STRATFORD/AVON RIVER ENVIRONMENTAL MANAGEMENT PROJECT

OPEN DRAIN IMPROVEMENT

Technical Report R-6

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PREFACE

This report is one of a series of technical reports resulting from work undertaken as part of the Stratford-Avon River Environmental Management Project (SAREMP).

This two year Project was initiated in April 1980, at the request of the City of Stratford. The SAREMP is funded entirely by the Ontario Ministry of the Environment. The purpose of the project is to provide a comprehensive water quality management strategy for the Avon River basin. In order to accomplish this considerable investigation, monitoring and analysis has taken place. The outcome of these investigations and field demonstrations will be a documented strategy outlining the program and implementation mechanisms most effective in resolving the water quality problems now facing residents of the basin. The project is assessing urban, rural and in-stream management mechanisms for improving water quality.

This report results directly from the aforementioned investigations. It is meant to be technical in nature and not a statement of policy or program direction. Observations and conclusions are those of the authors and do not necessarily reflect the attitudes or philosophy of all agencies and individuals affiliated with the project. In certain cases the results presented are interim in nature and should not be taken as definitive until such time as additional support data is collected.

Reference to equipment, brand names or supplies in this publication is not to be interpreted as an endorsement of that particular product or supplier.

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This report has been prepared using imperial measures. A metric conversion table has been included in Appendix 1.

ABSTRACT

Work began in the fall of 1980 on a major drain improvement demonstration carried out on the uppermost reaches of the Avon Municipal Drain in North Easthope Township. The work was initiated by the Stratford/Avon River Environmental Management Project in cooperation with two private landowners. Remedial measures undertaken on the drain included bottom cleanout, bank stabilization, improvement of tile outlets, buffer strips, fencing to control livestock access to the watercourse and the construction of a sediment basin. This report describes each of these measures except the livestock fencing and sediment basin construction which are described in Technical Reports R-7 and R-12 respectively. The combined impact of the conservation measures is aimed at reducing sediment loadings to the Avon River in a cost effective manner. Response to the demonstration work has been very favourable. Continued monitoring and inspection of the work will determine its long-term impact on water quality.

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1.0 INTRODUCTION

1.1 Background

Open drainage ditches must operate effectively and efficiently in order to ensure that drainage systems perform their intended function. Proper drainage operation requires the use of appropriate design and maintenance standards. Unfortunately such standards have not been used in rural areas to any great extent. Commonly, open municipal drains are constructed with steep side slopes, no buffer strips, and poor tile outlets. After excavation and other operations,soil surfaces are often left exposed rather than being protected with mulch or covers of grass. As a result of poor design and maintenance, drain banks are unstable and quickly deteriorate. This leads to sediment-clogged, inefficient, drainage systems and impaired water quality. Moreover, costly cleanouts and drainage reconstruction operations are required more frequently[1].

The responsibility of designing and maintaining an efficient open municipal drain rests not only with the engineer and contractor who respectively design and carry out the work; but also with the municipality and particularly the individual landowners who must rely directly upon the drainage system long after the initial construction is completed. The Stratford/Avon River Environmental Management Project and the Thames River Implementation Committee, working with the Upper Thames River Conservation Authority (U.T.R.C.A.), wished to promote their concerns for proper open drain construction and maintenance by becoming actively involved in a sizeable demonstration project. After discussions with two private landowners farming the land adjacent to the uppermost reaches of the Avon Municipal Drain, and with the township council, it was decided that an extensive reconstruction of the open drain across Lots 15 and 16, Concession II of North Easthope Township, could be effectively used for demonstration purposes. This section of the Avon Drain had been last cleaned out in 1970.

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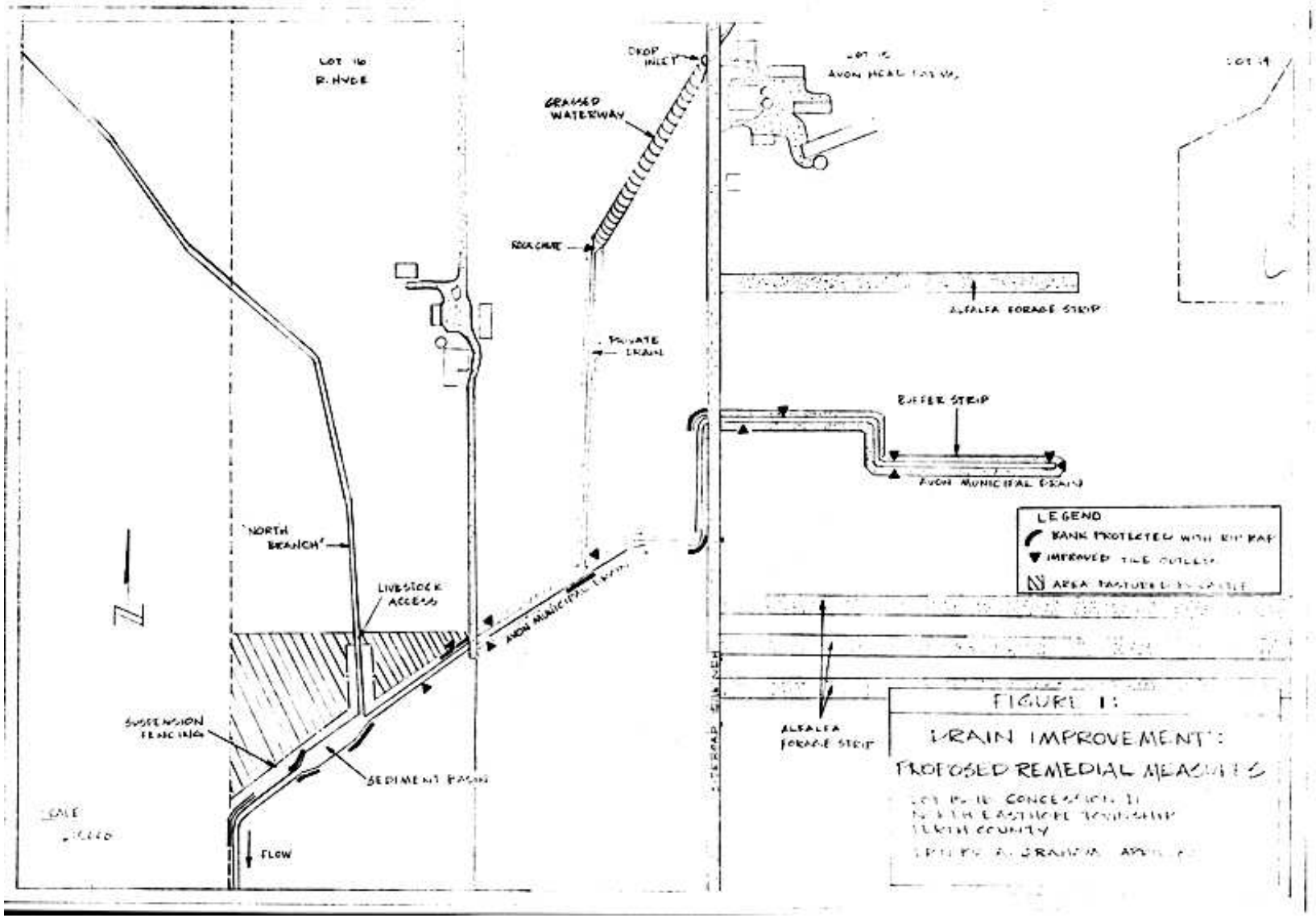
1 Prout, T. "Agricultural Drainage and Conservation Authorities" in Talk of the Thames, Thames River Implementation Committee, Fall 1981.

