A WATER MANAGEMENT STRATEGY FOR SUBWATERSHED NO. 3 IN THE COOKS CREEK CONSERVATION DISTRICT

by

Kurt Bradford Simonsen

A Practicum Submitted In
Partial Fulfillment of The Requirements
For The Degree
Master Of Natural Resources Management

Natural Resources Institute
The University of Manitoba
Winnipeg, Manitoba
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ABSTRACT

Subwatershed No. 3 in the Cooks Creek Conservation District requires a water management strategy to address and mitigate numerous water management concerns expressed by the local landowners, personnel of the Cooks Creek Conservation District, municipal councillors and other outside interest groups. This study investigates these water management concerns and develops various alternative water management strategies.

Water management concerns were developed by delineating the various publics who may have an interest in any proposed strategy and identifying their respective concerns. The dominant water management concern expressed was the flooding of the clay soils in Subwatershed No. 3 after heavy rainfall events. Such flooding has reportedly resulted in a reduction in crop yields. Additional concerns pertained to the inadequate maintenance and condition of the existing drainage infrastructure, stormwater discharge from the Village of Oakbank into the Subwatershed and the impact of discharging lagoon effluent from the Village of Oakbank into the drainage infrastructure.

Water management strategies consisted of an investigation of various drainage infrastructure improvement options in an

attempt to mitigate some of the concerns expressed. The preferred strategy involves reconstruction of much of the drainage infrastructure along with the construction of new drainage works. The preferred strategy has an estimated cost of $406,000.

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Chapter I

INTRODUCTION

1.1 Preamble

Any water resource development project today should be treated as a whole and as part of the whole interaction of man and his environment. The proposed project, therefore, should be multi-purpose, comprehensive and interdisciplinary in nature. It is no longer practical to define a water resources project with a single-purpose objective. Project objectives must address the social, environmental and economic needs of man and his environment. The consequences of water management decisions are, in general, irreversible and must be considered carefully.

The provision of land drainage infrastructures is no exception to this rule. Land drainage activities have many far-reaching effects upon man and his environment. Interdisciplinary and multi-purpose coordination and cooperation is necessary to generate comprehensive solutions to conflicting issues, concerns and influences expressed by those people impacted by proposed drainage works. An integrated and coherent long-range planning rationale is, therefore, required to ensure that any drainage development project incorporates the various physical, biological, aesthetic, economic, judicial, environmental and other aspects of man's environment. The lack of an adequate long-term planning rationale may result in drainage developments (or any water resource development) based only on short-term considerations.

In Manitoba, we hear frequently of difficulties or delays in field operations and crop losses caused by excessive soil moisture and flooding. Most of those reports originate from farmers located in the flat, impermeable clay soils of the Red River Valley. Extreme cases of waterlogged soils have resulted in some seeding or harvesting intentions not being completed resulting in total crop failure. Subsequently, there has been an ongoing demand by farmers in these areas for the provision of an improved drainage infrastructure.

The question one must ask, therefore, is - to what extent and level should drainage be provided in these areas? Past drainage research focused entirely on the drainage problem itself; that is, the construction, design, materials, maintenance, etc., of a drainage infrastructure. The prime objective was always the construction and functional improvement of drainage works to obtain the maximum financial return for the benefiting farming community. Today, however, drainage should be analyzed with respect to its impacts on hydrology, wildlife, water quality and other physical, economic, environmental and social aspects beyond the scope of the farming community and its interests. Drainage must be approached with a multi-purpose and integrated planning rationale. Full public participation in the planning and decision-making process will ensure that society's interests in all aspects of development projects are identified and considered.

This report documents an attempt to develop a water management strategy for a proposed drainage improvement project in a small subwatershed in agro-Manitoba. The approach adopted was, firstly, to delineate the various publics and interest groups that may be impacted by the project and to assess their respective water management concerns. Secondly, the land use trends and agricultural characteristics of the subwatershed were investigated together with a review of the design methodologies and design criteria commonly used for the construction of drainage infrastructures. Based on these criteria, optional water management strategies were investigated for the proposed subwatershed drainage infrastructure and a preferred strategy highlighted.

This report presents the various alternative water management strategies investigated for the proposed drainage infrastructure in the subwatershed and discusses the implications of the preferred strategy.

1.2 Background

The Cooks Creek Conservation District (CCCD) was formed in 1979 under the authority of the Conservation Districts Act of 1976. The Conservation Districts Act combines and represents the resource management objectives of the Watershed Conservation Districts Act of 1972.

The Conservation Districts Act attempts to address all aspects of soil, water and related resources in areas defined by natural boundaries of a watershed or municipality. The Act also provides guidelines for the formation and administration of conservation districts under the Conservation Districts Program of Manitoba.

A conservation district is typically divided into sub-districts to ease administration and to ensure local participation. Each sub-district forms a sub-district committee and elects a chairperson who becomes part of the main board of the conservation district. The purpose of a conservation district board is to conduct the business of the district. The main board of the conservation district--with the financial, administrative and technical assistance from the

Province--sets long- and short-term goals for the district and develops programs and budgets designed to meet the needs of the district. Boards generally hire their own conservation district manager, and other staff as required, to conduct the day-to-day activities of the district.

The CCCD encompasses an area of approximately 862 km^2 of predominantly flat agricultural land located immediately east of Winnipeg (Figure 1). The land generally consists of fertile clay soils which are prone to flooding from heavy rains during the growing season, often resulting in crop losses. The CCCD was, therefore, incorporated under the Conservation Districts Act in 1979 in response to a local need for practical solutions to water management and other resource related problems.

One of the initial tasks of the CCCD Board was to oversee the development of the Cooks Creek Diversion which was approved as Project No. 401 of The Canada-Manitoba Subsidiary Agreement on Value-Added Crops Protection. This agreement was signed in 1979 with the objective to increase and further diversify agricultural production with emphasis on livestock and output of products for agricultural processing.

The Cooks Creek Diversion consists of a 16-km channel to divert waters from Cooks Creek to the Red River Floodway. The

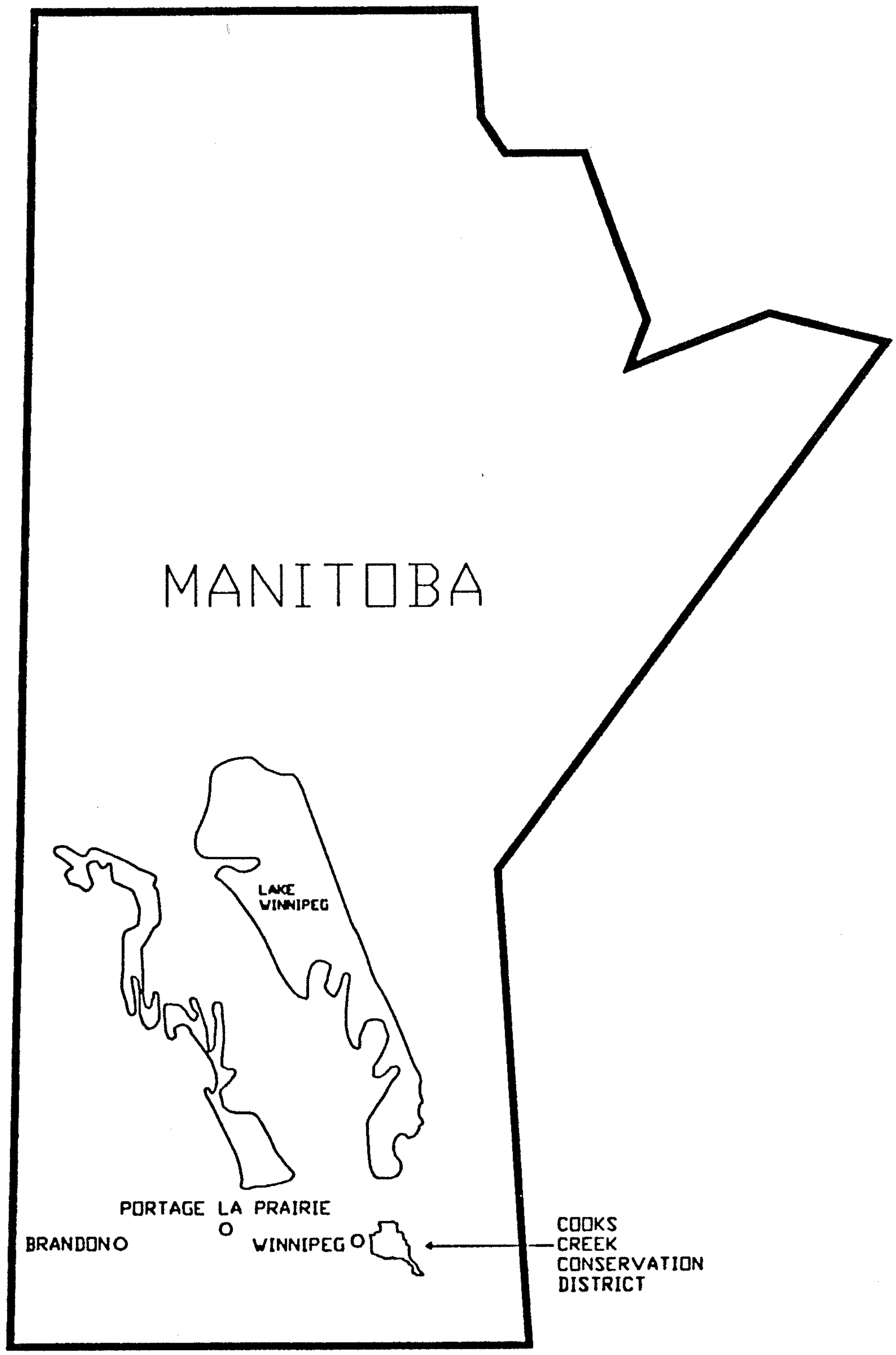


Figure 1 Cooks Creek Conservation District location plan

main purpose of the project was to provide an improved standard of agricultural drainage by rebuilding, if necessary, the entire network of drains within the project area impacted by the Diversion (Figure 2). It was intended that the diversion of agricultural flows from the Cooks Creek Channel to the Floodway, via the Diversion, would relieve the hydraulic stress on the Swede Drain and the Cooks Creek Channel, thereby improving their outlet capacity to receive additional surface waters from proposed drainage improvement works in the project area.

The project area consists of heavy clays which are predisposed to ponding of surface water and prolonged saturation. Land capability evaluations indicated that, with proper water management in the form of a comprehensive drainage system, the soils in this project area have the potential to support crops such as canola, sunflower, annual pulse crops and corn (Canada-Manitoba Subsidiary Agreement on Value-Added Crops Production, 1979). The Cooks Creek Diversion project, therefore, attempted to accomplish the following:

1. to divert large flows from Cooks Creek to the Red River Floodway;
2. to improve the drainage capacity of approximately 222 km^2 of agricultural land identified in the project area impacted by the Diversion (Figure 2);

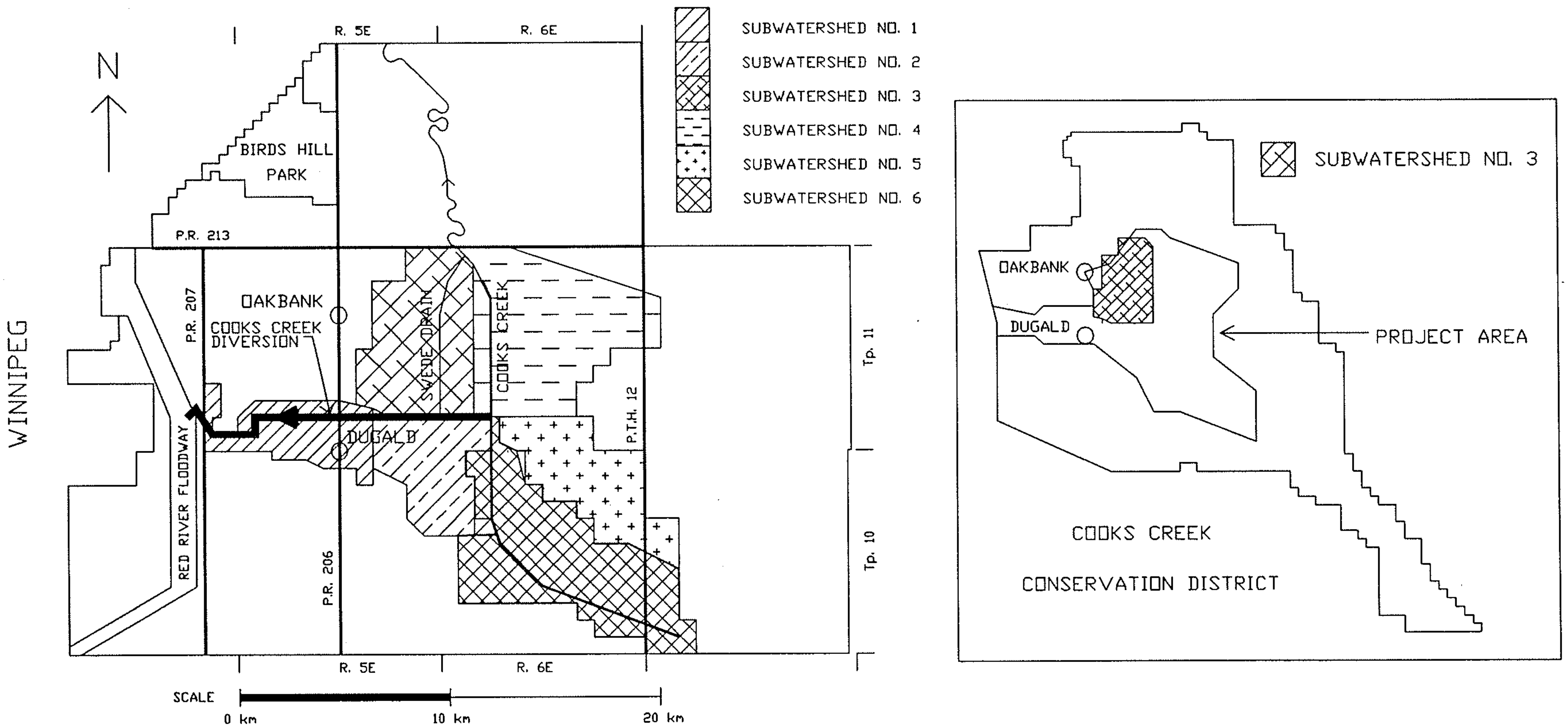


Figure 2 Cooks Creek Diversion and associated subwatersheds

3. to provide a lateral drainage tributary (subwatershed) network;
4. to provide the opportunity for production of crops such as canola, sunflower, annual pulse crops and corn which, at the signing of the Subsidiary Agreement, were thought to be higher in value than existing cereal crops in terms of processing opportunities they would generate in the province; and
5. to provide on-farm drainage improvements.

Approximately $2.5 million, cost-shared by Manitoba and Canada, was applied to the construction of the Cooks Creek Diversion. On August 25, 1982, an agreement between the Province and the CCCD was signed under which both parties agreed to carry the project to conclusion, on a cost-shared basis, beyond the funding limitations of the Federal/Provincial Subsidiary Agreement.

The project area is being developed in two phases: Phase I--the construction of the Diversion Channel; and Phase II--the development of a lateral drainage tributary network. The Phase II project area has been identified from previous studies and subdivided into six subwatersheds (Manitoba Conservation Districts Authority, 1986) (Figure 2). Improvements to these subwatershed drainage networks, along with improved on-farm drainage, is expected to provide a more efficient removal of excess surface runoff occurring during heavy rainstorms. With construction of the Diversion completed in the fall of 1988, the local agricultural community, as represented by the CCCD, is now anxious to proceed with Phase II of the project, the development of the tributary subwatershed drainage networks.

Development of the tributary subwatersheds defined by the project area requires that the CCCD prepare integrated water management strategies for each subwatershed detailing the drainage infrastructure requirements. A priority schedule has been identified for subwatershed development as follows: Subwatershed 1, 2, 3, 6, 5, 4 (Manitoba Conservation Districts Authority, 1986). At the time of this report, preliminary drainage improvement strategies and cost estimates had been developed for Subwatersheds Nos. 1 and 2. This report identifies water management strategies for Subwatershed No. 3. Phase II of the entire project is scheduled for completion in 1994.

1.3 Problem Statement

The development of a water management strategy for Subwatershed No. 3 requires an assessment of all needs, priorities and concerns regarding proposed drainage infrastructure improvements as well as a critical review of current standards and design methodologies for agricultural drainage. Subwatershed No. 3 is faced with many competing land use pressures. Its proximity to Winnipeg has brought many rural residential landowners to the area who show less enthusiasm for agricultural drainage improvements than the local farmers. Local farmers are also concerned about the excessive amounts of time during which surface water remains ponded on their land after a heavy rainstorm. Rapid expansion of the Village of Oakbank has also contributed to the water management problems with increased stormwater and sewage effluent being discharged to the Subwatershed's drainage network. All such technical, social and environmental aspects must be addressed in the planning of a water management strategy and all interests must be taken into account.

In addition to the various technical, social and environmental aspects that must be considered in a water management strategy, there is the specific requirement for suitable on-farm drainage when considering improvements to an agricultural drainage network. Unless on-farm drainage is adequate, benefits from upgrading lateral drains and from the construction of the Diversion Channel are likely to be minimal. An investigation was required, therefore, to assess the current status of on-farm drains in the Subwatershed.

1.4 Objectives

The primary objective of the research was to prepare alternative water management strategies for Subwatershed No. 3 in the Cooks Creek Conservation District. Specific objectives were as follows:

1. to identify water management concerns upstream, downstream and within the Subwatershed pertaining to land drainage;
2. to investigate the impact of stormwater runoff and lagoon effluent discharged into the Subwatershed's infrastructure from the Village of Oakbank;
3. to assess the agricultural characteristics of the Subwatershed and the associated drainage requirements;
4. to review existing agricultural drainage practices and design methodologies in order to determine suitable criteria for drainage design in the Subwatershed;
5. to develop alternative water management strategies and corresponding improvements to the lateral drainage infrastructure in the Subwatershed;
6. to assess the associated costs and potential advantages and disadvantages of the alternative water management strategies;
7. to highlight to the Cooks Creek Conservation

District a preferred strategy; and

8. to investigate on-farm drainage mechanisms and their associated costs and the level of commitment by local landowners to improve their on-farm drainage network, if required.

1.5 Limitations

The following limitations should be noted by the reader of this report with respect to the scope of this research.

1. This study was a conceptual feasibility study and, as such, formal construction drawings were not prepared.
2. It was not the intent of this study to undertake a detailed engineering analysis or hydraulic modelling of the existing or proposed infrastructures.
3. Due to the immense complexities involved in determining the monetary value of the benefits of the drainage strategies identified in this report, it was considered beyond the scope of this research to conduct detailed economic cost-benefit studies for each strategy identified. Instead, a general description of the advantages, disadvantages and problems of each strategy was provided.

Chapter II

METHODS

Four basic methods were adopted for the purpose of performing this research: personal interviews; a review of background literature, reports, drawings, maps, surveys, and photographs; personal on-site inspections including some surveying; and the application, on a conceptual basis, of general drainage hydraulic principles to determine the size, shape, cost and location for either the new or improved drainage channels identified in the various strategies. The general methodology used in the course of this study is described below.

The development of alternative water management strategies for Subwatershed No. 3 began with the identification of the various publics directly impacted or who otherwise have concerns as to any drainage improvement works that may be proposed. The identification of these publics was accomplished primarily through discussions with the client (the Cooks Creek Conservation District in conjunction with the Manitoba Conservation Districts Authority) and a review of background literature.

In addition, since personnel of the Water Resources

Branch of the Manitoba Department of Natural Resources prepared most of the planning studies for the Cooks Creek Diversion project, its staff were consulted to obtain an idea of other publics who may also have concerns about the project. Once the impacted or concerned publics were identified, many were informally interviewed to gain an understanding of their water management concerns. It should be noted that these interviews did not follow a formal survey or questionnaire format but were formulated to be conducive to informal discussions of respective water management concerns. An interview often resulted in the formulation of new questions for following interviews and sometimes the identification of other publics to be approached for interviews. These interviews did not produce data for statistical or scientific analysis as the objectives and resources for this study did not warrant such an approach. Those interviewed included the following:

- landowners, both within the Subwatershed as well as upstream and downstream of the Subwatershed;
- various council members from the Rural Municipality (RM) of Springfield;
- Personnel from the Department of Environmental Planning of the City of Winnipeg;
- regional personnel from the Municipal Planning Branch of the Manitoba Department of Municipal Affairs;
- numerous personnel from the Water Resources Branch of

the Manitoba Department of Natural Resources;

- land resource and water management specialists from the Manitoba Department of Agriculture;
- numerous CCCD Board members;
- local agricultural representatives from the Manitoba Department of Agriculture; and
- personnel from the Engineering and Construction Branch of the Manitoba Department of Natural Resources.

Assessment of agricultural characteristics of the Subwatershed was made through an analysis of soil survey maps and a review of background agricultural reports that pertained to the project area. Meetings were also convened with the local landowners, the agricultural representative for the area and land resource specialists from the Manitoba Department of Agriculture to discuss agricultural characteristics specific to the Subwatershed. Drainage requirements, based on the agricultural characteristics of the site, were determined through an analysis of background literature and discussions with personnel from the Water Resources Branch of the Manitoba Department of Natural Resources and additional staff from the Manitoba Department of Agriculture. In addition, numerous local farmers were interviewed to obtain their perspective on specific drainage problems and drainage requirements. Local farmers were also queried as to their current cropping patterns and whether such patterns would change if an improved drainage infrastructure was provided. The land in the Subwatershed was then assessed and classified as to its agricultural capability.

An inventory of existing drains, watercourses and crossings was made through personal inspection of the site. This inventory included a mapping of all existing culvert crossings and an assessment of the condition of existing CCCD drains and municipal drains. The purpose of this inventory was to ultimately determine if the existing drains met the necessary requirements for agricultural drainage and to determine which drains, if any, would require upgrading. Actual on-farm drainage characteristics, patterns and problems were determined through discussions with local farmers.

A review of agricultural drainage practices and design methodologies was conducted through literature reviews and discussions with personnel from the Engineering and Construction Branch and the Water Resources Branch of the Manitoba Department of Natural Resources.

When an assessment of the Subwatershed's water management concerns, agricultural characteristics, drainage requirements and existing infrastructure had been completed and a drainage design standard selected, alternative water management strategies were developed.

Development of the assorted strategies began by delineating all land areas contributing surface waters to the drainage infrastructure of the Subwatershed. The land area serviced by each drain was determined and the respective design capacity for each drain was calculated. These respective design capacities for each drain were compared to the calculated existing capacities for each drain to determine those that would require upgrading.

Once land areas serviced by each drain were delineated, adjustments were made to define more precisely the Subwatershed boundaries. Subwatershed boundaries were determined not just by encompassed drainage areas but rather in conjunction with agricultural characteristics, land use trends and the determined need for drainage improvements.

Various infrastructure strategies were investigated in an attempt to provide, at the least possible cost, the required level of drainage improvement as determined by the water management concerns, land use trends and agricultural characteristics of the site. Strategies investigated ranged from the status-quo option to construction of diversion drainage channels and improvement works in an attempt to discharge surface waters from the Subwatershed to an appropriate outlet. A general assessment of the benefits, costs and problems of each strategy was made and discussed.

It should be noted that it was not within the scope of the research to perform detailed engineering designs or hydrologic modelling of the various strategies.

Costs of the various water management strategies were determined primarily through estimates of earthwork requirements for drain construction and culvert size requirements for various crossings. Approximate unit costs for earthwork and culvert installations were determined through consultation with local contractors and discussions with personnel from the Engineering and Construction Branch of the Manitoba Department of Natural Resources. Costs for other works required such as bridge reconstruction, land acquisition, spreading rights, utility relocation, road reconstruction and engineering fees were based on the "Cost Estimate Unit Price Tables for Fiscal 1988/89" published by the Water Resources Branch of the Manitoba Department of Natural Resources.

Obviously, without adequate on-farm drainage, agricultural benefits derived from drainage improvements are likely to be minimal. Therefore, an investigation into on-farm drainage mechanisms, costs, problems and commitment to improvement was required. This investigation was accomplished through discussions with local farmers and on-farm drainage specialists from the Manitoba Department of Agriculture.

Chapter III

BACKGROUND ESSENTIALS

Does one really need a water management strategy for Subwatershed No. 3? The answer to this question is unequivocally, yes. Any time man attempts to use the earth's water resources for his purpose, he must do so with some strategy in mind to achieve his objectives. A simple objective might consist of a single landowner desiring potable water in his home. To achieve such an objective, his strategy might entail pumping potable water from a well and disposing of the resultant wastewater to a septic field. A more complex objective might consist of providing hydro-electric power to the people of a large city. Such an objective requires a complex water management strategy consisting of careful monitoring and control of stream flow and reservoir volumes to ensure an adequate water supply for power generation. The intention of these examples is to indicate that, no matter what the purpose may be regarding water resource use, it can only be accomplished through some sort of carefully conceived strategy. The strategy, be it simple or complex, must satisfy the objectives and concerns of all users of the water resource, not just least possible cost. The question, therefore, is not whether one needs a water management strategy in Subwatershed No. 3 but rather, what is the best strategy that can be implemented, at a reasonable cost, to meet the objectives and concerns of those impacted? Obviously, one must carefully investigate the various parameters of land and water resource use specific to the Subwatershed and its surrounding area to determine the nature and scope of the water management strategy to be implemented.

The purpose of this chapter, therefore, is to familiarize the reader with the study area's resources and their use. A knowledge of such information is mandatory prior to the implementation of any water management strategy.

3.1 Land Use

3.1.1 Regional Setting

Although not a specific objective of this research, an investigation into land use trends and policies was deemed necessary. Land use trends and policies, both within and surrounding the Subwatershed, could play a major role in the development of any water management strategy as land and water resources are inter-related.

Figure 3 shows the boundaries of the Subwatershed within the RM of Springfield and its location with respect to the Village of Oakbank and the City of Winnipeg Additional Zone.

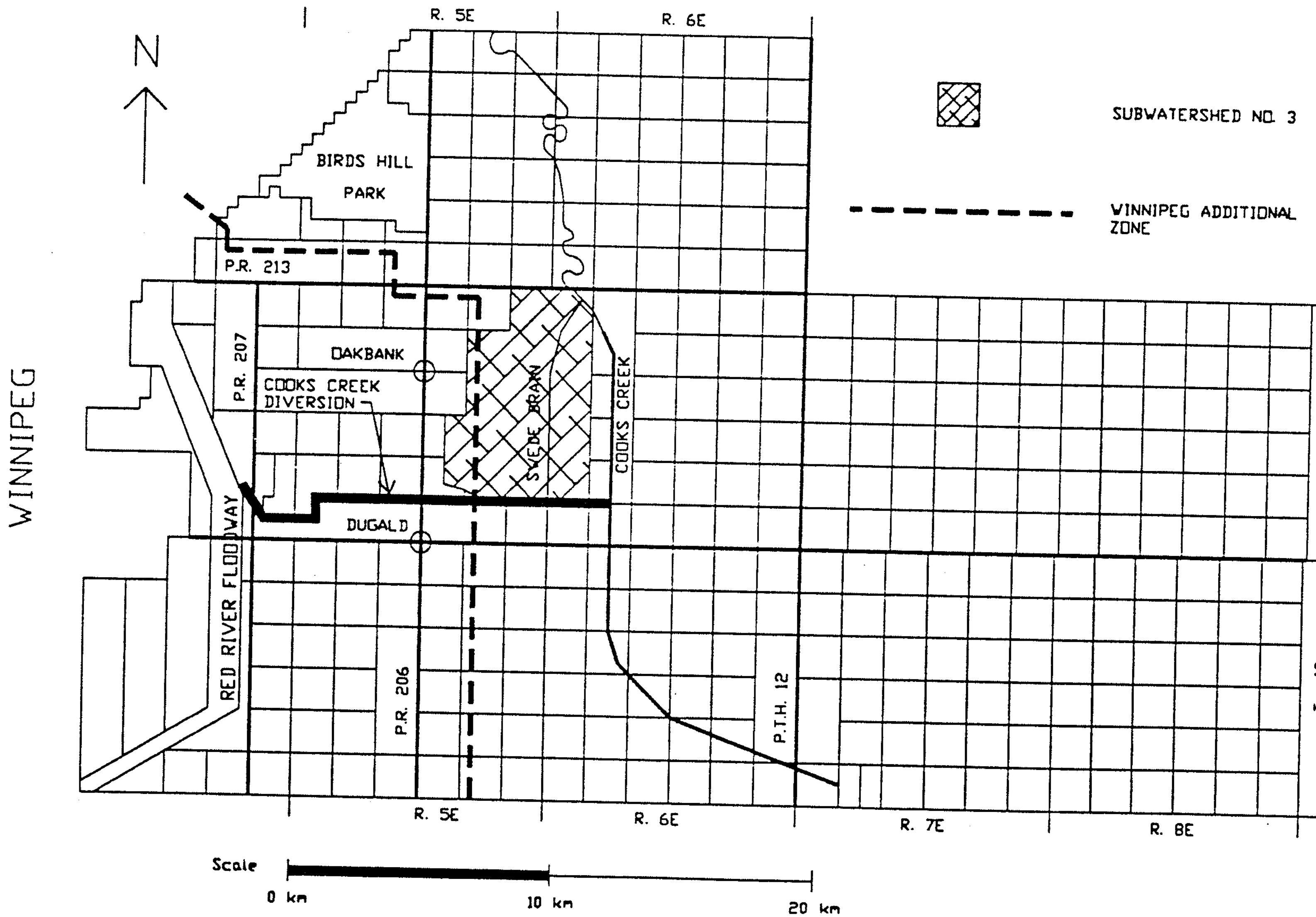


Figure 3 The Rural Municipality of Springfield

The Subwatershed encompasses approximately 3,640 ha of predominantly agricultural land. Land falling within the Additional Zone boundary is subject to the policies, objectives and regulations of the Department of Environmental Planning of the City of Winnipeg. This Additional Zone was established by City of Winnipeg By-Law number 2960 in 1981. The purpose of the Additional Zone is to provide a mechanism by which the City can endeavour to control development and to maintain and protect productive agricultural areas by controlling urban expansion within the Additional Zone (the City of Winnipeg By-Law Number 2960, 1981).

The close proximity of the Subwatershed and surrounding areas to the metropolitan centre of Winnipeg has resulted in it being an attractive and practical residential alternative to a highly urbanized environment. The lower population density and rural setting provides a living environment particularly attractive to certain people.

The demand for accessible rural residential housing has subsequently caused a construction boom in Oakbank with the development of numerous housing subdivisions in the Village. At the time of this report, a 300-lot subdivision was under construction in the Village of Oakbank east of Provincial Road 206. In addition to these community housing subdivisions, many rural residential developers and private families are seeking small 2 ha to 5-ha lots on the agricultural land base both within and surrounding the Subwatershed. Such lots provide the ideal residential climate demanded by the rural residential home owner with close proximity to Winnipeg and the privacy and spaciousness of a country setting.

The recent surge in demand for rural residential lots has seen the Village of Oakbank grow at an unprecedented rate during the past few years. Population statistics for Oakbank reveal this trend (Table 1).

Table 1 Population statistics for Oakbank

Year	Population
1951	183
1956	193
1961	277
1966	292
1971	375
1976	650
1981	775
1988	1,600

Source: Statistics Canada and the RM of Springfield

The agricultural land consists of lacustrine clay soils which are productive for agriculture but subject to water ponding after periods of heavy rain due to the flatness and impermeable nature of the soils. The resulting saturation and ponding has resulted in some crop losses. (A more detailed description of agricultural characteristics of the

Subwatershed is provided later in this chapter.) Much of the land located north of Provincial Road 213, in the vicinity of Birds Hill Park, and to the east of PTH No. 12, contains soils having severe limitation for crop production. Most of this land is either pasture land interspersed with deciduous woodland, shrubland or meadow (RM of Springfield Development Plan, 1980). Much of this land has been subdivided for rural residential development.

3.1.2 Previous Land Use

Subwatershed No. 3 lies entirely within the region covered by glacial Lake Agassiz. This glacial lake was the recipient of alluvial sediments brought in by its delta-forming affluents. It was these sediments that formed the lacustrine clays of Subwatershed No.3

These fine-textured clay deposits are imperfectly drained and are characteristically found on flat or depressional topography such as in Subwatershed No.3. Due to insufficient fall across the clay plain, intermittent streams (such as Cooks Creek) were unable to cut adequate channels and, in former times, were lost in marshes or meadow areas (Ehrlich et al., 1953). Subwatershed No. 3 was no exception to this physical development. Before being artificially drained, Subwatershed No. 3 consisted largely of low-lying marshland

and was the recipient of surface waters from the upland areas around present-day Birds Hill Park. As settlement proceeded, and land development expanded, the marshlands of Subwatershed No. 3 were artificially drained to Cooks Creek.

3.1.3 Development Plans and Policies

Subwatershed No. 3 is impacted directly or indirectly by three development plans, namely: The RM of Springfield Development Plan, the Oakbank-Dugald Community Plan and the Greater Winnipeg Development Plan for the Additional Zone. The Oakbank-Dugald Community Plan, prepared by the City of Winnipeg Department of Environmental Planning, focuses its planning objectives and policies within the boundaries of the community and is simply designed to provide guidelines for community development. The primary residential policy of the plan states, "The Municipality shall discourage development of residential sites, within the community, by requiring each subdivision proposal to be integrated into an overall design for the development of the area...." and, "the Municipality will require the provision of appropriate buffers, as well as require the development to meet certain design specifications devised to minimize conflicts with adjoining non-compatible activities" (City of Winnipeg, Department of Environmental Planning, 1977). Many landowners within the Subwatershed have voiced complaints that the rapid expansion of Oakbank has resulted in an increase in stormwater flows to the drainage infrastructure in the Subwatershed due to increases in stormwater runoff and lagoon effluent discharges.

The Subwatershed is directly impacted by the policies and objectives of the RM of Springfield Development Plan. The Springfield Development Plan provides, as one of its primary objectives, "to conserve the Municipality's farm lands for continued agricultural use and provide land use stability in transitional areas between farm and rural residential development by discouraging future small lot subdivision and the conversion of agricultural lands to non-farm uses in designated agricultural areas". The plan, however, does provide for "the ability of farmers to give building sites to members of the family when the member of the family assists on the farm or, in the opinion of council, has an established need to be located in close proximity to the farming operation". The Plan also stipulates that, "to contain expansion of suburban sprawl and the highly dispersed nature of non-farm development in Springfield....", the above shall be accomplished by "directing future development to established communities and rural service centres" (The RM of Springfield Development Plan, 1980).

Portions of the Subwatershed also lie within the boundaries of the City of Winnipeg Additional Zone. The policies and programs as described in the RM of Springfield Development Plan apply to all areas within the RM of Springfield except that portion being part of the Additional Zone. The present Springfield Development Plan, however, makes recommendations as to the use of the land within the Additional Zone and the City of Winnipeg Additional Zone By-Law requires that the Additional Zone Plan incorporate municipalities' recommendations in development decisions. Policies of the Additional Zone, in general, favour the protection of agricultural land and stipulate that urban expansion be confined to communities such as Oakbank and Dugald in the RM of Springfield (City of Winnipeg, Department of Environmental Planning, 1981).

At the time of preparation of this report, the CCCD was in the process of preparing its resource management plan. The purpose of this plan is to identify long-term goals and priorities for resource management in the CCCD. Subwatershed No. 3 would obviously be impacted by any planning objectives and policies identified in this plan. This all-inclusive resource management plan is scheduled to be completed by the fall of 1989.

3.1.4 Land Use Trends

During the years prior to 1979, agricultural land was subjected to the uncontrolled purchase of small lots by speculative non-resident rural residential developers. These lots, ranging in size from 2 ha to 32 ha were in turn rented to local farmers until the land could be resold at a profit or the owner himself decided to reside on the property. A quick review of land ownership patterns in the Subwatershed revealed that, of the total area encompassed by the Subwatershed (approximately 3,600 ha), approximately 20 percent of the land, or 720 ha, was owned by rural residential landowners or corporations. The remaining 80 percent of the land (or 2,880 ha), was owned by local farmers. Of this 2,880 ha, approximately five of the larger farmers owned 55 percent, or 1,580 ha of the resident farmer-owned land base. The remaining 45 percent of the resident farmer-owned land base was owned by approximately 25 smaller farmers or hobby farmers. These smaller farming operations and hobby farmers, along with many of the rural residential landowners, rented portions of their land, usually to one of the five larger farmers in the Subwatershed. As a result, the majority of the agricultural production in the Subwatershed was accomplished by the five larger farmers of the area. It was estimated that, of the 3,600 ha of arable land in the Subwatershed, these five farmers farm approximately 75 percent of this land or 2,700 ha.

