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Environmental Protection Technology Series

Joint Construction Sediment Control Project

Office of Research and Development
U.S. Environmental Protection Agency
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EPA REVIEW NOTICE

EPA-660/2-73-035
April 1974

JOINT CONSTRUCTION SEDIMENT CONTROL PROJECT

By

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Annapolis, Maryland

and

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Contract No. 15030 FMZ
Program Element 1B2042

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ABSTRACT

During the period of this demonstration, a natural and agricultural region is being converted to an urban community. This project consists of (1) the implementation, demonstration, and evaluation of erosion control practices; (2) the construction, operation, and demonstration of the use of a stormwater retention pond for the control of stormwater pollution; and (3) the construction, operation, and maintenance of methods for handling, drying, conditioning, and disposing of sediment. In addition, a gaging and sampling program was conducted as part of this project to determine the effects of urbanization on the hydrology and water quality of natural areas. This project was conducted in the Village of Long Reach, Columbia, Maryland.

This report was submitted in fulfillment of Grant No. 15030 FMZ by the Water Resources Administration, State of Maryland, under the partial sponsorship of the Environmental Protection Agency. Work was completed as of June 1973.

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ACKNOWLEDGEMENTS

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The contributions provided to this program by the Howard Research and Development Corporation, the developers of Columbia, Maryland, and the Columbia Parks and Recreation Association, Inc., are also gratefully acknowledged.

SECTION I

CONCLUSIONS

1. Detailed planning and schedules for erosion control are dependent upon construction schedules. Unforseen delays can sometimes negate a well-planned erosion control scheme. The publication "Guidelines for Erosion and Sediment Control Planning and Implementation" can provide guidance that can minimize the effect of unscheduled delays.

2. Erosion control practices, products and/or techniques must be tailored to individual sites and must be based on topography, soil conditions, construction operations, etc.

3. Planning of the erosion control scheme must anticipate potential problems, which may be created by future activities. It must consider such items as the location of future construction in relation to that already complete, the time lapse involved, the effective alternative available during the interlude, as well as the cost of, and benefit from, the installation of selected techniques.

4. Design and implementation of erosion and sediment control measures must be somewhat flexible in order to facilitate decisions made on site. These decisions can only be made by specialists who understand the construction activities and the erosion and sediment control activities.

5. Construction of underground utilities must be planned and coordinated in a manner that will cause minimal surface disturbance and eliminate repeated disturbance of stabilized areas.

6. Trees that are to be preserved on wooded lots undergoing development must be carefully selected and then protected from damage throughout the duration of construction activities.

7. Stumps should be removed from wooded lots by the use of a stump cutting device rather than by bulldozing or blasting.

8. Any wood from clearing operations that is not sold for timber or reserved for fireplace use should be processed by a "wood-chipper" and the chips should be returned to the lot or removed to other areas for use in other erosion control programs.

9. The demand for waste glass to produce products currently, on the market (all glass brick, glass and clay brick, glassphalt, etc.) far exceeds the supply and the possibility of using waste glass to make erosion control products is negative.

10. The cost of erosion or sediment production measurements of individual lots could not be justified. The small watershed approach must be selected unless nearly unlimited funds for monitoring are available.

11. Investigations indicate that the use of lanthanide silicates and rare earth tracers and neutron activation analysis for the identification of erosion sources and for quantitative evaluation of soil loss was not warranted.

12. The weirs, rain gages and level recording devices used in this demonstration have proven to be accurate, reliable, and easy to maintain.

13. Automatic, point-integrating samplers have serious deficiencies in their operational characteristics. In addition, the suspended sediment data they generate are of questionable value since they are not representative of actual in-stream conditions.

14. The use of "pit" type samplers for bed load investigations in small streams is useless. Generally, the state-of-the-art of bed load, swash load, saltation load, etc., measurement is very primitive.

15. Comparative performance evaluations between the experimental and the reference subwatersheds were inconclusive because of the considerable delays in home construction in both areas.

16. The type of design used for the dam and retention pond is adequate from a stormwater management and sediment trap standpoint. In addition, its presence in the development was readily accepted by the residents.

17. During the demonstration, the experimental subwatershed generally produced less storm runoff, per unit area than the reference subwatershed. No explanation for the occasional exception could be determined.

18. Small runoff events generally produce a greater difference in runoff per unit area between the two subwatersheds than do larger runoff events.

19. As development progressed in the two subwatersheds, less of a difference in the runoff yields between the two subwatersheds resulted.

20. The overall, long-term trend in the main stream channel is one of channel downcutting in the upper reaches of the stream and shoaling by deposition or aggradation in the lower reaches. Continued cutting of the outside banks and deposition at the toe of meanders as well as general channel widening occurred.

21. The plan implemented for sediment and erosion control during development in the demonstration area works very well on a macro scale. Only minor amounts of clay sized particles escaped the watershed under study due to the large combination storm water and sediment retention pond.

22. More erosion control and stormwater management techniques must be implemented in upstream areas and channel reaches if channel erosion in urbanizing areas is to be kept within acceptable limits.

23. The residential population will accept sediment control ponds especially if they can be converted to aesthetically acceptable and harmonious use after construction is complete.

24. The lotic environment of the stream has been almost destroyed due to lack of stability, heavy sedimentation, and abrasive particle transport: loss of pools and protective cover presents little chance of natural recovery by former populations.

25. Stream channel recovery may be possible, in part, if:
   - the stream banks are stabilized with vegetation
   - pools are reestablished
   - sediment transport is greatly reduced
   - the stream bottom is stabilized
   - runoff containing organic compounds is strictly controlled
   - stormwater management practices are implemented to reduce the volume of periodic surges
   - base flow during dry periods can be maintained.

26. The lentic environment of the pond gives the impression of an ecosystem showing rapid trends toward a natural succession of life-forms.

27. Based on laboratory tests, it does not appear that chemical additives will reduce the final moisture content in sediment drying. However, some polyelectrolytes do improve the initial dewatering rates.

28. Actual cost figures were higher (on a per cubic yard removed basis) during the removal of sediment from the forebay and pond than the cost reviews conducted early in the study had indicated.

29. The establishment of a grass filter strip around the perimeter of the conventional sediment drying bed proved to be effective in removing solids being carried in water draining from the sediment.

30. Grass seed germination occurred first on plots of sediment that were conditioned by the addition of digested sewage sludge.

31. Grass coverage and density was greater on plots conditioned with fertilizer (10-10-10) or sewage sludge.

32. Under base flow conditions, little difference in the quality of discharge water was noted between pond influent and pond effluent.

33. Alkalinity, hardness, and chloride measurements on samples collected from the stream and pond remained the same throughout the demonstration.

34. Nitrite, nitrate, and total phosphate measurements, on samples collected from the stream and pond increased significantly during the course of the demonstration.

35. Based on limited observations, the actual trap efficiencies during selected storm overflow conditions were generally higher than those predicted on a theoretical basis.

SECTION II

RECOMMENDATIONS

Continue operation of all stream and rain gaging stations to refine the present storm water retention pond evaluation criteria and develop more definitive evaluation parameters.

Perform similar studies on a number of storm water retention ponds to establish more detailed design criteria to meet specific requirements.

Continue gaging of the reference and experimental subwatersheds in order to fully explore the changes in the hydrologic parameters which occur when a watershed goes from essentially undeveloped to urban.

Make further trials of the EPA Storm Water Management Model when the project watershed is at a more extensive degree of development.

Continue gaging the demonstration area after development is complete to gather much needed information regarding runoff conditions in an urban area.

Continue the ecological monitoring of the pond to determine what further degradation or recovery it experiences during the remainder of the development period and into the post development period.

Conduct a comparative evaluation of other urban runoff models using the basic data generated on this project.

Conduct a detailed study to try to determine why the reference subwatershed occasionally produced less runoff than the experimental subwatershed.

Continue the support of further applied research projects in erosion and sediment control associated with construction activities.

Conduct research and development of automatic suspended sediment sampling equipment. Emphasis must be placed on completely automatic, remote station, depth integrating samplers.

Continue research into methods and/or approaches to the reuse of sediment removed from sediment basins.

Continue research, via applied research projects, into the maintenance aspects of sediment and erosion control practices, devices, methods, etc.

Continue research into the long-term use of sediment basins for stormwater management, recreational use, etc.

SECTION III

INTRODUCTION

This project, the "Joint Construction Sediment Control Project," was conducted in the Village of Long Reach, Columbia, Maryland. It was operated by the Water Resources Administration, State of Maryland, under an Environmental Protection Agency demonstration grant. Hittman Associates, Inc., of Columbia, Maryland, was the prime contractor for this project. Howard Research and Development Corporation, the developers of Columbia, and the Columbia Parks and Recreation Association, Inc., a nonprofit corporation representing the community use, participated in this project.

During the period of this demonstration program, a formerly natural and agricultural region was partially converted to an urban community. This project consisted of:

1. The implementation, demonstration, and evaluation of erosion control practices

2. The construction, operation, and demonstration of the use of a local storm water retention pond for the control of storm water pollution

3. The construction, operation, and maintenance of methods for handling, drying, conditioning, and disposing of sediment

In addition, a gaging and sampling program was conducted as part of this project to determine the effects of urbanization on the hydrology and water quality of natural areas.

This demonstration project was generally conducted within a 190-acre watershed in the Village of Long Reach. A variety of practices were demonstrated and evaluated in order to develop general criteria and guidelines for implementation of storm water pollution and erosion control techniques. Specifically, it was to:

1. Evaluate the effectiveness and costs of conventional and advanced methods of erosion control in urban areas (surface landscape techniques)

2. Evaluate the effectiveness and costs of various methods for the transport, drying, conditioning, and disposal of sediment

3. Evaluate the effectiveness and acceptability of introducing storm water and sediment retention ponds in urban communities

The demonstration area is located in the Village of Long Reach, the fourth of seven proposed villages to be developed within the planned city of Columbia, Maryland. Located in Howard County, Columbia lies approximately midway between the metropolitan areas of Washington, D. C. and Baltimore, Maryland. Figure 1 shows the geographic location of the demonstration area.

In essence, the approximately 190-acre demonstration area encompasses the watershed of a storm water retention pond constructed in Long Reach. The general topography consists of rolling hills with a dense, forested overgrowth following the major stream channels and some of the swales.

Within the demonstration watershed, two similar and adjacent subwatersheds were chosen for analysis. On one subwatershed, termed the reference subwatershed, standard, State-approved methods of erosion control were used, while on the other, termed the experimental subwatershed, advanced and unique erosion control techniques were studied. For both subwatersheds, a program of sampling and evaluation was conducted. Figure 2 shows the location of the reference and experimental subwatersheds within the demonstration area.

At the start of the demonstration, the area was essentially rural in character. It was originally planned that the village would be almost

