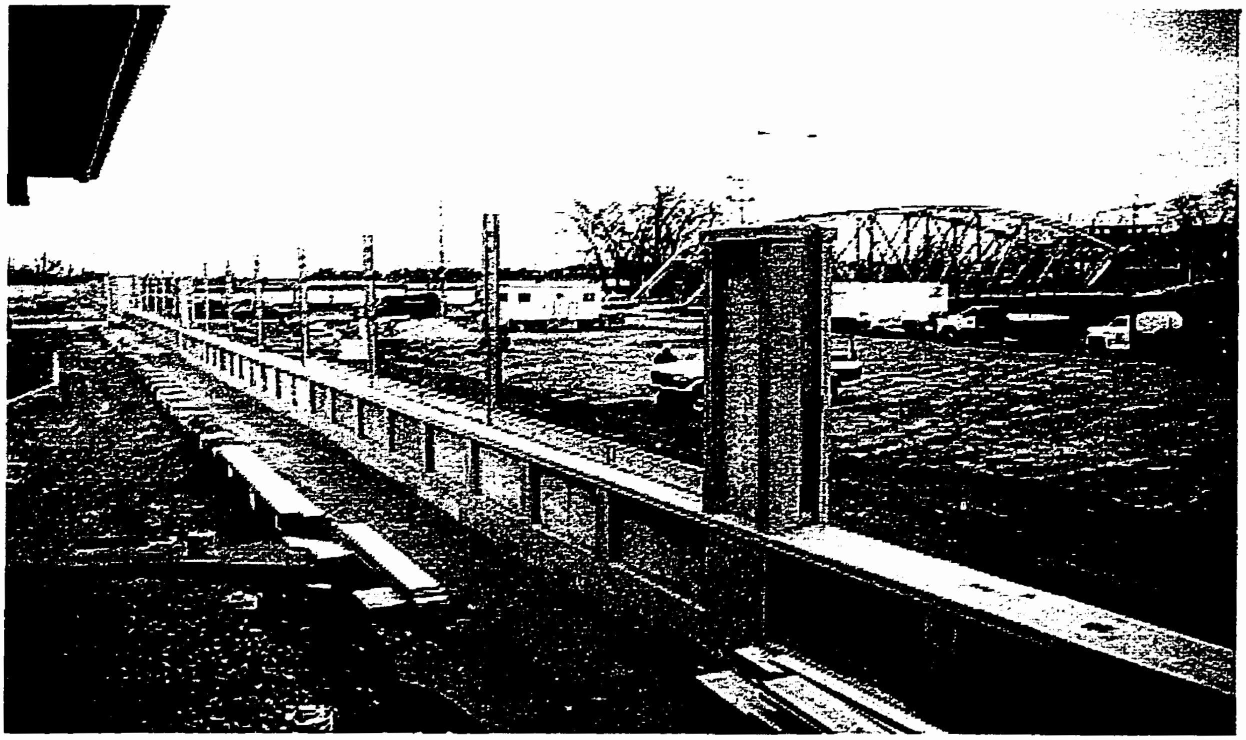


Figure 3.5.1i Floodwall construction in Grand Forks, North Dakota Source: Flood Control of America

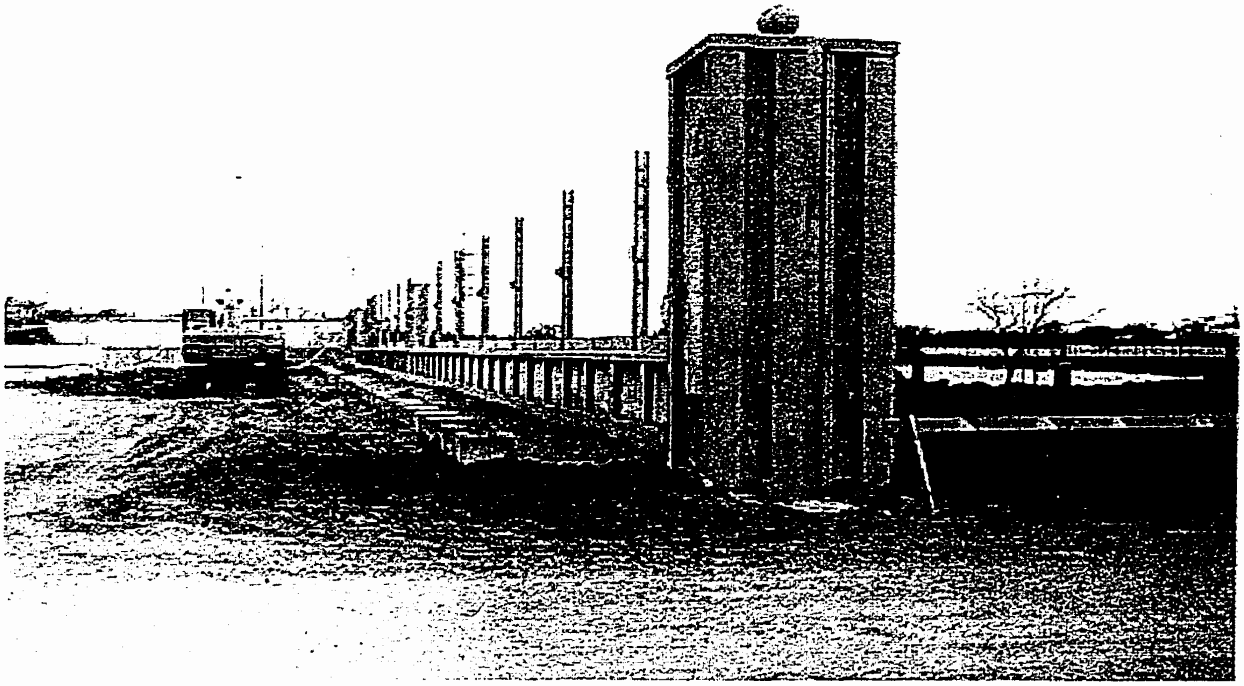


Figure 3.5.1j Floodwall construction in Grand Forks, North Dakota Source: Flood Control of America

Figure 3.5.2 PVC Flood control dike Source: U.S. Army Corps of Engineers

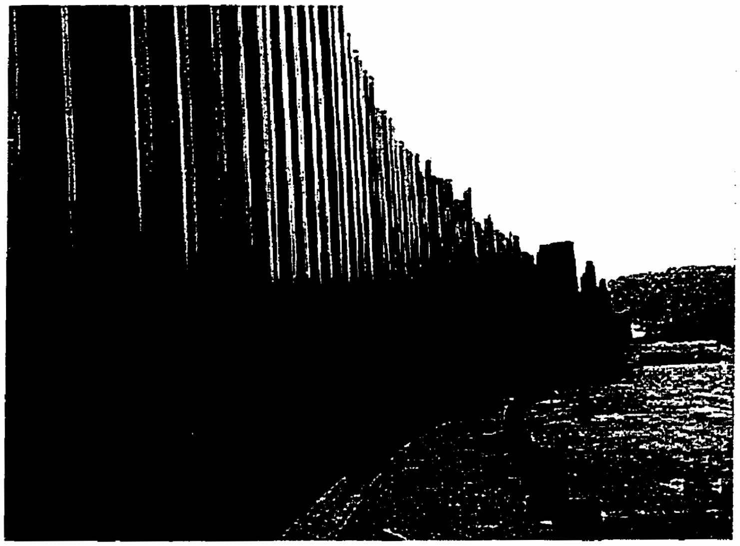


Figure 3.5.3a Sheet piling for fixed flood wall Source: U.S. Army Corps of Engineers

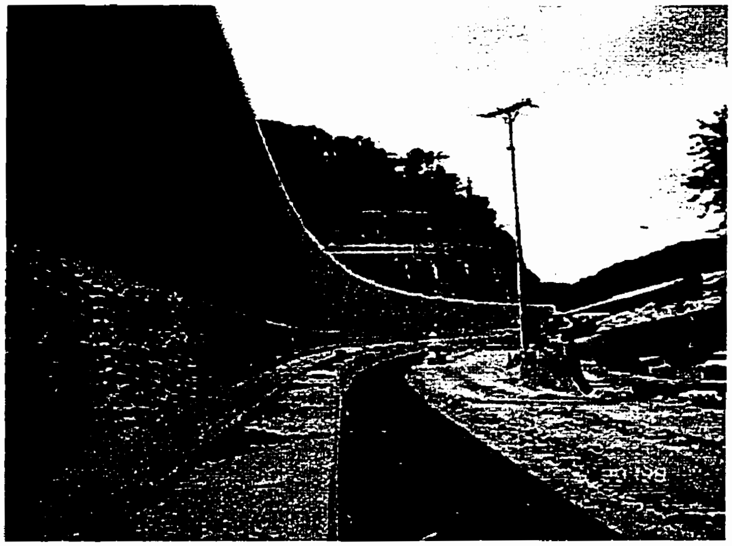


Figure 3.5.3b Large Concrete Flood Wall Source: U.S. Army Corps of Engineers

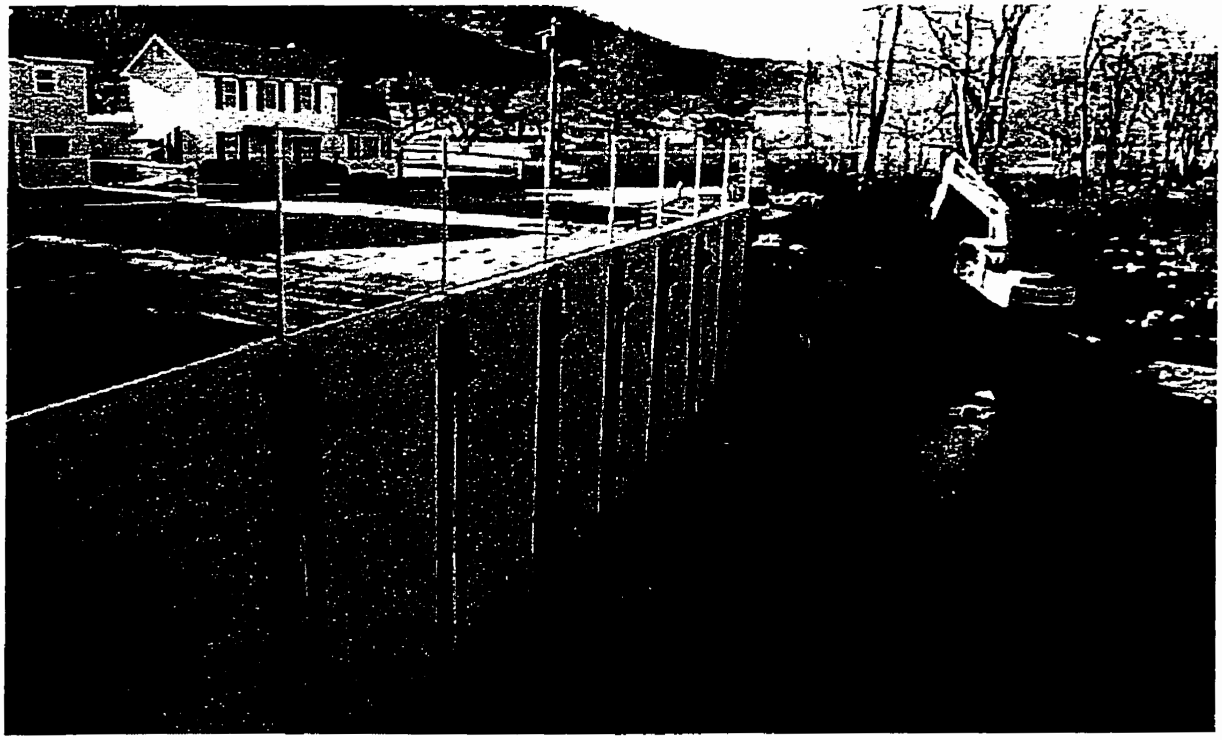
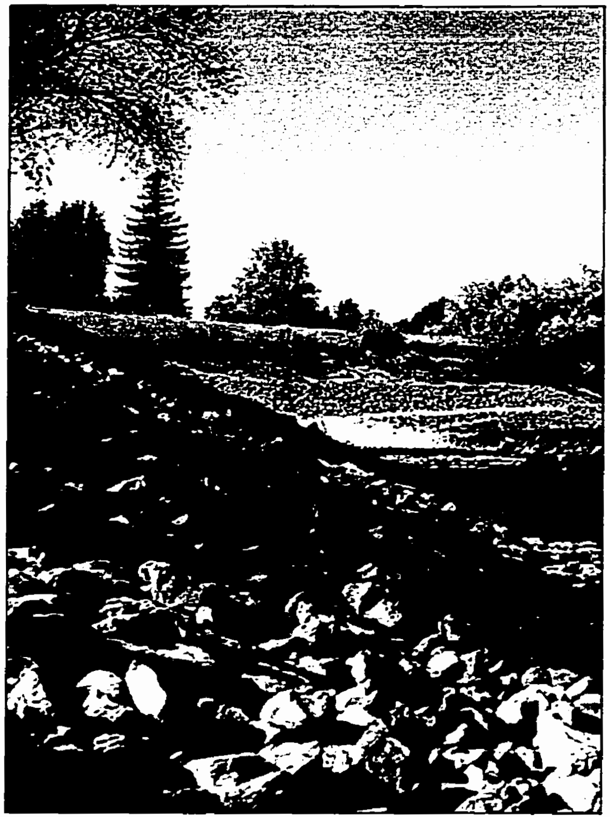


Figure 3.5.3b Large Concrete Flood Wall Source: U.S. Army Corps of Engineers

4.0 ANATOMY OF A DIKE



Green are the fields and fruitful; men and flocks,
Straightway at ease here on the new-born earth,
Make their abode along the massive dyke
Built by a daring and industrious people.
Here within, a land like paradise,
Without, the flood that rages to the brink.
As it crumbles the dyke, ready to rush in in fury,
The people, as one man, hurry to close the
breach.
Goethe, in "Faust" in Wagret 1968: 279)

4.0 ANATOMY OF A DIKE

Nature is its own best regulator; it is only when humans interfere that an imbalance ensues. While we tend to think of dikes as built structures, they are also naturally occurring landforms, and, ironically for us, they are a function of the rivers that we seek to control. A natural dike is a product of the sediment deposited in successive flooding events over a long period of time. In geomorphic terms the dike is an averaging of the deposits of sediment that are left with each successive flood. Natural dikes are typically the highest ground on a floodplain (Figure 4.0). They tend to remain dry during all but the highest floods. Their high elevation, which tends to slope gradually into the adjacent floodplain, forces excess water from incoming streams to flow down the river valley until it can penetrate the dike. These structures typically lie parallel to the direction of water flow where geologic conditions are often complicated.

4.1 Geologic Conditions of Subsoil, and Seepage

One of the most important factors in creating a diking system is the ground on which it is built. Geologists and engineers generally agree that the ideal soil conditions for the sub-base of any flood control structure is a homogeneous soil, and clays are preferred. Heterogeneous sub-base soils under and within a diking system increase the chances of underseepage. To avoid dike failure due to underseepage (see section 5.4), special measures to counteract the heterogeneity of the soil must be taken (Peter 1982 p.31) Such measures include keying into the soil a clay core (Figure 4.1) so as to prevent the seepage from passing under the structure, and the use of various moisture barriers submerged in the body of the dike.

4.2 Dike Fills

Material to be used as fill must be carefully chosen to allow for structural integrity and strength of the dike itself, and to counteract and balance existing permeability or impermeability, which are critical to the safe functioning of the system. The slope of a particular dike also demands that appropriate materials be used to maintain adequate stability, cohesion, and density. Fill material of fine particulate size and soils composed mainly of fine clays with little or no organic content are preferred. Other considerations, less often of concern to the engineer, but of great importance to the landscape architect, include provision for landscape applications to make the system visually less obtrusive, and to provide for social and recreational use by the community wherever possible.

4.3 Rockfill

There are many forces that act on a dike - wind, river current, amount of precipitation, and temperature - but perhaps one of the most significant erosional forces undermining the integrity of a dike are wind produced waves. Designers of diking systems can choose from a number of possible fill materials in order to diminish or prevent erosional forces of wind-forced waves from damaging the dike. These vary greatly in terms of their visual appeal, from asphalt to rip rap, to concrete blocks, and woven willow mats. Each solution has its own set of variables and limitations.

The decisions as to which solution is most appropriate for a given situation are governed by the particular design problem that is being addressed. For example, the construction of the Brunkild Dike in1997 was done with such haste that the issue of the erosional forces of wind forced waves had to be dealt with as a separate issue after most of the structure had been completed. The choice is also greatly influenced by cost of the material and installation.

The use of rockfill, or rip-rap (Figure 4.2a,b), as an erosion prevention measure is becoming more and more common because it can serve several purposes. It prevents the full kinetic energy of wave and flow action from reaching the actual slopes of a dike through absorption and filtration of its energy. Without some form of filtration or barrier, the fines can be eroded and the integrity of the slope undermined, with the unfortunate and expensive result that the structure fails. Rockfill also provides interest in form and texture and shadows. It also has the advantage of providing habitats for aquatic animals, as well as for native grasses, and rushes. Rockfill can be used in the prevention of piping when placed at the downstream toe of a dike (Stephenson 1979 p.112)

When choosing rockfill, uniformity of size and shape are preferred; fines should be avoided if possible, and a minimum size of .5 metre diameter is essential in order to prevent the kinetic energy from the waves from causing the rockfill to tumble down the slope (Stephenson 1979 p.177). Should it be necessary to use rockfill that is not of an adequate size or where a particularly high wave action due to strong prevailing winds is common to an area, the rockfill should be placed in Gabions to prevent tumbling and shifting downslope.

4.4 Slopes

Designing a dike requires consideration of slope ratio, slope angle, surface characteristics, and length. The angle of the slope is a function of the situation for which it is needed. A steeper slope may be required if space is limited. Optimum slopes are a ratio of 3:1. The exposed outer slope of a dike is subject to both mechanical and thermal strains. Mechanical strain arises from the dynamic effects of weather, primarily wind and wave action, and precipitation, as well as from the pressure that the resting water itself places on a structure. Thermal strain refers to the constant variation in temperature gradients such as frost-heave, expansion and contraction of soil particles, and the subsequent shifting in weight distribution. A related major problem, particularly for dike slopes built with soils of a high clay content, is the problem of cracking or crumbling due to loss of moisture. To prevent this type of surface failure it is necessary to employ moisture retaining measures such as the traditional choice of sod covering. Although, a visually and ecologically preferable alternative would be the use of native vegetation such as native grasses or riverbottom species such as native willows, dogwood, and smaller herbaceous species.

4.5 Moisture Barriers

Moisture within a dike can lead to the breakdown of the subsoil, and dike failure. The protection of subsoil in not simply an issue of waterproofing against the floodwaters. A barrier must also permit the transmission of water in a filtration capacity, and help maintain the stability of the subsoil layer. However, if the subsoil itself is impermeable there is no need for this protective barrier, providing that the dike is composed of a homogenous silty clay. Typically the moisture barrier is composed of a clay or concrete core within the centre of the dike (see Figure 4.1), that prevents the lateral movement of water, through the structure, while at the same time it permits the percolation of rainwater through. Moisture barriers are also employed on the exterior slope of the structure as a temporary erosion prevention measure, as was used in the Brunkild dike (Figure 4.5) during the flood of 1997.

4.6 Vegetation

Dike designs have typically restricted vegetation on the structure itself to surface dressing in the form of turf or grass (Figure 4.6), which is useful for soil stabilization, and moisture retention. More often than not, the chosen turfs and grasses are non-native. While this kind of non-native vegetation is a better erosional deterrent than undressed soil, long-term maintenance can be costly, and ecological fit and appropriateness to a particular landscape are sacrificed. As with xeriscaping it makes better sense both ecologically and economically to use material that is native to that particular environment.

There are two primary difficulties associated with vegetation on dikes. The first is related primarily to the behavioral aspects of various root systems. Roots systems of plants that are deep reaching, considered by local authorities as noxious, or have a tap root, have a tendency to weaken the integrity of the structure. For example, firs are generally considered bad, as they are prone to wind shear pulling up wide shallow root wads that then weaken the structure's surface. But there are techniques that will permit many types of vegetation on dikes, such as careful species selection, and special techniques that are being employed such as pruning 10-15 feet off the top, or 'spiral' pruning of firs, to help reduce wind shear. The second and less severe, is an issue related to the necessary periodic visual inspection of dikes. The presence of extensive shrubs and other low lying vegetative coverage tends to obscure the surface of the dike. While it is necessary to visually inspect a dike, new technologies are available, such as Ground Penetrating Radar (GPR). More effective than visual inspection, this technology may prove to be an essential tool in assessing structural integrity of aging dikes and dikes that are subject to extreme temperature fluctuations, and virtually eliminates the need for visual inspections.

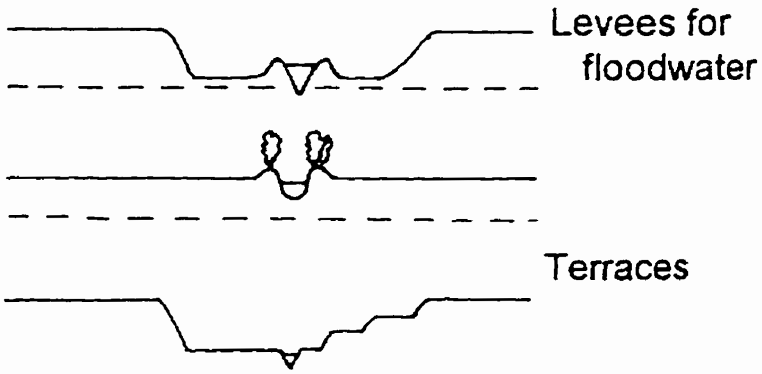


Figure 4.0 Natural dike formation Source: Forman, 1995

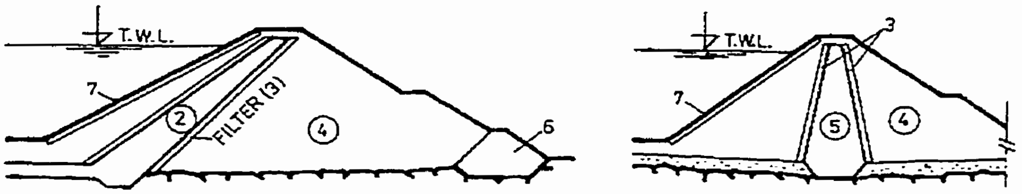


Figure 4.1 Anti-underseepage measures for heterogenous subsoil conditions
Source: Peter, 1982

Figure 4.2a Rip Rap at the toe of a dike along the Bow River in Calgary

Figure 4.2b Rip Rap

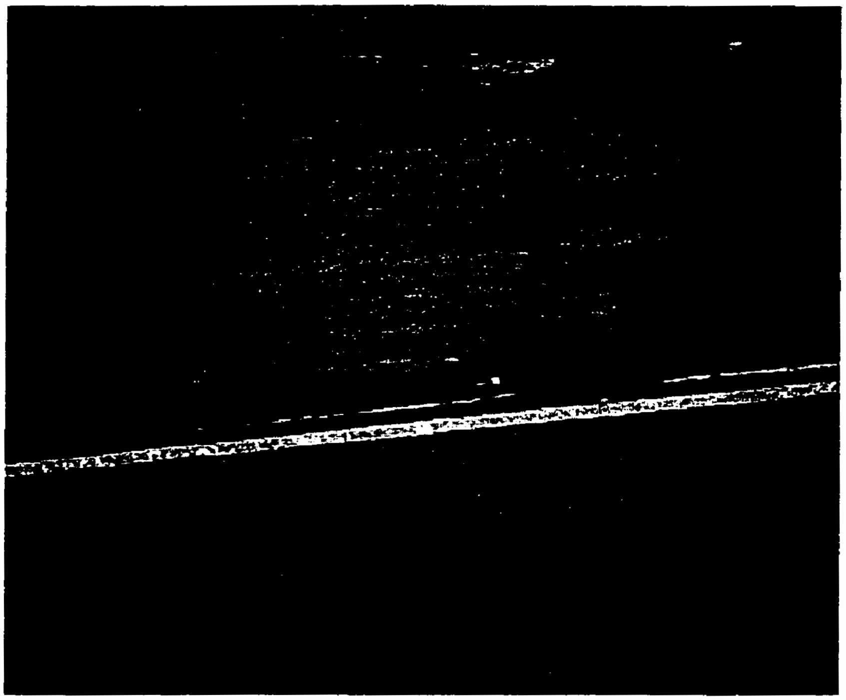
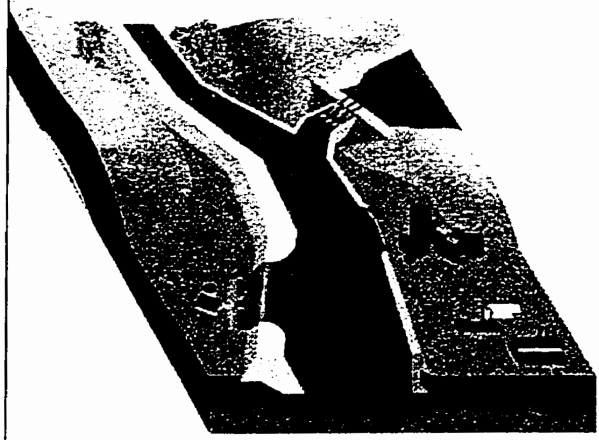


Figure 4.5 Moisture barrier on Brunkild dike

Figure 4.6 Typical grass covered dike

5.0 DIKING FAILURES



"All of a sudden a tree 60 feet high shot into the air like a bomb had exploded under it. The water came through with a roar like a yard full of freight trains"

(Excerpt from Nature's Fury by Eric Sanderson, 1948:22)

5.0 DIKING FAILURES

Dikes may fail in a number of significant and inter-related ways, the most common of which include: overtopping, piping, saturation, underseepage, (Figure 5.0), erosional forces, temperature fluctuation, and animal impacts. Often one or more of these factors in combination are responsible for dike failure. Preventing damage to a flood barrier from dynamic forces such as the above named requires careful preparation and skill of execution.

5.1 Overtopping

Overtopping is a failure of the dike due to floodwaters reaching and flowing over the top of the structure (see Figure 5.0). There are several reasons for this type of failure to occur. The most obvious being when the actual crest of the floodwater exceeds the design height of the structure.

Overtopping also occurs when the downstream toe of a dike becomes eroded and washed out materials settle in the river bed and raise it. Another reason that overtopping might occur is increased wave action resulting from high winds. Increased wave action may have either or both of the following consequences: the greater height of the waves may raise crests to a level above the top of the structure; or it may cause or aggravate erosion of the structure itself. As the integrity of the dike base is compromised, other forms of failure, such as piping and underseepage, become inevitable.

5.2 Piping

Piping (see Figure 5.0) is the most complex of the problems associated with diking failure, and under certain conditions can lead directly to overtopping. The term "piping" describes several types of diking failures. The first type is common to the Mississippi River Valley and the Danube Valley in Austria. Sherard, in his *Technical Memorandum USBR* (1953) characterizes this failure as "A concentrated leak occurring through and under the embankment." Piping of this kind is due primarily to soil conditions in which layers of sediment generally increase in grain size with depth. such a soil sequence may be loam at the top, underlaid by sand, then sandy gravel, gravel, all resting on an impervious bottom layer, such as clay. Flood water percolating down these fissures is stopped at the clay layer, thereby increasing the vertical pressure gradient. The water is then forced to spread out along the top of the impermeable layer at the base of the dike. The vertical pressure gradient then forces water upwards until it penetrates a surface, and begins to flow on or through the dry side of the dike. This kind of piping deformation is usually quite small, and does not occur with any great frequency.

The second type of piping is more common, particularly in urban and exurban environments where there are culverts that pass through or under the dike. If these conduits are not plugged during high water or in periods of increased wave action, pressure from the weight of floodwater will force seepage through these conduits to flood the dry side of the dike.

A third, and the most common form of piping failure, is "filtration deformation" (Peter 1982). This failure is due to the erosional effects of gravel under unfavorable conditions of poor dike subsoil and river-bed subsoil. These conditions "give rise to a large water height (H), increased velocities (u,v), flow rate (q) and pressures (p) within a short distance from the area threatened during the flood" (Peter 1982). Simply put, the construction of a dike on soils with high porosity and relatively large grain size allows water to flow easily into the subsoil, where it can undercut the structure. The structure then sinks to fill the void caused by the underflow, and results in overtopping or general structural failure.

Rapidly moving debris-laden floodwater are also an erosional force that may lead to piping. The scouring effect of fast waster at the base of the structure causes undercutting and consequent slumping of the structure. Again, overtopping is likely to be the result as the dike sinks into the space created by erosion at its base.

5.3 Saturation

Piping, overtopping, heavy rains or snow melt can all lead to saturation (see Figure 5.0) of the structure if they are not carefully managed. Quality and kind of soil used in construction is a key factor in saturation, which can lead to failure or slumping of the slope.

5.4 Underseepage

Wind-produced waves, as noted earlier, cause erosion of the sub-base of the structure over time (see Figure 5.0). The resulting instability, in the form of cracks, fissures, and damage to protective layers, will ultimately lead to slope stability failure and sliding, seriously compromising the structure's ability to contain floodwaters.

5.5 Animal Impacts

Animals can also have a significant impact on the integrity of a dike, depending upon the soils makeup. "In a homogeneous embankment, and especially in the body of a dike, channeling by animals is very dangerous. This danger is usually gravest for dikes built on silts and clay which are eroded easily" (Peter 1982).

5.6 Erosional Forces

Most erosion at the base of a dike structure results from wind produced waves which damage the surface and slope on the water side of the containment wall. If not not corrected, undercutting and slump are likely to occur. Erosion can, however, also occur on the dry side a dike, if it is exposed to high winds carrying rough soil particulates.

5.7 Damage Due to Thermal Fluctuation

In climates where exposed structures are subject to frequent periods of freeze-thaw, a dike may develop structural weaknesses in the form of cracks or fissures, which, like other problems mentioned above, cause slumping and eventual dike failure. In extreme circumstances, portions of the dike may crumble and collapse entirely. Prolonged exposure to extremely dry conditions can also lead to failure in high clay content structures, resulting from a drying out of the most exposed layers of the body of the dike.

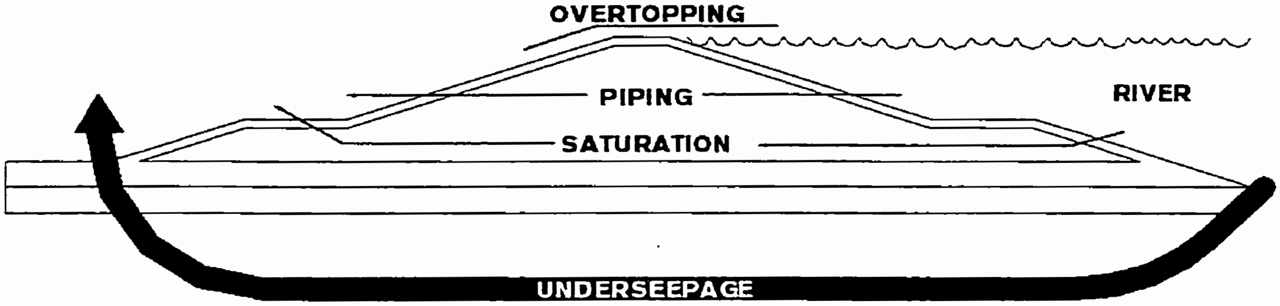
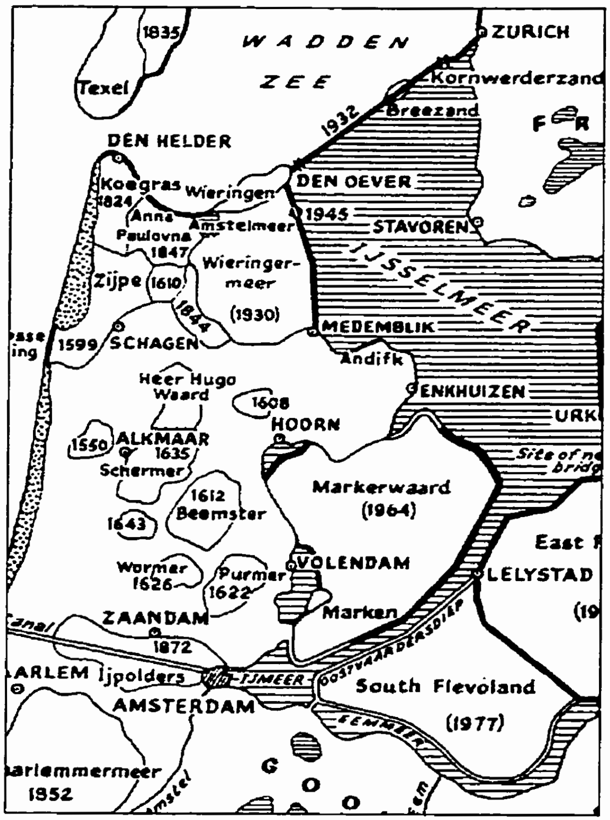


Figure 5.0 Potential dike failures, overtopping, piping, saturation. and underseepage.

6.0 DIKING IN HISTORY



"Een volk dat leeft bouwt aan zijn toekomst "
('A living nation builds for its future")

(Inscription on the monument that marks the closing of the Zuiderzee dike)

6.0 DIKING IN HISTORY

And so to escape the flood, Noah went into the ark.... Genesis 7:20.
But Noah forgot about dikes.

Ever since people began to build their settlements in floodplains alongside rivers and lakes, inundation of the land, whether from the oceans or the rivers, has been a recurring, often annual event. In some places, such as ancient Egypt, the annual flood was a prayed for event that made survival and prosperity possible. In other places, flooding was a devastating disaster. Permanent habitation of the floodplain has a long history. Cities, towns, and rural communities since humanity's beginnings have emerged on sea coasts and in river valleys in order to use the waterfront's food and energy resources, as well as its transportation potential. Today, however, flooding and threats of flooding put greater numbers of people at risk than ever before. As the world's population grows, so does competition for resources, and in countries where the population pressures are intensifying, such as India, Mexico, China, Central and South America, and Southeast Asia, many people have no alternative but to live where the land is least desirable and therefore least expensive. Often this is on the floodplain.

6.1 Ancient Hydraulic Societies

The struggle between civilizations and their rivers is as old as civilizations themselves. The historian J. van Veen has identified the need to control water as the defining characteristic of the great civilizations of the ancient world (Wagret 1968:vi). The earliest societies of far eastern Eurasia, the Indian subcontinent, the Fertile Crescent, and the Nile Valley, among others, understood early and well that in seasons of too abundant water, dikes had to be built to contain unwanted flood, and in seasons of short supply, dikes were the means by which water could be directed from storage reservoirs to dry fields.

In the Fertile Crescent area of Mesopotamia nearly 8000 years ago, hydraulic engineers designed systems of ditches, dams, canals, and dikes to manage the flow of water in two great rivers, the Tigris and the Euphrates. The Sumerians were responsible for the development of much of the technology necessary to controlling the rivers and enhance their fertile valleys. Among the earliest written records from Mesopotamia are lists of flood dates and extent of inundation. Using systems of dikes, Sumerian engineers built canals as much as twenty-five yards wide between the two great rivers, and a network of innumerable smaller channels to contain excess waters and distribute them over the land (Butterfield 1981:37). A tablet now in the British Museum contains algebraic calculations for the design of the dikes, dams, channels, and wells of the Sumerian water control system (Newson 1992:5).

Like the first farmers and engineers of Mesopotamia, the people of Ancient Egypt also manipulated the flow of water in their life-giving river, the Nile. The rise and fall of waters in the Nile were more predictable than the movements of the Tigris and Euphrates, and required a somewhat less complex system of river management, but the creation of a calendar for predicting periods of high and low water was a high priority. The earliest written records, kept by the royal scribes, tracked the height of the annual flood and compared it with the year's grain yield (Butterfield 1981). The relatively predictable nature of the the upper Nile, and the records of the annual inundation flood allowed the Egyptians to divert floodwaters into embanked plots for storage, and to direct water to specific fields for irrigation. The remains of the "world's oldest dam," built between 2950 and 2750 BCE, are in Egypt, and the most important date in the Egyptian calendar was the day on which the annual flood began (Ward 1978:3). The construction and maintenance of an efficient diking system was of paramount importance to Egyptian survival. As archaeologist Brian Fagan has described it: "Each summer, as the Nile swelled over its banks, small groups of villagers stood watch over their levees, clearing canals and ditches, frantically shoring up collapsing dikes to steer the water to the right drainage basin or storage reservoir" (Fagan 1999:101).

In far eastern Eurasia, the diverse societies of China also developed strategies for controlling rivers for the benefit of agriculture. China's Hwang Ho River, for example, has been both a resource and an enemy for the many people who have farmed its floodplain for over 4000 years. Again, as in Mesopotamia and Egypt, some of the earliest and still extant written records in China were concerned with understanding rivers and floods. Agricultural records for the year 2297 BCE note a great flood of the Hwang Ho that year. Records for succeeding years tell how the legendary leader Yu The Great "controlled and tamed" the rivers of China by building massive dikes and dams (Ward 1978:3).

6.2 Classical Mediterranean Empires

The great classical civilizations of Greece and Rome, with their huge empires, were based to a large degree on the ability of their engineers to control rivers through complex systems of aqueducts and canals which transported river waters hundreds of mile to irrigate lands for a growing population. Western Europeans learned of dikes and diking systems from the Romans, who had borrowed the idea from their predecessors in the Italian peninsula, the Etruscans, who in their turn had borrowed the idea of dikes from the peoples of the eastern Mediterranean (Wagret 1968:171). Causeways, built by Roman engineers everywhere that the Rome's imperial armies went, served as the inspiration for the Schagen (mud) dikes used from the thirteenth to the fifteenth centuries in the low coastal countries on the southern shores of the North Sea. These early Dutch dikes were typically made from a combination of peat, sand, and clay, and had characteristically steep slopes held together by turf. Mud dikes were also common to Germany, France, and England.

6.3 Diking of the Netherlands

From the beginning of its history, the Netherlands has been the scene of a constant struggle between its inhabitants and hydrological forces exerted externally from the sea, and internally from the rivers. Evidence of this relationship can be seen in the languages of the inhabitants, but is more directly reflected in the number of place names ending in *-dijk* and *-dam* still in use today. The former term is used in reference to places along particular sections of diking, while the latter refers to places at the mouth of a river or inlet where there exist, or once existed, dam structures. The essence of this struggle is made evident through an understanding the geological history of the region.

> During the last great ice age (25,000-7,000 BCE), the area of Europe which is now The Netherlands was covered by the western European Ice Sheet. The tremendous weight of this ice sheet is thought to have depressed that portion of the earth's crust upon which it [The Netherlands] lay, pushing up a peripheral bulge along its forward edge. As this edge of the ice sheet was relatively thin and light in weight, most of the present area of Holland is within the zone formerly occupied by the bulge (Lambert 1985).

Much of the earth's crust is still rising from the low levels it reached while weighed down by the great ice sheets, but this is more than compensated for by rising oceans fed by ice melt. Terrestrial levels continue to drop relative to sea level, falling at a geological pace each year, with 38 % of the total land surface below the high water level. Most of The Netherlands exists only because of its dikes. Flooding continues to be so frequent that the Dutch name their floods as North Americans name hurricanes and tropical storms.

6.3.1 The Polderlands

The natural landform of The Netherlands is a product of the stormy relationship between the people living on the land, and the sea. As long ago as 1000 CE, people of the region began building dikes to create polders. A polder is an area of land lying just at or somewhat below sea level, which has been reclaimed for agricultural use through the construction of dikes and drainage of sea water. Dike building was also the standard response to inundation when unusually high tides carried sea water inland. Early dikes were no more than low embankments, but within a century, sluices had been added to allow for drainage of agricultural fields during periods of high water (Lambert 1985:91).

6.3.2 The Zeider Zee

The ongoing struggle between the Dutch and the North Sea led to the largest construction project in the country's history. Before 1919, one of the features of the Dutch coast was a saltwater inlet of the North Sea, covering nearly 800 square miles. It was known as the Zuider Zee (pronounced ZIGH-dr-zee, and meaning Southern Sea). Construction lasting thirteen years, from 1919 to 1932, produced a twenty-mile long dike, known as the Ijsselmeer, which enclosed the inlet, cutting it off from the sea. The dike can be seen in the upper middle portion of the zoom-out. More than half a million acres of agricultural land were reclaimed, and what remained of the original Zuider Zee was flushed by freshwater from the Ijssel River, and became a large freshwater lake.

The second stage of the project consisted of reclaiming 550,000 acres in an area covering 2,200 square kilometres, and involved the construction of five polders which were subsequently drained. The first polder to be completed was the Wieringermeer, in the northwest. It was actually diked directly from the sea, not from the Ijsselmeer. It was dry two years before the mouth of the Zuider Zee was closed off. To help dry out the polders, reeds, which grew naturally on the former sea bottom, were left to grow. The reasoning behind this was that transpiration moves water into the air faster than evaporation alone, so letting natural vegetation assist with the drying out process was efficient both in terms of money and time. When the soil had dried sufficiently, the reeds were cleared and replaced with colza, a plant related to cabbage and turnips. When the colza had absorbed yet more water and salt from the former sea bottom, grain crops were planted. Cultivation was continued for five years before the land was dry and sweet enough to produce commercial crops.

Beginning in 1932, land was leased to commercial farmers, or incorporated in municipalities where three agrarian-based towns later grew. The first agricultural crops were harvested in 1933. In those early years, the Zuider Zee Dike was a mud structure, but it has since been modified considerably, and today supports a highway connecting northern Holland with Friesland. Reclamation of the polder lands continued to the end of the 1980s. Southern Flevoland, the southernmost of the polders, was the last to diked and drained. it can barely be seen in the 1964 image, diked but undrained. By 1973 it had been drained and was under cultivation to make it suitable for commercial agriculture. The 1987 image shows Southern Flevoland covered with working farms.

Markerwaard was diked even later, and appears in the 1973 image as light-toned water. The dike separating merkerwaard from the rest of the Ijsselmeer was still partially completed in 1973, and reached its final shape in 1987. The Markerwaard was not drained, but has been designated a freshwater reservoir would also acts as a buffer against flood waters.

An inscription on the monument of the Dike pays tribute to the positive attitude of the Dutch: "God Created the Earth but the Dutch Created the Netherlands" (www.macalstr.ed). "A living nation builds its own future" (Wagret 1968:17).

6.4 North America

The first European settlers in the Americas chose lands which were perceived to have adequate resources for subsistence, including access to water. The greatest proportion of them were agriculturalists, who sought out lands that were relatively flat, boulder-free, and most importantly for their crops, fertile. Land near rivers often fit the desired criteria, and in addition, the rivers served as major transportation routes, as sources of food, and as reservoirs for irrigation of adjacent fields. The best lands for agriculture were a product of the periodic inundation of the water courses.

Aboriginal peoples in the 16th and 17th centuries had a healthy respect for the unpredictable power of the rivers, and their ability (or inability) to reclaim lands adjacent to the river's course. They had learned, from their long relationship with land and river, that the river's cycles were inevitable and nearly always uncontrollable. To be sure, some native North Americans did practice the hydraulic sciences, particularly in Central America (Maya and Aztec), and in what is now the American Southwest (Anasazi and ancestral Navajo), by building canals for the diversion and delivery of irrigation waters. But they, as well as other American aboriginal farmers, chose not to settle for long periods of time within the floodplains. They built their permanent structures well beyond the reaches of rivers. Conversely, the early immigrant farmer sought to control the waters in order to continue to live on the fertile lands. Various technologies were employed, including river diversion using canals and dike construction.

The settlement patterns of the first Euro-American farmers determined the location of many North American cities. In spite of periodic flooding, towns that began as camps and hamlets at the river's edge continued to grow into towns and cities as human populations grew. Today, as global warming and more frequent and more intense El Nino episodes bring greater threats of flooding, and increasing numbers of people are threatened, we are compelled to re-examine our relationship with the river.

The study of flooding and flood control in North America dates back only as far as the mid-nineteenth century. Based Data collections are being used to help determine flood characteristics of particular rivers and watersheds.

The act of diking and the methods employed at the middle of the last century, continued and changed little over the next century. More and more aggressive diking of the Mississippi valley watershed continued, undeterred by the warnings of Charles Ellett, in his 1853 analytical account of the ongoing flooding *Inundations of the Delta of the Mississippi.* In his account, he states that "the draining of the natural swamps and backwater sloughs, the continued building of dikes, and the harsh agricultural drainage practices along the Mississippi had, by 1853, caused increased and more severe flooding in the area".

Several decades later, the same saga began across the border in Canada. The Fraser Valley in British Columbia, highly prized for its fertile and productive lands, became the focus of intense and extensive diking to allow for settlement and harvesting, unhindered by annual flooding from the Fraser River. The Sumas Dyking Act (Figure 6.4a) was passed in 1882 encouraging private settlement, and farming of the lands of the Fraser Valley. Diking was encouraged at the private level, to be make permanent occupation possible, and to allow for systematic cultivation. This continued, unsuccessfully, until severe flooding in 1894 (detailed in an article in the Fraser Valley Chronicle, (Figure 6.4b)) forced the government to pass legislation bringing the responsibility for dikes and all flood control measures under provincial control.

Flood control and management of the Fraser Valley continues today and has become an integral part of the Fraser River Action Plan (FRAP). Recognizing that the river is under stress, and with a goal of improving the long-term health of the valley, the plan is being carried out jointly by Environment Canada and the Department of Fisheries and Oceans. The plan focuses on the reduction of pollution, the improvement of fish and wildlife productivity, and emphasizes above all, sustainable development in the Fraser Basin.