With the implementation of the RM of Springfield Development Plan in 1979, subdivision of the agricultural land base into rural residential lots has become increasingly difficult. Much of the rural residential construction occurring today in the Subwatershed is taking place on lots purchased prior to the implementation of the Development Plan in 1979. Today, creation of many of the rural residential subdivisions is accomplished by the non-resident or resident landowners who further subdivide their plots or local farmers who subdivide their land for the purpose of providing residential lots for members of their families. Such practices are acceptable under the conditions of the Springfield Development Plan. Recently, there have been concerns voiced suggesting that family members inheriting or purchasing lots from the "family farm" are now in turn selling them, at very profitable prices, to independent speculators desiring rural residential lots. Such practices could seriously jeopardize the agricultural land base in the Subwatershed and would require a re-evaluation of the planning policies and rules designating who the potential user of a subdivision can be.

The local farmers in the Subwatershed seemed split on issues of land subdivision. Half saw land subdivision as an ideal way to raise large sums of cash to supplement a poor cash flow situation they might be experiencing in their farming operation. Other farmers saw land subdivision as a threat to agricultural survival through increased land prices and a decline in the agricultural land base. Such pressures for future land subdivision, due to the demand expressed by potential rural residential landowners and the desire for cash-poor farmers to sell, will in all likelihood continue to threaten the agricultural land base in the RM of Springfield and Subwatershed No. 3. Recent statistics reported in Table 2, showing the loss of agricultural land in the RM of Springfield, highlight this trend.

Table 2 Loss of agricultural land in the Rural Municipality of Springfield

Year	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
ha Lost	106	16	15	23	22	24	35	19	23	13	15

Source: Bruce MacLean, Land Resource Specialist for the Province of Manitoba, Eastern Region

3.2 Existing Drainage Characteristics

3.2.1 The Cooks Creek Diversion Project

The Cooks Creek Diversion project was provided for in 1982 under the Canada-Manitoba Subsidiary Agreement on Value-Added Crops Production. The primary purpose of the project was to increase the agricultural drainage capacity within the 200-km^2 area contained in the project area (Figure 2). At the time of signing this Agreement in 1979, it was felt that an improved standard of drainage in the project area would provide an opportunity for the production of crops such as canola, sunflower, annual pulse crops and corn. It was felt that these crops were, on average, higher in value than traditional cereal crops due to the generation of added value that such crops could produce in terms of processing opportunities to the province.

The Diversion was designed to intercept large flows in Cooks Creek and divert these flows to the Red River Floodway. The intent of the Diversion was to increase the drainage capacity in the project area through provision of a new outlet (the Diversion project), an improved lateral drainage tributary network (in the various subwatersheds) and on-farm drainage improvements. This improved drainage infrastructure was to ultimately provide a more rapid and efficient removal of excess surface water caused by heavy summer rains (Manitoba Conservation Districts Authority, 1986).

The project is being developed in two phases: Phase 1, the construction of the diversion channel; and Phase 2, the development of a lateral drainage tributary network in Subwatersheds Nos. 1 to 6.

The Cooks Creek Diversion was designed primarily to function as an alternative outlet for design agricultural flows generated upstream of the Diversion in the Cooks Creek watershed. The diversion of such flows, therefore, would relieve the Cooks Creek and Swede Drain, downstream of the Diversion, of excessive hydraulic loading and result in improved outlet capacities in the project area. The design of the Diversion Channel was based, therefore, primarily on agricultural requirements without specific regard to flood improvements. The project was intended to provide a standard of drainage substantially above existing standards in order not only to counter recognized drainage problems but to remove constraints which presumably prevented the growing of higher-value crops (Manitoba Department of Natural Resources, no date).

A design agricultural "value-added" drainage standard based on a discharge Q given by $Q = 0.479A^{0.765}$ was used in the design of the agricultural flows in the diversion

where: Q = discharge in m^3/s

A = area in km^2

(A more complete discussion of this standard is provided later in Chapter 3.5.4 "Agricultural Drainage Requirements and Subwatershed No. 3".)

The 16-km Diversion Channel was completed in the fall of 1988 at a total cost of approximately $5 million. At the time of this report, preliminary engineering studies had been completed for the upgrading of the drainage infrastructure in Subwatersheds Nos. 1 and 2.

The Diversion was designed to make optimum use of the Cooks Creek channel capacity downstream of the Diversion inlet. Channel capacities studies along Cooks Creek between the Diversion entrance and the confluence with the Swede Drain have determined that the existing below-prairie channel capacity could carry discharges ranging from 17 m^3/s at the point of the Diversion to 25.5 m^3/s at the confluence with the Swede Drain and approximately 56 m^3/s immediately downstream of the confluence. The local agricultural flows Q of $0.479A^{0.765}$ from lands serviced along Cooks Creek between the Diversion and the confluence with the Swede Drain, range from 11 m^3/s to 20 m^3/s and are approximately 25.5 m^3/s immediately below the Swede Drain. On this basis, the Cooks Creek Channel could carry approximately 6 to 7 m^3/s of additional agricultural flow (Bodnaruk, 1982).

The operation of the Diversion in conjunction with Cooks Creek is controlled by two weirs, one in the Cooks Creek Channel and one in the Diversion. Given the 267-km^2 drainage area serviced by Cooks Creek upstream of its junction with the Diversion, the design agricultural flow in Cooks Creek is approximately 34 m^3/s based on a discharge Q of $0.479A^{0.765}$. Of this flow, 27.5 m^3/s is diverted down the Diversion and 6.5

m^3/s is diverted down Cooks Creek. During low flow conditions, the Diversion is designed to pass the entire upper Cooks Creek flow to the lower Cooks Creek branch to a maximum of 2.8 m^3/s. Flows larger than 2.8 m^3/s begin to pass down the Diversion. For the two percent flood event, flows of approximately 58.5 m^3/s in the upper Cooks Creek are diverted, based on 37.0 m^3/s down the Diversion and 21.5 m^3/s down the lower Cooks Creek Channel. Figures 4, 5 and 6 show the operation of the Diversion Project at various flow conditions along Cooks Creek.

3.2.2 Subwatershed No. 3

The purpose of the following discussion is to provide the reader with a brief description of the drainage particulars and the current system of jurisdictional responsibilities of the drainage infrastructure in Subwatershed No. 3. A detailed description of drainage characteristics and drain capacities observed in this research are discussed in Chapter 5.3 "Critical Assessment of Existing Drains".

Figure 7 shows the approximate boundaries of Subwatershed No. 3 as well as the land area outside the Subwatershed boundaries contributing surface runoff to the Subwatershed. The obvious question one may ask after studying this figure is why does not the Subwatershed boundary include the entire

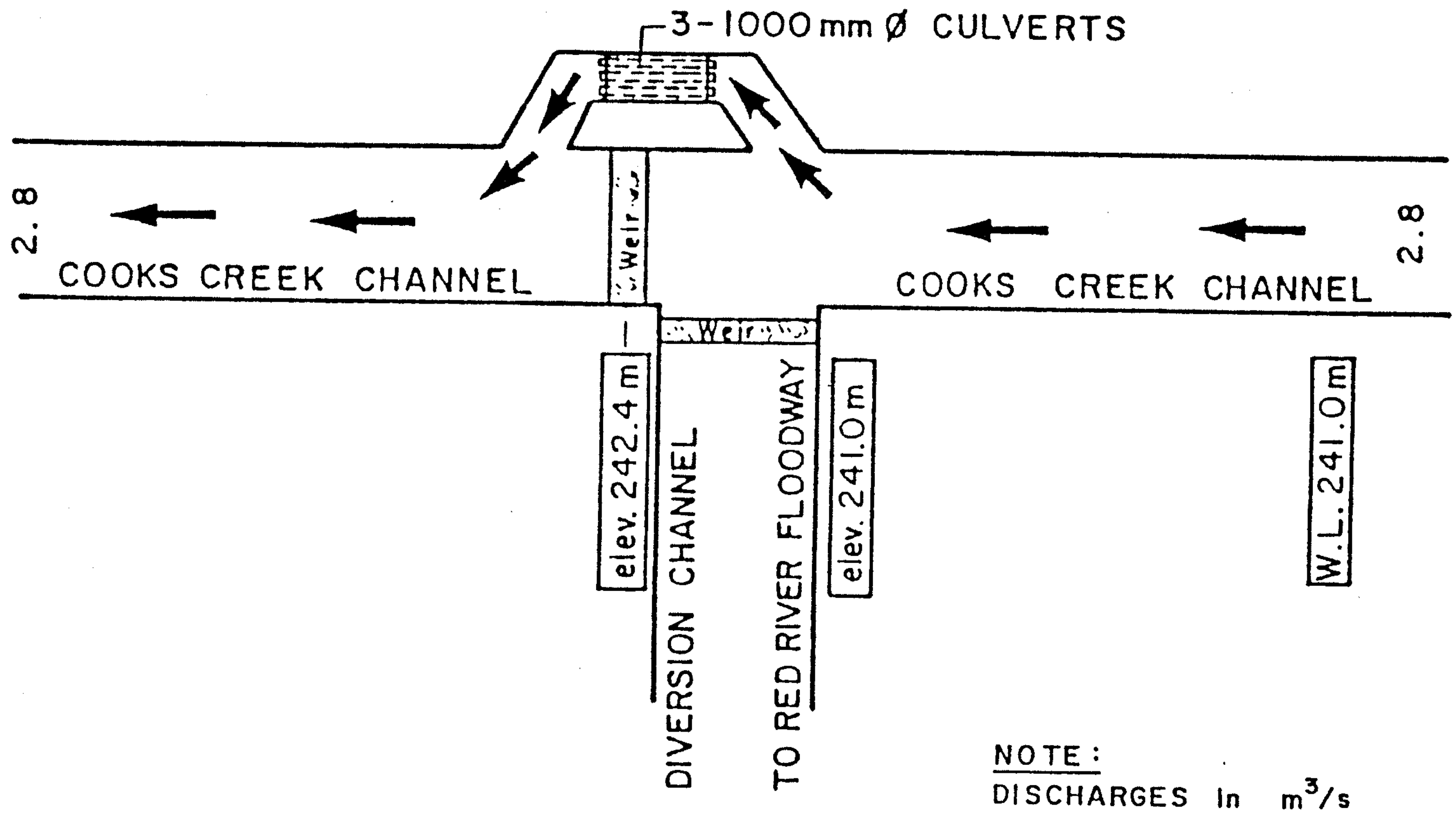


Figure 4 Low flow condition - Cooks Creek Diversion operation

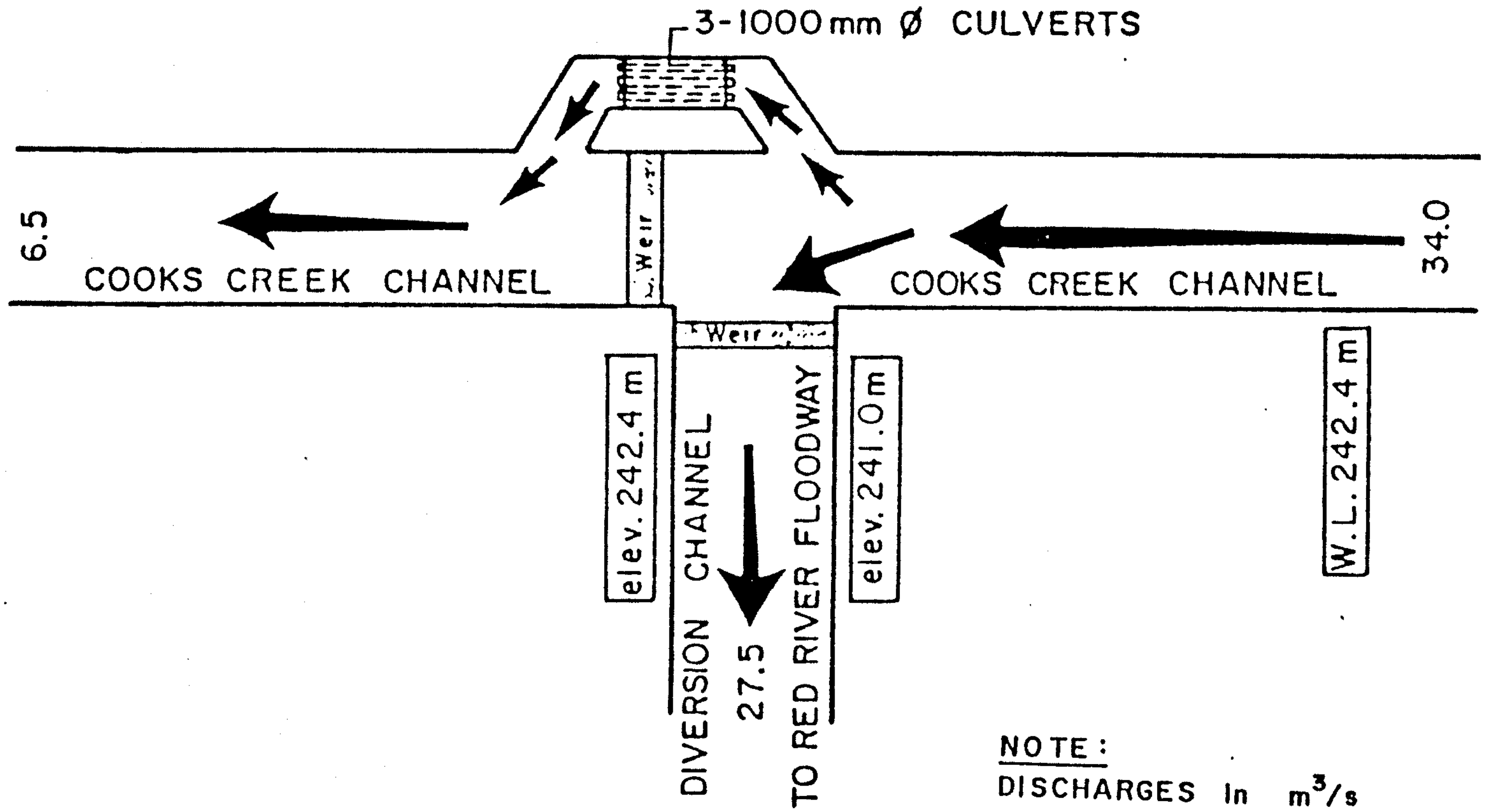


Figure 5 Agricultural flow condition - Cooks Creek Diversion operation

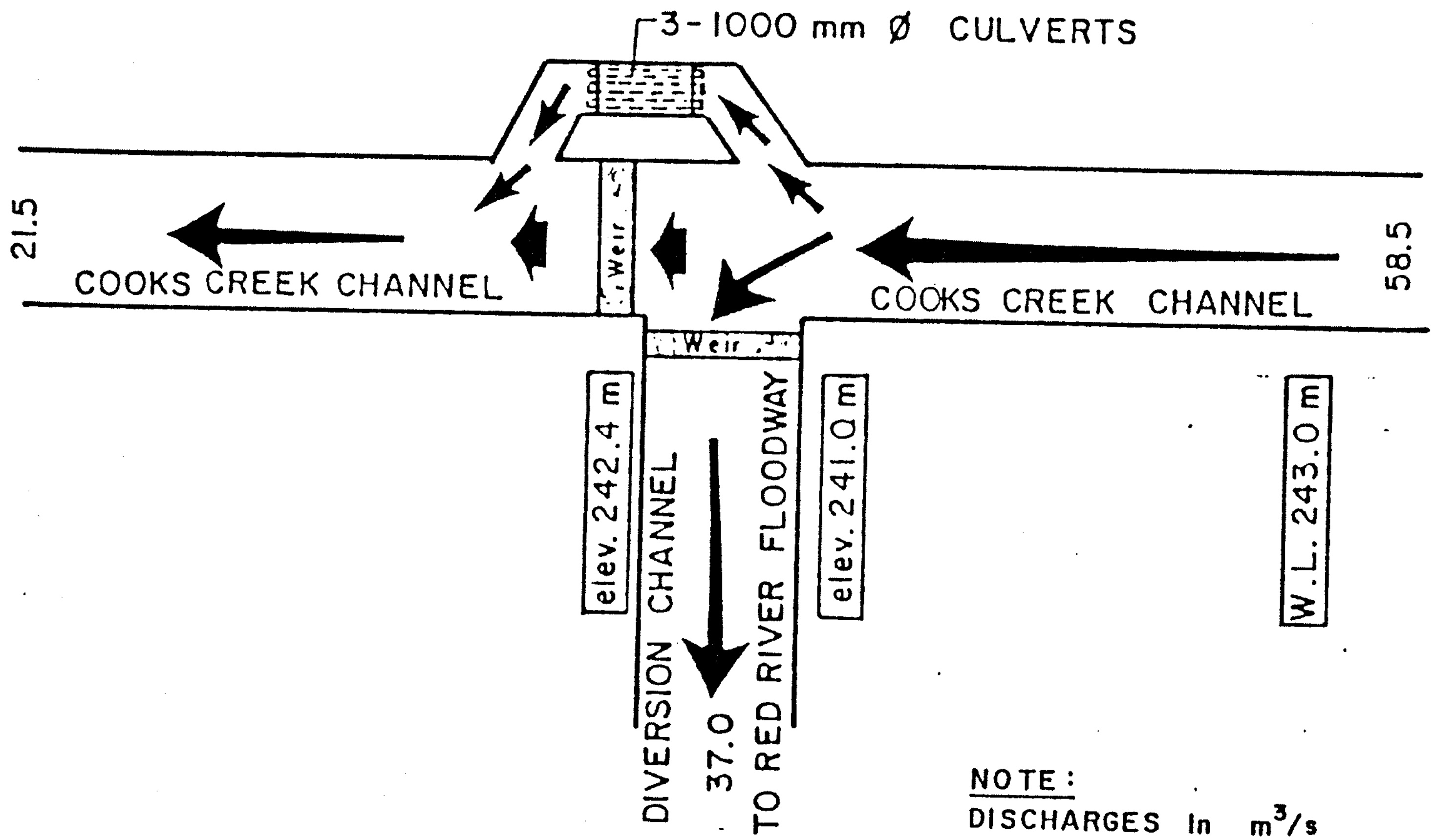


Figure 6 Flood flow condition - Cooks Creek Diversion operation

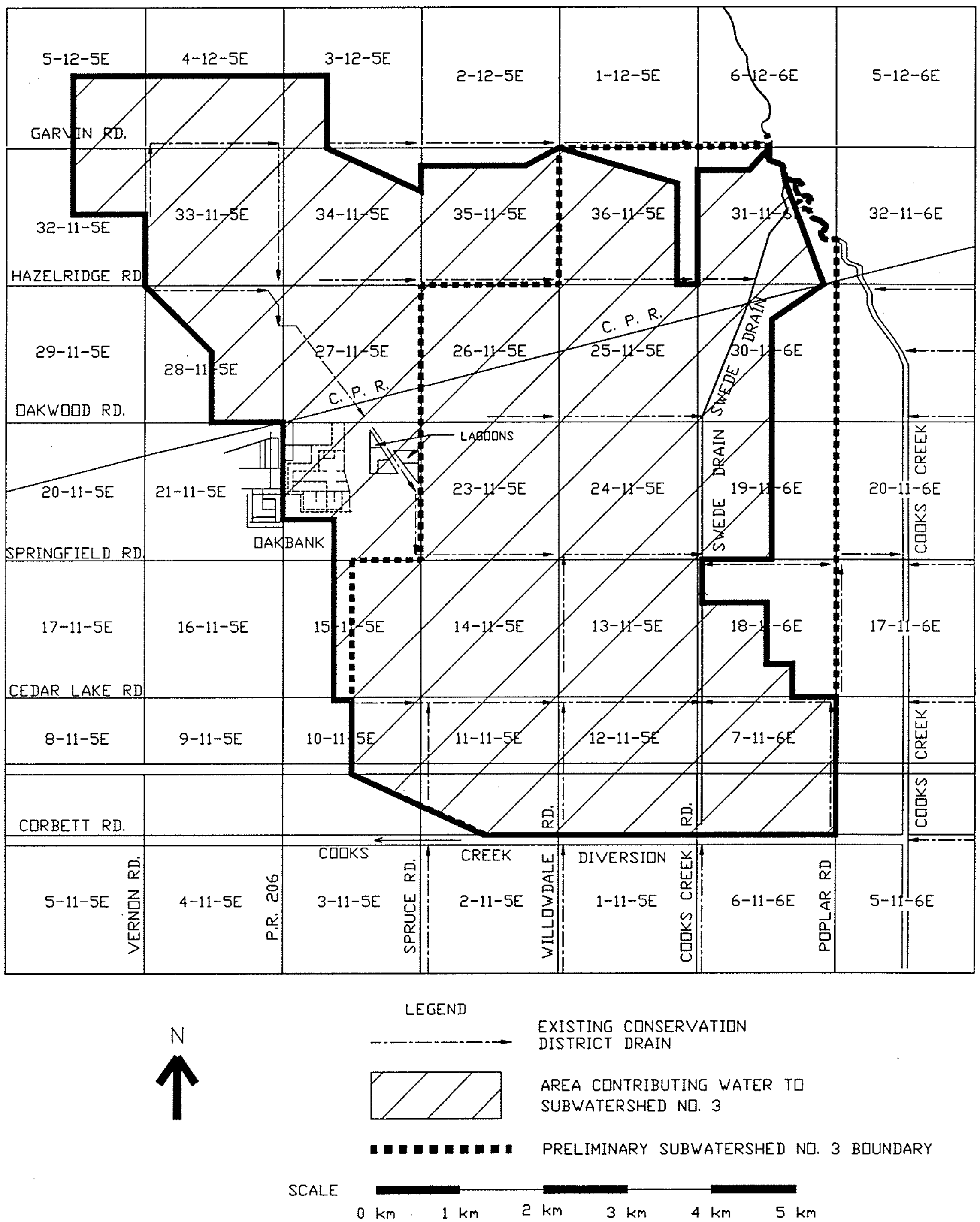


Figure 7 Approximate area contributing surface water to Subwatershed No. 3

watershed area? Subwatershed boundaries in the project area were determined from previous Phase 1 studies associated with the Diversion project. Boundary definitions of the respective subwatersheds were based on a number of factors, one of which was the subwatershed drainage area. Some of the factors used in delineating subwatershed boundaries were land use, topography, agricultural characteristics, legal boundaries, as well as known or observed areas of water management problems. The boundaries for Subwatershed No. 3 were based on these same factors. The land area enclosed by the Subwatershed No. 3 boundary was observed to be primarily agricultural land having a relatively severe problem with ponded water after the occurrence of a heavy rainfall event. Lands contributing runoff to the northwest of the Subwatershed (that is, from Sections 27, 28, 32, 33, 34 - 11 - 5E and 3, 4, 5 - 12 - 5E), although they were agricultural with similar soil characteristics to Subwatershed No. 3, were found not to have as severe a drainage problem due to their higher elevation and greater topographical relief and, thus, were not included in the Subwatershed. Since the primary purpose of the Diversion project was to provide agricultural benefits through the removal of "crop production constraints, namely the areas present susceptibility to excess moisture conditions" (from the Canada-Manitoba Subsidiary Agreement on Value Added Crops Production, 1979), the land base to the north of the Subwatershed was also omitted from the Subwatershed and project area boundary. As one moves north from the Subwatershed, much of the land base is a mixture of deciduous woodland interspersed with pasture land and, thus, was omitted from the Subwatershed and project area. Subwatershed No. 3 boundaries are more accurately defined in Chapter 5.2 "Delineation of Subwatershed Boundaries".

The location and direction of flow of the existing drains under the authority of the CCCD are shown in Figure 7. Such drains are the sole responsibility of the CCCD. Before investigating the jurisdictional responsibilities of the drainage infrastructure in the Subwatershed it is necessary to briefly review the classification of drainage waterways in the province.

All natural and artificial waterways in southern Manitoba are classified as follows (Carlyle, no date).

First Order Waterway - upper, single, unbranched tributary having a drainage area of 1.6 km^2 or less;

Second Order Waterway - one which has a drainage area of more than 1.6 km^2 or has a tributary or tributaries of the first order;

Third Order Waterway - is formed at the confluence of two second order waterways or may have any number of first and second order tributaries; and

Fourth, Fifth, Sixth, etc. Order Waterways - are defined similarly to the third, with each having any number of lower order waterways and with an increase in order where two waterways of the next lower order meet.

Under the current provincial waterways policy, the Government of Manitoba assumes responsibility for construction and maintenance of most waterways of order three or higher. The remaining waterways are the responsibility of the local municipalities. When a conservation district is formed, those orders of waterways, indicated on drain designation maps of the proposed district, then become the responsibility of the conservation district. The funding responsibility for construction and maintenance of these drains is typically shared 75 percent by the Province and 25 percent by the conservation district. Thus, all the drains highlighted in Figure 7, including the Swede Drain and the reconstructed portion of the Cooks Creek Channel, are the responsibility of the CCCD. The maintenance of roadways and respective drains adjacent to roadways, not designated CCCD drains, are the responsibility of the local municipality (in Subwatershed No. 3, this is RM of Springfield).

As can be seen from Figure 7, all CCCD drains in the Subwatershed ultimately discharge into the Swede Drain which intersects Cooks Creek in Section 31-11-6E. Cooks Creek then flows in roughly a northwest direction ultimately discharging into the Red River immediately north of East Selkirk, Manitoba.

Construction of the Diversion has now resulted in all drains south of the Diversion (that is, along Spruce Road and Willowdale Road, including the Swede Drain) discharging directly into the Diversion Channel. Prior to the Diversion project, these drains discharged into the Cedar Lake Road Drain which in turn discharged into the Swede Drain.

One of the more major drains collecting and contributing flows to the Subwatershed is the "Lagoon Drain" or "Oakbank Drain". (For the purpose of this report, this drain will be called the Oakbank Drain). The Oakbank Drain originates along Hazelridge Road in Section 28-11-5E and proceeds diagonally through 27-11-5E. The drain then connects the Oakbank sewage lagoons and proceeds south along Spruce Road to Springfield Road. The Drain then proceeds east on Springfield Road to ultimately discharge into the Swede Drain. Obviously, this Drain is responsible for the collection and discharge of surface runoff contributed by an extensive land area both within and outside the Subwatershed. Not only does the Drain collect surface runoff from surrounding agricultural lands, it also collects effluent discharged from the Oakbank lagoon and stormwater runoff from that portion of the Village of

Oakbank east of Provincial Road 206. Such extraneous flows must obviously be accounted for in the design of any drainage improvement works in the Subwatershed. The remainder of the CCCD drains in the Subwatershed are used primarily for the collection and discharge of agricultural runoff from adjacent farm land.

In general, all surface water collected on agricultural land in the Subwatershed is discharged to CCCD drains via a complex network of on-farm drains. These on-farm drains may discharge directly to CCCD drains or municipal drains. Those which discharge to municipal drains ultimately discharge to CCCD drains via culvert crossings beneath municipal roads.

Areas of severe ponding after heavy rains occurred largely in Sections 23 and 24-11-5E and in Sections 13 and 14-11-5E. Severe ponding was also reported to be a problem along the Cedar Lake Road Drain in Sections 11 and 12-11-5E. Conversations with local farmers indicated that severe ponding problems, causing major crop losses, occurred greater than five out of every ten years in these areas. Other less severe areas of reported ponding problems were reported to pond, on average three out of every ten years, causing major crop losses. Figure 8 shows the approximate location of these problem areas subject to ponding after heavy rainfall events.

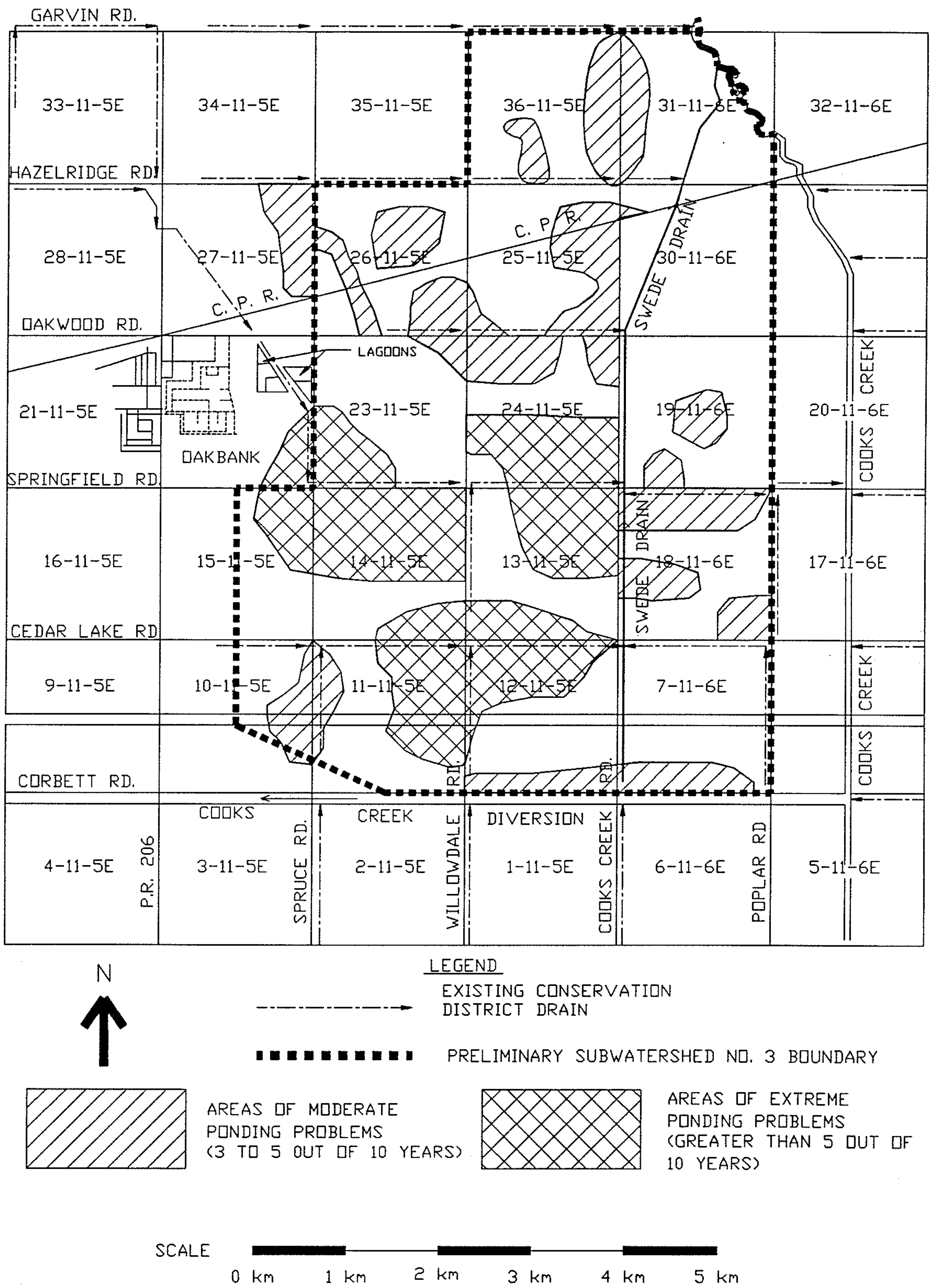


Figure 8 Problem areas subject to ponding

It is extremely important to keep in mind that this figure represents <u>approximate</u> areas of reported ponding before the construction of the Diversion project. The severity, frequency and location of ponding problems for a specific year or rainfall event depends on numerous variables such as location and duration of rainfall, condition of soil, type of crop planted, condition of on-farm drains and condition of adjacent drains, etc. Therefore, this map should be used as an approximate guide only for the location of problem areas. The location of these problem areas was determined primarily through discussions with local landowners, interpretation of aerial photographs and on-site observations.

What impact was the Diversion project designed to have on the drainage characteristics of the Subwatershed? Previous studies conducted prior to the Diversion project have determined that the Cooks Creek Channel, free of obstructions, has sufficient inherent capacity to contain a ten-percent frequency discharge (that is, exceeded less than once in ten years on the average). This capacity offers a fair degree of protection to lands immediately adjacent to the Creek and those serviced by the steep tributaries flowing into the Creek from the east. Channel gradients along the Swede Drain and some of the Swede Drain's smaller tributaries found in Subwatershed No. 3 are so flat, however, that the resulting flows and water levels in Cooks Creek near the Swede Drain outlet were too high to allow proper egress from those tributaries. Beaver dams downstream of the confluence of the Swede Drain and Cooks Creek, and numerous culvert restrictions in existing drains, also artificially raise the water surface in the Swede Drain and its tributaries. Studies conducted have indicated that because the Swede Drain and its tributaries in Subwatershed No. 3 are so flat and because the water level in the Cooks Creek is relatively high to allow for proper egress from the Swede Drain tributaries, the water surface in Cooks Creek would have to be lowered approximately 0.6 to 0.9 m to provide suitable gradients for the lateral tributaries to carry agricultural discharge to Cooks Creek (Whalen, 1977).

The Diversion project set out to relieve water levels in Cooks Creek, thereby providing an improved outlet capacity for agricultural flows for those lands downstream of the Diversion (that is, Subwatersheds Nos. 3 and 4). Studies completed by the Hydrology Section of the Water Resources Branch of the Manitoba Department of Natural Resources attempted to model the impacts of the Diversion on Cooks Creek water levels. Hydrograph analysis has shown a decrease in water levels in Cooks Creek, downstream of the Diversion, of approximately 1.4 m for a ten-percent event. Equivalent studies have shown a reduction in Cooks Creek water levels of 1.1 m for a 50-percent event (Harden, 1983).

Even though the Diversion project is now complete, this is not to say that drainage problems will be solved in Subwatershed No. 3. The inability of a drainage infrastructure to adequately discharge agricultural flows may be due to several causes. Each of these may or may not be relevant to the drains in Subwatershed No. 3. The drains may not have been designed or constructed with sufficient gradient or adequate size. Backwater effects may be created in the drains by obstructions to flow such as undersized culverts, blockage of drains with debris, vegetation growth or beaver dams. Many of the drains in Subwatershed No. 3 have insufficient channel capacity and obstructions resulting in their inadequate performance. Thus, numerous drains in Subwatershed No. 3 may require reconstruction to adequately discharge agricultural flows.

3.3 <u>Water Management Concerns</u>

Before a water management strategy can be developed for Subwatershed No. 3, one must firstly appraise and rank the water management concerns in the area. Without an adequate understanding of just what the water management concerns are, a planner or designer may misallocate priorities or funds in the planning and construction of required works.

Water management concerns were determined almost exclusively through discussion with local landowners, CCCD personnel, RM of Springfield councillors, Municipal Planning Branch personnel, and various personnel with the Water Resources Branch of the Department of Natural Resources and the Manitoba Department of Agriculture. Each of these concerns are discussed below. Although other water management concerns were expressed, many of these were typically "site-specific" and pertained to an individual landowner's specific water management problems.

3.3.1 Surface Water Ponding

The dominant water management concern voiced by the majority of the individuals interviewed was the ponding of surface water on agricultural land after excessive spring snowmelts and summer rainfall events. The fine-grained clay soils of the Subwatershed are intensely farmed; however, their impermeable nature, high moisture retention qualities and flat topography results in their susceptibility to excess precipitation. Such excess precipitation tends to pond on the ground surface resulting in crop saturation causing reduced crop yields and, in extreme cases, total crop failure. Local landowners suggested that it was not uncommon to have areas of their land flooded for up to five days or more after a severe rainfall event. Thus, one of the primary concerns was the provision of a better drainage infrastructure to protect against crop losses caused by inundation of farmlands following summer rains.

3.3.2 Inadequate Maintenance of Existing Drainage Infrastructure

A second major concern voiced by landowners was the lack of maintenance provided with respect to the existing drainage infrastructure. For a drainage infrastructure to operate efficiently, it must undergo regular maintenance and repairs. Obstructions to flow in drains due to blockage of culverts, siltation, vegetation growth, etc. must be removed through a strict maintenance program. Provisions must also be made available for the emergency maintenance of drains.