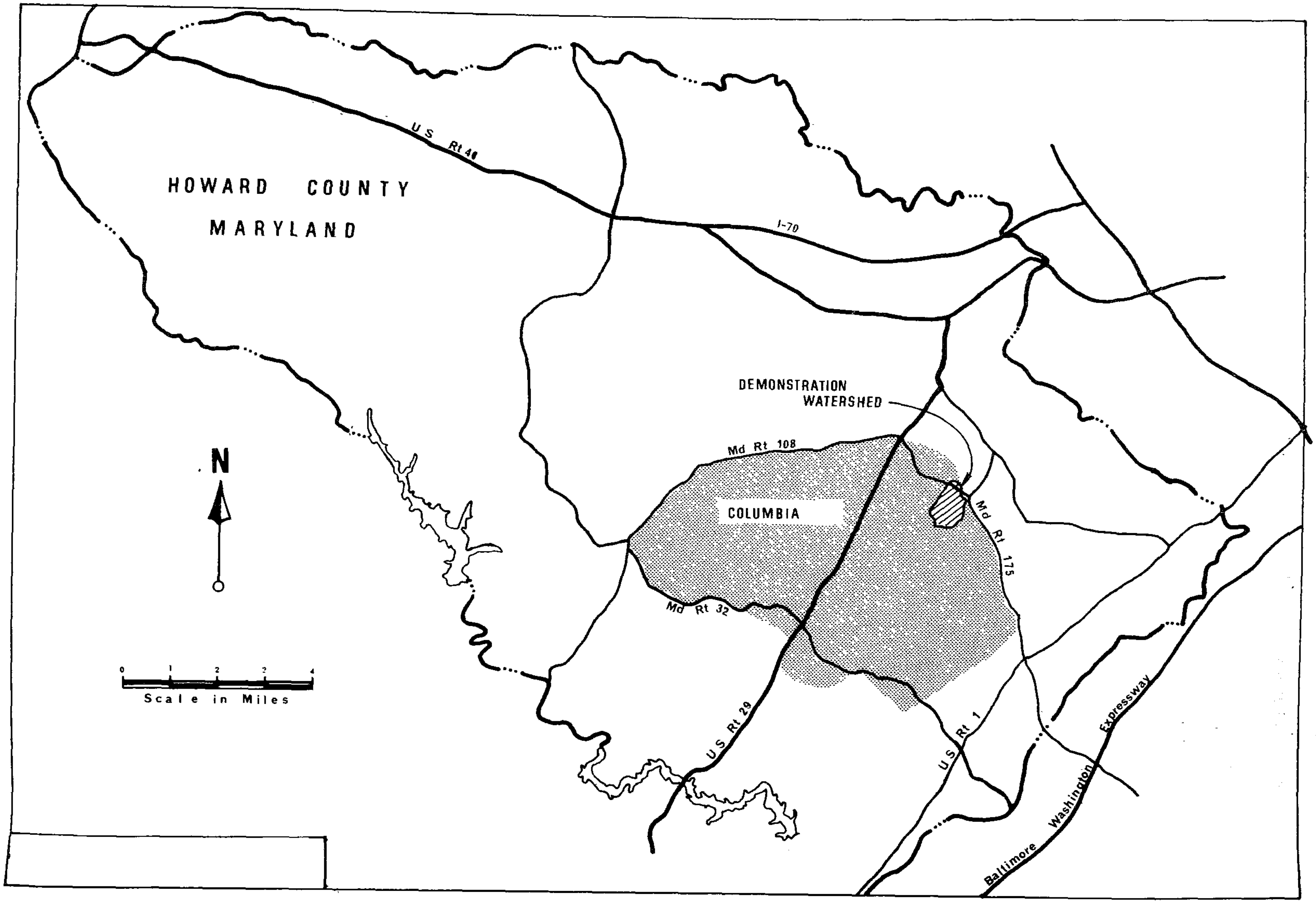

Figure 1. Geographic Location of Demonstration Area

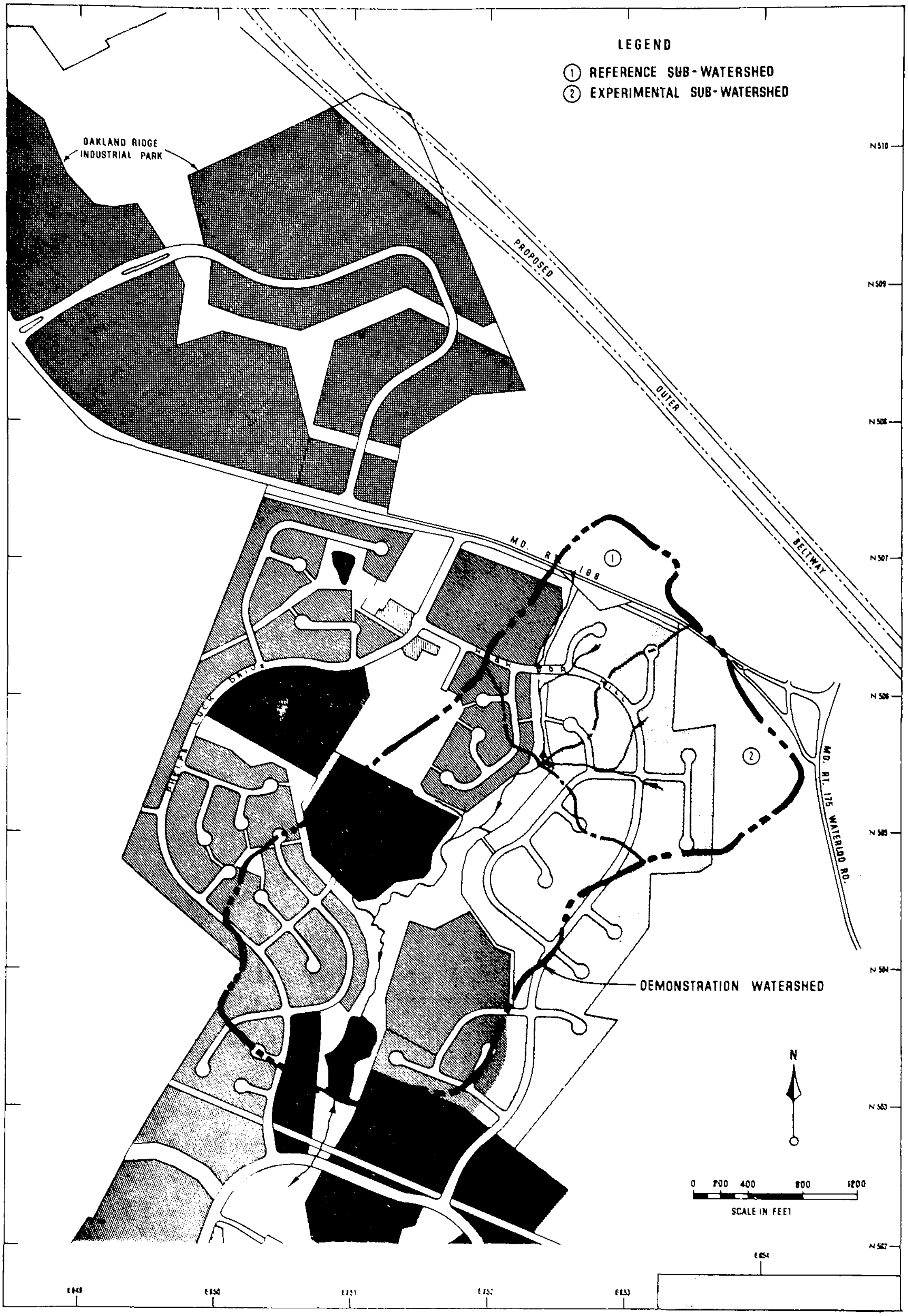

Figure 2. Demonstration Watershed and Subwatershed Locations

completely developed by the end of the demonstration period. Planned land development within the vicinity of the demonstration watershed is shown in Figure 3. As shown, five basic land uses were planned, including apartment and townhouse developments; single-family, medium-density housing; single-family, low-density housing; commercial zoning; and open space. The commercially-zoned property is to be used for the village and neighborhood centers that include small shops, food stores, meeting places, and some recreational facilities. Generally, the open space has been left in its natural state for use as parks, hiking trails, etc. The exception is the large tract near the center of the village. It is the site for an elementary school. Table 1 summarizes the planned land use for the demonstration watershed and for both subwatersheds.

TABLE 1. PLANNED LAND DEVELOPMENT FOR THE DEMONSTRATION WATERSHED

	Demonstration Watershed (Acres)	Reference Watershed (Acres)	Experimental Watershed (Acres)
Single-family, low-density	51.7	12.5	24.2
Single-family, medium-density	53.1	6.6	----
Apartments and townhouses	19.0	----	----
Commercial	-----	----	----
Open space	17.6	4.0	0.4
Roads	22.7	2.5	3.7
Total in Columbia	164.1	25.6	28.3
Not in Columbia	26.1	9.2	16.9
Total Watershed	190.2	34.8	45.2

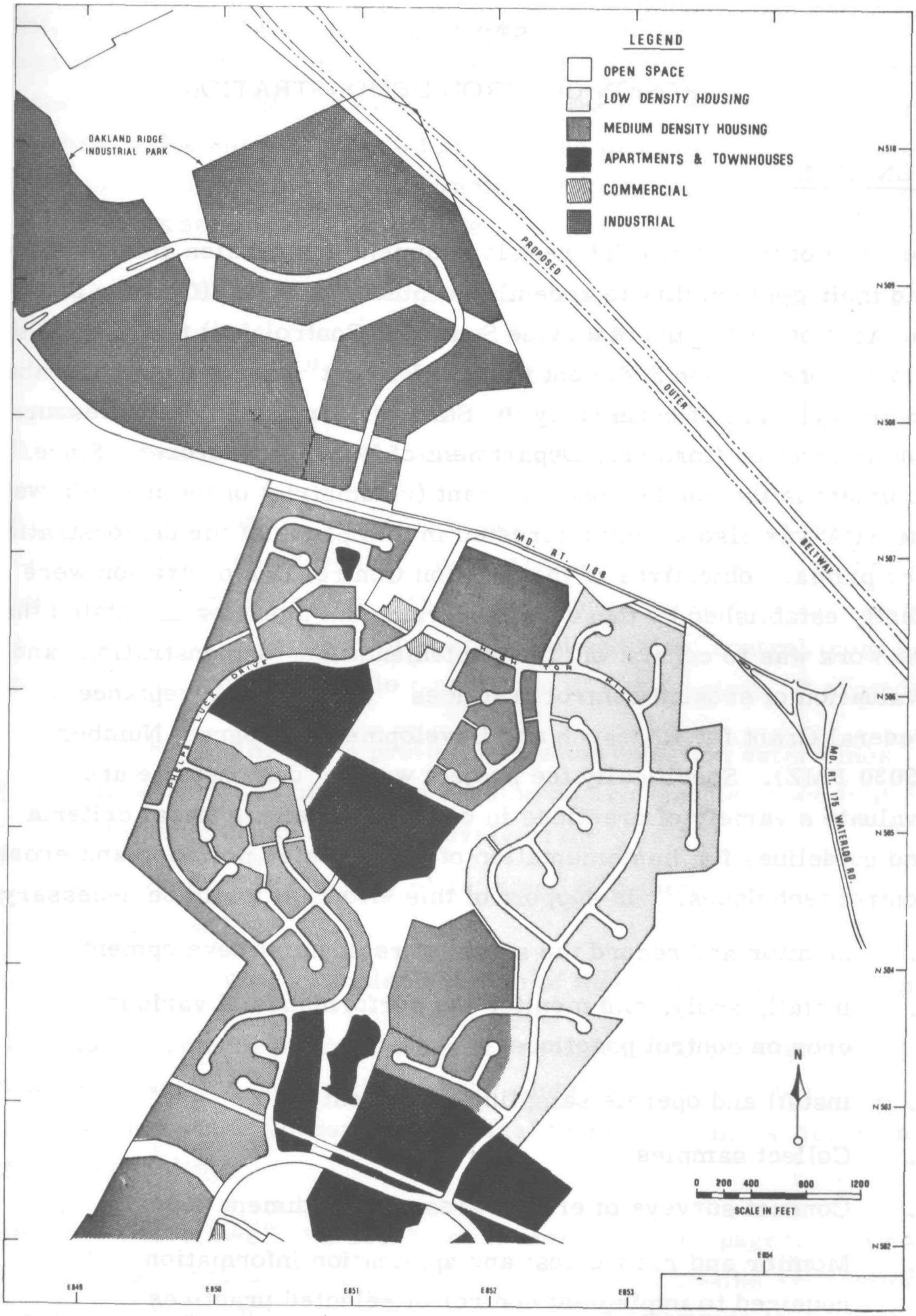

Figure 3. Planned Land Development: Village of Long Reach, Phelps Luck Neighborhood

SECTION IV

EROSION CONTROL DEMONSTRATION

GENERAL

Because of the intense interest in sediment and erosion control techniques and their applicability to recently adopted legislation (Chapter 245 of the Acts of 1970 - the Statewide Sediment Control Act) this part of the "Joint Construction Sediment Control Project" was designated as the "primary" area of concern by the State of Maryland, Water Resources Administration (formerly Department of Water Resources). Since sediment is the number one pollutant (volumetric) of the nation's waters, the EPA was also keenly interested in this phase of the demonstration. The primary objectives of the Erosion Control Demonstration were jointly established by these two governmental agencies and stated that the work was to consist of "the implementation, demonstration, and evaluation of erosion control practices " (Offer and Acceptance of Federal Grant for Research and Development, Program Number 15030 FMZ). Specifically, the project was to "demonstrate and evaluate a variety of practices in order to develop general criteria and guidelines for implementation of storm water pollution and erosion control techniques." In support of this effort, it would be necessary to:

1. Monitor and record the status of residential development
2. Install, apply, and monitor the performance of various erosion control practices
3. Install and operate sampling equipment
4. Collect samples
5. Conduct surveys of eroded areas and sediment deposits
6. Monitor and record cost and application information required to implement control of selected practices

They also recognized an immediate need for the compilation and publication of data generated during the conduct of this segment of the demonstration. Highest priority was assigned to the task of preparing and presenting a document that would provide the public with information that could aid in the planning and implementation of sediment and erosion control practices and techniques.

"Guidelines for Erosion and Sediment Control Planning and Implementation" is that document (Ref. 1). Published as Environmental Protection Technology series report number EPA-R2-72-015, the "Guidelines" was released to the public sector by the Office of Research and Monitoring, U. S. Environmental Protection Agency in August 1972.

The principal purpose of the "Guidelines" is to help those people engaged in urban construction prevent the uncontrolled movement of soil and the subsequent damage it causes. The "Guidelines" presents a comprehensive approach to the problem of erosion and sediment control from beginning of project planning to completion of construction. It provides:

1. A description of how a preliminary site evaluation determines what potential sediment and erosion control problems exist at a site being considered for development
2. Guidance for the planning of an effective sediment and erosion control plan
3. Procedures for the implementation of that plan during operations

In addition, technical information on 42 sediment and erosion control products, practices, and techniques is contained in four appendices. A cross-index and a glossary of technical terms used in the document are also provided.

Since the "Guidelines" is a document of more than 200 pages, data contained in it will not be repeated in this report. It contains application criteria and should be used as a supplementary reference to this report.

In addition to these primary charges, the Erosion Control Demonstration contained several additional tasks. Surveys and evaluations of readily available sediment sampling equipment were to be conducted. Using the results of this effort,equipment was to be procured for field installation and monitoring of sediment production from both small and large areas. The feasibility of using "tracer techniques" and other, more conventional, methods of determining soil removal and deposition were also to be investigated. Those items that showed promise and could be utilized within the program budget were to be demonstrated. The possible use of recycled glass bottles for the manufacture of products that could be used in erosion control work was also to be investigated.