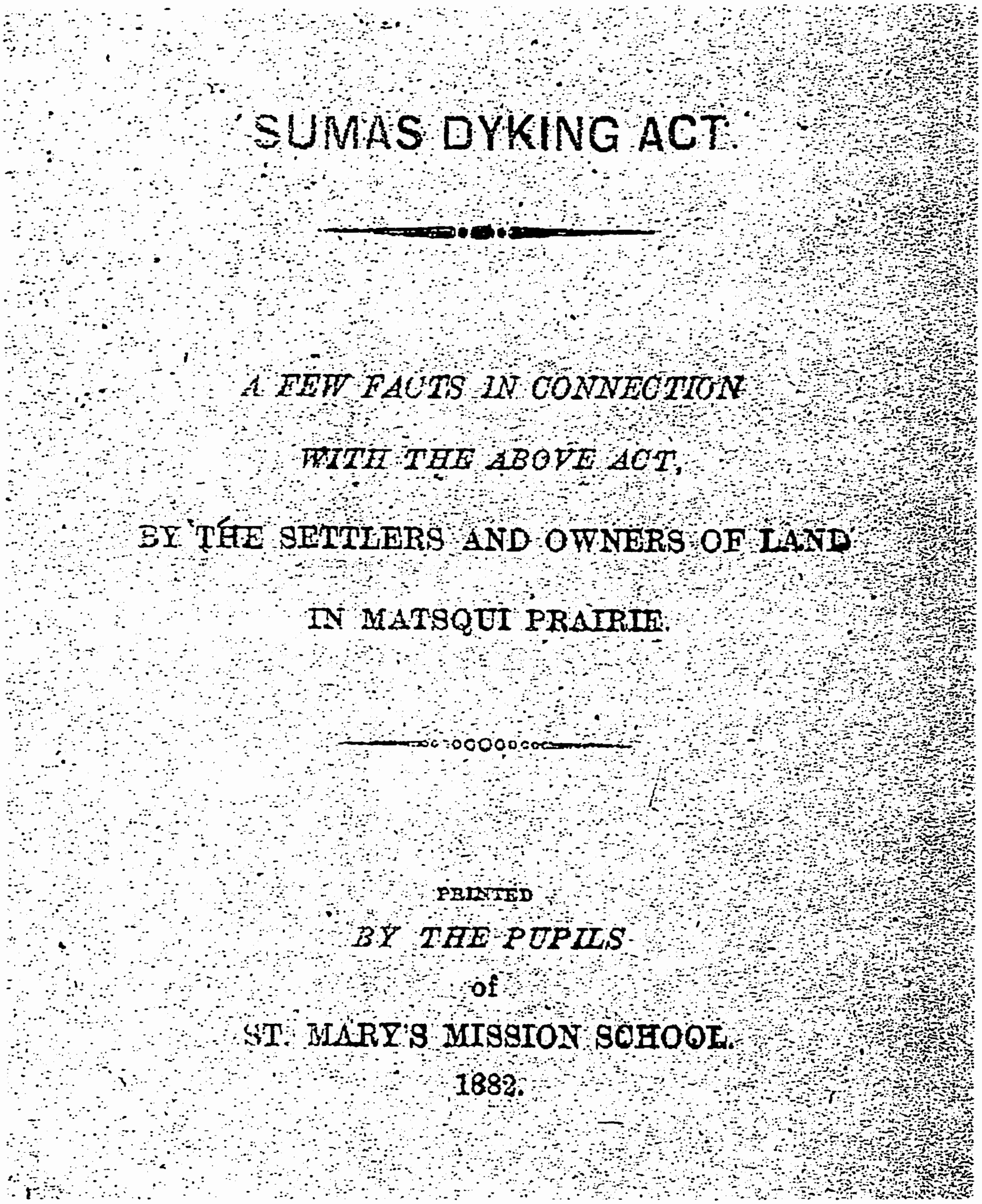
The plan examines the effects of land use on the area, and evaluates proposed plans for the Valley using demonstration projects to assess changes in the environmental quality of the affected watersheds. The FRAP is in a constant state of change as new works are proposed, and the results of research into the effects of changes within the valley are analyzed. The plan sets the tone for all activities and guidelines that are to occur within the Fraser Valley, including the construction and maintenance of flood control structures and diking.

The B.C. Ministry of Environment, Lands and Parks (MELP), and the Department of Fisheries and Oceans (DFO) jointly oversee flood control in the valley, with the former focussing on the structural, land based components, and the latter responsible for the components of dikes that reside below the normal water level, and have a bearing on fish habitat. The B.C. Dike Maintenance Act now governs the operation and maintenance of flood protection works.

In March of 1999 one of the most significant findings with regard to dikes in the valley was published by MELP and the DFO, "Environmental Guidelines for Vegetation Management on Flood Protection Works to Protect Public Safety and the Environment".

This report outlined guidelines for the management of vegetation on flood protection works focussing on protecting both public safety and the environment. In the report, they present the minimum standards under the Dike maintenance Act for vegetation management on dikes. These guidelines recognize, based on the last decade of empirical evidence, (since the last report) that there are environmentally beneficial aspects of having certain types of vegetation on and around diking structures, that will not compromise the integrity of these structures. According to these guidelines, this opens up the opportunity, in a number of situations, to implement/ utilize, enhance and protect the riparian vegetation on and around dikes.

These guidelines begin to shed light on a number of vegetative species and accompanying strategies that can be used to reduce the negative ecological and visual impact that dikes have traditionally had. These strategies will be discussed later in section 8.



SUMAS DYKING ACT.

A FEW FACTS IN CONNECTION
WITH THE ABOVE ACT,
BY THE SETTLERS AND OWNERS OF LAND
IN MATSQUI PRAIRIE.

PRINTED
BY THE PUPILS
of
ST. MARY'S MISSION SCHOOL.
1882.

Figure 6.4a Sumas Dyking Act of 1882 Source: B.C. Provincial Archives

FRASER VALLEY DYKES.

The Great Area They Make Safe for the Operations of the Farmer.

How Government Aid Has Made a Success Where Private Effort Failed.

The problem of converting the 100,000 acres odd in the Fraser valley, which are more or less influenced by overflow and the action of tidal waters, into cultivable land, has been one confronting the settlers of New Westminster district ever since settlement was first effected. Perhaps in no part of Canada and certainly not in British Columbia can there be found more fertile lands than exist in this delta valley, and it would be difficult otherwise to find anywhere conditions more favorable to agricultural success. The fruitfulnes of the soil under good cultivation has been remarkable and wherever the products of the Fraser valley have been exhibited they have invariably elicited admiration and surprise. It was therefore a matter of great moment to the Westminster district and to the province as a whole that some system should be devised whereby these lands could be conserved to the uses of settlement and add to the wealth of the province.

Many partial efforts have been made in the past, but owing to the uncertainty of the seasons and the flooding of the Fraser river, these have been more or less a failure as a private enterprise.

After the floods of 1894 the government turned its attention to dyking matters and devised a scheme of reclamation and protection by sections including in each a certain tract of land, the dyking of which was placed in the hands of commissioners. Unfortunately for the experiment the depression which had set in became very marked, and it was decided after a good deal of consideration that the best and cheapest method was to perform the work under the direct control of the government, and legislation was introduced and passed in 1897 and extended in 1898 which consolidated the dyking enterprises in the Fraser river valley, bringing the whole under one control and subject to a uniform charge in the matter of expenditure.

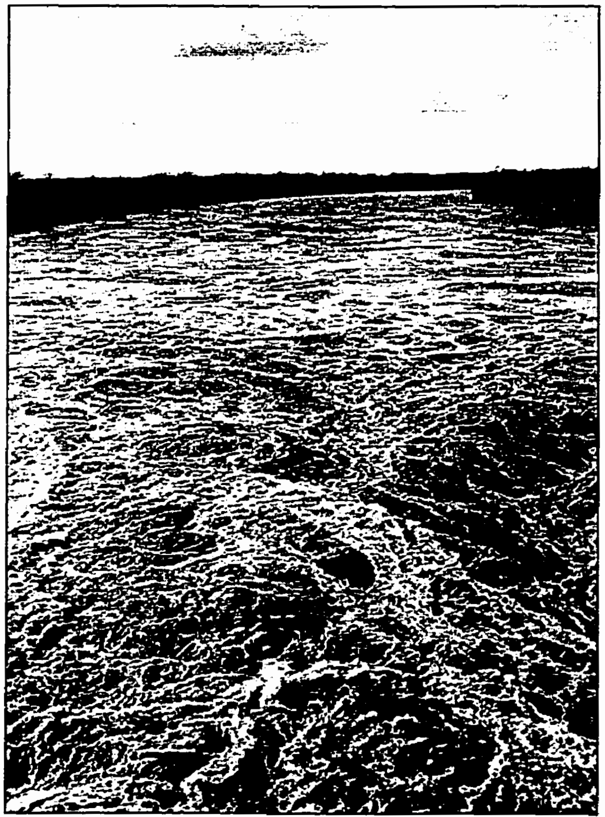
In order to indicate the progress of dyking matters in Westminster district, it will be necessary to give a review of the original condition of the lands and the various stages which have led up to the present completion of the enterprises.

ORIGINAL CONDITION OF LANDS.

The lowlands were of great agricultural and pastoral value, but were rendered valueless from overflow except as pasture during certain seasons. The lower or more frequently flooded areas being grass lands, and the higher or less frequently flooded areas being covered with brush. The soil is in places peaty, but for the most part of a rich, loamy character. All this land, its value being evident, was taken up by settlers and others early in the history of the province and has been held practically in an unimproved state and not capable of systematic cultivation until an effective system of dyking could be inaugurated. Thus for years, except in favored spots, the valley of the Fraser has lain dormant and yielding not one-hundredth part of what it was capable of under more favorable conditions.

Figure 6.4b 19th Century Article on Fraser Valley Dikes Source: B.C. Provincial Archives

7.0 THE RED RIVER SITUATION



"The potential for extreme flooding is great. However, the probability that all these factors will coincide is small."

(Ed Kuiper, hydraulic engineer, Professor emeritus, and assistant floodway designer, in a Winnipeg Free Press Interview, March 6, 1999)

7.0 THE RED RIVER SITUATION

The outward appearance of the landscape of present day Manitoba offers only glimpses into its long and varied history. Its present physical form is, like all landscapes, the product of numerous forces acting on it over a long period of time.

7.1 Geologic History

The foundation of Manitoba's landscape is the eroded remains of a Precambrian mountain system consisting of volcanic, metamorphic, and granitic intrusive rocks, the oldest of which are estimated to be 2.6 billion years old (Davies et al 1962). This eroded plain resides at the surface of the province in the north and east, but it lies under approximately 7,500 feet of primarily sedimentary deposits in the south-west corner of the province, (Winnipeg is approximately 700 feet above this Precambrian shield), (Manitoba Mineral Resources Division 1979). These sedimentary deposits are the remains of organic depositions on the floor of a vast inland sea that covered a large proportion of the continent between 450 million and 50 million years ago, known as the Ordovician Period. The deposits consist of sandstones, dolomitic limestones, dolomites, dolomitic conglomerates, calcareous shales, and limestones, which together form the bedrock of the majority of the northern portion of the Red River Valley.

The bedrock on the western side of the Red River Valley is dolomite which was a product of the sea during the Silurian Period between 360 and 320 million years ago. In the southern part of the valley however, the bedrock was formed during the Jurassic Period, between 155 and 130 million years ago, and consists of a variety of shales including grey, varicoloured, calcareous, as well as sandstone and limestone. And, most recently, the base of the south-west corner of the province having been laid down during the Cretaceous Period, 130 to 60 million years ago, consists of sand, shale, and a variety of clays (Davies et al 1962, Manitoba Mineral Resources Division 1979).These sedimentary layers have subsequently been covered with a thick layer of deposits due to chemical weathering of the parent material.

The most recent and perhaps single most influential factor giving form to the present landscape of southern Manitoba was the Wisconsian glaciation, or "little ice age" which began around 75,000 years ago. Between 24,000 and 22,000 years ago, two glacial ice sheets, the Laurentide originating from the east, and the Keewatin originating from Hudson Bay, began scraping their way across Manitoba, picking up clays and silt deposits as they moved. Between 16,000 and 13,000 years ago, the Keewatin ice sheet retreated into what is now northern Ontario. During the same period, the Laurentide ice sheet retreated rapidly, leaving behind the clay deposits, and the water from its rapid melt covered most of southern Manitoba, and formed Lake Agassiz.

A subsequent advance, then retreat of the Laurentide ice sheet, around 10,000 years ago blocking the eastern outlets of Lake Agassiz, and inundating the southern portions of the Red River Valley in Minnesota and North Dakota.

The Lacustrine Period was perhaps the most influential in determining the present landscape of southern Manitoba, and the Red River Valley.

At the end of this period of glaciation in southern Manitoba around 10,000 years ago, a vast lake covered the heart of North America. From the Clearwater River in northern Saskatchewan to the 45th parallel, glacial Lake Agassiz was formed by two great ice sheets as they melted and retreated northward into Northern Ontario, and Hudson Bay. (Figure 7.1a)

Part of the lake reached down into the United States, in the vicinity of the Minnesota-North Dakota border. When ancient Lake Agassiz drained, it left behind traceable shorelines and a nearly flat valley.

The resulting soils of southern Manitoba are a product of three main factors including, glacial upheaval and deposition, lake processes, such as terracing, beach formation, wave action, and sedimentation, and riverene processes such as alluvial deposition, siltation, and delta formation. (Hurst, 1982) The current surficial geological conditions of Manitoba can be seen in Figure 7.1b.

7.2 Ideal Flood Conditions

Due to the enormous weight of the glacial ice sheet that once covered southern Manitoba, the landmass is still depressed, and although it is subsiding, the almost glacial rate at which it is rising indicates that it will take a considerable amount of time to return to its previous level. Any depressed area is typically prone to flooding, but combined with underlying clay deposits, and the northerly flow of the Red River create conditions that are highly conducive to flooding.

7.3 The River

The Red River Basin covers a drainage area of 116,500 square kilometres (Figure 7.3). The area extends from Wahpeton, North Dakota in the United States, to Lake Winnipeg, 100 kilometres north of Winnipeg, Manitoba, in Canada. Despite an elevation change of 71 metres between these two points, the basin is relatively flat. This elevation change takes place over 872 kilometres, with an average slope of less than 1/10th of 1 percent, the basin is considered to be almost flat. "The flatness of the terrain also means few natural large water storage sites are available." (International Red River Basin Task Force Report 1997:7) This flat profile of the floor of the Red River Valley is a result of levelling of the floor of Lake Agassiz.

The flat nature of the valley, and large size of its drainage basin however, are only a few of the problems that contribute to the frequent occurrence of flooding. As the Red River is north flowing, it melts at or near its headwaters before it begins to melt downstream. Meltwater running downstream flows northward where ice still may exist on the river itself and on the lands it passes through. The Red River is also a river with relatively low banks running through level low-lying land (in other words, a floodplain). The kind of flooding that occurs when melt water in the river cannot continue to flow down river to its outlet because of ice obstacles and adjacent land is flat and not very high relative to the river itself is called "freshet flooding." Rivers that answer this description are very common in the arctic, which is low lying land, with north flowing rivers that themselves have not cut deeply into the land to create high banks.

During severe flooding, the width of the river expands to fill the entire valley, a total distance of approximately 40 kilometres, or 20 kilometres on either side of the river. Over this distance silt rich in nutrients is deposited throughout the floodplain. It is because of this age old process that the soils in the valley are so fertile and have long attracted agricultural peoples.

The silt that the river deposits has been picked up on a long journey to its outlet at Lake Winnipeg. The water takes on a reddish-brown hue from the small particles held in suspension, and gives the river its name. Its banks are typically tree-lined, but in many places particularly in rural areas, the trees have been harvested and few shrubs remain.

The banks themselves are typically characterized by abrupt but shallow drop offs, sheared by the river, and often signs of erosion are visible, particularly on outside bends, and in areas devoid of vegetation.

In Canada, more than 700,000 people live in the Red River Basin, of which, 90 percent reside in urban centres. In the U.S. another 384,000 in North Dakota, and another 92,000 people in Minnesota, with more than half of the American populations residing in rural areas. (International Red River Basin Task Force Report 1997:8)

7.4 River Use

Before the era of permanent occupation by European settlers, recurring inundation had little effect on human activity on the banks of the Red and Assiniboine Rivers. Indigenous peoples used the rivers as transportation routes, but did not inhabit The Forks, or the river banks to the north and south. They came seasonally, usually in late summer, and for short periods, during which they traded and conducted diplomatic and social affairs.

The first European fur traders came in the mid-eighteenth century and, like the aboriginal peoples, used the rivers mainly for transportation and fishing. Because it was so central to the cross-Canada transportation systems of the 18th and 19th centuries, the first permanent settlement in the prairie west was at the juncture of the Red and Assiniboine Rivers, known as The Forks. These two rivers provided highways leading to and from all directions: the east was accessible via the Winnipeg River, Rainy River, Lake Superior, and ultimately east to the Great Lakes, the St Lawrence, and the Atlantic Ocean; to the south, water transport was available into the heart of Dakota and Souix territory, and via the Missouri and Mississippi Rivers to St Louis and eventually to New Orleans; to the north, canoe, York boat, and steamer could access Lake Winnipeg, York Factory, and Churchill; to the west a network of lakes and rivers accessible from The Forks led to the two great branches of the Saskatchewan River, Fort Edmonton, the Athapasca country, the Mackenzie River Basin, and the Rockies.

The first permanent settlers, arrived at The Forks in the first two decades of the 19th century, and together with already well-established fur trade elements, founded the Red River Settlement. Almost immediately they had their first experience of high water and river overflow. A major flood in 1809 delayed the construction of the North West

Company's Fort Gibraltar for a year (Losey 1999:395). The next half century brought three more floods of major importance, in 1826, 1852, and 1861, each of them peaking at more than thirty-two feet above normal river level.

In the early 1870s, the great influx of immigrants to the Canadian prairies began. In that decade alone, the Red River burst over its banks three times. Major floods of greater impact followed in 1882 and 1892. In the twentieth century, the Red River again overflowed its channel in 1904, 1916, 1946, and 1950. During the last of these, the river peaked at 30.3 feet, the highest since the 1861 record of 32.5 feet. Red River Settlement became the City of Winnipeg, and population continued to rise for the next century. As parkland and prairie became agricultural land, flooding became a more serious problem. Continued suburban and exurban development upriver from Winnipeg, combined with current agricultural practices in southern Manitoba and in North Dakota, increases both the threat and potential severity of flooding.

7.5 Red River Flood History To 1950

The inevitability of Red River flooding, and consequent damage to property was pointed out by Sandford Fleming, chief construction engineer for the Canadian Pacific Railway, in his Report on a possible continental railroad route through Manitoba.

> It is futile to assume that the Red River shall never again overflow its banks. Man is utterly powerless to prevent its occurring periodically, and whenever it occurs the disastrous consequences will be intensified in proportion to the increased number of inhabitants within the submerged district (Fleming 1879).

At the time of writing, Fleming no doubt had in mind the three floods which had caused so much trouble in Winnipeg in the nine years previous to his survey.

A first step towards flood protection was taken by city and provincial authorities early in the 20th century, when dikes were incorporated into the existing infrastructure of the city. New roads being built along the river's edge had to be elevated so that they also served as dikes for local communities. One example is Churchill Drive in the community of Riverview.

7.6 The 1950 Flood and Its Aftermath

In spite of repeated floods and threats of floods, and increasing numbers of people, farms, and businesses under threat of inundation on an almost annual basis, serious initiatives to prevent flooding were slow in coming, and the little that was done gave less than adequate protection to the city. In the spring of 1950, the Red River spread out to cover the City of Winnipeg completely, with near disastrous consequences for the population. The flood and its consequences (including citizen demand for better protection) caught the attention of political authorities responsible for the safety of the population. The result was a series of plans for major flood prevention structures.

Within months of the 1950 disaster, a series of flood control measures were approved by city council. They included the construction of thirty miles of elevated boulevards set at 26.5 feet above datum (above 1948, but below 1950 levels). The plan also called for the construction of "22 pumping stations to lift sewage over the boulevards," in order to prevent sewage backup. Also proposed in the plan was the erection of a steel and timber dike for downtown Winnipeg. Steel sheets were to be placed in front of St. Boniface Hospital, and a mud dike was planned as protection for the CNR tracks. A secondary dike was approved for Elm Park, where 169 residences were especially vulnerable to flooding.

The next year, Mayor Duff Roblin initiated the development of the Red River Floodway. An Act of the Winnipeg City Council under Roblin's administration (1952) created The Greater Winnipeg Diking Board, and charged it with responsibility for augmenting flood control measures which had been approved one year earlier. An early initiative of the Diking Board was the production of a nine volume engineering report detailing flooding and flood control in the Red River Valley. Despite its nine volumes, the study had all the limitations of an engineered approach, and included little or nothing on the history of flooding in the region, economic discussion, geography of the region, or social analysis and context. Three recommendations of the study were later realized: (1) a detention basin at Ste. Agathe formed by a 25-mile dike across the Red River Valley south of Greater Winnipeg; (2) a diversion of the Assiniboine River around Portage la Prairie with a 17-mile channel cut north to Lake Winnipeg; and (3) the Greater Winnipeg Floodway, a 26-mile long ditch intended to divert flood water at St.Norbert around the city and back into the Red River at St. Andrews north of the city. In addition the Province enacted the Dyking Authority Act in 1952, outlining the authority and control over erection, repair, and modification of "dykes" and or lands that may relate to flood protection.

Subject to the same political apprehension and debate as the larger projects which were to follow, the planning and construction of a system of primary diking was the object of local scrutiny by residents in specific communities who were directly affected. The board faced a variety of problems which were not easily solved by engineered solutions alone. The human factor in reaching safe and adequate design solutions required a deep understanding of local communities. Herein lie the roots of today's movement toward a more integrated (holistic) approach to problem solving at a smaller scale.

Fearing high costs, civic and provincial authorities moved at an almost glacial pace towards creating flood prevention measures. As a result, the city was not prepared for the flood of 1956, when once again, homes, businesses, and farms were threatened, and in some cases, flooded.

Construction of the Red River Floodway Project (RRFP) finally began on October 6th, 1962. It was the first major step towards the protection of the city of Winnipeg against the threat of annual inundation. The project spanned nearly 7 years and displaced more than 100 million cubic yards of earth, more earth than the St. Lawrence Seaway or even the Panama Canal. Several years behind schedule, the R.R.F.P. was delayed for a variety of reasons, including long political debates, and the fears of politicians that they would fall into disfavour with voters because of the project's high construction costs. Public attitudes concerning the value of the floodway to the city swung back and forth. During the construction years, not all observers applauded the plan; the floodway, known locally as "Duff's Ditch," was a frequent subject of newspaper cartoons and local jokes for a number of years. In the years following its completion in 1969, however, the floodway has protected the city from total inundation twenty times. Major floods were averted in 1970, 1976, 1980, 1982, 1986, 1990, and 1997 by the alternate route for excess waters.

Yet, the Floodway, as important as it has been in protecting the city, still does not answer the needs of many suburban and exurban communities. Since 1969, thousands of people have experienced dislocation and millions of dollars of damage have been caused by floods resulting from inadequate secondary diking protection (Figure 7.6).

7.7 Analysis of Diking Conditions after 1997

Heavy precipitation occurred in major segments of the basin in the fall of 1996. Late October and November saw another 15 cm fall, therefore the soil moisture was much higher than normal fall levels. The proceeding winter had significantly higher levels of snowfall. In Fargo, North Dakota, for example, 297 cm of snow fell compared to a long term average of 99 cm, the city's previous record was 226 cm. Grand Forks experienced a record accumulation of 248.6 cm. Overall most areas within the basin experienced snowfall levels of 2 to 3 times that of average.

Heavy spring precipitation also fell on Crookston, Minnesota on April 5th and 6th, totalling 9.2 cm breaking the previous two day total in April by more than 3 cm.

There was yet another precursor of the severe flooding that occurred in the spring of 1997. Higher than normal temperatures during one week, followed by lower than normal fluctuations, created 'typical' ideal flood conditions. The rapid snow melt did not permit the frozen ground to thaw and prevented percolation, therefore the water had nowhere to go except follow the topography. At the same time as the record breaking precipitation in Crookston, the Red was cresting at Wahpeton-Breckenridge a height of 5.8 metres, nearly 3 metres above flood stage (3 metres).

On April 18th the Red hit a maximum peak stage at Fargo-Moorhead, of 11.9 metres, and a peak stage of 16.3 metres on April 22 at Grand Forks. During this time many of the tributaries of the Red had exceeded their 100 year flood levels.

Across the border in Canada, the media coverage of their neighbours to the south prompted a flurry of activity in the Towns and hamlets along the Red. Ring dikes were built with the help of the local residents and Canadian military around St Adolphe, St Agathe, Rosenort, Morris, St Jean Baptiste, Roseau, and Dominion City, and in Winnipeg preparations were also being made for the impending waters.

As the waters surged northward, evacuations of the towns of Morris, Rosenort, and others ensued.

An examination of the current flood protection plan had city of Winnipeg officials in a quandry about the possibility of flood waters reaching around the city's defenses to the south west of St Norbert and entering the city through the La Salle River corridor. The solution chosen was to build what was later to become known as the Z-dike, or Brunkild Dike. An extension of the existing dike that protects St Norbert from overland flooding to the south, the project required nearly every large earth moving vehicle, civilian, and military, in southern Manitoba. The herculean task of building this primitive yet immensely long earth structure was completed in just 10 days. The hastily constructed dike formed a barrier that stretched from Hwy 75 at St Norbert 24 kilometres to the town of Brunkild to the west. The dike was successful in preventing the waters of the Red from reaching those of the LaSalle River.

The Brunkild Dike

Constructed in less than 10 days, the Brunkild dike was built during the 1997 flood to prevent potential flooding to the north of the Floodway gates. The dike is the continuation of an existing dike which stretches twenty-three kilometres from the floodway toward the town of Brunkild, west of Highway 75. The initial impetus for the continuation of the existing dike an examination of the sequential movement of the waters of the Red around the existing dike towards the channel of the La Salle River. The very real threat was recognized when aerial photographs showed that if the floodwaters reached the little La Salle River, they could bypass the City's flood defenses and enter through the "back door," via St Norbert. The decision was made to extend the existing dike westward by fifteen kilometres.

Construction of the dike was a joint effort of the Canadian military and many local and municipal construction crews. Construction crews worked around the clock using municipal, military, and privately-owned equipment, and completed the dike just prior to cresting.

The Brunkild dike is essentially an earthen structure built from local materials of Manitoba podzolic clay deposits. Its banks were reinforced against erosion caused by wind-blown waves with orange plastic winter fencing and lengths of white plastic tarpaulin anchored by stones. In the days of greatest desperation, high-tech met low tech, alongside geotextile mesh, derelict vehicles, were used to help reduce erosional effects.

St Norbert

In the spring of 1997, the Red River rose to near record height, submerging more than 5% of the province's total agricultural lands, and flooding the town of St Agathe, along with several other hamlets. Most of those whose homes lay in the course of the advancing waters were able to reach safety well in advance, as the media had already place Grand Forks North Dakota on the world stage, an having seen the devastation in the small american town watched in anticipation of the water advancing northward toward a city of 650,000 people.

At present there exist two primary earthen dikes in the St Norbert area. The first dike connects the western bank of the floodgates to highway 75, and then extends westward along the southern boundary of St Norbert to La Barriere Park. The dike is a typical earthen dike, constructed from local clays with a dressing layer of soil, and covered in a thin layer of sod to prevent erosion. The second begins where Place St Norbert intersects with Pembina Highway, from there it runs directly to the east along the north side of the Villa Maria Retreat, and then south along the east side of the property and eventually heads due south to end at the north terminus of Lord Avenue.

The dike then commences again at the other end of Lord avenue, and parallels the river along behind the St Norbert Cathedral until it terminates just behind a seniors residence, along Lord Avenue.

During the flood of 1997 nearly, 7,000 army, and 17,000 civilians fought the floodwaters of the Red River. Volunteers filled and placed 4,000,000 sandbags in hastily erected temporary diking. These temporary measures will, of course, no longer be in evidence the next time the Red River tries to rise out of its bed, and it is inevitable that comparable flooding will occur again. Many parts of the City of Winnipeg will once again require flood prevention measures, particularly such areas as Kingston Row, Kingston Crescent, parts of St Norbert, Wildwood Park, Lyndale Crescent, Victoria Crescent, Glenwood Crescent, and Scotia Street. Permanent structures are necessary if these, and other areas, are to be adequately protected in the future.

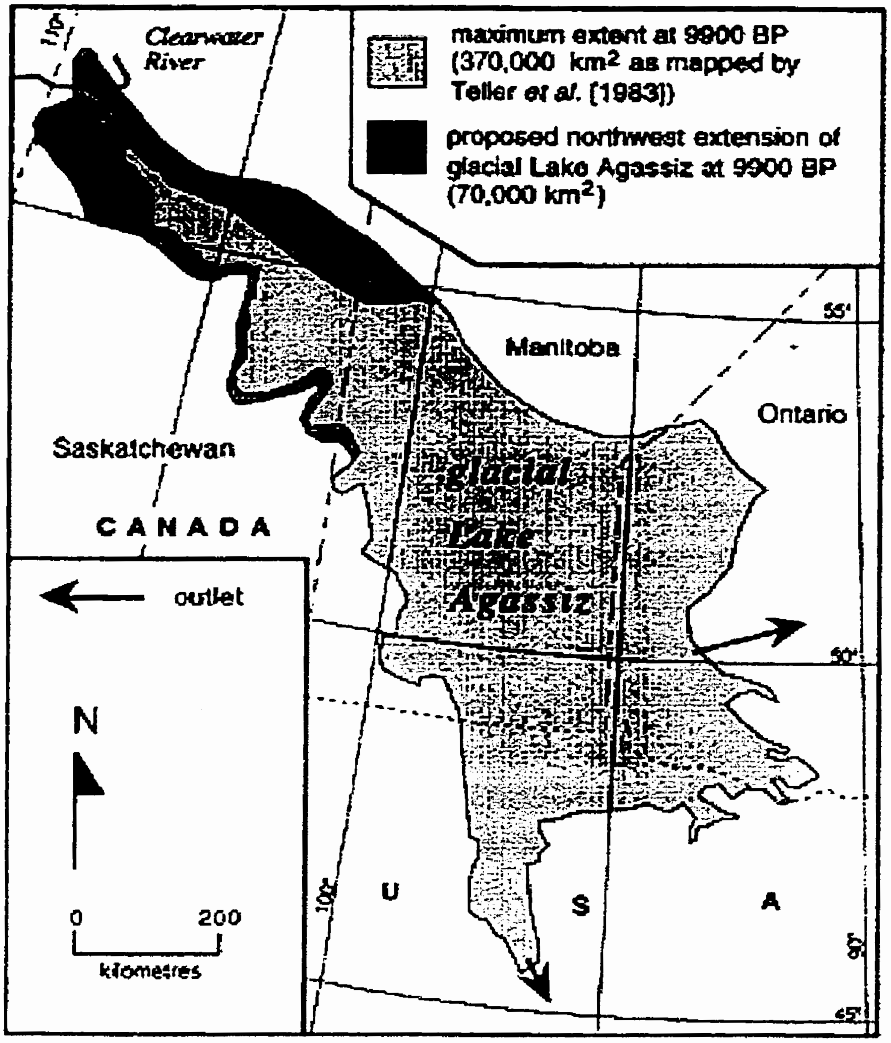


Figure 7.1a Glacial Lake Agassiz Source: Geological Survey of Canada

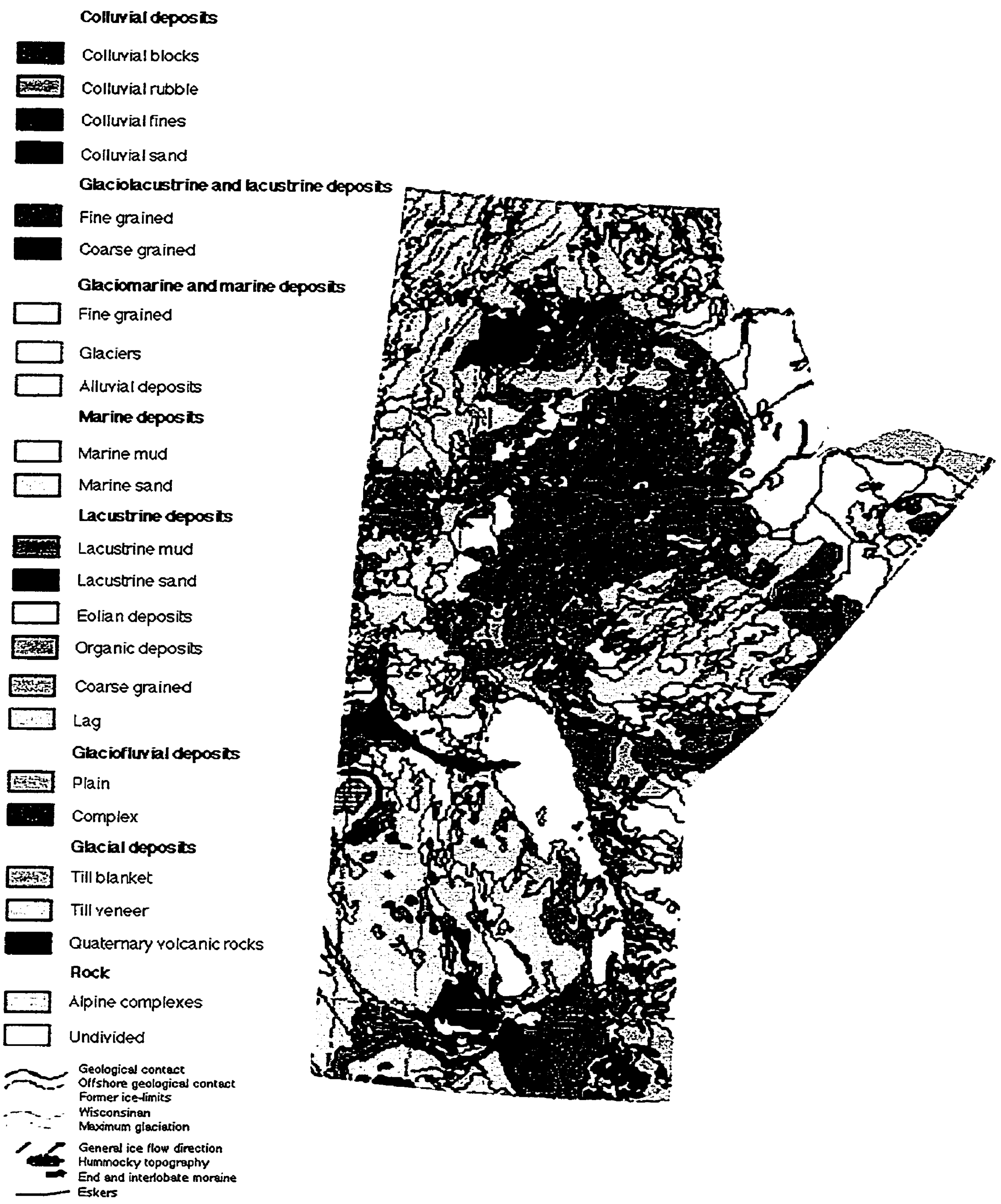


Figure 7.1b Geology of Manitoba Source: Geological Survey of Canada

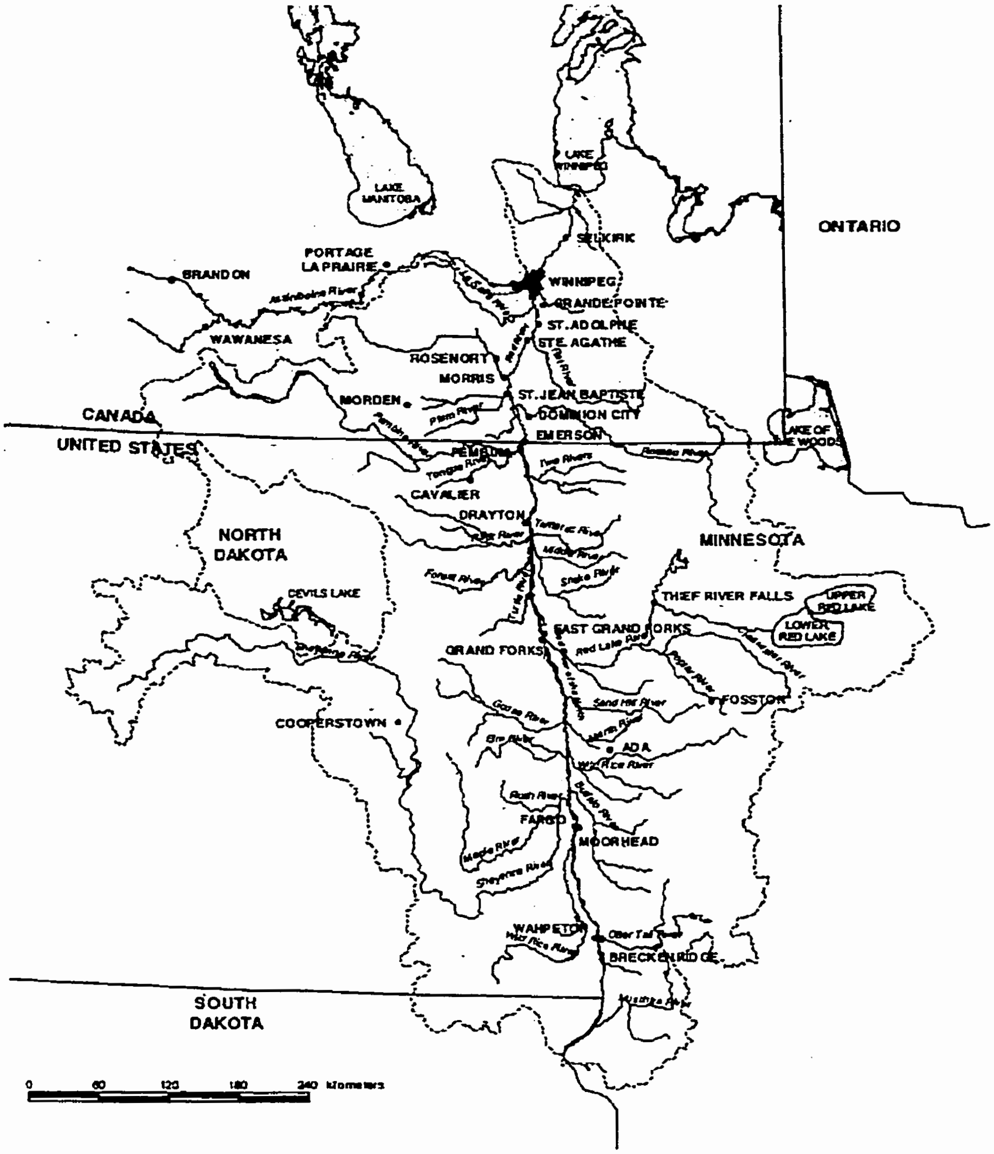


Figure 7.3 The Red River Drainage Basin Source: Geological Survey of Canada

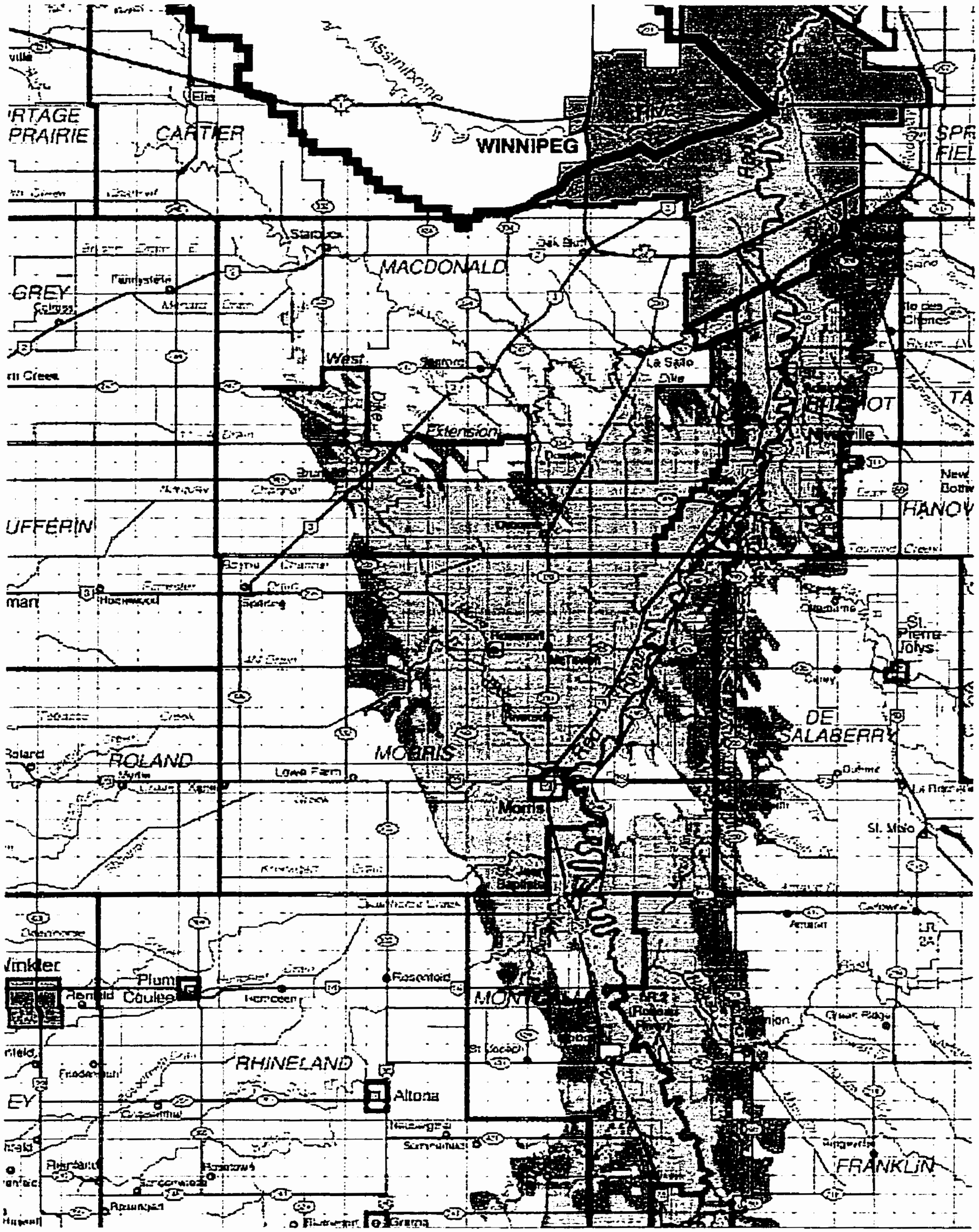
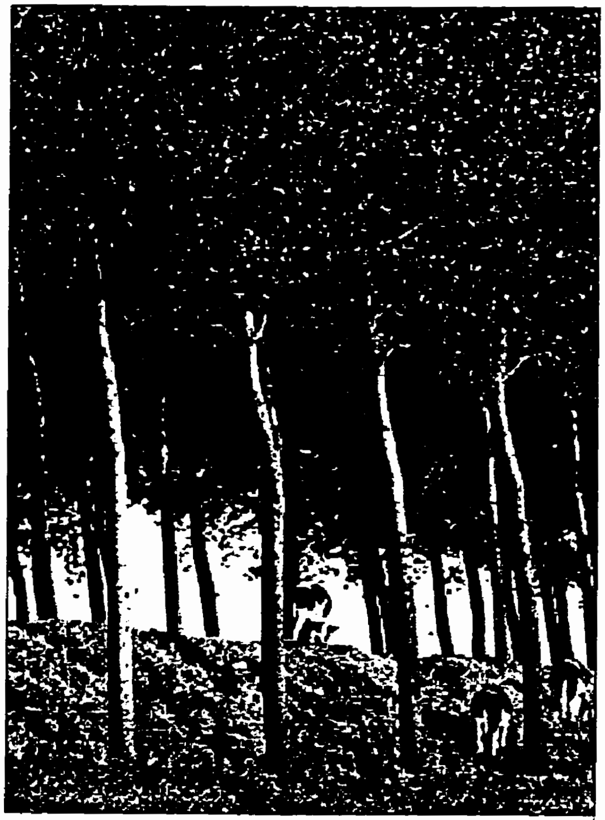


Figure 7.2 Areas flooded by the Red River in 1950 and 1997 - Source:Government of Manitoba

PART II: DESIGN AND APPLICATION

SECTION 8.0 DESIGN PRINCIPLES



> "Most flood related research is very engineering-oriented, but engineering isn't everything"
>
> (Bumsted. In Novum 1998: 1)

8.0 Design Principles

8.1 Introduction

A basic assumption of this study is that societies often have seemingly contradictory goals. People want protection from flooding, while at the same time looking with disfavour on the protective devices. They want a built environment that ensures their safety, while also demanding that the 'natural' environment remain unspoiled. Clearly, human communities on the floodplain or low river valley must be protected from flood. Equally obviously, the structures intended for that protection often become obstacles to the smooth functioning of the community's social and recreational life, as well as to the community's ability to preserve wildlife habitats.