Landowners voiced concerns about the lack of routine maintenance and of excessive delays in the emergency repairs of drains. Many drains in the Subwatershed have been deprived of maintenance for a number of years. Thus, many drains in the Subwatershed showed signs of excessive vegetation growth, siltation and erosion. This has resulted in a decline in drain performance over the years and, therefore, the inability of many of the drains to adequately remove ponded water from adjacent lands within a reasonable length of time.

Landowners also expressed concerns over the timeliness of emergency repairs to drains. For instance, oftentimes culverts may become blocked with debris or drains may silt in after a severe dust storm in the Subwatershed. Landowners have voiced concerns about the excessive time required (often days) before such necessary repairs can be made by the CCCD.

An additional concern respecting drain maintenance was the presence of numerous beaver dams in the vicinity of the confluence of the Swede Drain and Cooks Creek Channel. Many people interviewed felt the presence of these beaver dams, and their resulting backwater effects, was one of the primary reasons for poor drain performance. The CCCD has attempted to remove both the dams and beavers in the past but has done so with limited success. The number of beavers in this area is anticipated to be quite large and trapping efforts in the past have failed to solve the problem. In addition, access to the beaver dams has required intrusion onto private lands and local landowners have objected to the presence of heavy equipment on their property and the blasting or demolition of beaver dams.

Regarding maintenance of agricultural drains, many people interviewed questioned the ability of the CCCD to perform the necessary work. The CCCD lacks staff and the necessary equipment to accomplish this task itself and, therefore, must rely on the availability and response time of local contractors or the regional office of the Engineering and Construction Branch of the Manitoba Department of Natural Resources. The administrative time required in obtaining such resources has resulted at times in delays in the maintenance of drainage works.

The amount of money spent on maintenance of CCCD drains in the Subwatershed varies from year to year. It is estimated that approximately $8,000 to $9,000 per year may be spent on drain maintenance in the Subwatershed. Much of this money is spent on vegetation control in the Oakbank and Swede Drains due to excessive cattail growth as a result of receiving lagoon effluent from the Village of Oakbank.

3.3.3 Drain Jurisdiction Responsibilities

All orders of designated provincial waterways became the responsibility of the CCCD upon formation of the District in 1979. The various local municipalities continue to assume responsibility for roadways and drainage works adjacent to roadways not designated as CCCD drains.

This split jurisdiction has resulted in confusion among local landowners, municipal planning officials and other government agencies as to who is responsible for which drain and what the scope of that responsibility may be. Landowners were in general confused as to who to contact (the RM of Springfield or the CCCD) to request for items such as culvert crossing, maintenance demands, or permission to discharge on-farm drains. Municipal planning officials and other officials from other government agencies seemed confused and voiced their concerns to more fully understand which drains were whose responsibility and who to contact to request approvals for proposed residential land subdivisions or other land use plans. It should be noted that the RM of Springfield and the CCCD seemed to have a clear understanding of the drains for which each was responsible. The confusion primarily lies among local landowners and other government agencies.

This split jurisdiction has resulted in further problems when considering major construction activities proposed by the RM of Springfield (such as roadway upgrading or maintenance of road washouts, for instance) in any right-of-way containing a CCCD drain. Local municipalities, such as the RM of Springfield, are fortunate in having the flexibility to undertake various construction and maintenance programs within a right-of-way whenever the need or a problem arises. The RM of Springfield has its own technical staff and equipment to design and construct such improvement works. Should such activities impact on drains within CCCD jurisdiction, the municipality has voiced concerns regarding the excessive time required for the CCCD, and its affiliated government departments, to conduct the necessary studies and receive the necessary approvals for any cost-sharing arrangements that may be proposed. Such approval processes often delay the projects.

3.3.4 Lagoon Effluent

Another major concern expressed by local landowners along the Oakbank Drain and the CCCD was the impact of discharging lagoon effluent from the Village of Oakbank sewage lagoon. Wastewater from this lagoon is discharged typically twice per year (in the spring and fall) into the Oakbank Drain where it ultimately discharges into the Swede Drain, Cooks Creek and the Red River. This nutrient-rich waste has caused tremendous amounts of vegetative growth (particularly cattails) in the Oakbank and Swede Drains. This dense growth of cattails (particularly in the Oakbank Drain) has had a tremendous impact on the hydraulic performance of these drains thereby impeding their efficiency to discharge agricultural runoff. The Swede Drain was also subject to cattail growth but the problem was not as extreme as in the Oakbank Drain. This excessive vegetation growth has resulted in the CCCD having to conduct an extensive cleaning operation of these drains, usually in the fall of each year. Such cleaning operations in the Oakbank and Swede Drain has cost the CCCD approximately $500/km.

Further expansion of the Village of Oakbank, with the construction of a 300-lot residential subdivision to the east of Provincial Road 206, will require further lagoon expansion which undoubtedly will add to the vegetation problem in the receiving drains.

3.3.5 Oakbank Stormwater

The Village of Oakbank currently discharges a portion of its stormwater to the drainage infrastructure in Subwatershed No. 3. The Village is equipped with an underground land drainage sewer running the length of Provincial Road 206 from approximately the southern limits of Oakbank to the junction of Provincial Road 206 and the CPR tracks. This land drainage sewer collects stormwater off Provincial Road 206 and discharges it to a pumping station located at the junction of Provincial Road 206 and the CPR tracks. This pumping station in turn pumps the collected stormwater to the south drain along Oakwood Road which ultimately discharges into the Oakbank Drain.

The 300-lot subdivision being constructed in the Village to the east of Provincial Road 206 has been designed to discharge its stormwater to the Oakbank Drain as well. Although this subdivision is not equipped with land drainage sewers, it will be equipped with roadside ditches and serviced by a major swale intersecting the Oakbank Drain immediately south of the Village's lagoons. The CCCD has expressed concerns regarding the ability of the drainage infrastructure (particularly the Oakbank Drain) to accept additional flows from the Village of Oakbank. At the time of preparation of this report, engineers for the RM of Springfield were investigating feasible options for the drainage system for the development in an attempt to address some of these concerns.

3.3.6 Culvert Capacity

Many landowners and CCCD personnel felt many of the drains were hydraulically restricted, primarily by undersized culverts located at crossings. A detailed engineering analysis investigating the design flows and culvert hydraulics for each drain would be required to confirm these notions.

3.3.7 Spring Flood Protection

The need for spring flood protection was another concern voiced by some landowners in the Subwatershed. Spring flooding has resulted in some localized property damage in the past, primarily to municipal property such as roads and bridges. Some local farmers have voiced concerns about the undue length of time required for floodwater to recede from their land thereby delaying seeding operations in the spring.

It should be noted that, although spring flood protection was a concern, it was not considered a dominant concern. Most farmers gave the impression that much more significant and detrimental losses have occurred from crop damage as a result of excess summer precipitation. Most landowners felt the completion of the Cooks Creek Diversion project would alleviate, to some extent, some of their spring flooding concerns.

3.3.8 On-Farm Drainage

The CCCD and the Manitoba Conservation Districts Authority have voiced concerns respecting the existing level of on-farm drainage and the respective commitment by local farmers to improve their on-farm drains should an improved drainage infrastructure be constructed. Obviously, any potential agricultural benefits derived from an improved drainage infrastructure would be negligible if the existing level of on-farm drainage is inadequate and there was a lack of commitment by local farmers to improve their on-farm drains.

3.3.9 Rural Residential Development

The increasing amount of rural residential development in the Subwatershed has also contributed some water management concerns. Each residential development adjacent to a CCCD drain requires an access crossing over the drain to the respective residence. Such access crossings require culvert installations which in turn require increased maintenance. The increasing number of these crossings can also gradually impede the hydraulic performance of a drain.

3.3.10 Other Concerns

Although not directly a water management concern, many people interviewed seemed to feel there was a lack of communication between themselves and the CCCD. This problem was voiced especially by municipal councillors, local agricultural representatives and municipal planning officials. Many local landowners also voiced some concerns respecting communication difficulties. Discussions with these people left this researcher with the impression that many of these people felt "in the dark" respecting the CCCD's plans, projects and activities. Many people seemed confused as to what a conservation district was and the respective purpose, function and responsibilities of a conservation district to the community. In general, there seemed to be some local understanding that a conservation district was to be a multi-resource management organization; yet many landowners and councillors felt the CCCD to date has had a single-purpose mandate, namely, to provide, regulate and approve land drainage works only.

At the time of preparation of this report, the CCCD was in the process of preparing its long-term management plan. This process will involve active public participation in the input and preparation of the plan. Such an exercise will perhaps "crystallize" the objectives, roles and functions of the Conservation District in the minds of the public. Despite this exercise, improved communication would seem to be required between the CCCD and those people impacted by its actions.

3.4 Agricultural Characteristics

3.4.1 Soils

The soils of the Subwatershed consist almost exclusively of heavy clays. Glacial retreat and the subsequent formation and drainage of glacial Lake Agassiz have yielded the deposits characteristic of the Subwatershed and the entire Red River Valley (Manitoba Department of Municipal Affairs, 1973). The dominant clay soils comprising the Subwatershed are known as Red River and Osborne clays. A review of soil survey maps prepared by the Canada/Manitoba Soil Survey in 1975 indicated that almost 90 percent of the Subwatershed is composed of these Red River and Osborne clays. The remaining 10 percent of the soils consist of either Dencross clay, Glenmoor clay or Marquette clay. Of the Red River and Osborne clays in the

Subwatershed, the Osborne clay dominates. Of the 90 percent of the land base occupied by the Red River and Osborne clays, the Osborne clays account for approximately 65 to 75 percent of the respective area.

The Osborne clays consist typically of poorly drained fine-textured humic soils developed on moderately to strongly calcareous lacustrine alluvial deposits. Surface drainage is poor because of level or depressional topography and because permeability is very slow for these clays. Rates of surface water infiltration into these soils is restricted because of their fine texture and usually high antecedent soil moisture conditions (Canada-Manitoba Soil Survey, 1975 and Slevinsky, 1977). Unless artificially drained, these soils are seasonally ponded. The agricultural suitability of these soils ranges from poor to fair, depending on the amount of artificial drainage and the degree of surface stoniness (Canada-Manitoba Soil Survey, 1975).

The Red River series consists of imperfectly drained soils developed on a calcareous fine-textured lacustrine deposit. Runoff is slow and internal drainage is slow. Internal drainage is often impeded by high antecedent soil moisture in early spring. These soils, like the Osborne soils, require artificial drainage to prevent water ponding during periods of excessive rainfall and flooding (Slevinsky, 1977).

3.4.2 Agricultural Productivity and Limitations

In general, most of the agricultural soils within Subwatershed No. 3 are highly productive and suitable for intense agriculture under proper growing conditions. Crop yields can, however, be greatly reduced when the clay soils are subject to heavy rains or flooding (Slevinsky, 1977).

The Red River and Osborne clay soils, characteristic of the Subwatershed, have been classed as having an agricultural capability of 2W and 3W, respectively[1]. Class 2 soils have been designated as those soils having moderate limitations that reduce the choice of crops or require conservation practices. These soils have a good water holding capacity and are naturally well supplied with plant nutrients and are responsive to inputs of fertilizer. They are moderately high to high in productivity for a fairly wide range of crops. The W sub-class indicates that these soils are imperfectly drained fine-textured soils and that they are generally found on level or gently sloping topography. Surface runoff is slow and internal drainage is very slow. Delayed seeding and reduced yields because of wetness occur in seasons of above-average

[1] Soil Capability for Agriculture, Canada Land Inventory, ARDA, Winnipeg - Map Sheet 62 H, 1966

rainfall. Surface drains are required to remove standing water (Canada-Manitoba Soil Survey, 1975).

Class 3 soils have moderately severe limitations that reduce the choice of crops or require conservation practices. The limitations are slightly more severe then Class 2 soils due to one or two of the following: climate, soil characteristics, low fertility, texture, salinity, erosion, topography, overflow, wetness, stoniness and depth of soil to bedrock (Canada-Manitoba Soil Survey, 1975). The W sub-class once again defines excess water, other than from flooding, as one of the principal limits for agricultural use.

These fine-textured clays found in southern Manitoba and characteristic of Subwatershed No. 3 are generally limited to grains such as wheat, barley, flax, and canola. Where drainage is provided, be it artificial or natural, more specialty crops such as corn, sunflowers and sugar beets are being grown. In general, these clay soils have severe management problems due to their rapid ponding after heavy rains, prolonged waterlogging and problems with the operation of farm machinery after a wet period (Schellenberg and Bodnaruk, 1983). A high level of drainage is necessary in order to achieve a sufficient improvement in the agricultural productivity of these soils. Under such proper water management conditions, these soils are highly productive and suitable for agricultural cultivation (Whalen, 1977).

In 1977, a report was prepared investigating the relationship between soil moisture and crop yields in the RM of Springfield (Slevinsky, 1977). The report entitled "The Effect of Excess Moisture on Cereal Production within the RM of Springfield" investigated yield information for wheat and oats on the Red River and Osborne clay soils found in the RM of Springfield. A portion of the study area included an investigation of "problem" and "non-problem" soils in Subwatershed No. 3. "Problem" areas were deemed to be those areas subject to excessive moisture conditions while "non-problem" areas were those areas where reported excessive moisture conditions were not deemed the major limiting factor in crop production. Yield data, based on Manitoba crop insurance records, for these respective areas were studied for an 11-year period, 1965 to 1975, and generally showed decreased yields on both "problem" and "non-problem" lands when summer precipitation amounts or frequency of precipitation was excessive causing surface water ponding. In general, "problem" areas showed lower yields than "non-problem" areas.

The report concluded drainage improvements would be considered warranted in both the problem and non-problem areas. Therefore, drainage in the RM of Springfield appears to be inadequate to handle above-normal moisture conditions on all

Osborne clays. The report also concluded that, by minimizing the effects of excessive moisture, increased yields for all areas could be realized. The report found an average difference in yield of 0.58 T/ha for wheat and 0.48 T/ha for oats between "problem" and "non-problem" areas (Slevinsky, 1977).

In conclusion, the soils of the Subwatershed seemed ideally suited for cereal crop production. The dominant limiting factor to crop production seemed to be excessive wetness, particularly after heavy rains, due to the poor internal drainage characteristics of the soils. As a result, these potentially productive soils are subject to ponding of surface water and prolonged saturation. The time and frequency of saturation has resulted in crop deterioration and, in extreme cases, total crop failure.

3.4.3 Current Agricultural Practices and Future Cropping Patterns

Agricultural practices in the Subwatershed consisted primarily of cereal crop production. At the time of this report, approximately 70 to 80 percent of the Subwatershed's agricultural land base consisted primarily of cereal crops (typically wheat and barley). The remaining 20 to 30 percent of the land base consisted of oilseed crops (typically flax and canola) and forage crops (typically alfalfa, red clover and birdsfoot trefoil).

The majority of the farmers in the Subwatershed are strictly grain farmers. However, three of the larger farmers have mixed farming operations. One operates a large dairy farm in conjunction with grain production. The other two raise geese and bees respectively in conjunction with their grain operation. Some farmers had seeded specialty crops such as lentils, peas, faba beans and sunflowers and reported good production from these crops in a dry year and when they were able to drain excess surface water.

Of the crops produced in the Subwatershed, the following represents an approximate breakdown of the land areas devoted to each crop: (These proportions are likely to change from year to year depending on economic circumstances.)

Wheat	50%
Barley	20%
Flax	10%
Canola	10%
Forage and Other	10%
Total	100%

Discussions with local farmers indicated the lack of adequate agricultural drainage to be one of the limiting factors in crop production. Almost all farmers felt that better yields could be achieved with an improved drainage infrastructure. When asked if their cropping patterns would change if an improved drainage infrastructure was provided, almost all said they would attempt to develop specialty crops such as peas, canary seed, lentils, faba beans and sunflowers. Without an improved drainage infrastructure, serious adaption of these specialty crops was deemed to be too risky due to their susceptibility to damage from excessive moisture conditions. Without an improved drainage infrastructure, most would continue to rely on the traditional cereal, oilseed and forage crops currently being planted.

In general, most local landowners in the Subwatershed rated their land as excellent for the growing of traditional crops such as wheat, barley, flax and canola with the proviso that adequate drainage could be provided. Almost all landowners felt their crop yields would increase if an improved drainage infrastructure was provided. Most farmers, especially the larger farmers, felt that, with an improved drainage infrastructure, they would seed more land into specialty crops given the proper economic climate for these crops.

3.5 Agricultural Drainage Requirements

3.5.1 The Concept of Precipitation Excess

Agricultural drainage requirements are often determined by the amount of precipitation excess or the duration of time that precipitation excess remains on the field after a rainfall event. The purpose of the following discussion is, therefore, to introduce the reader to the concept of precipitation excess and the variables which must be considered when attempting to quantify precipitation-excess parameters. It is not the intent of this discussion to provide a technical description of methodologies used to calculate precipitation excess. Such methodologies can be quite complex and are considered beyond the scope of this report.

Rainfall is essential to crop production but excessive amounts of rainfall can lead to soil saturation resulting in reduced crop yields or total crop losses. Such losses can depend on the stage of growth of the crop, the type of crop, soil characteristics and the amount of time the crop is subject to excess moisture. The objective of agricultural drainage is, therefore, to remove excess water from agricultural land during the growing season (Whitney, 1987). Where new or improved agricultural drainage systems are technically feasible for alleviating precipitation excess, their economic feasibility becomes particularly relevant to guide drainage planning.

The concept of precipitation excess is a relative one and, therefore, it can be difficult to define and quantify. Precipitation excess is often defined as the soil moisture level which is greater than adequate, optimal, or tolerable for specific plants. The persistence of such a condition, therefore, gradually results in retardation of plant growth. The use of this definition results in a variation of quantifiable precipitation excess values depending on the type of plant and its tolerance of moisture. The impacts of precipitation excess using this definition is confined not merely to the growing season but also to the seeding and harvesting periods. Excess precipitation in the seeding and harvesting season can result, in extreme cases, in complete crop failure. Therefore, precipitation excess using this definition must be carefully measured with respect to type of crop, time in the growing season, duration of precipitation excess and watershed characteristics to name a few of the variables (Rigaux and Singh, 1975).

Precipitation excess can be defined with respect to the time duration for which there is surface water flowing into drainage ditches following a particular rainstorm for that watershed. The duration of precipitation excess, therefore, depends on climatic factors and the physical characteristics of the watershed (Rigaux and Singh, 1975). This definition of precipitation excess is often more appealing due to its practicality. Scientists, engineers, agronomists and farmers often use duration of precipitation excess, measured usually in days, as a measure of the magnitude of the excess precipitation problem.

Other more theoretical approaches measure precipitation excess in units of days from discharge hydrographs. Various techniques are presented in the literature with respect to hydrograph modelling to define precipitation excess based on drain discharge data. One of the major obstacles with such techniques is the requirement for accurate drain discharge records for the watershed in question and the corresponding correct interpretation of the generated hydrograph (Rigaux and Singh, 1975). It is considered beyond the scope of the report to provide a detailed explanation of the various hydrograph techniques.

Precipitation excess on agricultural land, defined with respect to the number of days of saturation and the resulting runoff, is dependent on numerous variables. Some of the variables include the following (from Rigaux and Singh, 1975):

- daily precipitation records
- antecedent precipitation index

- existing drainage capacity
- difference in elevation between the outlet and the highest point in the watershed
- length of the main watercourse
- the drainage area
- land use or vegetative cover of the watershed
- soil type and drainage characteristics of the soil
- topography of the area

Quantification of such variables to predict precipitation excess for a specific storm event can be an onerous task and, many times, subject to the interpretation of the researcher in quantifying the variables. This is not to say that estimates of precipitation excess are impossible. In 1973, an extended research study was undertaken to investigate a suitable methodological approach for the evaluation of agricultural drainage proposals in Manitoba. The study produced a three-volume report in 1975 entitled, "Benefit-Cost Evaluation of Improved Levels of Agricultural Drainage in Manitoba"[2]. Volume 1 of this report concentrated on quantifying precipitation excess variables for the purpose of providing information for a cost-benefit analysis for the provision

[2] By L. R. Rigaux and R. H. Singh, Department of Agricultural Economics, University of Manitoba, in cooperation with the Water Resources Division, Manitoba Department of Mines, Resources and Environmental Management.

of agricultural drainage. Volume 2 of the study attempted to assess the impact of excess moisture on crops based on historical production records for wheat, oats, barley and flax over the period between 1968 to 1972. Volume 3 focused on the physical relationship of the previous volumes to develop a computer model to predict benefits for various levels of drainage improvement. The results of Volume 1 of this study produced a synthetic hydrograph model to predict precipitation excess times. This model effectively calculated precipitation excess times and corresponding discharges from a specific watershed for a particular storm event. The model, however, is extremely complex and demands the quantification of all the above mentioned variables. Details of this model are considered beyond the scope of this report.

3.5.2 The Impact of Precipitation Excess

What are the impacts of excess water on crops? The Soil Conservation Service of the United States Department of Agriculture has identified and discussed the effects of excess moisture on crops as follows (United States Department of Agriculture, Soil Conservation Service, 1973).

1. Evaporation, which takes heat from the soil, lowers soil temperature. Also, wet soil requires more heat to warm up than does dry soil due to the high specific heat of water as compared to that of

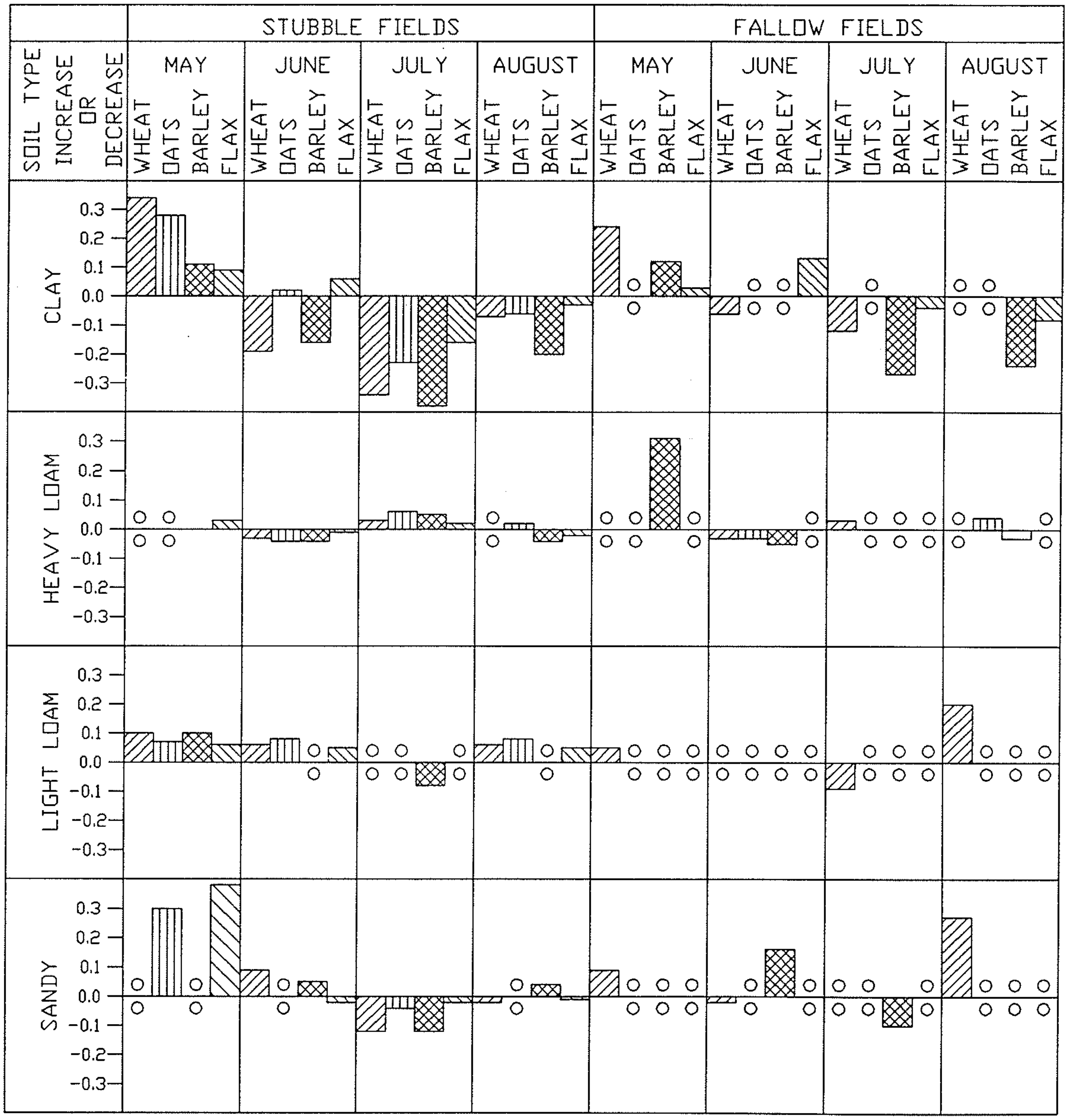
soil. Thus, the growing season is shortened.

2. Saturation or surface ponding stops air circulation in the soil and prevents bacterial activity.
3. Certain plant diseases and parasites are encouraged.
4. A high water table limits root penetration.
5. Soil structure is adversely affected.
6. Salts and alkali, if present in the soil or ground water, tend to be concentrated in the root zone or at the soil surface.
7. Wet spots in the field delay farm operations or prevent uniform treatment.

Generally, it has been observed that losses in grain yields are directly related to the duration of flooding. This is not to say that flooding is the sole cause of losses in yields but rather that flooding, if it occurs for an extended period of time, can result in yields being reduced from their optimum, given crop conditions for that year.

Numerous studies have been conducted in a number of Manitoba watersheds to determine the impacts of precipitation excess on various soil and crop types. The Rigaux-Singh study and report of 1975 analyzed 32 situations in Manitoba representing four crops grown on four soil types on fallow and stubble land. The results of the study are shown in Figure 9. The study revealed that crop losses occur mostly in the

CHANGES IN YIELD IN TONNES PER HECTARE
PER DAY OF PRECIPITATION EXCESS



○ INSIGNIFICANT OR NEGLIGIBLE

Figure 9 Changes in yield - per day of precipitation excess
Source: Adapted from Rigaux and Singh, 1975

clay soil areas of the province. The largest crop damage occurred from precipitation excess in the months of June, July and August. Yield losses amounted to up to 0.34 T/ha per day of precipitation excess for wheat whether on stubble or fallow field. In terms of the four crops investigated (wheat, barley, flax, and oats), barley was found to show the greatest absolute damage, followed by oats, wheat, and flax. The results also indicated that drainage investments would generate the largest benefits in clay soils. Obviously, these benefits must also be related to the costs of providing the drainage infrastructure.

It is not entirely unreasonable to extrapolate these findings to Subwatershed No. 3. Although the lost yield in T/ha per day due to precipitation excess may vary, the general observation is likely to be the same. As indicated previously, Subwatershed No. 3 consists primarily of heavy clay soils. Results of the Rigaux-Singh studies, therefore, seem to suggest that crop losses on these soils are much greater during periods of precipitation excess in the months of July and August. Precipitation excess in the month of May would seem advantageous to crop production.

Actual monetary values of crop losses due to precipitation excess can be extremely difficult to determine. The losses for a particular watershed would obviously depend on the type of crops grown, the proportion of the watershed occupied by the respective crops, their respective yield decrease due to precipitation excess and the price received by the farmer for the harvested crop. Studies conducted in the RM of Springfield, which included some of the lands in Subwatershed No. 3, suggested a conservative estimate of an average gain of 0.58 T/ha per year of wheat production if excessive moisture effects could be minimized (Slevinsky, 1977). Gains were anticipated to be slightly higher for oats and barley. Similar studies conducted in the Marsh River watershed, to the east of Morris, Manitoba, suggested a gain of approximately 0.40 T/ha per year for wheat, 0.69 T/ha per year for barley and 0.11 T/ha per year for oats on Osborne clay soils if suitable drainage was provided (Slevinsky and Schellenberg, 1980). As previously noted, Subwatershed No. 3 is composed primarily of the same Osborne clay soils. Considering these studies, it would seem reasonable to expect similar yield increases in Subwatershed No. 3 for the respective crops due to the similar conditions.

Monetary values gained or lost due to precipitation excess are specific only to the year in question. Agricultural commodity prices can vary widely from year to year and the same variation in price results in wide variations in cropping patterns by farmers. This variability makes the accurate quantification of precipitation excess impacts and corresponding monetary benefits of drainage improvement works very difficult to determine.

The purpose of the above discussion was to emphasize the fact that precipitation excess impacts on crops is a relative concept. The impacts obviously depend on the type of crops grown in a watershed, the time of year precipitation excess occurs, the levels of existing drainage provided, soil types, the duration of precipitation excess, the proportion of the watershed occupied by the respective crops and the price of the harvested product. Past studies, however, have indicated that benefits can be achieved for the traditional crops of wheat, oats, barley and flax if a suitable drainage infrastructure is provided to alleviate precipitation excess problems on clay soils. It can also be seen from previous studies that precipitation excess occurring in the months of July and August, for a period of 24 hours or more, can result in significant crop damage during this critical growing period.

3.5.3 Agricultural Drainage Requirements and the Rigaux-Singh Study

Given the above discussion, how does one determine, therefore, the agricultural drainage requirements to design for when considering drainage improvement works? The approach of the Province of Manitoba was the development of four categories of cropping standards to guide the planning, design and building of drainage works in agro-Manitoba. Each standard was an attempt to reflect long-term agricultural production once the limiting factor of excess soil moisture is removed. The four standards are: (Manitoba Department of Natural Resources, 1984).

a) Special Crops: Little tolerance to excess moisture. Crop losses occur within a few hours.

b) Cereal Crops: Limited tolerance to excess water. During the active growing season, crop losses will occur within 36 hours.

c) Forage Crops: Moderate tolerance. These crops can withstand flooding for up to four days during the active growing season without showing yield reductions.

d) Pioneer Standard: Applied to native hay and pasture lands. Yields may increase with flooding. However, excess water should be drained within ten days during the active growing season.

Generally, areas with agricultural soil capability ratings of Class 1, 2 or 3 warrant drainage services to the special crops or cereal crops standard (Manitoba Department of Natural Resources, 1984).

These general standards, developed in 1984 by agrologists, continue to serve drainage engineers today as initial guidelines for the level of drainage to be provided. The decision to build a drainage system, however, must be based, at least in part, on whether the expected benefits in increased crop production exceed the costs of construction and operation. This comparison of benefits and costs should determine the relative standard to which the drainage infrastructure is to be constructed. The necessity to consider benefits and costs at various levels of drainage led to the Rigaux-Singh study to examine an appropriate methodological approach.

The Rigaux-Singh study attempted to provide an analytical benefit-cost framework for optimizing the benefits available for various levels of drainage investment. The study evaluated costs and benefits for various levels of drainage improvements in fifteen separate watersheds throughout Manitoba. The watersheds were selected so that they were of varying size and shape with varying topography, soils and existing levels of drainage development representative of the agriculture land bases throughout the province. The concept of the research study was that crop loss is directly related to precipitation excess during the growing season where precipitation excess was defined as the measure of the time, in hours, that land had water laying on its surface.

In the study, comparisons of crop yields were made between areas of various known or determined levels of drainage for various soils. Numerous assumptions were made in an attempt to quantify factors such as topography, soil type, crops grown, land use, fertilizer use, existing drainage, soil moisture and growing season stage. The result of the study was an economic benefit relationship relating crop damage to the level of drainage provided.

The extreme complexity of the analysis, the assumptions used in the analysis and the numerous variables to be addressed by such an analysis make the application of the technology difficult to defend.[3] In general, however, the model did produce results that seemed reasonable and provided a general relationship between drainage level and crop yield relationships that one would expect for various soils (Schellenberg and Bodnaruk, 1983).

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[3] Many people interviewed during the course of the research appreciated the thoroughness of the Rigaux/Singh study but questioned its reliability given the number of variables to consider and the complexity of the model.

One of the primary strengths of the study was the rationale relating the level of drainage to be provided to the economics of the problem (Figures 10 and 11). Figure 10a illustrates the idealistic relationship that one might expect when considering level of drainage improvement versus crop yield. The level of drainage improvement is often defined by the formula $Q = CA^K$ where:

- Q = discharge in m^3/s or ft^3/s of the drain in question;
- C = a coefficient relating the characteristics of the watershed to the level of protection required for the drainage area.
- A = drainage area in question in km^2 or $mile^2$
- K = exponent in the nonlinear relation between Q and A.

The shape of the curve would obviously vary for different soils and for different proportions of land in crop as shown in Figure 10b. In a general sense, should there be no drainage improvement, there will be some minimum level of protection resulting in a given average crop yield. The average yield will improve with the level of drainage to a point where additional drainage provided is no longer a factor.