Once the remedial measures were in place, the associated costs and benefits could be evaluated by means of visual monitoring and water quality sampling. As the selected drain demonstration actually involved the uppermost reach of the Avon Drain, specific erosion problems could be accurately traced and identified. Benefits of the work should be gauged by future water quality monitoring. This same rationale was used, a short time after this demonstration project was chosen, in selecting this sub-watershed area for intensive application of numerous erosion control measures. The Demonstration Sub-Watershed approach is detailed in the Rural Overview Report of the Stratford/Avon Project.

1.2 Site Description

The Avon Municipal Drain originates on and flows as an open ditch easterly for about 1300 feet across Lot 15, owned by Avon Head Farms (see Figure 1). The year-round flow in the ditch is essentially fed by sub-surface tiles draining the adjacent cropland, and one tile which acts as an overflow from a nearby spring-fed pond. The surrounding fields are intensively cropped in corn and have been for several years. Overland runoff from the surrounding acreage was responsible for accelerated sheet and rill erosion which detached and transported noticeable amounts of topsoil and delivered it directly to the open watercourse. No vegetated buffer strips existed alongside the drain banks. Numerous problem locations were evident where the overland flows had concentrated before entering the open drain causing small gulleys to erode into the bank. These were commonly located where the sub-surface tiles also outletted.

In most cases, tile outlets were either improperly installed or lacking altogether. Both the outlets and the surrounding banks were subject to noticeable erosion. The drain itself was severely clogged with a 12 to 16 inch depth of collected sediment. This adversely affected the channel flow and the efficiency of the tile outlets. Except for these tile outlets, the ditch banks, in general, were well vegetated and appeared stable.


LOT 16
R. HYDE
DROP INLET
GRASSED WATERWAY
ROADSIDE
PRIVATE DRAIN
ALFALFA FORAGE STRIP
BUFFER STRIP
AVON MUNICIPAL DRAIN
LEGEND
BANK PROTECTED WITH RIP RAP
IMPROVED TILE OUTLET
'NORTH BRANCH'
LIVESTOCK ACCESS
SUSPENSION FENCING
SEDIMENT BASIN
FLOW
ALFALFA FORAGE STRIP
FIGURE 1:
DRAIN IMPROVEMENT:
PROPOSED REMEDIAL MEASURES

After crossing the 15/16 side road, the Avon Drain passes through Lot 15, farmed by Mr. Ronald Hyde (see Figure 1). Two additional open drains enter the Avon Drain on Lot 16. There are no available records of these drains, so they are assumed not to be municipal or award drains. The smaller of these two ditches has an intermittent flow and drains approximately 50 acres. The second drain (referred to in this report as the North Branch) is substantially larger and services about 306 acres. Year-round base flows in this ditch exceed those of the Avon Drain at the point of their junction.

For approximately 1200 feet downstream of the side road, the condition of the Avon Drain was similar to that noted on Lot 16: generally stable, vegetated banks; but poorly protected and badly eroded tile outlets. As well, the channel was clogged with sediment. The deposition in this stretch of channel was not as severe as deposition further upstream. The apparent reduction in sediment-laden runoff can be partially attributed to the surrounding land use which employs a sod-based rotation of agricultural crops.

About one-half the distance across Lot 16, the Avon Drain passes through a pastured field where cattle had been allowed unrestricted access to the watercourse for a number of years. This practice had led to severe slumping and very unstable bank conditions. Scouring had taken place at the junction of the Avon Drain and the North Branch drain. Sediment deposition in the channel through this section of drain was estimated to be about 12 to 14 inches in depth. This could be largely attributed to bank erosion and to eroded material originating from upstream areas.

2.0 METHOD

2.1 Site Meeting

A site meeting was held in September of 1980 to discuss the drain situation. The Drainage Commissioner of North Easthope Township, the respective landowners (L. Lichti and R. Hyde) and representatives from the Stratford/Avon Project were in attendance. It was the opinion of all those at the meeting that any excavation to be done should be limited to the channel grade line stated in the most recent engineer's report, prepared in 1969.

2.2 Approval

It was a prime concern of the Stratford/Avon Project that any work conducted on the drain for purposes of demonstration conform to standards promoted by the Upper Thames River Conservation Authority and the Ontario Ministry of Agriculture and Food. Both landowners were interested in employing remedial measures to improve the state of the Avon Municipal Drain. Agreement was made for technical and financial assistance offered by the Stratford/Avon project and the Thames River Implementation Committee. Engineering Practice Agreements were signed by the concerned parties (see Appendix 2).