For five thousand years or more, people in riverine environments subject to frequent flooding welcomed the annual flood and benefitted from the nutrients it deposited on the land. Their main hydrological problem was a shortage of water during periods of low river flow. To solve the problem, they developed technologies to deliver water to dried-out soils, and created complex irrigation systems. These benefits of the river's repeated inundations and depositions are now derived from irrigation systems capable of delivering needed water to crops and fields, and from manufactured fertilizers which replace the nutrients once supplied only by flood waters. Annual or sporadic flooding has become a curse where it was once a blessing, and floods are perceived to be at odds with the human environment.

Flooding, which once nourished the soil on which agricultural communities depended, and provided cheap and efficient transportation, destroys the permanent structures of the community. In order to protect their built environments, riparian communities have controlled unwelcome water by creating dikes and floodways to confine or divert the river.

Diking systems to control flood waters in urban areas have historically tended to be made up of characterless, rectilinear forms imposed on the landscape as single-purpose limited-use structures. The traditional sod-covered earthen berm, for example, seldom takes into account the human and ecological systems that pre-dated its existence within the landscape. The protective structures intrude upon the very communities they were intended to protect, disrupting human social life, and damaging the natural relationships of plants and animals within their habitats.

Despite its long history, the diking process has been studied and managed only within the discipline of the hydrological engineer. Pavel Peter, a professor of geotechnical engineering at the Slovak Technical University in Czechoslovakia, has been critical of both dike construction and dike design. With regard to dike construction, Peter believes that since the mid-twentieth century, "new gains in our knowledge of the functional properties of soils commonly used in earth dams are ignored [by diking engineers] both from the point of view of stability and from the possibilities of seepage and uplift control in embankment subsoils" (Peter 1982).

In his critique of dike design, Professor Peter contends that twentieth century hydrological engineers believe that their methods, inherited from the hydrological engineers of ancient China, India, and Mesopotamia, indicate a mature and therefore "superior" discipline. This, says Peter, is "an erroneous supposition."

> A thorough study of the present state of the design and construction of levées and canal embankments persuades us that the reverse is true (Peter 1982).

As Peter suggests, the problem is more complex than the simple prevention of inundation. In their utilitarian nature, dikes are short-term, sporadic-use structures. Their possible function and role as year-round, permanent components of a community can no longer be overlooked.

The basic assumption of this study is, above all, realistic. It recognizes that people will continue to live where flooding is a constant threat. Floodplains and ancient lake beds tend to be prime agricultural land which attract agricultural settlement. Major centres are likely to develop in the midst of these agricultural areas as supply and service centres. Cities also tend to be built in locations which provide relative ease of travel and transport for moving produce out of the area and imported goods in. Because both these conditions, so necessary for city development, exist in the riparian environment, people have, throughout human history, chosen floodplains and ancient lake beds for the establishment of farms, marketplaces, and transportation centres, and continue to do so. They do so because the advantages are numerous, and human occupation of floodplains continues, as pervasive and inevitable as flooding itself. Having invested in the development of these communities, riverside societies place a high priority on the protection of rural, exurban, and urban environments from floodwaters.

Another reality that engineers and designers need to recognize is that the desire for protection from inundation and the desire to live in a visually attractive environment which enables human social life are both legitimate human needs, contradictory though they may seem. Clearly, human communities in a riverine environment must be protected from flooding. Riparian communities have accomplished this by creating dikes and floodways to confine or divert the river. In the process of satisfying the human need for physical security, protective structures have often become obstacles to the smooth functioning of the community's social and recreational life, as well as to the community's ability to preserve wildlife habitats.

Civil authorities responsible for the physical safety of communities must recognize that when protective measures are taken in haste to meet an emergency that has not been anticipated or prepared for, solutions tend to be *ad hoc* and superficial. Economic and political factors have always played a role in the decision-making process with regard to flood control, but other considerations, such as ecological principles, visual appeal, and quality of human social and recreational existence have, for the most part, been neglected. The integration of protective structures into the physical and social environments of plants, animals, and people is often incomplete or even neglected entirely. Because of growing citizen concern for the physical environment and the quality of human social life, as well as property values, both private citizens and public servants are beginning to search for ways to make diking less ecologically disruptive, more visually pleasing, and, at the same time, responsive to the social needs of increasing crowded communities.

As well as attempting a realistic approach to the problems of diking and human quality of life, this study is humanist in its insistence that society's desire for a safe built environment that is both visually attractive and user-friendly should be satisfied as far as possible. It is also optimistic in its assumption that communities can be protected from the devastating effects of flooding without major, negative impacts on both social and 'natural' environments.

Integrating dikes into a community's social life, protecting the environment, and preserving the ecological integrity of a region are all desirable goals on their own. There is, however, yet one more reason why governments and the public should be concerned with modifying and adapting diking systems to serve more than one purpose. As federal and municipal budgets become tighter, the infrastructure of our cities continues to decay. The public purse cannot provide parks, playgrounds, or outdoor recreational facilities adequate for growing urban and suburban populations, or for badly needed environmental protects. Dikes, which we must accept as permanent parts of the landscape, can provide the venue for these socially and ecologically important undertakings. Combining the two disciplines of the landscape architect and the structural engineer can turn under-utilized, single-purpose spaces into multi-purpose facilities that meet several of the community's needs at the same time and at less cost.

Most dikes in existence today take on the form of utilitarian draconian artifacts that fail to reflect local context. Rather they reflect an antiquated notion about the triumph of man over nature that dates back to medieval times, when towns, villages, and cities developed from a conscious attempt to seek refuge from the brutality of the surround savage wilderness. What is needed is a shift in attitude towards an acceptance of those natural processes that are affected by these structures so as to filter out only the necessary components while leaving intact as much of the natural systems as possible. In recent years, a more enlightened and involved public interested in the preservation of physical environments and the creation of more community-friendly social environments has become more demanding of the process that gives form to their community. Decisions regarding the location and placement of permanent flood prevention measures such as dikes within the context of a community or neighbourhood are beginning to be examined in a different light. To answer the needs of the public in this regard, designers and builders of diking structures must focus more on assimilation and less on imposition. An obvious implication of this shift in social values is that engineers can no longer be the sole arbiters of design; the landscape architect or planner must be involved. Affected communities must also be drawn in as active participants in the decision-making process.

With most existing dikes the damage has already been done, and all that is left to do is to mitigate losses. Reparations can be done so as to assist in the natural recovery of plant and animal species. What is of particular interest are situations that are in flux. Where there is a need to add to or modify existing segments of a dike, whether subtle or drastic changes, there are opportunities to improve integration and to reduce negative environmental and visual impacts. If these changes are governed by sound ecological and architectural principles it would improve the likliehood of the success of these mitigative measures.

A context-sensitive approach to diking has emerged in The Netherlands during the past decade. Destruction of ecological and social landscapes was so commonplace in The Netherlands before the 1990s that the government created a special body to investigate and make recommendations. In 1992 the Boertin Commission established a set of guidelines for modifications and construction of dikes. Prior to the guidelines, dikes served only the single purpose of protecting against flood waters. Construction often resulted in the destruction of historic and culturally valuable resources, in favour of protecting public and private land. The dike remained an artifact apart and unconnected in any contextual way to its immediate surroundings, serving only the single purpose of protecting against flood waters.

A major step toward integrating dikes into their physical and social environments, the LNC Approach, came out of the Boertin Commission's studies. LNC refers to 'landscape,' 'natural,' and 'cultural' values. As already noted in the introductory section of this study, landscape values were defined as all natural features in an area, such as forests, lakes, and curves in the river. Cultural values, which include historical artifacts, refer to ruins, historic buildings, monuments, and heritage sites. Natural values refer to changes in ecological infrastructure or quantities or types of vegetation. The LNC Approach has been criticized, in part, for its subjectivity and broad definitions. The major criticism, however, has been its blurred definition of the 'natural' component. Since the theory was suggested by the Commission, there has been considerable debate in The Netherlands as to whether or not there are any truly untouched or natural lands existing at all. The same, fortunately, cannot be said for many parts of North America. While it is true that much land has been subjected to the plow and the timber harvester, there are also many thousands of square miles that have been ignored because their inaccessibility makes them economically unfeasible. The LNC Approach, therefore, holds some promise for application in the North American context.

8.2 Design Principles

Certain general principles concerning the integration of diking systems into local environments emerge from the historical and sociocultural research already discussed in this study. These general principles concern placement of dikes and diking systems, attendant ecological systems, human sociocultural systems, and dike forms. They are all inter-related. All are necessary, and none is sufficient on its own. The sequence in which the principles are presented does not imply relative importance or significance. Rather, it is intended to facilitate the study of a community in all its aspects, and point to the inter-dependence of the elements in the suggested design.

In creating a sequence of principles, the element most difficult to change has been placed first. This is the river itself and its related topography. Placement of dikes depends on the position and condition of the river, and designers have few options regarding placement. Floral and faunal wildlife is more amiable to relocation or reconfiguration than the river itself is, but there are still limits to the control humans beings have over where and how plants will grow or animals and insects will feed and raise families. Because human beings can survive, and even thrive, in a wider range of environments than specific plants and animal can, they come next in the sequence. The form a dike takes, while not infinitely flexible, allows its designers still more discretion, and comes next. The creation of an architectural vocabulary which will tie all elements of the diked landscape into a consistent whole is the final step in the sequence because it depends on the decisions made concerning all the other elements.

The following is a set of general principles for integrating a diking system into its local environments, both physical and social.

8.2.1 Placement, Form, Size, and Dressing of Dikes

The primary purpose of any dike or diking system is to protect land, property, people, and both floral and faunal wildlife from inundation. Changes to the physical appearance of a diking structure involving alterations at the surface level or additions to the basic structure must not compromise its ability to do its primary task. While it is evident that the traditional linear, steep-sided physical form of diking can support considerable modification, it is important to remember that the basic form and internal structure must be maintained. Any adaptations or additions must be approved by the local governing agency in charge of engineering standards.

PLACEMENT

Dikes are routinely placed in close proximity to the edge of the river. Minimum distance for dike setbacks relative to peak discharge of the river is established by hydrological engineers, and provides space for shoring up unstable sections of the system. While the configuration of river and areas the dike will protect may dictate placement of a dike, this is not always the case. Setbacks could, however, be increased without compromising the function of the system, as well as allowing for greater storage capacity of flood-stage waters. Where there is adequate space, placing the dike at a distance from the river will protect the dike itself from the erosive assaults of wave and ice activity. Riparian corridors have proven effective in preventing dike failures. A setback distance of as little as sixty metres would serve to optimize the protective distance between the river and the dike, and would reduce maintenance costs associated with dike dressing. Particularly in cases where the intervening area is forested, dikes have been shown to be at significantly lower risk of failure than when they are closer to the river.

There are also advantages for ecological systems in larger setbacks. The space created would allow for the restoration or creation of riparian habitats on the water side of the system. In these zones there could be reforestation of native riverine vegetation, including the creation of a Riverbottom Forest Habitat. The new spaces could provide recreational and educational opportunities for human populations as well.

The relationship between dikes and other features of the natural and built environments depends on the placement and form of the dikes, and their proximity to one another and to other elements in the environment. This relationship determines whether a dike, as it stands, will function as a conduit or as a barrier for people and wildlife. The location of a dike within the larger environment may alter the relationship between ecological patches by promoting or inhibiting movement between patches. A trail system to be used by hikers, cross-country skiers, bicyclists, or Sunday strollers, for example, would provide recreational possibilities.

FORM, SLOPE, AND SIZE

Drawn from the concept of flood benches, the dike can have different forms depending on the immediate context. At times it may be highly confined in order to meet space requirements, particularly as it passes between residential sites and the river. In other locations where there is more room, it can spread out to become seating for sports fields, scenic overlooks, and social space for nature observation.

The 'typical' dike has both landward and riverward slopes of 2:1. Simple arithmetic suggests that the space needed for the structure, based on a design height of 3.675 metres and a crown of 3.67 meters, would be 18.95 metres from landward to riverward side at the base. While this results in diking systems that are routinely linear, relatively narrow, and fairly steep-sided, they do not have to be, as long as the core of the dike is adequate for its job. When the landscape architect is involved in the early stages of dike design and construction, he can suggest, for instance, that the dike be oversized.

Structures typically called 'oversized' dikes have landward and riverward slopes of 3:1. The overall space needed for such a structure, based on a design height of 12 feet and a crown of 12 feet, would be 81 feet. Although this allows for increased amounts of vegetation on both slopes, the basal dimension is too large for existing setbacks in many residential areas. However, a dike with a landward slope of 3:1 and a riverward slope of 2:1, with both height and crown of 12 feet, would require a setback of only 71 feet 6 inches.

From the landscape architect's point of view, the oversized dike is desirable, in that it creates space for possible other uses in later stages of development. Picnic areas, scenic outlooks, bicycle, ski, and walking trails, can all be incorporated into the system during original construction. Similarly, wildlife habitats may be easier to preserve when more space is available on the tops and sides of dikes.

Oversizing also facilitates the use of larger trees and, therefore, a wider range of choices. It also allows for more gradual sloping, at least on the inland side of the dike. A relatively gradual slope, unlike the usual steep side, will allow for more vegetation, in itself an aid to the integrity of the dike. More graduated slopes will also provide areas for social activities, as well as making the structure more visually appealing. (Figure 8.2.1)

DIKE DRESSING

Design improvements for dikes may be simply an issue of appropriate choices. There is no rule that states that a dike can only support vegetation in the form of turfgrass. True, there are issues relating to structural integrity, which could be affected by vegetation that loosens the slopes of a dike. But while there are some species and varieties that should be avoided, there are also many varieties of grasses and shrubs that actually strengthen the stability of slopes.

The most common dike dressing is sod, chosen partly because it resists erosion and enhances soil stability, and partly because of its relatively low cost. One of the standard arguments for the choice of generic 'kentucky blue' sod as dressing material is that it works to prevent soil erosion, ensure bank stabilization, and is economically attractive. Other choices are possible, including native vegetation.

Native vegetation will always have an advantage over imported flora because it is hardy under local conditions of precipitation, insolation, and temperature. To determine which native grasses would be as efficient as kentucky blue, test areas could be planted with a number of varieties.

Flora other than grasses should be considered as dike cover. Many varieties of plants will grow on the tops and slopes of dikes with the addition of soil to provide an adequate growing medium. As noted earlier, trees, as opposed to shrubs, can be useful as dike dressing. The recommended size is a diameter of 4 inches or less. Whatever is chosen must be non-invasive. Trees and shrubs with long tap roots are contraindicated because of their propensity for driving deep into the ground and breaking up soil, rocks, and other materials in their way.

It is also possible, at least in theory, to dress dikes with non-vegetative materials, such as asphalt. However, several recent scientific studies have shown that the presence of vegetation is actually beneficial to the function of a dike (Beeson & Doyle 1990). These studies examined dikes for detectable erosion during a major flood event, comparing channel location from pre- and post-flood aerial photography. Of 748 bends examined on four different streams that had just experienced flooding, non-vegetated bends were five times more likely to have undergone detectable erosion than vegetated bends. Woody vegetation and grasses used as surface dressing directly prevented the erosion of the dike's soil body, binding it together with their root system. This not only assists in unifying the structure, but also reduces the possibility of piping failure by preventing weakness on the surface.

Protection of the dike itself is not the only advantage of vegetative dressing. Large, non-invasive shrubs can play a small role in creating microclimates, especially in areas almost enclosed with the bends of a meandering diking system, all to the benefit of the human community. Some dressings create ecological opportunities by attracting birds, small animals, and insects.

8.2.2 Preservation and Enhancement of Ecological Resources

The basic general principle regarding ecological resources is to preserve existing wildlife as much as possible, and to enhance the 'natural environment' wherever possible. Population and economic growth are creating a demand for solutions that deal intelligently with the interface between infrastructure and the natural environment. whenever possible, existing ecologically significant areas, such as river bank, native prairie, or wetland, should be identified, preserved or enhanced. To harmonize with the local environment, non-indigenous materials, both plant and construction, should be kept to a minimum, and replaced wherever possible with native materials. What is proposed here is an environmentally-oriented approach to flood control by replacing concrete diking with naturalistic diking that also provides park and recreational space for human communities and appropriate habitats for wildlife.

Ecological principles applied to the design and placement of dikes will create optimum edge habitat for wildlife, and help maximize opportunities for species diversity. Curvilinear, rather than rectilinear edges, are especially useful in attracting many varieties of birds, insects, butterflies, reptiles, and small mammals. A straight-sided dike facing west, for instance, receives equal amounts of sunlight and shadow at specific times of day along its entire edge, as well as equal amounts of wind. Curved edges experience variation in insolation and air movement, and provide a number of different microclimates, which, in turn, attract a variety of species. An undulating plan not only creates ecological opportunities, but also adds variation and visual interest for humans.

Examples might be to re-introduce native vegetation where it has been lost, or to incorporate bee-attracting plants which will serve a useful purpose for both agriculture and domestic gardening.

It is important at this point to keep the large picture in mind. Some sites that need to be preserved can only be safeguarded if they are separated from neighbouring sites. Canada Goose nesting grounds, for instance, if such exist in an area, might need to be deliberately made inaccessible.

8.2.3 Preservation and Enhancement of Human Resources

As in the above principle and example, the landscape architect should be concerned to preserve the cultural, historical and social aspects of the area around the diking system, and to enhance these environments where necessary and possible. Enhancement might be achieved through dirt, gravel, or stone paths on the inland side of the dike, connecting historic venues. These would give inhabitants better access to their historic and heritage sites for educational or recreational purposes, as well as making the sites more interesting for tourists.

A well-defined network of paths for recreational purposes would also serve as access routes for inspection and dike or landscape maintenance. This would maximize infrastructure dollars, and should be popular with governing bodies and tax payers alike. Existing regulations for dike maintenance require a 10 to 12 foot road or lane as an access route for repair vehicles. At the present time, dike inspectors tend to dislike highly vegetated areas because they impede visual inspection. However, new techniques could assist in the inspection process and virtually eliminate the need for extensive visual examination of a site. One such technique is magnetic resonance imaging. The access roads, mentioned above, would serve as suitable tracks for truck-mounted imaging systems. This would be consistent with both primary and secondary requirements for the dike top, and would not discourage the extensive use of vegetation on the slopes.

Some parts of the landscaped dike should be illuminated to allow late afternoon use during the dark winters, and evening use all year long. Lighting along at least some of the pathways could also be a safety feature for pathway users.

Local history can be celebrated within the actual materials of the diking system. On the land side of the protective system, dikes could be supported by retaining walls instead of the sloped turf so common in most systems. These retaining walls could incorporate seating, viewing points, rock wall gardens, and other character-creating elements. A concrete retaining wall or other concrete surfaces might feature reliefs of scenes showing the ancient Manitoba lake bed, an aboriginal campsite, depictions of early explorers, homesteaders and pioneers, or illustrations commemorating the red River Uprising, or the many floods experienced by the community throughout the centuries. Flood markers in a revegetated forest would add possibilities for education by providing a destination for school field trips, and might even become part of a Flood History Walking Tour.

The proximity of cultural resources to the dike will determine the extent to which cultural resources can be included in the diking design. The landscape architect should take advantage of any opportunities to connect the two.

8.2.4. Development of an Architectural Vocabulary

The final general principle is to create an architectural vocabulary based on and sympathetic with the local context. Disregard for local context is an understandable result of the urgency with which most of these structures were erected, but intrusive structures, especially those intended to remain in the landscape for a long period, should reflect and complement the context in which they are created. A diking system can only be 'at home' in its neighbourhood if it is consistent with the ambience of that neighbourhood. Given this premise, diking structures should be unifying elements tying together all components in a single system, and enhancing the environment as well as protecting it. (But, bear in mind, as pointed out above, that protection may mean separation, not integration).

At the regional level, dikes must be viewed as part of a larger infrastructure. The landscape architect will need to examine all of the individual components as they relate to the large system in order to assess the impact of the whole system of dikes within a given area. Dikes alter not only the form of the landscape; they also change the nature of the relationships between watershed, species movement, and human activity, such as pedestrian and vehicular access.

At the community level, dikes have the potential to bring together elements within the community that may be spatially separated. The placement of dikes has, in the past sometimes resulted in fragmentation of a community, physically, in its social systems, and in its natural features. An example not far from home can be found in East Grand Forks, just up-river from the Canadian border. Reeves Drive, on the west bank of the red River, is the site of many of the area's oldest homes. The initial proposal of the U.S. Army Corps of Engineers included the construction of a dike that would have bisected Reeves Drive, and destroyed five or more turn-of-the-century homes. In a small city such as Grand Forks, the heritage value of these homes is very high. Examples like this illustrate the conflict between the need for protection from the river and the value of what we are trying to protect.

As of August 1998, the best solution offered by the Army Corps of Engineers to the Reeves Drive dilemma was to move at least five homes forward on their lots to make room for a floodwall. A floodwall, requiring less land than a dike, would provide protection for much of the neighbourhood, but the five endangered homes would be on the river side of the wall. Engineers are now researching methods for stabilizing soil along the river banks in the hope of finding a way to put the floodwall at the very edge of the river, and possibly saving all the Reeves Drive homes.

The efforts of Grand Forks citizens' committees to find a plan that would not destroy part of the cultural heritage are reminiscent of the efforts of St Norbert people in having their historic sites given official status. Historic and cultural elements within a community must be recognized by dike designers as vital components of the community, as important as residences and business buildings.

At the local scale, dike design should be in harmony with natural and sociocultural elements of the community. The system should connect elements within the community and enhance them by incorporating, or making provision for the future development of, social, recreational and ecological spaces. For example, a dike that runs past a school can be redirected to optimize the functional space available for school activities. The slope of the dike might also complement those activities by incorporating, within the structure itself, seating from which to view sporting events on the inland side of the dike.

It is important to develop a strategy by which similar, yet disparate, features of the landscape and community can be brought together, not only to enhance the meaning of each individual element within the system, but also to restore a sense of cohesion to the community, and create a whole that is greater than the sum of its parts.

Examples of this can be seen in the landscaping of the tank farms and refinery facilities along the Yellowhead Highway approach to Edmonton. The installations are, both functionally and visually, industrial. The built landscape echoes this look. Playground areas feature jungle gyms, slides, swings, and sand boxes with an industrial character. Outdoor furniture in the picnic sites that dot the area features legs and arms that repeat the lines of the pipes connecting the storage tanks. Paths accessing the picnic and playground areas use stiles to cross over the many pipes, and feature simulated-pipe handrails. In short, the landscape speaks in the same architectural vocabulary as the facilities.

8.3 Application of Principles to Specific Cases: A Suggested Design Methodology

In order to apply the general principles to a specific case, thoroughly familiarity with the affected community is essential. Achieving this understanding will involve amassing data about each element in the physical, ecological. and human environments. The following steps are suggested as a guide to this end.

8.3.1 Generate a Detailed Map of the Study Area

Designers of diking systems will need, before anything else, an overview of the existing area which shows topography, its wildlife, and its human communities. A detailed, highly precise map is the first requirement. Analysis of the community as portrayed on the map will show how areas connect with one another, and how they are used in relation to one another. The mapped resources will provide insight into both the possible locations for potential design modifications to the existing structures, and also how these can be enhanced through connectivity and augmentation of resources. The first step is, therefore, to create such a map, using aerial photographs, satellite images, municipal plats, and first hand observation of the area.

8.3.2 Analyze General Form, Placement, and Dressing of Diking Structures

Identify distinct or discernible areas (precincts) along the dike. Identify native vegetative species, noxious invasives, and plants with growth habits that are known to be advantageous or detrimental to a dike's structure.

8.3.3. Identify and Map Ecological Resources Within the Diking Area

To determine if and how these areas need to be connected, or possibly separated for conservation or preservation. Analyze them for their fit with the general placement and form of the diking structures.

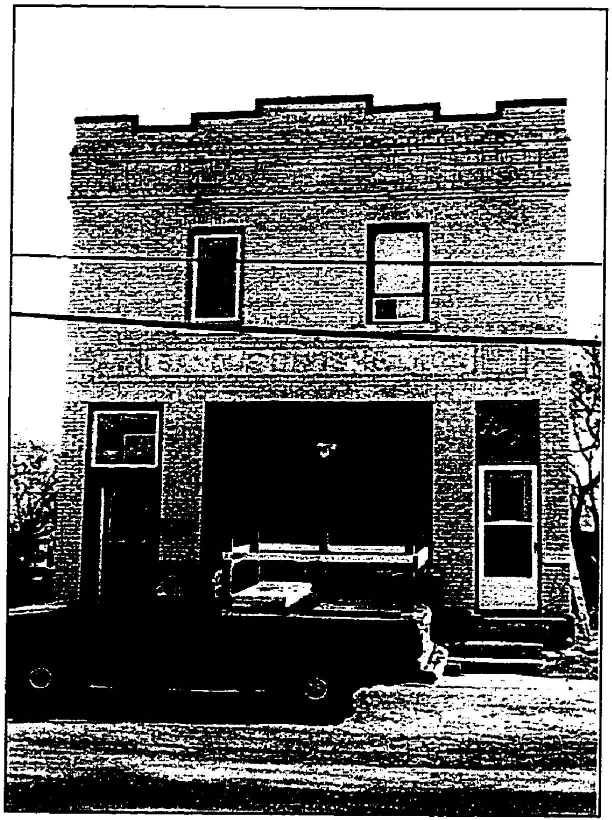
8.3.4 Identify and Map the Human Presence and Use Patterns

The human environment includes its people's histories, cultural attitudes, social and recreational behaviours, and their daily routines within the community. It will probably be necessary at this point to collect information about the community's use of various areas which is not revealed on the map, these include: the presence of desire lines created by people in their daily movements and their relationship to diking structures, and access to various areas and facilities; the history of the community; historical/ heritage elements which, in the view of government cultural and parks departments, need to be protected; and elements in the community which the local population values and wants to preserve.

Information on the history and demographic breakdown can be found in written histories and census data. Personal observation by the designer, is also an important source of data. Attitudes and desires of the local population, may have to be sought in door-to-door surveys or at town meetings and on the editorial pages of the local newspaper. However the information is acquired, it is important that the local people have some share in the decision-making process.

Information about human use, needs, and desires must be examined to determine how they fit with the needs of wildlife communities, and how they can be integrated with cultural and historical resources. During this analysis it is also important to determine if some areas need to be connected to each other, or to ecological resource areas, or if some areas need to be separated from each other or from ecological resource areas.

9.0 ST NORBERT: COMMUNITY PROFILE AND SITE ANALYSIS



"Now there is no region in the world where agricultural drainage is so intensive as within the prairie watershed of Glacial Lake Agassiz. This move to break through the lips, the rims, and the seals holding back the shallow prairie waters has been followed in nearly every portion of this region and in some localities all of the original lakes and marshes are now permanently removed"

(Hochbaum, 1967, p. 45).

"The landscape is the visible scene and, at the same time, the manifestation of all those elements, factors, influences - call them what you will - both physical and human, which give the surface of the earth its character at any given point in time"

(Lambert, 1985:1)

SECTION 9

9.1 THE DIKE AND THE REGION

The diking system is a prominent part of the regional landscape of southern Manitoba. Its manmade landforms are visible from a height of 10,000 feet. As elements in the landscape of southern Manitoba and St Norbert, the dikes are elevated, linear earthworks that rise as distinct forms in opposition to the prairie. Similar to Hadrian's Wall in Great Britain, their massive serpentine forms slice through the natural topography, but rather than separating two cultures, they mark the transition between the riparian and the built environments. They are also disruptive to the ecological processes at work in the riparian zone.

The system of protective structures throughout the Winnipeg region is an artifact of earlier times and outmoded thinking. Built for a single purpose, the existing dikes reflect prevailing attitudes of their creators. In their present form, they are unresponsive barriers, fulfilling their primary purpose of protecting people from the dangers inherent in nature, but insensitive to the other needs of people, flora, and fauna. A basic assumption of this discussion is that dikes, diking systems, and transportation infrastructure should fit within the socio-cultural fabric of the human and wildlife communities. They can and should create a sense of connection between the regional and the local. Within the local situation, they should reflect the complex inter-relationships of various social, cultural, and historic systems.

Thousands of words have been written and hundreds of videos created describing and chronicling the 1997 Red River flood. A number of studies and reports by The International Joint Commission Red River Task Force and The Research Workshop on the Social Dimension of the Flood of the Century, among others, have been produced which touch on issues of post-flood psychological and social impacts to the human population of flooded areas. Both The Joint Commission and the Research Workshop reported that surveys of communities in the Red River Basin, done immediately after the flood, showed people to be very much in favour of more dikes, stricter regulations on evacuation, greater and speedier government response in providing sandbags, and immediate military assistance in sandbagging and temporary dike construction. Neither investigation attempted to study and understand people's attitudes toward diking systems once a flood emergency is past.

One hint about people's attitudes toward dikes and other flood protection strategies is tucked away, almost casually, in The International Joint Commission's interim report. The Task Force noted that tension and conflict within the community arose when some residents removed parts of the diking system on their property. "City authorities granted permission to some residential property owners to cut their permanent dikes. Over recent years, this was done for aesthetic reasons. These arbitrary decisions placed one city community at much greater risk from the flood and fostered community strife."

The key phrase, "for aesthetic reasons," suggests that property owners lose their liking for dikes in times when their personal habitat is no longer threatened. When residences, roads, schools, parks, and playgrounds are secure from the rampaging river, people turn their attention to "aesthetic" concerns. They begin to resent the system that is intended to protect them. The most frequently mentioned complaints in regard to the dikes have to do with "eyesores," that is, the loss of what the population sees as visually attractive, with reduced access to valued sites, and with the loss of formerly well-used areas of community activity.

While divisive, the dike's elevated and continuous form can also be connective. Its length and linear configuration can create a corridor (or corridors) with potential for connecting a variety of habitats, as well as social-cultural spaces. The regional framework includes roads, highways, parks, hamlets, and a myriad of social and ecological spaces. The continuous nature of the dike provides opportunities for the inclusion of these spaces into a larger framework of socio-cultural activities through the creation of nodes and linkages between spatially separated components of the landscape. To the people of St Norbert, the dike is an element that connects them to those places, joining the aspects of their lives on a common thread.

9.2 ST NORBERT

St Norbert, Manitoba, is small enough and varied enough in both its physical and social settings to be used as a case study for the application of the design principles and methodology suggested in Section 8. By applying the general principles to a specific community, it becomes possible to examine potential design interventions for their usefulness in integrating dike structures into the local community.

As suggested in Section 8, the first step toward creating a design that integrates a diking system into a community is to become thoroughly familiar with all the inter-related aspects of the community in question. This involves gathering and analyzing information about the physical, ecological, and human characteristics of the community in great detail. This is particularly true of a community like St Norbert, where small patches of original prairie flora and fauna still survive, which retains traces of ancient habitation dating back a thousand or more years, which has a two hundred year history of uninterrupted permanent occupation by diverse groups of people, and which contains sites of many events of historical significance for all Canadians.

Photographic and cartographic material, along with engineering and wildlife reports are most likely to contain information about physical conditions in the community. Sources of information about the human community could include written and oral histories, census data, and personal observation, and possibly community surveys.

The following sub-sections set out as much as possible of the specific information and analysis which will underlie changes to, and restoration of, a physical and human landscape in danger of being destroyed either by flood or by flood protection structures.

St Norbert is an unusual community in that it is composed of a number of different environments, including riverine, agricultural, and suburban residential. It is also mostly below the high water levels for the 1 in 160 year flood.

For its size, the community contains what seem to be a disproportionately high number of sites of historical significance which are highly valued by the local community. The interest which the local population takes in the preservation of its historic and heritage sites is demonstrated by their very strong representation on the membership lists of the St Norbert Historical Society, the Manitoba Historical Society, Heritage St Norbert Inc, the Manitoba Heritage Council, and the number of residents who have represented St Norbert on the Economic Development Council of Manitoba Bilingual Communities.

Like so many other communities, it includes a diking system that tends to disregard its historic and cultural features, and does not adequately respond to the social and recreational needs of its residents. The flood of 1997 has provided an opportunity to re-examine the issue of diking, with the intention of making it a useful part of the community.

9.2.1 Site Analysis

9.2.1.1 Location of Study Site

Located on the southern fringe of the City of Winnipeg, St Norbert has convenient access to the city, and at the same time attracts people who prefer a rural or semi-rural environment over the typical suburban setting. Areas of low and medium density housing, a central main street, and both new and older suburbs, are mixed with lands that vary from prairie grasslands and farms to the south and west, to bands of riverbottom forest that intersect at the junction of the Red and La Salle Rivers.

St Norbert (Figure 9.2.1.1) is bounded to the east by the Red River, to the west by Brady Road, to the north by the perimeter highway, and to the south by a line that runs perpendicular to Turnbull Drive, and parallel to, and including, Minerva Avenue.

The suburb is accessible from the north along Pembina Highway, and to the south from Highway 75, which bisects the community, dividing it into two distinct halves.The east side of the highway is characterized by older neighbourhoods set out on a grid system, designed by one of the Benedictine monks. It contains many heritage sites, as well as the confluence of the Red and La Salle Rivers. The west side is mainly residential, with newer homes set out on a typical curvilinear subdivision plan.

9.2.1.2 Geology and Soil Conditions (Figure 7.1b)

St.Norbert resides in the topographical region known as the Red River Plain, a low-lying basin which was once part of the prehistoric Lake Agassiz basin. For the most part the ancient lake bed is clay. It slopes gently from south-west to north-east. Limestone and dolostone are the most common underlying beds.

The soils of the Red River Plain fall mostly into the category of black earths with a high level of organic matter originating in prairie grass vegetation, and a high mineral

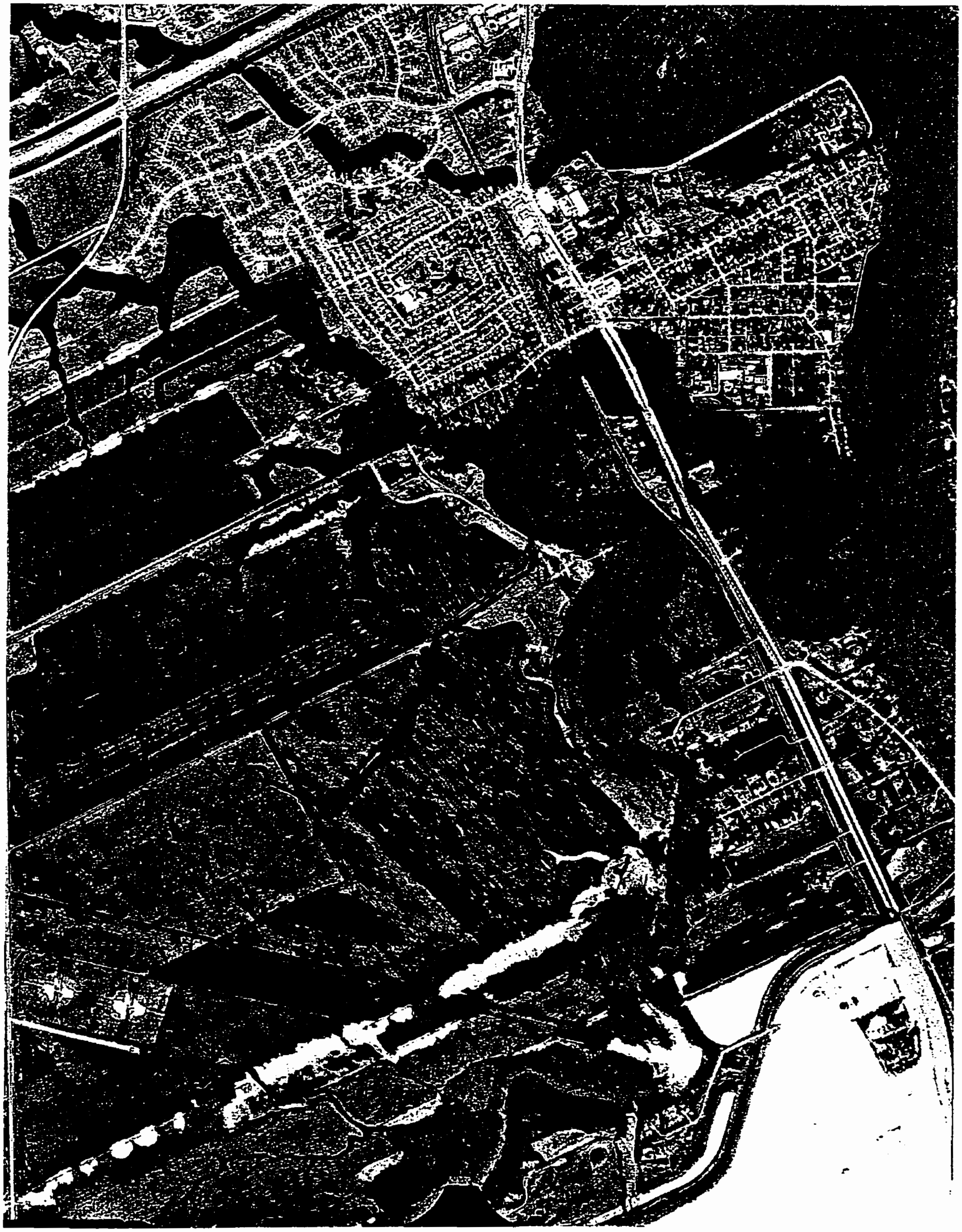


Figure 9.2.1.1 St Norbert

content. Nutrient levels are high, but the soil generally has poor permeability, high runoff, and is susceptible to freeze-thaw conditions.

9.2.1.3 Topography

The St Norbert area is characterized by two river systems, the Red and the La Salle rivers. These two rivers are the major determinant in the formation of the current topographical variation in St Norbert. The changes in elevation created by river erosion and deposition reflect natural processes, resulting in undulating curvilinear contours and forms. The only natural breaks in the flat plain are the drainage channels cut into the lacustrine clays by the two rivers. Cross-sectional gradient changes are clearly evident through examination of the landscape perpendicular to the river corridors.

The other determinant is human intervention. The topographical evidence of human occupation on the landscape can be seen in the elevated and rectilinear forms of roadways, dikes, private residential lots, railway embankments, and agricultural drainage structures. The extensive system of drainage ditches and spoils are clearly evident amid the agricultural fields in aerial photographs.

9.2.1.4 Hydrography and Hydrology

The La Salle River originates in the Rural Municipality (R.M.) of Portage la Prairie, approximately five miles southeast of the City of Portage la Prairie. It meanders eastward, paralleling the Assiniboine River, entering the R.M. of Ritchot in the northwest corner, and emptying into the Red River just north of St Norbert Park.

The river corridor may be described as the zone with visible topographic variation in an otherwise flat landscape, and is also easily identified by the bands of riparian vegetation.

The landscape is constantly evolving due to both human-influenced and natural processes. The Red and La Salle Rivers are evidence of these processes. In part due to the alluvial surficial deposits, the rivers are slowly but continually shifting location. According to William Rannie, the La Salle River channel was once at the present day forks of the Assiniboine and the Red (Rannie 1990).

Flood control measures taken to protect urban and agricultural land have permanently changed the natural fluvial processes of inundation and deposition. Interference with these natural process, which had a formative effect on the shape and ecological character of the original landscape, appear now to have compromised the health of the riverbottom forests in the area (Reily and Johnson 1982; Waters and Shay 1995).

Drainage practices in agricultural land have also had a profound and permanent effect on the natural drainage patterns of the landscape, with drainage ditches bisecting the landscape, perpendicular to the natural water courses (Waters and Shay 1995). These changes were foreseen as early as the 1960s, as the following quote shows.

"Now there is no region in the world where agricultural drainage is so intensive as with the prairie watershed of Glacial Lake Agassiz. This move to break through the lips, the rims, and the seals holding back the shallow prairie waters has been followed in nearly every portion of this region, and in some localities all of the original lakes and marshes are now permanently removed" (Hochbaum 1967:45).

9.2.2 Ecological Factors (Figures 9.2.2a, b)

The most prominent physical characteristics of the St Norbert area are the corridors of riparian vegetation that line its rivers, the La Salle and the Red. The riverbank environment provides not only spaces for plants and wildlife, but also recreation opportunities in the form of trails and walks.

St Norbert is an enclave that harbours not only people, but also a wide variety of flora and fauna, including wood ducks, deer, grey herons, and foxes, all found alongside grazing animals and fields of flax. In the heart of St Norbert, the La Salle River corridor is home to beaver, muskrat, and several varieties of fish, reptiles, and amphibians. The diverse landscapes found in the area provide a suitable environment for a wide variety of plants, including some species that are unique to the area. By far the most diverse ecological area in St Norbert, and indeed the prairie habitat, is the riverbottom forest (Figure 9.2.2c).