Documentation of all field work and construction progress was accomplished by aerial photographs and repetitive bench mark photography from numerous locations throughout the demonstration area.

UTILITY CONSTRUCTION

Construction of roads, utilities, and homes in the experimental and reference subwatersheds was originally scheduled for completion during the duration of the demonstration project. However, construction schedules established by the developer throughout the demonstration watershed were delayed considerably from those originally established. The delays were especially significant in the experimental subwatershed and precipitated a shift in emphasis from the monitoring of construction operations and the application of erosion control measures and techinques associated with general suburban construction to those specifically associated with the installation of roads and public utilities, i.e., storm and sanitary sewers, water, gas, electricity, and telephone, and those individual home sites that did undergo development. It is noteworthy that at the end of the first year of operation (June 1971) only 18 lots were under development in the reference subwatershed and home construction had not yet begun in the experimental subwatershed. At the end of the 21-month period scheduled for the conduct of the erosion control demonstration,a total of only 19 lots had been, or were being, developed in the reference subwatershed and only five lots were under development in the experimental subwatershed. The total number of lots or portions of lots available for development in the reference and experimental subwatersheds is 61 and 60 respectively. These numbers convert to percentages of only 31 percent and 8 percent of development potential initiated or realized during the course of the demonstration period.

In keeping with the overall Columbia plan, all utilities are subsurface installation. The schedule delays presented a unique opportunity to observe and monitor the construction of all utilities in considerable detail. It has also been possible to observe and treat the erosion control and sediment production problems associated with utility construction. The consensus of the technical specialists working in, or acting as advisors to, the program in erosion and sediment control is very favorable in that the opportunity to acquire detailed data during the construction of utilities is very unique, if not an absolute first. It is also felt that, because of its unique character, this type of data is in demand and will be readily received and used by those associated with the environmental stress imposed by construction activities. Data generated from this experience was used extensively in the "Guidelines."

Erosion control problems encountered during the installation of utilities indicate that responsiveness to these problems is much more important than exhaustive planning. Detailed planning and schedules for erosion control are dependent upon construction schedules and unforeseen delays can completely negate a well-planned erosion control scheme. This is especially true when vegetative practices are involved. Effective treatment requires a "see it today, treat it tomorrow" philosophy. It also requires that erosion control products and equipment for their application be available for immediate use.

These observations do not negate the need for planning and scheduling. They do indicate that some flexibility must be maintained in order that a change or delay will not completely negate a well concieved sediment and erosion control plan. Standard specifications, currently available for erosion control work, are often unable to provide a workable solution to a particular problem. Individual erosion control practices, products, and/or techniques must be tailored to an individual situation based on topography, soil, construction operations, etc. The perfect example is the establishment of an interim vegetative program that will be destroyed by construction before it can mature to an effective age. The use of a synthetic product that can give immediate relief to the problem is clearly indicated in this case.

Planning of the erosion control scheme during utility construction must anticipate potential problems created by future activities as well as consider real situations created by utility construction that has been completed. For example, consider the case where storm sewer, sanitary sewer, and water utility construction is complete and a period of inactivity is expected before electricity, telephone, and gas are to be installed. The design of an erosion control scheme must consider such items as the location of future construction in relation to that already complete, the time lapse involved, the effective alternatives available during the interlude, and the cost of, and benefit from, the installation of selected techniques.

No standards have yet been developed to cope with these situations. However, three pertinent observations can be made at this time: (1) Design and implementation of erosion control measures must be flexible in order to facilitate decisions made on a site-by-site basis; (2) these decisions must be made by persons knowledgeable in both the construction and erosion control fields; and (3) scheduling of utility construction should, wherever possible, consider the following suggestions:

1. Area disturbed during construction needs to be reduced.
   It was observed that 96+ percent of the total area (4.49 acres) adjacent to the roadway (sidewalk right-of-way and roadway banks) in the experimental subwatershed was disturbed by

excavation, spoil pile, material storage, or equipment travel during utility construction.

2. Construction schedule duration needs to be compressed in order that the duration of "bare soil" conditions can be reduced. This can only be achieved through closer cooperation and coordination of individual utility construction activities.

It should also be noted that the "utilidor" concept, i.e., more than one utility is buried in a common trench or conduit, is very desirable from an erosion and sediment control standpoint. This scheme requires the disturbance of smaller areas and could eliminate the repetitive disturbance of a given area by the separate construction of individual utilities.

HOMESITE CONSTRUCTION ON WOODED LOTS

Many practices, products, and techniques were demonstrated in conjunction with the development of homesites. The general experience and data generated during this effort has also been incorporated into the "Guidelines" and will not be repeated here. However, since much of the work was conducted in conjunction with the development of wooded sites, some repetition of the most significant observations is warranted.

Trees to be preserved must be carefully selected. Damaged and/or diseased specimens on any lot can most economically be removed during the initial clearing operations. Trees selected for retention must be protected. They can tolerate only very minor disturbance of the soil under the canopy and the protection provided must extend out to the canopy margin (drip line). It is seldom possible, or desirable, to save trees that are close to home foundations. This is especially true if the home has a basement. If construction activity encroaches inside the drip line of trees close to a home, its chances of survival are greatly reduced. The undesirability of a dead or dying tree in close proximity to a home comes from the danger of its becoming a "dead fall" during a windstorm and the potential danger this poses to the structure and its inhabitants. It also costs more to remove a tree that is close to a structure since it is usually removed a piece at a time so that the adjacent structure will not suffer damage.

Two wooded lots, upon which homes had been constructed, were selected for study and implementation of remedial tree removal or treatment. Both were originally cleared before construction and the remedial work reported below was required to (1) remove trees whose root systems were severely damaged during home construction to the extent that they could not be expected to survive; (2) remove trees that were diseased or had incurred previous damage and should have been removed during the original clearing operation; and (3) prune or trim trees that were slightly damaged but were judged to have a reasonable chance to survive. Cost data are for March 15, 1972, and are the actual costs of work on the two lots as performed by a local tree removal specialist. Eight men were required for a total duration of 12 hours to accomplish the work. Their effort was allocated as follows:

Tree surgery	2 men
Felling and cutting	2 men
Material removal and cleanup	3 men
Feeding woodchipper	1 man

Following are excerpts from the job description and cost sheets for each of the two lots.

Description for Lot 1	Take Down & Trim	Clean Up
Take down one "Red Oak" tree	50.00	40.00
Take down one "White Oak" tree	85.00	100.00
Take down and clean up nine small trees		185.00
Take down oak tree near lumber pile	65.00	
Dead-wood "Pin Oak" side of house	45.00	20.00
Dead-wood "Pin Oak" back of house	75.00	35.00
Dead-wood "Pin Oak" near road	75.00	35.00
Trim Beach tree	50.00	10.00
Total	445.00	425.00

Description for Lot 2	Trim & Take Down	Clean Up
Take down one "Red Oak" close to house	$100.00	$ 25.00
Take down one "Double tree"	85.00	25.00
Take down one "Hickory tree"	65.00	45.00
Take down one "Oak tree" near street		125.00
Take down seven "Medium trees"		140.00
Take down seven "Small trees"		35.00
Trim "Red Oak" next to house	20.00	15.00
Take down "Red Oak" next to house	50.00	45.00
Dead-wood "Oak tree" near street	25.00	15.00
Extra deadwood cleanup		65.00
Total	$345.00	$535.00

Stumps should be removed by the use of a stump cutting device rather than by bulldozer or blasting. The stump cutter disturbs only the tree stump areas and the chopped wood is then returned to the area that used to be the stump.

Following is the job description and cost data (April 3, 1972) for stump removal using a "Stump Cutter" on two lots in the experimental sub-watershed.

Description for Lot A	
Hickory stump side of house	$ 35.00
Double Chestnut Oak stump	20.00
Oak stump near double stump	20.00
2- White Oak stumps in back of house	20.00
Maple stump near road	10.00
2- Gum stumps	20.00
Red Oak stump in front of house	35.00
Small Red Oak next to driveway	15.00
Total on stumps	$175.00

Description for Lot B

Take out stumps on lot, includes taking loader in to move stumper around over the rough ground.

Total price of taking stumps out	$150.00
Cost of hauling loader plus loader time	35.00
	$185.00

Time requirements for stump removal by the "Stump Cutter" are dependent upon stump diameter, stump height and depth to which stump is to be removed. Stump parameters encountered during this phase of the demonstration are as follows:

Diameter	Height (above ground)	Depth (below ground) of Removal	Time Required
5 in.	12 in.	4-6 in.	5 minutes
10 in.	12 in.	4-6 in.	15 minutes
15 in.	12 in.	4-6 in.	20 minutes
20 in.	12 in.	4-6 in.	30 minutes
25 in.	12 in.	4-6 in.	45-70 minutes
30 in.	12 in.	4-6 in.	60-90 minutes

In addition, an average time of 15 minutes of setup time is required at each stump.

There need be no "waste" wood products associated with tree removal. In temperate climates the disposal of wood cut to fireplace length is easy and can often be profitable. Any wood not sold for timber or destined for fireplace use should be processed by a "woodchipper" and the chips returned to the lot or removed to other areas to be used in the erosion control program.

More information on the above mentioned subjects is contained in the "Guidelines."

PRODUCTS, PRACTICES, AND TECHNIQUES

A total of 45 products, practices, and/or techniques were investigated during the term of the demonstration project. They were divided into four major categories for purposes of evaluation and reporting. The major categories and the individual entries are:

1. Chemical Soil Stabilizers, Mulches, and Mulch Tacks

   Aerospray® 52 Binder

   Aquatain

   ® Curasol AE

   ® Curasol AH

   DCA-70

   Liquid Asphalt

   NC1556.2 L (experimental product - not available commercially)

   Petroset® SB

   Plastsoil (small plot demonstration only - not used in on-going program)

   Terra Tack

2. Erosion and Sediment Control Structures

   Check Dam

   Chutes/Flumes

   Diversion Dike

   Erosion Check

   Fabriform® Erosion Control Mats

   Filter Berm

   Filter Inlet

   Flexible Downdrain

   Gabions

   Interceptor Dike

   Level Spreader

   Sandbag Sediment Barriers

   Sectional Downdrain

   Sediment Retention Basin

   Straw Bale Sediment Barriers

3. Fiber Mulches, Mulch Blankets, and Nettings

- Excelsior Blanket
- Fiber Glass Matting
- Glassroot®
- Jute Netting
- Mulch Blankets
- Netting
- Plastic Filter Sheet
- Sorghum, dehydrated (small plot demonstration only - not used in on-going program)
- Straw or Hay
- Woodchips
- Wood Fiber Mulch

4. Special Erosion and Sediment Control Practices

- Construction Coordination
- Mulch Anchoring
- Pumped Water Management
- Roughness and Scarification
- Stump Removal
- Traffic Control
- Tree Protection
- Vegetative Filter Strip
- Woodland Clearing and Excavation

Technical and product information on all but the experimental or small plot demonstration products are contained in the appendices attached to the "Guidelines for Erosion and Sediment Control Planning and Implementation."

Only three of the practices listed above were used by the developer in addition to the routine establishment of vegetation throughout the duration of the demonstration program. They include sediment retention basins, interceptor dikes, and filter inlets at storm drain inlets. Installation and maintenance data are presented in Table 2.

TABLE 2. EROSION CONTROL INSTALLATION AND MAINTENANCE DATA (SUMMER 1971 PRICE BASE)

Practice	Average Cost of Installation	Maintenance Performed	Cost of Maintenance
Sediment Retention Basin	$3200.00*	None	$----
Interceptor Dike	6.00-12.00**	None	----
Filter Inlets	6.60***	Remove sediment after storms	1.75****

*Average cost to the Howard Research and Development Corp., for construction of basins in and around the demonstration area.

**Built with motor patrol or small dozer in 15-30 minutes - $24/hr. with operator.

***20 cubic feet of crushed rock at $0.2975/cu. ft. = $5.85 plus 30 minutes of labor time at $3.50/hr. = $1.75.

****30 minutes of labor time at $3.50/hr. = 1.75.

In addition to the information presented in the "Guidelines" and in Table 2, additional information on some of the newer products is presented below since some of the Chemical Soil Stabilizers, Mulches, and Mulch Tacks had not been extensively utilized prior to 1970. Selected descriptive, cost and application information on seven of these products is presented in Table 3.

Three types of wood fiber or fiber glass mulch were used on various areas in the demonstration program in addition to those areas that were stabilized with the conventional wheat straw. Information on these products, i.e., Glassroot®, Hydro Mulch, and Silva-Fiber® is presented in Table 4.

Detailed cost data are not presented for other products, practices, and techniques since cost parameters are very dependant on items such as site conditions, labor, heavy equipment costs, transportation, etc.

TABLE 3. SELECTED DESCRIPTION, COST, AND APPLICATION INFORMATION FOR CHEMICAL PRODUCTS

Product	Raw Material Cost*	Soil Stabilizer	Mulch (on seeded areas)	Mulch (in Hydroseeder slurry)	Mulch Tack	General** Manufacturer's Recommended Application Rate/Acre
Aerospray® 52 Binder	$2.90/gallon	Yes	Yes	No	No	30-45 gallons
Aquatain	2.75/gallon	No	Yes	Yes	No	130 gallons
® Curasol AE	2.67/gallon	Yes	Yes	Yes	Yes	30-65 gallons
® Curasol AH	3.00/gallon	Yes	No	No	Yes	30-45 gallons
DCA-70	2.50/gallon	Yes	Yes	Yes	Yes	30-45 gallons
Petroset® SB	2.25/gallon	Yes	Yes	Not tested	Yes	***
Terra Tack	2.00/pound (packed as powder)	No	Yes	Yes	Yes	15-20 pounds (mulch tack) 50 pounds (soil stabilizer)

*Small volume (50 gallon/pound) lots, Summer 1971.