The proposed work was presented to the Township Council for approval in accordance with the Drainage Act (1975). Full approval was subsequently granted. The Drainage Commissioner would inspect the work both during, and periodically after, construction. The proposed work also had to be ratified by the Ontario Ministry of Natural Resources under the Lakes and Rivers Improvement Act (1970).

2.3 Design

The remedial measures proposed for Lot 15 included: a bottom cleanout and adequate tile outlet protection for six subsurface tiles. This work would be completed in the fall of 1980.

Establishment of permanently vegetated buffer strips, once the excavated spoil had been levelled on the adjacent banks, was scheduled for the spring of 1981 (Figure 2).

Work to be completed on Lot 16 in the fall of 1980 included: the construction of a sediment basin in the channel of the Avon, a bottom cleanout, bank stabilization using rip rap where necessary, bank re-shaping, installation and protection of five tile outlets, and excavation of a limited livestock access on the 'North Branch' drain. Seeding of disturbed banks and levelling of the excavated spoil would be carried out in the spring of 1981. In addition, suspension fencing was to be erected on the north side of the Avon Drain to restrict livestock from the watercourse (Figure 2).

2.4 Hiring of Contractors

In order to demonstrate and promote a reasonable and cost-effective approach to this type of work, the Stratford/Avon Project and the landowners agreed to utilize on-site materials and labour as much as possible.

Two area contractors were hired by the project to conduct work on the drain. One was required to truck rip-rap to the farm and then to utilize a front-end loader to transport the material on-site. A second contractor was hired to perform the excavations and drain work. Upon recommendation from both the Upper Thames River Conservation Authority and the Drainage Commissioner, a hydraulic hoe was to be used rather than the conventional dragline machine. This would ensure a more controlled and efficient operation. A 1.5 cubic yard ditching bucket would be used on the hydraulic hoe.

2.5 Stone Rip-Rap

The required amounts of stone rip-rap to be used for tile outlet protection, bank stabilization and livestock access, were trucked to the individual locations along the drain on Lot 16 prior to any excavation so that the material would be available when needed.

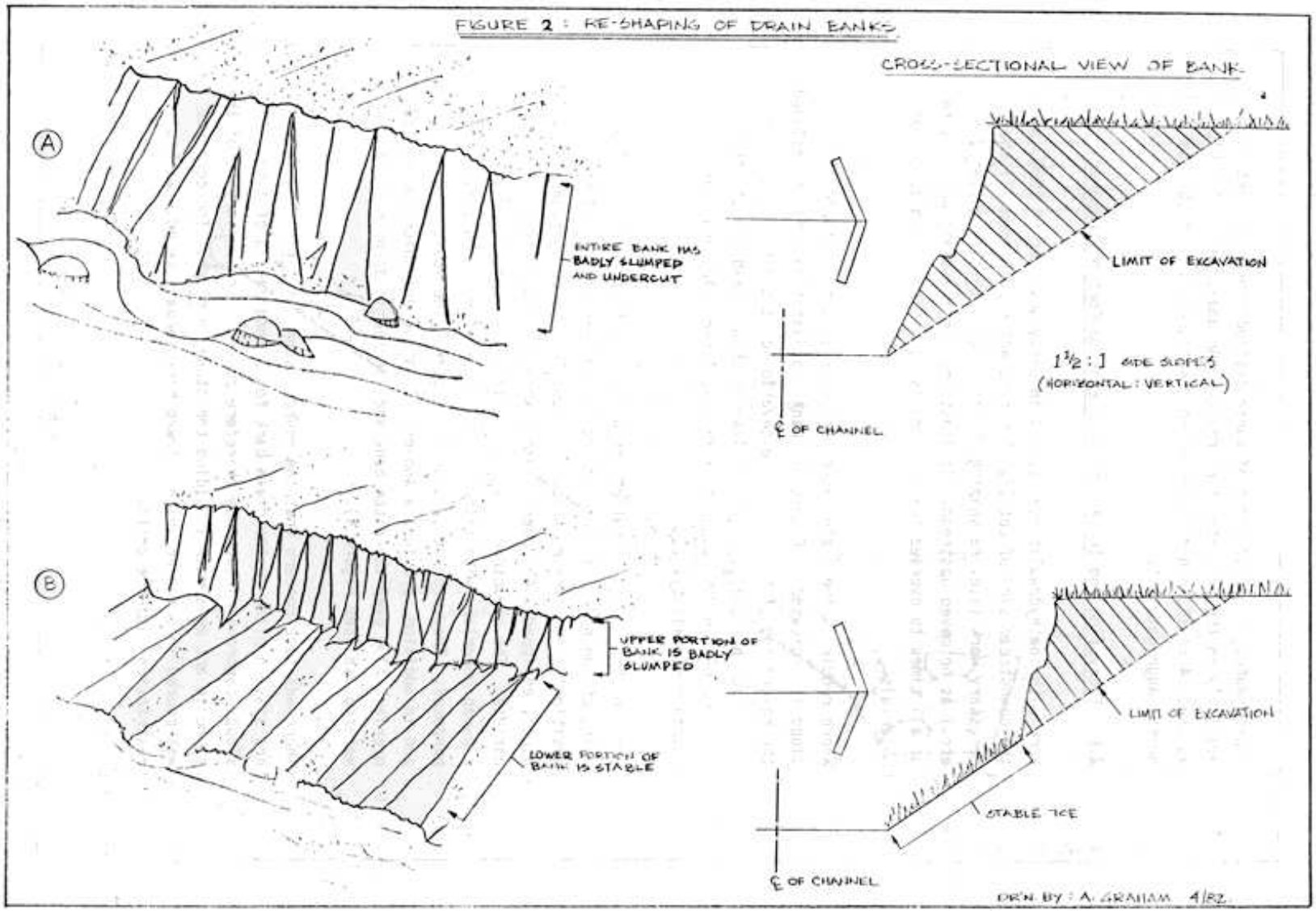


FIGURE 2 : RE-SHAPING OF DRAIN BANKS
CROSS-SECTIONAL VIEW OF BANK
A
ENTIRE BANK HAS BADLY SLUMPED AND UNDERCUT
LIMIT OF EXCAVATION
1½ : 1 SIDE SLOPES (HORIZONTAL : VERTICAL)
℄ OF CHANNEL
B
UPPER PORTION OF BANK IS BADLY SLUMPED
LOWER PORTION OF BANK IS STABLE
LIMIT OF EXCAVATION
STABLE TOE
℄ OF CHANNEL
DR'N BY : A. GRAHAM 4/82

Approximately 77 cubic yards of various-sized broken concrete was available on the property at no charge. An additional 165 cubic yards of 4 to 12 inch diameter stone was trucked to Lot 16 from a nearby aggregate pit.