The riverbottom forest (RBF) is home to the majority of the plant and animals species found in the area (Waters and Shay, 1995). It is believed to have one of the highest species diversity levels of any riparian landscape containing large numbers of plant and animal species. Dependent on silts deposited in spring flooding to replenish soil nutrients, the vegetation found in the forest stabilizes the river banks and decreases

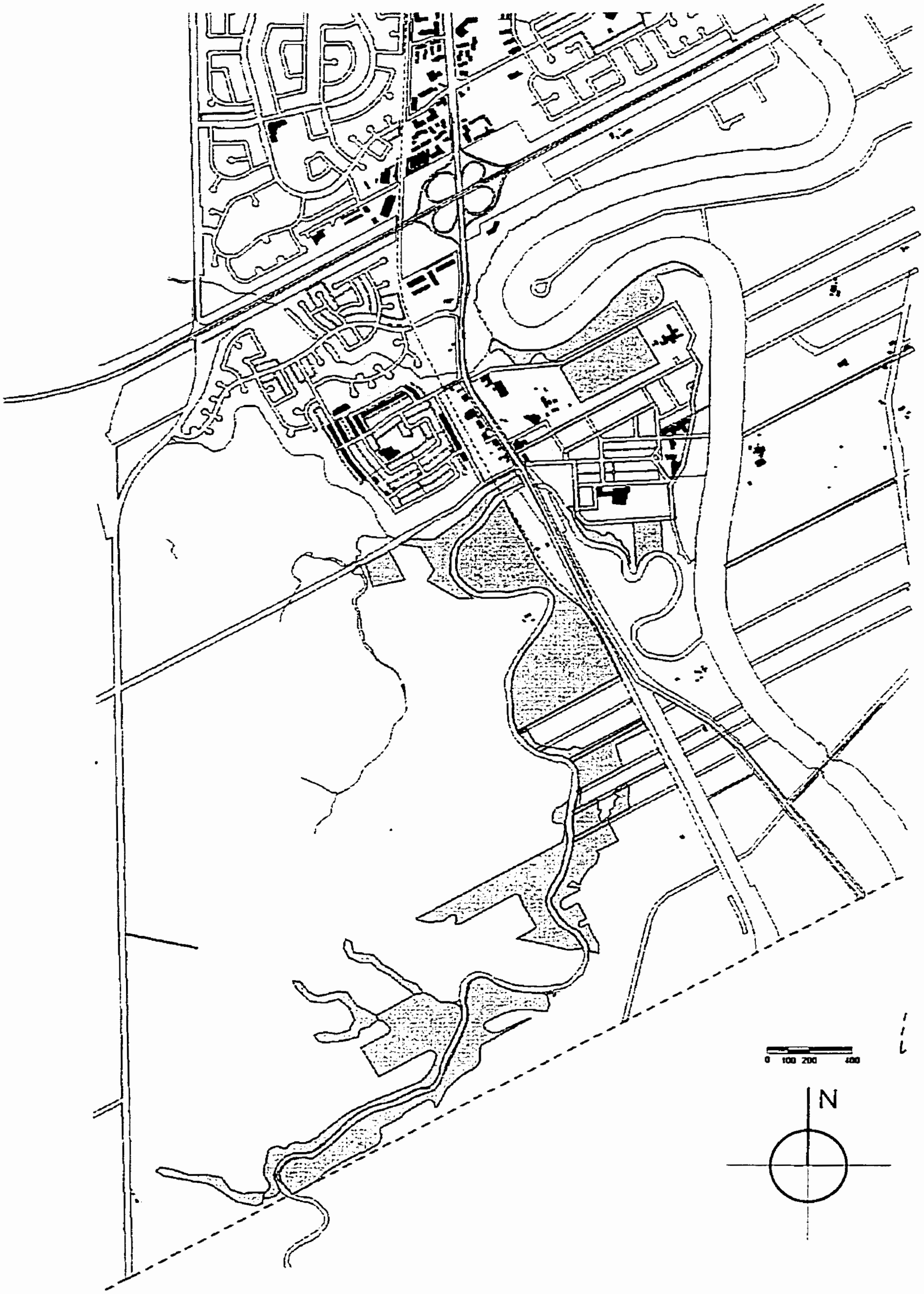
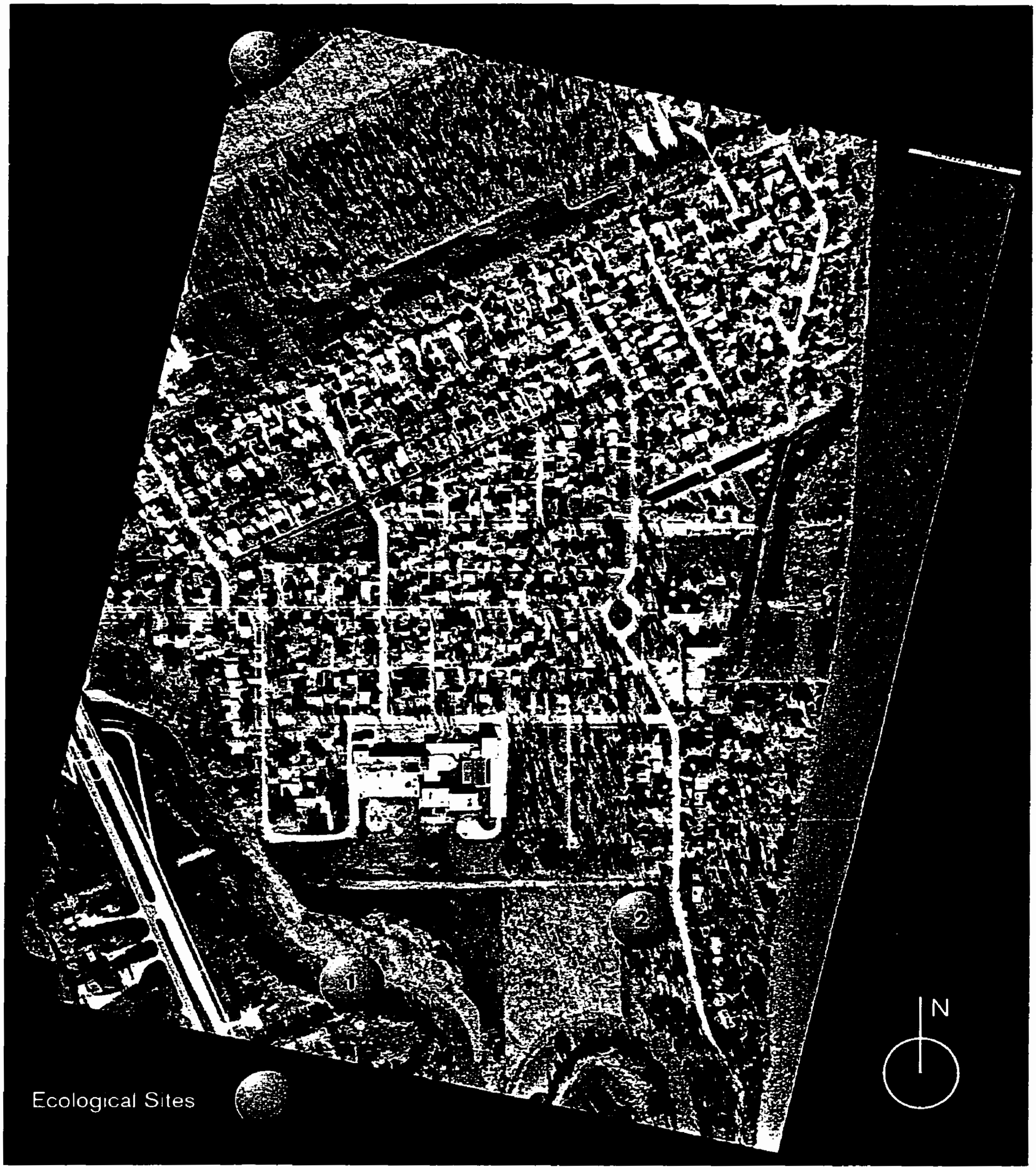


Figure 9.2.2a Ecological Sites



1) Riverbottom Forest Along La Salle River North of Villa Maria
   South of School Grounds
2) Sherwood Forest (South of Cemetery)
3) Riverbottom Forest Along Red River

Figure 9.2.2b Ecological Resources

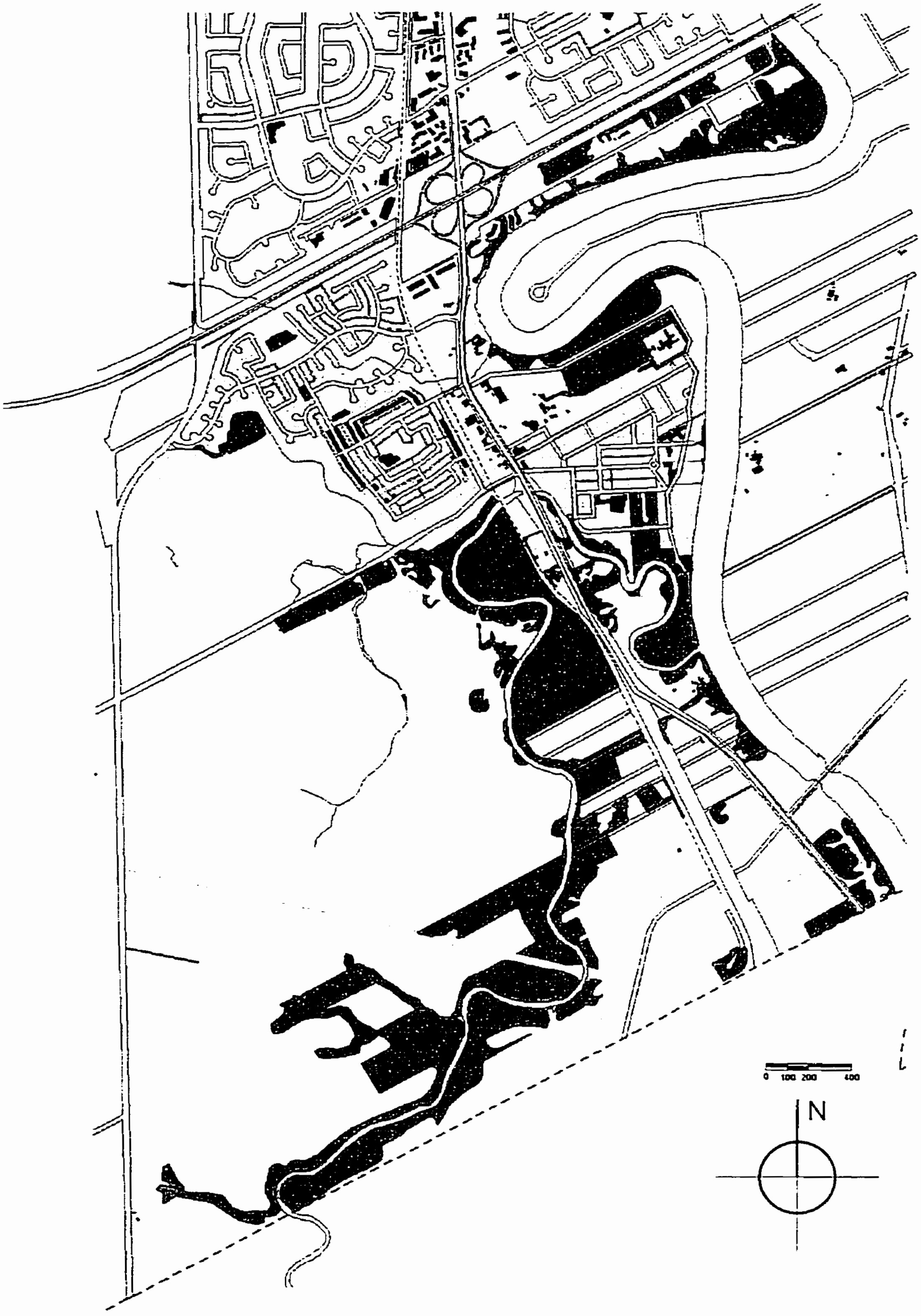


Figure 9.2.2c Riverbottom and other forested areas.

erosion.

Riverbottom forests can generally be divided into three sections; the channel shelf or riverbank, the floodplain, and the terrace. The riverbank is the gently sloping area immediately adjacent to the edge of a river, stream, or creek. This area of the riverbottom forest is dominated by trees such as willow and cottonwood. Few shrub species thrive in the riverbank area because of yearly flooding and damage from spring ice breakup. Instead, this part of the forest has more grasses and annual wildflowers.

Above the riverbank is the relatively flat floodplain. This part of the forest is dominated by trees such as green ash, basswood, American elm, and Manitoba maple. The greatest variety of species is usually found on the floodplain. Here the plant community consists mainly of flood-tolerant perennial species. Common shrub species include: American hazelnut, beaked hazelnut, down arrowwood, and chokecherry. Many flowers and grasses, as well as woody and non-woody vines also exist in the floodplain zone.

The terrace lies above the floodplain, on the highest elevation within the riverbottom forest. Farthest from the river, this area is not flooded as often, and is dominated by plants such as bur oak which prefer a drier habitat.

Although these three sections of riverbottom forest have distinct characteristics, it is usually difficult to tell where the boundaries are between them. Dutch Elm disease has killed many of the American elm trees causing a shift in the dominant tree species from elm to green ash.

Many of the riparian sites alongside the dike in St Norbert have been disturbed and are in need of restoration both for the ecological and structural potential.

The tree species found in river bottom forests of St Norbert include Manitoba maple, green ash, American elm, eastern cottonwood, American basswood, and peach-leafed willow. Shrub species that are commonly found in the area include red-osier dogwood, red-fruited choke cherry, Saskatoon, nannyberry, and poison ivy. Grass species common in the riverbottom forest econiche include reed canary grass and slender wheatgrass. Common herb species are star-flowered Solomon's seal, carrionflower, veiny meadow-rue, sweet-scented bedstraw, wild grapevine, and Sweet Cicely.

Wildlife species that have been found to inhabit the riverbottom econiche in St Norbert are numerous. The following list, while lengthy, is by no mean comprehensive. There are large numbers of rodents, including gray squirrels, Richardson's ground squirrel, red squirrels, flying squirrels, raccoons, beaver, and muskrat. Bird species include wood ducks, northern orioles, mallards, red-winged blackbirds, blue-winged teals, house sparrows, swallows, robins, the eastern kingbird, black-capped chickadees, white-breasted nuthatches, juncos, cedar waspwings, Philadelphia vieros, catbirds, and the cowbird.

The moist shaded areas of the riverbank and river are home to a number of reptiles and amphibians, including snapping turtles, western painted turtles, red-sided garter snakes, western plains garter snakes, leopard frogs, woodfrogs, and the common Canadian toad.

A number of studies have been conducted along the La Salle and Red Rivers. A botanical study by Jennifer Shay and Isabelle Waters (1995) examined a number of sites along the La Salle River corridor.

A series of studies conducted by The Manitoba Critical Wildlife Habitat Program, (CWHP) in the St Norbert area (Figure 9.2.2.1) have been undertaken to determine the ecological value of specific sites located primarily along the banks of the Red and La Salle Rivers. The studies reveal that sites along the two rivers vary in terms of ecology, health, and degree of disturbance. Nearly all the sites studied are described as riverbottom forest, although in various stages of disturbance. As each of these sites resides along the river, several are relevant to the design of this practicum, and it is necessary to examine them for potential to inform the design of a linear greenway diking system.

9.2.2.1 Specific Site Studies (Figure 9.2.2.1)

St Norbert 11

This 20-acre site is located south of Cloutier Drive, on the west bank of the red River, and is classified as riverbottom forest habitat. The site also contains some oak forest habitat on the terrace, including some large oak tress. The site was determined to have a particularly high diversity of shrubs and trees. It also had one of the lowest mean densities

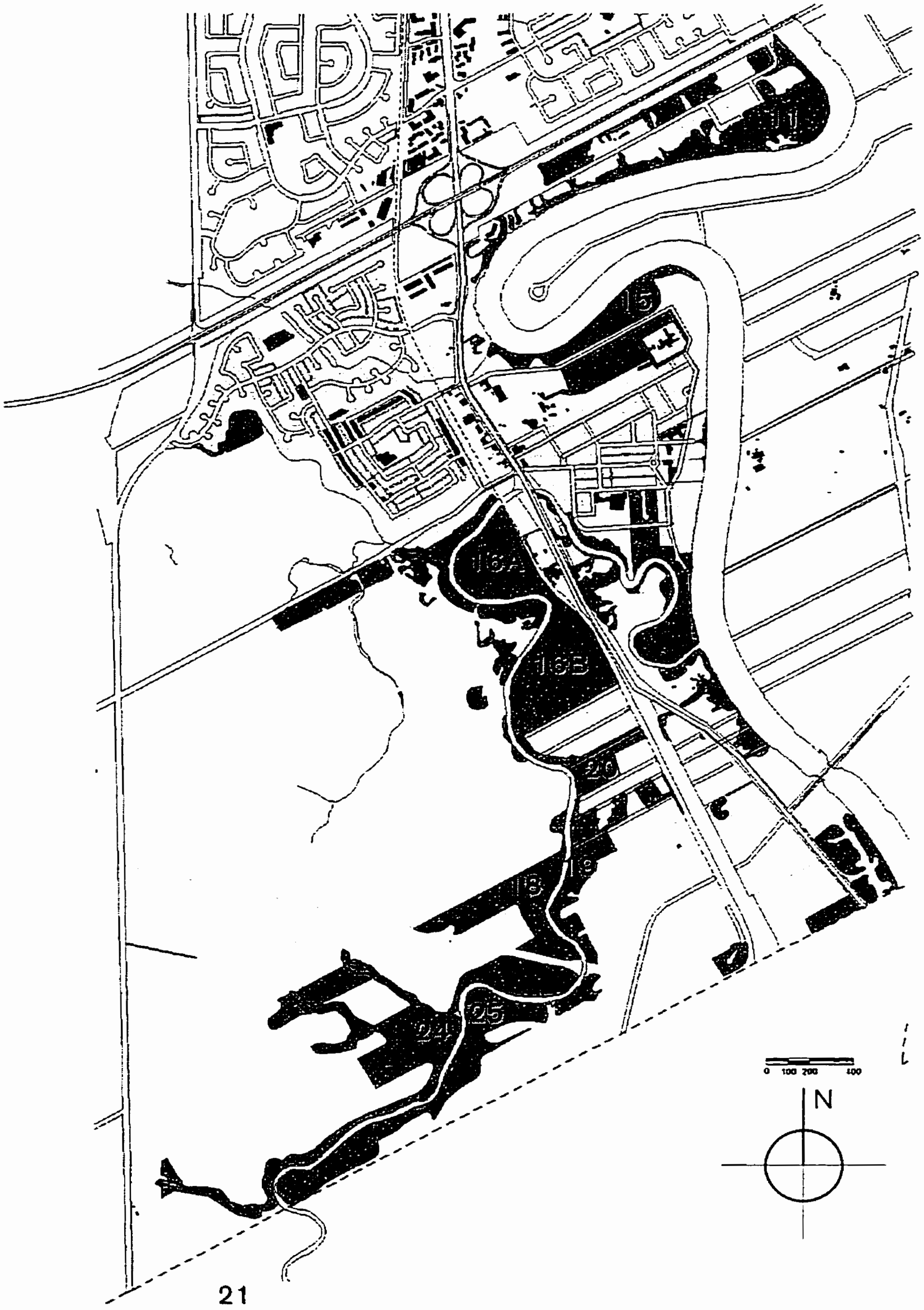


Figure 9.2.2.1 Locations of Manitoba Critical Wildlife Habitat study sites

of shrubs. According to the study, at the time of the inventory the site was for sale for a future housing development, although the site was graded as A, indicating prime land for ecological preservation. It has subsequently been developed.

St Norbert 15

This site is located north of Lemay Avenue, on the west bank of the red River.It was classified as riverbottom forest habitat. At the time of inventory the site was flooded, and many nettle and burdock plants were observed. The site had a very low number of tree species present and the lowest overall species diversity of the ten sites observed. On the other hand, the site had the highest mean tree density of all sites observed, while having the lowest mean shrub density among the sites sampled. It also contained the largest diameter cottonwoods of all sites observed. It was graded as B, indicating having some ecological value.

St Norbert 16A and 16B

These sites are located on the east bank of the La Salle River, north of Father La Bronte Avenue to Pembina Highway. Together they total 40 acres, and were classified as riverbottom forest habitat. At 16A, the existence of very large and old oak trees along the terrace indicates that that portion of the site is relatively untouched. Large cottonwoods were identified on the portion of the site described as floodplain. Several paths were seen continuing through both sites, indicating frequent pedestrian or cyclist use. Site 16A had the highest herb diversity index value of all riverbottom forest sites observed.

Site 16B had the highest number of tree species, the second highest herb diversity, and the second highest species richness of the riverbottom forest sites inventories. It also had one of the highest numbers of shrub species. It was graded A.

The two sites together form a complete picture of the riverbottom forest typology providing for a number of diverse riparian habitats, corresponding with the high number of animal species observed.

St Norbert 18

Located on the west bank of the La Salle River, South of Perrault Ave, this site is classified as riverbottom forest habitat. According to the study, the site has had very little disturbance, yet there are a relatively large number of weed species present. The study also indicates that riverbottom flooding was also evident at the time of observation. The site had a high species richness, with 23 shrub species observed. The site was graded A/B+.

St. Norbert 19

Located on the east bank of the La Salle River south of Perrault Avenue, this site is classified as riverbottom forest habitat. Like Site 18, it has suffered little disturbance, but shows a number of weed species present. Riverbottom forest flooding was evident at the time of observation. With an overall high species diversity for the site it was given a grade of A/B+.

St. Norbert 20

This site is located on the east bank of the La Salle River north of Perrault Avenue, and south of Father LaBonte Avenue. It is classified as riverbottom forest habitat, shows few signs of disturbance and a high number of weed species. As in neighbouring sites, riverbottom flooding was evident at the time of observation. With an overall high species diversity for the site it was given a grade of A/B+.

St. Norbert 21 - La Barriere Park

This site is located west of Waverly Street, and south of Rue Des Trappistes, along the La Salle River. This park is a combination recreation and nature park. Most of the grass areas of the park are mowed and classified as C quality habitat. Two sections are designated as A quality habitat, and the rest of the park is B quality habitat. The park contains approximately 10-15 acres of riverbottom forest habitat located along the La Salle River with a series of walking and cross-country skiing trails. It is an excellent example of riverbottom forest, dominated by American elm and American basswood. Screech owls, northern orioles and wood ducks have been seen nesting in this forest.
The site was graded B.

St. Norbert 24

This site is located on the northwest bank of the La Salle River, east of Waverly Street near La Barriere Park The medium site is classified as riverbottom forest habitat. It supports the largest healthy American elm trees of all the riverbottom forest sites observed. At the time of the study there were indications of frequent human use, including a fire pit, and a trail that paralleled the river. Despite the human use patterns, the site was graded as A.

St. Norbert 25

The site is located on the southeast bank of the La Salle River west of Pembina Highway near La Barriere Park. This medium sized site is classified as riverbottom forest habitat. It had the greatest average density of young shrubs of the riverbottom forest sites observed, and also contained the largest green ash trees of all the sites studied, as well as large Manitoba maple and trembling aspen trees. Large areas close to the river were dominated by wood nettles and there were many trails through the area. The site was graded as A.

9.3 The Human Community

9.3.1 History and Demography of St Norbert

The area of St Norbert where the La Salle River joins the Red was probably first used by Paleo-Indian peoples as long ago as 7000-6000 BCE, the same people at the same dates as are known to have gathered periodically for trade and social events at The Forks. As was the case at The Forks, their occupation was seasonal, and has left few traces on the landscape. By around 1600 CE, aboriginal people in larger numbers were visiting and possibly occupying the area on a more or less permanent basis. In the mid 1700s, the first fur traders from Montreal found Assiniboine, Cree, and Ojibwa communities there. The fur traders, however, preferred to build their posts at The Forks, mostly because it was directly on the major river routes leading to the St Lawrence, to the western prairies, and to the beaver-rich north lands.

From the fur traders' point of view, the St Norbert area was of interest only because it gave easy access to the bison herds. Dried, pounded bison meat (pemmican) was the fuel on which the fur trade ran. Without it, the long yearly canoe voyages and the operation of the fur trade in western Canada would have been impossible.

The first permanent settlers in what is now St Norbert were Métis, who began to build homes there around the turn of the 19th century. They were the first professional bison hunters and pemmican producers. To these seasonal occupations, they added other part-time economic activities: freighting, subsistence farming, and horse breeding. Their presence did not significantly change the landscape, except for the clearing of some fields for gardens, crops and pastures.

In the years after 1812, the Red River Settlement at, and to the north of, The Forks experienced a population increase, as the mostly Scottish Selkirk settlers and retired Scottish and English fur traders and their families took up residence there. St Norbert remained predominantly Métis and Catholic. The everyday languages were French and Michif, a new language emerging out of a combination of French, Cree, and Ojibwa. In 1835, a census taken by the Hudson's Bay Company counted seventy-two heads of families in St Norbert (Manitoba Historic Resources 1996:5). Like their ancestors on the St Lawrence, they used the river lot system of land division. Each lot had minimal river frontage and an extended back yard stretching away from the water to gardens and fields, then to stands of trees which supplied wood for their fireplaces, buildings, and smithies, and beyond that to open prairie which was used to cut hay for the livestock. A typical holding might stretch as much as three kilometres beyond the river's edge. A few signs of Métis river lots dating from the early 1800s are still visible: clumps of trees left as wind-breaks around buildings, and long, narrow strips of once ploughed fields.

By the 1840s, the Catholic Church began to provide religious and educational services to the growing population. The Grey Nuns offered basic religious education and primary schooling in 1844. In 1854, a priest was assigned to the La Salle River community. Within two years the first log church was ready for occupancy, more priests had arrived, and a school for boys was in operation. Two years later, in 1858, Bishop Taché officially gave the community Parish status, and named it St Norbert. One of the Bishop's first acts was to build and staff a convent and girls school to be run by the Grey Nuns. The Church's census at the end of the 1850s listed 101 families, and a total of 700 people (Manitoba Historic Resources 1996:6).

By 1860, the fur trade had changed drastically. Steamboats were navigating the Red River between Fort Garry and St Paul, the bison herds were almost extinct, and agricultural expansion into prairie land had reduced the importance of pemmican production. St Norbert residents had to find other ways to earn a living. A Canadian government census of St Norbert, taken in the two years immediately following Confederation in 1867, counted 124 farming families out of a total of 192 families in the community. These 124 farm families each typically owned three horses, six cattle, and three or more oxen. Freighting became a full-time job for many men, and a few families operated inns for the increasing number of travellers between St Paul and Winnipeg (Manitoba Historic Resources 1996:7).

When the new Canadian government proposed to transfer Rupert's Land, including the Red River Settlement, to Canada in 1869, the Métis people of St Norbert feared that they would be overwhelmed by eastern land developers and settlers, mostly from Ontario. They were also concerned about preserving their Catholic francophone culture. They met in St Norbert Church to decide how to express their resistance to changes in their political and social organization, and perceived threats to their language and religion. In July 1869, led by Louis Riel of St Vital, the people of St Norbert opposed Canada's right to send a Lieutenant-Governor, a government survey party, and an armed force onto their land, without first having consulted the residents. The Métis militia, consisting of about 100 men, set up a road block across the Pembina Trail at La Barriere, near St Norbert, and successfully prevented the survey party from continuing its work.

During the winter and spring of 1869-70, the provisional government set up by Riel in Red River negotiated with the Canadian government. Canada agreed to the entry of Manitoba into Confederation as a separate province, not as an extension of Ontario. The Manitoba Act (1870) guaranteed the people of Manitoba religious freedom and a denominational school system, as well as making the new province officially bilingual (French and English). It also set aside just over five and a half million hectares of land for Métis children (Manitoba Historic Resources 1996:11).

In the first federal census (1870-71), 1,055 people, roughly 1/12th of the total population of Manitoba, lived in St Norbert (Manitoba Historic Resources 1996:10). During the next decade, however, the population dropped significantly, as many Métis moved west, where they believed they could maintain greater autonomy. Again fearful of the continuing influx of anglophone settlers, the Catholic Church bought river lots from the departing Métis, and began to recruit francophone Catholic settlers from Quebec to settle on them. By 1885, they had managed to bring eighty-five French-Canadian families to St Norbert. These new settlers and those that followed reinforced the Catholic and francophone nature of the St Norbert community.

In the prosperous years from 1870 to the end of the century, the St Norbert population continued to grow, and along with it, suitable institutions and services emerged. Joseph Lemay built and operated a steam powered sawmill and flour mill, beginning in 1871. The old Grey Nuns' convent was enlarged, and a new parish church was built. In 1872, an open-air chapel, the Chapelle de Notre-Dame du Bon Secours, was added to the Church's establishment. Railroads came to St Norbert in the 70s and 80s, making it easier to export St Norbert lumber and agricultural products. A Cistercian (Trappist) monastery was established in 1892, and the monks followed their religious vocation by leading a silent, cloistered life of prayer, and offered spiritual comfort and counselling to the community. They also created a model farm, operated a dairy capable of supplying the community with milk, cream, butter and cheese, produced honey, and offered the services of a variety of tradesmen. In 1903, the Sisters of Mercy established the St Norbert Orphanage, also known as Asile Ritchot and Asile Bethléem.

In the first decades of the twentieth century, civic leadership in St Norbert was embedded in the Catholic Church, as it had been since the 1840s. A parish priest drafted the 1905 village subdivision plan for laying out streets and avenues. Interestingly, the plan did not follow the river lot lines, as the City of Winnipeg Plan did; instead it laid out avenues parallel to the Red River and the Pembina Trail. Lobbies for the extension of public transportation (streetcars) to St Norbert and for paved roads between St Norbert and Winnipeg were also led by a local parish priest.

The first major real estate boom came in 1910 with the Province's announcement that its Agricultural College was to be moved to St Norbert. The Catholic and francophone character of the area was threatened by the loss of large amounts of land to anglophone speculators. Higher property taxes accelerated the process when many Métis and French-Canadian owners were forced to relinquish their land. St Norbert's population increased significantly once again in the 1950s after sewer and water utilities were built, and again in the 1960s when the Red River Floodway offered greater protection from the constant threat of flooding.

Were the fears of newcomers, as well as the passage of time, would change the essential nature of the community justified? The 1986 Federal Census of Canada suggests that, demographically, they were. The total population of St Norbert in 1986 was 20, 255, compared to 16, 920 in 1981 (Manitoba Bureau of Statistics 1990:3). Of the 1986 population, 15,675, or 80.6% of the total, named English as their mother tongue, that is, the first language learned and still spoken. Only 1,165 (6%) named French. Another 805 persons (4%) could not distinguish between English and French as mother tongues, and identified themselves as bilingual from infancy (Manitoba Bureau of Statistics 1990:Table 1).

Asked to identify which of the official languages they spoke, 16,905 (83.8%) said English only. Fifteen individuals (0.1%) said French only. Three thousand forty (15.1%) spoke both official languages. Two hundred twenty-five (1.1%) individuals did not speak or understand either official language (Manitoba Bureau of Statistics 1990:Table 4). Asked to identify the language usually spoken at home, 17,555 (90.0% of respondents) said English. Six hundred forty-five (3.3%) said French. A total of 870 (4.3%) said both languages were spoken equally often in the home (Manitoba Bureau of Statistics 1990:Table 4).

In response to the question on ethnic origin, 4,350 (38.3%) persons claimed to be entirely of British origin; 1,350 (11.9%) claimed to be entirely of French origin; one hundred ninety-five individuals (1.7%) claimed to be entirely of Aboriginal origin. Eight thousand eight hundred fifteen (43.7%) claimed multiple ethnic origins (Manitoba Bureau of Statistics 1990:Table 4).

The 1986 Census indicates that St Norbert is no longer a Métis community. "Métis" was not included as an ethnic category in the 1986 Census, and persons who considered themselves of Métis origin would necessarily have had to count themselves in the "multiple ethnic origins" category. St Norbert is also no longer a solidly francophone community. It is also impossible to assess the Catholicity of present day St Norbert. Questions on religious adherence were asked on the 1986 Census form, but the results were not made public.

However, one cannot spend any amount of time in St Norbert, from a brief visit to the Farmers' Market or a half day tour of historic sites, to a six-month long in-depth survey of the community as a federal census enumerator, without getting the impression that St Norbert residents in general, no matter how they identify themselves linguistically and ethnically, are interested in their two hundred history. They also make it clear that they are determined to maintain their historic sites and preserve the community's now multicultural heritage.

9.3.2 Human Land Use Patterns

As St Norbert is on the rural-urban fringe, it is the intersection of a number of different environments, resulting in diverse use patterns. Agricultural, high to low density residential, institutional, recreational, religious, historical, and pastoral uses are all evident in a relatively small area of concentration. The largest proportion of land is designated agricultural, and surrounds the residential, institutional, and commercial core. The majority of the residential lands are low density, with a few pockets of high density clustered about the intersection of Pembina Highway and the Perimeter Highway. A second area of high density housing is located on the west side of Pembina Highway along Houlde Avenue and Glendale Boulevard. (Figure 9.3.2).

Within the core area, only a small proportion is allotted to open space for human use. This opens up important possibilities to make the dike a connecting link between areas in this fragmented landscape.

9.3.3 Historic, Cultural, and Heritage Sites (Figures 9.3.3a, b, c, d)

There are two 'Main Streets' in St Norbert, the historic and the current. The first is the traditional small town 'Main Street' from the turn of the century, running along Avenue de l'Eglise. All that remains to indicate the former prominence of the street are a couple of buildings from the turn of the century. The other 'Main Street' is a product of Pembina Highway, which bisects the community, dividing it into two distinct areas.

St Norbert's Historic and Heritage Sites are highly valued by the people of the community, and of the province of Manitoba. Plaques commemorating important events of the past have been placed in a number of locations in St Norbert due to the efforts of groups such as the St Norbert Historical Society, the Manitoba Historical Society, Heritage St Norbert Inc, the Manitoba Heritage Council, and to residents who have represented St Norbert on the Economic Development Council of Manitoba Bilingual Communities. As the St Norbert Arts and Cultural Centre web site points out, "A spirit of activism and dedication to preserving community heritage has long been a tradition in St Norbert." During the 1980s it was a citizens' group that lobbied (successfully) for the preservation of the

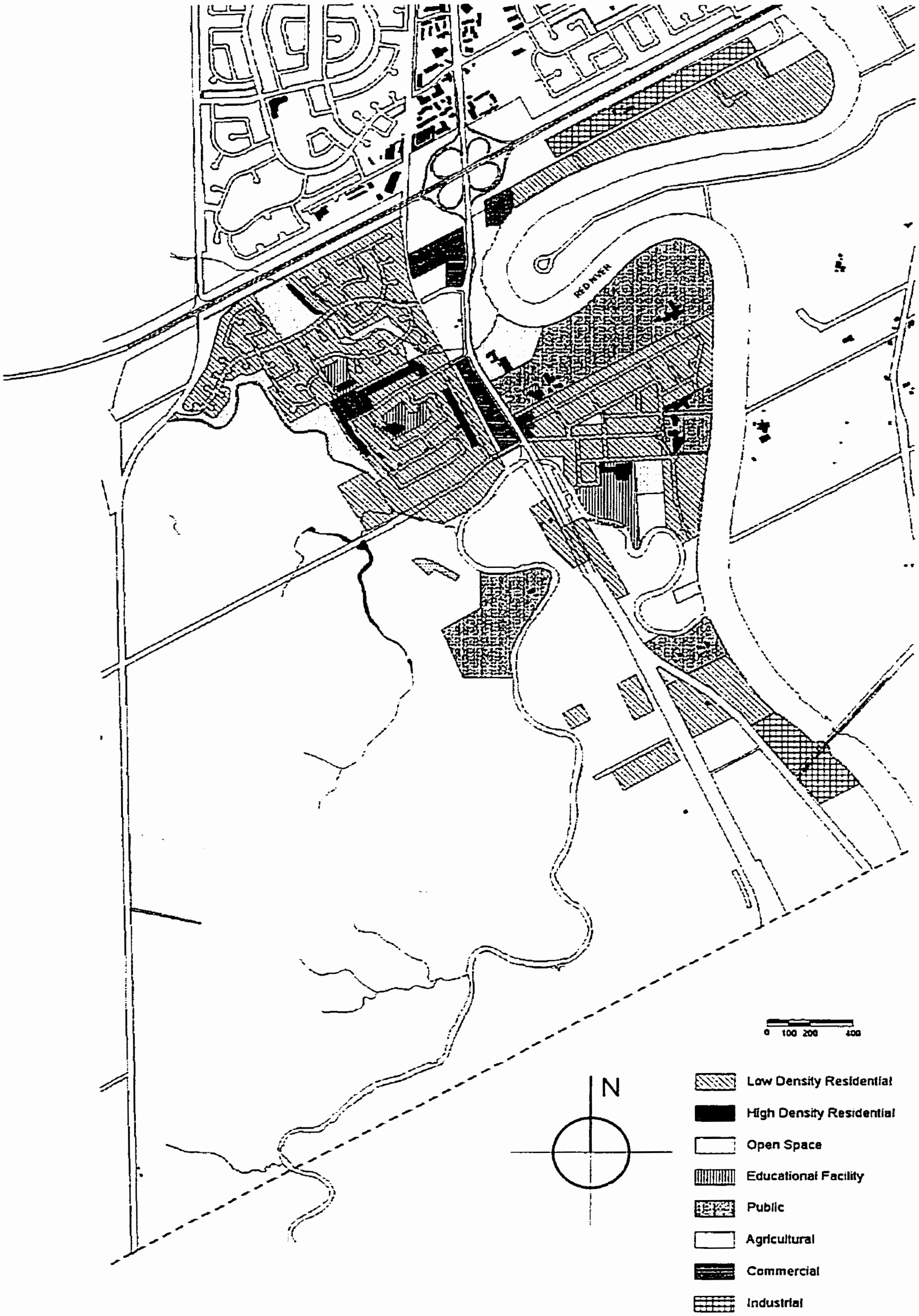


Figure 9.3.2 Human Land Use Patterns

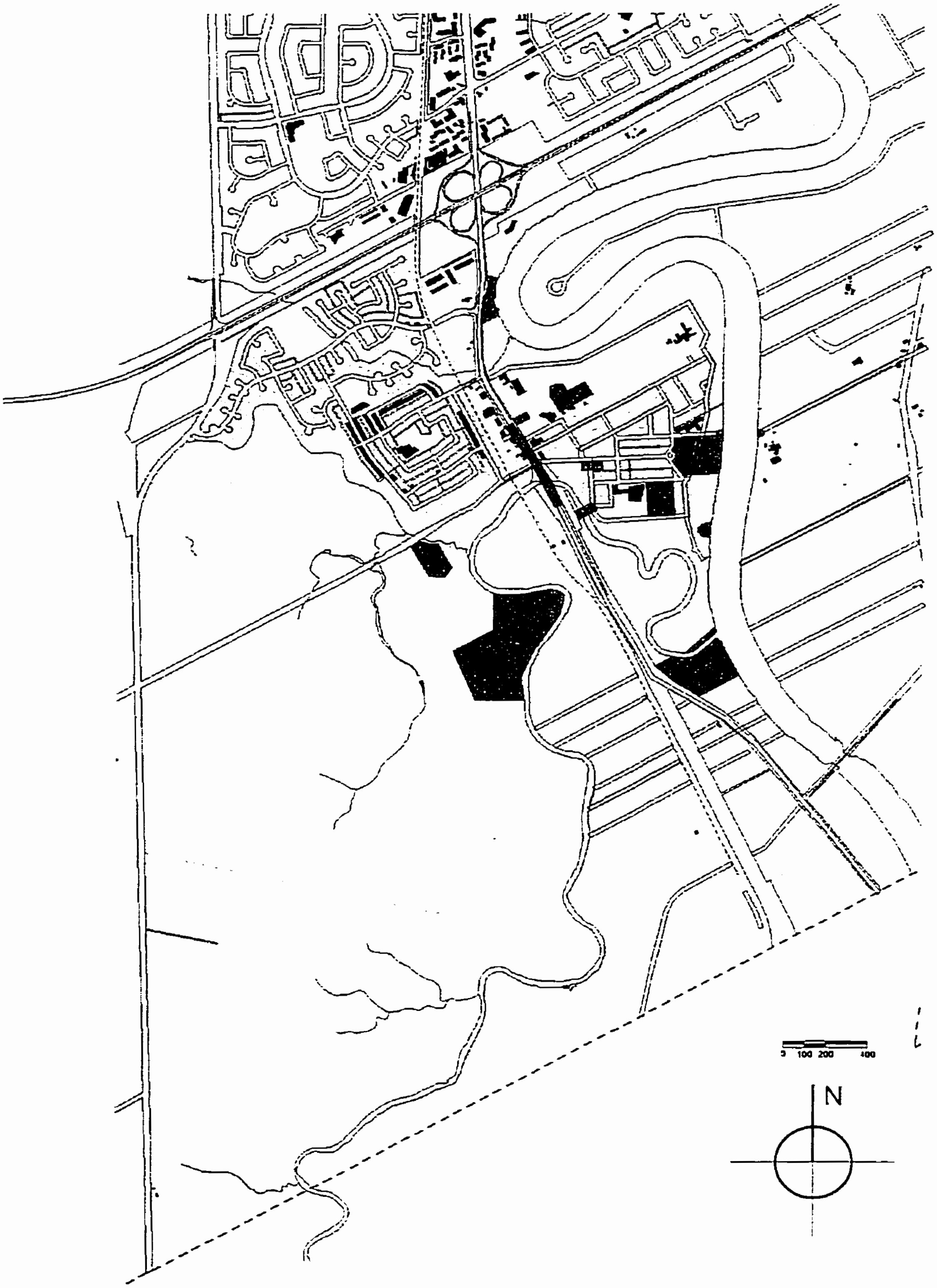


Figure 9.3.3a Historical and Heritage Resources

1) Place St. Norbert
2) Ferry Crossing
3) Church/ Cathedral Site
4) Métis Burial Ground
5) Cemetery
6) Prehistoric Indian Campsite
7) Bridge Site
8) Avenue De L'Eglise
9) La Barriere

Figure 9.3.3b Historic and Heritage Resources

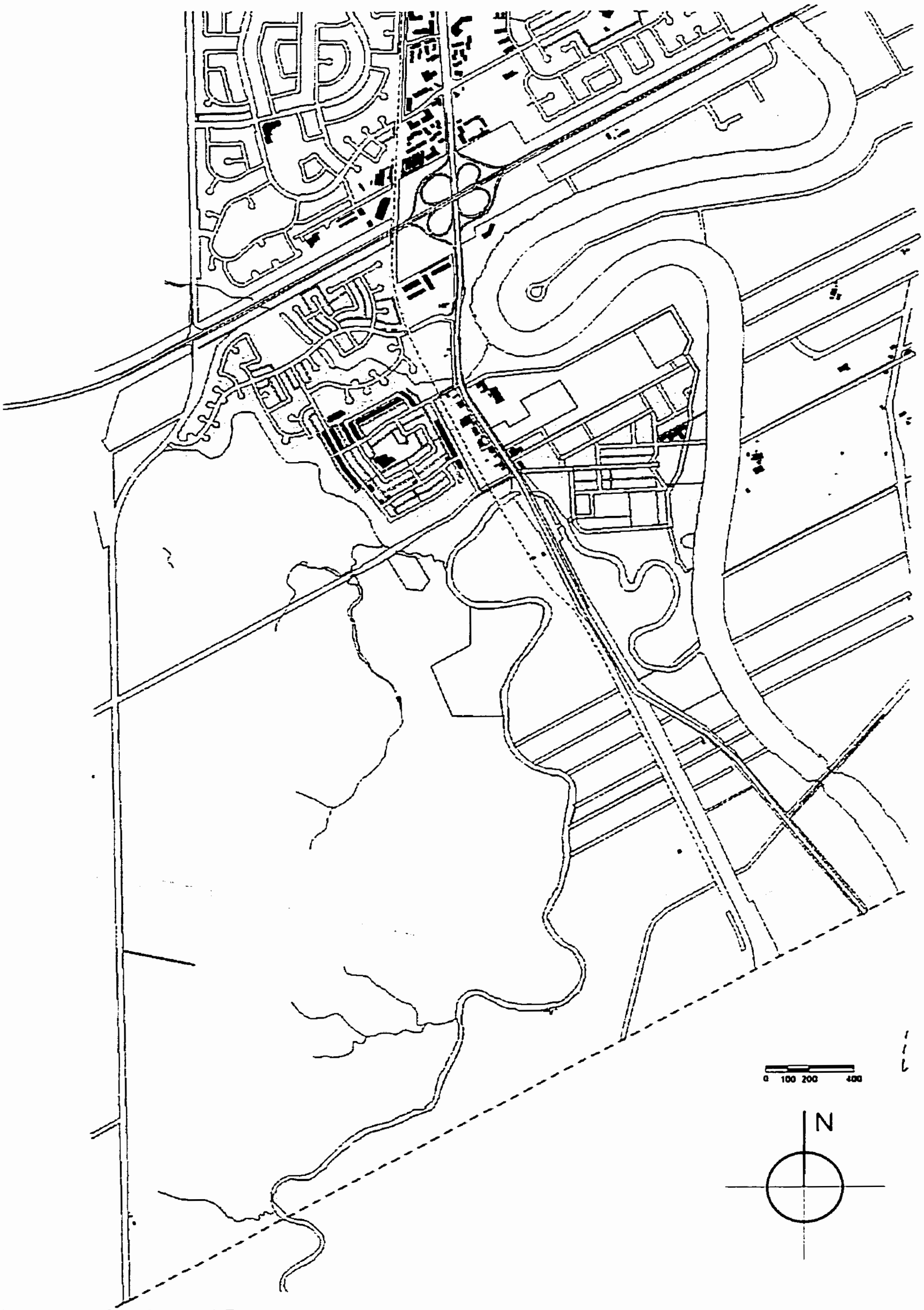


Figure 9.3.3c Cultural Resources

1) Villa Maria Retreat
2) Church/ Cathedral Site
3) Prehistoric Indian Campsite
4) Cemetery
5) Emersion School
6) Avenue De L'Eglise
7) Pembina Trail
8) River Lot Remnants
9) Place St. Norbert

Figure 9.3.3d Cultural Resources

Trappist Monastery ruins and the restoration of its Guest House. Continuing interest and involvement of St Norbert residents in preserving the community's history and heritage was recognized in 1999 when one of the Manitoba Heritage Awards went to the restorers of the St Norbert Orphanage seminary building. Any plan for construction and landscaping of public spaces in St Norbert should take into account existing and proposed historic sites designated by residents. Descriptions of some sites which St Norbert people believe are worth preserving follow.

9.3.3.1 Geological Traces

The oldest site of historic interest is the conjunction of the Red and La Salle Rivers, where the geological structure of the ancient river systems created from glacial outwash at the end of the last great ice age can still be seen.

9.3.3.2 Prehistoric Indian Sites (Figures 9.3.3b, d)

Possibly the most fragile of St Norbert's ancient sites are two campsites dating to the 8th century CE. They were used by Paleo-Indians, possibly people of the Blackduck Culture complex. One campsite is located on the Red River south of the cathedral, and between homes on Lord Avenue. The other is located where the Red and La Salle Rivers meet, on the north bank of the La Salle River directly opposite St Norbert Heritage Park.

9.3.3.3 Religious Heritage Sites (Figures 9.3.3b, d)

Many historic buildings and heritage sites in St Norbert are church-related. They include the Métis Cemetery, the Parish Church, the Chapelle de Notre-Dame du Bon Secours, and the Trappist Monastery on Rue d'Eglise. All have been maintained, preserved, and rebuilt when necessary, and are important in the cultural and religious life of St Norbert. R.W. Lausman, in his practicum for the M.L.A. degree at this university, recognized the importance of ecclesiastical structures and sites in the St Norbert landscape. "Its [the Church's] prominent cultural and historical resources are interpreted to recognize the role of the church within this landscape and the role of the Métis people " (1990)

Fifteen hundred Métis founders of the original St Norbert community and their descendants are buried in the Métis Cemetery. The cemetery, as well as being a consecrated religious site, is an important heritage site to Métis.

The first Parish Church, built in 1869, was replaced in 1937. As well as having cultural significance in the community, it has profound visual appeal. R.W. Lausman has said of it that it is the "visual focus to the entry to the community" (1990:51). The outdoor Chapelle de Notre-Dame du Bon Secours, built by the Grey Nuns in the 1870s, was named a heritage site in 1994.

Also of importance to the community are the ruins of the abbey church, Notre Dame des Prairie. Built in 1892 by Trappist monks, the Abbey itself was destroyed by fire in 1912, rebuilt by the monks, and then fell into ruins when the monks left in 1978. The remaining buildings are examples of unique religious architecture in Manitoba. In the early 1980s, they received historic building designation due to the efforts of Heritage St Norbert Inc. In 1988, through provincial legislation, the ruins and surrounding land became an official heritage site. The outdoor grotto with its shrine and rock gardens continues to be a site for social events, from weddings and graduations to family picnics. The guest house, where the monks offered a safe retreat and spiritual counselling was restored and remodeled by the St Norbert Arts and Cultural Centre, and now serves as a gathering place for the community, and contains a restaurant. Artists' workshops and conferences are often held here, and live theatre "Shakespeare in the Ruins" productions are staged there every summer. People from Winnipeg and other parts of southern Manitoba, as well as St Norbert residents, use the site, support it through donations, and see it as one of Manitoba's important heritage parks.

9.3.3.4 Historic Sites (Figures 9.3.3b, d)

(a) Remnants of the French River Lot System

Among artifacts of the landscape important to preserving St Norbert's history are the slight traces of the French river lot system of land division. The shapes of the long, narrow ploughed fields are still faintly visible, especially from the air. Another reminder of the earliest Métis settlers is the site of a farmstead on Rue Du Monastere. This farmstead was partially excavated in 1979, and is highly valued by Métis peoples.

(b) Red River Ferry Crossing

Aerial photography reveals the location of the historic ferry crossing on the west bank of the Red River. The site is on a direct axis to a corresponding site across the river where Forbes Road terminates at the east bank of the Red.

(c) Old Bridge Site

A few maps dating from the turn of the century indicate that a bridge once connected historic Pembina Trail to St Norbert across the La Salle River. Physical evidence of its existence are to be found adjacent to the Immersion School, where one can see remnants of wooden piles in the river, and a remnant of the road on the south side of the La Salle that appears to begin at the river and terminates before it reaches Pembina Highway.