**Detailed application criteria available from manufacturer.

***Rates determined from simple formula or nomograph supplied by manufacturer. Application rates consider: (1) desired depth of penetration, (2) soil particle size, (3) abrasive force to protect against, and (4) topography.

TABLE 4. MULCH DESCRIPTION, COST, AND APPLICATION INFORMATION*

Product	Raw Material Cost	Manufacturer's Recommended Application Rate	Application Equipment Required	Mulch Tack Required to Prevent Wind Erosion
Glassroot®	$15.40/35 lb. pkg.	35 lb/4000-5400 sq. ft. (280-380 lb/acre)	Glassroot® dispensing kit and 15 cfm air compressor	None
Hydro Mulch	3.50/50 lb. bag	1000-1500 lb/acre	Hydroseeder	None
Silva-Fiber®	3.75/50 lb. bag	1000-1400 lb/acre	Hydroseeder	None
Wheat straw	48.00/Ton	1 1/2-2 ton/acre	Straw Blower	Chemical Mulch tack or liquid asphalt

*Price Base – summer 1971.

A part of this segment of the Erosion Control Demonstration was the conduct of an investigation to determine the feasibility of using recycled waste glass to produce an erosion control product/s. This seemed especially pertinent, since several erosion control products made of fiber glass were on the market.

The possible utilization of recycled glass in erosion control was discussed with representatives of the Glass Container Manufacturers Institute. The potential market for glass products in the erosion control field, the economics of producing recycled products, and the required physical characteristics of the products were discussed.

The conclusions drawn from this investigation must be regarded as generally negative because the need for glass to produce products that are currently on the market (all glass brick, glass and clay brick, glass phalt, etc.) far exceeds the supply of used glass. It was further determined that, if all of the used glass in existence could be made available for reuse in these products, the supply would still fall short of the demand.

Monitoring and Sampling Investigations

One of the major charges of the demonstration program was to try and determine the comparative effectiveness of an advanced or accelerated erosion control program to a routine program. It was for this reason that "reference" and "experimental" subwatersheds were selected and delineated (see Section III).

The first effort toward the accomplishment of this goal was a review of the measurement techniques, both conventional and novel, that might be utilized on this project. It was recognized that the evaluation and comparison of the performance of the various erosion control practices would require techniques that will measure quantitatively the effectiveness of soil retention. Conversely, the amount of soil lost during individual storms and over the periods during which the practice is in effect might be used to measure the effectiveness of the practice. The measurement techniques must, therefore, be capable of measuring the loss of soil during individual storms or over periods of time.

Consideration was also given to the utility of measuring sediment production at individual locations within the subwatersheds. This approach was abandoned because there was no encouragement that "individual small plot" evaluation schemes could be maintained during the development activities. The "applied research project" intent also dictated that any monitoring scheme be harmonious with the development and construction activities scheduled for implementation during this time period and that demonstration project activities not be an unusual or costly burden to the developer and builders involved.

It was also recognized that stream gaging facilities were going to be installed to provide basic data for other major areas of investigation. Four installations were planned and a double stream gage was to be constructed at the confluence of the streams from the reference and experimental subwatersheds.

With these considerations in mind, the investigation of various physical measurement and monitoring techniques was conducted. Summary information on the various techniques is listed below.

(1) Conventional Survey Techniques. Topographic maps would not be sufficiently accurate to measure soil losses for overall areas. Even if feasible, they would require an excessive amount of effort. For these reasons, conventional survey techniques can only be used for estimating the quantities of material deposited in sediment traps, the storm retention pond, stream channels, etc.

(2) Laser Leveling. Consideration was given to the use of the newly developed laser level as a method of direct measurement of soil loss and deposition. Accuracy

of one-thousandths of a foot is obtained with a level rod and an audible light detector. However, it would still be necessary to use conventional surveying techniqes to provide horizontal control, and therefore was not recommended.

(3) Aerial Photographic Mapping. Although it was recognized that detailed topographic maps can be prepared from aerial photos taken at low altitudes, their use is subject to the same limitations as conventional topographic mapping.

(4) Aerial Stockpile Inventory Technique. A variation of aerial topographic mapping has been used to inventory stockpiles of coal, aggregate, sand, etc. The accuracy and cost of this type of survey precluded its use on this demonstration project.

(5) Automatic Samplers. Several automatic samplers are commercially available for collecting water and sediment samples at intervals. They use either a pump or a vacuum to collect the samples, and a clock is used to control the sampling intervals. The vacuum samplers normally use 24 bottles, and the pumped samplers have up to 145 bottles. Sampling with both types of samplers can be initiated by a simple stream stage sensor.

(6) U.S. Single-Stage Suspended-Sediment Sampler. An extremely simple automatic sampler has been developed for use in areas where observers are not available. It consists of a sample container stoppered with two inverted "U" tubes. The lower "U" tube is the sample intake; the upper intake is the air exhaust. The sampler operates on a siphon principle. As designed, it collects a composite sample.

The use of clustered single-stage samplers designed to operate at various levels or in sequence by controlling the air vents by a simple rainfall control was also considered.

(7) Radioisotope Sediment Concentration Sensors. A nuclear direct sensing device for suspended sediment concentration has been developed by the U.S. Atomic Energy Commission. This device uses a small amount of cadmium-109 to determine the density of the water sediment mixture. A concurrent electrical conductivity measurement is used to correct for solute concentrations. This device was not judged to be applicable to the monitoring requirements of this project.

(8) Grab Samples and Field Analysis Techniques. To supplement automated sampling techniques, grap samples can provide needed data to evaluate local effects and/or special situations.

(9) Bedload Samplers. In addition to measuring the quantities of waterborne sediment, it would also be desirable to measure the quantity and type of sediment moved along the bottoms of major streams. Bedload samplers are available for use in this capacity. However, past experience (ARS, U.S. Army, USGS, etc.,) with bedload samplers was not encouraging since problems associated with the collection of representative samples and the operation and/or maintenance of these devices during periods of high volume flow are considerable. Then, too, computation of bedload amounts and parameters of delivery to points downstream is a very "unexact" science.

During the course of the preliminary investigations conducted during the preparation of the grant application, it was recognized that an alternative to physical measurements and sampling techniques might be the use of tracer techniques to quantitatively measure the loss of soil from selected areas.

The evaluation of the possible use of lanthanide silicates and rare earth tracers and neutron activation analysis as a method for the identification of sources of erosion and for quantitatively evaluating the amount of soil loss was conducted concurrently with the investigation of the physical measurement and monitoring techniques. In the literature search, no directly comparable application of this technique was found. Even though the use of tracers and activation analysis appears to be a feasible method for monitoring and measuring soil loss, basic research work would be required to develop practical methods for the application of this technique to soil erosion and transport. For qualitative measurements, techniques are required for uniformly applying the tracer material to the soil particles in such a way as to not change the erosion and transport characteristics of the materials. In the few applications of this technique, the tracer and base materials were specially prepared and placed. No attempts had been made to apply tracers to materials in place.

With respect to using different tracers to identify sources of pollution, a number of possibilities exist. Further investigation indicated that it might be possible to use activation analysis techniques to discriminate between very dilute mixtures of compounds containing beryllium, boron, carbon, fluorine, rare earths and lanthanide, and other compounds. However, experimental work involving irradiation of a number of samples would be required to screen the possible tracer materials and to determine their detectability in the presence of the activated materials normally present in soils. Based on these investigations, it was concluded that the work required to apply these techniques would be beyond the scope of the present project and the possibility of obtaining useful information would be limited.

Monitoring and Sampling Scheme

Using the information generated from these investigations a gaging and sampling scheme was selected that (1) could be expected to meet the requirements of all major work areas of the demonstration project; (2) could be compatible with the construction scheduled for the area; (3) was available using "off-the-shelf" equipment and extant technology; and

(4) showed reasonable promise that similar installations could be used to monitor runoff, erosion, and sediment parameters in support of future requirements in the research or enforcement areas.

The scheme selected for demonstration utilizes three rain gages and four completely automatic stream gaging and water sampling installations. Locations are shown on the aerial photograph of the demonstration area (Figure 4).

The three permanent rain gaging stations utilize weighing-bucket type, continuous recording gages. Two of the gages are Belfort Instrument Company products utilizing spring-wound clock drives and ink pen recorders. The Belfort gages were originally equipped with gears which provided for one chart revolution every eight days. With this gear arrangement, rainfall intensities could be estimated every 15 minutes. Midway in the project, the Belfort gears were changed to provide one chart revolution every 24 hours. This enabled rainfall intensities to be determined every five minutes. This more accurate determination enabled a better sensitivity analysis to be conducted between rainfall intensity and the resultant runoff. The third rain gage is a Fisher-Porter punch tape model powered by a 7-1/2 volt dry cell. Data is automatically punched on a tape at 5 minute intervals in 1/10 of an inch of rain increments.

Two of the stream gaging and sampling stations were constructed at the junction of the tributaries draining the reference and experimental subwatersheds. They were located so that differences in the runoff and suspended solids produced in the experimental subwatershed, where advanced erosion control practices were applied, could be compared to the reference subwatershed, where only minimal practices were required. Two other gaging and sampling stations were established immediately upstream and immediately downstream from the four-acre pond.

The tandem stream gages (farthest upstream) (Figure 5) are precalibrated, broadcrested, V-notch weirs developed and tested by the U. S. Department of Agriculture. The concrete weir caps have 2:1 side slopes

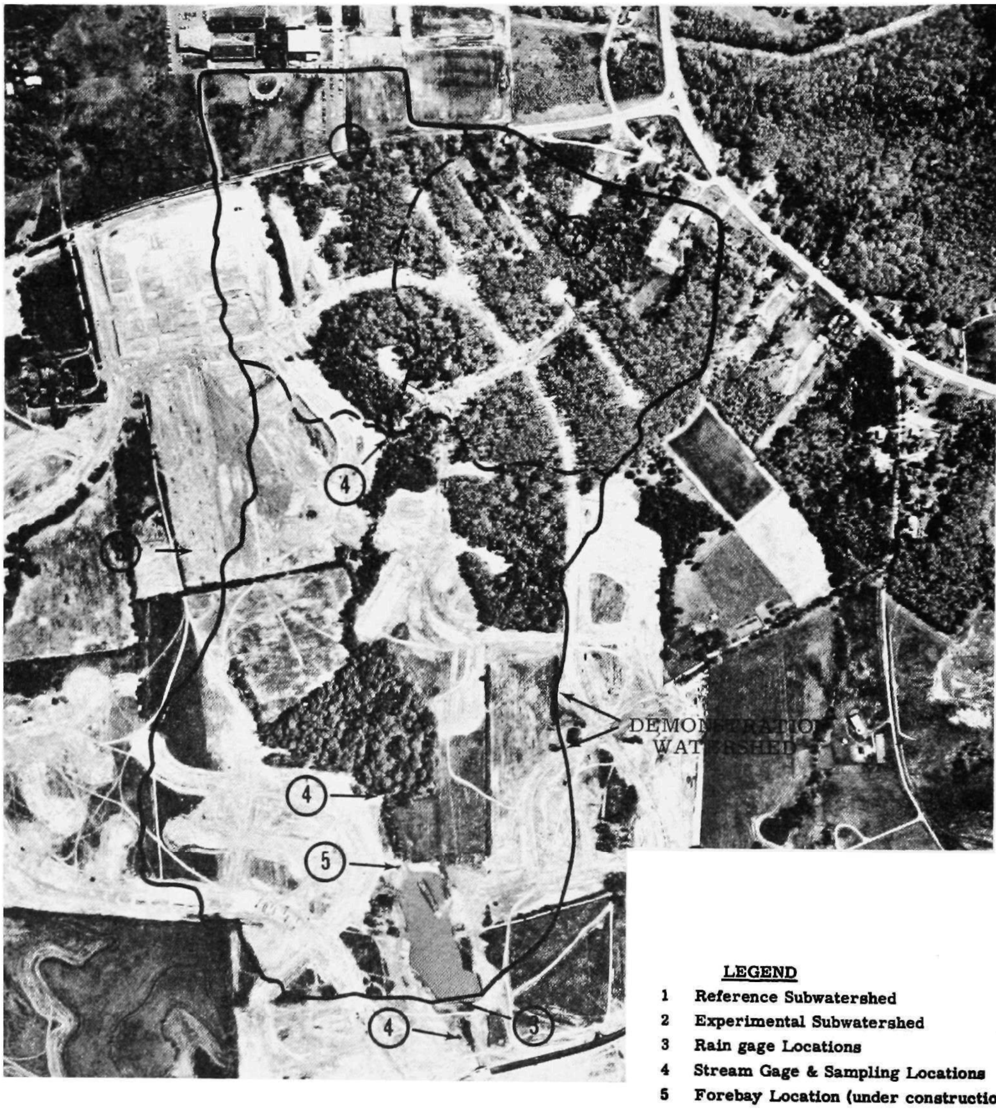

Figure 4. Demonstration Watershed and Subwatershed Locations

and were poured and formed directly on steel sheet piles driven a minimum of six feet below the elevation of the stream channel. Earth berms extend from the end of the weir caps to the limit of the calculated 50-year, post-development floodplain.