Figure 11a shows typical cost and benefit curves for various improvements in drainage. From these curves, a

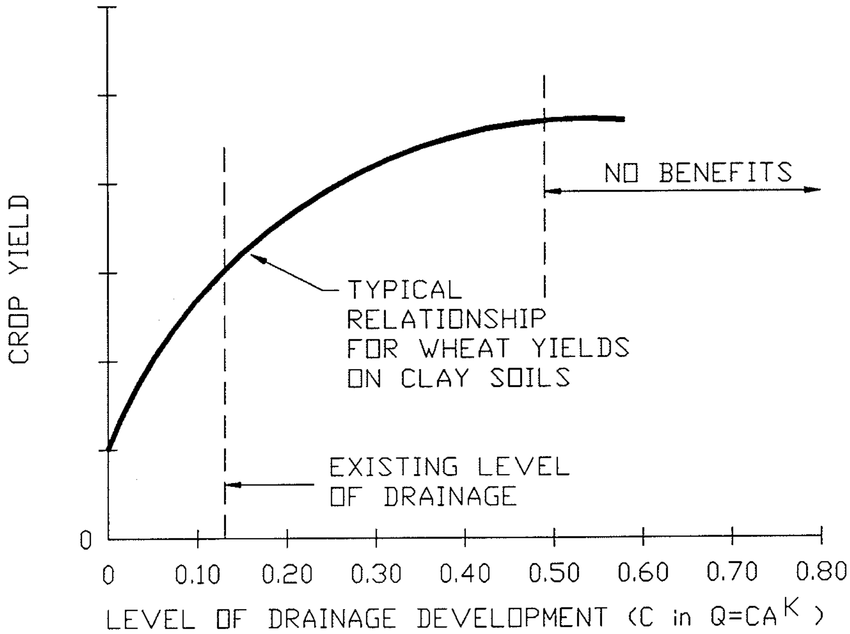


Figure 10A

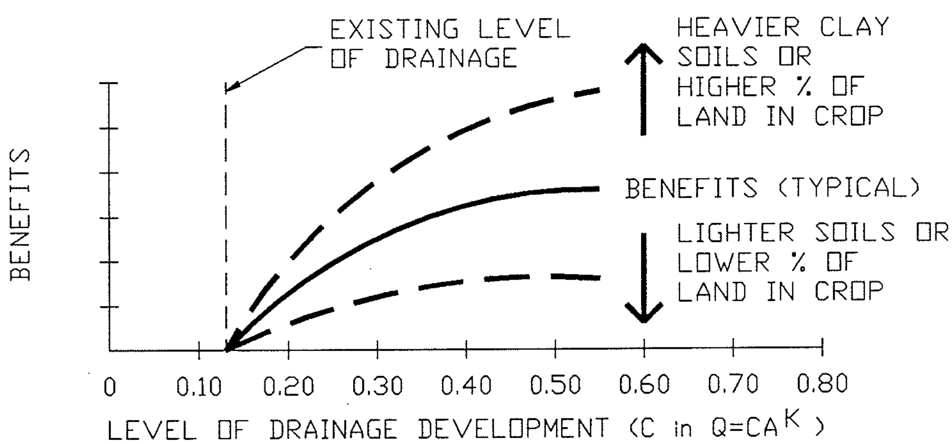


Figure 10B

Figure 10 Typical crop yields and benefits versus level of drainage development

Source: Adapted from Schellenberg and Bodnaruk, 1983

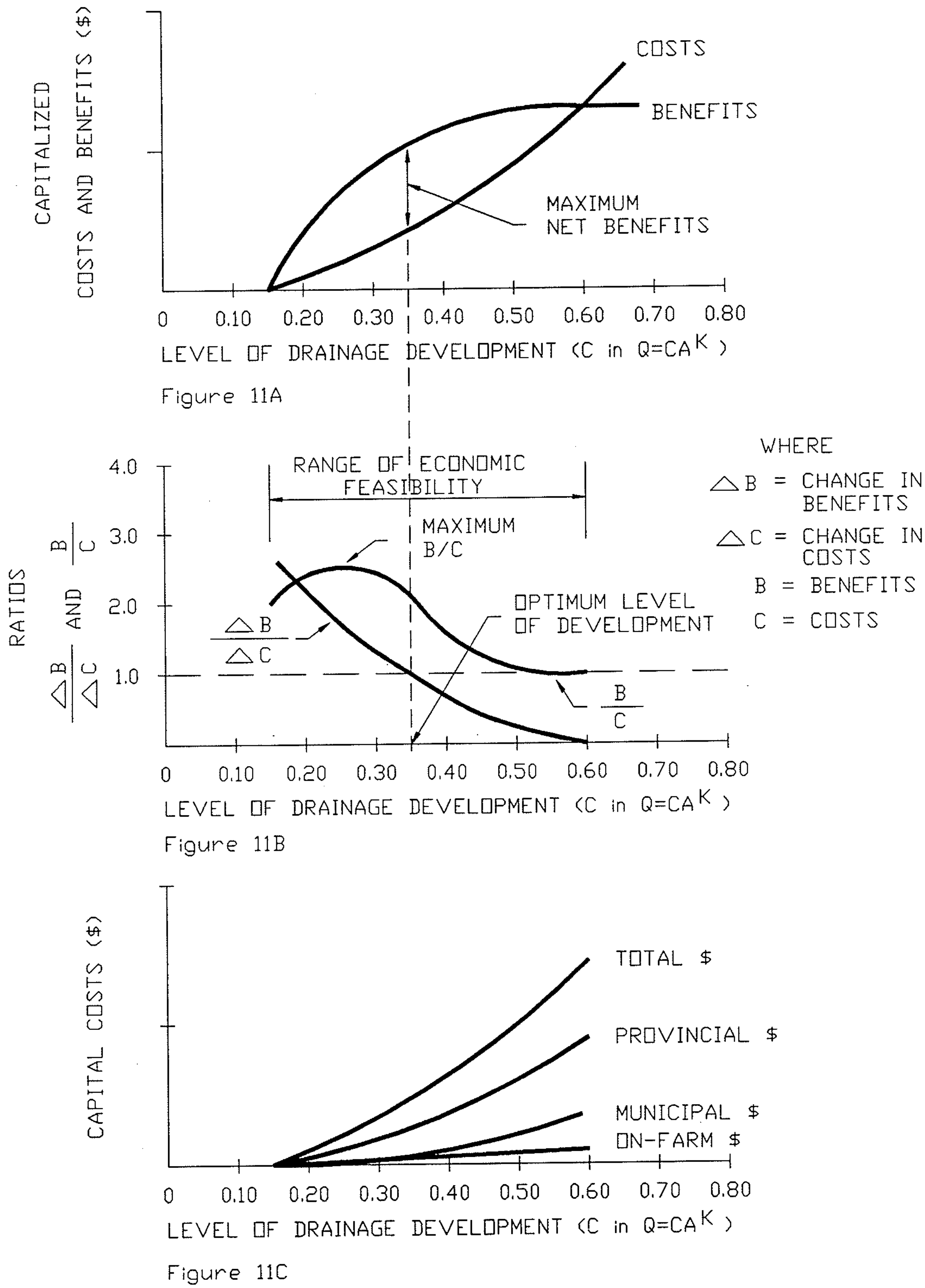


Figure 11 Typical cost and benefit relationships versus level of drainage development

Source: Adapted from Schellenberg and Bodnaruk, 1983 marginal benefit-cost curve and a benefit-cost curve (Figure 11b) and a capital cost breakdown (Figure 11c) are developed. The optimum level of drainage that should ideally be provided is at the point where for greater levels of drainage improvement, the incremental cost begins to exceed the incremental benefit.

Ideally, one would like to construct all drainage improvement works to the "optimum" level. Unfortunately, drainage improvement works are extremely capital-intensive and must compete for funds with other capital projects. Due to budget constraints, they are seldom designed to their "optimum" level but rather to a level where the benefit/cost ratio is at a maximum and greater than 1.0. Such decisions free more funds to be used on other capital projects. Those drainage projects with the higher benefit/cost ratios should be constructed first until the drainage budget has been exhausted.

In general, the Rigaux-Singh studies demonstrated benefits could be achieved through drainage improvements in those areas of Manitoba consisting mainly of heavy clay soils with very little topographical relief. Those areas of the province having steep topography and light loamy soils were found to produce only marginal increases in benefits given various levels of drainage improvement. The study also provided a rationale for the determination of optimum levels of agricultural drainage requirements when considering the costs and benefits of such works.

3.5.4 Agricultural Drainage Requirements and Subwatershed No. 3

Despite some of the shortcomings and misgivings of the Rigaux-Singh methodology, the Province of Manitoba began to attempt to use this approach in 1979 for a number of drainage projects that were cost-shared with the Government of Canada under the "Canada-Manitoba Subsidiary Agreement on Value Added Crops Production". The Cooks Creek Diversion project (Project No. 401) was included in this Agreement. Under the terms of this Agreement, it was required that the design and supply of the improved drainage network for the Cooks Creek Diversion project would "involve analysis by means such as those developed by Rigaux and Singh". The objective of the project was "to provide opportunity for the production of crops, including those of a value-added nature, in the Cooks Creek basin. Achievement of the objective will be through reduction or removal of crop production constraints, namely, the area's present susceptibility to excess moisture conditions" (from The Canada-Manitoba Subsidiary Agreement on Value-Added Crops Production, 1979). Benefits of the project identified under the Agreement included the production of so-called "value-added" crops, which, in general, was taken to mean specialty crops such as canola, sunflower, annual pulse crops and corn. At the time of the Agreement, these crops were felt to be "on the average higher in value than the existing cereal crops". The Agreement noted also that "reduction of excess moisture conditions will result in yield increases of approximately 12 percent for those areas which remain in cereal production and for those areas already producing value-added crops", thereby acknowledging that higher returns on a given parcel of land, in effect, also constituted "value-added" and, hence, qualified for funding under the Agreement.

Because the Rigaux-Singh methodology was so complex and time-consuming and since time constraints were a primary concern under the terms of the Five-Year Subsidiary Agreement, simplified procedures were adopted for the Rigaux-Singh analysis. For example, and with specific reference to the Cooks Creek Diversion project, it was decided that "sophisticated economic feasibility studies such as the Rigaux-Singh computer analysis would require excessive study time and would cause unacceptable delays in carrying out the drainage projects. Short-cut methods would have to be applied to recommend design levels and demonstrate economic feasibility" (Bodnaruk, 1980).

To determine the appropriate level of drainage protection to be provided to the Cooks Creek Diversion project area, including Subwatershed No. 3, the anticipated benefit estimates for various levels of drainage were based on the extrapolation of benefit estimates for other drainage projects where the Rigaux-Singh analyses had been applied. Determination of the benefits of drainage improvements resulting from the Cooks Creek project were based on a study of benefits determined in the Roberts McTavish, Mills Wheatland, and the Domain Drain watersheds. These watersheds are all located south of Winnipeg in the Red River Valley on clay soils having very little topographic relief, similar to the situation in the Cooks Creek Diversion project area. A detailed Rigaux-Singh type analysis was performed on each of these drainage watersheds to determine the approximate benefits for various levels of drainage improvement. The benefit curves derived for each of these projects were then analyzed and extrapolated to the Cooks Creek Diversion project and compared to estimated costs of providing drainage infrastructure improvements.

Based on an analysis of these curves, it was estimated that a drainage standard for which $Q = 0.479A^{0.765}$ (where Q = discharge in m^3/s and A = area in km^2) would result in an average crop yield benefit of \$43/ha per year for wheat production, assuming a wheat price of approximately \$202/T in 1981. Assuming a 15-year project life and a real interest rate of 5 percent, the present value of drainage benefits was estimated to be $8.6 million for the Cooks Creek Diversion project given that the Diversion Project was constructed from Cooks Creek to the Red River Floodway. On the basis of rough cost estimates for the drainage infrastructure improvement in the project area, the benefit/cost ratio was calculated to be approximately 0.80 (Bodnaruk, 1981).

Although this benefit-cost ratio was unfavourable, one must keep in mind the nature of the analysis. Quantification of impacts of precipitation excess and benefits due to drainage improvement is extremely complex and subject to many variables, including the interpretation of the researcher. The analysis conducted on the Cooks Creek Diversion project was an extrapolation of benefits calculated in similar watersheds and considered wheat production only. A detailed cost-benefit analysis would obviously have to incorporate allowances for other crops that potentially may be grown, including specialty corps. The analyst would also have to accurately predict future crop prices and choose an appropriate discount rate while accounting for the numerous other variables that would impact the analysis. For the Cooks Creek Diversion project, the standard of $Q = 0.479A^{0.765}$ was therefore considered to be reasonable based on previous value-added studies having similar conditions to that of the Cooks Creek Diversion project (Bodnaruk, 1982). Considering the variables which one must consider, the benefit-cost ratio for the project could widely fluctuate to levels greater than unity or less than unity, depending on the assumptions made by the analyst.

With reference to Subwatershed No. 3, it was subsequently decided, in the course of this study, to continue to use this drainage standard of $Q = 0.479A^{0.765}$ in the design and costing of drainage improvement works. This would retain consistency with the standard adopted for other drainage works in the Cooks Creek Diversion project area since the same standard had been used in the preliminary design of drainage infrastructure improvements in Subwatersheds Nos. 1 and 2 as well as in the design of the already constructed Cooks Creek Diversion. Designing for a standard other than $Q = 0.479A^{0.765}$ at this stage in the project would involve intense justification by the analyst and detailed calculations of corresponding benefits and costs. Such an analysis was considered beyond the scope of this research and was not attempted.

The $Q = 0.479A^{0.765}$ drainage standard would provide agricultural protection for flows to approximately a 20-percent event which would amount to a slightly more than doubling the existing standard of drainage in the project area, including Subwatershed No. 3 (Bodnaruk, 1982).

3.5.5 Losses from Poor Agricultural Drainage

One of the primary losses from poor agricultural drainage is its impact on crop production due to the effects of excess soil moisture. These effects of excess soil moisture on crops have been discussed in Chapter 3.5.2 "The Impact of Precipitation Excess". Studies have indicated that an average difference in yield of 0.58 T/ha per year for wheat can be expected on lands in the RM of Springfield when considering drainage "problem" and "non-problem" areas (Slevinsky,1977).

Losses from poor agricultural drainage are not, however, limited to losses incurred as a result of decreased crop yields. Agricultural lands with poor drainage can have depressed land values. Poor drainage has also been reported to create a health hazard due to mosquitoes which breed in ponds and field drains. Excessive soil moisture is also the cause of soil compaction by animals or machines. Excessive soil moisture also inhibits warming of the soil in spring thereby delaying germination. Plant diseases are also more prevalent when roots are subject to excessive moisture conditions (Luthin, 1965)

For the purpose of this report, a cursory investigation was conducted to calculate approximate annual losses in crop production alone, without any consideration of other adverse effects of inadequate drainage. The following assumptions and information were used in the analysis.

- The majority of crop losses occurred in those areas shown in Figure 8.
- Since wheat was the dominant crop seeded in the Sub-watershed and since landowners will likely continue to concentrate on wheat production in those areas of reported ponding, wheat was used in the calculation of yield losses.
- Yield losses of 0.58 T/ha of wheat per year were assumed in those areas of reported ponding problems.
- Price for wheat = $173/T based on prospective grain prices for 1989 as published by the Manitoba Department of Agriculture.
- Probability of severe ponding is 40 percent for those areas reporting moderate ponding problems and 80 percent for those areas reporting severe ponding problems.
- Total land area reporting moderate ponding problems was assumed to be 765 ha.
- Total land area reporting severe ponding problems was assumed to be 789 ha.

Based on the above information, potential annual loss of wheat production in the areas of moderate ponding is:

0.58 T/ha X 765 ha X $173/T X 0.4 = <u>$30,700</u>

Potential annual loss of wheat production in the areas of severe ponding is:

0.58 T/ha X 789 ha X $173/T X 0.8 = $63,300

Thus, the total potential annual loss of wheat production in Subwatershed No. 3, due to excessive soil moisture, is approximately $30,700 + $63,300 = $94,000

Chapter IV

DRAINAGE DESIGN METHODOLOGIES AND DESIGN STANDARDS

4.1 Introduction

Before one can devise and cost various water management strategies for Subwatershed No. 3, a brief investigation of drainage design methodologies and design standards is required. The purpose of this chapter, therefore, is to provide the reader with a brief overview of the various methodologies and standards used in drainage infrastructure design and construction as well as a brief review of on-farm drainage mechanisms. This chapter is not intended to be used by the reader as a technical manual for the design and construction of drainage works in Manitoba but is written to provide the reader with a conceptual idea of some of the design methodologies and construction standards used when considering construction of a drainage infrastructure.

Before discussing the respective design methodologies, it may be helpful to first consider applicable types of drainage. Methods for land drainage can be classified into two categories - surface and subsurface drainage. In surface drainage, the land is reshaped and ditches are constructed to divert ponded water from fields using gravitational flow of water over the ground surface. This field surface water is then discharged to a drainage collection infrastructure, consisting of open-channel drains, where water is collected and ultimately discharged to a suitable outlet. Surface drainage is typically adapted to flat land where the soil is fine-textured and slowly permeable (Ontario Ministry of Agriculture and Food, 1986). With subsurface drainage, deep ditches and buried drainage conduits are installed to convey excess ground water to a gravity or pumped outlet (United States Department of Agriculture, Soil Conservation Service, 1973). In Manitoba, only surface drainage was used until 1967 and continues to be the predominant form of drainage today due to its simplicity and relatively low cost. Very little subsurface drainage has been installed in the province (Penkava, 1976). Subsurface drains work best on soils that are permeable enough to allow free subsurface water to move readily through the soils to the drains (Manitoba Department of Agriculture, 1985). In the case of Subwatershed No. 3, since removal of ponded water after heavy rains is the primary concern and the land consists of impermeable clay soils, surface drainage techniques would seem to be the most appropriate and cost-effective method of drainage.

Because of the numerous drainage design methodologies highlighted in the literature, it was decided to concentrate descriptions of the various methodologies to those currently being applied in the province of Manitoba in calculating agricultural flows. These methods include the following:

- SCS curves method
- regional method
- rational method
- transitional method
- benefit-cost methodology

4.2 Design Methodologies

4.2.1 SCS Curves Method

The SCS curves method was developed by the Soil Conservation Service (SCS) of the United States Department of Agriculture. Criteria for the design of drainage systems using this methodology were based largely on empirical formulae. Such formulae were based on rates of surface water removal over the past 60 years and have been refined by observational experience and gauged data (United States Department of Agriculture, Soil Conservation Service, 1973). The general equation of the curves is written as follows:

$$Q = CA^K$$

where: Q = required channel capacity in m^3/s or ft^3/s

A = drainage area in km^2 or $mile^2$

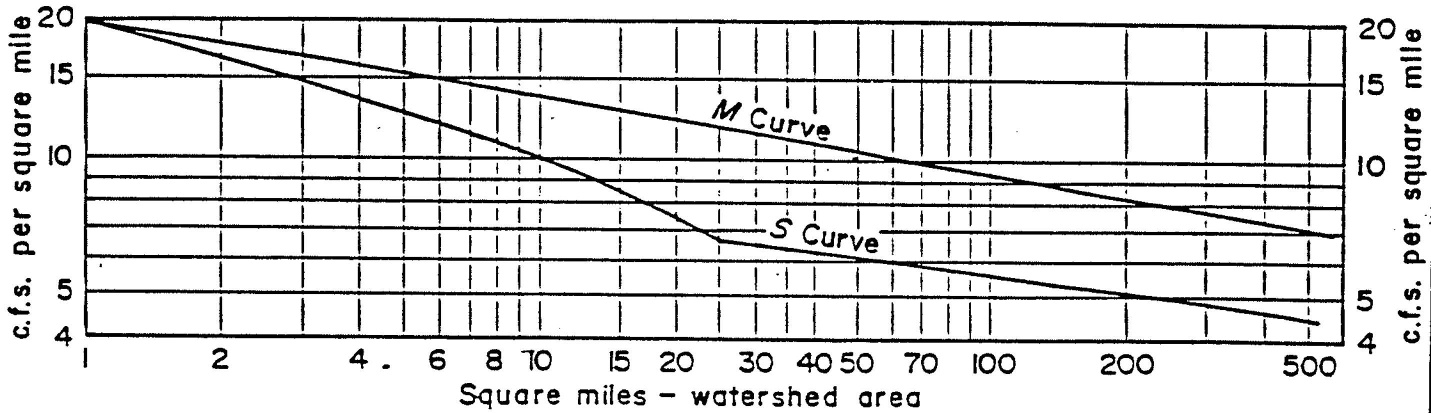
C = a drainage coefficient

K = exponent in the nonlinear relation between Q and A

The exponent K varies between watersheds and represents the decrease in rate of flow per unit area as the size of the watershed increases. The coefficient C incorporates factors related to the level of protection required for the drainage area, as well as the conversion from area to discharge units in the formula (Ontario Ministry of Agriculture and Food, 1986).

The various equations derived by the SCS curves method are usually expressed as a curve where rates of water removal vary according to the size of the drainage area. Such curves are published by the Soil Conservation Service of United States Department of Agriculture and the American Society of Agricultural Engineers.

For the Red River Valley of Minnesota and North Dakota, two specific drainage curves, entitled the S and M curves, are recommended (Figure 12). These same curves were applied uniformly throughout the province of Manitoba as a drainage design standard in the past and are still widely used in parts of the province today. The M curve is typically applied to land with a topography having an average slope greater than 0.25 percent and is generally associated with high rates of



M curve developed by Minn. Dept. of Drainage and Waters. S curve developed by John T. Stewart, U.S.D.A., 1907.

DRAINAGE COEFFICIENTS FOR RED RIVER VALLEY, MINNESOTA - NORTH DAKOTA

M curve should be used for conditions producing high rates of runoff including: steep slopes, impervious soils, crops requiring better drainage, and areas having intensely developed systems of farm drainage.

S curve should be used for conditions producing small rates of runoff which may include: flat slopes, pervious soils, crops requiring ordinary drainage and areas with least development of farm drainage systems.

DESIGN MEMORANDUM GENERAL
FLOOD CONTROL
ROSEAU RIVER, MINNESOTA
RED RIVER VALLEY M CURVE
ST. PAUL, MINN. DISTRICT - CORPS OF ENGINEERS
FILE NO. R2-R-5/54

Figure 12 S and M design curves

runoff for crops requiring better drainage in areas having intensely developed systems of on-farm drains. The S curve is used for land which has an average slope not greater than 0.25 per cent and is generally associated with cropland (Engineering and Construction Branch, Manitoba Department of Natural Resources, 1980). In addition to the S and M curves, the province has adopted a modified S curve which is typically applied to forage land and pasture land having a topography with slopes of up to 0.38 percent. This modified S curve produces discharges much smaller than the S or M curves to reflect the land use, topography and drainage requirements of forage cropland in Manitoba. It should be noted that the curves shown in Figure 9 are in Imperial units of measurement.

The application of the S and M curves developed in the United States to drainage infrastructures in Manitoba was assumed to be adequate for Manitoba conditions. Unfortunately, this application did not always allow adequately for differences in soil types, climatological differences or seasonal precipitation variations between the conditions in the United States and in Manitoba. The approach was perpetuated, however, for the sake of convenience and served well in a pioneering role where lands could be made reasonably productive and provide protection for excessive wet conditions sufficient to permit some farms to survive and even prosper (Schellenberg and Bodnaruk, 1983). These standards are still used today, particularly where new drainage works are proposed in an area where all other upstream or downstream areas have already been designed to the S or M curve standard.

4.2.2 The Regional Method

The regional method is based on regional flood frequencies from a statistical analysis of streamflows at stream gauging points throughout Manitoba which predict respective flow magnitudes and return periods. Regional curves are thus based on peak flows, most commonly the result of snowmelt, and in some cases by rainfall events.

The basic form of the equation in the regional method is once again $Q = CA^K$

where: Q = discharge in m^3/s

C = a drainage coefficient

A = area of watershed in km^2

K = exponent in the nonlinear relation between Q and A

Determination of the coefficients C and K in the formula is based on a statistical analysis of a plot of measured discharges at various stream gauging stations versus the respective watershed area serviced by these stations. Obviously, as the drainage area increases, the discharges measured by downstream gauging stations should also increase. Such a plot of stream discharge versus drainage area produces a scatter curve where each point represents a measured discharge on a stream for a given drainage area and for a particular event.

Stream gauge records from watersheds have shown that the rate of flow per unit area decreases as the total area of the contributing watershed increases. The exponent K is roughly determined by plotting recorded stream discharges versus drainage areas on logarithmic paper where the curve previously plotted now approximates a straight line. A regression analysis is performed to determine the most suitable straight line and the slope of this line is the value of the coefficient K. Variations in K, therefore, define regions of different hydrologic characteristics. Currently, southern Manitoba is divided into approximately seven different regions each having a different K-value.

Values for the coefficient C are computed by solving the equation $Q = CA^k$ for C at the various stream gauging stations for the particular frequency of occurrence of the event.

The regional method, therefore, bases its rationale on the analysis of stream gauge data for an upstream watershed. In Manitoba, most of these upstream watersheds are quite large, generally greater than 100 km^2. When considering smaller watersheds, this methodology is considered to be inaccurate due to numerous assumptions inherent in the methodology not being satisfied. As a result, this methodology is usually confined to the calculation of discharges from watersheds having an area greater than approximately 40 km^2. It is generally felt that smaller watersheds possess neither the overall detention storage capabilities nor times of concentration, and the other attributes of larger watersheds which reduce peak flows. Smaller watersheds may also produce their highest runoff events with an extreme short-duration rainfall event rather than by snowmelt. Regional curves are more commonly based on peak flows due to snowmelt (Harden, 1986). For these reasons, different methodologies have been adopted for determining design flows in watersheds smaller than 40 km^2.

4.2.3 The Rational Method

The rational method is used by designers to estimate discharges of various frequencies from small drainage areas of less than 13 km^2 (Harden, 1983). The rational formula takes the following form:

$$Q = 0.0028\ CiA$$

where: Q = peak discharge in m^3/s

i = rainfall intensity for a given frequency (mm per hour) whose duration is equal to the time of concentration t_c

A = drain area in ha

C = a dimensionless runoff coefficient

One of the inherent difficulties in the rational formula is estimation of the time of concentration t_c and the runoff coefficient C. The time of concentration is the time required for runoff to reach the point in question from the farthest point of the basin. Many formulas for determining time of concentration do not recognize that times vary greatly with the nature of the watershed (Roads and Transportation Association of Canada, 1982). The formula commonly used to determine time of concentration in agricultural drainage works is given by:

$$t_c = \frac{0.057L}{S^{0.2}\ A^{0.1}}$$

where: t_c = time of concentration in minutes;

L = length of channel to head of basin in m;

S = net slope in percent; and

A = watershed area in ha.

Once the time of concentration is known, the corresponding rainfall intensity may be determined from intensity - duration - frequency curves.

The method assumes that, if a rainfall of uniform intensity and unlimited duration falls on a watershed, the runoff will reach a maximum at the time of concentration t_c. The formula does not allow for any retardation in flow by storage or for the momentum of flow in channels (Gray, 1973). Thus, discharges calculated using the rational formula are peak instantaneous discharges whereas the regional flood formulas discussed previously give peak mean daily flows. Use of the peak instantaneous flows would require greater channel capacities and typically more costly structures (such as bridges or culverts) to carry this capacity. Even in small watersheds, there is usually some storage available in ditches or agricultural drains to reduce peak flows. Also, if capacities of a culvert or drain are exceeded for a short period of time, there are usually minimal serious consequences. Thus, in Manitoba, peak instantaneous flows given by the rational method are often converted to mean daily flows for the design of drains and structures.

Another major limitation of the rational formula is in estimation of the runoff coefficient C. This runoff coefficient varies with factors such as land use, nature of the surface, surface slope, degree of saturation, rainfall intensity and surface storage (Gray, 1973). One typically resorts to tabulated values of C for a given watershed area. Such values can range from 0.08 to 0.70 and are subject to the judgement of a designer in the selection of a coefficient.

In Manitoba, use of the rational method is limited to small watersheds of less than 13 km^2 (Harden, 1983). In an analysis of synthetic hydrographs used to convert peak flows given by the rational method to mean daily flows, Harden noted that, if a watershed had a time of concentration of six to nine hours, the watershed tended to produce its maximum mean daily flow. For times of concentration greater than nine hours, the mean daily flow would begin to decline. Research has indicated that, for a time of concentration of greater than nine hours, a watershed would require an area of approximately 14 km^2 (Harden, 1983). The actual mathematical modelling details of this analysis are considered beyond the scope and purpose of this review and will not be discussed.

To simplify calculations and to compensate for design engineer judgement, some design flows computed by the rational method are provided in table or chart format for design engineers in the Engineering and Construction Branch of the Manitoba Department of Natural Resources. Mean daily discharges have been determined for various frequencies assuming a flat cropped clay soil as a standard for a unit drainage area. Rainfall intensities used were based on interpretation of 1981 Environment Canada intensity duration curves for Winnipeg. Correction factors have also been tabulated to account for land use, slope and soil type and the areal variation in precipitation intensity.

4.2.4 The Transitional Method

Given that the rational method is used for watersheds up to 13 km^2 and the regional method used for watersheds greater than 40 km^2, this leaves those watersheds of between 13 and 40 km^2. For these watersheds (between 13 and 40 km^2), the transitional method is employed.

The methodology currently used in the transitional method is as follows: the discharge relevant to the rational method is determined for a 13 km^2 area and the discharge relevant to the regional discharge for a 40 km^2 area. To determine discharges between these areas, a linear relationship is assumed between the discharge and the incremental drainage area in the range between these two extremes. For example, if the rational discharge at 13 km^2 is 14.15 m^3/s and the regional discharge at 40 km^2 is 21.23 m^3/s, then the transition discharge at 26 km^2 is:

$$14.15 + [21.23 - 14.15] \frac{26-13}{40-13} = 17.56 \ m^3/s$$

The use of this method results in a smooth transition between the rational method and the regional method.

In conclusion, one of the dominant methodologies used for calculating agricultural drainage continues to feature the use of the S and M curves. In an attempt to compensate for the limitations of the S and M curves, the rational method was applied to determine agricultural discharges based on frequency of occurrence for smaller watersheds between 0 and 13 km^2. The rational method attempts to incorporate factors such as land use, topography, soil type, and rainfall intensity characteristics of watersheds specific to Manitoba. The rational method was developed primarily since it was "not felt reasonable to use regional flood curves, developed for drainage one or more magnitudes larger, for small drainage areas" (Harden, 1986). The regional method is used to determine flows generated by a watershed based on regional flood frequencies for watersheds greater than 40 km^2. The transitional method is used to determine flows between 13 km^2 and 40 km^2.

It should be noted that the rational, transitional and regional methodologies are all used to determine resulting flows based on frequency of occurrence of an event (such as rainfall or spring flood). None of these methodologies makes recommendations as to what level of drainage should be provided to meet agricultural drainage requirements. These methodologies merely provide the designer with a tool to determine approximate discharges that may be generated given the characteristics of a watershed and storm or flood events. Use of these methodologies to design for agricultural requirements often depend on observed empirical data. For instance, from observation alone, design agricultural discharges which seem to satisfy cereal crop requirements in Manitoba, typically fall in the range of the 10- to 25-percent event. Therefore, agricultural drains are often designed within this range. Only the SCS curves method makes actual recommendations for agricultural drainage requirements.

4.2.5 Benefit-Cost Methodology

By the early 1970s, it was becoming apparent that application of the S and M curve standards often resulted in drainage reconstruction projects being either over-designed or under-designed. Since large-scale development of drainage projects can be an extremely costly endeavour, the need existed to determine feasible levels of development based on some sort of benefit-cost evaluation (Schellenberg and Bodnaruk, 1983).

In 1973, a research study was undertaken with the objective of developing a methodology by which benefits and costs of agricultural drainage projects could be evaluated throughout agro-Manitoba. The details of this cost-benefit study in determining agricultural drainage requirements have already been discussed in Chapter 3.5.3 of this report "Agricultural Drainage Requirements and the Rigaux-Singh study" and will not be discussed further.

The extremely complex nature of crop response and hydrologic analysis and the large number of assumptions used in the analysis have resulted in the benefit-cost methodology difficult to defend, appreciate and apply. Because the technology is complex and time-consuming and involves numerous assumptions, "short-cut" methods have been adopted in the determination of benefit-cost relationships. These short-cut methods involve analyzing benefits determined from other various projects where a detailed analysis has been completed and extrapolating these benefits to the particular project in question.

Because the application of the Rigaux-Singh model is so complex and time-consuming, many cost-benefit analyses currently being performed in evaluating proposed drainage infrastructure improvements continue to be done by these extrapolation methods. The Water Resources Branch of the Manitoba Department of Natural Resources is currently attempting to develop more practical methods of applying the rationale.

4.3 Drainage Design Standards

Before attempting to design and cost drainage improvement works, one must be aware of some of the various standards currently recommended regarding drainage channel hydraulics and channel parameters. This section makes no attempt to teach the principles of channel hydraulics but is intended to inform the reader of some of the various channel parameters which one must consider when contemplating drainage improvement works. It is these parameters on which much of the design and costing work outlined in Chapter V of this report is based.

Design standards for agricultural drainage channels specify requirements for channel side slopes, hydraulic grade line elevations, maximum velocities and culvert size specifications at crossings. All of these factors must be investigated in the design and costing of an agricultural drainage channel.

4.3.1 Channel Flow

The standard equation used to calculate open-channel flow is known as the Manning equation (Manitoba Department of Natural Resources, Hydraulic Design Manual, 1980). The Manning equation is defined as follows:

$$Q = \frac{AR^{0.667} S^{0.5}}{N}$$

where: Q = flow in m^3/s

A = cross sectional area of channel in m^2

R = hydraulic radius in m

S = slope of channel as a dimensionless decimal fraction

N = coefficient of roughness

In this equation, proper selection of N is essential to channel design. The coefficient of roughness, N, is an attempt to account for channel roughness due to channel surface and roughness characteristics. N values can range from 0.012 for a concrete-lined channel to 0.15 for a channel with dense uniform stands of vegetation (Ontario Ministry of Agriculture and Food, 1986). For newly constructed drains, a typical N value of 0.03 to 0.05 is recommended (Manitoba Department of Natural Resources, Hydraulic Design Manual, 1980).

4.3.2 Channel Velocity

The maximum velocity of water flowing in a clay soil channel is limited to 0.76 m/s. Higher channel velocities can result in severe erosion of a channel. If the channel is constructed in very light sandy soils, channel velocities lower than 0.76 m/s are usually recommended.

4.3.3 Hydraulic Grade Line

The hydraulic grade line, or design water level in a channel, must be at an elevation to ensure that adequate drainage service is provided. The current policy of the Engineering and Construction Branch of the Manitoba Department of Natural Resources is that, at the agricultural design discharge, the hydraulic grade line is located at or below the natural prairie elevation.

4.3.4 Channel Cross-Section

Channel cross-section is an extremely important parameter in the design of any agricultural drain. The channel cross-section must be such that it allows for ease of construction and maintenance and meets hydraulic requirements. The recommended minimum channel cross-section consists of channel with a 3-m base having a minimum of 3:1 side slopes. Such a channel is readily constructed and easily maintained with today's modern equipment. Figure 13 shows an ideal channel cross-section within a right-of-way 30.2 m wide . This right-of-way is typical of the rights-of-way in Subwatershed No. 3. Unfortunately, many of the agricultural drains found in Subwatershed No. 3 do not conform to this minimum cross-

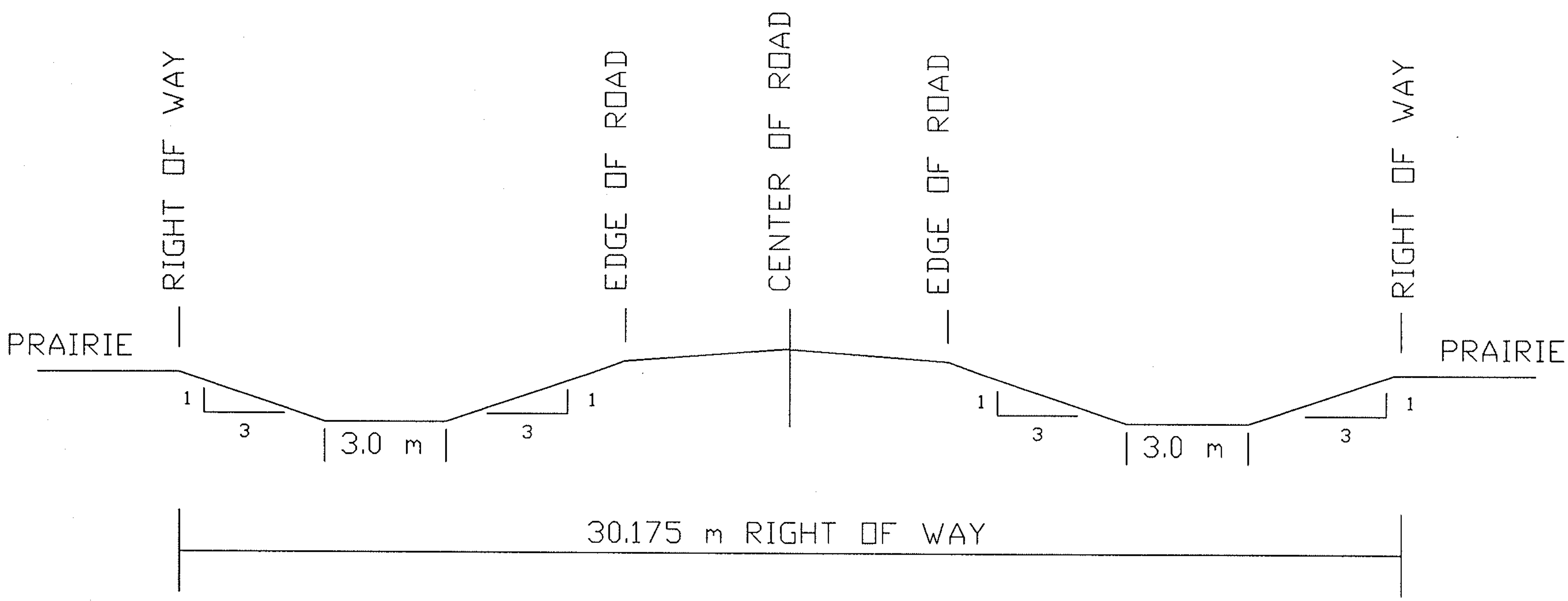


Figure 13 Typical municipal right-of-way cross-section

sectional requirement. Many of the drains in Subwatershed No. 3 have either become silted in, farmed over or eroded over the past number of years and as a result do not meet such minimum cross-section requirements. Many drains require excavation or regrading to meet these requirements. It is important to note that provision of such a cross-section, along with a suitable channel gradient, will generally result in a channel capacity that meets or exceeds the "value-added" standard of drainage recommended for Subwatershed No. 3.

4.3.5 Crossing Requirements

Crossings of agricultural drains or waterways is typically accomplished through the use of steel culverts or bridge crossings. The interdependence of the province's roadways, railways and waterways has resulted in the development of design standards to be observed when designing various crossings over waterways. These standards are intended to ensure that the hydraulic capacity of the waterway is maintained and to protect the crossings from potential damage due to a high-water event. The majority of the standards are stated based on the frequency of a flood event (that is, the percent frequency of occurrence of a particular flood event) and are outlined below (Engineering and Construction Branch, Manitoba Department of Natural Resources, Hydraulic Design Manual, 1980):

1. Provincial Trunk Highway (PTH)

   a) through grade opening - 2%

   b) access to PTH opening - 3%

   c) farm field access to PTH opening - agricultural discharge at or below prairie elevation. *

2. Provincial Road (PR)

   a) through grade opening - 3%

   b) access to PR opening - 5%

   c) farm field access to PR openings - agricultural discharge at or below prairie elevation. *

* By definition, a farm field access is an access from a PR or PTH that descends to prairie level at or near the edge of the right-of-way so that excessive flows can readily bypass the field access.