(d) Avenue de l'Eglise

Avenue de l'Eglise is another site which recalls the land use patterns of earlier times. The Avenue was an early 'Main Street' and formal entry into the community of St Norbert. The spire of Cathedral St Norbert frame the avenue which lies on a direct axis to the west of the Cathedral St Norbert. A few remnant buildings remain along the avenue, although the old Banque de Hochelaga has recently been purchased and converted into a residence.

(e) La Barriere

In 1869, many St Norbert and Red River Settlement residents objected to the takeover of the area by the Ontario government. Led by Louis Riel, they erected a barrier across Pembina Trail to prevent the newly-appointed governor from entering the precincts. The event was of great importance in Canadian and Manitoban history, ensuring that Red River Settlement, Pembina, and St Norbert would enter confederation as the Province of Manitoba, and not as an extension of Ontario. A monument commemorating the event stands at Place Saint-Norbert, and a plaque is located in St Norbert Provincial Heritage Park at Turnbull Drive and Highway 75. The actual site of the barrier erected by Louis Riel's followers in 1869 is believed to have been along what is now Pembina Highway at Avenue Le May.

(f) St Norbert Park and Early Franco-Manitoba Architectural Examples

St Norbert Park has become the repository for many historical artifacts. On site are two houses dating to the 1870-1875 period. Both are examples of early Franco-Manitoban domestic architecture. A third example is the Lemay House. It was built by Joseph Lemay in about 1870 when he began operating the first sawmill and flour mill in the community. The

Lemay House was later purchased by the Oblate Fathers and converted into an orphanage. As of the time of writing, it is occupied by the st Norbert Foundation, and specializes in substance abuse treatment for First Nations youths, in a pastoral setting.

9.3.4 Recreational Opportunities (Figures 9.3.4a, b)

(a) The Dike Crest

A prominent linear feature in the landscape, the dike crest is used by local residents for many purposes, including as a jogging path, dog walking trail, and cycling trail. The linear nature of the dike lends itself to use as a connective element in the landscape.

(b) Church and Cathedral Grounds

The Catholic church arranges for recreational activities in its precincts outside of church and worship hours.

(c) Pocket Parks 1 and 2

The first park is located across the St Norbert Cathedral on the west side of Lord Avenue between Avenue De l'Eglise and Ste-Therese Avenue. This small greenspace is a triangular-shaped passive greenspace, with benches and a crushed stone path bisecting it from north to south. The second park is larger, and is located on Ave. Le May, to the east of Pembina Highway. It is also a triangular passive greenspace, with benches, a pathway, and a small play structure.

(d) Immersion School Grounds

St Norbert Collegiate is located between Rue La Pierre, and Rue Campeau on the north bank of the La Salle River. The school grounds are south of the school and contain a small non-regulation sized soccer field that is truncated laterally by a new dike bisecting the open field area from east to west. The remainder of the school's open space is on the other side of the dike, to the south, between the river and the structure.

9.3.5 Scenic Views and Visual Appeal (Fig 9.3.5)

One of the most distinctive features of the St Norbert area is the natural beauty of its riparian bands lining the rivers and spreading into the crevasses in the landscape along the smaller intermittent stream corridors. What is of utmost importance is the preservation and, if possible, the enhancement of natural views, treelines, and the many glimpses of the

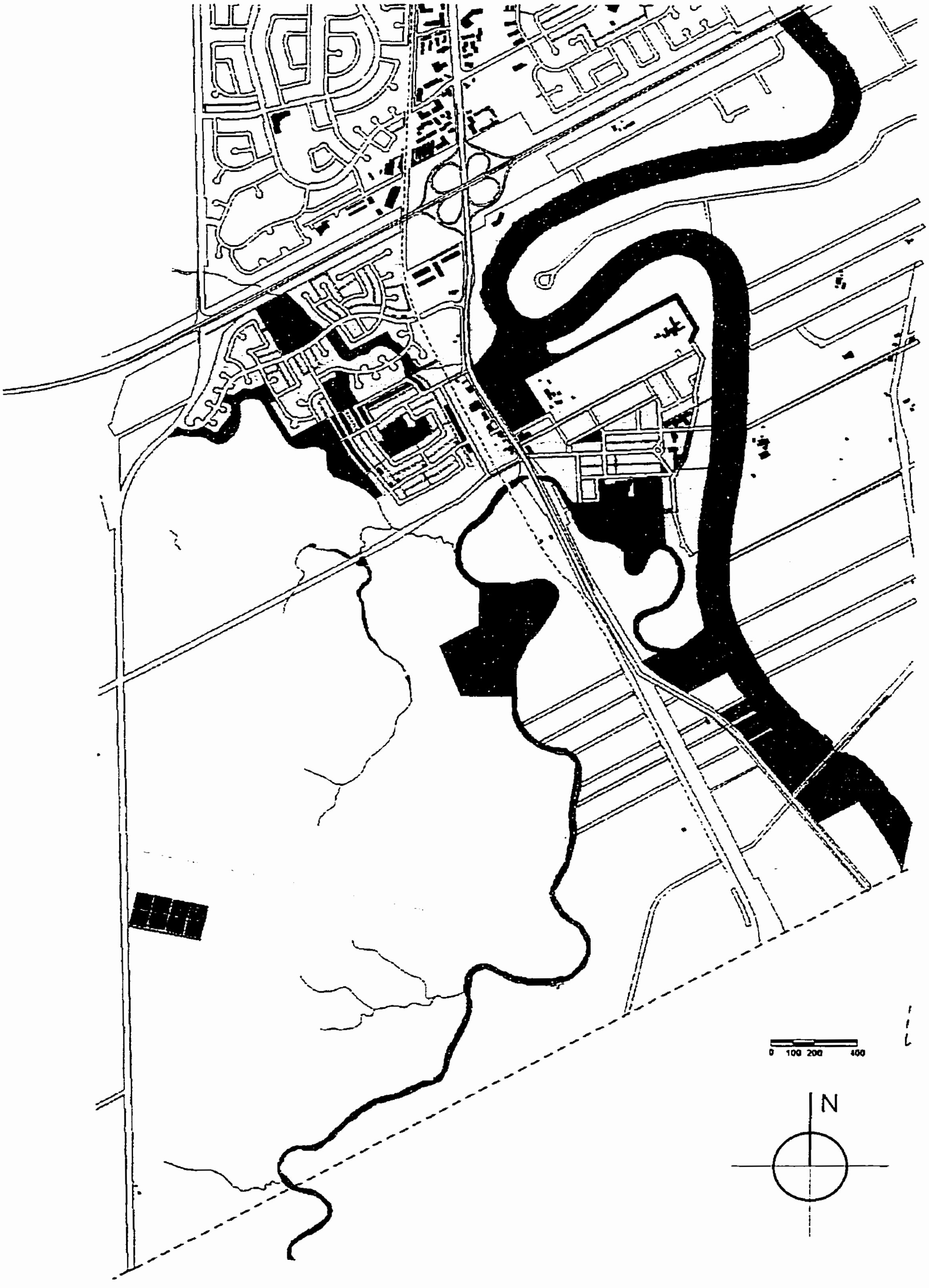
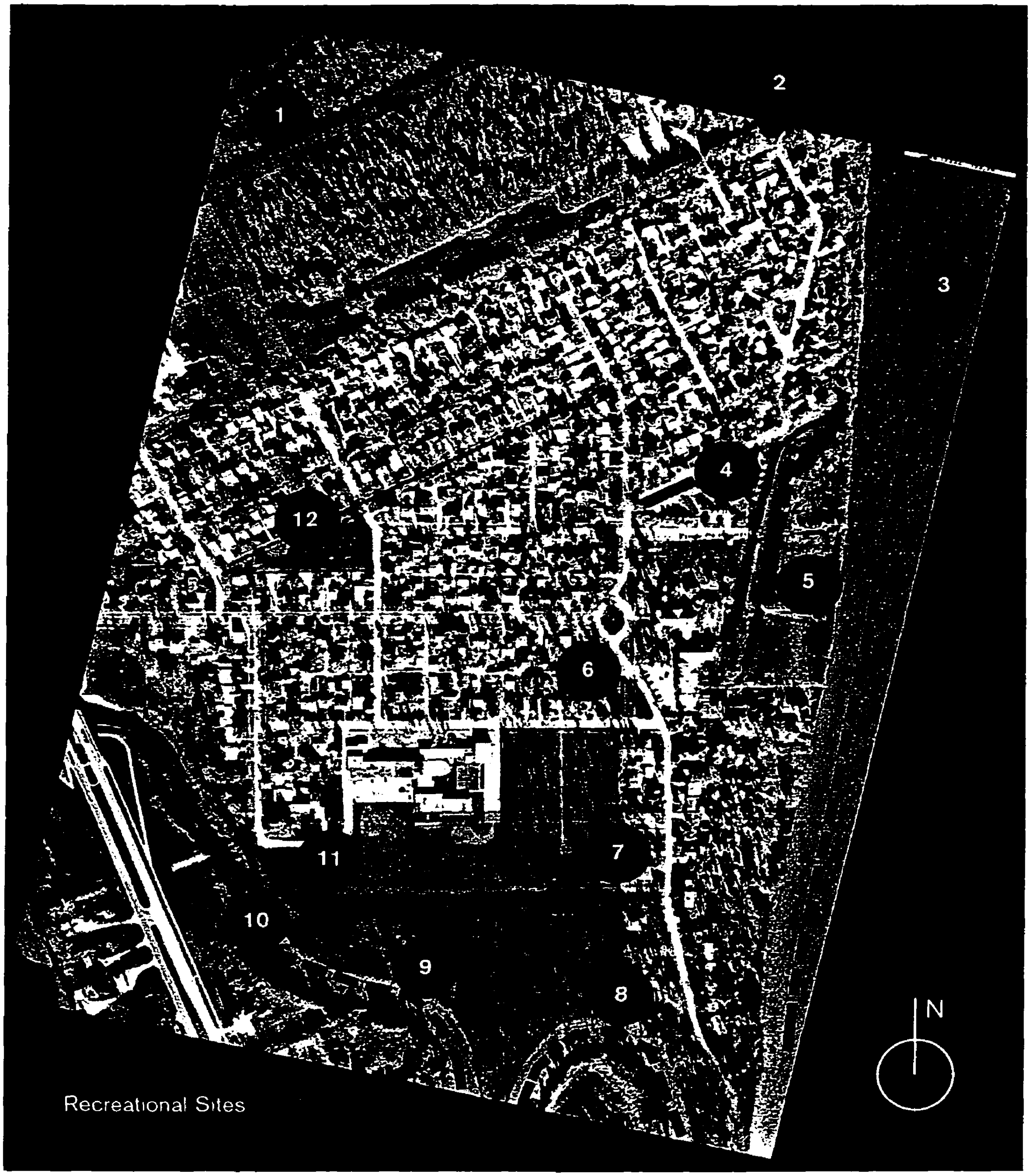


Figure 9.3.4a Recreational Resources



1) Dike Crest - North of Villa Maria
2) Dike Crest - East of Villa Maria
3) The Red River
4) Dike Crest - East of Cathedral
5) Church/ Cathedral Grounds
6) Pocket Park 1
7) Cemetery
8) Sherwood Forest (South of Cemetery)
9) Emersion School Grounds
10) The LaSalle River
11) Dike Crest - Bisecting School Grounds
12) Pocket Park 2

Figure 9.3.4b Recreational Resources

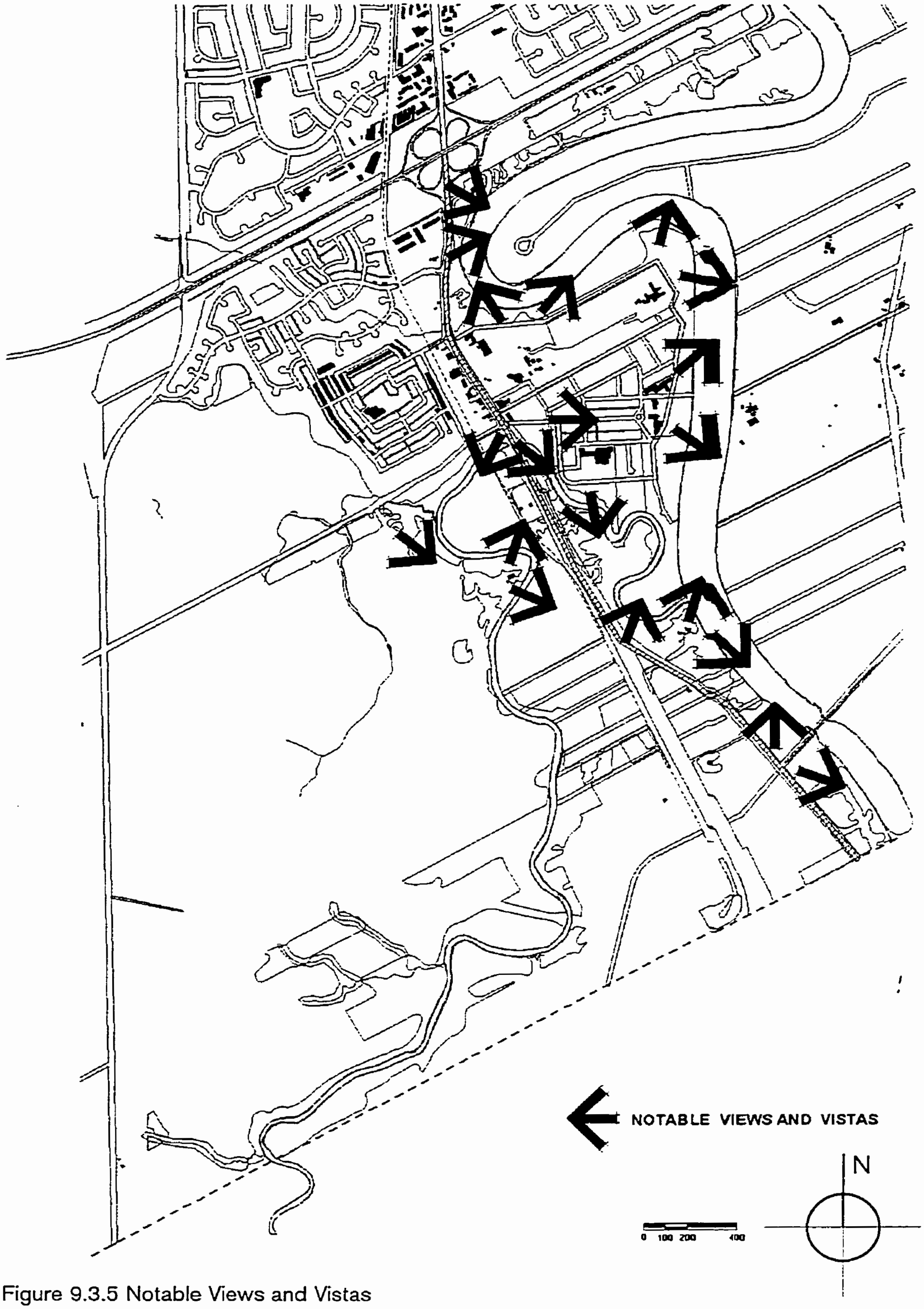


Figure 9.3.5 Notable Views and Vistas

river through the trees.

Another important view worth protecting is from Pembina Highway along Avenue De l'Eglise on a direct axis with the Cathedral, as well as views to and from the riverbanks of the Red and La Salle Rivers.

9.4 Existing and Proposed Diking (Fig 9.4)

William Rannie, a geographer at the University of Winnipeg, pointed out as long ago as 1980, that the rapid growth of southern Winnipeg, particularly in St. Boniface, St.Vital, and St.Norbert, was due in large part to the perception of reduced risks of flooding provided by the floodway and primary diking. If this public perception was ever correct, it most certainly is not so following the flood of 1997. In 1997, almost 4,000 people had to leave their homes in St Norbert. From temporary mass shelters, they waited for the Red River to reach its crest, not knowing if they would have homes and property to return to when the waters receded.

In the weeks before the river crested, emergency work crews hastily set in place 835,000 sandbags, most of them to protect between eighty and eighty-five buildings, mainly residences, against the rising water. Dikes were hastily constructed here, as they were in other threatened areas. The immediate need to protect the village took precedence over how the dikes would later affect the appearance and functions of the landscape. When the threat was no longer immediate, the temporary containment walls were removed. The time, effort, and cost of this endeavour, which is very likely to be repeated in years to come, argues strongly for the design and construction of additional primary diking, of a permanent nature.

The permanent dikes already in position in St Norbert, many of which were built after the 1976 flood had completely inundated the area, are typical of those constructed by various military engineering corps all over North America. Elevated roadways used in conjunction with earthen structures form much of the flood protection, a practice very common in North America. The system is practical and in general serves its purpose, but it is linear, non-dynamic, underutilized, strictly utilitarian, and dressed with concrete or clothed in non-indigenous grasses. The individual elements of the system are disruptive to adjacent riparian plant communities as well as visually unappealing. They replace a once scenic and

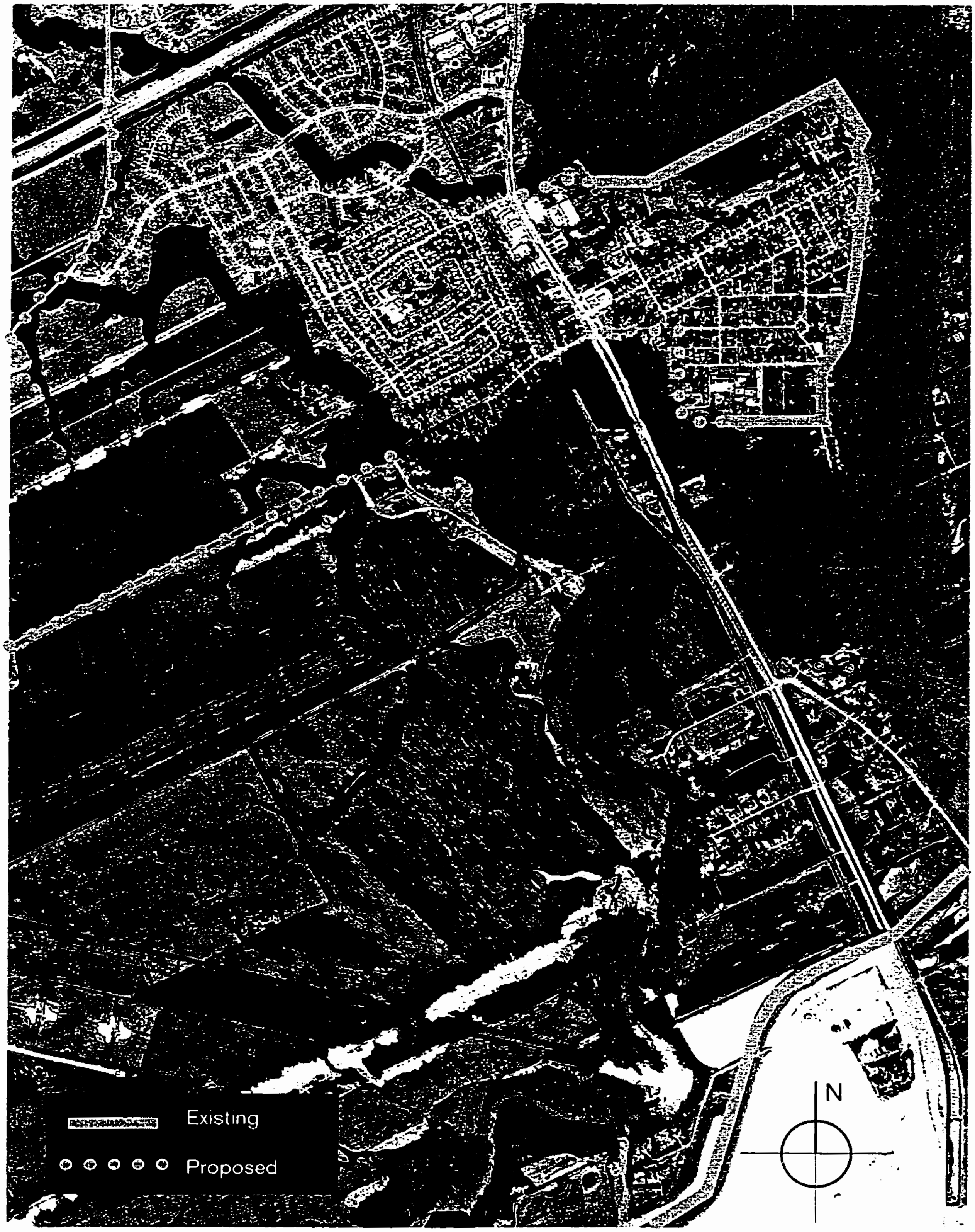


Figure 9.4 Existing and Proposed Diking in St Norbert Scale: 1:20 000

sought-after view of the river with unattractive lumps on the landscape. They cut off access to the river, intrude on the landscape and the lives of those they protect, and do nothing to enhance social and recreational life.

Some dikes were not removed, and it is now certain that significant portions of the diking system will be made permanent, and will be supplemented with yet more dikes. As of the year 2000, with the 1997 flood still a vivid memory, the St Norbert diking system is in a state of change. Hurriedly constructed secondary diking, thrown up as temporary protection, is gradually being replaced with permanent primary earthen diking. As the existing structure winds its way through the community, it passes a number of elements that have high social and cultural significance to the local residents. The close proximity of these elements along the dike suggests a variety of recreational possibilities, with regard to connections, linkages, and nodes. This presents the designer with a myriad of choices and problems, both in terms of recreation, and the challenge of tying together and integrating elements that are not physically linked, although drawn closer together by the presence of the dike.

The perception of these unique spaces as part of a larger picture is enhanced by the connection provided by the dike. The dike serves as a greenway corridor, but the structure can be more than merely a backbone in the system. The treatment of the dike itself can enhance the environments through which it passes. What is necessary, therefore, is the development of a strategy by which these similar, yet disparate, features can be brought together, not only to enhance the meaning of each individual element within the system, but also to restore a sense of cohesion to the community, and create a whole that is greater than the sum of its parts.

Too frequently neither modern scientific knowledge about soil mechanics, hydrogeology and hydrology, nor experience in modern construction technology, are take sufficiently into account when designing levées and embankments. Considerable progress has been made in canal embankment cross-sections in The Netherlands and the Mississippi Valley since 1935, but in almost no case have they been evaluated for their design potential. Designers of levées and canal embankments have been, and continue to be, somewhat complacent about the non-utilitarian aspects of dike design, drawing their inspiration from traditional earth structures alone, and neglecting the social aspects of these intrusive structures.

This complacency has apparently not affected designers of dams, who have made some progress in finding ways to incorporate dams into the social life of communities. The Commission Internationale des Grands Barrages, an international institution based in Paris, is systematically developing theory and reassessing current practices in dam design. Its recommendations have had a significant effect on dam design beyond the engineering aspects. The Commission's basic assumption that dams can and should provide social opportunities as well as essential functions might well be adopted in diking construction as well.

To determine how dikes as permanent landscape features might be integrated into the life of the community without compromising their basic purpose, a number of factors need to be considered. These include an understanding of their construction (which begins with an examination of dikes in cross-section), materials, forms, size, placement, and cover, and their relationships. Consideration must also be given to the historical and cultural features of a given landscape, and possible social uses of protective structures.

9.4.1 Cross-sections (Figures 9.4.1a, b, c, d)

A first priority in designing for the St Norbert dikes is an examination of cross-sections. Modifications or extensions which the landscape architect might wish to make in order to facilitate secondary uses and visual appeal must be compatible with the main purpose of the dikes. The following list is by no means comprehensive, but it does include many of the more common forms currently used. Several of which hold some promise in terms of visual appeal and for potential multiple uses. USACE Traditional (Figure 9.4.1a), Dutch Traditional (Figure 9.4.1b), Dutch New (Larger) (Figure 9.4.1b), International Profiles (Figure 9.4.1c), City of Winnipeg (Figure 9.4.1d).

9.5 The Dike and St Norbert (Figure 9.5a)

In St Norbert after 1997, new dikes cut through a school yard, making a soccer field and playground useless. Boating enthusiasts found their access to launching sites either eliminated or severely restricted. The Catholic community experienced difficulty in caring for the historic Métis cemetery and the grounds of the Senior Citizen's residence because of reduced access due to new dikes. Community members dedicated to

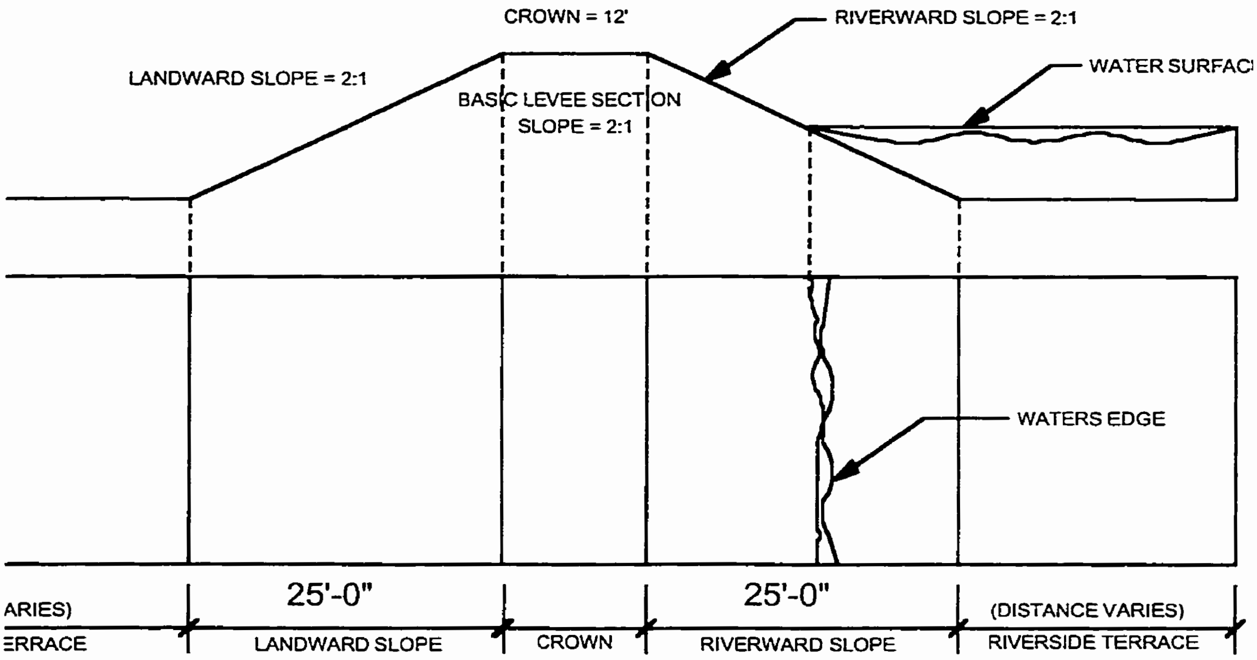


Figure 9.4.1a Traditional U.S.A.C.E. Dike Design Section

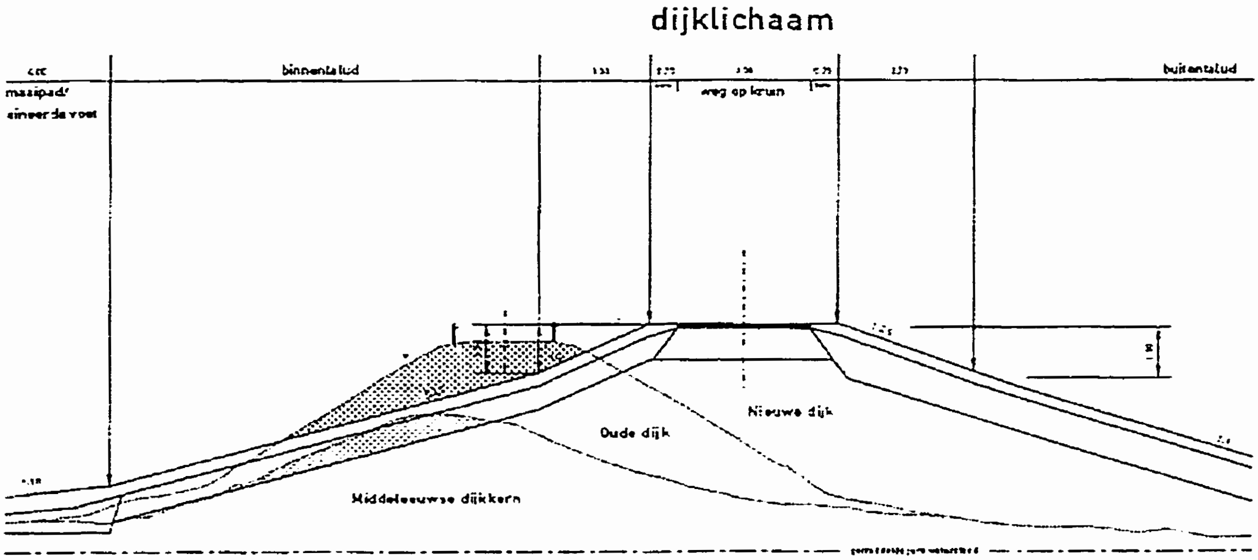
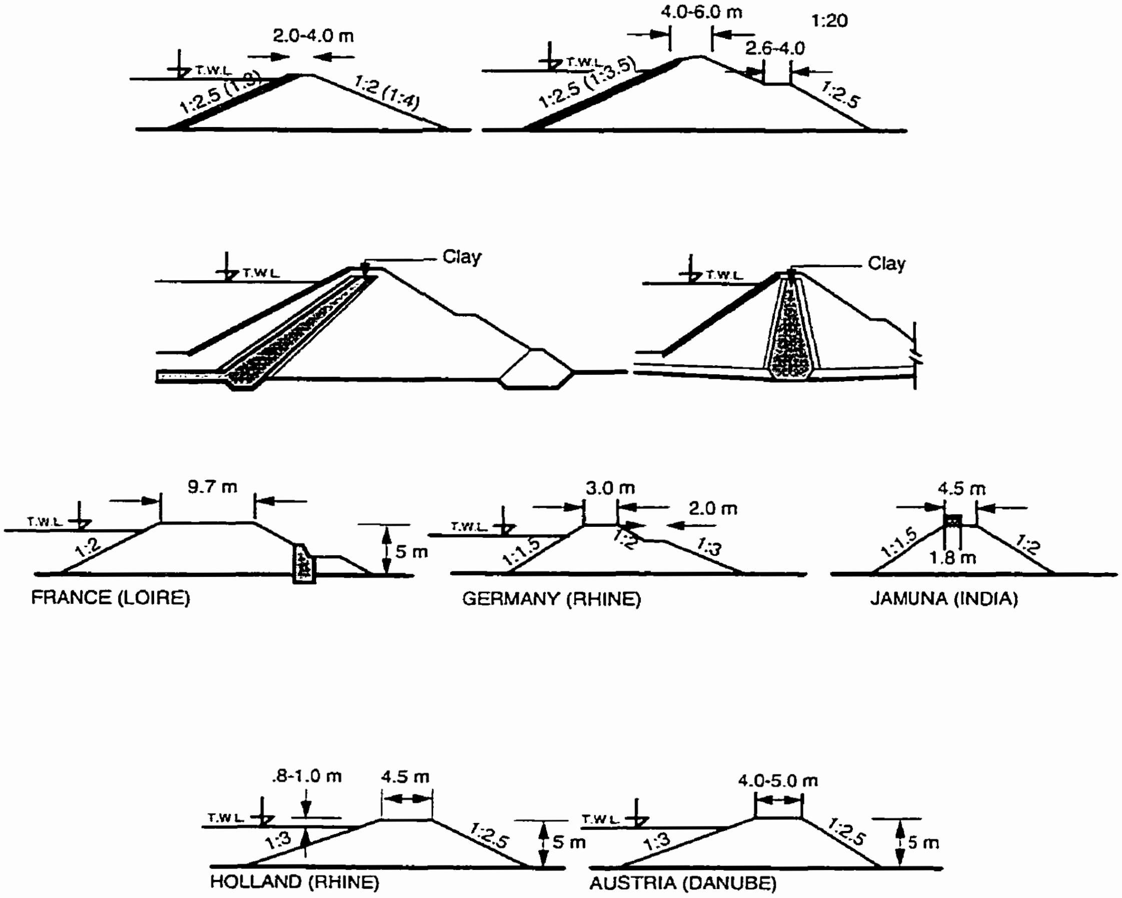


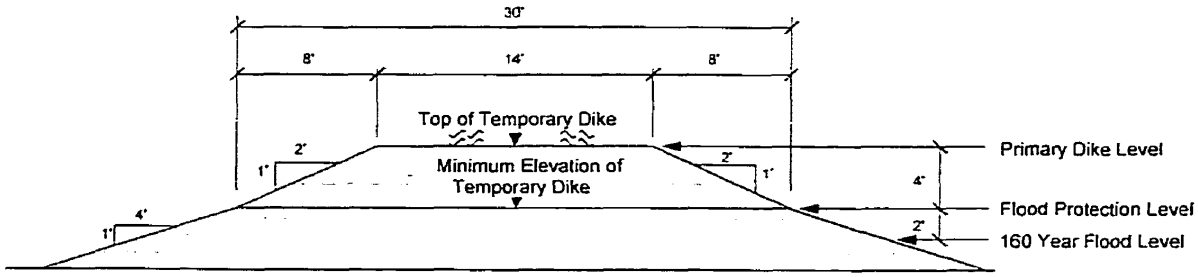
Figure 9.4.1b Dutch Traditional & New Dike Design Section Source: Topos



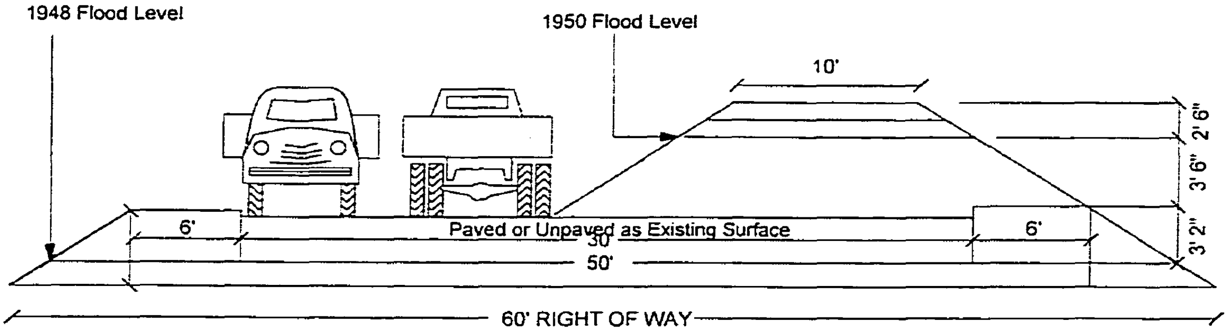
FRANCE (LOIRE) GERMANY (RHINE) JAMUNA (INDIA)

HOLLAND (RHINE) AUSTRIA (DANUBE)

Figure 9.4.1c International Dike Typologies Source: Peter, 1985



SECTION - TYPICAL PRIMARY DIKE WITH EARTH FILL FOR THE CITY OF WINNIPEG CIRCA 1997



SECTION - CITY OF WINNIPEG ORIGINAL BOULEVARD DESIGN CIRCA 1950

Figure 9.4.1d Winnipeg Dike Typologies Source: City of Winnipg

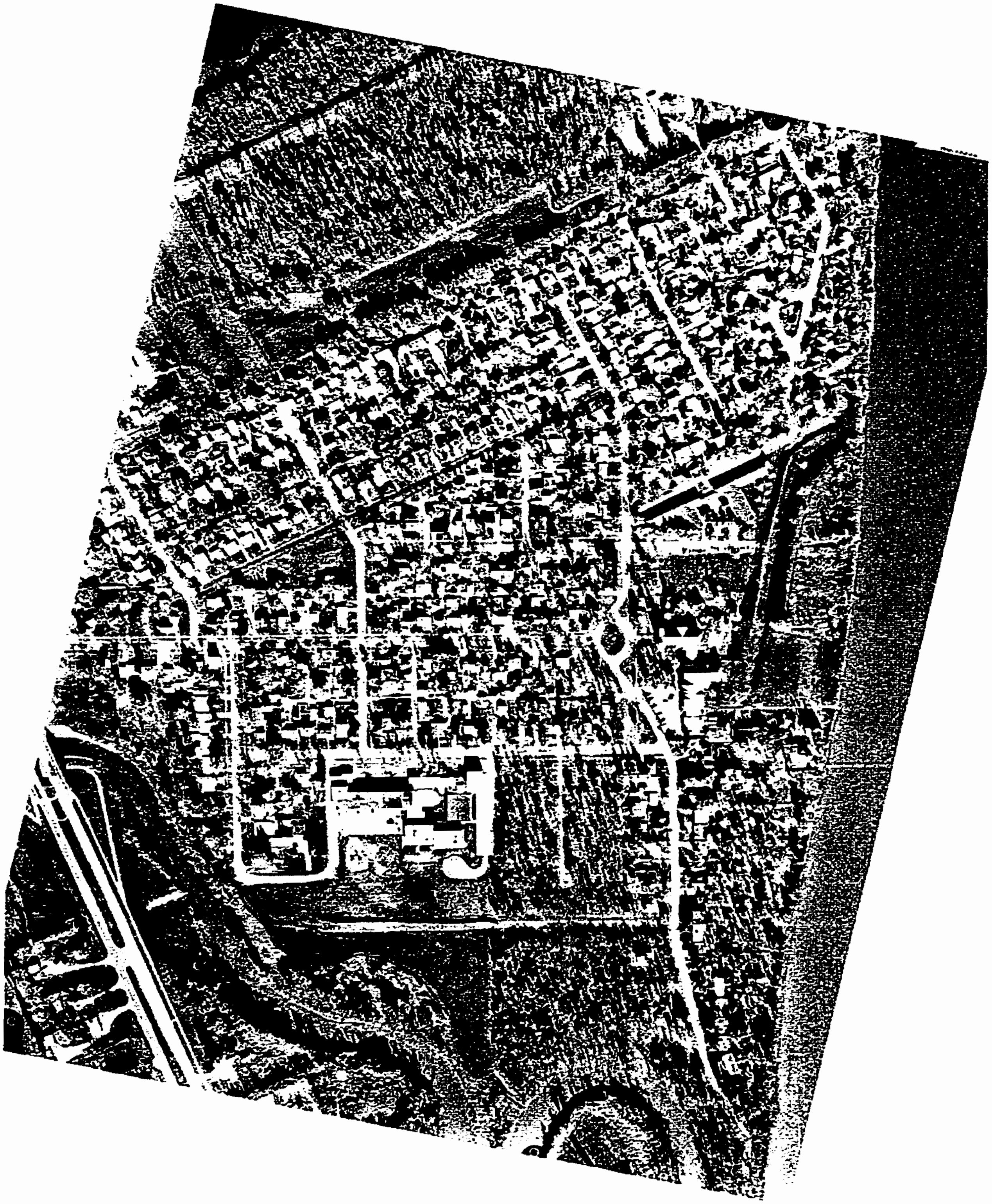


Figure 9.5a The dike and St Norbert

preserving historical and heritage sites, including archaeologists and Parks Canada officials, began to identify the dikes as a threat to preserving the past. Wilderness advocates worried about wildlife, the reduction of the river bottom forest areas, and the destruction of gopher and bird habitats. Many home owners discovered, after the 1997 clean-up, that their views of the river were either gone or compromised, and that their yards were suddenly smaller by the width of a dike. The common response, that of removing or cutting through permanent protective devices, is a dangerous one.

To residents of the local community with some understanding of geological history, the rivers themselves – the Red, the Seine, and the La Salle – are a constant reminder of the forces that shaped the local landscape. To others they are ever present artifacts recalling to mind the danger their homes, businesses, schools, and historic sites face from flood waters. While the dikes provide both real protection and a sense of security, they also are daily reminders of emergencies in the past and the potential for disasters in the future. As recently as 1997, residential yards, school grounds, church precincts, and recreational areas ranging from children's playgrounds to parks have been damaged by out-of-control rivers.

While the dike is the largest and most imposing feature in the St Norbert landscape, it is only one of a number of infrastructure elements visible on aerial photographs, which show highways, roads, train tracks, drainage ditches, and agricultural fields. These elements are both barriers and connectors, separating or uniting St Norbert and its larger geographical context. The St Norbert dikes function primarily as barriers, separating the waters from the land in fulfillment of their original purpose, but also splitting the community apart physically.

The dike's elevated and continuous form, while divisive, is also connective. Its length and linear configuration create a corridor (or corridors) with potential for connecting a variety of habitats, as well as social-cultural spaces. The regional framework includes roads, highways, parks, hamlets, and a myriad of social and ecological spaces. the continuous nature of the dike provides opportunities for the inclusion of these spaces into a larger framework of socio-cultural activities through the creation of nodes and linkages between spatially separated components of the landscape. To the people of St Norbert, the dike is an element that connects them to those places, joining the aspects of their lives on a common thread.

9.5.1 Developmental Opportunities

The diking system is a response to the region's geological forces, and is at the same time part of its geological history. It must be integrated into the St Norbert landscape so that access and usability of valued sites is restored, and in such a way that people's complaints about loss of visual attractiveness are addressed. While LNC Theory remains controversial as a philosophical approach, some elements of it can be useful in understanding the diking system as it now exists. Using an adaptation of the procedures suggested by LNC Theory, a number of high resource concentrations along the existing dikes can be identified. The vast majority of the areas identified (Figure 9.5.1a) as having high resource concentrations are situated to the east of Pembina Highway in the older part of St Norbert. Each of these areas comes into contact with the dike at some point along its 11.5 kilometre length.

The opportunities for interactions between the various landscape elements presented by the dikes in St Norbert are numerous as the protective structures come into contact with parks, forested areas, recreational facilities, and agricultural lands. When a structure crosses or intersects these elements, opportunities arise in the form of activity nodes (Figure 9.5.1b), which have the potential to serve as part of a system of spaces illustrating the natural or cultural history of the area. The use of interconnected nodes around a central spine is not a new concept in community planning or landscape architecture, but variations of the technique seem particularly appropriate in integrating dikes in the urban landscape of St Norbert.

Analysis revealed several areas that are in need of attention, and other areas that simply presented opportunities in terms of activity nodes, and/or linkages (Figure 9.5.1c).