The stilling wells and shelters contain both the sediment monitoring equipment and a Stevens Duplex Water-Level Recorder Type 2A35, which can simultaneously measure and record the water levels going over weirs 1 and 2.

Station No. 3 (Figure 6), just above the pond and forebay, is a weir similar to those at stations 1 and 2, except the side slopes of the weir cap are at 3:1. This station is also served by a Stevens Type A35 water level recorder.

Station No. 4 (Figure 7), below the pond, uses a sharp-crested, compound, 90° V-notch and rectangular weir as a control section. The V-notch is 10 inches high and the rectangular section is 2-1/2 feet high by 6 feet wide. The damping effect of the principal spillway facilitates the use of this small installation. The stilling well is equipped with a Belfort portable liquid level recorder.

When necessary, additional stream gaging is performed using a Gurley pygmy current meter. To date, this method has been used primarily to check the calibration of the permanently installed weirs.

An automatic water sampling station is located at each of the four permanent stream gaging sites. The samples collected from these automatic stations were supplemented by depth integrated hand samples.

At sites 1 and 2 (Figure 8), the sampling equipment is housed in a combined instrumentation and stilling well shelter. Approximately 13 feet upstream from each weir, the intake from a one-quarter horsepower pump provides sample water which flows through a turbidimeter and then through a fluidic sample bottle rack which periodically diverts the flow into a sample bottle. The turbidimeters are equipped with Rustrak recorders as well as visual observation equipment. During the storm events, the fluidic samplers were programmed to

Figure 5. Double Gaging Station

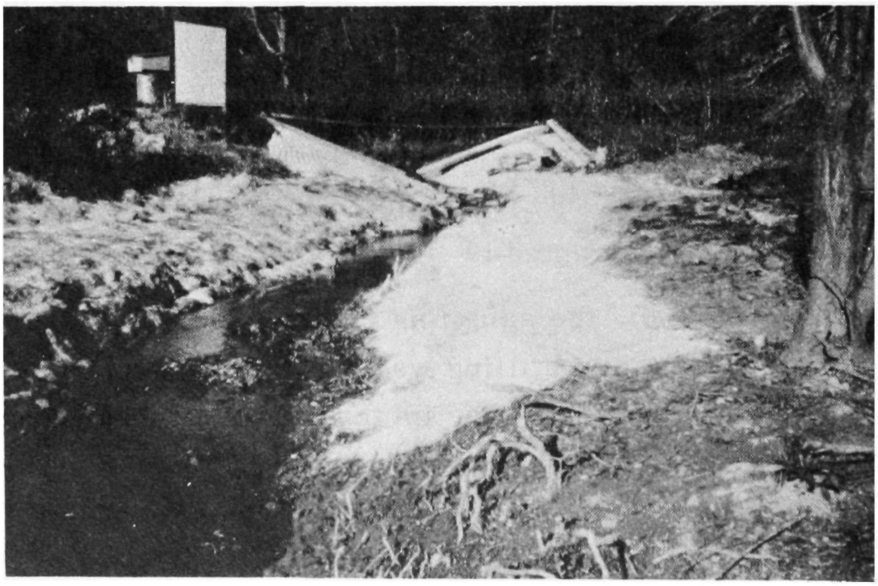

Figure 6. Gaging Station Above Pond

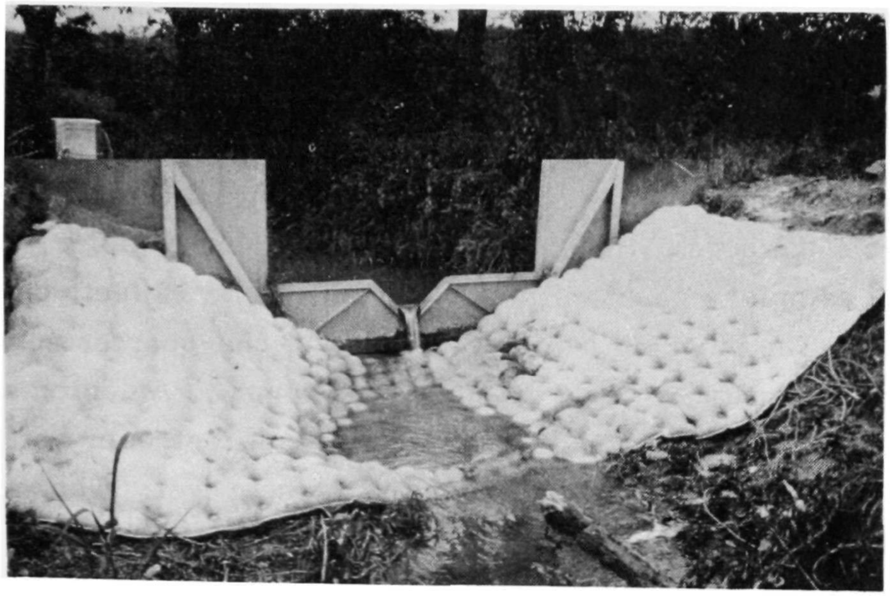

Figure 7. Gaging Station Below Pond

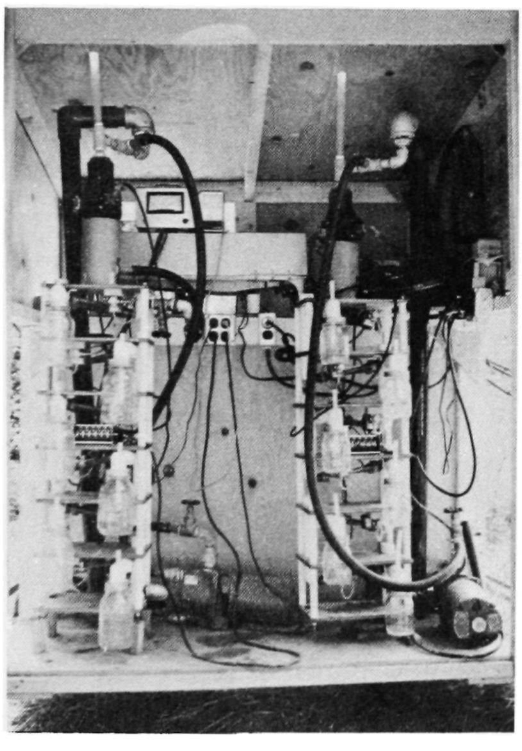

Figure 8. Interior of Instrument Shelter at Gaging Stations Nos. 1 and 2

sample every half-hour. A mercury switch automatically starts each pump and turbidimeter recorder at a given water stage and provides a cutoff after the stage falls below the predetermined level.

The automatic sediment monitoring equipment at site 3 (Figure 9) (upstream from the pond) consists of a PS-67 pumping sampler. The intake for the sampler is located in the stream, some 15 feet upstream from the weir. The pumping sampler is fed by a one-quarter horse-power pump which utilizes a 36 volt DC power supply. An automatic switch activates the sampler upon a sufficient rise in stream water level and stops it when the stage falls below the set level. The sampler can be set to take samples at virtually any time increment. During the field demonstration, it was set to sample every 15 minutes when activated.

The automatic sampling equipment at site 4 (Figure 10), below the pond, is a Serco, single-stage vacuum sampler. A switch activates the sampler upon a sufficient rise in stream level and 24 continuous samples are then taken at equal specified time intervals.

The primary purpose of the gaging, monitoring, and sampling program was to establish storm runoff volumes and gross sediment yields. The storm runoff is, in turn, related to the intensity and duration of the rainfall, land use, and ambient field conditions. As the area becomes more developed, the total volume of runoff for a given storm would, naturally, increase due to the larger amount of impervious area. Sediment volumes should, however, decrease as the area becomes stabilized.

In addition to the above mentioned equipment, four Mulhoffer type pit samplers were constructed for testing and evaluation in the stream channels. Two U. S. DH-48, depth-integrating, suspended-sediment samplers were purchased for use to supplement the time-integrated samples that were collected by the automatic sampling devices.

Four units of six single-stage samplers were fabricated for testing and potential use in the collection of samples at individual sediment

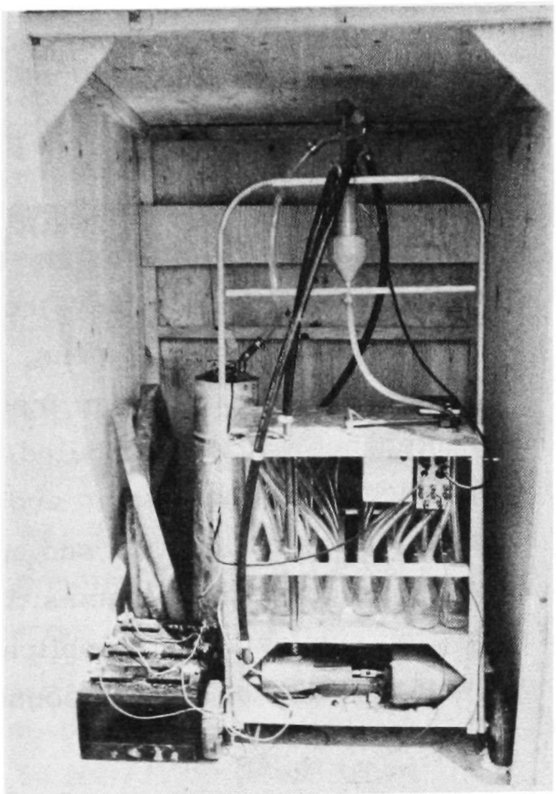

Figure 9. Interior of Sampler Shelter at Station No. 3

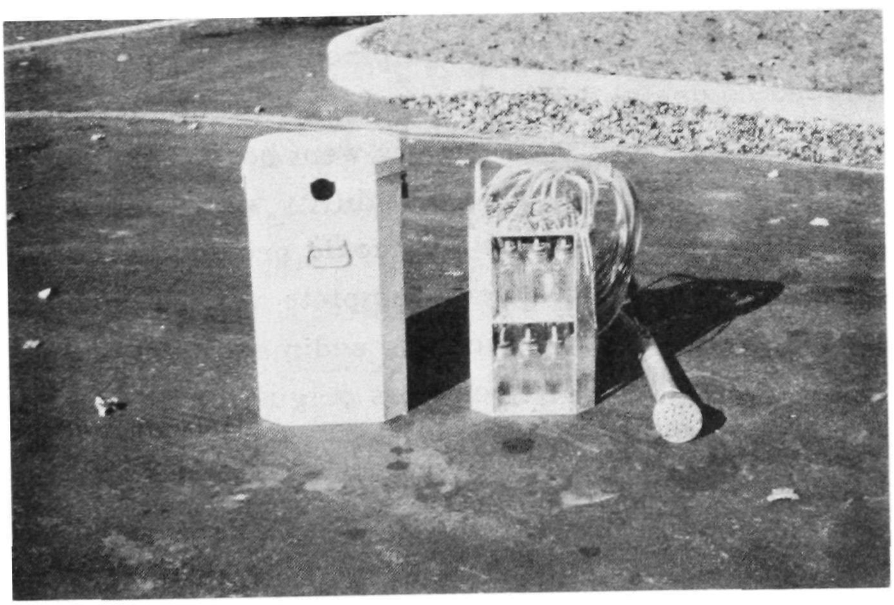

Figure 10. Serco Sampler at Station No. 4

retention basins selected for special study and analysis.

Monitoring and Sampling Analyses and Results

Equipment Performance Evaluation. The three broad-crested weirs, the compound weir, and the stage recording equipment has been operated throughout the duration of the project without any problems. Maintenance requirements involve chart changes, inking of pens, and the removal of sediment from the area immediately upstream from the V-notch weirs. Pen and chart maintenance can be scheduled. The cleanout of sediment must be accomplished after each storm and sometimes under base flow conditions to maintain the calibration and accuracy of the weirs. Failure to remove sediment buildup causes the weirs to act as flumes and their calibration curves are not applicable under these conditions. No cleanout was required at the compound weir because almost no sediment escaped the pond.

Only routine maintenance was required to keep the rain gages operating in a satisfactory manner. The addition of antifreeze to the collection buckets was required during the snow and freezing rain season.

Some rather severe problems were encountered with some of the automatic sampling and monitoring equipment. The recording turbidimeters produced no useful data. This was due to the fact that suspended solids concentration in the runoff quickly went beyond the 1000 JTU maximum of the instruments. This possibility was recognized before they were installed, but it was felt they could provide valuable data after the construction activities were complete and the area had become somewhat stabilized from an erosion and sediment control standpoint. However, development did not proceed as originally anticipated and no opportunity was provided for a fair evaluation of the equipment or the date that it could produce.

Of the three types of automatic samplers, the bottle racks using "fluidic" switching devices (P. A. Freeman Assocs.) were the most dependable and provided the most trouble-free operation. It did malfunction occasionally when a small twig with a critical length became lodged in the system. This occasional malfunction was not judged to be severe.

The PS-67 pumping sampler was often unable to cope with the high concentrations of suspended solids to which it was subjected. The major problem was caused by the deposition of sediment in the backflush holding tank. Because the runoff often had suspended solids concentrations in excess of 20,000 ppm, and because this water was held for 15 minutes at a time in the backflush tank, gravity sedimentation would often render the unit inoperable due to the fouling (by sediment) of the float devices in the backflush tank.