3. Railway

   a) through grade opening - 2%

4. Municipal Road

In general, crossing of an agricultural drain by a farm field access off a municipal road or a municipal road crossing of a drain are designed to pass the calculated agricultural flow. Usually these agricultural flows are much less than the 2-, 3-, or 5-percent flood event that is used when considering a Provincial Road, Provincial Trunk Highway, or Railway Crossing of a drain. This lesser standard was developed primarily to achieve a lower construction cost compared to those crossings along major highways or railways.

It is important to note that these standards reflect recommended requirements and can be subject to change, depending on site-specific characteristics. The standards were set primarily to protect the respective crossings from damage in case of a major flood event.

Typically, municipal roads, highways and railways are designed approximately 0.6 m to 1.0 m above the natural grade of the land. If the surrounding land is extremely flat, such as in Subwatershed No. 3, the occurrence of a major flood event usually will not overtop the crossing, causing damage to the crossing, but will flood adjacent prairie instead. Under conditions such as these, the designer must weigh the costs of damage to adjacent prairie with the costs of providing a hydraulically suitable crossing and a drainage channel. The purpose of this example is to highlight to the reader that, although guidelines have been prepared for the design of crossings, such guidelines are often subject to interpretation and modification depending on the site-specific conditions of each situation.

4.3.6 Culvert Requirements

The purpose of this section is to briefly describe for the reader some of the culvert design criteria used when designing culvert crossings. Since culvert crossings play a major role in any drainage reconstruction work (particularly in Subwatershed No. 3), it was felt that a review of some of the parameters should be provided. It is considered beyond the scope of this report to describe actual hydraulic engineering components of culvert design.

Culverts must discharge calculated design flows. In general, it is recommended that the water surface elevation in a drain should not be increased, as a result of the installation of culverts, by more than 0.21 m due to backwater effects in order to discharge calculated design flows. It is further recommended that the ratio of the headwater (height of water in the channel at the culvert entrance) to the diameter of the culvert not exceed 0.85 (Engineering and Construction Branch, Manitoba Department of Natural Resources, 1980). Adoption of this criterion means that culverts should, in general, never flow full under design agricultural flows. In addition, all culverts should have at least 0.6 m of cover to preserve the structural integrity of the culvert.

These criteria are generally used to define the size and number of culverts at any crossing. A 600-mm diameter culvert is recommended as a minimum at any crossing for the sake of ease of maintenance.

4.4 On-Farm Drainage Mechanisms

Any benefits derived from an improved agricultural drainage infrastructure will be minimal if suitable on-farm drainage has not been provided. Thus, the requirement for on-farm drainage is an integral part in the development of a water management strategy. The purpose of this section, therefore, is to briefly review some of the on-farm drainage mechanisms discussed in the literature. Chapter 5 "Results" briefly investigates on-farm drainage mechanisms currently used in the Subwatershed.

On-farm drainage mechanisms can be divided into two categories: (1) the random system and, (2) the parallel system of drainage. The random system consists of a single ditch or series of ditches transecting as many depressions as feasible along a course through the lowest elevations in the field towards an available outlet. The parallel system consists of constructing parallel ditches through the field (not necessarily equidistant) discharging into a common lateral drain (United States Department of Agriculture, Soil Conservation Service, 1973).

On flat poorly drained land consisting of slowly permeable soils, parallel ditches are recommended. Generally, these field ditches are spaced approximately 120 m apart or more, have a maximum depth of 0.8 m and have side slopes of less than 10 percent. Such flat side slopes allow these drains to be easily crossed with machinery. Grades for these can vary from a minimum of 0.05 percent on very flat land to a maximum of 0.3 percent on steeper slopes. Grades larger than 0.3 percent should be seeded to forage and treated as a grassed waterway (Manitoba Department of Agriculture, 1985).

Random ditches are used to drain isolated depressions which are too large to be filled in or smoothed over. There is no particular pattern to these types of ditches as their location is determined by the topographic constraints of the field. Gradients and side slopes for these ditches generally have the same characteristics as those for the parallel system of on-farm drains.

An essential requirement for any on-farm drain is a suitable outlet. In most cases, the outlet is a municipal drain, conservation district drain or provincial waterway. As a rule-of-thumb, the outlet drain should be ideally 0.9 m deep in order to provide sufficient gradient for an on-farm drain. Obviously, as field ditches become longer, they must also become deeper. Thus, the outlet drain must be deep enough to accommodate the minimum gradients for any on-farm drain.

Depending on the topography and soil texture, the outlet may require a grassed channel, rock fall chute, or culvert drop. The purpose of these structures is to prevent soil erosion and preserve the structural integrity of the field ditch and receiving drain (Manitoba Department of Agriculture, 1985).

Chapter V

RESULTS

5.1 Introduction

The purpose of this chapter is to detail to the reader the results of the analysis conducted in the development of water management strategies for Subwatershed No. 3. This chapter, therefore, delineates the Subwatershed boundaries, provides a critical assessment of existing CCCD drains, develops alternative strategies, determines the cost of the alternative strategies, highlights a preferred strategy, examines the impacts of the preferred strategy and assesses the status of on-farm drainage in the Subwatershed.

As can be inferred from the previous chapters of this document, Subwatershed No. 3 is currently experiencing numerous water management problems. Such problems briefly include: inadequate relief of excess precipitation on fields after heavy summer rains; increasing stormwater and lagoon effluent discharges from the Village of Oakbank; inadequate maintenance of Conservation District drains; channel restrictions due to undersized culverts, beaver dams, or siltation; and excessive spring flooding problems. The water management strategies developed in this chapter make every attempt to address these problems as well as other concerns expressed in Chapter 3.3 "Water Management Concerns". As the dominant water management concern expressed was the requirement for effective relief of excess precipitation after heavy summer rains, much of the analysis focused on ways and means to satisfy this primary concern while attempting to incorporate and mitigate, at minimum costs, other concerns expressed.

It is important to understand that drainage usually requires some form of mutual interdisciplinary coordination and cooperation among those impacted. Such relations are required since drainage of any kind seldom works in one way. In most cases, a drainage strategy can have multi-directional and far-reaching effects depending on the magnitude of the proposed works. A drainage effort may effect not only the required aspect (such as relief of urban stormwater or improved agricultural drainage) but may also impact the upstream and downstream ecology of a watershed or the environmental balance.

The point of this discussion is that no water management strategy will be effective unless each impacted party has a clear and undistorted view of the problem and is willing to mutually cooperate to achieve a solution. Thus, any strategy ultimately adopted by the CCCD that may be recommended in this report, should not be developed based on a unilateral action but rather through mutual coordination, cooperation, and communication among impacted parties.

5.2 Delineation of Subwatershed Boundaries

Preliminary Subwatershed No. 3 boundaries were established by previous Phase II studies and are shown in Figure 14. This boundary encompasses a land area of approximately 40 km^2. Proposed Subwatershed No. 3 boundaries are shown in Figure 15. The new Subwatershed boundary encompasses a land area of approximately 37.3 km^2.

The refinement of the Subwatershed boundary was based on a number of factors. These factors included such things as land use, existing drainage particulars, legal boundaries, agricultural characteristics, on-site inspections and reported areas of ponding problems. Given such criteria, the placement of the refined boundary is subject to the interpretation and personal judgement of the researcher in the analysis of the data. Since Subwatershed No. 3 is not a self-contained subwatershed, in the sense that it receives surface flows from outside the proposed boundary, the placement of these proposed boundaries can be subject to questioning. The following discussion attempts to briefly rationalize this researcher's reasons in refining the preliminary Subwatershed boundary. These recommended boundaries are not meant to suggest that

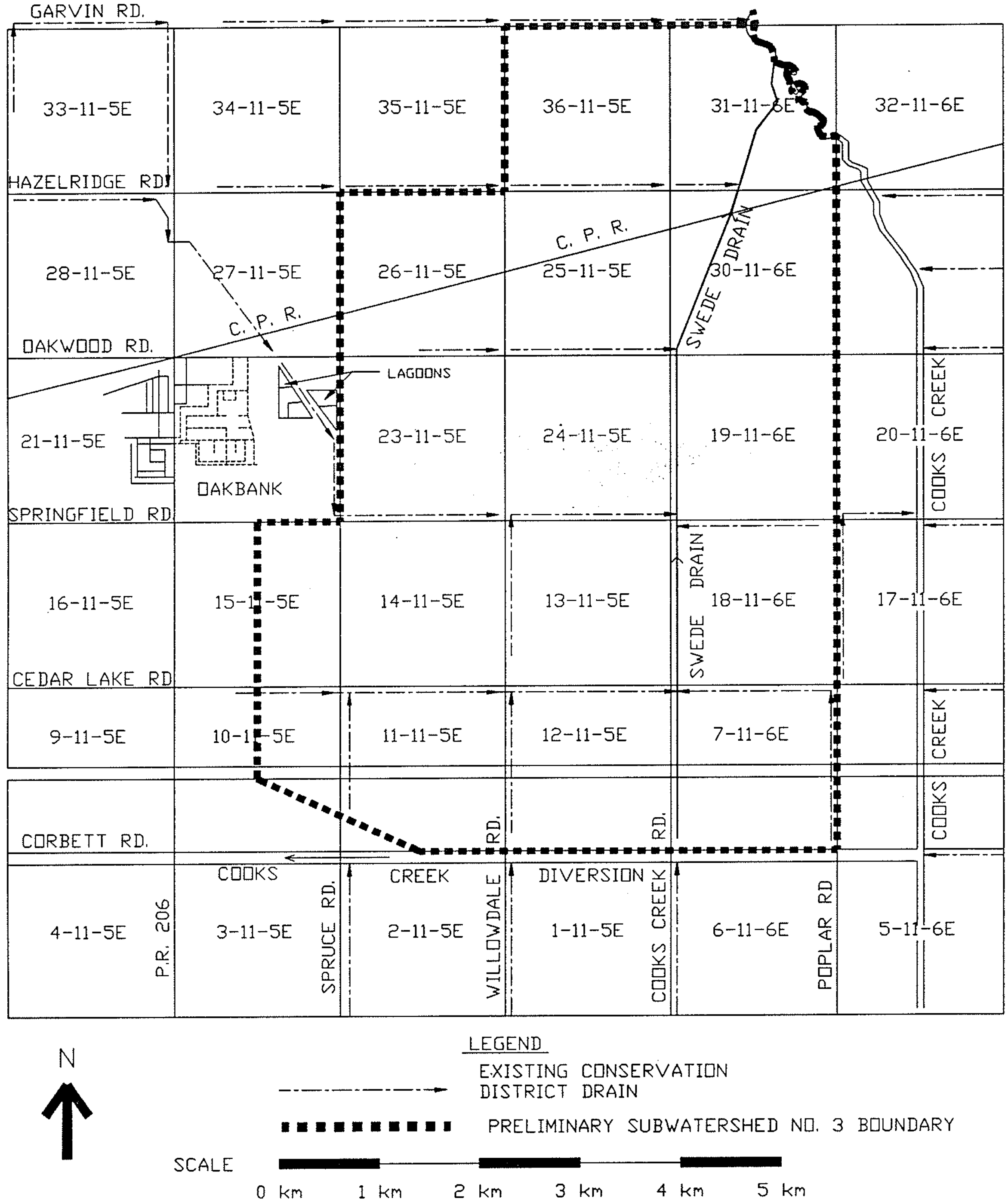


Figure 14 Preliminary Subwatershed No. 3 boundary

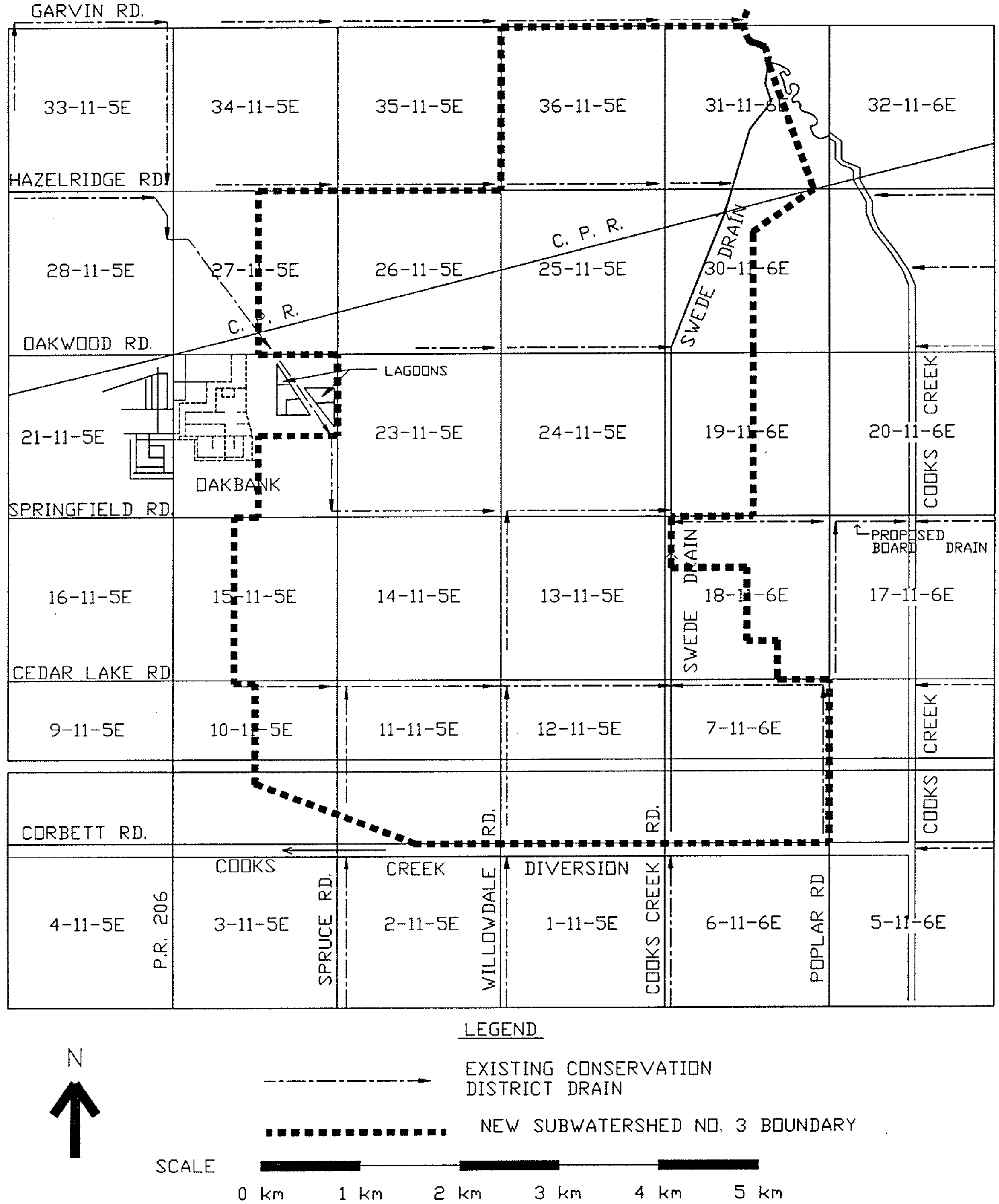


Figure 15 Proposed Subwatershed No. 3 boundary

further refinement is not possible. Further analysis by others in the future may result in a recommendation for additional refinements.

a) South Boundary

The south boundary of the Subwatershed in Sections 10, 11, and 12-11-5E and 7-11-6E remained essentially unchanged as defined from previous Subwatershed Nos. 1 and 2 studies.

b) East Boundary

The east boundary in Sections 7, 8, 19, 30, and 31-11-6E was significantly revised. Local topographic and drainage characteristics suggested that much of the surface water in the eastern and northern halves of 18-11-6E ultimately discharges to Cooks Creek. Much of the land in the eastern half of 18-11-6E drains to the west municipal drain along Poplar Road which ultimately discharges to Cooks Creek via the municipal drain on the south side of Springfield Road. Much of the water in the northern half of 18-11-6E discharges into the CCCD drain found north of Section 18-11-6E and south of Springfield Road. Although this drain was designed to discharge into the Swede Drain, landowners along this drain have suggested that it actually drains more effectively at times into the municipal ditch south of Springfield Road in Section 17-11-6E. To facilitate this drainage, a culvert has been installed to connect the CCCD drain in the north of

Section 18-11-6E with the municipal drain in the north of Section 17-11-6E. Although drawings of the CCCD drains suggested that the CCCD drain along the east side of Poplar Road in the west of Section 17-11-6E discharges into the CCCD drain north of Springfield Road in the south of Section 20-11-6E, such was not the case as no culvert exists to connect these drains. It is recommended, therefore, that the CCCD drain in the south of Section 20-11-6E become a municipal drain and the municipal drain in north of Section 17-11-6E become a CCCD drain. This would more effectively facilitate the drainage in the eastern half of Section 18-11-6E and western half of Section 17-11-6E to Cooks Creek (Figures 14 and 15). With the refined boundaries, these respective drains would now lie in Subwatershed No. 4. It was felt this recommended change should be highlighted for future studies.

The boundary was further refined in Sections 19-11-6E and 30-11-6E once again to account for local topographic and drainage characteristics. The majority of the water from the east half of 19-11-6E and 30-11-6E discharges to respective municipal drains which in turn carry this water to Cooks Creek.

The boundary in 31-11-6E was revised as well to reflect local topographic and drainage characteristics. This revised boundary begins at the intersection of Hazelridge Road and the

CPR tracks and extends in approximately a straight line to the confluence of Cooks Creek and the Swede Drain. Lands to the east of this boundary drain to Cooks Creek and lands to the west of this boundary drain to the Swede Drain.

c) North Boundary

The north boundary, located along the northern limits of Section 31-11-6E and Section 36-11-5E remains unchanged. Soil characteristics north of this boundary line change somewhat from the dominant Red River and Osborne clays found in Subwatershed No. 3 to a loamy sandier soil having moderate permeability characteristics. Although drainage of these soils is still required, it is not required with the same urgency as the Red River and Osborne clays. Those sections of land immediately north of 31-11-6E and 36-11-5E all discharge to Cooks Creek.

d) West Boundary

The west boundary of the Subwatershed received a few significant alterations. The previous westerly boundary along the west edge of 26-11-5E was moved further west to include the eastern half of Section 27-11-5E. Previous studies and personal observations indicated that the east half of Section 27-11-5E does not drain adequately, resulting in surface water ponding. Currently, all surface water is collected and discharged from the east half of Section 27-11-5E through a culvert beneath Spruce Road approximately half way between Hazelridge Road and Oakwood Road. Surface water is then discharged along a natural swale in 26-11-5E in a south-easterly direction, beneath the CPR tracks, to ultimately discharge into the Oakwood Road Drain running along the south of section 26-11-5E. (Drawing No. 1 appended to this report shows the preliminary Subwatershed boundaries as well as existing drainage patterns and location and sizes of all existing culverts.) It was felt this problem area should be included within the Subwatershed boundaries.

The previous westerly boundary along the west edge of 23-11-5E was modified slightly to include the southeast quarter of Section 22-11-5E. This was to accommodate surface water ponding problems observed on this portion of land. The northeast quarter of Section 22-11-5E was not included as this land belongs to the Village of Oakbank and is currently occupied by the Village's wastewater stabilization pond.

The westerly boundary in Sections 15-11-5E and 10-11-5E was modified only slightly to more accurately reflect local topography and site drainage characteristics. All surface water to the east of this boundary discharges into the Subwatershed while surface water to the west of this boundary drains to Provincial Road 206 and ultimately to the Cooks Creek Diversion.

Subwatershed No. 3 is not a self-contained subwatershed since it receives surface flows from outside the proposed boundaries. Figure 7 in this report highlights the entire watershed area contributing flows to the Subwatershed. Previous studies and this researcher's findings suggest that this entire watershed area need not be included in the Subwatershed boundaries. Drainage of the watershed area outside the Subwatershed's revised boundaries is not as significant a problem as those areas within the Subwatershed. Although the soil characteristics are similar, drainage is aided by greater topographic relief. These areas in general are much higher in elevation than land encompassed by the Subwatershed boundaries. As a result, the demand for improved agricultural drainage is not a dominant concern. Subwatershed No. 3's boundaries are defined primarily to highlight those areas where improved levels of agricultural drainage seem to be required and where drainage reconstruction works are recommended. Those flows emanating from outside Subwatershed No. 3 must be accommodated in Subwatershed No. 3 and the drains designed accordingly.

5.3 Critical Assessment of Existing Drains

A critical assessment of existing drains was conducted to assess their respective condition (that is, their state of repair), hydraulic capacity, culvert crossing limitations and any other site-specific problems and limitations associated with the drains. The purpose of this analysis was to determine, for each drain, the extent of upgrading that may or may not be required to facilitate improved agricultural runoff to the recommended "value-added" standard as discussed in Chapter 3.5 "Agricultural Drainage Requirements" of this report. The methodology used in conducting this assessment consisted of on-site inspection and a review of available plan-profile drawings of existing CCCD drains.

The reader should be advised that the assessment of drains, particularly their hydraulic capacity, can be somewhat of a subjective exercise based on the researcher's personal judgement of drain characteristics and previous experience. The condition and performance of a drain can vary with numerous factors such as the presence of excessive vegetation, siltation or erosion of the drain, available gradient and cross-section, depth of allowable flow in the drain as well as numerous other factors which may impact the hydraulic characteristics of a drain. It is, therefore, up to the researcher to interpret the impact of these factors in the assessment of the drains and to make such adjustments as the researcher may deem necessary based on the researcher's experience in the interpretation of these parameters.

From the discussion in Chapter 3.5 "Agricultural Drainage Requirements" , it would seem that damage occurs to crops from precipitation excess on clay soils primarily during the months of June, July, and August (Figure 9). Agricultural drains, therefore, should be able to discharge required flows during these critical months to provide adequate crop protection. For the purpose of this analysis, the drains in Subwatershed No. 3 were assessed during the months of June and July of 1988 in an effort to determine their respective condition and performance characteristics during these critical months.

The reader is advised that the analysis of existing hydraulic capacities of each drain was based largely on on-site inspections, discussions with landowners and an analysis of available plan-profile drawings. Many of the plan-profile drawings reviewed were based on survey information obtained five to ten years in the past and, thus, their accuracy may be questioned due to ongoing drain siltation and erosion. It was not the intention of this assessment to provide a detailed technical analysis of the hydraulic capacity of the drains and respective crossings but rather to provide a "best guess" as to the drain's hydraulic capacity and respective condition based on the interpretation of information available.

For simplicity of presentation, results of the drain assessment are summarized in Table 3. A detailed description of each drain's respective characteristics is found in Appendix A "Critical Assessment of Existing Drains". Figure 15 shows the existing CCCD drains and the revised Subwatershed boundaries.

Table 3 Summary of Drain Assessment

DRAIN	APPROXIMATE CAPACITY m^3/s	GENERAL CONDITION	CHANNEL LIMITATIONS	CULVERT LIMITATIONS	GENERAL COMMENTS
<u>HAZELRIDGE RD.</u>					
South 36-11-5E	1.7	fair	Excessive vegetation in easterly half of drain	Culverts at Cooks Creek Rd. junction inadequate	
South 31-11-6E	1.7	excellent	None	Culverts at Swede Drain junction inadequate	
<u>OAKWOOD RD.</u>					
South 26-11-5E	0.4	fair	Small cross-section and dense grass vegetation	All crossings inadequate to discharge value-added flows	Receives flow from 27-11-5E and 26-11-5E via swale under CPR tracks
South 25-11-5E	0.6	poor/fair	Westerly half congested with cattails	All crossings inadequate to discharge value-added flows	
<u>SPRINGFIELD RD.</u> (OAKBANK DRAIN)					
East 22-11-5E	0.7	poor	Excessive cattail congestion	None	Excessive cattail growth caused by drain receiving lagoon effluent
South 23-11-5E	0.7	poor	Excessive cattail congestion and little gradient	All crossings inadequate to discharge value-added flows	Excessive cattail growth caused by drain receiving lagoon effluent
South 24-11-5E	0.8	poor	Excessive cattail congestion and little gradient	All crossings inadequate to discharge value-added flows	Excessive cattail growth caused by drain receiving lagoon effluent
<u>CEDAR LAKE RD.</u>					
North 10-11-5E	0.7	good	None	None	
North 11-11-5E	0.6	poor	Excessive vegetation and zones of siltation and erosion	All crossings inadequate to discharge value-added flows	Requires regrading and excavation
North 12-11-5E	0.4	poor	Excessive vegetation. Zones of siltation and erosion. Signs of farming encroachment.	Culverts at Swede Drain junction inadequate	Requires regrading and excavation. Municipal drain on north side of road should be regraded
North 7-11-6E	0.3	fair	Vegetation congestion. Erosion of drain along bottom	None	May have to reset culverts to new elevation if drain reconstructed

DRAIN	APPROXIMATE CAPACITY m^3/s	GENERAL CONDITION	CHANNEL LIMITATIONS	CULVERT LIMITATIONS	GENERAL COMMENTS
<u>POPLAR RD.</u> East 7-11-6E	0.8	excellent	None	None	
<u>SPRUCE RD.</u> West 11-11-5E	0.3	good	Excessive Vegetation	None	Minor cleaning and regrading of drain required
<u>WILLOWDALE RD.</u> West 12-11-5E	0.3	fair	Excessive vegetation and gradient restriction.	One undersized culvert	Municipal drain along east side of road requires clearing/regrading
West 13-11-5E	0.4	poor	Excessive vegetation (trees). Signs of farming encroachment.	None	Requires brushing/regrading
<u>SWEDE DRAIN</u> West 7-11-6E	3.2	excellent	None	None	
West 18-11-6E	4.6	good	Dense cattail growth	None	Requires vegetation control to discharge value-added flows
West 19-11-6E	6.6	good	Dense cattail growth	Culverts at junction with Oakwood Rd. inadequate	Can nearly achieve value-added flows if vegetation control provided
Section 30-11-6E	6.6	good	Dense cattail growth, restricted cross-section and small gradient to carry value-added flows	Culverts at junction with Hazelridge Rd. inadequate	Drain lacks capacity to carry value-added flows
Section 31-11-6E	6.6	good	Dense vegetation. Drain terminates at Cooks Creek. Numerous beaver dams restricting flow	None	Drain lacks capacity to carry value-added flows

5.4 Development of Alternative Water Management Strategies

5.4.1 Some Considerations

The purpose of this discussion is to briefly outline to the reader some of the considerations, physical limitations and parameters that were incorporated when considering the development of water management strategies for Subwatershed No. 3.

Subwatershed No. 3 was found to act somewhat as a "collection basin" for waters outside its defined boundaries. Analysis of available topographic information of the surrounding area indicated Subwatershed No. 3 to be one of the lowest and flattest areas of land in elevation when considering the entire watershed area contributing flows to Subwatershed No. 3 (Figure 7). As a result, much of the land to the northwest of Subwatershed No. 3 has a natural tendency to discharge into it. To make matters worse, the land in Subwatershed No. 3 is extremely flat resulting in very little gradient available for quick and efficient discharge of collected runoff in the respective drains.

The lowest areas of land in Subwatershed No. 3 were found to lie in Sections 13, 14, 23 and 24-11-5E. Drainage for these areas of land is provided by the Oakbank Drain along

Springfield Road and the Cedar Lake Road Drain. It is interesting to note that it is these sections of the Sub-watershed in which the majority of the more extreme surface water ponding and agricultural drainage problems seems to be occurring. Before being artificially drained, these areas consisted largely of low-lying marshlands and were the recipient of surface waters from the upland areas around present-day Birds Hill Park. Thus, proposed water management strategies concentrated on attempting to relieve these specific areas of their respective drainage problems and water management concerns.

One of the primary parameters that must be considered in a drainage improvement strategy is the availability of an adequate outlet to receive anticipated flows from any proposed drainage improvements. Subwatershed No. 3 has available two possible outlets, namely: the Cooks Creek Diversion to the south and the Swede Drain to the east. Strategies must, therefore, investigate the possibility of using either of these outlets or the combination of these outlets for the most efficient discharge of surface waters.

In order to achieve maximum benefits from the entire area impacted by the Cooks Creek Diversion project (that is, Subwatersheds Nos. 1 through 6), it is important to make every attempt to develop the lateral drainage system to a consistent agricultural standard. The recommended standard, as discussed in Chapter 3.5.4 "Agricultural Drainage Requirements and Subwatershed No.3", is $Q=0.479A^{0.765}$ where Q is the discharge rate in m^3/s and A is the contributing drainage area in km^2. All channels, access crossings and culverts were designed to this standard. As for those areas of land contributing flows outside the Subwatershed boundary, agricultural flows for these areas were calculated based on the same agricultural drainage standard (that is, $Q=0.479A^{0.765}$). The application of this standard to these areas was felt to be justified since soil conditions and agricultural characteristics were found to be almost identical to those in Subwatershed No. 3. The primary difference between these extraneous lands contributing flows to the Subwatershed and those in Subwatershed No. 3 is the somewhat greater topographic relief allowing for the more efficient collection and discharge of surface water.

Another major consideration that must be accounted for in any of the proposed strategies is the accommodation of stormwater flows and lagoon effluent discharged from the Village of Oakbank. Discussions with CCCD Board members, R.M. of Springfield councillors and numerous local landowners have indicated concerns about the increased discharge of stormwater to Subwatershed No. 3 as a result of the new housing sub-division being constructed in the Village east of Provincial Road 206. One must, however, keep the size of this subdivision and its corresponding stormwater flows in perspective. The subdivision occupies approximately 0.6 km^2 and is drained by a network of roadside drainage ditches which discharge into a large "retention ditch" which in turn carries runoff to the Oakbank Drain immediately south of the lagoons. In comparison, the size of the total watershed area under consideration for this study (that is, Subwatershed No. 3 and those lands contributing flows to the Subwatershed outside the Subwatershed boundaries) is approximately 52 km^2. This large "retention ditch" was designed to store stormwater runoff collected from the subdivision and slowly discharge collected stormwater to the Oakbank Drain by means of a small-diameter culvert.

For the purpose of this study, numerous engineers were consulted to evaluate the impact of stormwater discharge from Oakbank to the Oakbank Drain in Subwatershed No. 3. In general, it was felt that, because of the small area occupied by the subdivision and the use of roadside ditches and the "retention ditch" for the collection and discharge of stormwater, the resulting discharge from the subdivision would not be significantly greater than agricultural flows and would be almost insignificant when compared with flows generated by the 52 km^2 watershed area. As a result, discharge from the subdivision was accounted for based on applying agricultural flows to that area occupied by the subdivision.

In the design of proposed drains or reconstructed drains, a minimum 3-m base was assumed with channel side slopes having a minimum slope of 3:1. This recommended minimum channel cross-section can easily be constructed with a scraper and allows for access of maintenance equipment. All drains in any of the proposed strategies, were designed to have a maximum water velocity of 0.76 m/s to prevent excessive soil erosion in the drains.

In conclusion, any proposed strategy for Subwatershed No. 3 must make every attempt to improve the drainage infrastructure in order to accommodate recommended design agricultural flows while, at the same time, it must be capable of discharging extraneous flows that may enter the Subwatershed from outside its boundaries. A proposed strategy must also attempt to address and mitigate those areas of conflicting influences that may occur upstream or downstream of the proposed project and examine the impact on the environmental balance.

The reader should be aware that it was not the intent of this study to provide detailed engineering design and analyses of proposed strategies. This study was conducted to investigate feasible water management strategies and determine their approximate costs in an attempt to address the water management concerns expressed by landowners in Subwatershed

No. 3.

5.4.2 Potential Water Management Strategies

This research has identified four potential water management strategies for the proposed infrastructure improvements in Subwatershed No. 3. A brief description of each strategy follows.

5.4.2.1 Option 1 - Use of the Existing Infrastructure

This option is essentially the "status-quo" option where use of the existing system is continued without any proposed reconstruction works. At first glance, this option may seem redundant but is one that should be given some consideration by the CCCD.

At the time of this report, the CCCD was in the process of preparing a Resource Management Plan for the entire Conservation District. The Management Plan has made an attempt to identify the resource management issues and options in the entire CCCD and has requested public input as to future goals, plans and action with respect to resource management issues. One of the questions to be addressed in the Management Plan is the sense of priority in completing the drainage improvement works within the Diversion project area (that is, Subwatersheds Nos. 1 through 6). Should public opinion give development of Subwatersheds Nos. 1 through 6 a low priority, in favour of allocating funds to other projects, the CCCD may have to opt for of this "status-quo" option. Figure 16 details the location of the existing CCCD drains that would be used in this option.

Consideration of this option is not altogether unreasonable. Although surface water ponding on agricultural lands was a dominant concern and has resulted in periodic significant crop losses, intensive farming of the land still successfully continues. The point of this discussion is, that although Option No. 1 does not provide for any reconstruction works, adoption of Option No. 1 is not expected to result in the demise of farming operations in the Subwatershed. Obviously, the adoption of Option No. 1 does nothing to improve the existing drainage infrastructure and, thus, problems from ponded surface waters would continue. Option No. 1, therefore, does nothing to contribute to the solution of particular drainage problems in the Subwatershed, however, the adoption of Option No 1 would not exacerbate any of the noted drainage problems.

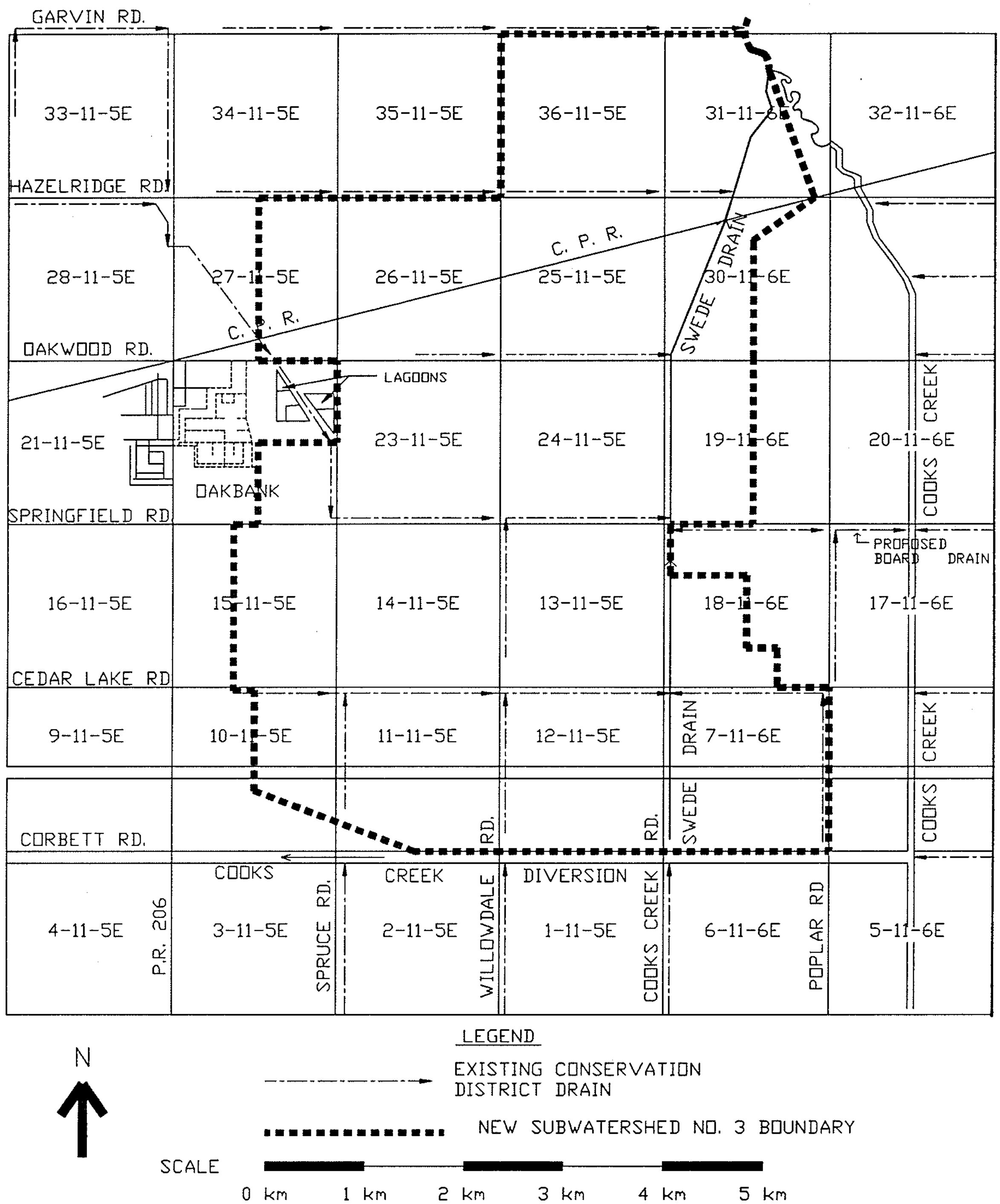


Figure 16 Option No. 1 - Use of the existing infrastructure

5.4.2.2 Option No. 2 - The Diversion of the Oakbank Drain down Spruce Road

This option, frequently proposed by local residents, consists of upgrading the entire drainage infrastructure to the value-added standard by diverting the Oakbank Drain, at its junction with Springfield Road, down Spruce Road to the Cooks Creek Diversion. By diverting the Oakbank Drain down Spruce Road the Cooks Creek Diversion would be used as one of the primary outlets together with the Swede Drain (Figure 17).