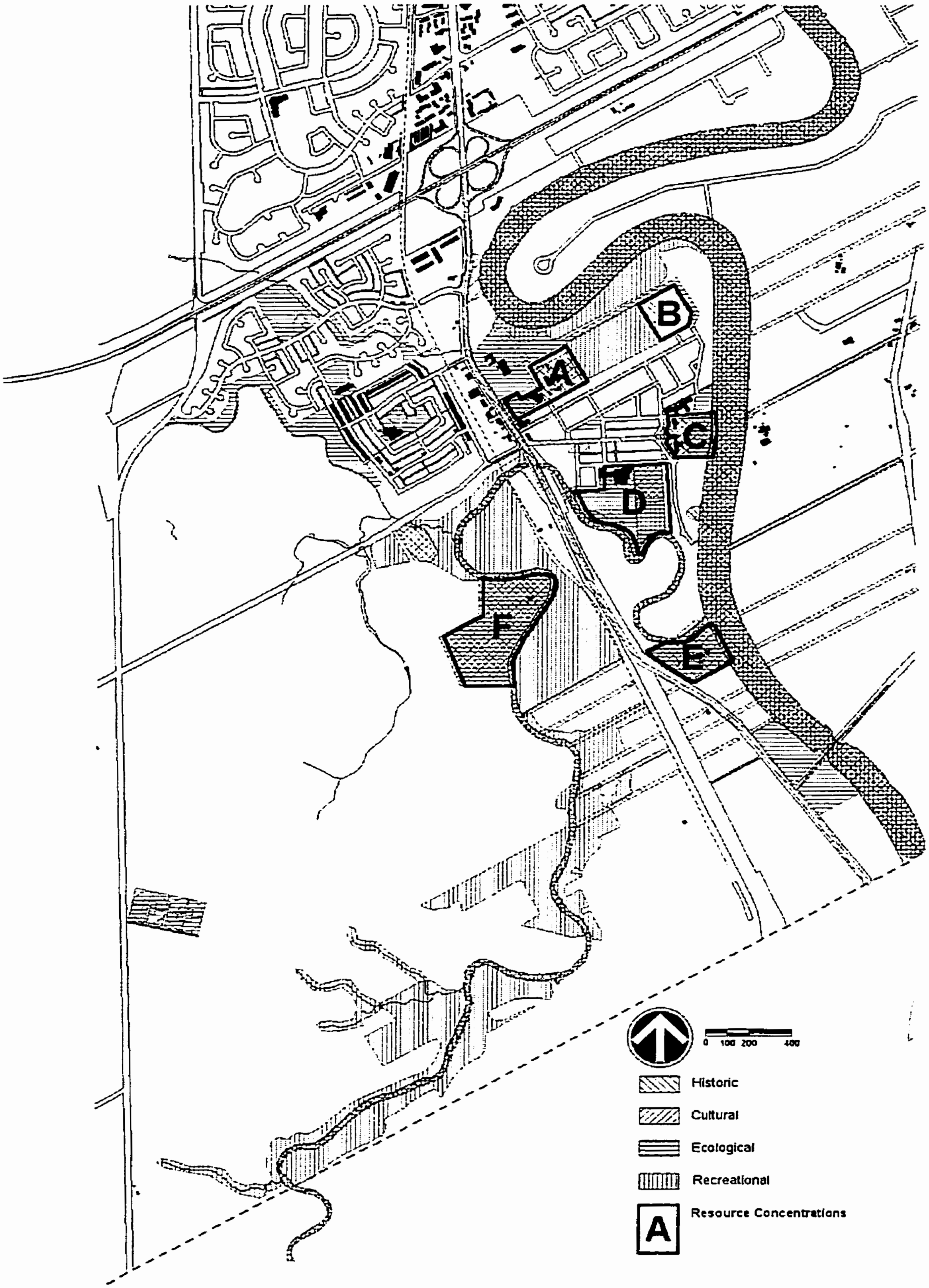


Figure 9.5.1a Resource Concentrations

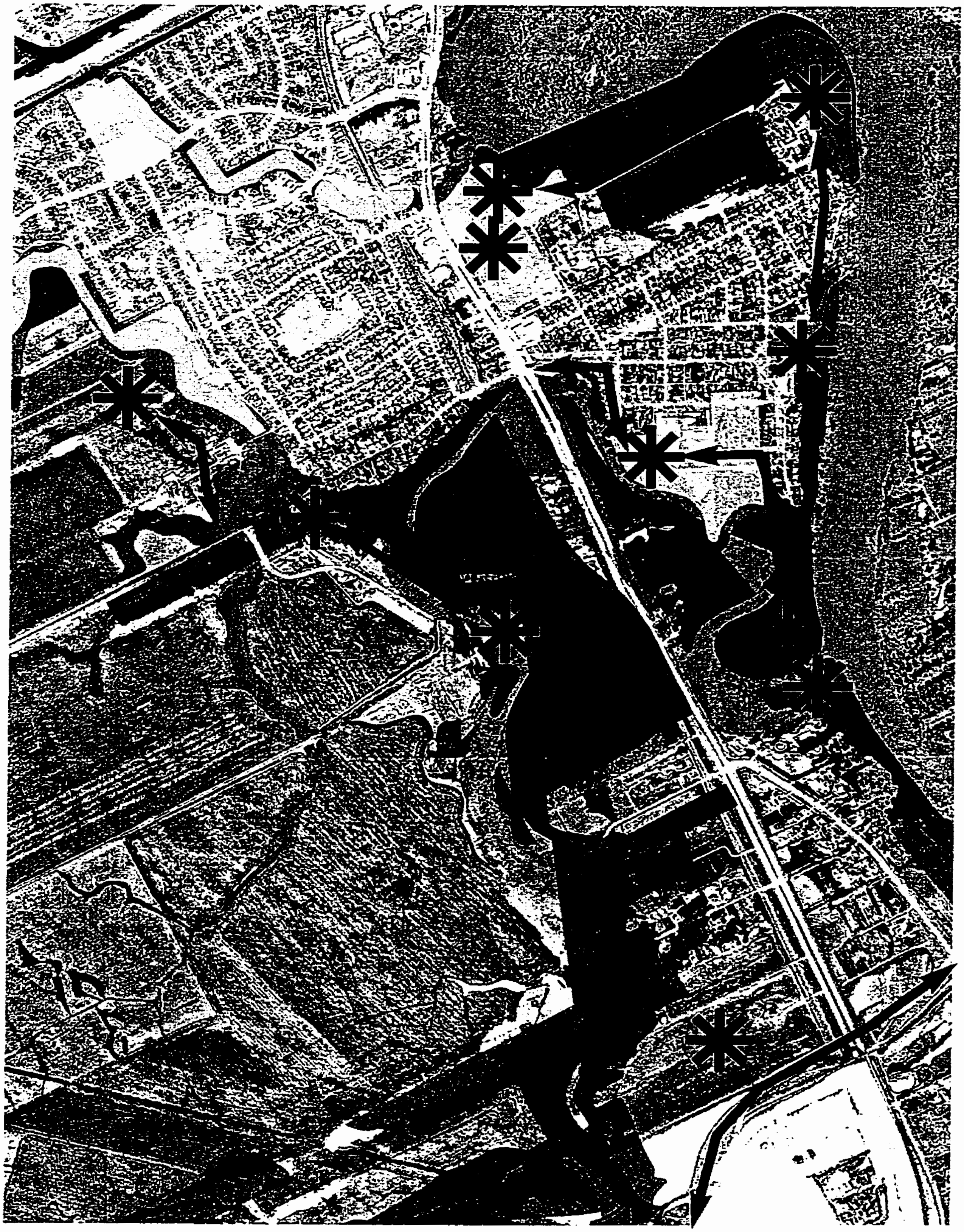


Figure 9.5.1b Important and Future Nodes, and Linkages

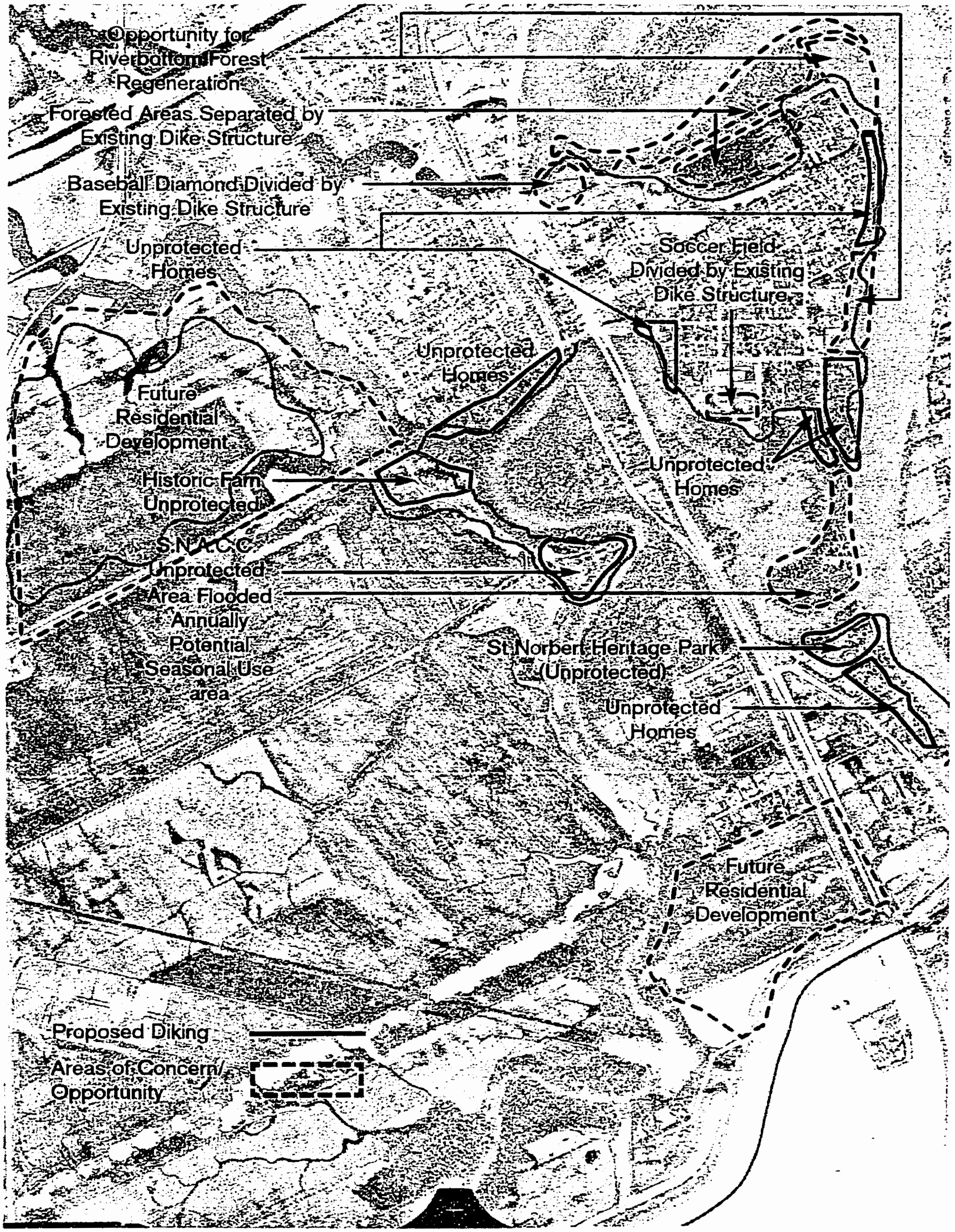


Figure 9.5.1c Design Opportunities and Proposed Dike Locations

10.0 - DESIGN PROPOSAL

"The landscape is the visible scene and, at the same time, the manifestation of all those elements, factors, influences - call them what you will - both physical and human, which give the surface of the earth its character at any given point in time"

(Lambert, 1985:1)

SECTION 10 DESIGN PLAN FOR ST NORBERT DIKING SYSTEM

Floods are a fact of life and an everyday occurrence. It is rare to open a newspaper or launch a news web browser without reading about a flood somewhere in the world. The universal method of controlling floods is by dikes and diking systems. In Winnipeg alone there are over 200 km of diking. Based on this number and the pervasiveness of the problem, there are likely tens of thousands of kms of dikes throughout North America.

Despite their frequent occurrence all over the world, dikes tend to follow a formula. They appear to be stamped out as like cookie-cutter solutions to a universal problem, disregarding context in favour of ease of construction. They are typically intrusive structures situated only for convenience of construction, and often placed where they are damaging to wildlife habitats and econiches, and physically divide communities. The divide forests, thereby limiting physical accessibility, redirecting species flow, and disrupting natural processes.

There is almost blind acceptance of their nearly mind numbing uniformity. A first step towards remedying the situation is to involve the landscape architect in the planning of these systems. The existing dikes in St Norbert are typical of those found all over North America: sod-covered, steep-sided, flat-crested, and lacking in woody vegetation. They reside on the landscape as imposing forms whose utilitarian purpose is evident in their appearance. They are both insensitive to context and lacking in visual interest.

There are three things can be done to mediate the negative impacts of a dikes.

1) Faced with an existing dike and limited space, the choices are also limited: create trails or picnic areas, add vegetation, or otherwise alter the surface appearance.

2) When the dike is pre-existing but space is not a concern, it might be possible to transform it by changing its size, height, slope and form, through oversizing or terracing.

3) When the dike is not pre-existing, the options are much broader. Of course this is the ideal situation, and one or more landscape architects should be part of the team from the earliest stage in the planning process.

In general the designs for the St Norbert diking system emphasize the establishment of minimum setbacks used in conjunction with reforestation to combine for an ecologically viable, connective buffer between the river and the dike. The form and placement of the dikes is a function of the particular design situation, and as such is directly influenced by the above principles, while still emphasizing several basic principles of ecology. The designs also emphasize the potential use of the spaces by the human community along the length of the dike, and including the dike itself. Complex, curvilinear, soft edges, rather than rectilinear ones, are used whenever possible to promote species movement, diversity, and higher usage patterns. The preferred slope treatment is always indigenous vegetation.

10.1 Terrace and Escarpment Forms (Figure 10.1a, b)

One way of integrating diking into the urban landscape is to create a system which allows the structures to be used for purposes other than, and in addition to, the primary one of water control. A restructured or augmented diking system could take many forms appropriate to the local situation. One approach is to draw inspiration from, and incorporate into the design, features from the topographical and physiographical landscape of Manitoba. These could include organic forms found in nature, such as river terraces repeating the ancient forms of the Manitoba Escarpment, eskers and erratics echoing glacial deposits, and geometry reminiscent of ripples formed on the bed of glacial Lake Agassiz, which had a significant influence on the present landscape of the Red River Valley. Where space allows, a dike can be 'opened up' to form spaces which complement existing landscape components and provide multiple alternative uses. To the local community, the existence of the dike is a reminder of these forces, and they could be celebrated within the design of the structures repeating the forms of natural flood terraces in terraced parks which demonstrate seasonal fluctuation and the conditions that influence these changes.

The basic stepped escarpment, broadened across the top and terraced on the landward side, could replace the narrow, linear dike. This landform is entirely alterable, while maintaining necessary elevational limits to suit the circumstances and context into which it is drawn. Variations in width and height of a terraced structure would not only depart from the 'typical' dike form, but would also provide possibilities for alternative uses and functions. Some portions of the dike could be designed for elevated viewing of the surrounding landscape and river, or for viewing sporting events.

Along various sections of the dike the height or width could be exaggerated so as to provide additional recreational opportunities. An expanded top surface would accommodate tee boxes for a summer driving range, and in winter could be flooded to create hockey or

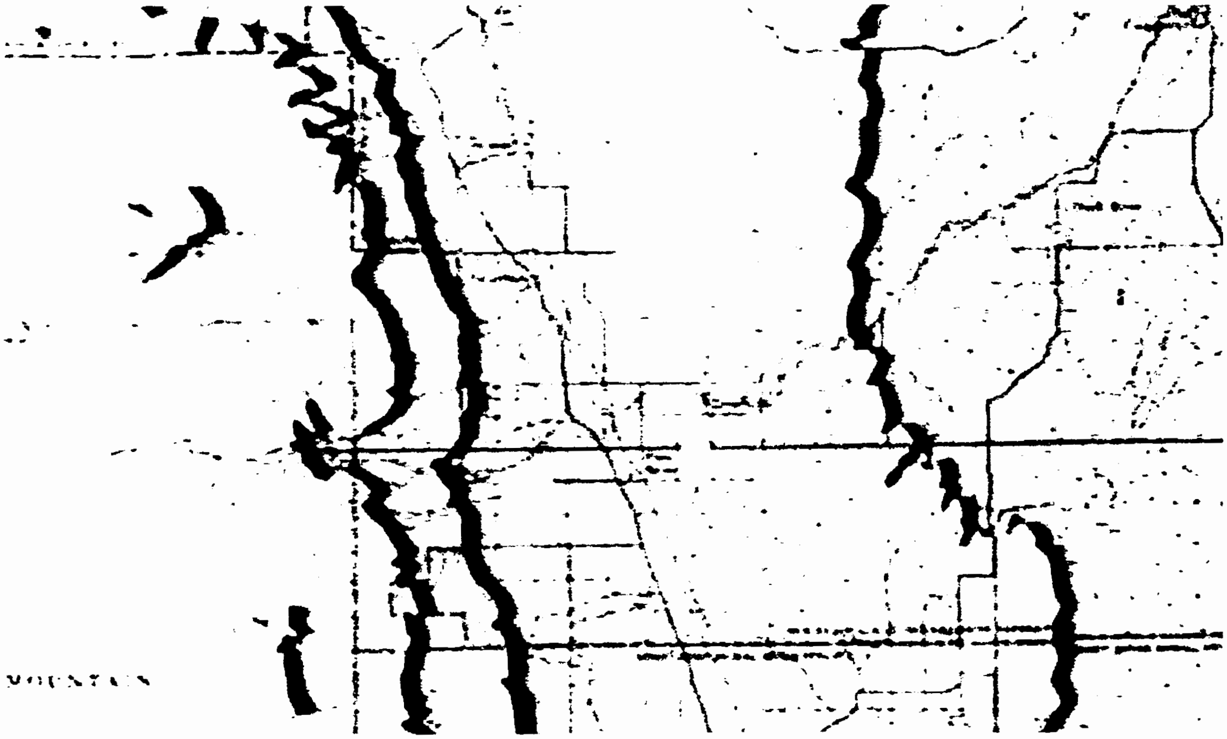


Figure 10.1a The natural formation of the Manitoba Escarpment

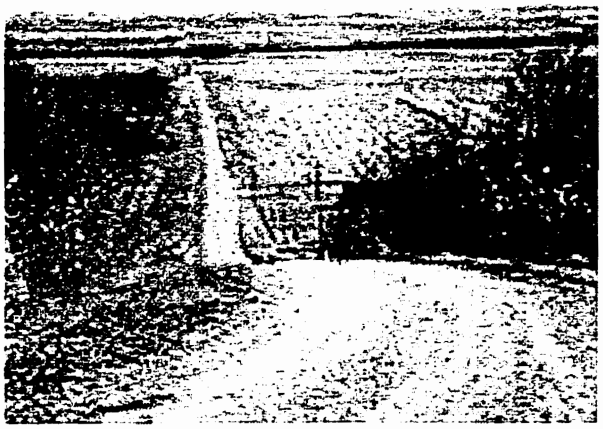


Figure 10.1b The Manitoba Escarpment

recreational skating rinks. Increasing the dike's elevation could provide a toboggan hill. Other parts of the dike which cannot be widened would be natural venues for jogging, hiking, cycling, and cross country skiing. All these activities could also take place on various terrace levels as well on on the dike crest.

The proposed augmented or rebuilt structure would, in some places, come into direct contact with the agricultural component of St Norbert. Given the large amounts of space available for expansion, the dike could then be opened out into the surrounding agricultural landscape. Wide terracing would allow for the cultivation of farm crops on expansive, gently sloping terraces, or for experimental gardens, horticultural test sites, or kitchen garden allotments.

The changing levels within a terraced structure would also provide a variety of species specific environments that would promote floral and faunal movement along the dike's length. Depending upon spatial constraints, viable ecological corridors could be created along the terraced flanks to help draw together disparate ecological niches, increasing habitat potential, and improving species movement between patches.

The master plan shows the relative proximity of each of the design sites within the larger context of St Norbert. (Figure 10.1c)

10.2 Reclamation - Villa Maria (Figure 10.2)

The coincidence of landscape elements in close proximity to the river and subsequently the dike could be addressed as part of a reclamation program for the river in times of flood, whereupon these areas could be designed to accommodate flood waters. This would serve dual purposes. The first would be the storage of excess flood waters; the second could be the expansion of the riparian zone between the river and the setback dike. The structure could then become a series of elevated terraces within the landscape that encompasses these spaces without losing its primary protective purpose.

As identified in the large scale analysis, the riverbottom forest situated to the north of Villa Maria and to the east of Heritage Park is currently divided into two smaller areas by a dike that bi-sects the site. This division appears to have compromised the health of the forest to the south of the structure, as reported in a report by the Manitoba Critical Wildlife Habitat

Figure 10.1c Master Plan Showing Design Interventions

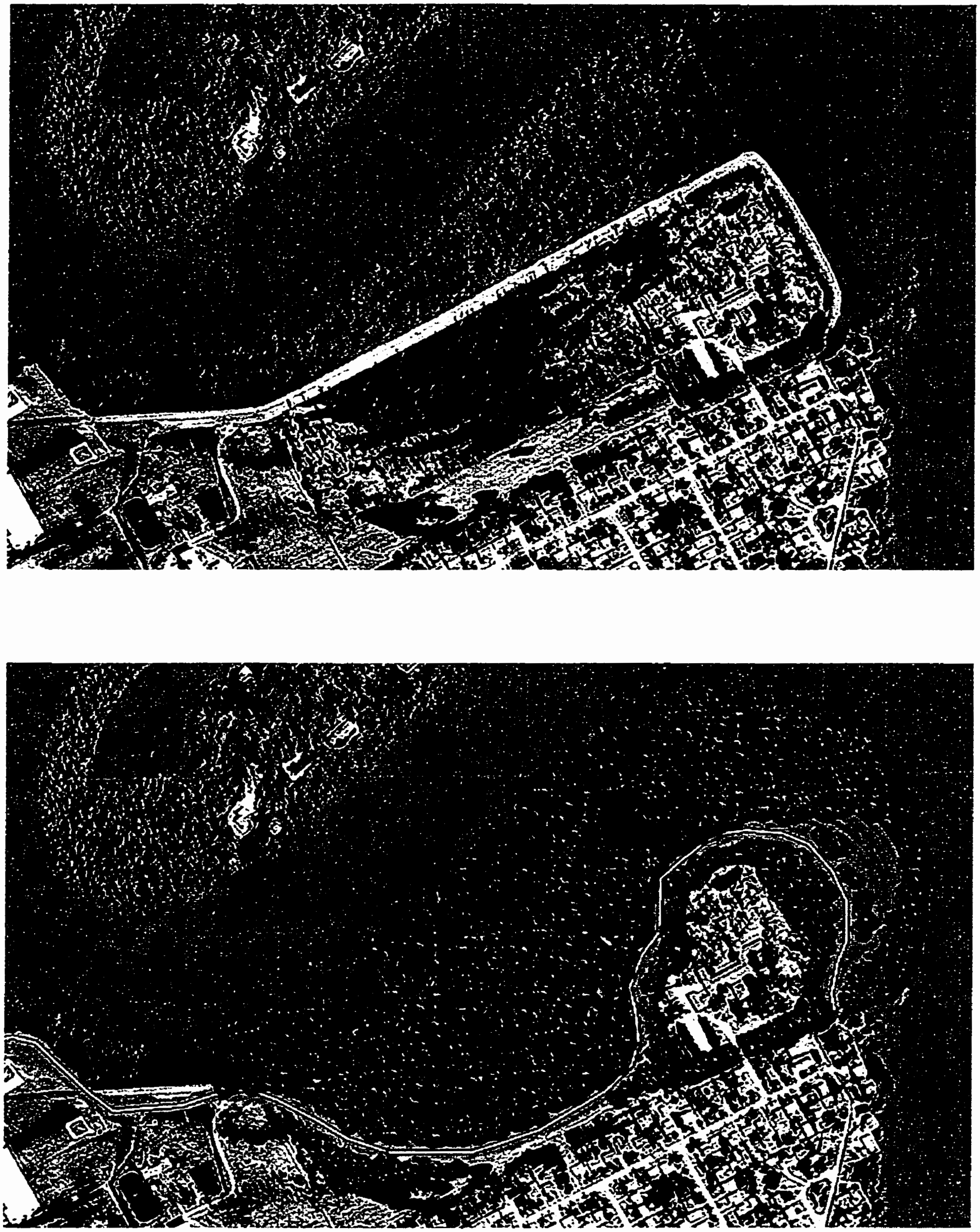


Figure 10.2 Above (Before), Below (After), Re-established forest, Relocated dike, and 'Flood Gallery'

Society. The problem is simply that the presence of the dike has disrupted the natural cycles of flooding and deposition, essential to the forest typology. In order to correct the problem, the redesigned dike is situated further to the south thereby increasing the viable patch area and reintroducing the "unhealthy" portion of the forest back to the natural cycle of inundation.

The design of this segment of diking would take advantage of the panoramic vantage point along on the inside curve in the river. By allowing the structure to expand out into a series of large terraces to form a "flood gallery", the stepped landform would provide viewing platforms for watching seasonal fluctuations in river levels and ice flows. Winter uses could include toboggan runs and cross country skiing.

10. 3 Heritage Preservation - St Norbert Heritage Park (Figure 10.3a, b)

Highly prized, and carefully preserved by local residents, the historic buildings and early settlement historiana of St Norbert Heritage Park all reside below the 1:160 year flood. As with many parts of the community, they have been protected by ring dikes during flood emergencies. Analysis of local flooding conditions shows that St Norbert Heritage Park will likely flood in the near future, and the present system of temporary measures will prove to be insufficient. The problem must be addressed as part of current flood protection planning. The design solution must include features that will help to reinforce the rapidly eroding riverbank.

The design suggested here is a vegetated earthen structure that twists its way around the park. Incorporated into the structure is an interpretive pathway that guides the visitor through the historical events surrounding the artifacts and buildings on site. The structure extends out to encompass several unprotected homes along the banks of the Red River to the south.

The proposed structure would provide an elevated vantage point from which to view the surrounding landscape and riverene context. An expanded crest would allow for a viewing platform. Due to spatial constraints, the structure would need to be located at the east end of the park, adjacent to the Red River. It could be designed with a toe that provides reinforcement to the rapidly eroding banks of the Red along the east face. As the park is at the junction of two rivers, the first structure would need to be complemented by landforming along the banks of the La Salle River to the north. Each of these could be designed with curves and niches so as to accommodate an undulating pathway, seating, and interpretive

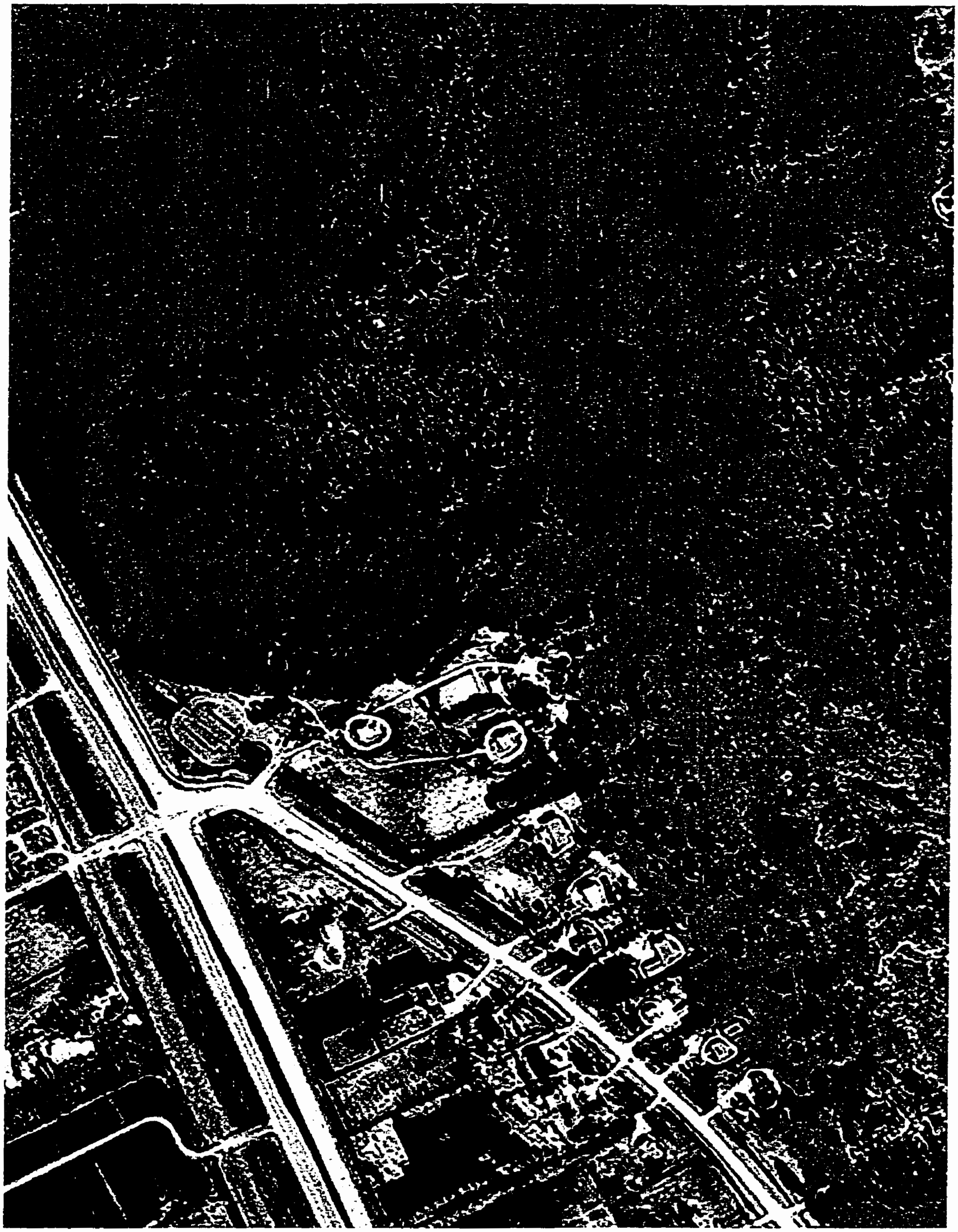


Figure 10.3a St Norbert Heritage Park, anually flooded site, and unprotected residences

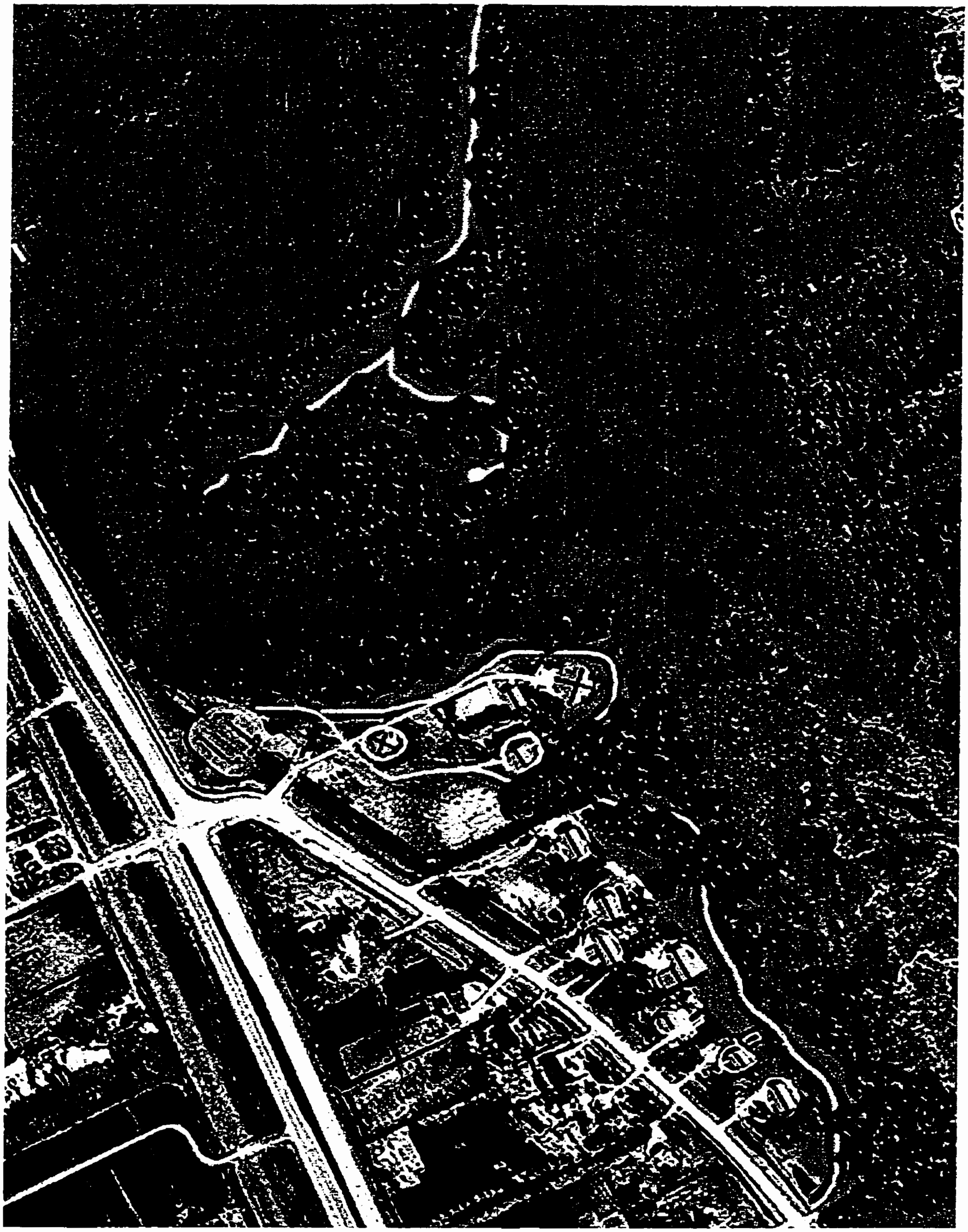


Figure 10.3b St Norbert Heritage Park, seasonal use site, and now protected residences

signage for the local context and park itself.

10.4 **Art Walk** (Figure 10.4a, b, c)

The St Norbert Arts and Cultural Centre (S.N.A.C.C.) is an important part of the cultural mosaic of the community. When rising flood waters in 1997 threatened the newly renovated structure, a temporary sandbag dike was constructed. Situated on a bend in the La Salle River, the likelihood of this event replaying itself is very high. The only way to provide permanent protection for the historic building is to build a permanent flood protection structure that would almost completely surround the site, that is, a ring dike.

The primary purpose of the dike would be to protect S.N.A.C.C., but lack of space between the centre and the river works against any major design interventions. The suggested structure is compressed to resemble a steep-sided earthwork, and takes a serpentine shape, which follows the natural setting. The similarly shaped sacred mounds of the mid-western American aboriginal people are an appropriate model for expressing the spiritual and artistic nature of the Centre's activities. The structure winds its way around the heritage site through a series of bends in the landscape to the north, ending at the Heritage Farm adjacent to Rue Des Trappistes. The crest would include an "Art Walk" or outdoor exhibition space that meanders back and forth across the top, taking the visitor to and from various art objects exhibited in the landscape.

10.5 **Future Residential Development** (Figure 10.5a, b, c, d)

The likelihood of continued residential development in St Norbert is high. A site owned by Genstar Land Development Corporation is a particularly good candidate for future residential development in the near future. The site is prone to flooding, and is earmarked for future flood protection measures. This provides an opportunity to anticipate the needs of the community and incorporate a control structure into the fabric of the community at the ground-breaking level.

The suggested design would include a golf course encircling the proposed residences. The protective dike would be broad and undulating, and woven into the contours of the golf course. Setbacks from the tributary to the La Salle form riparian regeneration zones and a future buffer zone between the development and the river. The

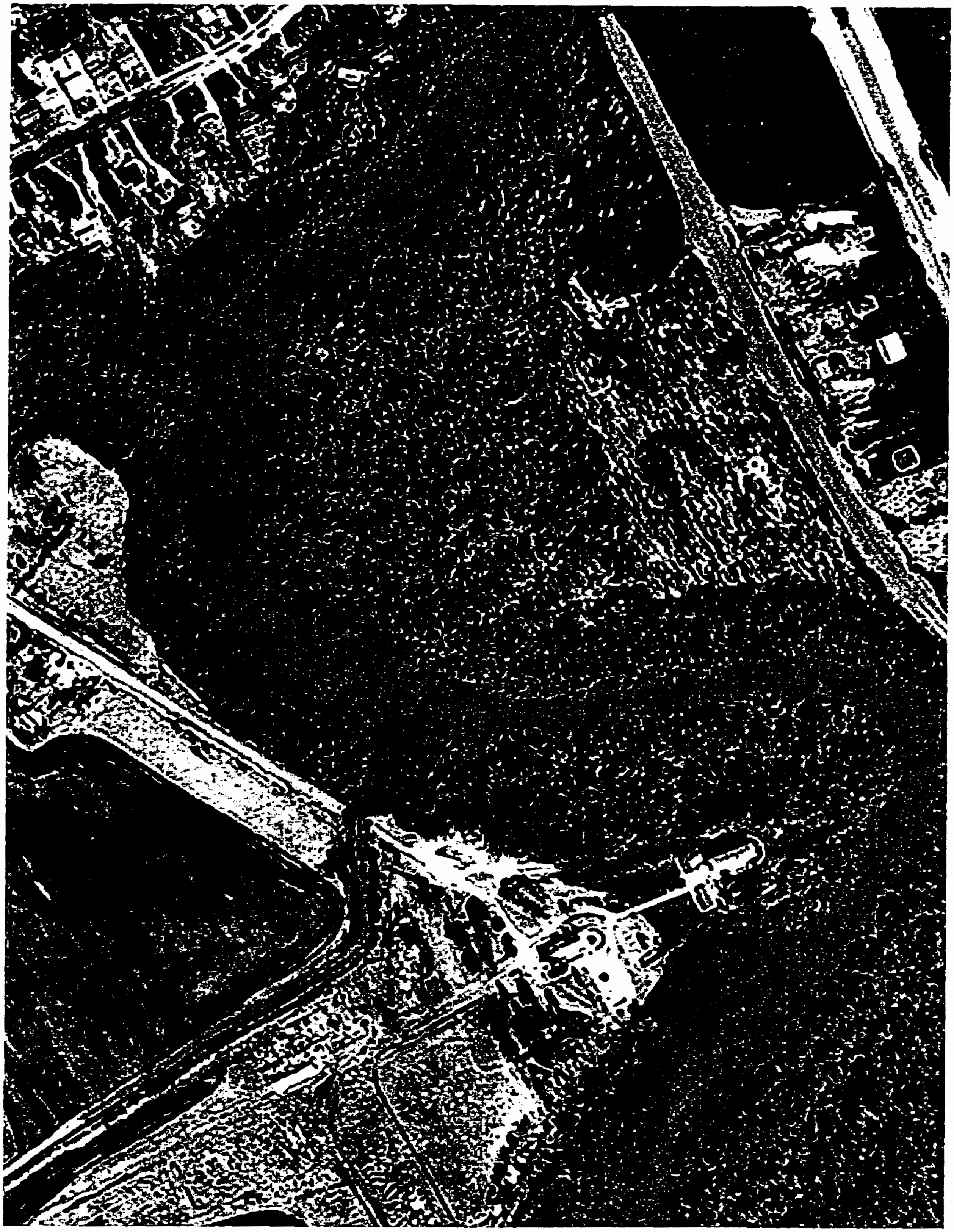


Figure 10.4a Before - St Norbert Arts and Cultural Centre

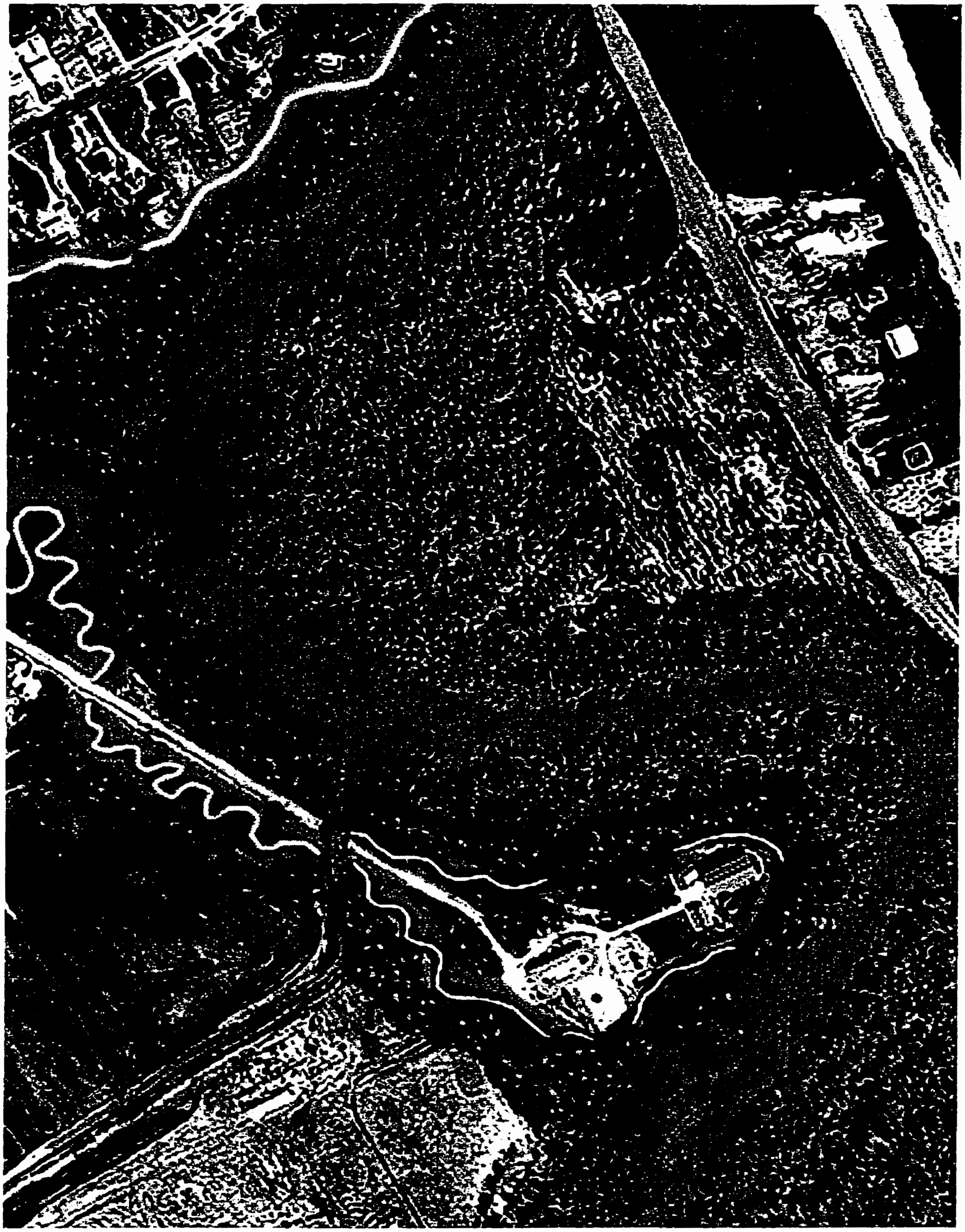


Figure 10.4b St Norbert Arcts and Cultural Centre with an 'Art Walk' incorporated into a dike

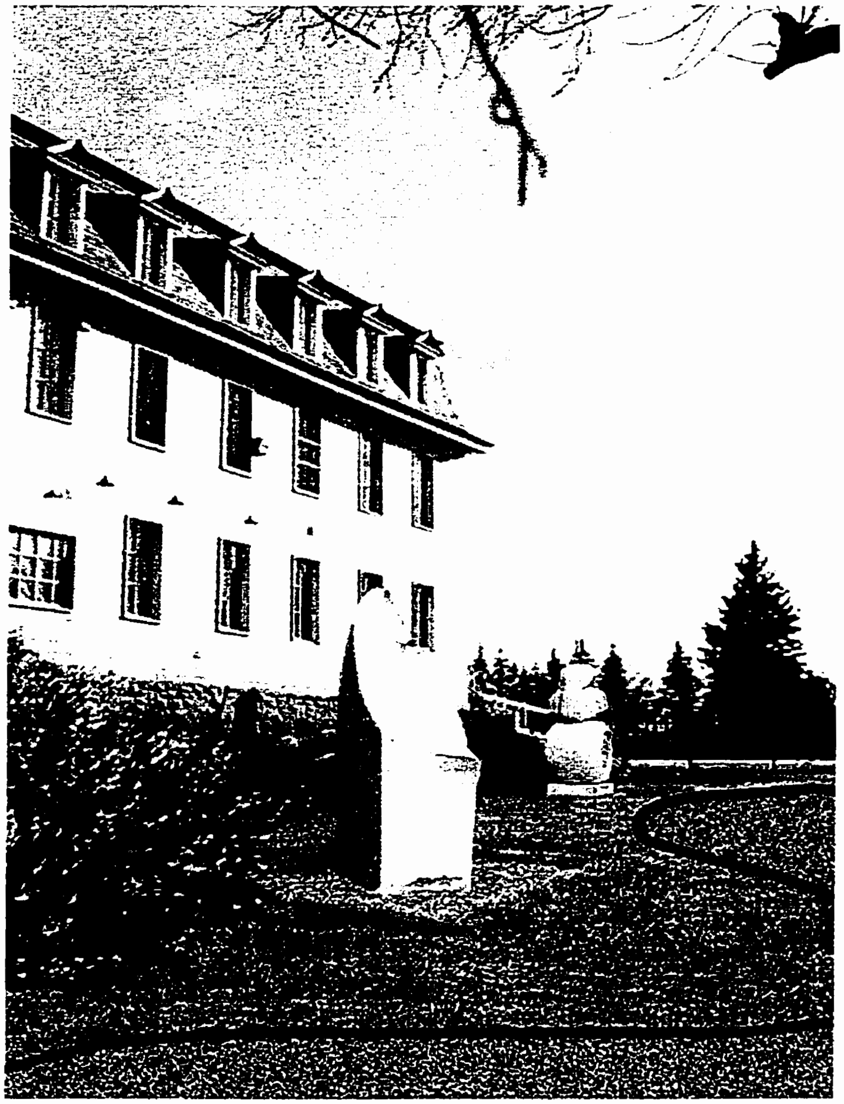


Figure 10.4c S.N.A.C.C. "Art Walk"

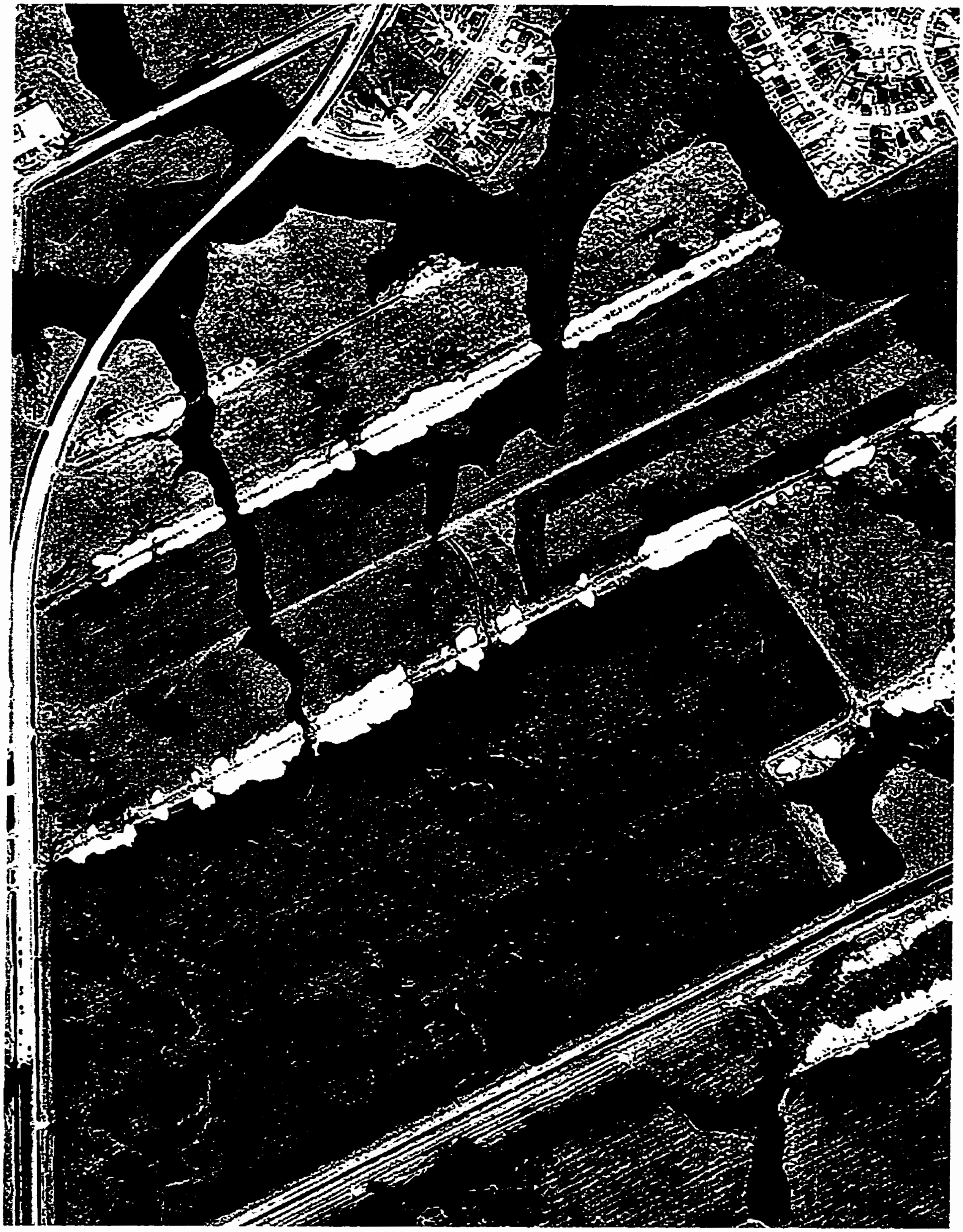


Figure 10.5a Site owned by Genstar Development Corp. - Before design of protected subdivision

Figure 10.5b Future residential development by Genstar with dike incorporated into golf course

Figure 10.5c Golf course integrated with dike

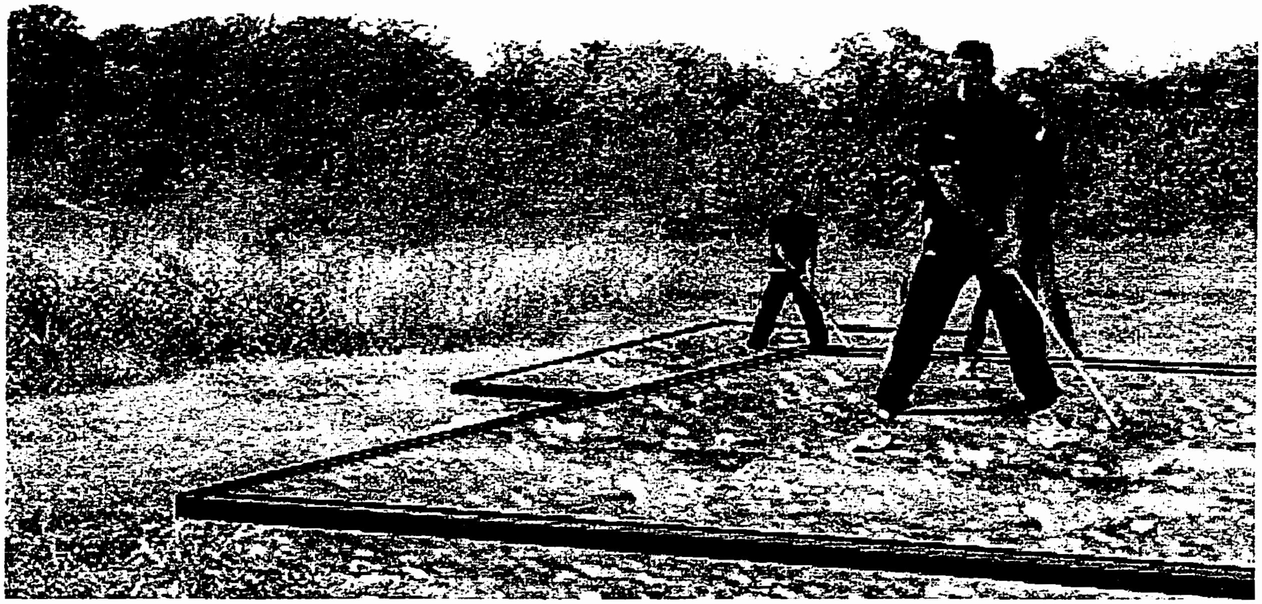


Figure 10.5d Tee boxes on extended dike crest

concept allows for passive recreation, including paths set back away from the course, while the dike incorporated into the undulations in the course provides for flood protection as well as an active recreation resource for the community.