Sustained problems were experienced with the spring-wound timing device and the vacuum-operated remote starting device on the vacuum sampler. Five different clock mechanisms were required during the demonstration project. In addition, the remote starting device could not be depended upon to activate the sampler after it had been in the field for more than 24 hours. It needs to be stated, however, that the sampler itself performed in a satisfactory manner when it was activated by hand.

All of the automatic samplers have a severe limitation in that they are point-integrating (pick up samples from a fixed location in the stream) devices. When the samples that they collected were compared to simultaneously acquired depth-integrated samples (U. S. DH-48), there was very little correlation or basis for comparison. This relationship (or nonrelationship) was experienced on every occasion. Therefore, the computation of suspended sediment load, gross erosion, etc., based on the data collected by the automatic equipment is speculative at best. In the judgment of the scientists and engineers working on the demonstration project, it cannot be used in scientific computations. For these reasons, intensive and immediate research and development is required to develop an automatic, depth-integrating sampler than can be used in remote facilities.

No useful information was derived from the "pit type" bedload samplers. When placed in the stream so that the top of the sampler was flush with the stream bed, one was buried to a depth from which it could not be retrieved without machiner. At other times, the samplers would be filled by sediment moved into the samplers by the baseflow of the stream. These devices were then abandoned.

The single-stage samplers operated satisfactorily until they were put in the field. There, they were quickly destroyed by heavy equipment travel, burial, or vandalism.

Subwatershed Comparative Evaluations. The comparative performance evaluations to be conducted between the experimental and reference subwatersheds were, at best, inconclusive. Three major factors contribute to this inconclusive evaluation. They are:

(a) The considerable delays in home construction in the experimental and reference subwatersheds. The fact that only 31 percent and 8 percent of the development potential was initiated or realized during the evaluation period renders any comparative analyses useless. Even though great quantities of both qualitative and quantitative information were generated, the direct comparison of the effectiveness of advanced erosion control techniques cannot be accomplished when only 31 and 8 percent of the areas to be compared can be integrated into the evaluation.

(b) The inability of point-integrating sampling equipment to collect representative samples of suspended solids being generated on the areas to be compared.

(c) The total lack of comparability between the point-integrated samples collected by the automatic equipment and the depth-integrated samples collected simultaneously by hand.

It should be recognized however, that these deficiencies are not truly negative; they do emphatically indicate that the state-of-the-art has a long way to go before reliable, definitive data can be generated from remote, automatic sediment sampling stations.

Sediment Retention Basin Analyses. One of the areas of interest in this demonstration was to see if information could be acquired regarding the trap efficiency of small (less than 1/4 acre) sediment retention basins. Five of these small basins were selected for study at various times throughout the term of the demonstration project. A summary of the problems encountered in the use of single-stage sampler for this type of field investigation follows.

In Case No. 1, a basin was constructed in the reference subwatershed to provide protection over the fall and winter until home construction could be resumed in the spring. It did not function at all during this period since the topography of the site was not modified to bring the sediment-laden runoff into the basin. Runoff moved around both ends of the structure.

Case No. 2 was a small basin in an adjacent subwatershed. There was no defined channel entering the basin. This resulted in almost sheet flow movement of runoff into the basin and the single-stage samplers deployed in this area did not operate since the runoff depth was never great enough to operate the samplers. The bank of six single-stage samplers installed to collect water moving out of the principal spillway was stolen.

In Case No. 3, a piece of heavy equipment ran over the sampler before it had a chance to function.

The sampler deployed in Case No. 4 was buried under a spoil pile before it had an opportunity to operate.

Case No. 5 involved the establishment of a detailed topographic survey of a sediment retention basin installed to remove sediment from runoff generated on a townhouse development site. It was planned to collect depth-integrated hand samples to establish the general quality of water moving into the structure. Resurvey after each runoff event would determine the volume of sediment trapped and it was hoped that trap efficiency information would be forthcoming. However, the builder used most of the basin area as a stockpile for surplus earth and no data were generated.

These attempts, then, did not generate any data that could be used to refine the trap efficiency curves, formulas, etc., that are extant.

SECTION V

STORMWATER STORAGE AND TREATMENT

STORMWATER STORAGE

Facility Description

At the downstream terminus of the demonstration watershed, a lake was constructed to act as a combination sediment trap and storm water management device. The lake was impounded by constructing an earth-fill dam with an impervious clay core across the main stream channel. Some shaping was then done to the stream valley bottom and sides to obtain the finished pond configuration.

The principal spillway is a drop inlet type structure of corrugated metal pipe having a 42-inch riser in the pond and a 24-inch pipe through the dam. The riser is fitted with an antivortex device. A drawdown device, consisting of a 10-inch horizontal pipe with a 15-inch perforated riser, is attached to the bottom of the principal spillway so that the pond can be completely drained if necessary. A turf-covered emergency spillway has been constructed on the west abutment to provide an escape route for storms whose runoffs are above the design capacity of the principal spillway. Figure 11 shows the basic plan and profile of the stormwater retention pond site.

During the course of this demonstration project, the hydraulic performance characteristics of the pond were monitored with respect to efficiency as a storm water management device. Stream gaging and sampling stations numbers 3 and 4 (Figures 6 and 7) monitored the water quantity and quality entering and leaving the pond. Cross sections of the pond bottom were surveyed quarterly. Operating records of the drawdown device valve openings and closings were kept in order to attempt an analysis of the effect of operating procedure on the pond's efficiency as a stormwater management device. In addition, the

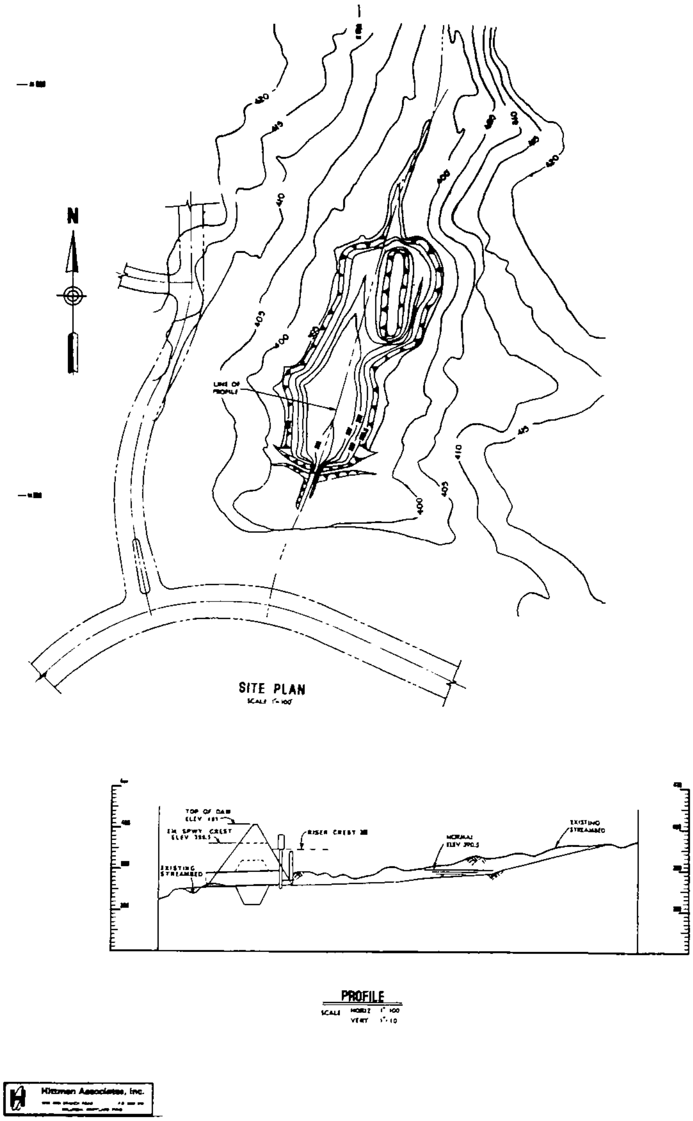

Figure 11. Demonstration Area Dam Site Plan and Profile

quarterly airphoto coverage kept track of the changes to the surface characteristics of the pond area and its watershed.

Table 5 shows some of the physical characteristics of the pond and its watershed at the start of and toward the end of the monitoring program for this demonstration project. The slight decrease in surface area was caused by minor grading and filling which was done around the edge of the pond in connection with the construction of a lakeside townhouse development. The dramatic decrease in storage volume is a direct result of sediment runoff due to construction activity. This was not unexpected since the pond also served as the primary sediment trap for its upstream drainage area. The slight change in the watershed area is due to the additional area over the original watershed boundaries which is serviced by storm sewers which empty into the main stream channel of the pond watershed. In Howard County, separate storm sewers empty into the natural stream channels. Hence, the storm sewer drainage boundaries generally follow the watershed boundaries. However, slight deviations between the natural watershed and the storm sewer service boundaries usually occur for the convenience of street layout. This situation is reflected in the slight increase in watershed area shown in Table 5.

Performance Evaluation

Quantitative evaluation of the hydraulic performance of such a storm water retention pond under actual field conditions is difficult at best, especially in the short period of time available under this program. Approximately one year of good gaging records were acquired. During this time, storms of varying rainfall intensity and duration occurred. To complicate the problem further, the requirements were that the pond be operated and evaluated with the water level at different prestorm levels.

To date, little consideration has been given to quantitatively evaluating the performance efficiency of storm water management devices. The

TABLE 5. PHYSICAL CHARACTERISTICS OF STORM WATER RETENTION POND AND WATERSHED

Characteristic	Date		Percent
	August 1970	April 1972	Change
Surface area, ft^2	162,000	159,000	-2
acres	3.72	3.65	
Volume, ft^3	610,200	513,400	-16
acre-ft	14.0	11.8	
Average depth, ft	3.8	3.2	-16
Total watershed area, acres	190.2	195.0	+2

first problem encountered is one of determining on what basis such devices should be evaluated. The resolution of this problem depends upon variables such as:

(1) The local hydrologic and meteorologic parameters

(2) The relationship between the degree of protection desired for given rainfall recurrence frequencies and cost

(3) The overall intended purpose of the device

(4) Its relationship to other stormwater management devices in the same or adjacent watersheds

(5) The degree of stormwater retention or retardation required

(6) The overall purpose and goals of the stormwater management program

As a beginning, two rather simple parameters which can be used to evaluate any stormwater management device would be its efficiency in reducing the peak runoff from any given storm event and its ability to delay the delivery of this peak storm runoff to downstream areas. The evaluation of these two parameters, whether singly or in combination, might be considered a rather simplistic approach to a complex problem.

However, most stormwater management programs to date are geared toward both reducing the peak flows and retarding the delivery of this peak to downstream areas. Also, data on these parameters are usually the most readily available and are the easiest to obtain. Therefore, it was to these two parameters that the analyses were addressed.

Table A-1 in Appendix A contains the raw data used in the performance evaluation of the pond when the water level was at normal riser elevation at the start of the storm. This tabulation includes all storms which deposited at least one-half inch of total rainfall in the watershed, as well as a number of lesser storms. It might be noted that all the storms recorded when the pond was at full capacity had return frequencies of less than one year, based on local intensity-duration-frequency curves.

In order to assess the impact which the various hydrologic and meteorologic parameters have on the operating characteristics of the pond when it is at full capacity, statistical analyses, including correlation and regression analyses, were performed on the collected data. The independent hydrologic and meteorologic parameters which were tested for significance include the total rainfall,average rainfall intensity, storm duration, peak inflow, and the elapsed time between the peak inflow and the peak outflow. As a measure of pond performance, three separate indicators were tested for significance with the above independent variables. The three pond performance indicators chosen were:

(1) Elapsed time between the peak inflow and outflow

(2) Percent difference in peak outflow versus peak inflow as defined by the equation:

$$D = \frac{O_p - I_p}{I_p} \times 100 \qquad \text{Equation (1)}$$

where:

D = percent difference between outflow and inflow, percent

O_p = peak outflow

I_p = peak inflow

(3) Peak throughflow as defined by the relationship:

$$T = \frac{O_p}{I_p} \times 100 \qquad \text{Equation (2)}$$

where:

T = peak throughflow, percent

and the remaining symbols are as defined previously

Table A-2 in Appendix A contains the data bank of the independent and dependent variables used in the statistical analyses.

During the final regression analyses, both linear and exponential models were developed and analyzed, using as many observations (storms) for the variables as the completeness of the data bank permitted. The relationship selected for each pond performance characteristic was the one which was judged to produce the closest fit to the collected data.

Of the two measures of the retention efficiency of the pond (the percent difference in peak outflow versus inflow and the peak throughflow), the peak throughflow was found to be more closely correlated with the hydrologic and meteorologic parameters tested. The relationship which was found to best describe this retention parameter of the project pond is:

$$T = -28.9 + 144R \qquad \text{Equation (3)}$$

where:

R = total rainfall for storm event, inches

The correlation coefficient for the above relationship is 0.897 for the 21 observations (storms) used.

No significant relationship could be found between the retardance characteristics of the storm water retention pond, as measured by the elapsed time between the peak inflow and outflow, and the dependent variables tested.