This option would offer the advantage of discharging extraneous waters collected outside the Subwatershed boundaries by the Oakbank Drain and discharging them to the Diversion instead of the Swede Drain. Stormwater flows from Oakbank, as well as the lagoon effluent, would also follow this new drain to the Diversion. This option would relieve the Oakbank Drain, along Springfield Road, of the excessive amounts of runoff it was required to carry in the past and, thus, it would greatly improve agricultural drainage in the extreme problem areas in Sections 13, 14, 23 and 24-11-5E. The Cedar Lake Road Drain in 10-11-5E and 11-11-5E would also discharge into the new Spruce Road Drain. All other CCCD drains would be upgraded to the value-added standard and would discharge to the Swede Drain.

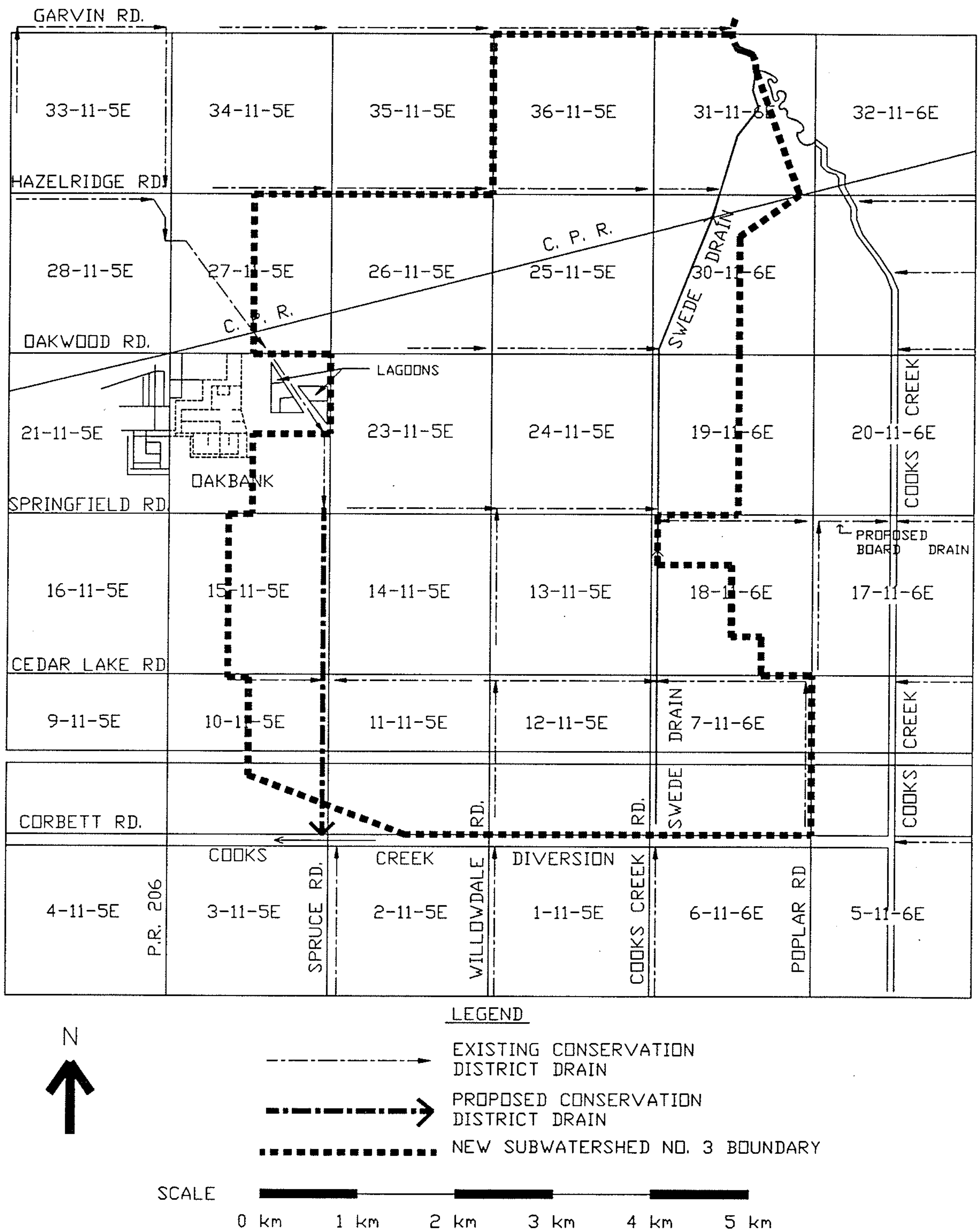


Figure 17 Option No. 2 - The diversion of the Oakbank Drain down Spruce Road

Diversion of the Oakbank Drain down Spruce Road to the Diversion would relieve the hydraulic loading on the Oakbank Drain along Springfield Road, allowing it to accommodate local agricultural flows more readily. This option would not require any reconstruction work on the Swede Drain to accommodate new value-added flows as much of the runoff would be diverted to the Diversion.

At first glance, this option would appear to be the ideal strategy to adopt to improve drainage parameters in the Subwatershed. Unfortunately, the proposal is technically infeasible. Analysis of design agricultural flows in the Diversion revealed that water levels in the Diversion were too high to efficiently discharge flows in the new Spruce Road Drain. The Spruce Road Drain, therefore, would require a costly discharge structure at its entrance to the Diversion, complete with "check valves", to ensure that Diversion flows would not back up into the Spruce Road Drain during design agricultural flows. The Spruce Road Drain, therefore, would discharge to the Diversion only when water levels in the Diversion have sufficiently subsided. As a result, very few drainage improvement benefits would be achieved by this option.

For the same reason discharging the Spruce Road Drain to the Cooks Creek Diversion is technically infeasible; so also are the potential options of diverting the Willowdale Road Drain and Swede Drain to the Diversion.

Diversion of the Springfield Road Drain or Cedar Lake Road Drain to Provincial Road 206 and then south to the Diversion is also technically infeasible. Bottom of drain elevations along Provincial Road 206 are too high for it to accept any discharge from these drains.

The purpose of the above discussion, therefore, was to inform the reader that such options were investigated but unfortunately found to be impractical. The implications of this analysis, however, suggests that the only outlet now available for drainage improvement works in the Subwatershed is the Swede Drain as presented in the following two options.

5.4.2.3 Option No. 3 - The Diversion of the Oakbank Drain down Oakwood Road

This option consists of upgrading of the drainage infrastructure to the value-added standard with the diversion of the Oakbank Drain down Oakwood Road to the Swede Drain (Figure 18).

This option offers the advantage of relieving the problem Oakbank Drain of much of the extraneous flows it is required

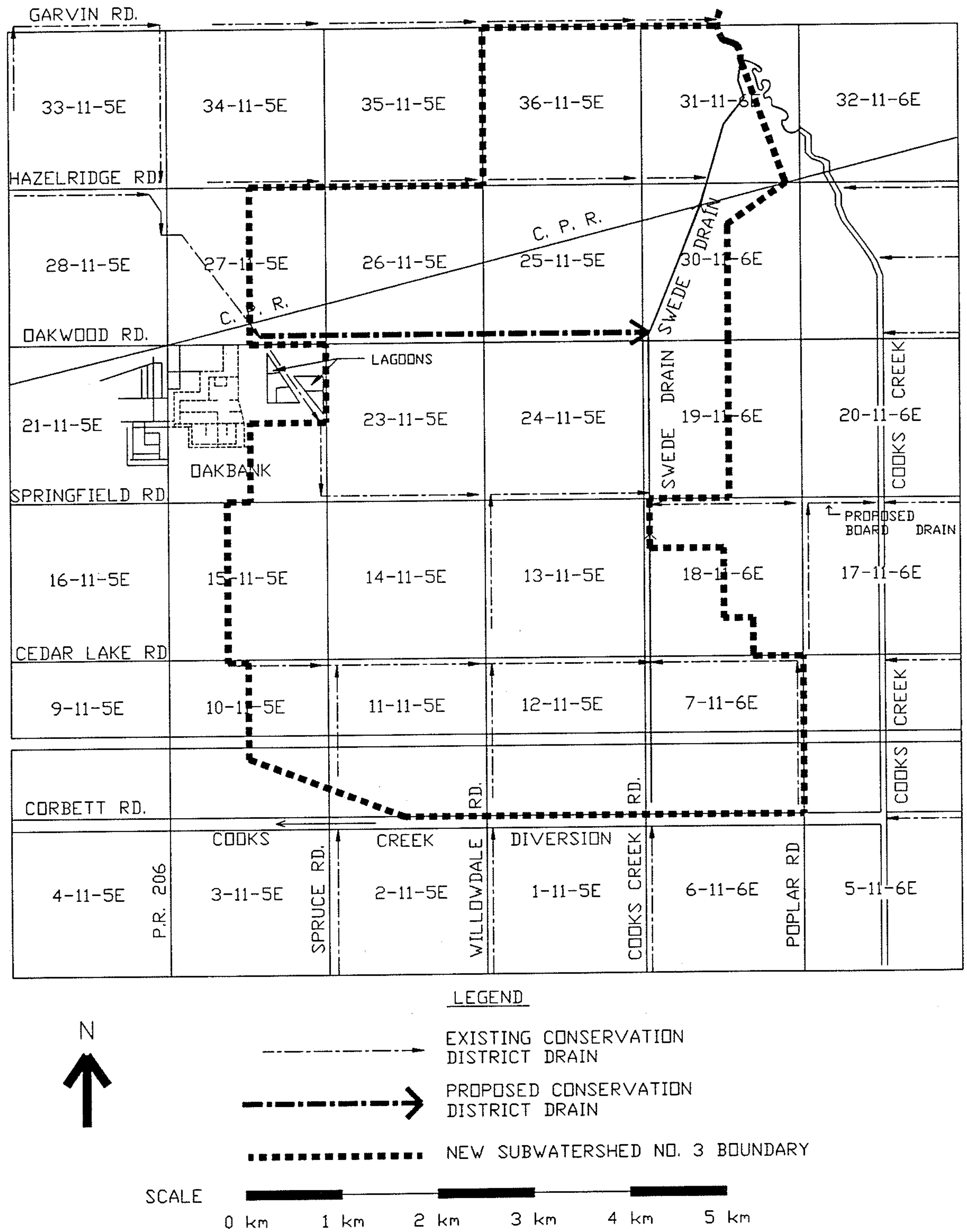


Figure 18 Option No. 3 - The diversion of the Oakbank Drain down Oakwood Road

to carry from those areas outside the Subwatershed boundary. The majority of these extraneous flows would now be carried by the Oakwood Road Drain to the Swede Drain. The Oakbank Drain under this option would be subject, therefore, to flows from stormwater and lagoon effluent discharges from the Village of Oakbank as well as agricultural flows from Sections 13, 14, 15, 23 and 24-11-5E.

Analysis of existing drain plan-profile drawings and topographic information suggests that the diversion of the Oakbank Drain down Oakwood Road would be much more hydraulically efficient than allowing these flows to continue down the Oakbank Drain along Springfield Road to the Swede Drain. Gradients along the proposed Oakwood Road Drain were found to be much greater than those along the Oakbank Drain allowing for more efficient and faster discharge of flows. The Oakbank Drain along Springfield Road was found to be extremely flat and is experiencing extensive cattail growth as a result of receiving nutrient-rich lagoon effluent. These unfavourable combinations limited this drain's effectiveness to accommodate the required flows. The large flows currently required to be discharged by this drain, together with its poor performance characteristics, have resulted in excessive amounts of time (sometimes days) to discharge required flows. This, therefore, restricts the use of this drain to receive agricultural flows from adjacent lands in the Subwatershed. Diversion of the Oakbank Drain down Oakwood Road would relieve the Oakbank Drain along Springfield Road of its hydraulic stress allowing for improved agricultural drainage along this reach.

The major limiting factor of this option is the apparent inadequate capacity of the Swede Drain to accommodate value-added flows downstream of the junction with the new Oakbank Drain. Table 4, at the end of this discussion, details the approximate capacities of the existing drains and their respective design capacities for the various options. Upgrading of the Swede Drain from this point to its confluence with Cooks Creek would be an extremely costly undertaking. The channel would have to be widened, requiring purchase of right-of-way, and a bridge crossing would also be required at the junction of the Swede Drain and Hazelridge Road.

Although this portion of the Swede Drain does not have the capacity to meet value-added flows, its resulting impact on the drainage performance characteristics in the Subwatershed is unknown. Assessment of its impact would require detailed hydraulic modelling of the Swede Drain and its interaction with its various tributaries, including the Cooks Creek Diversion and Cooks Creek downstream of the Diversion. It is anticipated that the Swede Drain performance characteristics, at its confluence with Cooks Creek, should improve, given reduced flows in Cooks Creek as a result of the Diversion project. Such modelling is beyond the scope of this study.

5.4.2.4 Option No. 4 -The Diversion of the Oakbank Drain down Oakwood Road and Reconstruction of the Swede Drain

This option is essentially the same as Option No. 3 but includes the upgrading of the Swede Drain from its intersection with Oakwood Road to its confluence with Cooks Creek to the value-added standard (Figure 19). Option No. 4 would effectively provide the entire Subwatershed with a drainage infrastructure to the value-added standard.

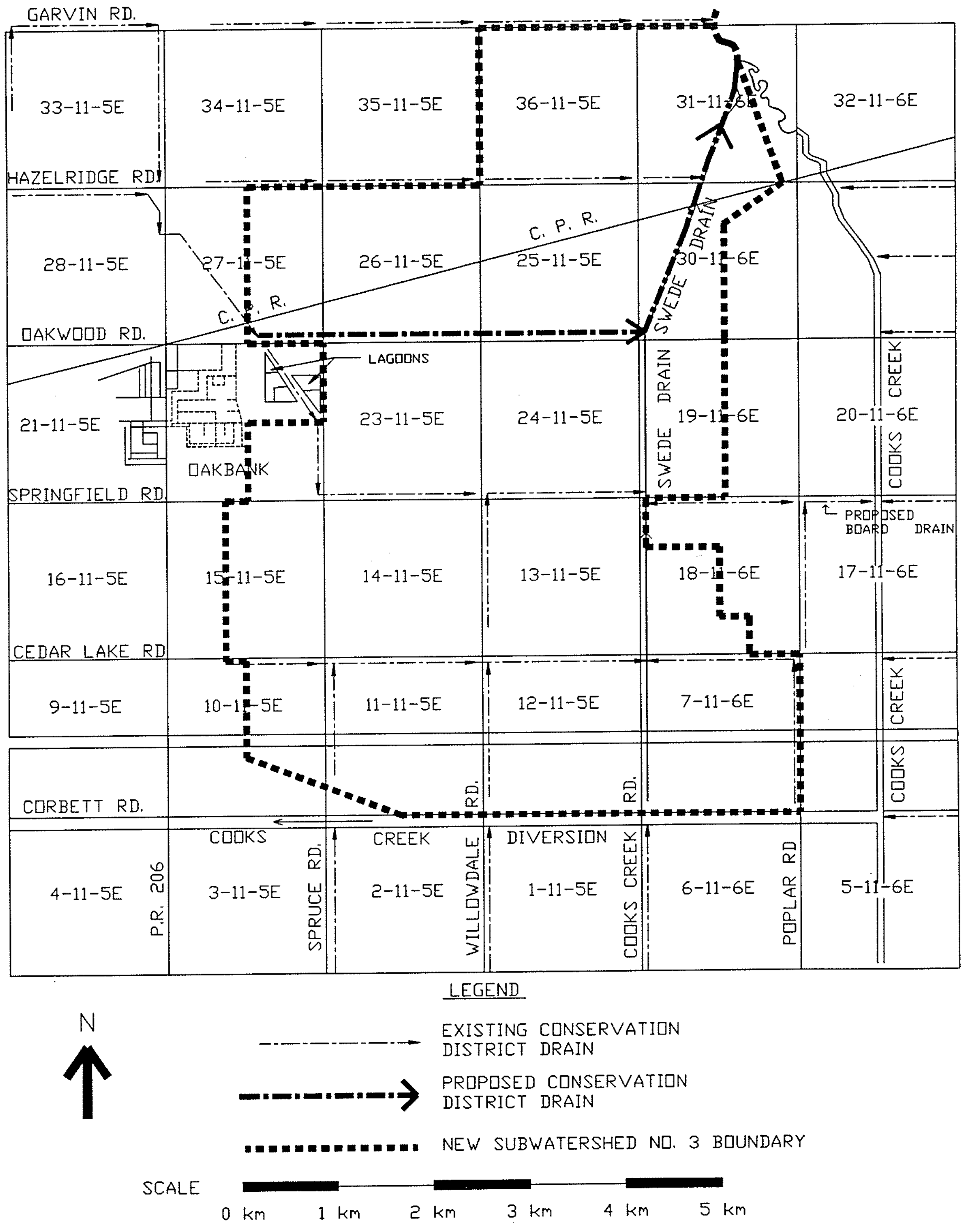


Figure 19 Option No. 4 - The diversion of the Oakbank Drain down Oakwood Road and the reconstruction of the Swede Drain

Table No. 4

Approximate existing capacity of drains (Option No. 1) and proposed design capacities for feasible Options 3 and 4 designed to value-added standard

Drain	Option 1 Existing Capacity of System m^3/s	Option 3 Oakbank Drain Diverted down Oakwood Road m^3/s	Option 4 Oakbank Drain Diverted down Oakwood Road and Swede Drain Upgraded m^3/s
Hazelridge Rd.			
S-36-11-5E	1.7	2.2	2.2
S-31-11-6E	1.7	2.2	2.2
Oakwood Rd.			
S-27-11-5E	-	2.6	2.6
S-26-11-5E	0.4	3.6	3.6
S-25-11-5E	0.6	3.9	3.9
Springfield Rd.			
E-22-11-5E	0.7	0.9	0.9
S-23-11-5E	0.7	1.5	1.5
S-24-11-5E	0.8	2.6	2.6
Cedar Lake Rd.			
N-10-11-5E	0.7	0.6	0.6
N-11-11-5E	0.6	1.3	1.3
N-12-11-5E	0.4	2.1	2.1
N-7-11-6E	0.3	0.6	0.6
Spruce Rd.			
W-11-11-5E	0.3	0.4	0.4
Willowdale Rd.			
W-13-11-5E	0.4	0.5	0.5
W-12-11-5E	0.3	0.7	0.7
Poplar Rd.			
E-7-11-6E	0.8	0.8 *	0.8 *
Swede Drain			
W-7-11-6E	3.2	3.2 *	3.2 *
W-18-11-6E	4.6	4.6 *	4.6 *
W-19-11-6E	6.6	6.6 *	6.6 *
30-11-6E	6.6	6.6 **	8.3
31-11-6E	6.6	6.6 **	9.6

NOTES:

* Existing drain capacity meets or exceeds value-added standard

** These values are the existing capacities of the Swede Drain. If designed to value-added standard, these values should be as noted in Option No. 4.

5.5 Cost of Alternative Strategies

The purpose of this section is to detail the approximate costs of the feasible options identified in the previous discussion.

In estimating the costs of the various options, numerous assumptions were made and are outlined as follows.

a) Excess excavated material would be spread on adjacent farmlands to a maximum depth of 0.2 m.

b) Spreading rights would be purchased from landowner where required.

c) Where culvert crossings required upgrading through placement of additional culverts, existing culverts would not require upgrading.

d) Excavation costs were based on best "guestimates" of excavation volumes.

e) Construction would be done under dry conditions.

f) All costs are based on 1988 prices.

g) All work would be contracted on an invitational basis without the preparation of formal tender documents.

h) Contingencies of 20 percent and engineering costs of 20 percent of capital costs.

i) Annual maintenance costs for the proposed drainage infrastructure would be four percent of capital costs.

The reader should be aware that these cost estimates represent cursory estimates only. A more detailed analysis, consisting of detailed surveys of the drains, required cut and fill calculations and detailed design of culvert crossings could alter these figures somewhat. Given the above mentioned assumptions and costing methodology, it is not anticipated that the total costs for each option would vary by more then plus or minus 20 percent. These estimates, however, cannot anticipate future costs at the time of construction nor circumstances or conditions which may be noted by a more detailed analysis.

5.5.1 Option No. 1 - Use of the Existing Infrastructure

Obviously, this option is the cheapest of all options presented as the drainage infrastructure would not undergo any reconstruction works. The only costs associated with this option would be the regular operation and maintenance costs, estimated at $8,000 per year.

5.5.2 <u>Option No. 2</u> - The Diversion of the Oakbank Drain down Spruce Road

This option was found to be infeasible and, therefore, cost estimates were not prepared.

5.5.3 <u>Option No. 3</u> - The Diversion of the Oakbank Drain down Oakwood Road

Cost estimates for this option are outlined in Table 5.

TABLE 5

Option No. 3 - Costs estimates for the diversion of the Oakbank Drain down Oakwood Road

Drain	Earthwork	Culverts	Spreading Rights	Utility Relocation	R.O.W.	Total
Hazelridge Road						
S-36-11-5E	1,500	8,000	--	--	--	9,500
S-31-11-5E	500	2,400	--	--	--	2,900
Oakwood Road						
S-27-11-5E	16,000	10,000	1,700	--	1,000	28,700
S-26-11-5E	32,500	45,600	4,000	6,500	4,500	93,100
S-25-11-5E	25,000	40,000	2,000	6,000	2,000	75,000
Springfield Road						
E-22-11-5E	1,500	--	--	--	--	1,500
S-23-11-5E	2,000	6,000	--	--	--	8,000
S-24-11-5E	2,000	9,000	--	--	--	11,000
Cedar Lake Road						
N-10-11-5E	--	--	--	--	--	--
N-11-11-5E	8,300	9,100	--	--	--	17,400
N-12-11-5E	13,000	10,000	1,000	--	--	24,000
N-7-11-6E	4,000	2,000	500	--	--	6,500
Spruce Road						
W-11-11-5E	2,000	--	--	--	--	2,000
Willowdale Road						
W-13-11-5E	3,500	1,000	--	--	--	4,500
W-12-11-5E	3,000	3,000	--	--	--	6,000
Poplar Road						
E-7-11-6E	--	--	--	--	--	--

Drain	Earthwork	Culverts	Spreading Rights	Utility Relocation	R.O.W.	Total
Swede Drain						
W-7-11-6E	--	--	--	--	--	--
W-18-11-6E	--	--	--	--	--	--
W-19-11-6E	--	--	--	--	--	--
30-11-6E	--	--	--	--	--	--
31-11-6E	--	--	--	--	--	--
Total	114,800	146,100	9,200	12,500	7,500	290,100
Contingencies	20%					58,000
Engineering	20%					58,000
Total Cost						$406,100

Annual Maintenance Cost = 0.04 x $290,100 = $11,600

5.5.4 <u>Option No. 4</u> - The Diversion of the Oakbank Drain down Oakwood Road and Reconstruction of the Swede Drain

Capital costs for this option include those described in Option No. 3. Additional capital costs for this option result from upgrading of the Swede Drain to value-added standard in Sections 30-11-6E and 31-11-6E. Capital costs for the upgrading of the Swede Drain are as outlined below:

Section	Excavation	Culverts	R.O.W.	Structures	Total
30-11-6E	33,200	38,000	8,000	70,000*	149,200
31-11-6E	40,000	---	8,000	45,000**	93,000
TOTAL	73,200	38,000	16,000	115,000	242,200

* Represents bridge crossing over Hazelridge Road.
** Represents gradient control structure.

Adding this additional capital cost to the capital cost for Option No. 3 results in a capital cost for Option No. 4 of $290,100 + $242,200 = $532,300. Therefore, the total cost for Option No. 4 is as follows:

Capital Cost	$532,300
Contingencies 20%	$106,000
Engineering 20%	$106,000
Total Cost	$744,300

Annual Maintenance Costs = 0.04 X $532,300 = $21,200.

In summary, the costs for each option are as follows:

	TOTAL COSTS	ANNUAL MAINTENANCE
Option 1	-----------	$8,000
Option 2	NOT FEASIBLE	
Option 3	$406,100	$11,600
Option 4	$744,300	$21,200

5.6 Preferred Strategy

Although the CCCD has the final authority in its choice of options, this researcher prefers Option No. 3, upgrading of the drainage infrastructure to the value-added standard with the diversion of the Oakbank Drain down Oakwood Road. This option has a total cost of approximately $406,000. Implementation of this option would relieve the Oakbank Drain along Springfield Road of its current hydraulic demands, allowing for improved agricultural drainage in those areas where more extreme ponding problems have been observed (that is, in Sections 13, 14, 23 and 24-11-5E). Upgrading of the remaining CCCD drains to the recommended value-added standard should offer the remaining areas of the Subwatershed with a significantly improved level of drainage performance.

As mentioned, Option No. 3 has the limiting factor of the Swede Drain being undersized to accommodate value-added flows in Sections 30 and 31-11-6E. The actual hydraulic impact of this restriction is unknown and would require a sophisticated hydraulic modelling of the drainage infrastructure. Such an analysis is beyond the scope of this research. It is this researcher's opinion that the impact may prove to be minimal. Subjecting this portion of the Swede Drain to design value-added flows could potentially cause an increase in design water levels in the Swede Drain and some short-duration minor flooding events along this reach, particularly at the confluence with Cooks Creek. It is not anticipated that such flows would pose any danger to roads or crossings. One must keep in mind that the Swede Drain south of Oakwood Road is now over capacity when considering value-added flows and is capable of effectively "storing" backwater that may result due to excessive flows in the Swede Drain in Sections 30 and 31-11-6E. This excess water could be discharged as water levels subside. It is extremely important to realize that the above discussion is strictly the opinion of this researcher. All technical questions or queries as to the actual hydraulic particulars would have to be addressed through a detailed hydraulic modelling of the drainage infrastructure.

As can be seen from the cost estimates provided, upgrading of the Swede Drain in Sections 30 and 31-11-6E would cost approximately $338,000 (including engineering and contingencies). This would result in the total cost of upgrading the drainage infrastructure to approximately $744,000 (that is, Option No. 4). It is the opinion of this researcher that such an expense would be unacceptable to the CCCD when one considers that any benefits would accrue to only 37 km^2 of agricultural land in Subwatershed No. 3. One must also keep in mind that this is only one of six subwatersheds scheduled to undergo drainage infrastructure improvement works in the project area and the estimated costs of upgrading infrastructures in these subwatersheds must also be considered. Such cost estimates for Subwatersheds Nos. 4, 5 and 6 have yet to be completed.

Drawing No. 2 appended to this report details the preferred strategy and highlights existing and proposed CCCD drains as well as the location of culvert crossings requiring upgrading.

5.7 Implications of the Preferred Strategy

The purpose of the following discussion is to provide the reader with an analysis of the anticipated implications of the recommended strategy (that is, Option No. 3). This section, therefore, attempts to investigate the impacts of the preferred strategy on some of the water management issues discussed in Chapter 3.3 "Water Management Concerns" of this report and briefly touches upon other resources which may be implicated by the preferred strategy.

5.7.1 Agricultural Drainage Benefits

Agricultural drainage is anticipated to significantly improve with the adoption of Option No. 3 (the diversion of the Oakbank Drain down Oakwood Road and upgrading the remaining infrastructure to the value-added standard.) As discussed, this option would relieve the excessive hydraulic stress on the Oakbank Drain along Springfield Road, allowing for a significant improvement in its ability to accept agricultural runoff from adjacent lands where extreme ponding problems were observed (that is, in Sections 13, 14, 23 and 24-11-5E). Upgrading of the remaining drainage infrastructure should provide much improved relief to those areas where more moderate ponding problems were observed.

The actual amount of time required to relieve excess ponded water is extremely difficult to determine and depends on the specific rainfall event, condition of the soil, type of crop, level of uniform drainage provided and condition of the improved collection infrastructure. The Subwatershed was designed to the value-added standard which was based on an extrapolation of cost-benefit studies performed on other subwatersheds in Manitoba having characteristics similar to those of the project area in the CCCD. Based on these studies, the standard was expected to provide a significant improvement in drainage characteristics and resulting crop benefits for a given expenditure on drainage improvement works in the project area. Prediction of the actual times that ponded water could be expected to remain on the fields, and corresponding crop benefits or losses, would involve complex hydraulic modelling of the infrastructure in conjunction with its agricultural characteristics and was considered beyond the scope of this study.

Despite this fact, numerous drains in the Subwatershed would be able to discharge more than double their original capacity if upgraded to the value-added standard and properly maintained. Such added capacity could be expected to vastly improve the relief of ponded waters on lands after heavy rainfall events, especially in those areas where extreme ponding problems were observed.

Whether or not cropping patterns change through the adoption of more specialty crops with improved drainage depends on numerous factors such as price, seasonal constraints and the willingness of the farmer to plant such crops. Surface water ponding, which has been one of the limiting factors in the planting of specialty crops in the Subwatershed, should be relieved much faster with the construction of an improved drainage infrastructure. However, it is this researcher's opinion that the local farming community would probably want to observe its operation and maintenance over a number of growing seasons to gain confidence in its successful operation before committing to specialty crops. It is considered more than likely that the more traditional crops of wheat, barley, oats, flax and canola would continue to be the dominant crops seeded in the Subwatershed with perhaps a small percentage of the land seeded ultimately to specialty crops after the drainage infrastructure had proven itself.

5.7.2 Stormwater from the Village of Oakbank

Both stormwater and lagoon effluent would continue to be discharged to the Oakbank Drain alongside Springfield Road and would flow through the Swede Drain in Subwatershed No. 3 as in the past. The diversion of the Oakbank Drain at Oakwood Road, however, should easily allow for the Oakbank Drain along Springfield Road to accommodate stormwater and lagoon effluent flows from the Village as well as agricultural runoff from adjacent lands. The anticipated stormwater flows from the proposed subdivision in the Village are expected to be no larger than those of agricultural flows. The subdivision occupies an area of approximately 0.6 km^2 and is drained by a network of roadside ditches into a large retaining ditch prior to its discharge to the Oakbank Drain. These ditches effectively act as "storage reservoirs" for the gradual discharge of stormwater.

5.7.3 <u>Lagoon Effluent</u>

The discharge of lagoon effluent, and its resulting dense growth of cattails in any drain receiving such effluent, will continue to be a major problem. Excessive cattail growth, caused by a recipient drain's prolonged exposure to nutrient-rich lagoon effluent, can impede the hydraulic performance of a drain and, thus, the drains function to receive agricultural runoff. In an effort to curb dense vegetation growth, numerous drains in Manitoba have been sprayed with chemical herbicides, such as Roundup. The application of these herbicides has proven to be somewhat successful in controlling problem vegetation. Because the Oakbank Drain is subject to such dense growths of cattails, it might be advisable to consider the application of a herbicide in both the Oakbank Drain along Springfield Road and the Swede Drain. Control of such dense vegetation would significantly improve the performance of these drains and is considered mandatory for their effective operation.

Obviously, application of any herbicide in agricultural drains could have environmental implications. One must keep in mind, however, the scope of such an application in agricultural drains when considering adjacent farmers regularly spray much larger land areas with herbicides on a regular basis. Discussions with local herbicide suppliers have indicated that, if applied properly, there should be no chance of contamination of surface waters in agricultural drains as a result of treating these drains with a herbicide to control vegetation growth. Most herbicides move through the plant from the point of contact and affix themselves to the plant root system.

The above discussion is not to say that the use of herbicides in agricultural drains is without environmental implications. Numerous environmental groups in the media are questioning the safety of the application of any pesticide or herbicide. The reader should be made aware, however, that herbicide application has been successful in the past with little or no reported environmental damage. It was considered beyond the scope of this report to conduct an environmental assessment of the impacts of herbicide treatment of agricultural drains except to make the reader aware of its potential.

Should the CCCD decide against the use of herbicides to relieve cattail growth due to lagoon effluent in the Oakbank and Swede Drain, then an extensive program of mechanical removal, through the use of brush mowers, would have to be implemented whenever such vegetation becomes excessive. Control of this cattail growth, especially in the Oakbank Drain along Springfield Road, is considered vital.

Alternatives to discharging lagoon effluent down the Oakbank Drain could perhaps involve the construction of a pumping station at the lagoon site and pumping such effluent to the Cooks Creek Diversion. Such an option, although feasible, would be extremely costly. A second option to discharging lagoon effluent down the Oakbank Drain could be to discharge the effluent down the proposed Oakwood Road Drain. A survey of the discharge route from the lagoon outlet, to its intersection with the proposed Oakwood Road Drain, would determine bottom of drain elevations for the proposed Oakwood Road Drain to accommodate lagoon discharge. The proposed Oakwood Road Drain would have a much steeper gradient than the existing Oakbank Drain allowing it to more readily discharge received effluent. If, during construction of the Oakwood Road Drain, the bottom of the drain is treated with a chemical herbicide or sterilant, the problem of excessive cattail growth should be alleviated somewhat.

5.7.4 Spring Flooding

Any proposed water management strategy for Subwatershed No. 3 will have very little impact on spring flooding problems. Subwatershed No. 3 unfortunately lies in the lowest part of its contributing watershed. As a result, it is subject to receiving much of the spring runoff from its surrounding area. Relief from such water is hampered by snow and ice-blocked drains and culverts, resulting in meltwater being stored on agricultural land. Cooks Creek itself must also be free of ice before any flood waters recede. Only when Cooks Creek begins to flow and all drains are relieved of their snow and ice is spring flooding alleviated. It is not anticipated that drainage infrastructure improvement by itself would alleviate spring flooding of agricultural lands.

5.7.5 Maintenance

Along with the provision of upgraded drainage works is the required implication of adequate maintenance. A long-term maintenance program is essential to the proper functioning of any drainage infrastructure. Excessive vegetation must be kept under control. Erosion damage or siltation of the drains must be repaired and culverts must be inspected and maintained to ensure their proper operation. Without such proper maintenance, hydraulic performance of a drain can be substantially impaired. Proper maintenance of the proposed infrastructure is considered essential.

Unfortunately, the CCCD lacks the required equipment and staff to perform such maintenance operations itself. Currently, any maintenance of drains is accomplished through contracting of such work to private contractors, the local rural municipalities or the Engineering and Construction Branch of the Manitoba Department of Natural Resources. Such contracting of maintenance works often requires lengthy administration times and is subject to the availability of contractors. These factors often result in undue amounts of time required for emergency repairs to CCCD drains. This problem, in all likelihood, will continue until the CCCD acquires its own maintenance staff and equipment.

The success of any infrastructure improvement, however, will require a more extensive maintenance program than currently exists in the Subwatershed. From the assessment of the various drains in the Subwatershed, it was obvious that some drains have not had scheduled maintenance for numerous years. The CCCD currently focuses most of its attention on the clearing and brushing of the Oakbank Drain and the Swede Drain in the Subwatershed. Maintenance of all drains within the improved infrastructure should consist of annual vegetation control, culvert cleaning if required and regrading of siltation or erosion areas within the drains.

The beaver dams in Section 31-11-6E along the Swede Drain have reportedly caused numerous problems in the past by artificially raising the water levels upstream in the Swede Drain. Extensive efforts in the past to remove such dams have been hampered by the reluctance of local landowners to concede to the presence of heavy equipment or blasting efforts on their property to remove problem dams. More intensive efforts in the future to remove such dams may be required by the CCCD. Such efforts may ultimately require purchase of right-of-way along the Swede Drain and Cooks Creek in this section to allow for access and maintenance of this reach with heavy equipment.