10.6 Agricultural Dike (Figure 10.6)

The agricultural lands that make up the majority of the landscape of St Norbert will necessarily come into contact with any flood control structure. The St Norbert diking system will at various places cross the agricultural landscape. At these junctures, there is an opportunity to celebrate the subtle undulations in the prairie landscape. Inspired by the prairie escarpment, the dike could be designed so as to spread out into wide planting terraces, that could be easy cultivated. In keeping with agricultural tradition, the crest could be planted with hedgerows to help further reduce winds and therefore topsoil erosion.

10.7 St Norbert Collegiate (Figure 10.7)

This site is a large open space between the main school building and the La Salle River. The most prominent feature of the site is a 2.5 metre high earthen dike that bisects the space, but is incomplete, terminating abruptly at the centre. The site is bordered on three sides (east, south, and west) by remnant riverbottom forest. The eastern edge is a dense and relatively healthy site, known locally as "Sherwood Forest". The western and southern sides, in contrast, are narrow wooded bands confined to the lowest area within the site. The low area to the south consistently floods each spring, and has been stripped of nearly all of its original riparian habitat. The Flood Protection Level (F.P.L) is 232.78 metres at the west end of the site at Rue Campeau, and 232.73 metres at the east end of the site near Rue St Pierre. Given the present contours, more than half of the school grounds are below the average F.P.L.

There are two primary activity areas within the site: a playground at the north-west portion of the site, and a soccer field along the north border. The soccer field is now truncated by the earthen dike along its southern length, and unusable for its initial purpose. The school had previously been very involved in soccer, and took great pride in their teams. The destruction of the field effectively eliminated the school from provincial competition and made hosting of tournaments in St Norbert impossible. The local community continues to use what is left of the field on a regular basis for a variety of pick-up games.

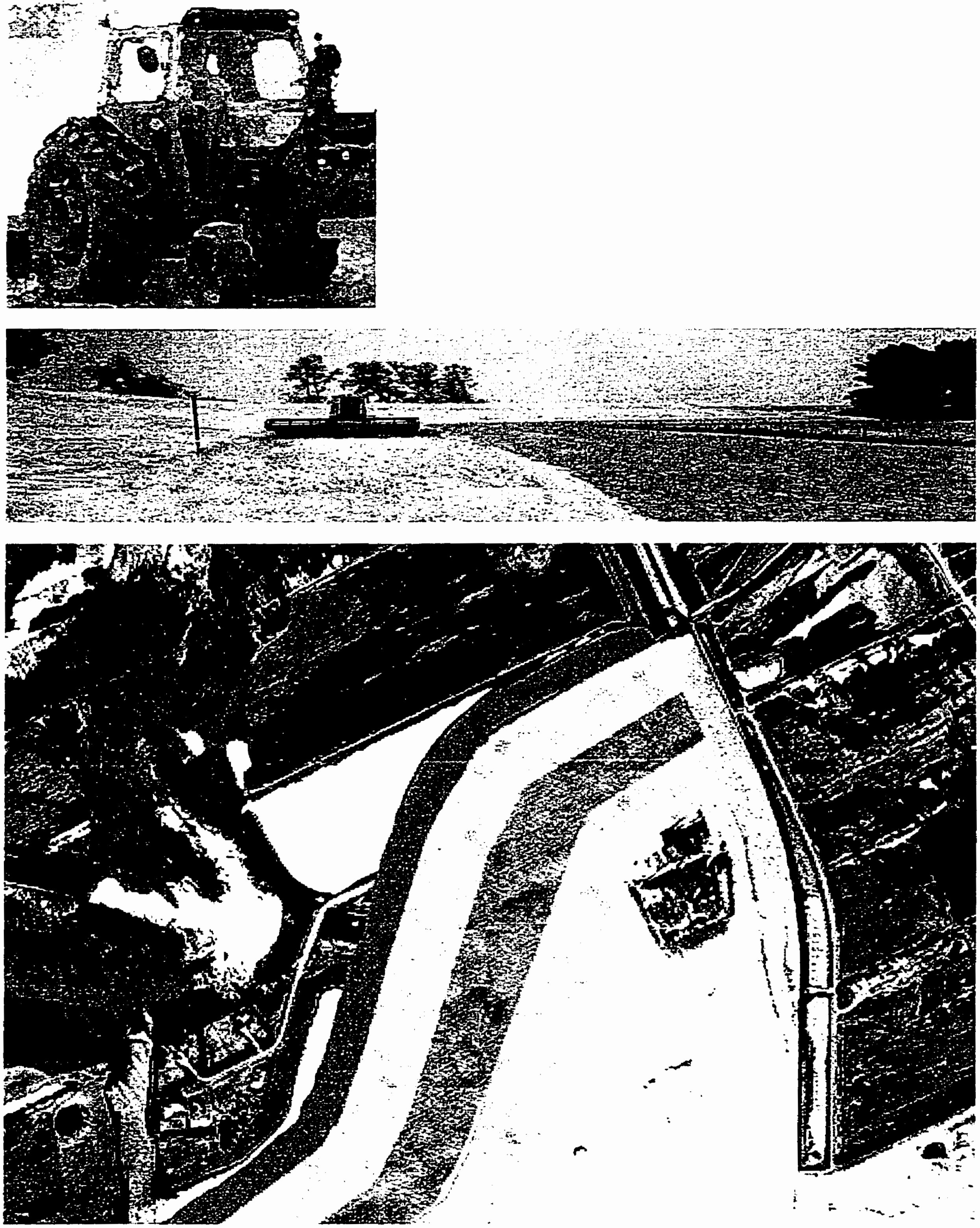


Figure 10.6 Agricultural Dike

Figure 10.7 St Norbert Colleg

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2) Stone Flood Columns mark
3) Curvilinear dike pathway de
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7) F.I.F.A. Regulation size socc
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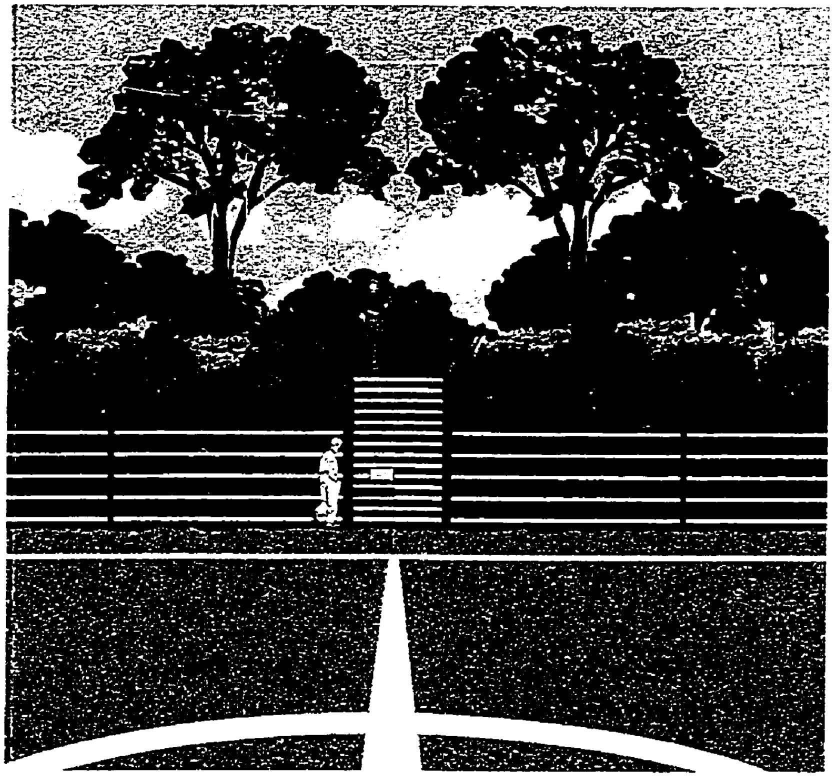
8) Establishment of a needed
9) Seating opportunity for view
10) Proposed dike joins existin

Figure 10.7 St Norbert Collegiate

1) Historic bridge site is a recreational water access point
2) Stone Flood Columns mark trail entry/exit
3) Curvilinear dike pathway defines and divides larger spaces of the schoolyard into outdoor rooms.
4) Reforestation of riverbottom forest habitat helps connect the forest structure, and helps protect the dike's structure. Setback distance is optimized for river the size of the La Salle.
5) Bleachers built into dike slope give elevated vantage point overlooking the playing field.
6) Trees drawn through from the riverbank to help define the large open spaces.
7) F.I.F.A. Regulation size soccer field replaces truncated field, oriented to minimize sun glare
8) Establishment of a needed bus turnaround.
9) Seating opportunity for viewing soccer games.
10) Proposed dike joins existing dike.



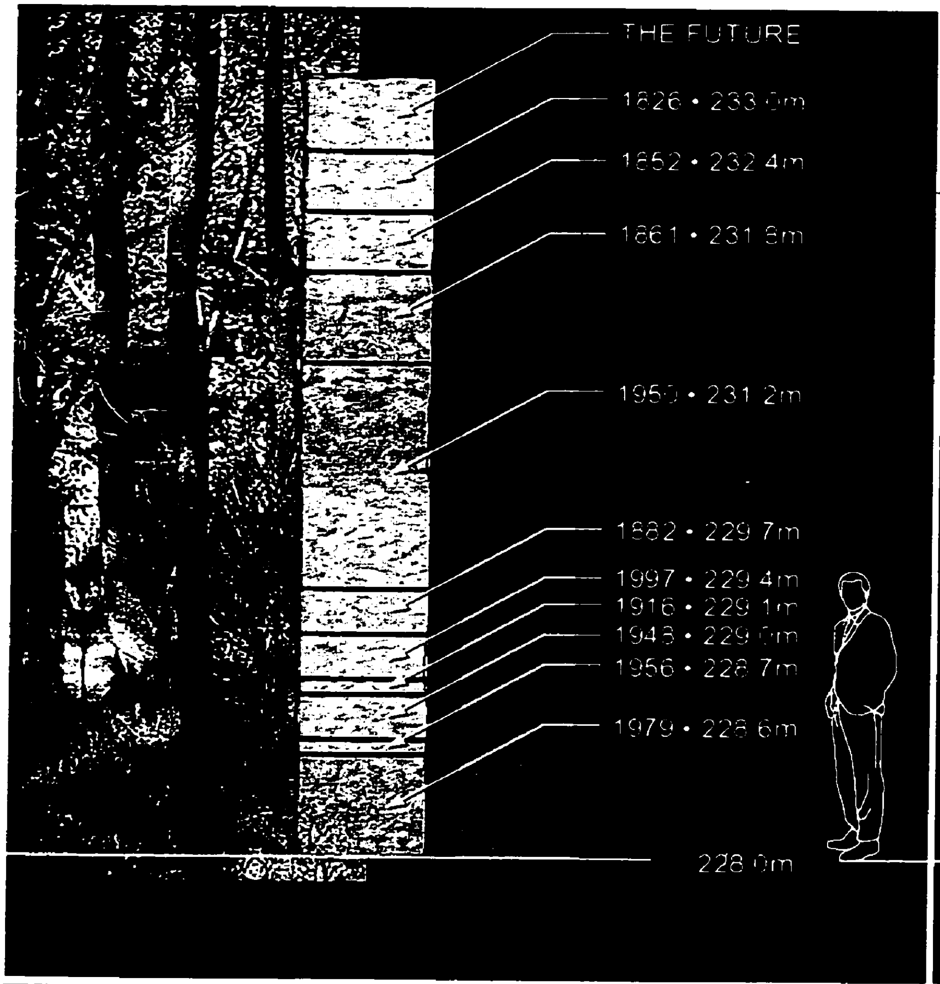
The general goal here was to give some definition to the space and allow for a variety of activities. A particular goal was to restore a full sized soccer field, in response to the community and school's enthusiasm for the sport. The suggested design strategy is to manipulate the dike and school grounds to improve usability, while at the same time enhancing the existing riparian remnants as an ecologically viable buffer. The design preserves the integrity of the dike, while at the same time providing a high level of safety for users.

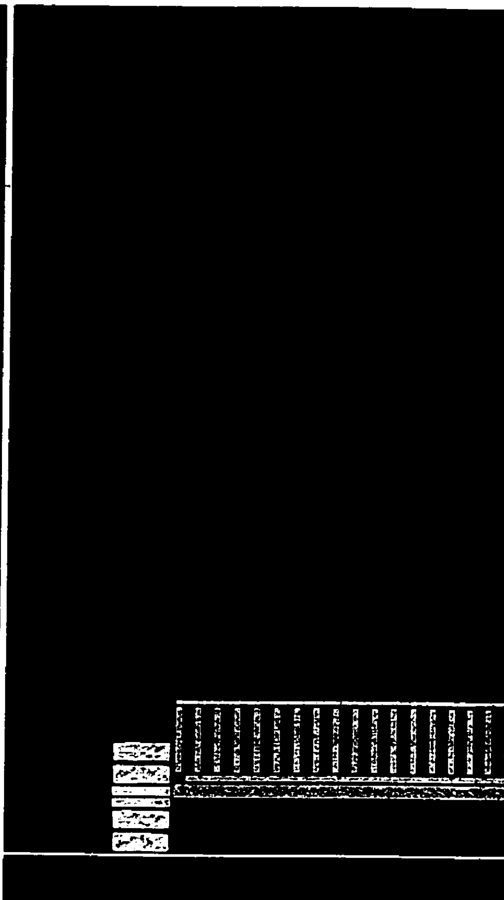
The dike itself should be relocated farther south to enable a re-establishment of the once existing riparian buffer, and to make room for the other main feature of the proposal – the construction of a regulation size soccer field, oriented so as to minimize having to look into the sun. The dike should be at the extreme setback distance to maximize habitat potential, and to optimize its protective function. The proposed dike would enter the grounds from the upper north-west portion of the site through a pair of stone "flood columns", and proceed in an S-curve following the existing river contours until it reaches the soccer field where it heads south. At the point where it passes along the western edge of the soccer field, the proposed structure would have bleachers built into its eastern slope for viewing activities on the field. The dike should then continue south and wrap around the southern end of the field to exit at the western corner of the soccer pitch, where it is marked by two more flood columns.

An important heritage artifact is also associated with the school site. The foundations of the pioneer settlements bridge are located on its western fringe along the La Salle River. The present proposal recognizes the historic site by establishing a canoe launch which could serve educational as well as recreational purposes. The launch is connected to the rest of the site via a much needed pedestrian walkway that links it directly to the school entry.

10. 8 The Cathedral Site (Figure 10.8a, b, c)

The character of the architectural elements (Figure 10.8a) is derived from the surrounding historical landscape, and is intended to reflect the sense of monumentality of the process and form of these early social spaces.





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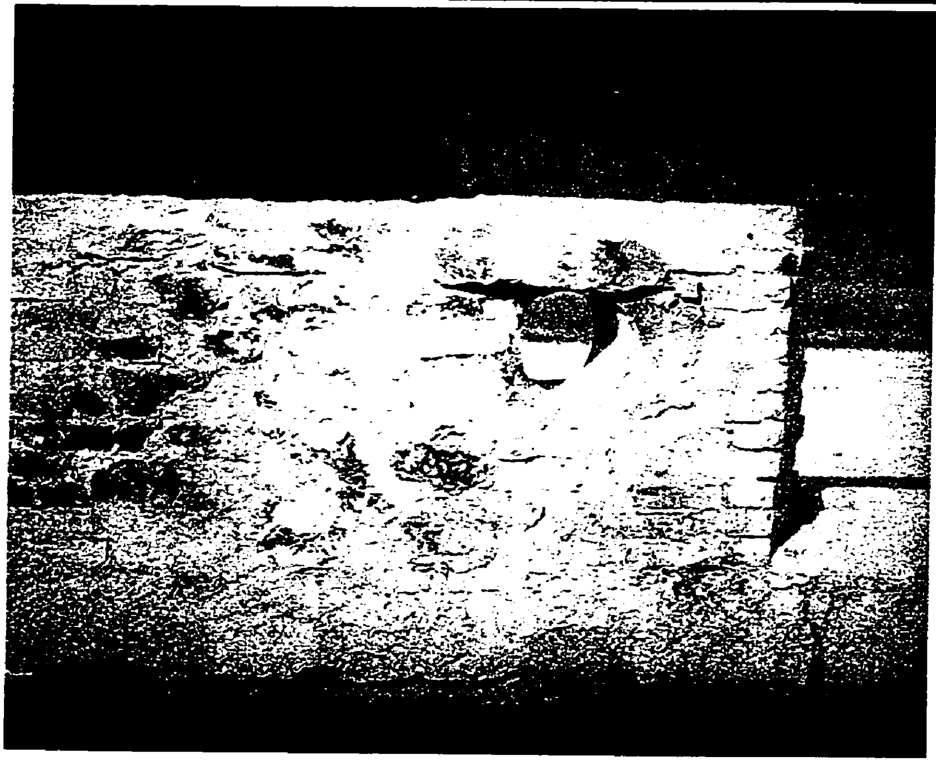

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Figure 10.8a Architectura

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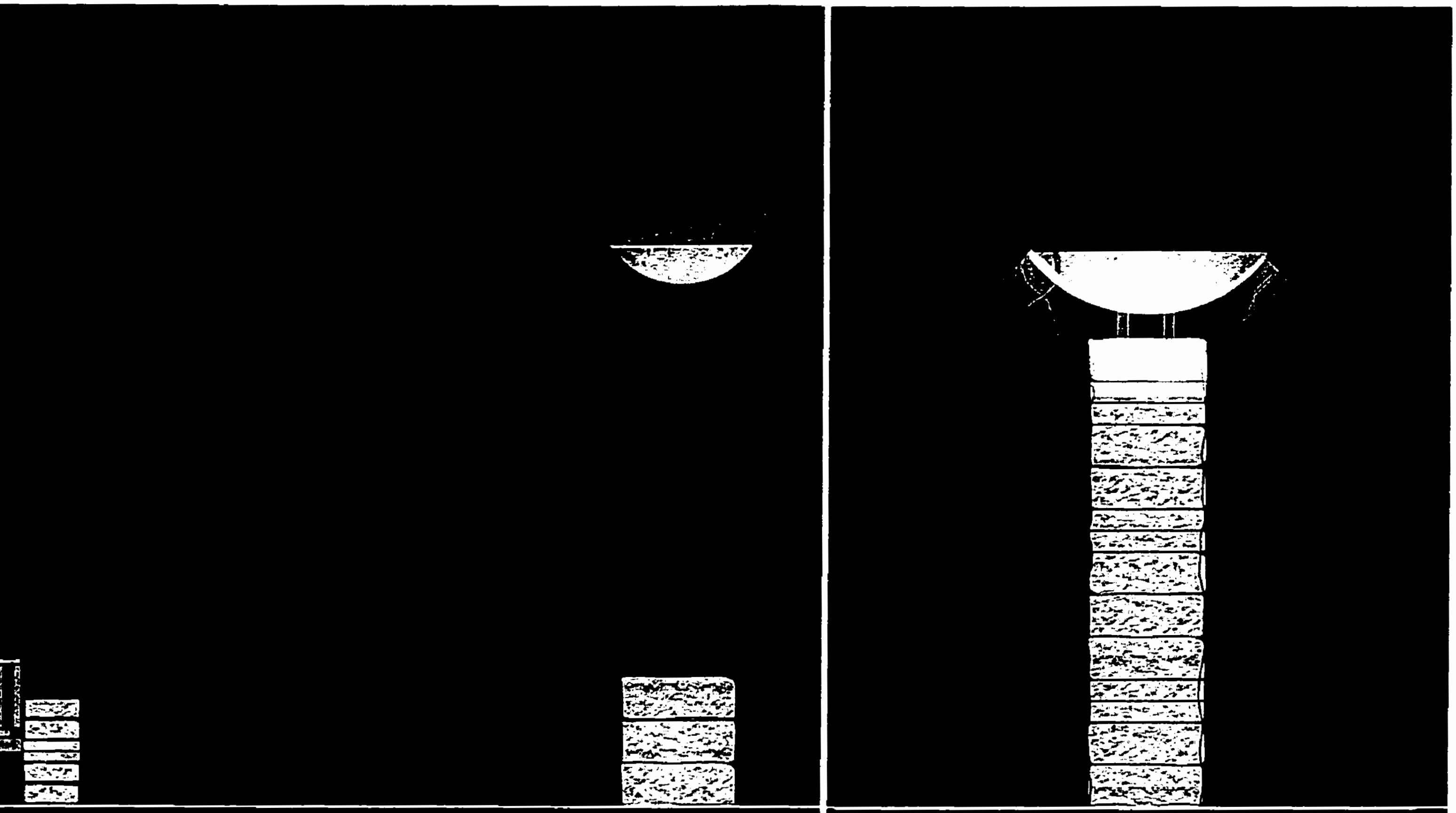

LIGHT ELEVATION
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PLANTER/ LIGHT ELEVATION
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Figure 10.8a Architectural Vocabulary

The Trappist Monastry and the foundations of scattered remnant historic buildings served as inpiration for the large stone stone elements in the design. The large scale of the stone blocks relates to the monumentality of the historic cathedrals that are assoiated with the area. The use of copper as a natural elemnent in the designs was chosen as a material that changes with the seasons recalling the annual changes in river levels that comes with each spring melt.

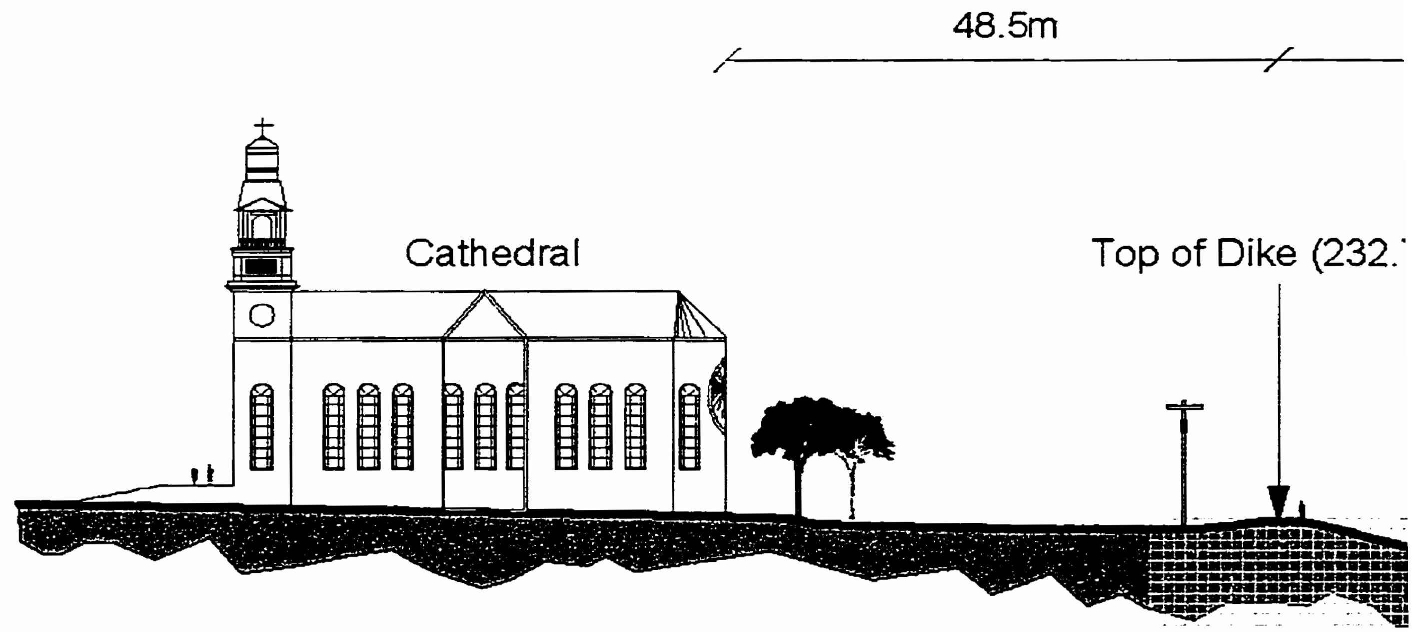
The use of lighting that is oriented toward the sky is will cast indirect light to partially illuminate tree canopies and architectural features withing the landscape.

The present Cathedral ground is a large open grass expanse that begins adjacent to the cathedral proper, wraps around the building on two sides, and flows over the dike and down the slope of the riverbank to within a couple of metres of the Red River. From there the dike continues along the river for nearly 200 metres to the north, where it ends at the residential site for this study.

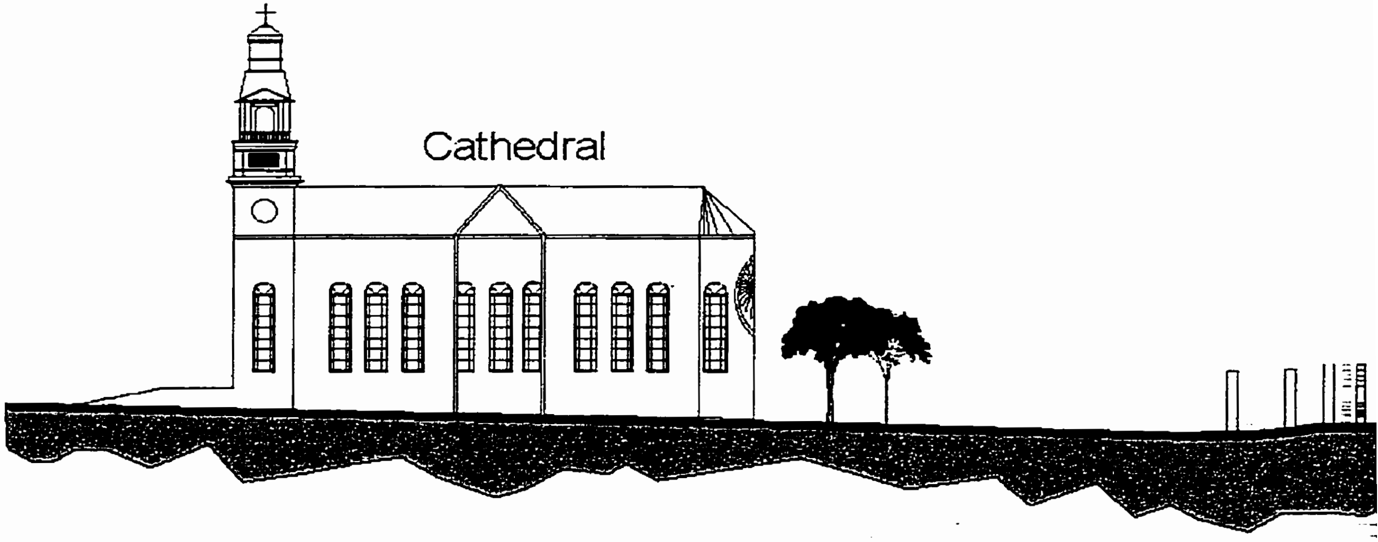
The main design focus here was, again, to re-establish the riparian buffer between the dike and the river, thereby maximizing ecological and protective aspects of the site. The proposed curvilinear dike would enter the site at the south-west corner adjacent to a Senior Citizen's residence, flanked by stone elements, where it begins a promenade winding its way north-west following the existing contours to form the eastern boundary of an unmapped and unmarked burial ground for 1500 of the early Metis founders of the area. To the east of the dike path is the regenerating riverbottom forest, and to the west is the perimeter of the burial site. The site boundary is marked with large stone columns, and is bordered by a semi-circular pathway that branches off the main dike pathway. From there it continues winding its way heading north-east past a grove of "Living Memorial" trees that separate the sacred ground from the main focal point of the site, tentatively called the "Flood Fountain", is located at the terminus of Rue Du Couvent. This space is intended to serve as a gathering place for visitors, for informal church gatherings, and as a venue for a variety of activities and events undertaken by the occupants of the Senior's and clergy residences. The fountain is surrounded by a ring of trees which overhang a circular arcade of stone columns, and provide both shade and a feeling of enclosure. The focal point of the space is a large stone column set into the centre of the fountain, at an elevation which will allow it to depict the different historic flood levels experienced in the area. The combination of column and water is intended to symbolize a flood level meter.

The outer circle of trees is framed in by a series of "flowing" retaining planters that hold back the structure of the dike and create a further sense of enclosure to the space. These elements have surfaces that would be amenable to relief images of the local culture or history worked into the outward surface. The design incorporates two smaller, but needed, seating areas that stem off the dike structure providing for interactive spaces for the two residences located at either end of the site.

The dike pathway continues from the fountain area and winds its way back toward

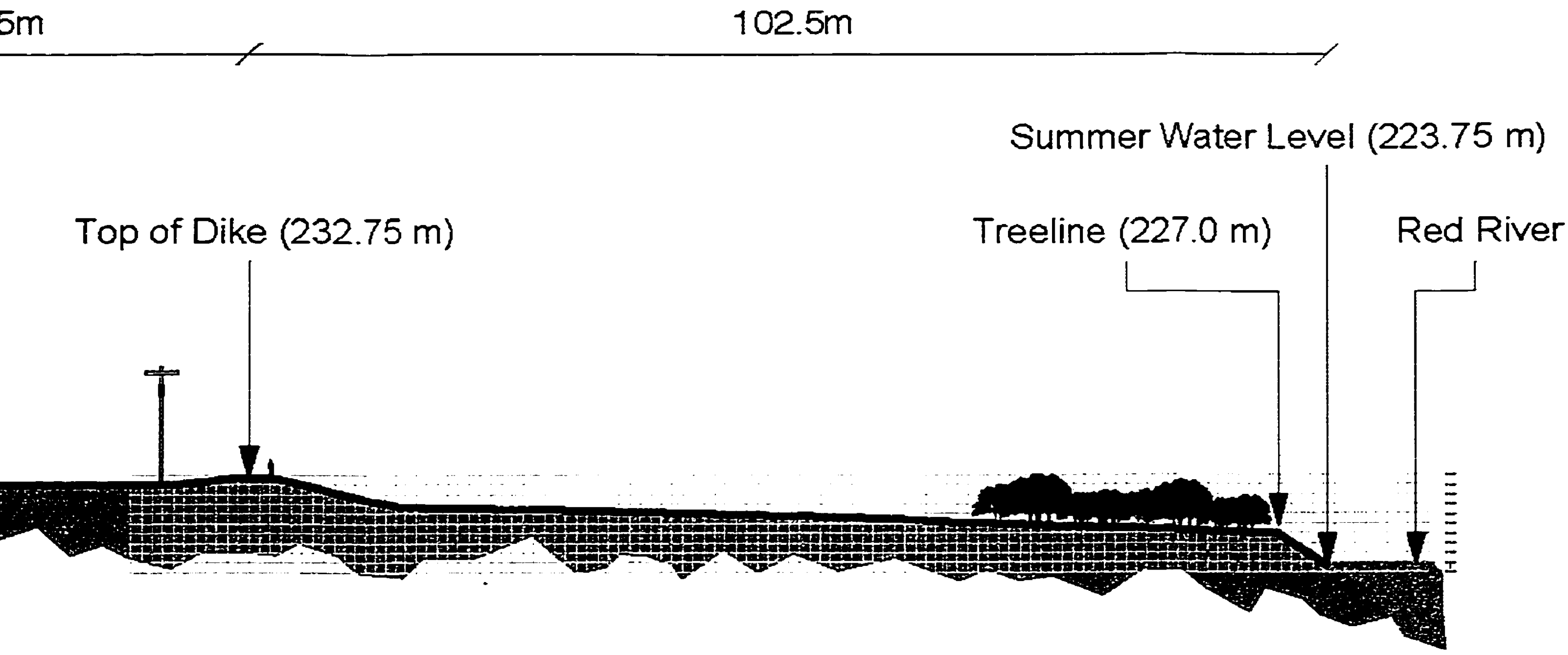


ST. NORBERT CATHEDRAL SECTION - EXISTING



ST. NORBERT CATHEDRAL SECTION - PROPOSED

Figure 10.8b Cathedral Sections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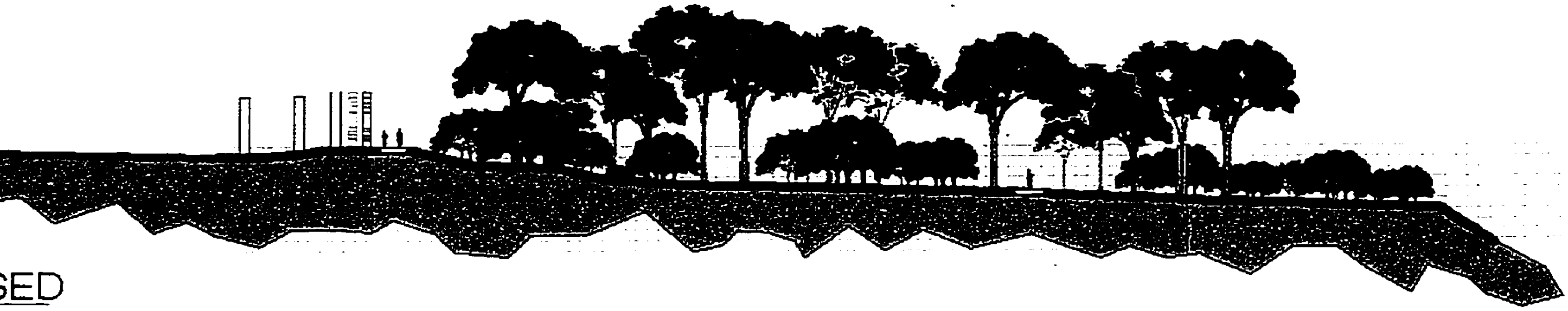

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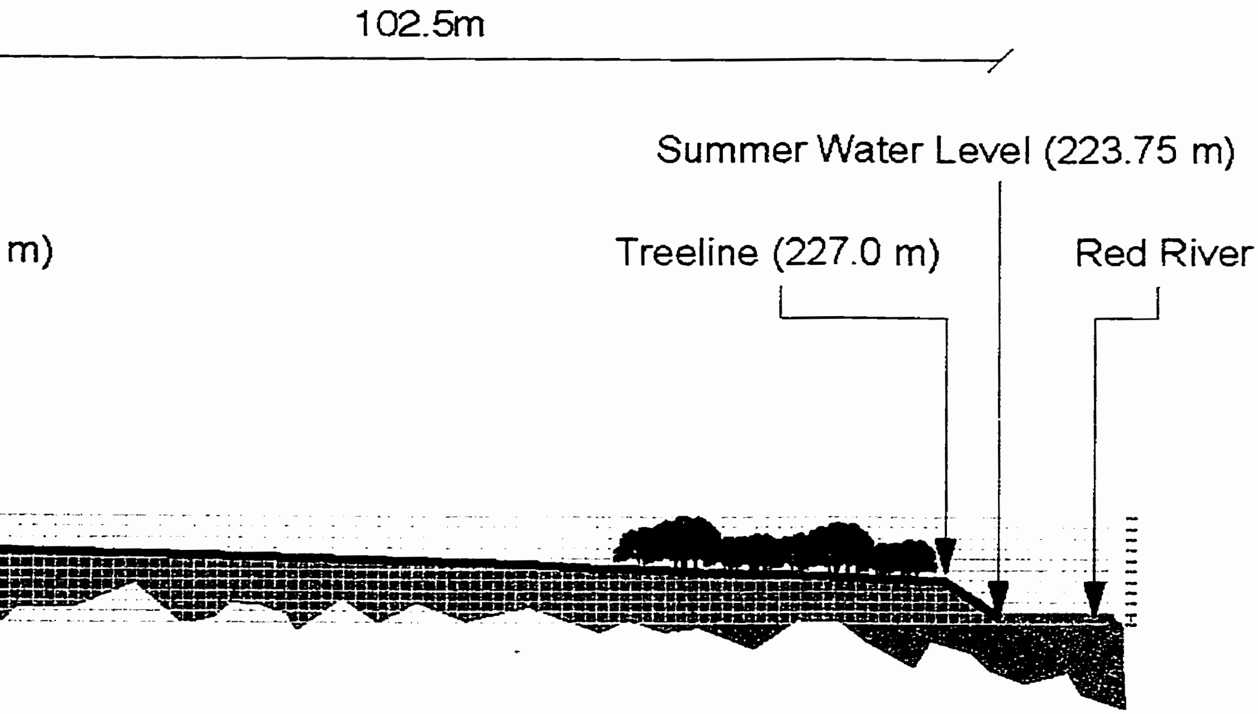
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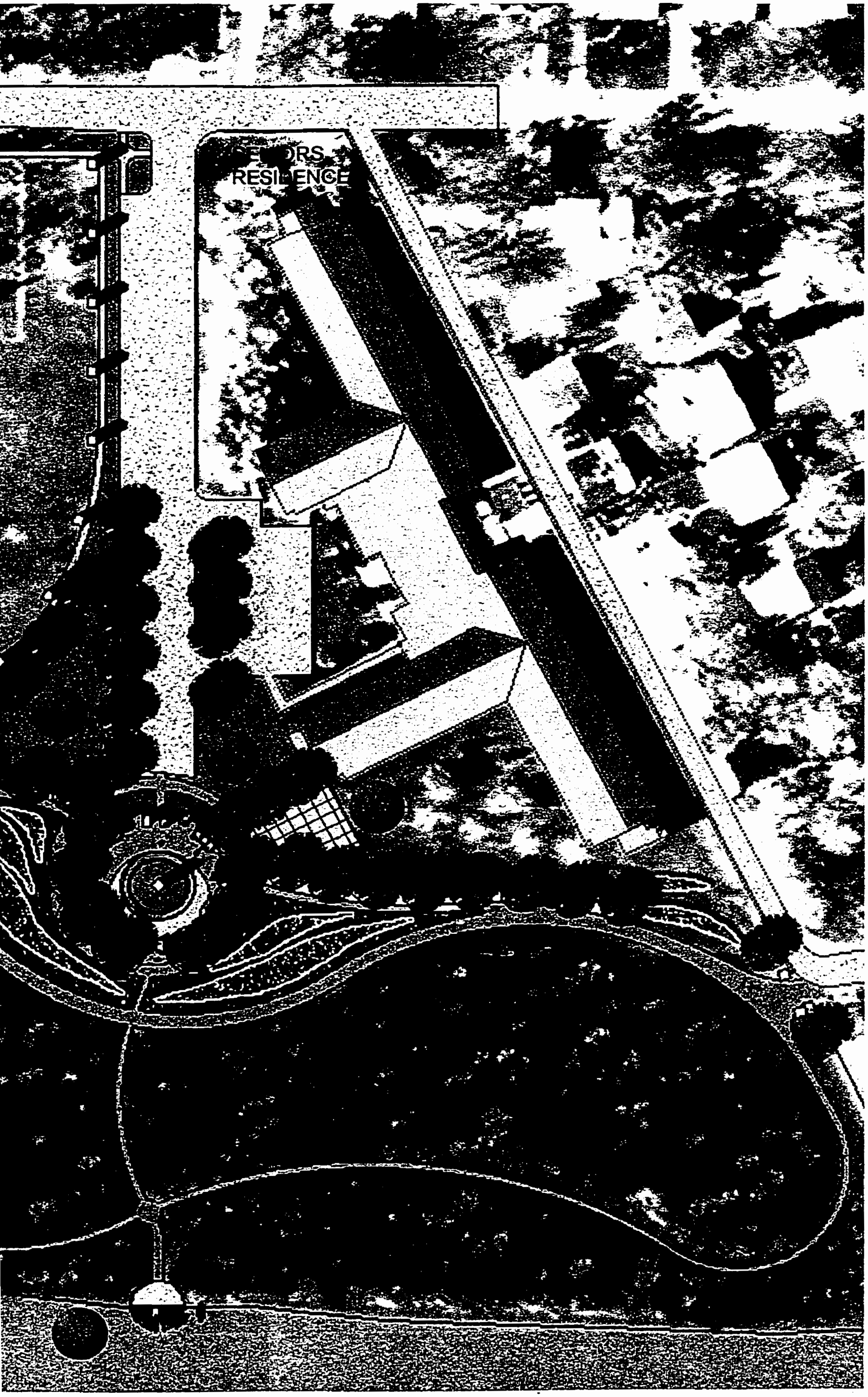

Figure 10.8c St Norbert Cath

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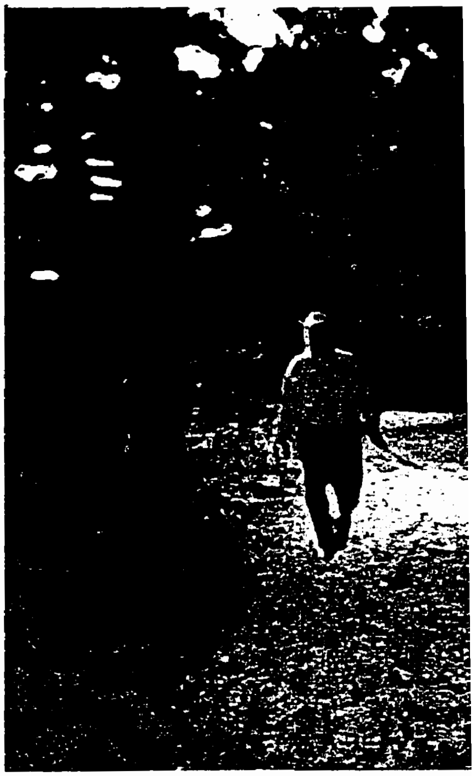
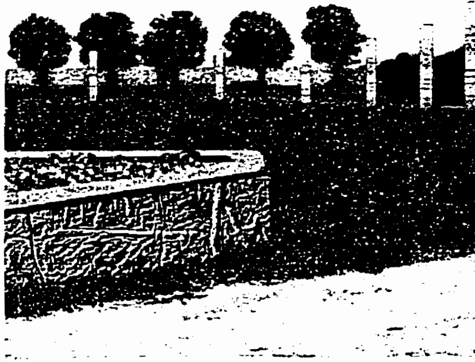




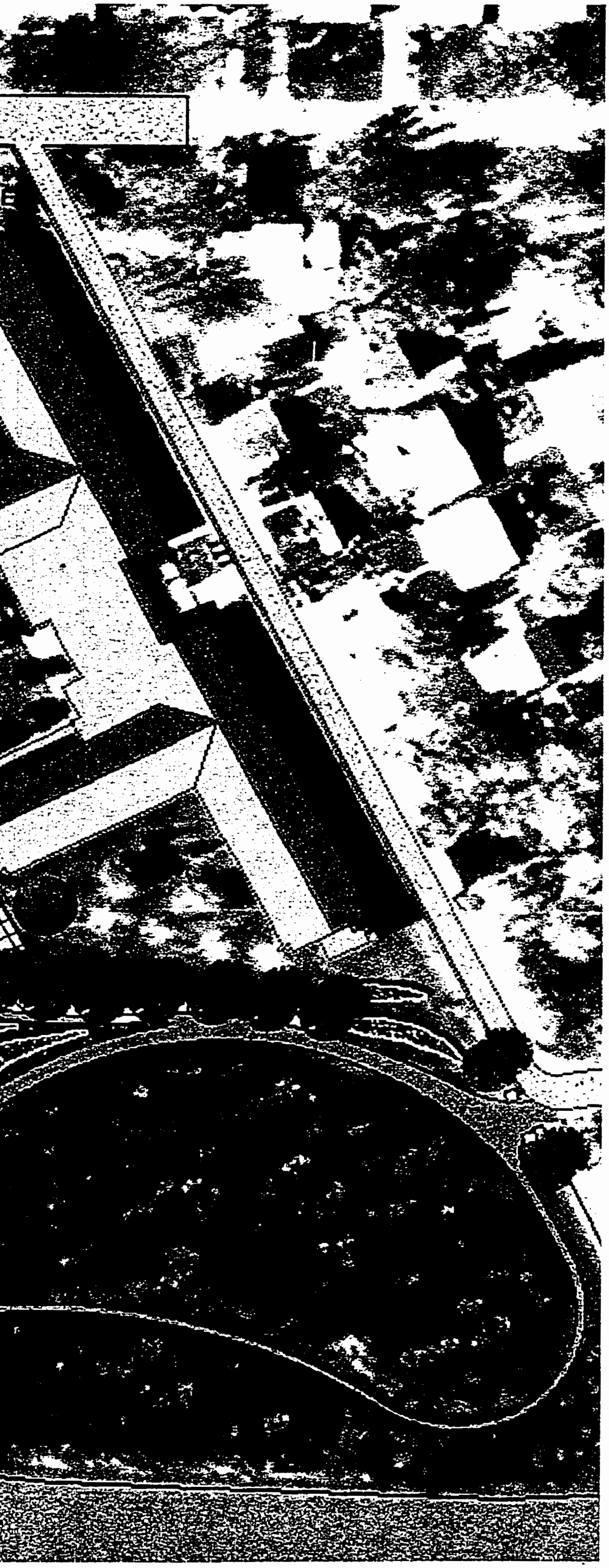
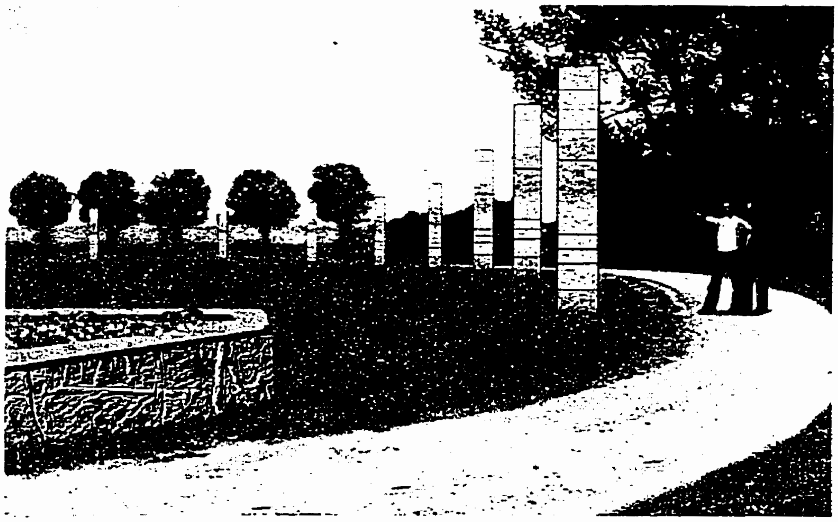


Figure 10.8c St Norbert Cathedral

1) Design opportunities - New seating areas with gardens for the seniors residences.
2) Flowing planters/retaining walls draw inspiration from flood terraces
3) 15 stone columns delineate the burial area of 1500 Métis.
4) Grove of trees is a living memorial, and separates the "Flood Fountain" from the sacred space.
5) The Flood Fountain is a gathering and learning space that illustrates historic flood levels.
6) Historic Ferry site is now a boating and fishing dock.
7) Natural drainage area is maintained and enhanced.
8) Existing access for seniors is enhanced with a dock.



the river at the terminus of Lord Avenue. It then leaves the dike, changing in dimension and texture to wind its way back through the re-generating forest, where it intersects a central axial path that retraces an old access road to a historic ferry site on the banks of the Red. A proposed canoe launch celebrates the site, and is one of two that provide access to the Red River for fishing or small craft boating, and mooring.