Statistical analysis was also attempted of the hydrologic and meteorologic data collected when the pond level was below normal riser elevation at the start of a storm. Table A-3 in Appendix A presents the basic data collected under this task. Because of the wide variability in the data and the short-term record available, no specific relationships or significant correlations could be found between the pond retention and retardance characteristics and the basic hydrologic and meteorologic data.

Discussion

It was found that, at least for storms with return frequencies of less than one year, a simple relationship exists for predicting the retention efficiency of the project storm water retention pond. The relationship, reported as Equation (3), shows that the peak throughflow for a given storm event is positively and quite significantly correlated with the total storm rainfall. Other independent variables tested did not show any significant degree of correlation with the pond retention characteristics. The variability and short-term nature of the data, however, preclude any extensive testing or refinement of this relationship at this time. In all probability, it is doubtful whether this exact relationship will hold for other storm water retention ponds built on watersheds with different characteristics and to different specifications. However, the analyses performed are a good starting point for future research into the retention characteristics of storm water management ponds.

The difficulty with developing exact expressions which describe the operating characteristics of such ponds in the field lies in the intrinsic nature of natural hydrologic systems. Factors which produce variances in the data include:

(1) The watershed area which drains directly to the pond or to the pond outfall gaging station (No. 4). Of the total demonstration watershed, the area draining directly to the pond and to gaging station No. 4, and the area of the pond itself, comprise roughly eight percent of the total drainage area. This means that the runoff

contributed by this eight percent of the watershed is gaged by station No. 4, but not by station No. 3. The effect of this can be seen in the tables in Appendix A, especially for small storms and when the pond is operating with the water level below normal riser elevation. The direct pond drainage area contributes to a higher and sooner peak outflow than if the pond were isolated from any direct runoff or rainfall.

(2) Flow over the emergency spillway causes a discontinuity in the retention and retardation characteristics of the pond. During a storm, when the water elevation in the pond reaches the level where the turf-covered emergency spillway begins to flow, more water is delivered in a shorter period of time to gaging station No. 4 than if the normal overflow riser had carried the entire flow. In essence, once this level is reached, the retention and retardation efficiency of the pond is reduced. Because of the short period of hydrologic record available, no quantitative data could be gathered on this point. However, it appears that the demonstration pond emergency spillway begins to accept overflow whenever the return interval for the rainfall event approaches one year.

This study was performed on a single storm water retention pond. The obvious extension of this study would be to:

(1) Continue gaging the study pond to refine the present evaluation criteria and develop more definitive evaluation parameters

(2) Perform similar studies on a number of storm water retention ponds to establish more detailed design criteria to meet specific requirements

Both of these types of studies could define the effects of varying watershed slopes, direct pond drainage, spillway capacity designs, etc., on the retention and retardation of actual ponds if sufficient long-term records are available. Then designs might be formulated which meet the specific requirements of any storm water management plan.

Design Criteria

Through the study of the project storm water retention pond, certain basic design criteria for other storm water retention ponds can be established. The present pond is designed according to U.S. Department of Agriculture, Soil Conservation Service criteria. The drawdown device is manually controlled.

Such a design is entirely acceptable for a storm water retention pond. Based on the experience acquired from the operation of the project retention pond, some minor refinements in the outlet design could be made to increase the pond's efficiency as a storm water management device. Perforation of the upper section of the normal outfall riser would create more storm water detention, as the accumulated water would release slowly through the perforations until the top of the riser is reached. Then, the normal drop inlet spillway would also begin to discharge storm flow. In addition, an emergency spillway, such as the one presently installed in the project pond, would provide an escape route for the occasional large storm.

The inclusion of perforations in the upper part of the normal overflow riser would result in a greater fluctuation in the pond water level elevation between base and storm flows than if the pond were continually operated at normal riser elevation. Such a situation should be taken into account if development is planned in the vicinity of the pond.

STORM WATER TREATMENT

Methods for the treatment of storm water before its release from the pond were investigated. The purpose of this was to determine if a water quality significantly higher than would normally be released from the pond could be economically achieved. If the preliminary analyses indicated that such a feasibility existed, the selected treatment system(s) would then be demonstrated.

The preliminary investigations narrowed the type of treatment down to two basic methods. One involved the use of an inclined tube settler at the outfall to the pond and the other was the addition of polyelectrolytes either separately or in combination with the tube settler. The inclined tube settler had not been previously used on storm water runoff. Polyelectrolytes, on the other hand, have been used previously on storm water; for example, at Lake Needwood in Montgomery County, Maryland (Ref. 2).

An analysis of the trap efficiency of the combined pond and forebay system concluded that water leaving the pond would have suspended solids concentrations generally less than 100 mg/ℓ. This analysis was later verified during the course of the demonstration project by actual field data. Discussions with manufacturers of inclined tube settlers revealed that the removal efficiency of inclined tube settlers is greatly reduced at concentrations of less than 100 mg/ℓ. Consequently, the idea of installing such a device was abandoned since it would not economically add materially to the trap efficiency of the pond.

Previously, the use of poyelectrolytes has improved settling of the suspended solids in storm flows into lakes (Ref. 2). At low concentrations, it has been necessary to also add ferric salts to economically obtain settling, even withpolyelectrolytes. Based on these facts and the computed excellent natural trap efficiency of the pond and forebay system, the addition of polyelectrolytes was also rejected on the basis that their use would not contribute to a significant increase in pond outflow water quality.

PUBLIC ACCEPTANCE AND FLOODPLAIN UTILIZATION SURVEYS

In conjunction with the storm water aspects of this demonstration program, the Columbia Parks and Recreation Association, Inc., a nonprofit corporation responsible for the development and maintenance of open space in Columbia, conducted a survey of the residents of the Village of Long Reach. Generally, their survey was designed to gather opinions and suggestions in three major areas. First, they requested suggestions as to how the residents would like to see the area adjacent to the lake and the floodplain upstream developed for recreation. Secondly, they asked the residents how they were currently utilizing the lake and floodplain areas (the construction activities have not been completed and only minor recreation development had been accomplished). Their third major interest was concerned with the basic desirability of a four-acre pond and the effect of this pond on real estate, aesthetic and recreational values.

One hundred fifty questionnaires were prepared for distribution. The Village Board of Long Reach assumed the responsibility for the distribution of the forms to the residents. Addressed and stamped envelopes were also included for the return of the completed forms.

The questionnaire consisted of 16 questions and it was estimated that they would be completed by interested residents in approximately 15 minutes.

Of the 150 questionnaires distributed, 27 were returned to the Columbia Parks and Recreation Association. The 18 percent return of questionnaires was judged to be a very good response to the questionnaire survey.

The questions and responses that are pertinent to the demonstration program are listed below.

Because of the qualitative nature of many of the questions, the comments on the responses are presented below. Interpretations and conclusions can then be formulated by the reader without the possibility of compilation prejudices being inserted during the preparation of this report.

Question:

Are you aware that a research project is being conducted in the Long Reach drainage area upstream from Tamar Drive?

Yes – 12 No – 15

Question:

Are you aware that sediment has been removed from the Hittman Pond at Tamar Drive?

Yes – 9 No – 18

Question:

Did this sediment removal impose any degree of hardship and if so, how?

No – 26

No Answer or Blank – 1

Comments:

1. It still seems to be quite dirty
2. Except for eyesore

Question:

As a resident, what comments can you make regarding the sediment removal at the Hittman Pond.

No Answer or Blank – 17

Comments:

1. It was carried out with the utmost efficiency & with little or no inconvenience to the residents of Long Reach.

Comments (continued):

2. We have lived here six weeks and have not seen any work being done at the pond.

3. Excess sediment in the pond is a danger to anyone accidently falling in & a potential "Killer" to any fish or plants growing in the pond.

4. I approve.

5. I know that sedimentation leads to eventual eutrophication and that removal of sediment was probably necessary to maintain the pond. Eventually I would think the pond would fill in completely because of construction runoff.

6. If the sediment is removed & replaced by stocking the pond with fish it would be an added attraction to Long Reach.

7. The removal must in some way be beneficial if the Columbia Association and Long Reach Village Board are sponsoring the project.

8. Probably a good idea to make the pond more useable for boating and fishing.

9. I don't feel that the pond will be free of the large amount of sediment until construction is complete and the open space is fixed up.

10. I feel the removal of sediment made the Hittman Pond cleaner & more desirable area to picnic in.

Question:

Do you feel that the Lake's existence enhances property values adjacent to and Village wide?

Yes – 22 No – 4

No Answer or Blank – 1

Comments:

1. Very much so.

Comments (continued):

2. As evidence to this fact, builders charge a premium for lots adjacent to the lake.

3. The presence of the pond improves our community generally and enhances property values.

4. Even though it and the surrounding area does not look good.

5. Unless it is allowed to become an eyesore and health hazard through lack of maintenance.

6. Not necessarily. (Accompanies a "no" answer)

7. Most definitely. (Accompanies a "yes" answer)

8. I feel it enhances property adjacent to it right now.

Question:

Have you used this area for any recreational activities and if so, how?

Yes – 16 No – 11

Comments:

1. Picnic – tadpole collecting – children play there.

2. Bird watching – hiking.

3. Just walks

4. Picnics and passive recreational purposes

5. Walking, exploring woods, bicycling, etc.

6. Riding & walking the trail along the feeder stream & skipping stones with the kids & walking the adjacent fields. Significantly, contemplating the two springs that have been left to deteriorate near the big trees.

7. I pushed a bike around it twice.
I with the children sailed toy sail boats (sic). The area is not capable of supporting any recreational activities because of the condition of the ground – weeds, rocks,

Comments (continued):

7. very uneven ground, trash, cement piles – its worse than a cow pasture.

8. Walks & bike rides.

9. Picnics.

10. Picnic.

11. I tried out my fly-rod a few times, but never caught any fish. I would like to try out a small sail boat on the pond next summer.

12. We have had a few picnics down there and my sons enjoy playing in the stream under the bridge although we haven't been down there since the hurricane rains polluted the streams & lake.

13. To look at and enjoy the natural beauty.

14. Our family has had several picnics by the pond, we also find it a very pleasant area for walking which we do every day. We also hope the pond will be stocked for fishing.

15. We bicycle to the area & sit there for a rest. Hope to picnic there next spring & summer if the weeds in the area are cut regularly.

16. Bike path.

Question:

What kinds of recreation might you suggest in and around the Lake?

Comments:

1. Tot-lot. Picnic tables. Is it possible to spray for bugs during the spring & summer months

2. Picnic, fishing, skating.

3. Boating.

Comments (continued):

4. Long Reach needs teen and adult recreation facilities. Nobody wants them anywhere. I think the park might donate part of its land to basketball courts, tennis or some such activity.

5. Band concerts, picnic areas, boating?

6. No answer at this time.

7. Picnic Area.

8. Foot paths, sitting areas & open grass areas for unstructured play.

9. To be stocked with fish. Would not like to see a concession operated at the lake – whether C.A. (Columbia Assn.) and/or H.R.D. (Howard Research and Development Corp.), or any other private enterprise!

10. I think something could be done with the springs – restored spring house, for example.

11. Fishing, Picnic.

12. Mall 'city' basketball courts (sic). Good area to teach children boat safety. Also good for children with small boats to use area for docking.

13. Picnicing, a restful spot. Fishing for kids.

14. If you can clean it up, swimming.

15. Fishing.

16. Picnic tables – benches – Bar-B-Q Pits, Trash cans.

17. Picnic facilities with adequate trash containers & signs warning against littering! Fishing, sail boating – both oriented toward children.

18. Boating.

19. Picnics, bicycle path, etc.

Comments (continued):

20. Boating, fishing, ice skating, picnics.

21. Fishing, primarily, if not exclusively.

22. Boating, fishing, picnic tables, maybe a playground (a small one).

23. I understand plans are to stock the pond with fish. This is a good idea & we are in favor of it. Small boats such as canoes, or tiny sail boats would not be objectionable.

24. A. fishing B. Model boat contests C. Just an area where life may be found D. Picnicing (tadpoles, etc.)

25. Picnic Area – stock with fish so children can fish there.

26. Picnicing, boating (row boats) maybe fishing. A rock climbing and sand area made as natural as possible for smaller children would be an asset.

27. Fishing, ice skating.

Because of the general subjective nature of the survey, the small number of surveyed units, and the returned questionnaires, quantitative evaluation is not warranted . However, some conclusions and observations can be made. It can be safely reported that the physical process of the removal of sediment from the pond did not impose any degree of hardship on the residents of the Village of Long Reach. These same residents indicate that the presence of the four-acre pond in their neighborhood did enhance property values and that they desired to see the area remain as "natural" as possible and that recreational development should be oriented toward family activities, such as picnicing, enjoying nature, etc., and children's activities.

Raw data are included so that readers of this report may consider or use it in light of their own experience and/or requirements.

SECTION VI

HYDROLOGY AND ECOLOGY STUDIES

HYDROLOGY

The hydrology investigations under this project can be divided into three general categories:

1. Hydrology of urbanizing areas. The gaging stations described in Section IV were utilized to study the changes in the surface water hydrology brought about as a watershed goes from a completely natural state to a fully developed urban area.
2. Stream channel morphology studies. Cross sections were surveyed at eight different locations along the main stream channel and reference subwatershed tributary. These sections were resurveyed quarterly to determine what changes, if any, occurred in the channel configuration during the various phases of construction.
3. Application of the EPA Storm Water Management Model (Ref. 2). Originally, this computer model was to be applied three times utilizing data from the watershed while it was in different stages of development. The calculated results were to be compared to actual gaged data. The purpose of this study was to verify the model and to test its applicability to watersheds which support various degrees of urbanization.