2.6 Excavation and Installation of Erosion Control Measures

Work with the hydraulic hoe started in early November of 1980, at the downstream side of Lot 16. The contractor performed all the necessary work (i.e. re-shaping, bottom cleanout, tile outlets, etc.) as he moved upstream. At least one project staff was on site at all times to oversee the work and assist in the installation of materials.

Where required, the drain banks were re-shaped to a stable side slope as indicated in Figure 3. Bank stabilization efforts included the re-grading of the bank and excavation of a toe to support and stabilize the stone rip-rap. Filter cloth was laid beneath the stone to prevent the washout of fine soil particles and thus maintain stability.

Three of the five tile outlets required on Lot 16 were installed using of the hydraulic hoe for the initial excavation and the positioning of stone rip-rap. Ten-foot lengths of corrugated steel pipes, equipped with rodent guards, were used to protect the outlets. The structure was then stabilized and protected with rip-rap underlain with filter cloth. These structures served two purposes. They provided a stable outlet for the sub-surface tiles and in addition, provided a non-erosive structure which channelled overland flow over the ditch bank and carried it down into the watercourse (see Figure 4).

There was some concern that the rounded stone used for rip-rap would not stay in place on the drain bank for a long period of time. A sloppy concrete mixture was therefore poured over the surface of the stone to act as a matrix holding the stone in place. The concrete was poured in a manner which allowed bank seepage to move without restriction into the drain.

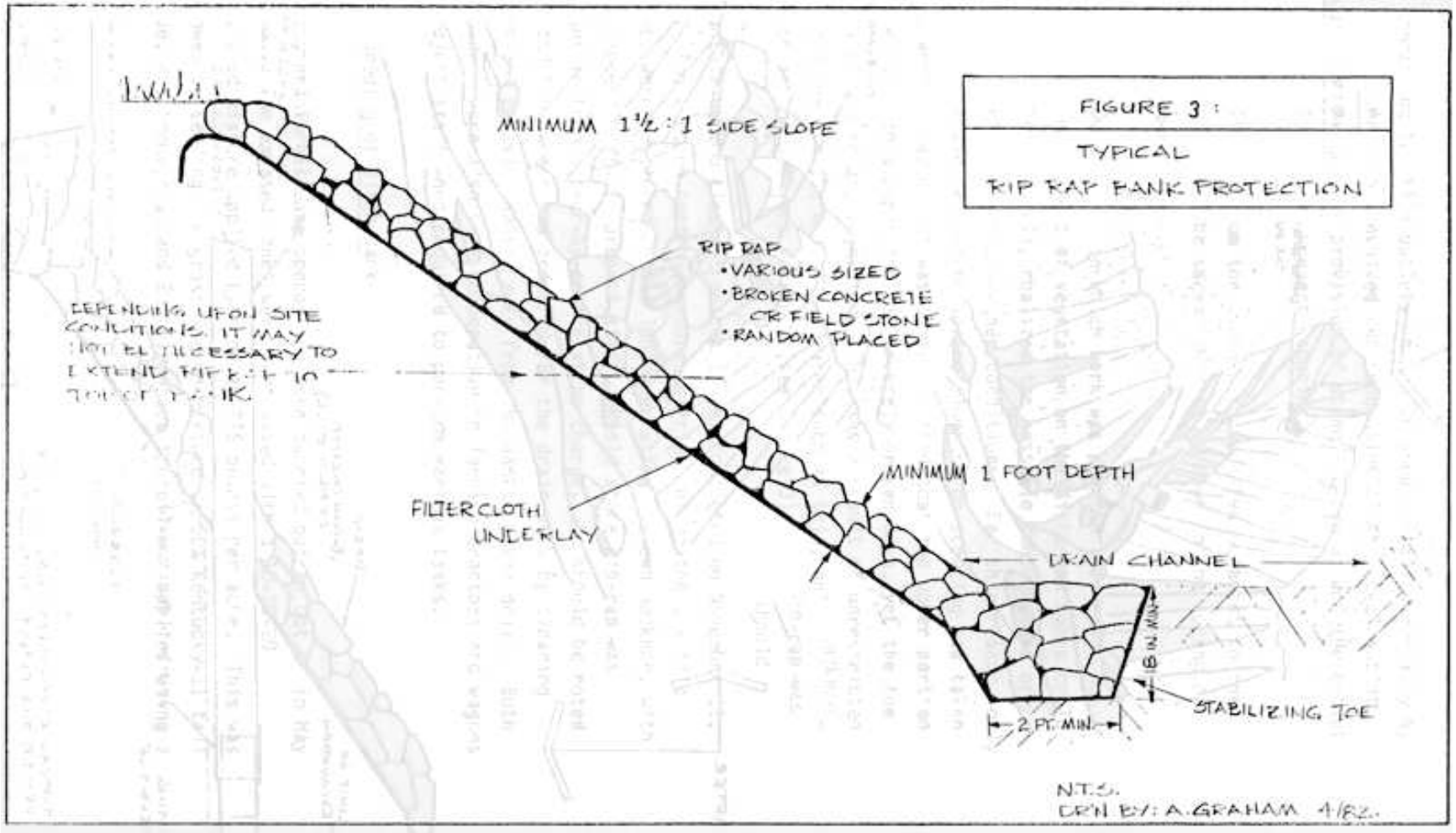


FIGURE 3 :