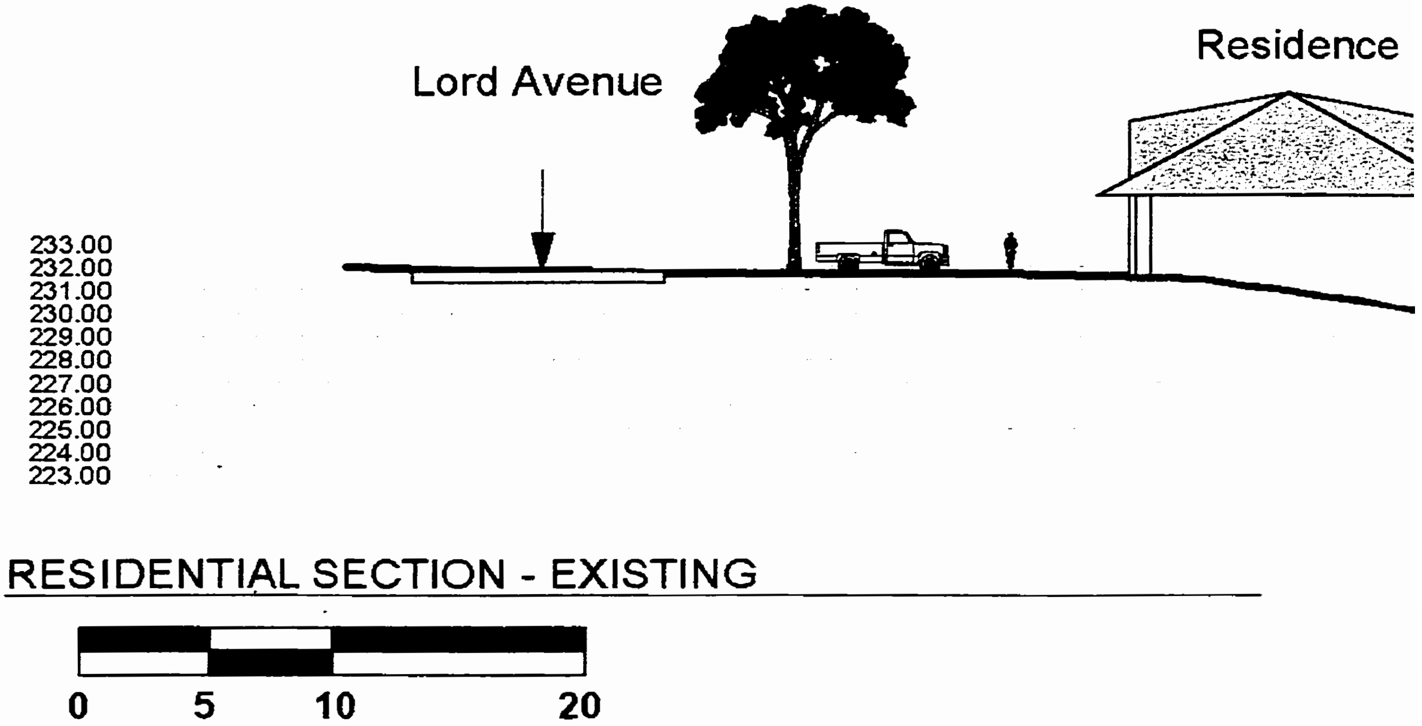
10. 9 Riverfront Property along Lord Avenue (Figures a, b, c, d, e, f)

The residential site is typical of riverfront properties, with views of the river, and some form of direct water access. A number of options are available with regard to the problem of flood protection in relation to spatially restricted sites. Two possible choices are described here.

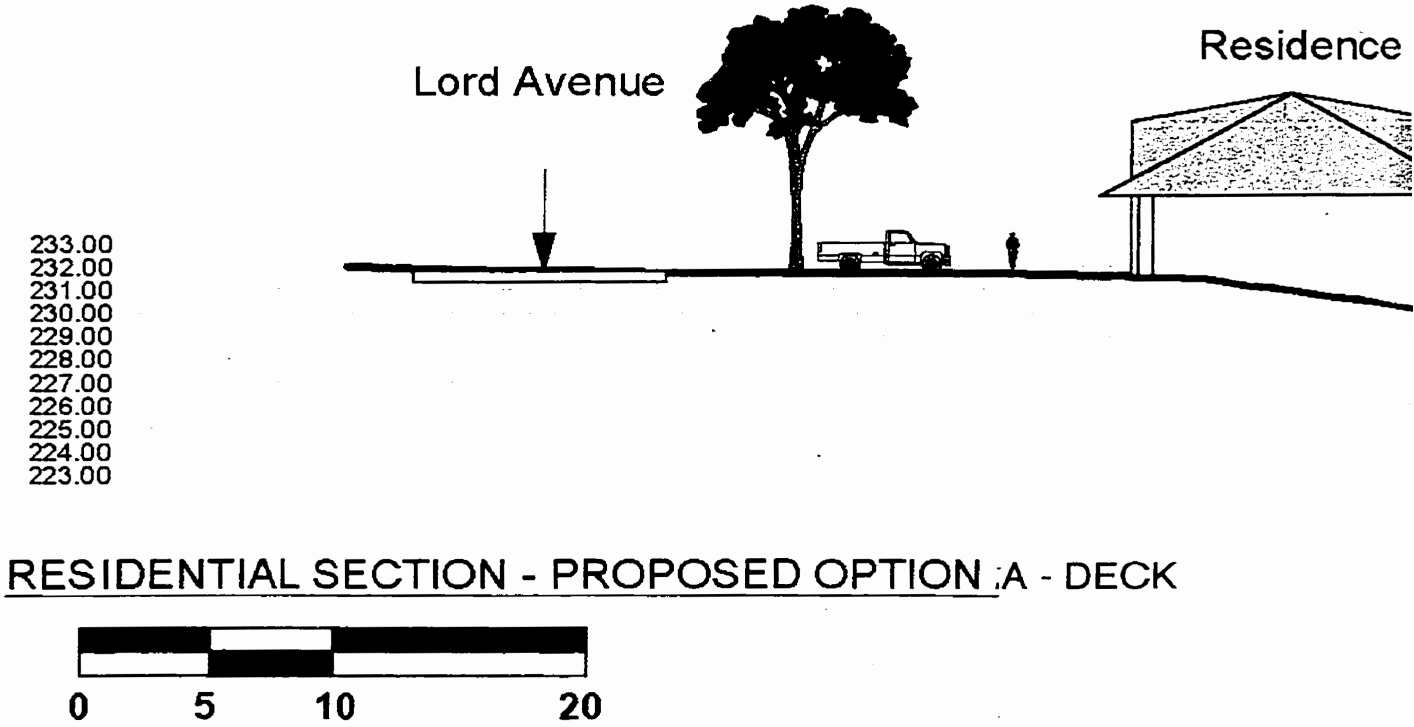
Given the potential for geological instability at the edge of the riverbank, a general setback of 10 metres from the top of the bank should be used. The limited amount of space left, between 10 and 20 metres (depending on the residence), would require one of the two following approaches for flood control.

The first solution (Figures 10.9a, b) is a dike that allows for upper deck access, and provides a venue for social interaction. This form of dike would limit the amount of "yard" space significantly when compared to the yards typical of the area. However, the presence of the dike need not prevent access to the remainder of the river front lot. Steps or stiles could be incorporated into the design of the structure as a part of the retaining system, (Figure 10.9c, d) or simply tied back into the structure, allowing access to and from the river-side of the back yard. Either method will restrict the sightlines to the river. The upper deck that extends to the dike crest would be better for permitting river views, but the drawback of this type of flood control is that it is relatively limiting with regard to usable backyard space given the close proximity of the river. The advantage is that it would allow for direct access via the dike crest to the river side of the yard.

Another method that is good for relatively small spaces is the use of a flood wall (Figures 10.9e, f). The drawback of this type of system is that there will nearly always be some form of structural presence. However, it provides protection when needed, and does not block views to and from the river. The subsurface structure and associated costs are generally a prohibitive factor in choosing this means of flood control for the individual homeowner, but perhaps as in the case along Lord Avenue where there is currently no

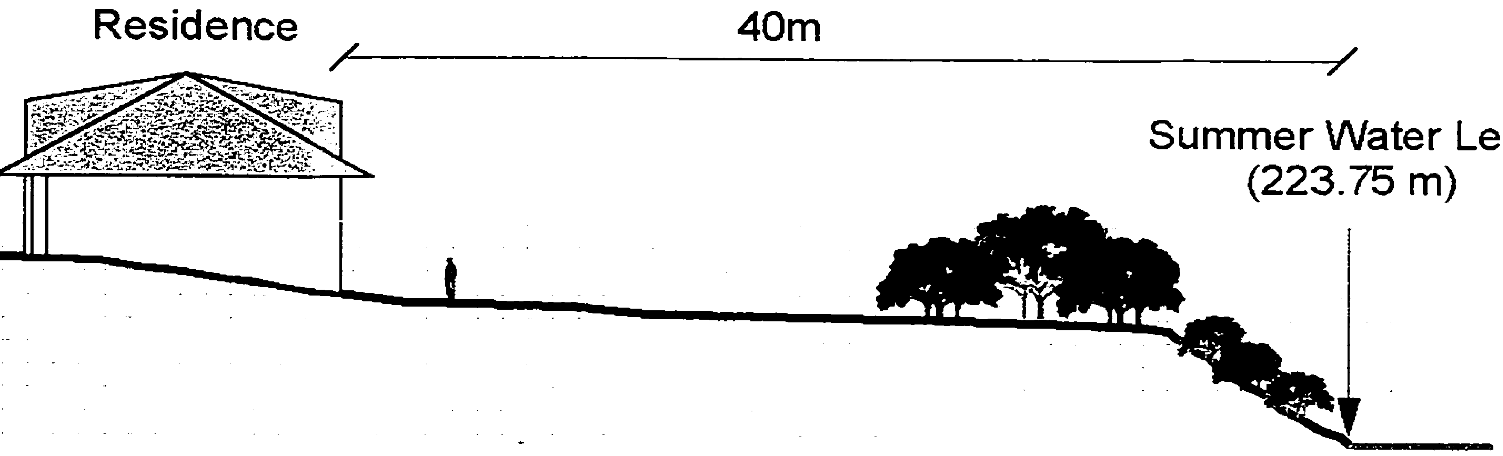


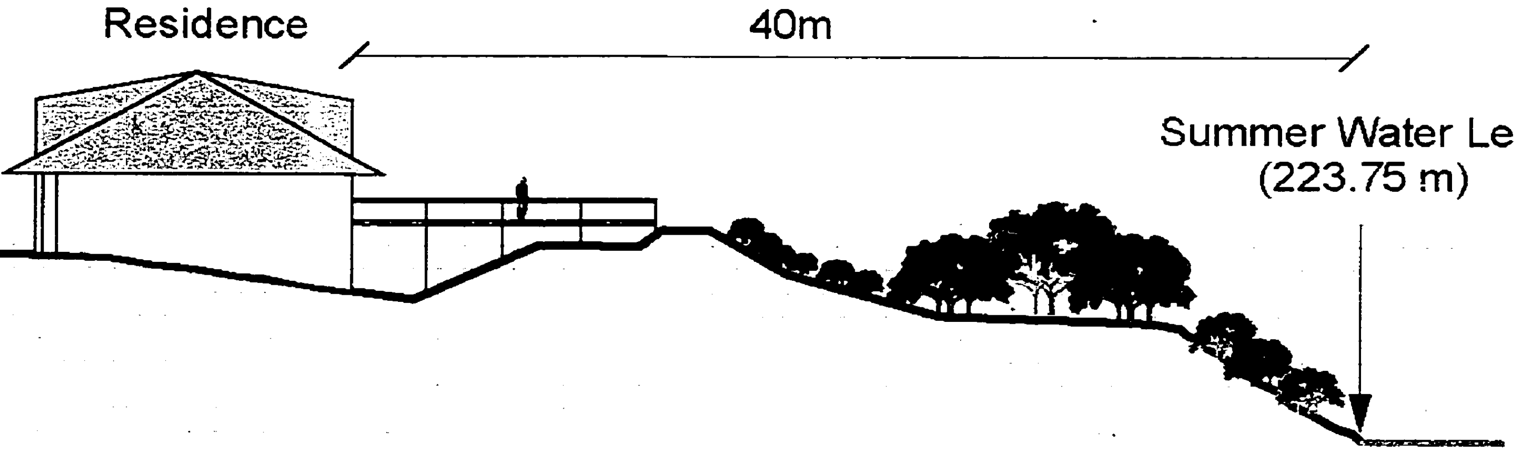
RESIDENTIAL SECTION - EXISTING



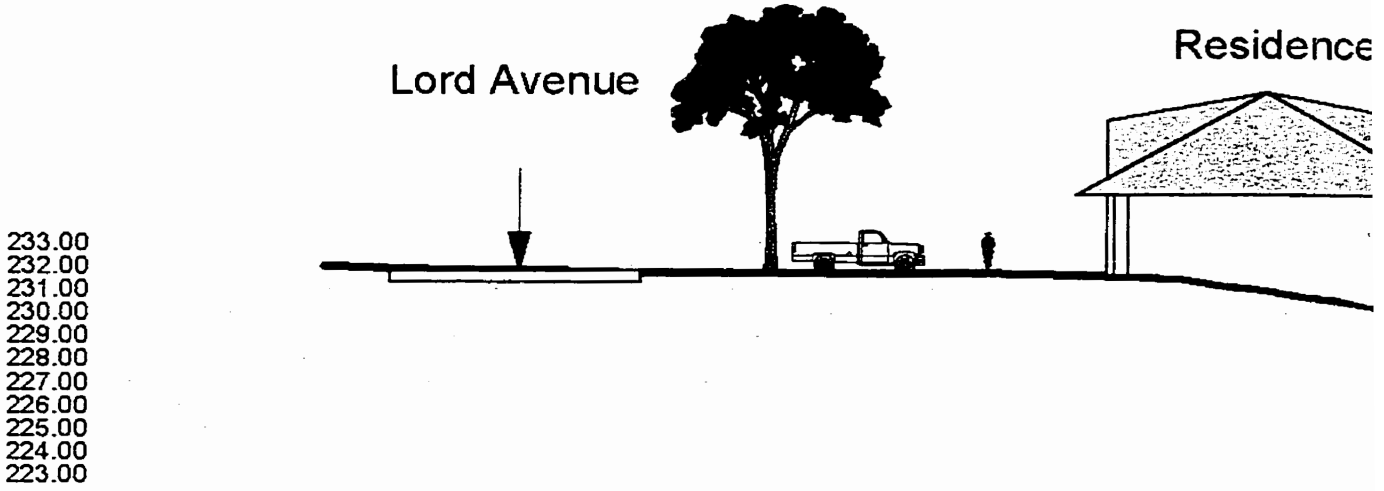
RESIDENTIAL SECTION - PROPOSED OPTION ;A - DECK

Figure 10.9a Residential Sections

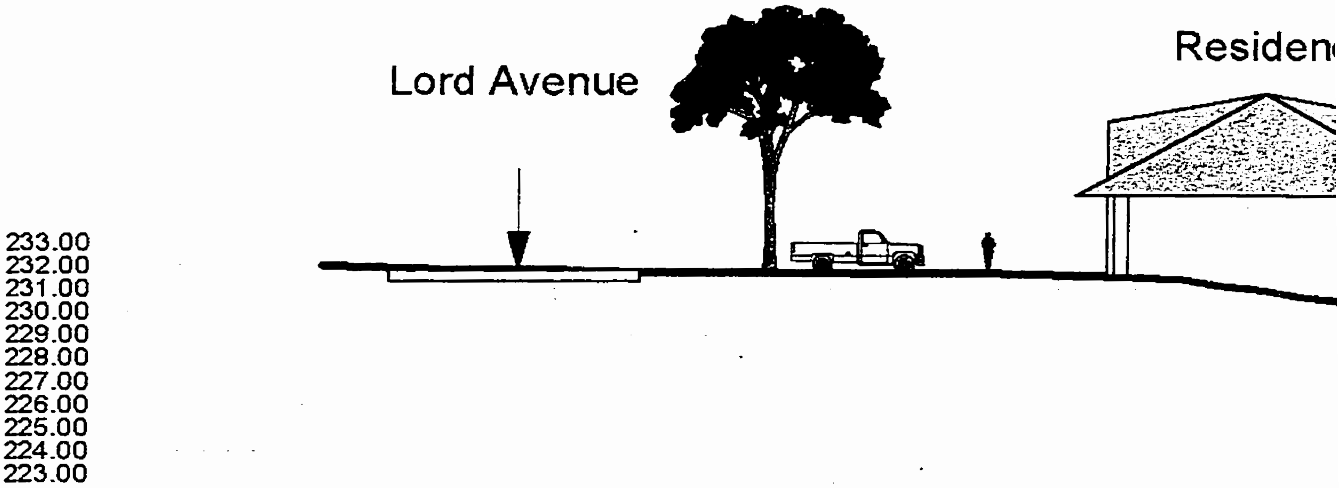

Residence
40m
Summer Water Level
(223.75 m)


Residence
40m
Summer Water Level
(223.75 m)

ECK



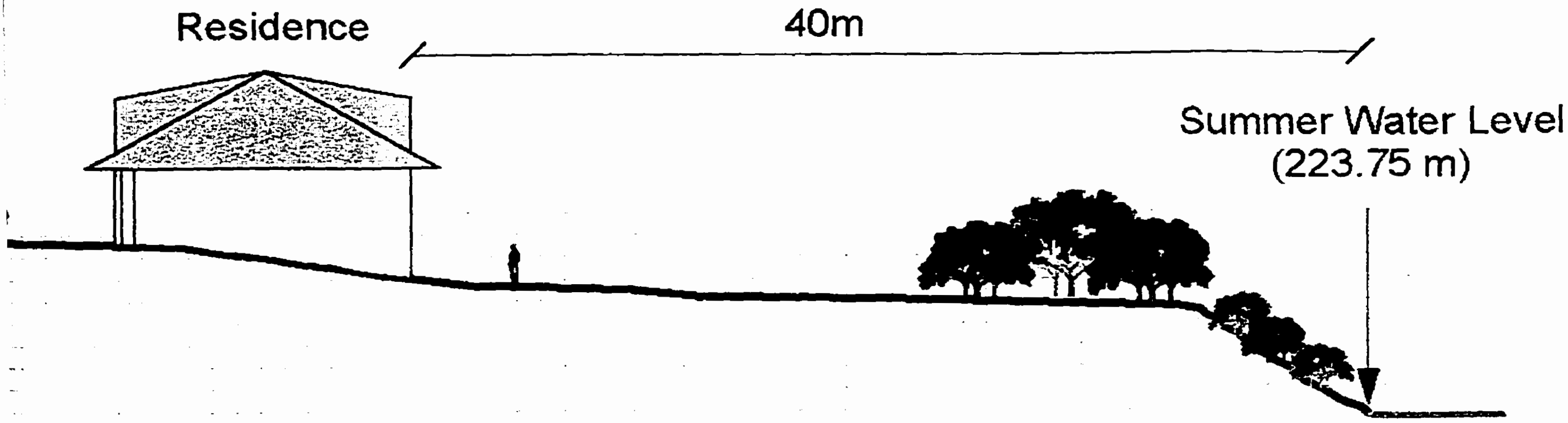
RESIDENTIAL SECTION - EXISTING

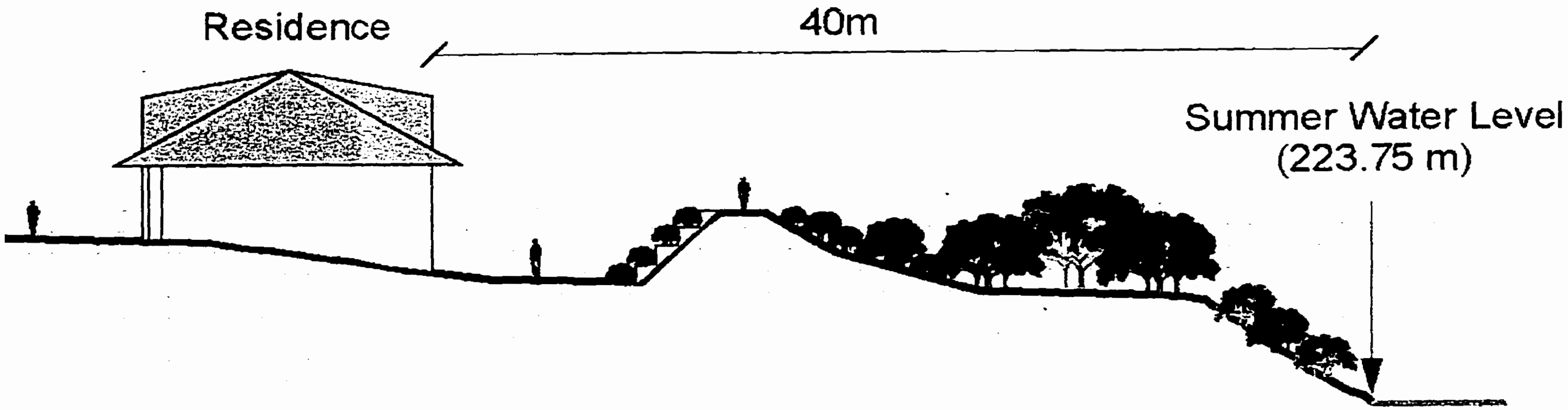


RESIDENTIAL SECTION - PROPOSED OPTION A - SMALL YARD

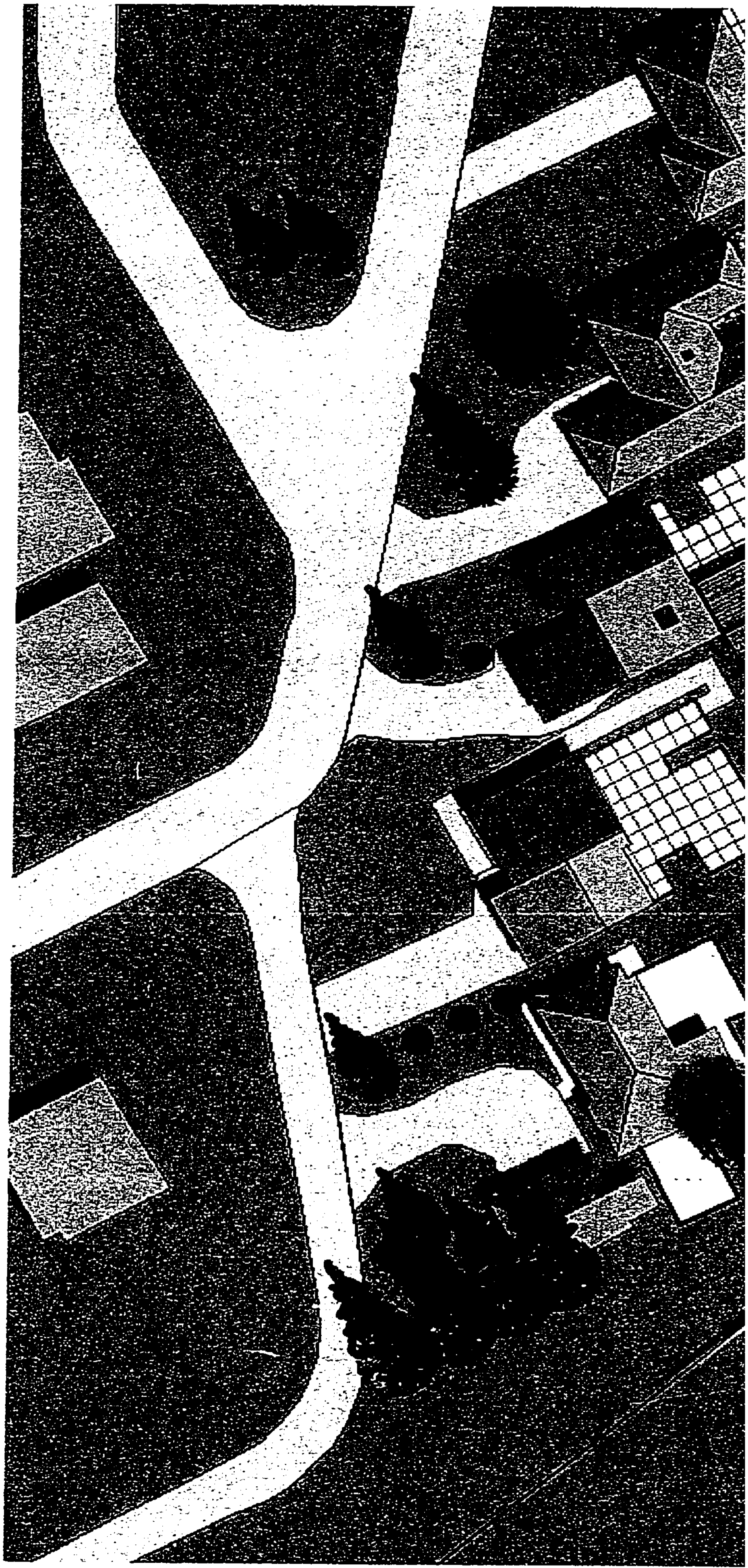
0 5 10 20

Figure 10.9b Residential Sections


Residence
40m
Summer Water Level
(223.75 m)


Residence
40m
Summer Water Level
(223.75 m)

A - SMALL YARD



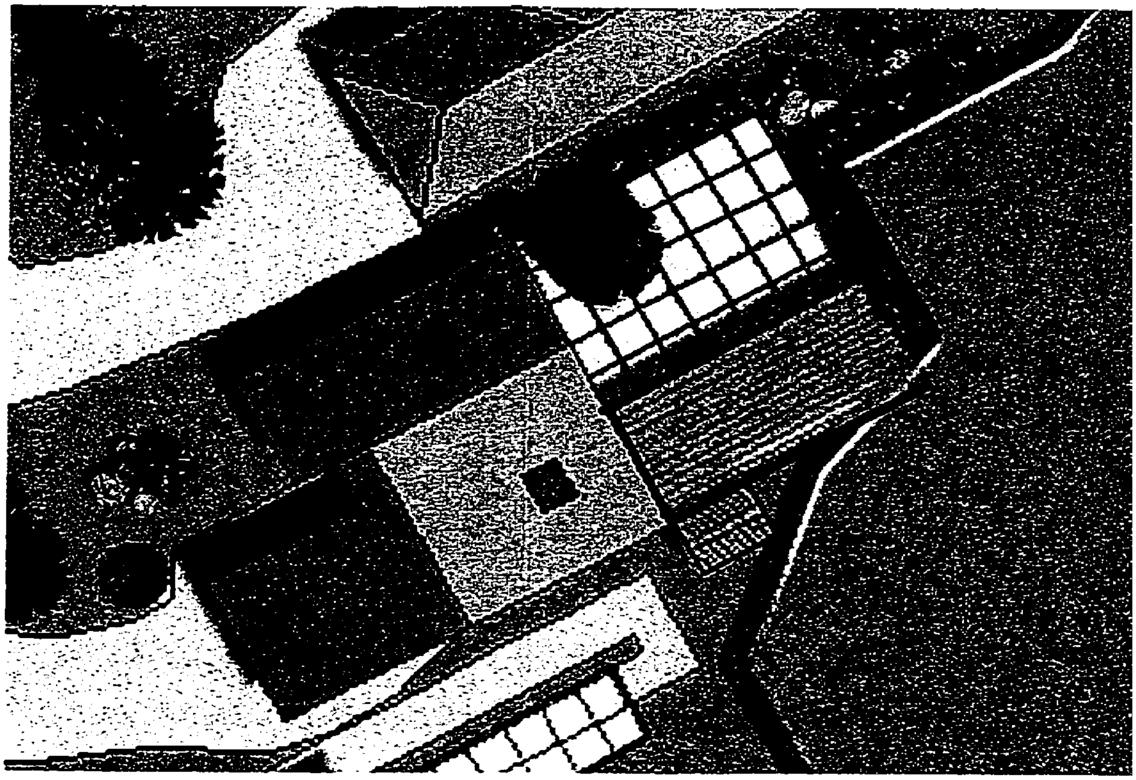
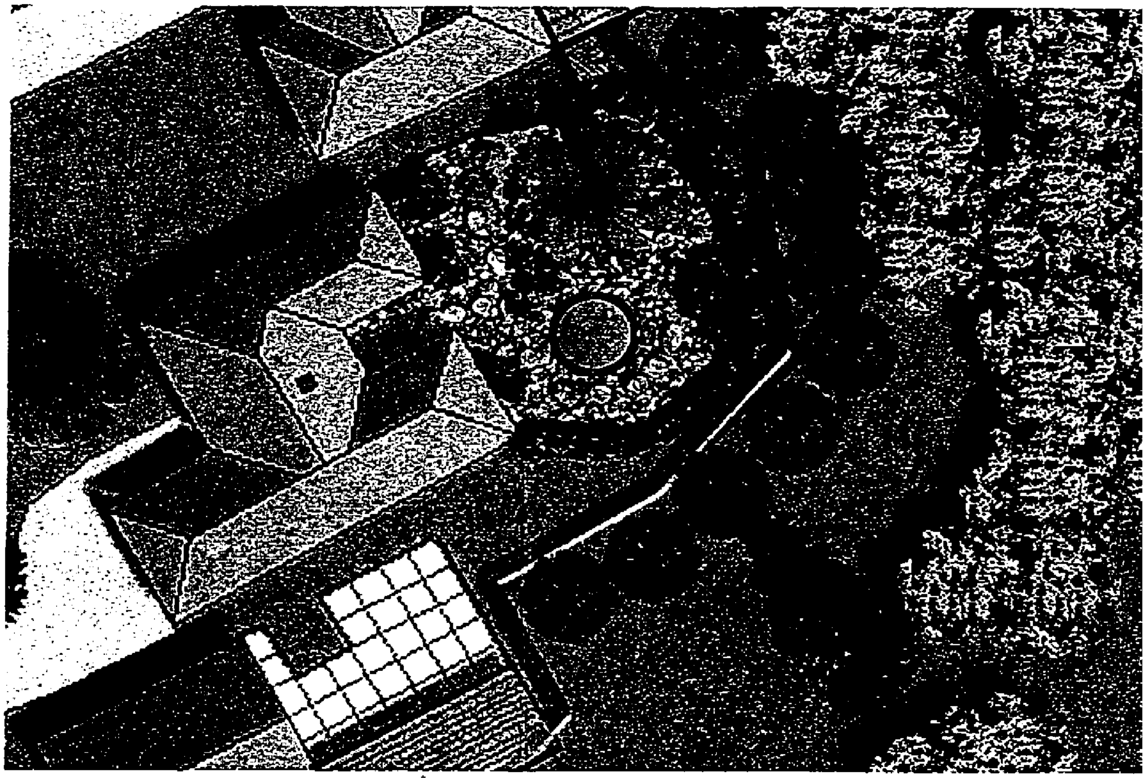


Figure 10.9c Lord Avenue Residential Sites Option A - Deck - Detail

Elevated deck and retaining wall

Figure 10.9d Lord Avenue Residential Sites Option A - Small yard - Deta

Rock garden and retaining wall.



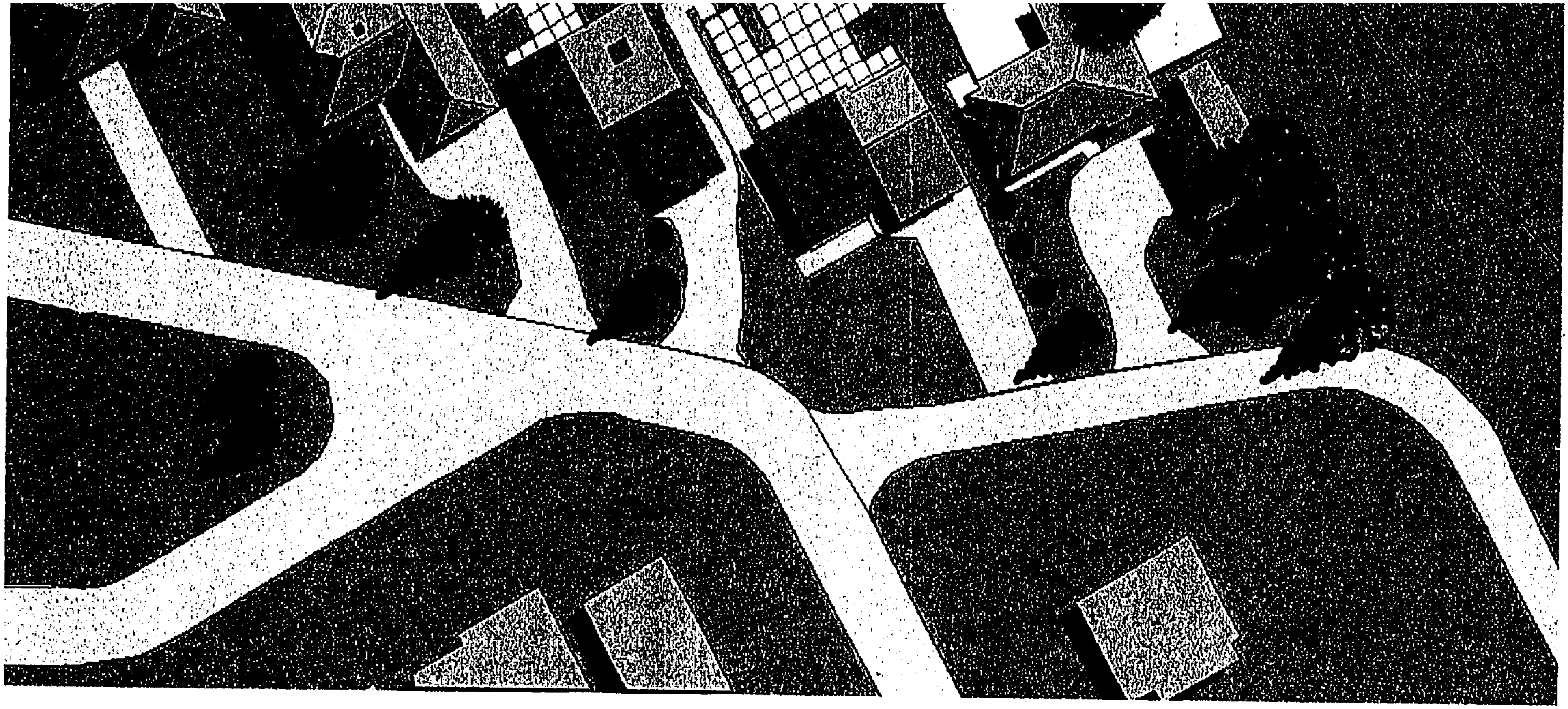


Figure 10.9e Lord Avenue Residential Sites - Option B - Floodwall - Remo

The use of a floodwall such as the one shown above illustrates the limited visu
its surroundings when not in use.

Figure 10.9f Lord Avenue Residential Sites - Option B - Floodwall - Partiall

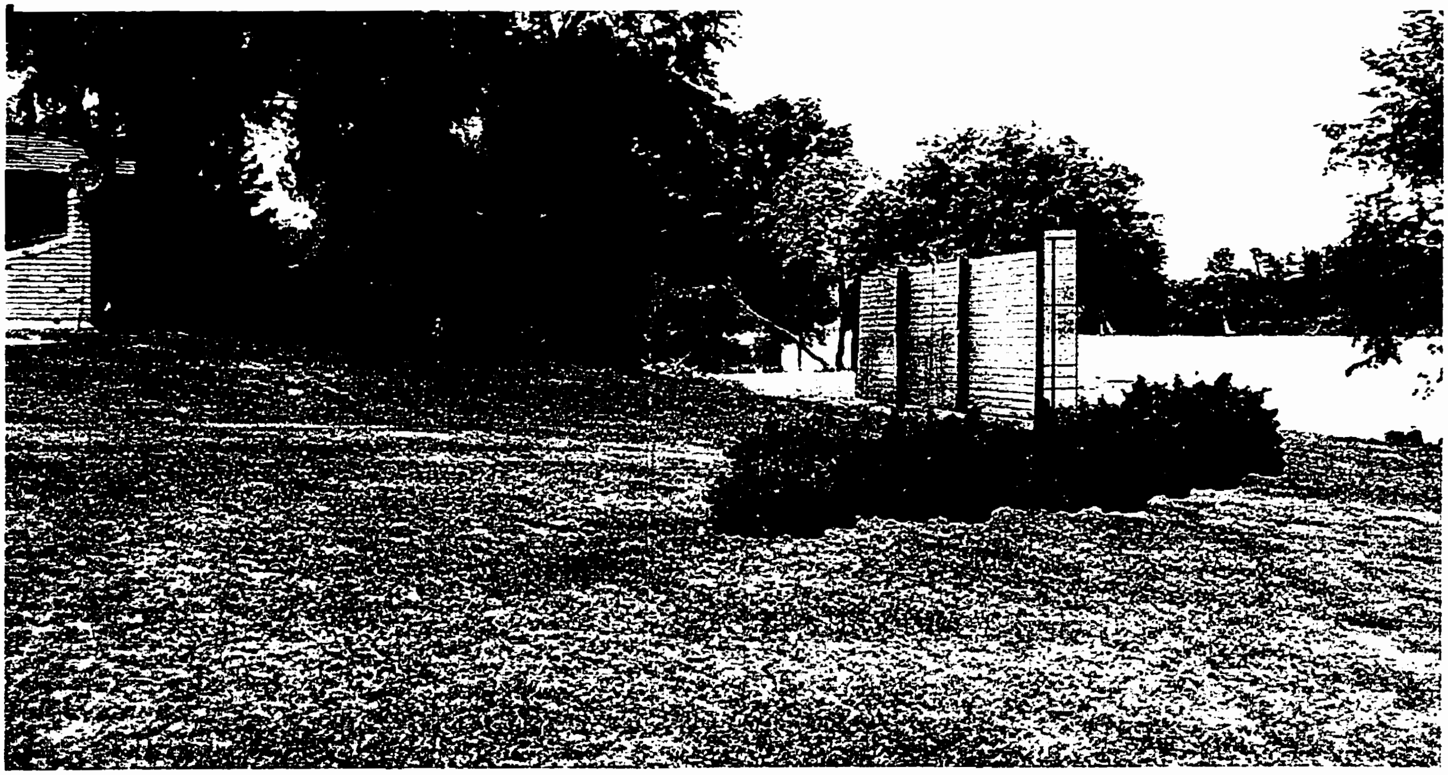
The visual impact of the wall when constructed is significant, but is limited to o
of time fully constructed

Figure 10.9e Lord Avenue Residential Sites - Option B - Floodwall - Removed

The use of a floodwall such as the one shown above illustrates the limited visual impact it has on its surroundings when not in use.

Figure 10.9f Lord Avenue Residential Sites - Option B - Floodwall - Partially Constructed

The visual impact of the wall when constructed is significant, but is limited to only a short duration of time fully constructed



permanent protection, it might seem to be a potential cost sharing project amongst the landowners.

CONCLUSION

Integrating dikes in the urban landscape means creating new dikes, or adapting old ones, for multiple uses. I believe that my examination of the problems of dikes and the suggested solution show that structures which have typically been temporally-limited, single-purpose, socially and ecologically disruptive landforms can be designed or adapted to preserve and enhance ecological processes, and to enrich and complement community life.

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