Drastic action, such as the purchase of right-of-way along this reach, could perhaps be delayed until after the Oakbank Drain diversion has been constructed so as to properly ascertain the impact of the diversion and the improved infrastructure on drainage performance in the Subwatershed. If it is concluded that the beaver dams are still a major source of restriction and cannot be adequately dismantled through existing efforts, then purchase of right-of-way allowances may be required to facilitate more extensive maintenance efforts.

5.7.6 Groundwater

Groundwater in the Subwatershed has its source in the carbonate rock aquifer that underlies the entire project area. Water from this aquifer is potable and most of the wells in the area draw from it. The depth to the aquifer is approximately equal to the depth to the bedrock which varies from 10 to 30 m. In general, the static level is less than 10 m below ground level. From previous studies conducted investigating the impact of improved drainage in the project area on groundwater, it was concluded that improved drainage should not cause any change in the availability of groundwater in the area nor should the construction of drains affect the potentiometric surface of the aquifer (Rutulis, 1986).

5.7.7 Fisheries

Cooks Creek provides spawning, nursing and feeding habitat for numerous fish populations exploited by commercial, sport and bait fishermen fishing the lower Red River and its tributaries. The most valuable species of fish found in the Creek are walleye, sauger, pike and sucker.

Fisheries Branch personnel of the Manitoba Department of Natural Resources have concluded that the factor limiting successful fish reproduction in the lower reaches of Cooks Creek is the rapid attenuation of flows after the snowmelt peak discharge. Adequate flows are required to ensure egg survival during the incubation period for up to 45 days after the peak discharge. The operation of the Cooks Creek Diversion was planned, therefore, to allow water to discharge to the Diversion once flows in Cooks Creek exceed 2.83 m^3/s. This would allow for sufficient riparian flows downstream of the Division and was deemed acceptable to the Fisheries Branch. (Hayden, 1984)

Conversations with Fisheries Branch personnel have indicated they have no concerns with the proposed drainage improvement works in Subwatershed No. 3.

5.8 Assessment of On-farm Drainage

Any proposed improvements to the drainage infrastructure in the Subwatershed will have minimal agricultural benefits without an efficient mechanism of on-farm drainage. The purpose of the following discussion is to assess the condition, mechanism and level of development of on-farm drains in the Subwatershed and to ascertain the level of commitment by the local farmers to improve their on-farm drains should an improved drainage infrastructure be provided.

It was found that on-farm drainage in the Subwatershed receives a significant amount of attention by the majority of farmers. Because of the nature and severity of surface water ponding in areas of the Subwatershed, on-farm drainage was found to be highly developed. Almost all of the larger farmers (farming more than 400 ha) indicated that, with an improved drainage infrastructure, they would expand their on-farm drainage efforts with the development of more on-farm drains and the improvement of existing drains. The limiting factor impeding such on-farm drainage development at the present time was the apparent inadequate capacity of the receiving infrastructure to accommodate surface water runoff which may be carried by new or improved on-farm drains.

Most farmers interviewed used the "random" system of drainage to drain flat depressional areas subject to the collection and ponding of surface water. The drains themselves were in general very well constructed. Almost all farmers owned or had access to farm scrapers and some owned crawler tractors. Those without such equipment borrowed or rented from those who had. Some farmers had retained the services of private contractors to construct their on-farm drains.

The majority of the smaller on-farm drains were constructed in such a manner to allow for the passage of equipment enabling the farmer to "farm through" the drains. Some of the larger, more major drains, were seeded to grass to prevent erosion.

If one were to suggest improvements in the current methodology of on-farm drain construction it would be to conduct a survey for the purpose of establishing required gradients and minimizing the amount of cut and fill required. Such surveys would also ensure that suitable fall can be obtained between the problem area and the bottom of the receiving ditch. The Manitoba Department of Agriculture provides survey assistance to farmers at a cost of $60 per quarter section or part thereof.

CHAPTER VI

DISCUSSION

One of the primary objectives of this research was to develop and recommend alternative water management strategies for Subwatershed No. 3 in the CCCD and to address reported drainage concerns. The need for such a strategy was apparent given the intense demand for improved relief of ponded water on agricultural lands after rainfall events and the use of the Subwatershed as a receiver of stormwater and lagoon effluent from the Village of Oakbank. In addition, the Subwatershed must also accommodate agricultural runoff outside the Subwatershed's boundary. Such waters must all be discharged by the Subwatershed's drainage infrastructure. Portions of the existing drainage infrastructure in the Subwatershed have proven themselves to be incapable of discharging such required flows within acceptable lengths of time. This has resulted in prolonged flooding and waterlogging of agricultural land in specific areas of the Subwatershed (at times exceeding seven days according to some local landowners) as the infrastructure attempts to discharge received surface waters. Such prolonged flooding and waterlogging has reportedly resulted in crop damage to crops grown in these areas (Whalen, 1977).

The preferred strategy to relieve such problems in Subwatershed No.3, as determined by this study, consists of the diversion of the Oakbank Drain down Oakwood Road and upgrading of the collector drains, with the exception of the Swede Drain, to the "value-added" standard. Such a strategy is estimated to cost approximately $406,000 including engineering and contingencies.

The question which the CCCD must now address is how much money it is willing to spend to achieve an improved level of drainage in Subwatershed No. 3 in conjunction with monies that will also have to be spent in Subwatersheds Nos. 1, 2, 4, 5 and 6, given its goals, plans, objectives and budget constraints. Such a question is extremely difficult to answer at this stage of the project's development since cost estimates for drainage improvement works in Subwatersheds Nos. 4, 5 and 6 have yet to be completed. It may well be that the total costs of improving all such drainage works are unacceptable to the CCCD. Without completing water management strategies and cost estimates for the respective strategies in Subwatersheds Nos. 4,5 and 6, the CCCD may misallocate funds in the provision of improved drainage works. It may well be, for example, that funds spent on improved drainage works in Subwatershed No. 5 could benefit much larger land bases than those in the remaining subwatersheds. Analyses and cost estimates, therefore, should be prepared for Subwatersheds Nos. 4, 5 and 6 to allow the CCCD to make informed and rational decisions as to where drainage improvements should be constructed and how best the monies should be spent.

One could perhaps query the design of the infrastructure in Subwatershed No. 3 to the recommended value-added standard. The value-added standard was chosen based on an extrapolation of benefits derived from a detailed cost-benefit analysis of other watersheds in Manitoba having similar characteristics. Such benefits were compared with approximate costs of infrastructure improvements in the Cooks Creek Diversion project area and, thus, the value-added drainage standard was adopted where the ratio of anticipated benefits to costs was at its maximum. One could perhaps argue that, in order to minimize costs, a lower standard could be chosen for the design of the drainage infrastructure in the Subwatershed. It is unlikely, however, that such a lower standard would appreciably reduce costs. It is important to recall that all drains in Subwatershed No. 3 were designed to accommodate a recommended minimum cross-sectional requirement; that is, a 3-m base with side slopes having a minimum slope of 3:1. This is roughly the smallest configuration that can be constructed with a scraper while at the same time providing for easy access for maintenance. This is not to say that channel cross-sections having a smaller configuration cannot be constructed. Such smaller configurations can be accommodated but would, in general, cost more than the recommended minimum due to the intricacies of construction. As it happens, almost all collector drains in the Subwatershed, if reconstructed to conform to the recommended minimum cross-section, would accommodate value-added flows or greater flows with a hydraulic grade line at or below prairie elevation. Thus, very little money would be saved on excavation. The exception to this rule lies in the reconstruction of the Swede Drain to accommodate value-added flows in Sections 30 and 31-11-6E. Although not recommended at the present time, due to its extremely high cost, this portion of the Swede Drain falls somewhat short of meeting value-added flows.

Culvert crossings in the preferred option account for approximately 50 percent of the capital costs or an estimated $146,000. Of this figure, approximately $95,000 represents required culverts along the proposed Oakbank Drain diversion route along Oakwood Road. Opting for a lower drainage standard (say 80 to 90 percent of the value-added standard) is not anticipated to dramatically reduce these culvert costs. Many of the culvert crossings in the Subwatershed were found to be so severely restrictive or damaged that their replacement is considered mandatory to provide any level of drainage improvement. Reduction in culvert sizes, due to adoption of a lower standard, are not expected to reduce culvert costs appreciably. Adoption of a standard, of say 80 to 90 percent of the value-added standard, would in all likelihood involve an almost negligible saving in culvert costs. The money saved in opting to the next smaller size culvert as a result of adoption of such a standard is minimal. Adoption of a drainage standard significantly lower than the recommended value-added standard would involve intensive cost-benefit studies to properly justify the selection of a new drainage standard.

Recalling Chapter 3.5.5 "Losses from Poor Agricultural Drainage", it was calculated that annual yield loss for wheat in those areas of reported ponding problems in Subwatershed No. 3 were in the order of $94,000 per year. If we assume, for Option No.3, a total cost of $406,000, a 15-year design life and a 5 percent real interest rate, the annual cost of providing the improved drainage infrastructure, including annual maintenance costs, is approximately $51,000 per year. Thus, annual benefits would seem to exceed annual costs and the capital costs seem to be well worth incurring. If we conduct the same analysis for Option No. 4, having a total cost of $744,300, total annual costs of providing the infrastructure, including maintenance, are in the order of $93,000 per year. Comparing this to anticipated annual benefits of $94,000 per year, consideration of this option becomes questionable. One must keep in mind that these cost-benefit calculations are conceptual in nature. It was not within the scope of this report to conduct detailed cost-benefit studies on the various options. It is also important to note that these calculations assume Option No. 3 will provide an appropriate level of drainage, despite the fact that the Swede Drain's capacity falls somewhat below the recommended value-added drainage standard.

If the CCCD wanted to proceed with Option No. 3 but was faced with limited funds, it might be advisable for it to concentrate its efforts on those drains which would relieve areas of reported extreme ponding problems. Such a strategy might involve the diversion of the Oakbank Drain down Oakwood Road and the upgrading of the Cedar Lake Road Drain. This strategy would provide some form of relief for the areas of extreme ponding problems in Sections 11, 12, 13, 14, 23 and 24-11-5E. Such a strategy would have a total cost of approximately $340,000, including engineering and contingencies. At a minimum, the CCCD could construct the diversion of the Oakbank Drain down Oakwood Road. This strategy would provide some relief to those areas of reported extreme ponding problems in Sections 13, 14, 23 and 24-11-5E. Such an option would have a total cost of approximately $276,000, including engineering and contingencies. The remaining drains could be upgraded as funds become available.

Before any drainage improvement works are constructed in

Subwatershed No. 3, it is important that the concerned parties understand who would ultimately benefit from such improvement works. The Village of Oakbank would benefit very little. The Village currently experiences insignificant problems with the discharge of its stormwater or lagoon effluent from its perspective. All problems that might occur as a result of such discharges occur downstream of the Village. Those lands contributing flows outside the Subwatershed boundary would also benefit very little as drainage in these areas is not a major concern. The only beneficiaries of such improvement works would be the landowners in the Subwatershed. Of the landowners in the Subwatershed, the small rural residential landowner would benefit very little. These landowners' primary concern is the rapid relief of waters during spring flood events. The proposed drainage infrastructure was not designed to accommodate spring flood events nor was it anticipated to improve, to any degree, spring flooding problems. Thus, the greatest beneficiary of such improvement works would be the local farmer who stands to benefit the most from more rapid relief of ponded water off his field after rainfall events. It is interesting to recall that the majority of agricultural land owned or rented in the Sub-watershed is farmed by only five or six of the larger farmers in the area. Thus, the majority of any financial benefits from monies spent on drainage improvement works would be largely realized by these five or six large farmers in the

Subwatershed and, to a smaller extent, the owners of those lands rented to farmers who should receive increased revenues through rental agreements from anticipated increases in crop yields.

Because the owners of the agricultural land stand to gain the greatest benefit, the CCCD may wish to consider the assessment of a special drainage levy on those landowners who stand to benefit the most from drainage improvement works in the Subwatershed. Such a policy, although likely unacceptable to the local landowners, would see the beneficiary of such drainage works pay a larger share of the costs of its provision.

Although the options described in this report primarily deal with drainage infrastructure upgrading, the CCCD may wish to consider some non-structural options. Such options could include the outright purchase of lands subject to severe ponding with the option of leasing such lands back to the farmer. The CCCD may want to investigate the possibility of subsidizing, for those landowners experiencing frequent ponding, an appropriate percentage of their crop insurance premiums in lieu of providing drainage improvement works. Such a strategy would, however, depend on the Manitoba Crop Insurance Commission's willingness to insure such lands that are frequently flooded. The CCCD may also want to promote the use of the land for water tolerant crops, such as for forage production or pasture land for cattle operations. Such non-structural options would likely be unacceptable to landowners. The land, even with its frequent ponding problems, has high value in its potential for crop land. Cropping of the land, although at times impeded by excessive soil moisture, has proved in the past to be relatively successful and would seem to be the best use for the land. In addition, the majority of the landowners have perceived an improved drainage infrastructure as the solution to relieving ponding of their lands and have looked to the CCCD, and the newly constructed Cooks Creek Diversion project, as a means of implementing this solution. To suggest to these landowners the implementation of some of these non-structural solutions would likely be totally unacceptable at this stage in the respective Subwatershed's drainage infrastructure development.

The problem of rural residential development in the Subwatershed has been ameliorated somewhat by the introduction of the Rural Municipality of Springfield Development Plan. Residential development is, however, still taking place. Existing landowners have the right to subdivide their holdings to provide suitable residential lots for their children. These lots may range from 2 to 8 ha in size. This policy is a favourable one so long as the children accepting such holdings contribute to the farming operation. When such offspring sell their holdings to residential developers such land is lost for future agriculture. The control of such residential development would require a rigid planning strategy and strict enforcement of such a strategy. Whether or not further losses of agricultural land take place in the Subwatershed, or the RM of Springfield, will depend on the enforcement of such a planning strategy.

The problem of required access crossings for each residential holding adjacent to a CCCD drain will inevitably continue for each residential development approved. The design of such crossings, therefore, must consider carefully the design flows of the drain, and all respective culverts must be sized accordingly.

Jurisdictional conflicts between the CCCD and the local rural municipalities within municipal rights-of-way is expected to continue. Currently, the CCCD is responsible for its designated drains and the municipality is responsible for the roadside ditches and municipal drains. Disputes over the design and cost-sharing of any municipal improvement works proposed by the municipalities which may impact positively or negatively on CCCD drains are certain to continue. Ideally, the optimal solution would be to have the entire infrastructure within a municipal right-of-way under one jurisdiction (the conservation districts or local municipalities). The implementation of such a plan, however, would prove to be extremely difficult since conservation districts do not include entire municipalities nor do municipalities include entire conservation districts. The CCCD also lack staff and maintenance equipment to maintain such services.

Any drainage infrastructure improvement works which the Cooks Creek Conservation District undertakes should not be done on a unilateral basis. Drainage of any kind can have multidirectional and far-reaching effects depending on the magnitude of the proposed works. Thus, communication with impacted parties, such as the Rural Municipality of Springfield, local landowners, agricultural representatives and Municipal Planning is considered essential. Proper communication will enable any job to be completed expeditiously and efficiently with a minimum of conflicts.

CHAPTER VII

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

7.1 Summary

The Cooks Creek Diversion project was provided for in 1982 under the Canada/Manitoba Subsidiary Agreement on Value-Added Crops Production. The project was designed to increase the drainage capacity of a 200 km^2 area of agricultural land in the Cooks Creek Conservation District.

Excessive spring and summer rains have caused reported losses to agriculture in this project area due to the prolonged ponding of such water on agricultural land. The project area consists of clay soils which are well suited for cropping; however, these same soils are very susceptible to excess precipitation. The project was designed to increase the drainage capacity in the project area through provision of an improved outlet (Phase I) and upgrading of the lateral drainage tributary network in the subwatersheds (Phase II).

Phase I involved the construction of a 16-km diversion channel to divert waters from Cooks Creek to the Red River floodway and was completed in the fall of 1988. Phase II involves the construction and upgrading of the lateral drainage network in the six identified subwatersheds in the project area. Feasibility studies are currently underway and cost estimates are currently being prepared for this stage of the project. Studies investigating strategies and cost estimates for Subwatersheds Nos. 1 and 2 have been completed and this study details proposed strategies and cost estimates for Subwatershed No. 3.

Subwatershed No. 3 has an area of approximately 37 km^2 and consists of fertile clay soils suitable for agriculture but subject to excessive periods of ponding after heavy spring and summer rainfalls resulting in crop losses. Extensive on-farm drainage efforts have done little to improve the situation due to the limited capacity of the existing drainage infrastructure to discharge required flows in acceptable periods of time. In addition, the drainage infrastructure in Subwatershed No. 3 receives additional agricultural runoff from outside its defined boundaries as well as stormwater and lagoon effluent discharges from the Village of Oakbank.

Much of the drainage infrastructure in the Subwatershed is unable to discharge design flows due to undersized culverts, excessive vegetation, siltation and erosion of the drainage channels, the presence of beaver dams downstream in the Swede Drain and Cooks Creek and the lack of suitable gradient in many of the drains. Many of the drains in the

Subwatershed were thus found to be in a poor state of repair and required upgrading to convey runoff to the value-added standard.

The dominant water management concern voiced by land-owners in the Subwatershed was the ponding of surface water on agricultural lands after excessive spring and summer rainfall events. The inability of the existing drainage infrastructure to efficiently discharge this ponded water has resulted in significant crop losses in the Subwatershed. Other concerns expressed included the inadequate maintenance of the drainage infrastructure, excessive vegetation of some of the drains due to discharge of lagoon effluent from Oakbank, increased stormwater flows from Oakbank, lack of sufficient culvert capacity at crossings and spring flooding.

Stormwater flows from the Village of Oakbank were found to have an almost negligible impact on the drainage infra-structure in the Subwatershed when one considers the resultant volume of agricultural flows the Subwatershed must accommodate from the land areas both within and outside the Subwatershed boundary. Effluent from the lagoon posed more of a problem due to its production of excessive vegetation growth along those drains discharging effluent. Strict mechanical main-tenance or chemical treatment of these drains with a herbicide would be required to control such excessive vegetation in the future. Adequate maintenance of any proposed drainage infrastructure upgrading in the Subwatershed was considered vital to its successful operation.

The various strategies investigated in this study ranged from the status-quo option to the investigation of various drainage options to accommodate the recommended value-added drainage standard. Optional drainage strategies consisted of upgrading the collector drains, with the exception of the Swede Drain, to the value-added standard in conjunction with the following options: the diversion of the Oakbank Drain down Spruce Road to the Diversion; the Diversion of the Oakbank Drain down Oakwood Road to the Swede Drain; and, the diversion of the Oakbank Drain down Oakwood Road to the Swede Drain with the upgrading of the Swede Drain to the value-added standard.

The preferred strategy involved diverting the Oakbank drain down Oakwood Road to the Swede Drain and the upgrading of the collector drains to the value-added standard. Such a strategy is expected to cost approximately $406,000 in 1988 dollars. This option would effectively involve reconstruction of the drainage infrastructure in the Subwatershed to the recommended value-added standard, with the exception of the Swede Drain in its lower reaches, which would remain in its present condition, slightly under value-added capacity.

Diversion of the Oakbank Drain down Spruce Road to the Diversion Project was found to be technically infeasible. Diversion of the Oakbank Drain down Oakwood Road and upgrading of the Swede Drain to the value-added standard was deemed cost-prohibitive at an estimated cost of $744,000.

On-farm drainage in the Subwatershed was found to be quite well developed. The severity of the ponding problem has resulted in many of the larger farmers having an extensive network of on-farm drains. Many of the farmers owned or had access to crawlers and farm scrapers for the construction and maintenance of their drains. The majority of the farmers indicated that they would further improve their on-farm drains if an improved drainage infrastructure was provided.

7.2 Conclusions

The provision of an improved land drainage infrastructure requires an integrated and coherent long-range planning rationale to ensure that drainage development projects incorporate the various physical, biological, aesthetic, economic, judicial, environmental and other aspects of man's environment. Therefore, some form of interdisciplinary and multi-purpose coordination and cooperation is necessary to generate comprehensive solutions to conflicting issues, concerns and influences expressed by those people impacted by proposed drainage works. Full public participation in the planning and decision-making process will ensure that society's interests, in all aspects of development projects, are identified and considered.

From the study, the following conclusions were made.

1. Four optional water management strategies were investigated for Subwatershed No. 3. Three of these strategies were deemed inappropriate due to technical, financial or performance-related reasons. The preferred option consisted of the diversion of the Oakbank Drain down Oakwood Road to the Swede Drain and upgrading the remainder of the drains, with the exception of the Swede Drain, to the value-added standard. This option was deemed the most effective in addressing many of the water management concerns expressed.

2. The dominant water management concern in the Subwatershed was prolonged surface water ponding on agricultural fields after heavy rainfall events. Other significant water management concerns in the Subwatershed included increased stormwater and lagoon effluent discharged into the Subwatershed from the Village of Oakbank, maintenance of the drainage infrastructure, culvert restrictions at

crossings, beaver dams located at the Swede Drain - Cooks Creek confluence and spring flood protection.

3. Stormwater runoff from the Village of Oakbank was determined to be no greater than improved agricultural flows and was almost insignificant when considering the entire Subwatershed's drainage area. Lagoon effluent, from the Village of Oakbank, being discharged into the drainage infrastructure, has resulted in excessive vegetation growth in the Oakbank and Swede Drains causing significant restrictions in their hydraulic efficiency.

4. The clay soils in the Subwatershed are potentially very productive and well suited to the growing of traditional crops such as wheat, barley, oats, flax and canola. The soil's impermeable nature, however, requires an efficient surface drainage infrastructure to relieve ponded water after heavy rainfall events so that such crops can achieve their full potential yields. Upgrading of the drainage infrastructure could potentially result in local farmers seeding more specialty crops such as sunflowers, peas, lentils, and faba beans but such practices are expected to evolve over a number of growing seasons as the upgraded infrastructure proves itself. Traditional crops such as wheat, barley, oats, flax and canola are expected to remain the dominant crops.

5. Based on studies investigating drainage infrastructure improvements in subwatersheds having similar soil characteristics to Subwatershed No. 3, the use of the "value-added" drainage standard $Q = 0.479\ A^{0.765}$ (where Q = flow in m^3/s and A = area in km^2) would seem appropriate for the design of drainage improvement works in the Subwatershed.

6. The existing drainage infrastructure is not capable of providing the required level of protection from surface water ponding due to insufficient channel capacity, undersized culverts, lack of gradient and lack of maintenance. Many of the drains in the Subwatershed were found to be inadequately maintained. An extensive maintenance program, with particular attention to those drains subject to extensive growth of vegetation as a result of lagoon effluent, would be required with any drainage improvement strategy.

7. The on-farm drainage network was found to be quite extensive and in general well constructed and maintained. An improved drainage infrastructure would likely result in future upgrading and development of on-farm drains.

7.3 Recommendations

Based on this research, the following recommendations are submitted.

1. Before any drainage reconstruction works in Subwatershed No. 3 are scheduled, studies should be completed to determine costs, flows and drainage infrastructure requirements in Subwatersheds Nos. 4, 5 and 6. This will allow the CCCD to make an informed allocation of monies as to where drainage improvement works (in Subwatersheds Nos. 1 through 6) should optimally be constructed.

2. Should the Cooks Creek Conservation District Board decide to proceed with drainage infrastructure improvements in Subwatershed No. 3, it is recommended that it proceed with the diversion of the Oakbank Drain down Oakwood Road and upgrade the remaining drains, as shown on Drawing No. 2, (with the exception of the Swede Drain) to the value-added standard (Option No. 3). The estimated total cost of this option is $406,100.

3. Hydrologic modelling of the Swede Drain and its tributaries should be conducted to ascertain its overall effectiveness before any decision is made by the CCCD to reconstruct the Swede Drain in Sections 30 and 31-11-5E.

Reconstruction of the Swede Drain to the value-added standard is estimated to cost $340,000 and was deemed cost prohibitive at this time.

4. The CCCD should adopt a strict maintenance program for maintaining any drainage improvement works. This maintenance program should include, at a minimum, vegetation control and any required regrading of all drains on an annual basis. Annual maintenance costs of the recommended option is estimated at 11,600 dollars.

BIBLIOGRAPHY

Bodnaruk, R.D. Value-Added Crops Projects. A Manitoba Government Inter-Departmental Memorandum from R.D. Bodnaruk, P. Eng., Drainage Systems Engineer, to L.J. Whitney, P. Eng., Water Development Planning Section, October 10, 1980.

---. Cooks Creek Value-Added Drainage Study. A Manitoba Government Inter-Departmental Memorandum from R.D. Bodnaruk, P.Eng., Drainage Systems Engineer, to L.J. Whitney, P. Eng., Water Development Planning Section, February 26, 1981.

---. Cooks Creek Value-Added Drainage Project. A Manitoba Government Inter-Departmental Memorandum from R.D. Bodnaruk, P.Eng., Drainage Systems Engineer, to L.J. Whitney, P. Eng., Water Development Planning Section, February 8, 1982.

Canada-Manitoba Soil Survey Winnipeg Region Study Area. 1975.

Carlyle, William J. Agricultural Drainage in Manitoba: The Search for Administrative Boundaries. Department of Geography, University of Winnipeg, Winnipeg, Manitoba.

Ehrlich, W.A., A. Poyser, L. E. Pratt and J.H. Ellis, Report of Reconnaissance Soil Survey of Winnipeg and Morris Map Sheet Areas. Manitoba Department of Agriculture, 1953

Gray, D.M. Handbook on the Principles of Hydrology. National Research Council of Canada, 1973.

Harden, Neil. Runoff From Small Watersheds. Province of Manitoba, Department of Natural Resources, Water Resource Branch, May, 1983.

---. Integration of Rational Method and Regional Flood Curve Design Discharges. January 7, 1986.

---. Cooks Creek Hydrographs. Manitoba Inter-Departmental Memo, March 22, 1983.

Hayden, W. Cooks Creek Diversion. A Memorandum from W. Hayden, Director, Fisheries Branch to T. Weber, Director, Water Resources Branch, November 27, 1984.

Luthin, J.L. Drainage Engineering. John Wiley and Sons, New York, 1965

Manitoba Conservation Districts Authority, Cooks Creek Conservation District Tributary Study - Phase II - The Cooks Creek Diversion Project. August, 1986.

Manitoba Department of Agriculture, "Designing Surface Drainage Systems", Soil Facts. Agdex No. 554, February, 1985.

---. "Subsurface Drainage", Soil Facts, Agdex No. 553, June, 1985.

Manitoba Department of Municipal Affairs, Rural Municipality of Springfield Development Plan Background Studies. 1973.

Manitoba Department of Natural Resources, Increasing Crop Production by Removing Excess Rainfall from Agricultural Lands. Winnipeg, May, 1984.

---. Cooks Creek Area Drainage Improvement Project - Basic Description. Date unknown.

---. Engineering and Construction Branch, Hydraulic Design Manual. November, 1980.

Ontario Ministry of Agriculture and Food, Design and Construction Guidelines. June, 1986.

Penkava, F., "Subsurface Versus Surface Drainage Water Quality and Environmental Impacts," Environmental Aspects of Irrigation and Drainage. Proceedings of a Specialty Conference Conducted by The American Society of Civil Engineers, University of Ottawa, July 21 to 23, 1986.

Rigaux, L.R. and R.H. Singh, Benefit Cost Evaluation of Improved Levels of Agricultural Drainage in Manitoba. Department of Agricultural Economics, University of Manitoba, in cooperation with the Water Resources Division, 1975.

Roads and Transportation Association of Canada, Drainage Manual. Vol. I, 1982.

Rutulis, M. Cooks Creek Diversion Project, Phase II - Groundwater. A Memorandum from M. Rutulis, Aquifer Data Geologist to J.P. Stefanson, Regional Water Manager Northeastern Region, May 27, 1986.

Schellenberg, H. and R.D. Bodnaruk, Economics of Drainage in Southern Manitoba. A paper prepared for the 1983 Canadian Water Resources Association Annual Conference, Saskatoon, Saskatchewan, June 15, 1983.

Slevinsky, L., Effect of Excess Moisture on Cereal Production Within the R.M. of Springfield. 1977.

Slevinsky, L. and H. Schellenberg, Estimation of Agricultural Drainage Benefits in the Marsh River Watershed. Winnipeg, Manitoba, June 27, 1980.

Stefanson, J.P., From a letter to Mr. J.H. Dick, Manager of the Cooks Creek Conservation District, December 29, 1983.

The City of Winnipeg, By-Law 2960, 1981.

The City of Winnipeg Department of Environmental Planning, Oakbank - Dugald Community Plan. December 14, 1977.

The Rural Municipality of Springfield Development Plan. March, 1980.

United States Department of Agriculture, Soil Conservation Service, Drainage of Agricultural Land. Port Washington, New York: Water Information Center, 1973.

Whalen, C.C., Rural Municipality of Springfield Drainage System Study. Winnipeg, 1977.

Whitney, L.J., Water and its Impact on Land Use in Manitoba. A paper presented to the 5th annual Red River Basin Land and Water International Summit Conference, Winnipeg, Manitoba, November 19 -20, 1987.

Personal Communications

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APPENDIX

CRITICAL ASSESSMENT OF EXISTING DRAINS

The following discussion provides a detailed description of the condition of each CCCD drain in Subwatershed No. 3.

HAZELRIDGE ROAD

South 36-11-5E In general, this drain appeared in fair condition showing very few signs of structural problems. The easterly 0.8 km, however, was heavily congested with cattails and brush and required cleaning. Cleaning the drain of excessive vegetation and some minor regarding would enable the channel to carry value-added flows. Excessive vegetation in the easterly half of the drain restricted the drain from achieving value-added flows. The existing culvert crossing at Cooks Creek Road showed signs of collapse and should be replaced in order to carry design flows.

South 31-11-6E This drain appeared in good condition having a channel capacity meeting the value-added standard. Some cleaning of cattails and light brush was required in the westerly half of the drain. The culverts (two 910-mm diameter culverts) discharging flows to the Swede Drain were found to be slightly undersized to discharge value-added flows and ideally should be replaced. One of these culverts could remain and the other replaced by a larger-diameter culvert to minimize costs.

OAKWOOD ROAD

South 26-11-5E This drain was very small in size and contained large amounts of dense vegetation (grasses) resulting in the drain having a channel capacity unable to meet value-added standards. As mentioned previously in Chapter 5.2 "Delineation of Subwatershed Boundaries", this drain receives flows from the easterly half of Section 27-11-5E via a natural swale through 26-11-5E which passes under the CPR tracks and discharges ultimately to the drain in question. Studies by the Water Resources Branch of the Manitoba Department of Natural Resources in 1983 have recommended that, in order to relieve drainage problems in Section 27-11-5E and 26-11-5E, the swale in Section 26-11-5E south of the CPR tracks to the CCCD drain in south 26-11-5E should be improved and that the CCCD assume jurisdiction over the waterway by acquisition of right-of-way (Stefanson, 1983). This researcher concurs with these findings. Improvement of the swale would provide more effective and reliable relief of drainage problems in Sections 26 and 27-11-5E. (Note: Drawings No. 1 and 2 show all existing and proposed Conservation District drains.)

Existing culverts along this drain through farm crossings, and at the junction with Willowdale Road, are undersized and require replacement to meet value-added standards.

South 25-11-5E This drain appeared in fair to poor condition and does not meet value-added flow requirements. The westerly half of the drain was found to be heavily congested with cattails and brush, thereby restricting flows. The easterly half of the drain has been reconstructed somewhat by cleanout efforts to remove windblown soil. The existing culverts at farm crossings, and at the junction with the Swede Drain, are undersized and require replacement to discharge value-added flows.

SPRINGFIELD ROAD

East 22-11-5E and South 23, 24-11-5E At the time this analysis took place, this drain (known as the Oakbank Drain or Lagoon Drain) was found to be in an exceptionally poor state of repair to accommodate required flows. As mentioned previously in this report, the Oakbank drain collects and discharges surface water from Sections 3, 4, and 5-12-5E and from Sections 27, 28, 32, 33, and 34-11-5E from outside the Subwatershed boundary. (See Figure 7 showing those areas outside the Subwatershed boundary discharging to the Oakbank Drain.) In addition, this drain also is required to discharge stormwater from the Village of Oakbank east of Provincial Road

206 as well as lagoon effluent from the Village's lagoon located in the northeast quarter of Section 22-11-5E. The drain is also used by adjacent farming operations in the Subwatershed to discharge agricultural runoff.

The condition of the drain was found to be totally inadequate to meet the hydraulic demands placed on it. Discharge of lagoon effluent has resulted in an extremely dense growth of cattails throughout the length of the drain thereby greatly restricting flow. This cattail growth has resulted in the CCCD conducting major cleaning efforts in this drain every fall (when the drain is dry) in an attempt to remove the vegetation and improve hydraulic performance. Unfortunately, however, these cattails grow extremely rapidly during the spring season such that during the critical months of June, July, and August, the drain is once again congested and filled with water so further maintenance becomes impossible.

Culvert capacities were also found to be inadequate to discharge required flows and were often plugged with debris. To further compound matters, the drain was found to have minimal gradient (0.02 percent approximately) further restricting the hydraulic performance of the drain. The result of all these factors causes the drain to be subjected to flows well beyond its capacity to adequately discharge them within a reasonable length of time (that is, 24 to 48 hours). This drain was reported to be at its full supply level for days or even weeks during those times when the Village's lagoon was being discharged in conjunction with spring and summer rainfall events. All these factors result in the inability of adjacent lands in Sections 13, 14, 15, 23, and 24-11-5E to adequately discharge agricultural runoff to the Oakbank Drain due to prolonged high water levels. Based on existing conditions, this drain requires extensive regrading and reconstruction to accommodate design flows.

CEDAR LAKE ROAD

North-10-11-5E This drain appeared in good condition and met value-added flow requirements. The most easterly 0.4 km, however, was congested with tall grass and small trees and should be cleared of such debris in the future.

North-11-11-5E This drain was heavily congested with cattails and brush at the time of the analysis and seemed to be suffering from excessive siltation and erosion in places. The restricted cross-sectional area of the drain, together with excessive vegetation, resulted in this drain unable to carry value-added flows. Culverts at farm crossings and at the intersection with Willowdale Road are also undersized to carry value-added flows.

North 12-11-5E At the time of the analysis, this drain was also heavily congested with cattails and showed signs of siltation in places. Farming operations over the past number of years seemed to have advanced further and further into the drain at certain locations thereby restricting the available cross-sectional area of the drain. This drain would require extensive excavation and regrading to accommodate value-added flows. Culverts discharging flows into the Swede Drain are also undersized and require replacement.

In addition, the municipal drain along the north side of Cedar Lake Road was also found to be heavily congested with vegetation as well as showing signs of siltation and the encroachment of farming operations. This municipal drain services a portion of the southeast quarter of Section 14-11-5E and the southwest quarter of Section 13-11-5E. Cleaning this drain of vegetation, along with some minor regrading, would greatly improve its performance and its ability to accept and discharge agricultural drainage in these sections.

North 7-11-6E This drain appeared very shallow and narrow in places and was heavily congested with trees on the south bank of the drain. The drain was also showing signs of erosion along its bottom. The drain does not meet value-added flow requirements in its present condition. This drain will require some minor reconstruction along with the cleaning and grubbing of trees that have encroached on the right-of-way.

The culverts along the drain seemed reasonably adequate; however, it is anticipated they will have to be reset to new elevations to accommodate proposed drain reconstruction.

POPLAR ROAD

East 7-11-6E This drain appeared in excellent condition and met value-added discharge requirements.

SPRUCE ROAD

West 11-11-5E At the time of this analyses, this drain was heavily congested with cattails and tall grass restricting the drain's hydraulic performance. A simple cleaning of the vegetation and minor regrading would easily bring this drain up to value-added capacity. The existing culverts should be adequate to discharge value-added flows and do not require replacement.

WILLOWDALE ROAD

West 12-11-5E This drain appeared in fair condition from the Cooks Creek Diversion to a point approximately 0.8 km north of the Diversion. A large cluster of trees was found in the drain at a point approximately 0.4 km north of the diversion and should be removed. Problems were noted in the drain in its most northerly 0.8 km. The bottom gradient flattens to approximately 0.25 percent and the drain becomes congested with cattails and tall grasses. The culvert at the farm crossing in this portion at the drain was also found to be undersized to accommodate value-added flows and should be replaced. This drain, therefore, requires some minor cleaning and regrading along with the replacement of one culvert to meet value-added discharge requirements.