TYPICAL

RIP RAP BANK PROTECTION

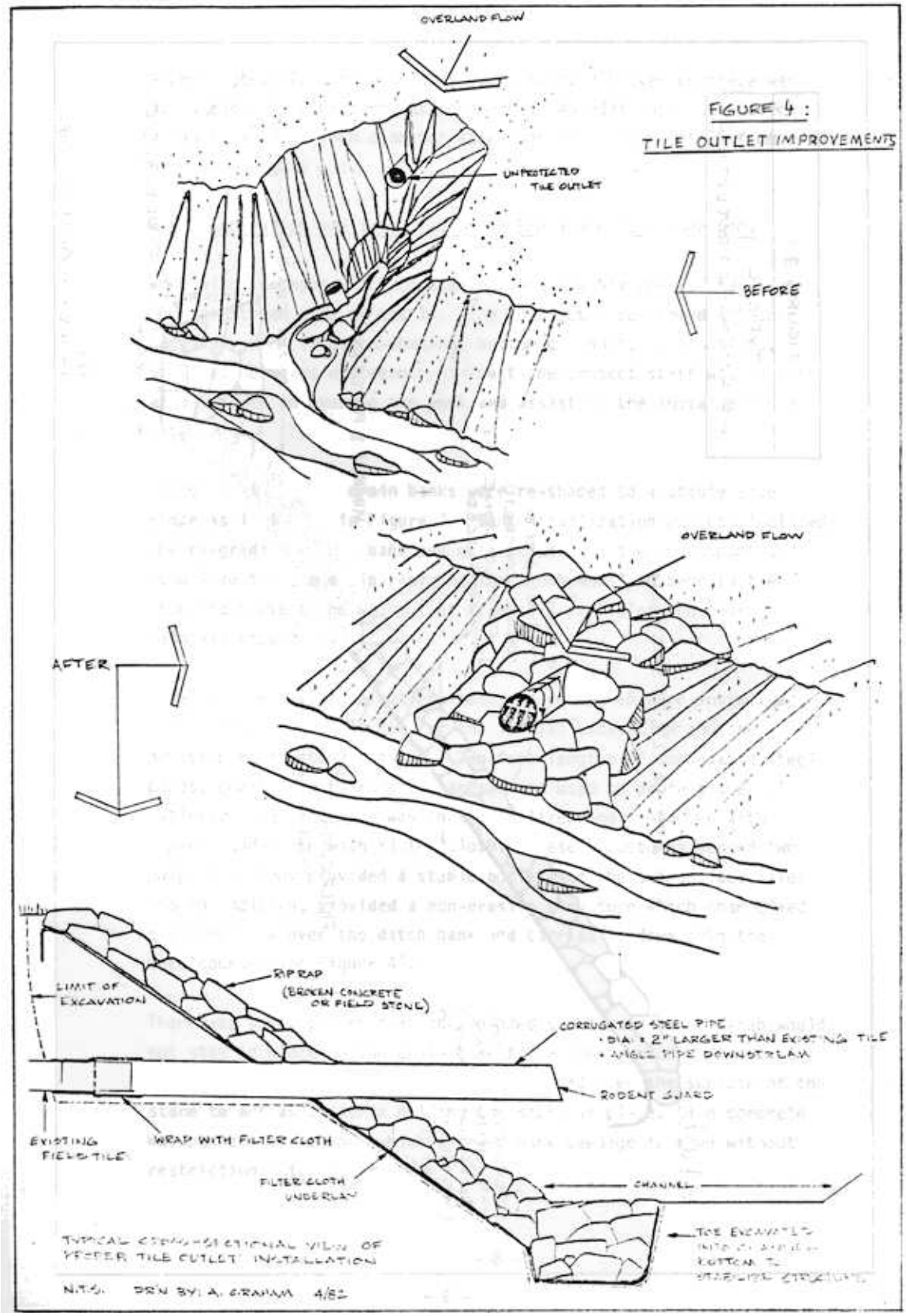


FIGURE 4 :
TILE OUTLET IMPROVEMENTS

The remaining two tile outlets on Lot 16 were installed manually by project staff. This involved the connection of the steel outlet pipes to the tiles and provision of stone rip-rap around the outlet to secure the pipe and prevent scouring.

The spoil excavated from the drain was deposited adjacent to the work site. It was to be spread and seeded down in the spring of 1981.

Due to the time of year in which work was done on the drain, no immediate establishment of vegetation on the disturbed banks could be achieved. Staff fully realized the possible consequences of erosive winter and spring weather conditions. For this reason, only those sections of bank where severe slumping or scouring had taken place were reshaped. It was common to find that the upper portion of the bank had slumped and was severely broken down, yet the toe was quite stable and vegetated. This was a result of unrestricted cattle access to the drain. In cases such as this, only the upper portion of the bank was reshaped (see Figure 3).

The actual bottom cleanout on Lot 15 was completed on November 11, 1980. The erosion control measures carried out on the six tile outlets were completed by the landowner using his own backhoe, with assistance offered by project staff. Field stone rip-rap was brought in from a near-by source at no charge. It should be noted that the landowners had prepared for the drain work by clearing fences and removing debris away from the banks of the drain. Both landowners were also very cooperative in lending tractors and wagons to project staff when required to perform various tasks.

2.7 Seeding of Ditch Banks

Seeding and fertilizing operations were carried out on Lot 16 in May of 1981. The exposed banks were fertilized with a 10-20-20 granulated mixture applied by hand at 275 pounds per acre. This was followed by seeding. A grass/legume mixture of 50% Kentucky-31 tall fescue, 25% bromegrass and 25% birdsfoot trefoil was applied using a hand-operated cyclone seeder at approximately 53 pounds per acre. All seeded areas were then raked

lightly in an effort to incorporate a good portion of the seed and fertilizer and promote faster germination. Soil moisture conditions, at time of planting, were considered very good.