The municipal drain following the west side of Willowdale Road along the eastern limits of Section 11-11-5E also requires cleaning and regrading. This drain receives runoff from the northeast quarter of Section 11-11-5E and requires minor cleaning and regrading to accommodate these flows.

<u>West 13-11-5E</u> At the time of the analysis, this drain was heavily congested with cattails and tall grass. The northern 0.2 km of this drain was also congested with a dense growth of trees on its east bank. The drain also showed signs of encroachment by farming operations and thus the east bank of the drain has an unacceptably steep slope which has resulted in some slope failure along the east bank of the drain. The existing culverts at one farm crossing and at the intersection with Springfield Road should provide adequate

capacity for value-added flows and need not be replaced. This drain requires regrading along with clearing and brushing in order to improve channel capacities to the value-added standard.

COOKS CREEK ROAD (SWEDE DRAIN)

West 7-11-6E The Swede drain between the Cooks Creek Diversion Project and Cedar Lake Road appeared in excellent condition and met value-added discharge requirements.

West 18-11-6E The Swede Drain from Cedar Lake Road to Springfield Road appeared in good condition. The drain does, however, experience relatively dense cattail growth in its base as it approaches Springfield Road. This portion of the Swede Drain met value-added discharge requirements and the culverts at the junction with Springfield Road are adequate to discharge value-added flows.

West 19-11-6E This portion of the Swede Drain must discharge not only those waters collected south of Springfield Road (which represents an area of approximately 12 km^2 but now is subject to the discharge from the Oakbank Drain which drains a area of approximately 20 km^2. The resultant lagoon effluent carried by the Oakbank Drain has resulted in a relatively dense cattail growth in the Swede Drain from its intersection with the Oakbank drain to its confluence with Cooks Creek. The presence of this vegetation in both the Oakbank and Swede Drain has resulted in the CCCD having to conduct annual clearing and brushing maintenance programs in these drains. The Swede Drain along this reach between Springfield Road and Oakwood Road can very nearly achieve value-added flows if the drain is adequately cleaned and maintained.

Cursory analysis of the culverts at the junction of Oakwood Road and the Swede Drain suggested they are undersized to meet value-added flow requirements and would have to be upgraded with placement of additional culverts or the construction of a bridge crossing.

<u>Section 30-11-6E</u> This portion of the Swede Drain between Oakwood Road and Hazelridge Road services an area of approximately 41 km^2. As mentioned previously, this drain was also subject to a dense growth of cattails in its base requiring clearing and brushing on an annual basis.

Unfortunately, the Swede Drain does not have the cross-sectional area nor the gradient to accommodate value-added flows and would require extensive channel enlargements to discharge value-added flows along this reach. To further compound matters, the culvert crossing at the junction of the

Swede Drain with Hazelridge Road was found to be inadequate to carry value-added flows. This crossing should ideally be replaced with a bridge crossing to more efficiently discharge required flows to the value-added standard.

From the above discussion, this reach of the Swede Drain would obviously require extensive and costly reconstruction works, based on this cursory analysis, to accommodate the design value-added flows from Subwatershed No. 3's watershed.

<u>Section 31-11-6E</u> It is in this section that the Swede Drain intersects with Cooks Creek at a point approximately 1.2 km north of Hazelridge Road. The Swede Drain was reconstructed in 1961 and 1962 from P.T.H. No. 15 to a point approximately 0.6 km north of Hazelridge Road. It is from this point that the Swede Drain follows its natural channel to its confluence with Cooks Creek.

The reconstructed portion of the Swede Drain along this reach appeared in good condition with only a mild congestion of cattails and other vegetation restricting flows. From the termination of the reconstruction, the Swede Drain meanders erratically through a densely wooded lowland before discharging into the Cooks Creek. The intersection of the Swede Drain and Cooks Creek consists of a large area of swamp land (approximately 4 ha) heavily congested with cattails.

It is in the vicinity of the confluence of the Swede Drain and Cooks Creek that numerous beaver dams have been constructed. The presence of these beaver dams has been blamed for the poor hydraulic performance of the Cooks Creek and Swede Drain during the cropping season. Numerous efforts in the past have been made to remove both the beavers and their dams. Such efforts, however, have been met with a marginal degree of success due to the estimated large population of beavers.

It should be noted that the land in this Section (31-11-6E) traversed by the Swede Drain north of its reconstructed right-of-way, and by Cooks Creek, is all private land. This further complicates access by the CCCD to maintain these reaches of the Swede Drain and Cooks Creek. Local landowners have objected in the past to the presence of heavy equipment and the blasting of beaver dams. As a result, Ministerial orders have had to be obtained under the Water Rights Act to authorize removal of beaver dams. Obtaining such Ministerial Orders has resulted in extensive delays in the past in the removal of these dams.

Given the hydraulic characteristics of the Swede Drain and the presence of these beavers dams, the Swede Drain does not meet value-added flow requirements in this reach.

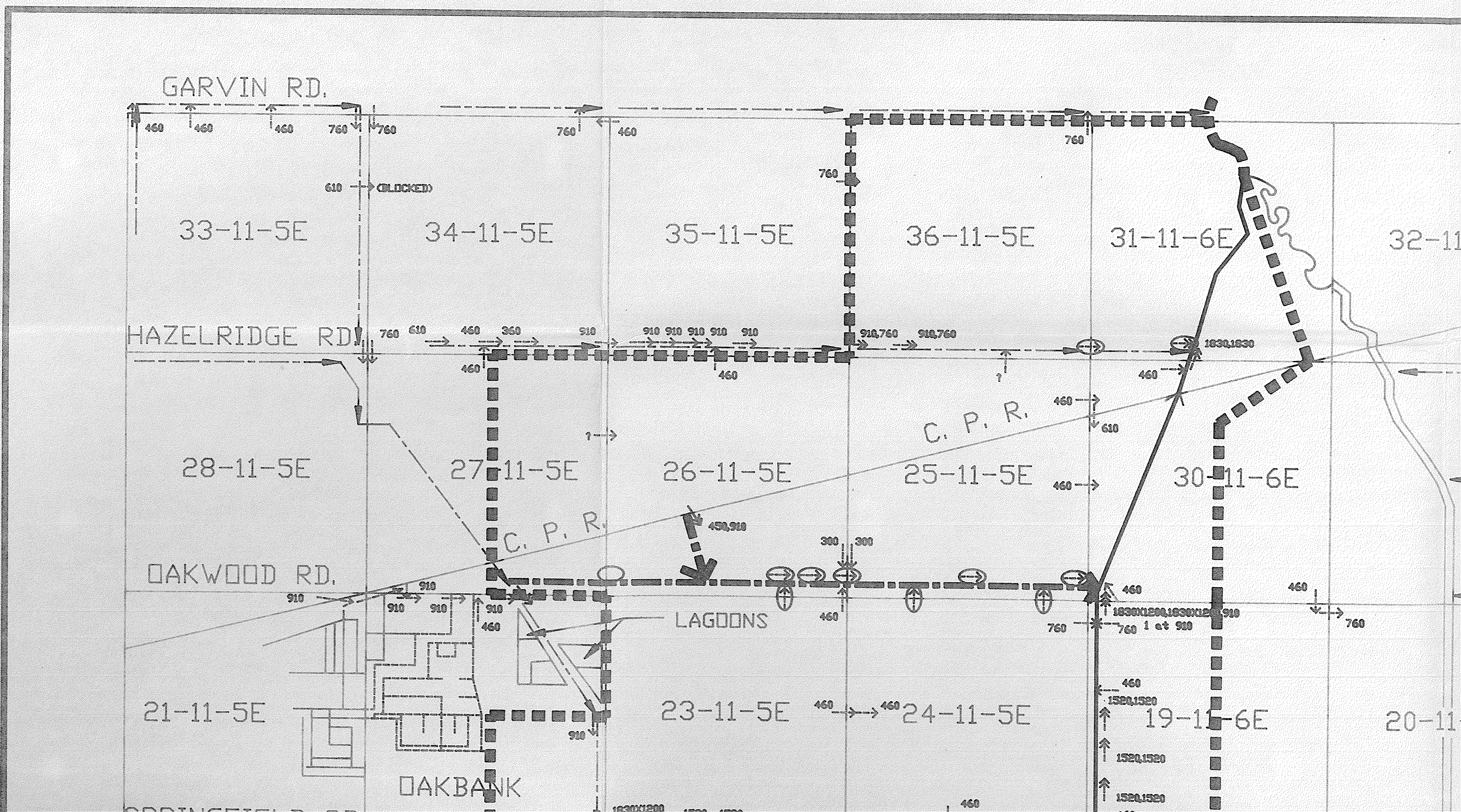
The capacity of Cooks Creek, downstream of the Swede Drain confluence, has been estimated to be greater than 50 m^3/s. Previous studies have suggested that this capacity is more than adequate to accommodate expected agricultural flows from the Cooks Creek watershed. As can be seen from Table 4 following this discussion, design value-added flows for Subwatershed No. 3 in this reach were calculated to be approximately 9.6 m^3/s.

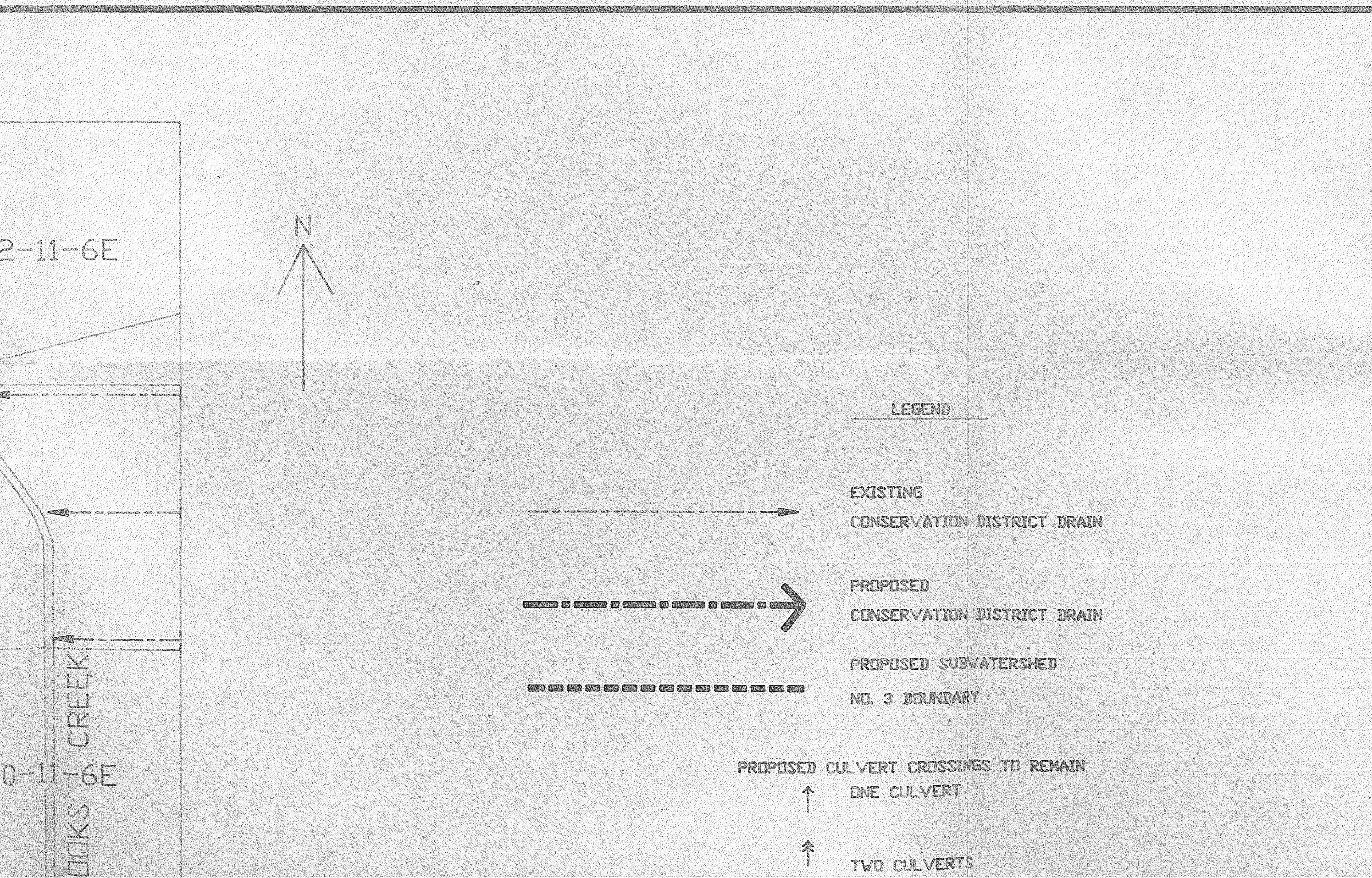
Assuming local agricultural flows from lands serviced along Cooks Creek from the Diversion to the confluence of the Swede Drain account for approximately 19.8 m^3/s and the operation of the Diversion discharges approximately a further 6.5 m^3/s to Cooks Creek during agricultural flows, total agricultural flows expected in the Cooks Creek channel in Section 31-11-6E would be approximately 9.6 + 19.8 + 6.5 = 35.9 m^3/s (say 40 m^3/s). This is well within the capacity of the Cooks Creek channel. This researcher, however, recommends that a more detailed study of expected agricultural flows from (that is, from Subwatershed Nos. 4, 5, and 6) be conducted before making a final assessment as to the overall adequacy of the Cooks Creek channel in Section 31-11-6E. It was not within the scope of this report to conduct such studies, and as such, will have to be done by others in the future.

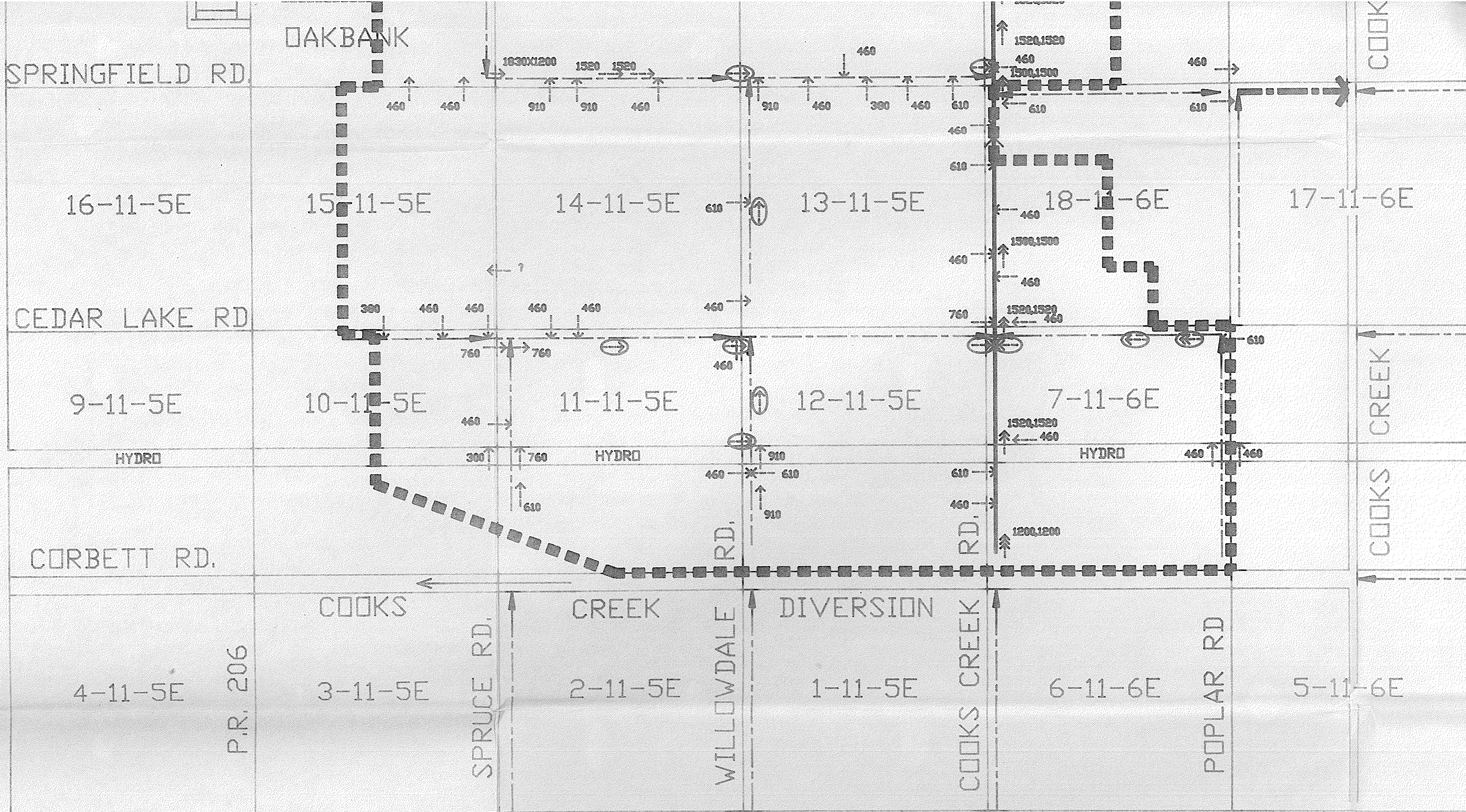
TABLE NO. 6

Approximate capacities of existing drains and required design capacities to "value-added" standard

Drain	Existing Capacity m^3/s	Design Capacity of Existing Drains to Value-Added Standard m^3/s
Hazelridge Road		
S-36-11-5E	1.7	2.2
S-31-11-5E	1.7	2.2
Oakwood Road		
S-26-11-5E	0.4	1.5
S-25-11-5E	0.6	2.0
Springfield Road		
E-22-11-5E	0.7	2.9
S-23-11-5E	0.7	3.6
S-24-11-5E	0.8	4.4
Cedar Lake Road		
N-10-11-5E	0.7	0.6
N-11-11-5E	0.6	1.3
N-12-11-5E	0.4	2.1
N-7-11-6E	0.3	0.6
Spruce Road		
W-11-11-5E	0.3	0.4
Willowdale Road		
W-13-11-5E	0.4	0.5
W-12-11-5E	0.3	0.7
Poplar Road		
E-7-11-6E	0.8	0.5
Swede Drain		
W-7-11-6E	3.2	2.8
W-18-11-6E	4.6	3.3
W-19-11-6E	6.6	6.9
30-11-6E	6.6	8.3
31-11-6E	6.6	9.6


GARVIN RD.
HAZELRIDGE RD.
OAKWOOD RD.
33-11-5E
34-11-5E
35-11-5E
36-11-5E
31-11-6E
28-11-5E
27-11-5E
26-11-5E
25-11-5E
30-11-6E
21-11-5E
23-11-5E
24-11-5E
19-11-6E
C. P. R.
C. P. R.
LAGOONS
OAKBANK
610 (BLOCKED)
1830,1830
450,910
1830X1200,1830X1200 910
1 at 910
1520,1520
910,760


2-11-6E
N
0-11-6E
OOKS CREEK
LEGEND
EXISTING
CONSERVATION DISTRICT DRAIN
PROPOSED
CONSERVATION DISTRICT DRAIN
PROPOSED SUBWATERSHED
NO. 3 BOUNDARY
PROPOSED CULVERT CROSSINGS TO REMAIN
ONE CULVERT
TWO CULVERTS



OAKBANK
SPRINGFIELD RD.
16-11-5E
15-11-5E
14-11-5E
13-11-5E
18-11-6E
17-11-6E
CEDAR LAKE RD
9-11-5E
10-11-5E
11-11-5E
12-11-5E
7-11-6E
HYDRO
HYDRO
HYDRO
CORBETT RD.
COOKS CREEK DIVERSION
4-11-5E
P.R. 206
3-11-5E
SPRUCE RD.
2-11-5E
WILLOWDALE RD.
1-11-5E
COOKS CREEK RD.
6-11-6E
POPLAR RD
5-11-6E
COOKS CREEK
COOKS

TWO CULVERTS

THREE CULVERTS

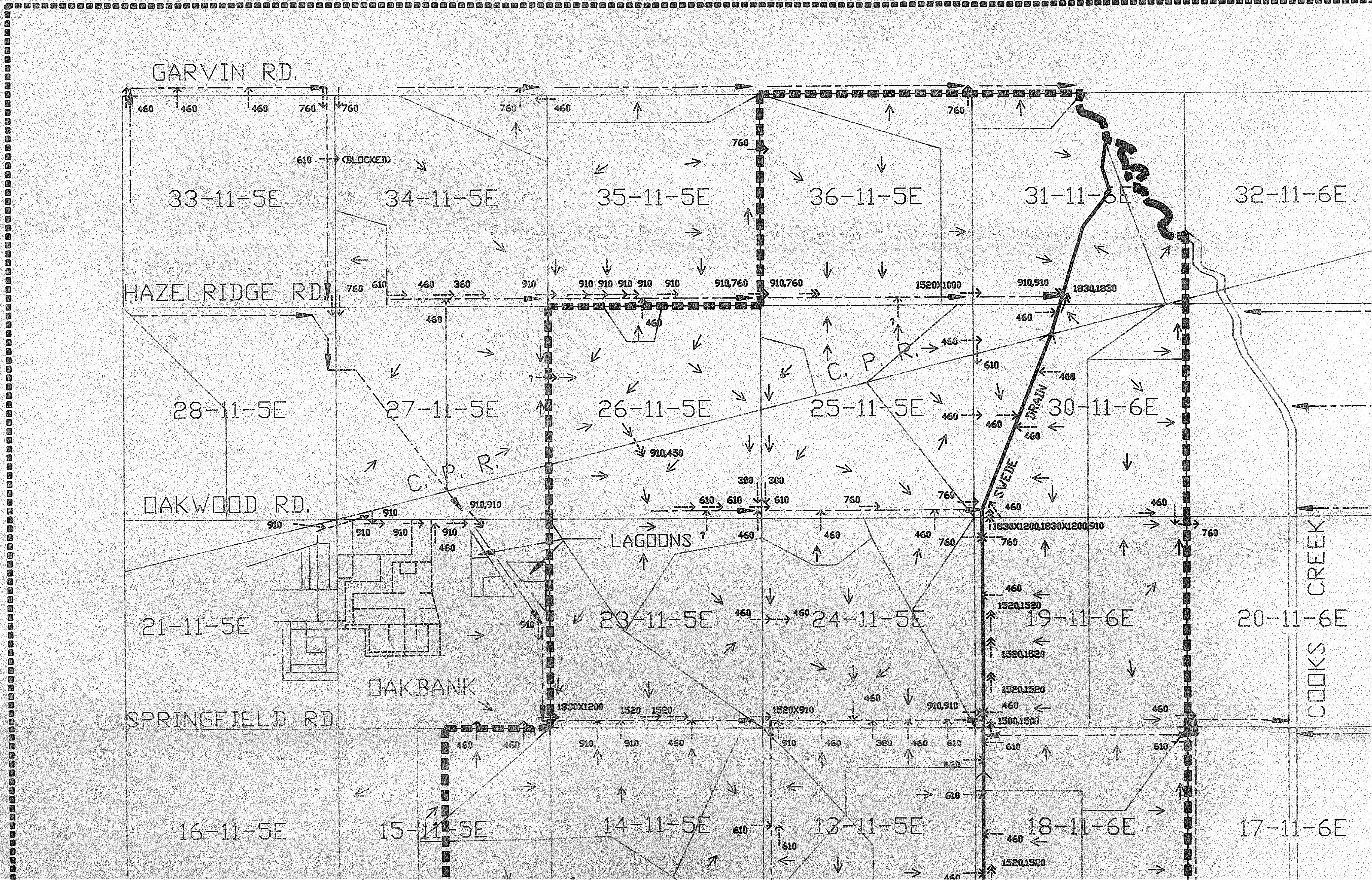
(ALL CULVERT DIAMETERS ARE IN MILLIMETRES)

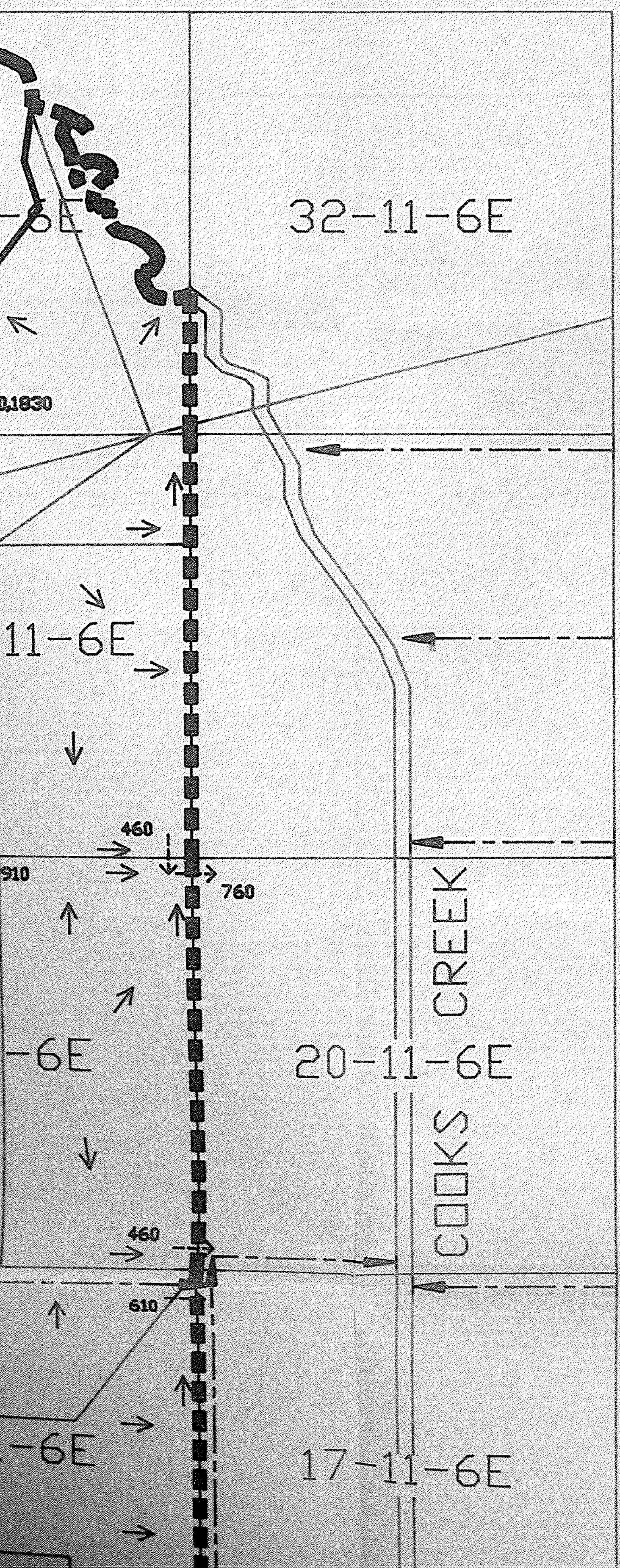
PROPOSED CULVERT CROSSINGS
REQUIRING UPGRADING

SCALE

0 km 1 km 2 km 3 km 4 km 5 km

DRAWING NO. 2 - PREFERRED SUBWATERSHED NO. 3
INFRASTRUCTURE


GARVIN RD.
HAZELRIDGE RD.
OAKWOOD RD.
SPRINGFIELD RD.
33-11-5E
34-11-5E
35-11-5E
36-11-5E
31-11-6E
32-11-6E
28-11-5E
27-11-5E
26-11-5E
25-11-5E
30-11-6E
21-11-5E
23-11-5E
24-11-5E
19-11-6E
20-11-6E
16-11-5E
15-11-5E
14-11-5E
13-11-5E
18-11-6E
17-11-6E
610 (BLOCKED)
C. P. R.
C. P. R.
LAGOONS
OAKBANK
SWEDE
DRAIN
COOKS CREEK
1830X1200
1520X910
1520X1000
1830X1200,1830X1200,910
910,450
910,910
1830,1830
1500,1500
1520,1520



LEGEND

EXISTING
CONSERVATION DISTRICT DRAIN

PRELIMINARY SUBWATERSHED
NO. 3 BOUNDARY

DIRECTION OF SURFACE WATER FLOW

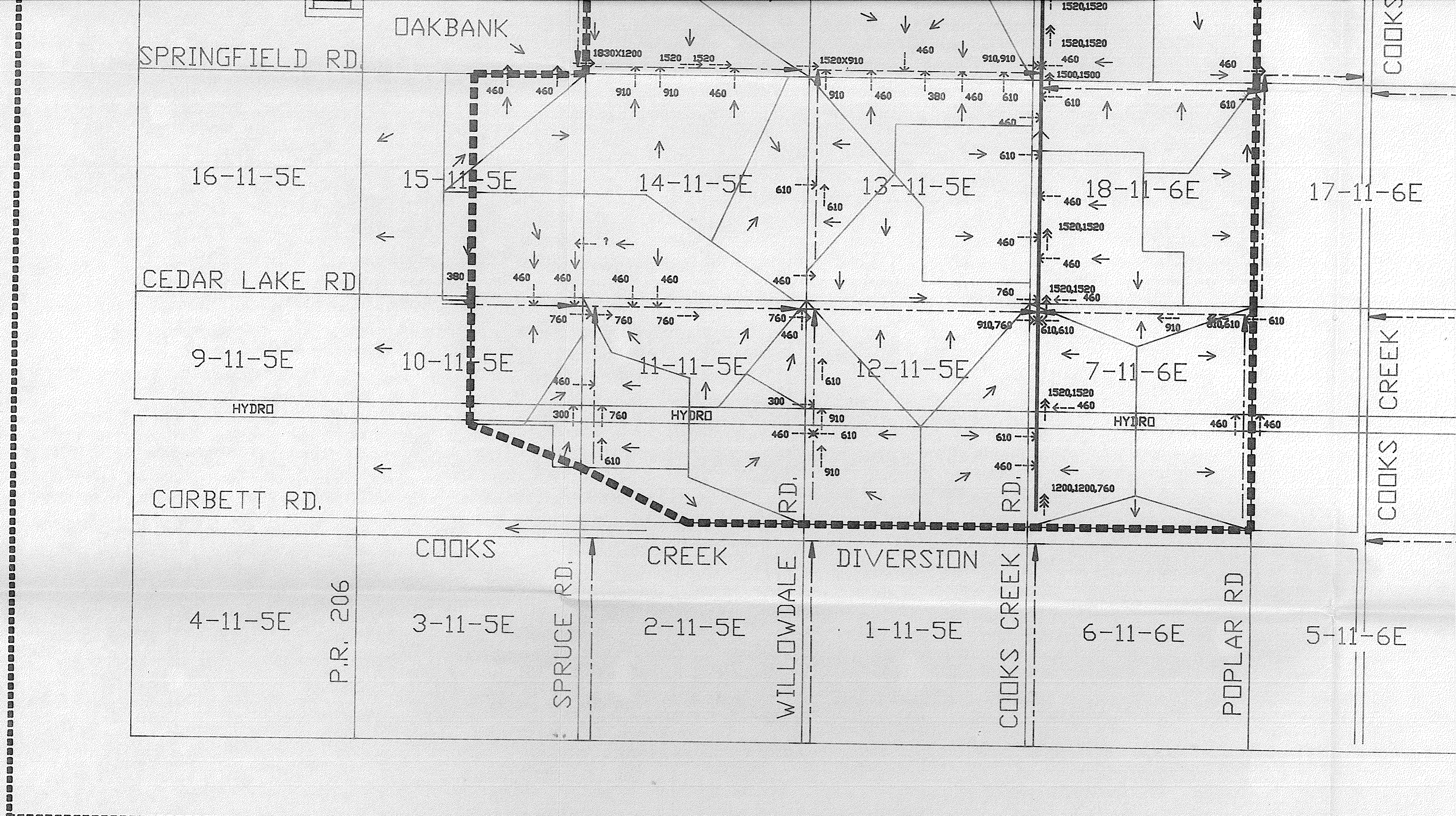
(ALL RESPECTIVE SECTIONS OF LAND HAVE BEEN SUBDIVIDED TO DEFINE EACH CULVERT OR CONSERVATION DISTRICT DRAIN SURFACE WATER DISCHARGES TO)

EXISTING CULVERT CROSSING INFORMATION

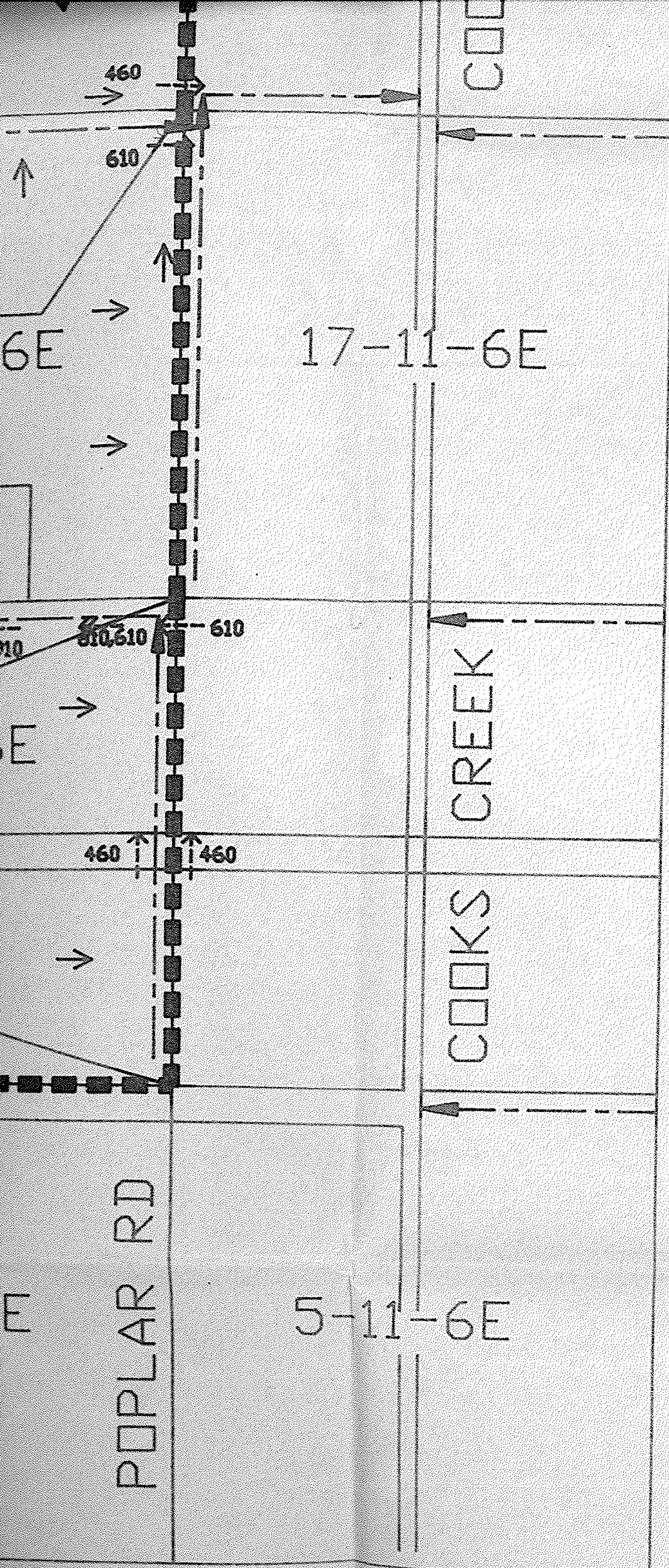
ONE CULVERT

TWO CULVERTS

THREE CULVERTS



OAKBANK
SPRINGFIELD RD.
CEDAR LAKE RD
CORBETT RD.
HYDRO
16-11-5E
15-11-5E
14-11-5E
13-11-5E
18-11-6E
17-11-6E
9-11-5E
10-11-5E
11-11-5E
12-11-5E
7-11-6E
4-11-5E
3-11-5E
2-11-5E
1-11-5E
6-11-6E
5-11-6E
COOKS CREEK DIVERSION
P.R. 206
SPRUCE RD.
WILLOWDALE RD.
COOKS CREEK RD.
POPLAR RD
COOKS CREEK
1830X1200
1520X910



ONE CULVERT

TWO CULVERTS

THREE CULVERTS

(ALL CULVERT DIAMETERS ARE IN MILLIMETRES)

SCALE 0 km 1 km 2 km 3 km 4 km 5 km

DRAWING NO.1 - EXISTING CONDITIONS -