2.8 Buffer Strips

A commercially available buffer mixture consisting of 30% alfalfa, 10% white clover, 20% birdsfoot trefoil, 30% timothy and 10% fescue was seeded at 55 pounds per acre. The mixture was sown with a companion crop of barley seeded at 1.5 bushels/acre on seven inch rows. A 10-20-20 granulated fertilizer was applied through the seed drill at 100 lb/acre. This operation was chosen to accommodate planting and harvesting equipment. The buffer strips were established to stabilize the drain banks and to filter sediment from overland runoff. Strip cropping was also initiated by Avon Head Farms in the spring of 1981 on the slopes surrounding the Avon Drain. Strip cropping consisted of laying out row crops (corn in this case) with alternate strips of a close-growing, erosion-resistant crop (forage). All strips were established at right angles to the predominant slope. The forage will act to build up soil structure, to reduce the velocity of overland runoff as it moves down the slope, and to promote infiltration. Technical report R-9 from the Stratford/Avon project details the strip cropping project.

2.9 Livestock Fencing and Controlled Access

A permanent fence was constructed on Lot 16 where cattle were formerly allowed access. Suspension fencing was chosen because of its practicality and relatively low cost compared to woven page-wire fencing. Future drain cleanouts can be performed easily because of ample machinery access on the side of the drain which was not fenced.

The access point to the drain, constructed in the fall of 1980, serves as a watering facility and a livestock and machinery crossover point. Erosion control measures were undertaken to minimize the bank erosion potential. Construction details, costs and a discussion of the work are included in Technical Report R-7.

2.10 Costs

Total costs associated with the drain cleanout and the related erosion control measures are outlined in Table 1. The Thames River Implementation Committee and the Stratford/Avon Project agreed to pay 60% of the total capital expenditures related to the demonstration work. The remaining 40% was paid in full by the landowner. Total expenditures included contractor costs and the total cost of materials installed on site. Costs for equipment, materials and labour supplied by either the landowner or the project are not included in total costs.

TABLE 1: Drain Reconstruction Cost Summary For The Avon Municipal Drain, Lot 15, 16 Concession II, North Easthope Twp.

NO.	ITEM	UNIT	UNIT COST	TOTAL COST
	LOT 15 CO-OPERATOR: AVON HEAD FARMS			
4	Hydraulic Hoe Excavation	HR	55.00	220.00
6	Corrugated Steel Tile Outlet Pipes (various sizes)			254.88
770	Black Synthetic Filter Cloth	FT^2	0.245	188.75
55	Buffer Strip Mixture	LB	3.15	173.25
1	Transport of Hydraulic Hoe	HR	35.00	35.00
	SUB-TOTAL			$871.88
	CO-OPERATOR (40%)	$348.75		
	PROJECT (60%)	$523.13		
	LOT 16 CO-OPERATOR: R. HYDE			
17	Hydraulic Hoe Excavation	HR	55.00	935.00
1	Transport of Hydraulic Hoe	HR	35.00	35.00
4	Corrugated Steel Tile Outlet Pipe(various sizes)	-	-	104.80
1923	Black Synthetic Filter Cloth	FT^2	0.245	471.25
1000	White Filter Cloth	FT^2	0.11	108.30
7.8	Concrete	YD^3	42.39	330.63
19.5	Front End Loader	HR	25.00	487.50
6	Dump Truck	HR	25.00	150.00
135.93	Stone Rip-Rap4"-12" Diameter	TON	3.18	432.25
3	Bulldozer to Level Spoil	HR	40.00	120.00
	SUB-TOTAL			$3174.73
	CO-OPERATOR (40%)	$1269.89		
	PROJECT (60%)	$1904.84		
	TOTAL COST OF DRAIN WORK:			$4046.61

3.0 RESULTS AND DISCUSSION

3.1 Function

The 1981 spring runoff progressed relatively slowly and caused no bank erosion problems on Lot 15 or 16. The tile outlet structures have not shown any signs of failure. There is no evidence of undermining of the rock structures. The bank protection installed along the Avon at the junctions of incoming drains appears to re-direct the incoming flows well enough to prevent bank erosion. Streamflows in the re-constructed channel are not obstructed by sediment accumulation as they were previous to the demonstration work.

The sections of drain banks which were re-shaped to a desired side-slope in the fall of 1980 maintained their stability over the winter and spring seasons. They experienced no major erosion problems even though vegetative sod cover was on these areas was virtually nil.

After seeding and fertilizing operations had been carried out in early May of 1981, a good sod cover was quickly established.

Once the cattle were fenced to prevent access, the drain banks stabilized as a vigorous growth of grasses took over.

The buffer strips which had been seeded on Lot 15 did not establish well. The barley companion crop did mature and was successfully harvested; however, the grass/legume mixture suffered noticeable competition from weeds. Atrazine residue in the soil also contributed to the stand's poor establishment. For these reasons, the buffer strips were ploughed down in fall of 1981. They were re-planted by the landowner in 1982 using the same grass/legume mixture.

Some problems have been experienced with muskrats burrowing into the drain banks. The burrows are easily detected in the banks which were re-shaped during reconstruction. The

stability of these sections is somewhat threatened. Some slumping has been noted as a result, particularly during periods of fluctuating water levels in the channel.

3.2 Community Response

Both the landowners and the project staff are very optimistic about the erosion control demonstration work that has been carried out on the two farm properties. The positive effects of the remedial measures are already being noticed to some extent. Bank erosion along the Avon Municipal Drain on Lots 15 and 16 has been greatly reduced. The entire drainage system is allowed to operate much more efficiently.

Substantial erosion control programs have been recently undertaken by each of these farm operators with some assistance from the Stratford/Avon Project. The surrounding farming community has shown considerable interest in the demonstration work. Government and industry personnel associated with agriculture have also shown interest in this work.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Choice of Machinery

The hydraulic hoe used to perform the bottom cleanout and re-construction work proved superior to a conventional dragline machine. Of particular importance was the efficiency and versatility of this equipment and the minimal disturbance of stable, vegetated banks that occurred during the cleanout . Much of the work quality can be directly credited to the skill of the operator.

4.2 Timing of Construction

There is a high risk involved in carrying out drain reconstruction work in the late fall of the year, primarily due to the extensive areas of disturbed soil which are left unprotected over the winter and spring seasons. There are a number of precautions which can be taken if construction must proceed at this time of year. Each of the following recommendations apply for drain work carried out at any time during the construction season. However, it is imperative that these precautions be taken for work done very late in the season:

(i) Perform only the bottom cleanout if present bank conditions are already acceptably stable. The bottom excavation should be rounded to prevent slumping.

(ii) Install artificial bank protection at vulnerable points to prevent scouring by the flowing water and slumping of the bank. Protection may be provided by rip rap (broken, angular arock), gabions (wire baskets filled with angular rock) or sacked concrete (jute bags filled with concrete). All rock structures should be underlain with filter cloth to prevent the washout of fine particles and to maintain the structure's stability.

(iii) Depending on weather conditions, it may be possible to establish a winter cereal grain (i.e. winter wheat, winter rye) on the disturbed soil surfaces. A rate of 1.5 to 2 bushels per acre is recommended. The top growth and root systems will afford some protection against erosion until a permanent grass/legume mixture can be seeded the following spring.

(iv) If fall seeding of any kind is not feasible, it may be advantageous to protect disturbed soil with a straw mulch cover, preferably anchored to the soil surface. An application rate of 1 to 2 tons per acre is ideal; this will sufficiently cover the exposed soil.

These and additional recommendations relating to drain construction are discussed in a handbook entitled Practical Guide For Municipal Drains prepared by the Thames River Implementation Committee.

4.3 Tile Outlet Protection

Adequate protection must be installed at each subsurface tile outlet to resist erosion and maintain proper operation of the tile system. Typical material and installation costs range from $35.00 to $300.00. Structure design may be quite straight forward in some cases involving only a steel outlet pipe and some rock protection, or circumstances may call for quite an elaborate rock structure accommodating not only the sub-surface tile outlet, but also overland flow runoff. Such a structure may include the steel outlet pipe, large amounts of rock rip rap, filter material and possibly concrete or gabion work. Conditions at each site will determine the amount of protection required.

4.4 Seeding Operations

Seeding the disturbed soil surfaces as soon as possible offer excavation is important for establishing an early cover on the banks. Raking the soil surface incorporated the seed and fertilizer and left the soil finely granulated. Although this is a preferred condition for seed

germination and establishment, it does set up erosive conditions. Some seed and topsoil may accordingly be lost during any rainfall after construction. The application of mulch will reduce this loss.

Germination of seed was somewhat delayed on areas where raking was not carried out. The manual raking operation would not be practical on a large-scale drain project. Raking would be justified if it could be done mechanically, perhaps by using a tractor-drawn drag which would lightly scarify the soil surface.

The general conclusion was that it is most important to use a high seeding rate (50-150 lb/acre) and to apply fertilizer generously (200-300 lb/acre of 10-20-20 or 15-15-15) immediately after the soil has been disturbed. This will assure a reasonable seed establishment under the given conditions.

4.5 Benefits of Drain Reconstruction and Maintenance

In order to accept conservation practices aimed at soil productivity and soil erosion control, private landowners must understand the associated short term and long term benefits. The drain reconstruction and conservation work carried out in these demonstration projects yield immediate benefits directly to the landowners. The improved drainage system exhibits efficient channel flow and enables effective functioning of field tiles. Sod vegetation along properly shaped drain banks and buffer strips adjacent to the drain ensures continued bank stability.

The section of the Avon Municipal Drain referred to in this report was last cleaned out in 1970. At that time, none of the erosion control measures detailed in this report were used. Over the following ten year period, the condition of the drain deteriorated to the state earlier described. The 10 year life span of that drain after cleanout represents an average figure for similar open drains in the region.

Project staff in cooperation with the landowners undertook major reconstruction and erosion control work along a 4000 foot stretch of open drain at a cost of slightly over $4000.00 (excluding costs of fencing and of labour and other services provided by project staff). On-going drain maintenance will ensure that this drain investment is protected. By keeping the channel un-obstructed and resolving minor erosion problems, the required frequency of major drain cleanouts can be reduced.

Reduced sediment loads will contribute to improved water quality. Such long-term benefits will be realized by not only the immediate landowners, but also those downstream.

APPENDIX 1

METRIC EQUIVALENTS

LENGTH

inch	= 2.54 cm	millimetre	= 0.039 in.
foot	= 0.3048 m	centimetre	= 0.394 in.
yard	= 0.914 m	decimetre	= 3.937 in.
mile	= 1.609 km	metre	= 3.28 ft

AREA

square inch	= 6.452 cm^2	cm^2	= 0.155 sq in.
square foot	= 0.093 m^2	m^2	= 1.196 sq yd
square yard	= 0.836 m^2	km^2	= 0.386 sq mile
square mile	= 2.59 km^2	ha	= 2.471ac

VOLUME (DRY)

cubic inch	= 16.387 cm^3	cm^3	= 0.061 cu in.
cubic foot	= 0.028 m^3	m^3	= 31.338 cu ft
cubic yard	= 0.765 m^3	hectolitre	= 2.8 bu
bushel	= 36.368 litres	m^3	= 1.308 cu yd
board foot	= 0.0024 m^3		

VOLUME(LIQUID)

fluid ounce(imp)	= 28.412 ml	litre	= 35.2 fluid oz
pint	= 0.568 litre	hectolitre	= 22 gal
gallon	= 4.546 litres		

WEIGHT

ounce	= 28.349 g	gram	= 0.035 oz avdp
pound	= 453.592g	kilogram	= 2.205 lb avdp
hundredweight(imp)	= 45.359 kg	tonne	= 1.102 short ton
ton	= 0.907 tonne		

PROPORTION

1 gal/acre	= 11.232 litres/ha	1 litre/ha	= 14.24 fluid oz/acre
1 lb/acre	= 1.120 kg/ha	1kg/ha	= 14.5 oz avdp/acre
1 lb/sq in.	= 0.0702 kg/cm^2	1 kg/cm^2	= 14.227lb/sq in.
1 bu/acre	= 0.898 hl/ha	1 hl/ha	= 1.112 bu/acre

APPENDIX 2:

ENGINEERING PRACTICE AGREEMENT

DRAIN MAINTENANCE: AVON MUNICIPAL DRAIN, Lot 16, Conc. 2, N.E.H.

A Subsidy of 60% of the Total Cost (exclusive of staff and farmer's labour, will be paid on all engineering practices undertaken as Demonstration Projects.

Upon total agreement between all parties concerned, namely: RON HYDE and the STRATFORD/AVON ENVIRONMENTAL MANAGEMENT PROJECT, the following responsibilities will be carried out by the said persons, within an agreed-upon time schedule.

Presentation of proposed plans to Township Council for approval. PROJECT

Booking of drainage contractor to conduct clean-out work according to Stratford/Avon recommendations. PROJECT

Ordering and provision of required corrugated steel tile outlets (complete with rodent guards). PROJECT

Supply of suitable rip-rap material to be made readily available if required for ditch protection. R. HYDE

Ordering and supply of required seed mixture to seed down excavated channel and banks as soon after disturbance as possible. Seed required for permanent buffer strips wall also be supplied. PROJECT

Actual excavation of ditch down to grade stated in 1969 engineer's report (Last clean-out). CONTRACTOR

Soil will be piled along ditch bank where it will be spread evenly in line. CONTRACTOR

Installation of tile outlets and adequate measures taken to protect them (i.e. rip-rap & filter cloth). CONTRACTOR

Installation of rip-rap as required to adequately protect the ditch banks. CONTRACTOR

Seeding operations of any excavated or disturbed soil surfaces (channel, banks and but for inclusive) .PROJECT

Supply of filter cloth material to be laid beneath any rip-rap installed where necessary. PROJECT

Installation of filter cloth material beneath rip-rap for bask stabilization or protection (other than tile outlets). CONTRACTOR

Establishment of adequate buffer strips along both sides of the drain for its entire length. These shall be 2-3 meters in width from the top edge of the ditch bank outward. Once established, these permanent buffers must be maintained and kept intact for an agreed-upon number of years. LANDOWNER IN CONSULTATION WITH STRATFORD/ AVON PROJECT.

Supply of suspension fencing and required materials (i.e. anchor posts, line posts, steel posts, hardware) to fully fence off the north side of the Avon Drain after construction is complete to restrict cattle access from the site. PROJECT

Construction of a suitable fence along the north side of the Avon Drain through Lot 16, Concession 2; where cattle presently have total access to channel. LANDOWNER IN CONSULTATION WITH PROJECT STAFF

ADDITIONAL

Design of a Sediment Basin in the Avon Municipal Drain at the West side of Lot 16, which will adequately settle out suspended soil particles from the Avon Drain's Peak flow at that point. PROJECT

Excavation of a Sediment Basin and installation of adequate protection (i.e. gabion-mat). CONTRACTOR

100% of the total cost of the Sediment Basin will be paid in full by the Stratford/Avon Project.

Total capital cost of the project to be charged against the Stratford/Avon River Environmental Management Project. The landowner will then be billed their 40% share of the capital cost.(Stratford/Avon. Project covers 60% of the capital costs). All payments will be paid in full upon completion of the 1980 work schedule.

STRATFORD/AVON RIVER ENVIRONMENTAL MANAGEMENT PROJECT

_____ DATE _____

LANDOWNER

_____ DATE _____

STRATFORD-AVON RIVER ENVIRONMENTAL MANAGEMENT PROJECT
LIST OF TECHNICAL REPORTS

S-1 Impact of Stratford City Impoundments on Water Quality in the Avon River
S-2 Physical Characteristics of the Avon River
S-3 Water Quality Monitoring of the Avon River - 1980, 1981
S-4 Experimental Efforts to Inject Pure Oxygen into the Avon River
S-5 Experimental Efforts to Aerate the Avon River with Small In-stream Dams
S-6 Growth of Aquatic Plants in the Avon River
S-7 Alternative Methods of Reducing Aquatic Plant Growth in the Avon River
S-8 Dispersion of the Stratford Sewage Treatment Plant Effluent into the Avon River
S-9 Avon River In-stream Water Quality Modelling
S-10 Fisheries of the Avon River
S-11 Comparison of Avon River Water Quality During Wet and Dry Weather Conditions
S-12 Phosphorus Bioavailability of the Avon River
S-13 A Feasibility Study for Augmenting Avon River Flow by Ground Water
S-14 Experiments to Control Aquatic Plant Growth by Shading
S-15 Design of an Arboreal Shade Project to Control Aquatic Plant Growth

U-1 Urban Pollution Control Strategy for Stratford, Ontario - An Overview
U-2 Inflow/Infiltration Isolation Analysis
U-3 Characterization of Urban Dry Weather Loadings
U-4 Advanced Phosphorus Control at the Stratford WPCP
U-5 Municipal Experience in Inflow Control Through Removal of Household Roof Leaders
U-6 Analysis and Control of Wet Weather Sanitary Flows
U-7 Characterization and Control of Urban Runoff
U-8 Analysis of Disinfection Alternatives

R-1 Agricultural Impacts on the Avon River - An Overview
R-2 Earth Berms and Drop Inlet Structures
R-3 Demonstration of Improved Livestock and Manure Management Techniques in a Swine operation
R-4 Identification of Priority Management Areas in the Avon River
R-5 Occurrence and Control of Soil Erosion and Fluvial Sedimentation in Selected Basins of the Thames River Watershed
R-6 Open Drain Improvement
R-7 Grassed Waterway Demonstration Projects
R-8 The Controlled Access of Livestock to Open Water Courses
R-9 Physical Characteristics and Land Uses of the Avon River Drainage Basin
R-10 Strip cropping Demonstration Project
R-11 Water Quality Monitoring of Agricultural Diffuse Sources
R-12 Comparative Tillage Trials
R-13 Sediment Basin Demonstration Project
R-14 Evaluation of Tillage Demonstration Using Sediment Traps
R-15 Statistical Modelling of In-stream Phosphorus
R-16 Gully Erosion Control Demonstration Project
R-17 Institutional Framework for the Control of Diffuse Agricultural Sources of Water Pollution
R-18 Cropping-Income Impacts of Management Measures to Control Soil Loss
R-19 An Intensive Water Quality Survey of Stream Cattle Access Sites