Hydrology of urbanizing areas

A total of twelve months of gaging records were acquired during the life of this project. This is not a long time, hydrologically speaking. However, this time span does include a record of the area from the time rough grading for the roads was finished up until approximately 40 percent of the area was developed at the project termination date.

Gages at the termini of the reference and experimental subwatersheds provided sharp contrasts in how runoff was generated and subsequently transported in a subwatershed. Land use in the reference subwatershed (see Figure 3) will consist predominately of medium and low density housing and open space school sites upon completion of development. Storm sewers drain the streets of this subwatershed directly into the natural stream channel. The experimental subwatershed will consist entirely of low density housing when development is complete. In contrast, however, this subwatershed is completely storm sewered. The runoff from the streets flows into storm sewers which collect the water and transport it by pipe directly to the main stream channel of the subwatershed at the terminus of the experimental subwatershed. The stream gaging station for the experimental subwatershed is located directly downstream from this main storm sewer outfall for the system.

The stream draining the reference subwatershed goes dry at the gaging station during the summer months of a dry year. This occurred, for example, during midsummer of 1970. Gaging station No. 2, on the other hand, should rarely record no flow since this subwatershed contains numerous springs and seeps which provide an almost continuous base flow.

In order to compare the reference and experimental watersheds on an equal basis, the base flows were subtracted from the storm runoffs and the runoffs for the two watersheds for the recorded storms were then normalized with respect to area. That is, from the standard discharge versus time hydrograph, a new, discharge-minus-base flow-per-unit-area versus time hydrograph was plotted for each station. Since the average slopes of the two watersheds are approximately equal, this normalization procedure reduces the number of variables which could produce a difference in runoff (or water yield) from each watershed. When this is done, the following conclusions can be drawn:

(1) Throughout the term of the demonstration project the experimental subwatershed generally produced less

storm runoff per unit area than the reference subwatershed. This is to be expected since the experimental subwatershed's natural ground cover is almost 100 percent forest while the reference subwatershed has a large quantity of open field. The experimental subwatershed is now completely storm sewered. That is, the natural stream channels have all been replaced by buried concrete storm sewers. The outfall to this storm sewer system is immediately upstream of gaging station No. 2. On the other hand, the storm sewers in the reference subwatershed empty into the natural stream channels. However, the reference subwatershed is subject to more intense development. Table 6 summarizes some of these characteristics of the two subwatersheds as related to their effects on the storm runoff yield per unit area.

(2) Smaller runoff events generally produce a greater difference in runoff per unit area between the two subwatersheds than do larger runoff events, although exceptions do occur as in any natural system. Figures 12 and 13 illustrate this difference. In Figure 12, the peak storm runoff (total runoff minus base flow) per acre for the reference subwatershed is almost twice that for the experimental subwatershed. Figure 13 shows a larger storm and its corresponding effect on the runoff yields per unit area of the two subwatersheds. The storms in Figures 12 and 13 ocurred within a few days of each other and thus the subwatersheds were in the same stage of development. In Figure 13 (the larger storm), the difference in runoff (minus base flow) per acre is much less than for the smaller storm (Figure 12. These two illustrative hydrographs are typical of the results obtained from most other storms.

(3) As development progressed in the two subwatersheds, less of a difference in the runoff yields between the two

TABLE 6. REFERENCE AND EXPERIMENTAL SUBWATERSHED CHARACTERISTICS AS RELATED TO STORM RUNOFF PRODUCED

Characteristic	Reference Subwatershed Description	Experimental Subwatershed Description	Subwatershed with greater storm runoff per unit area as a result of characteristic
Natural ground cover	60% open field, 40% wooded	95% wooded, 5% open field	Reference
Storm sewers	Storm sewers empty into natural stream channel.	No natural stream channels, completely storm sewered.	Experimental
Development	Medium and low density housing. Approximately 20% of area devoted to school site, including parking lot.	All low density housing.	Reference
Average slope of ground	Approximately 4%	Approximately 4%	Equal

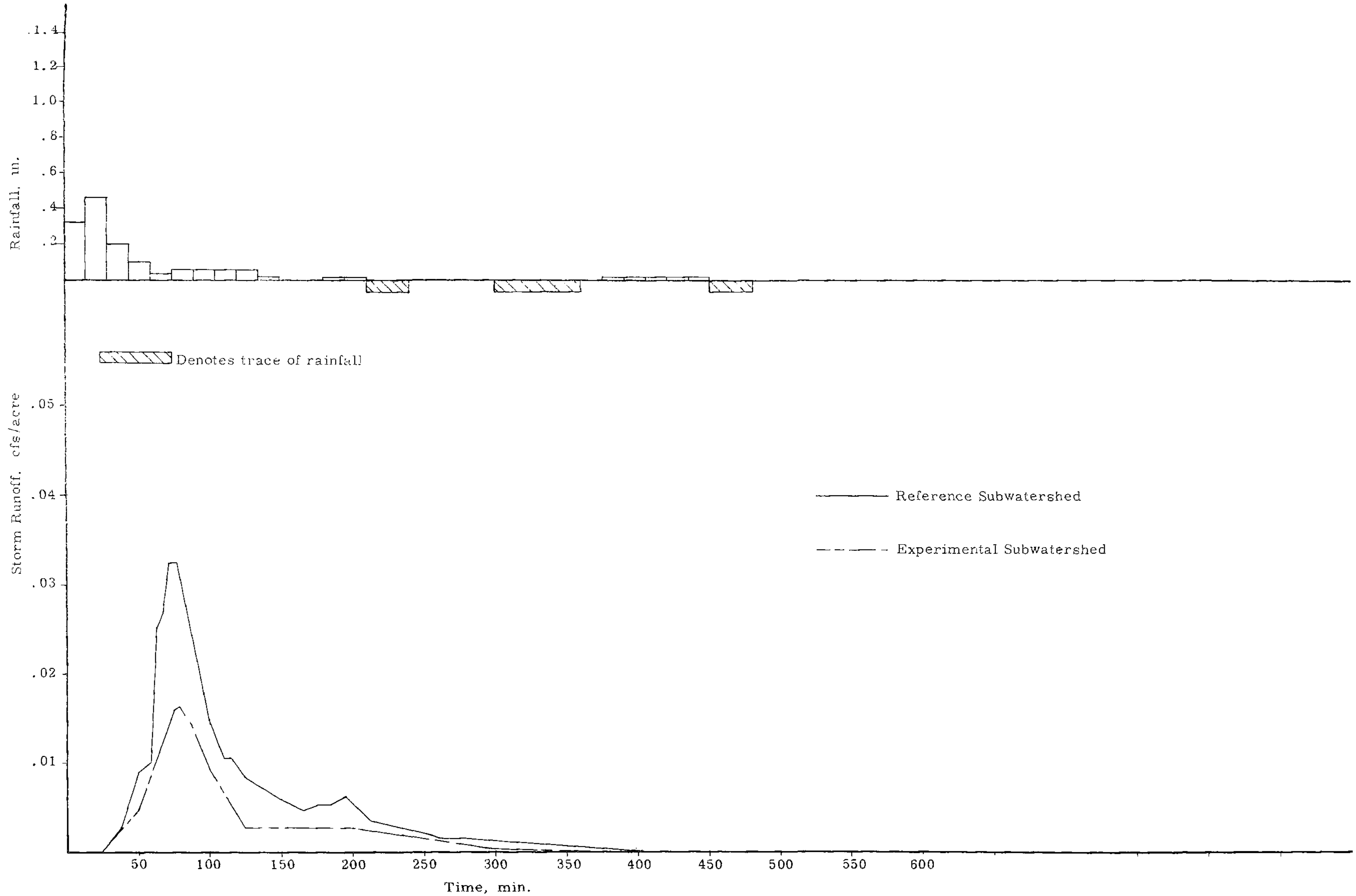

Figure 12. Storm Runoff Hydrograph for Storm of July 29-30, 1971

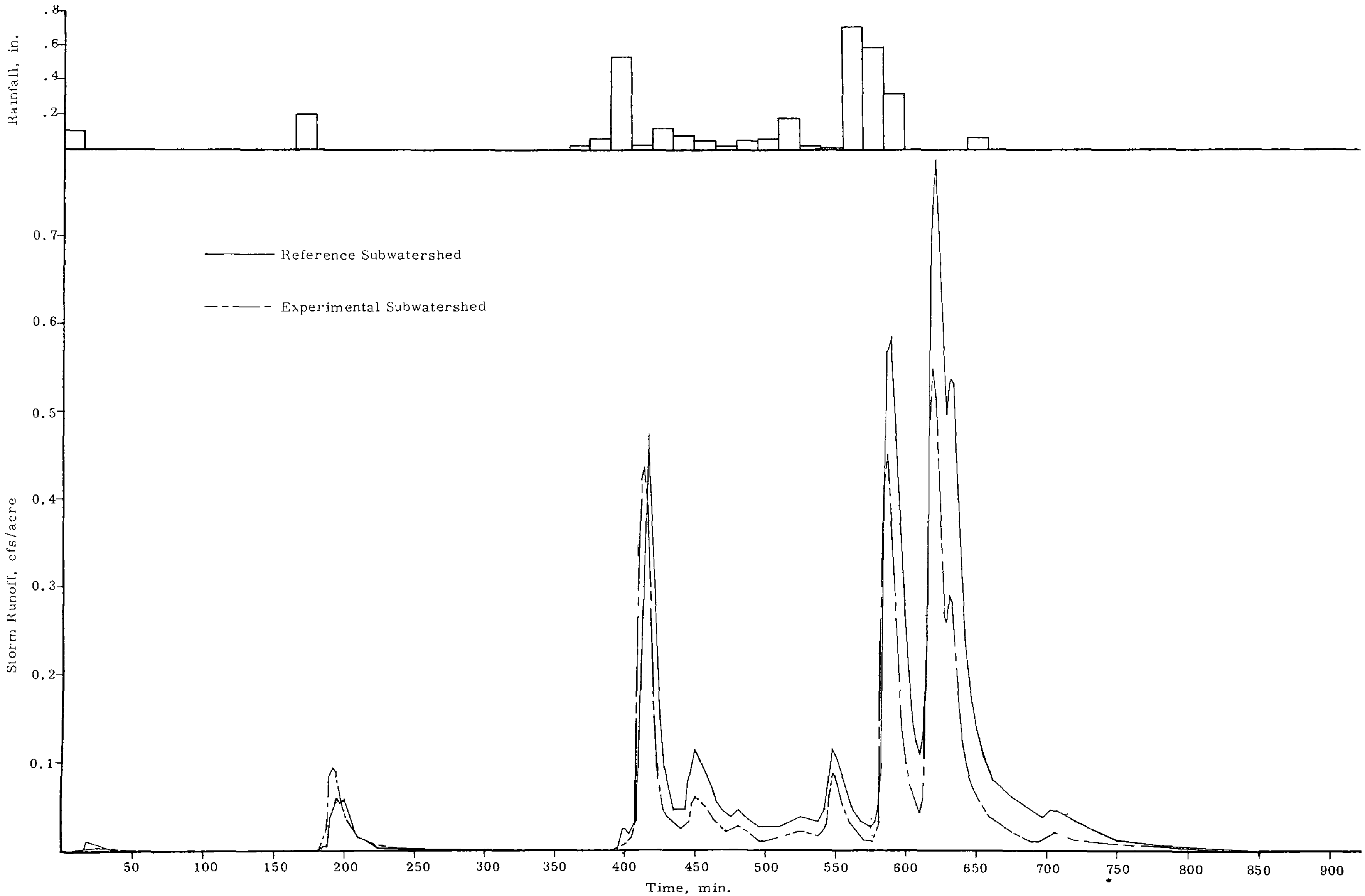

Figure 13. Storm Runoff Hydrograph for Storm of August 1-2, 1971

subwatersheds resulted. Figure 14 illustrates this point. This storm occurred toward the end of the demonstration project when more development had taken place in the two subwatersheds. Here, the closeness between the storm runoff yields per unit area for the two subwatersheds is apparent. This trend was observed as construction proceeded in the subwatersheds. Both large and small storms generally produced less of a difference in yield between the two subwatersheds.

The above preliminary conclusions can be drawn even though development is not yet complete within the project area. No change in other hydrologic parameters such as the response and lag time could be discerned for either subwatershed during the course of development. This is, perhaps, due to the fact that urbanization was not yet complete in the subwatersheds as the project drew to a close. Continued gaging of this area is thus recommended in order to fully explore the changes in the hydrologic parameters which occur when a watershed goes from essentially undeveloped to urban.

Stream Channel Morphology

Benchmarks were established and initial cross sections were surveyed at eight locations along the main stream channel of the demonstration watershed in October 1970. This time corresponded to the completion of rough grading of the major roads. No other development had occurred in the watershed. The sections were then resurveyed on a quarterly basis to determine the changes which a natural stream channel undergoes as the land use in a watershed goes from a predominately natural state to one of moderate urbanization. Figure 15 shows the locations of these eight stream channel cross sections. Appendix B contains the cross sections at these eight locations which illustrate the observed stream channel changes.

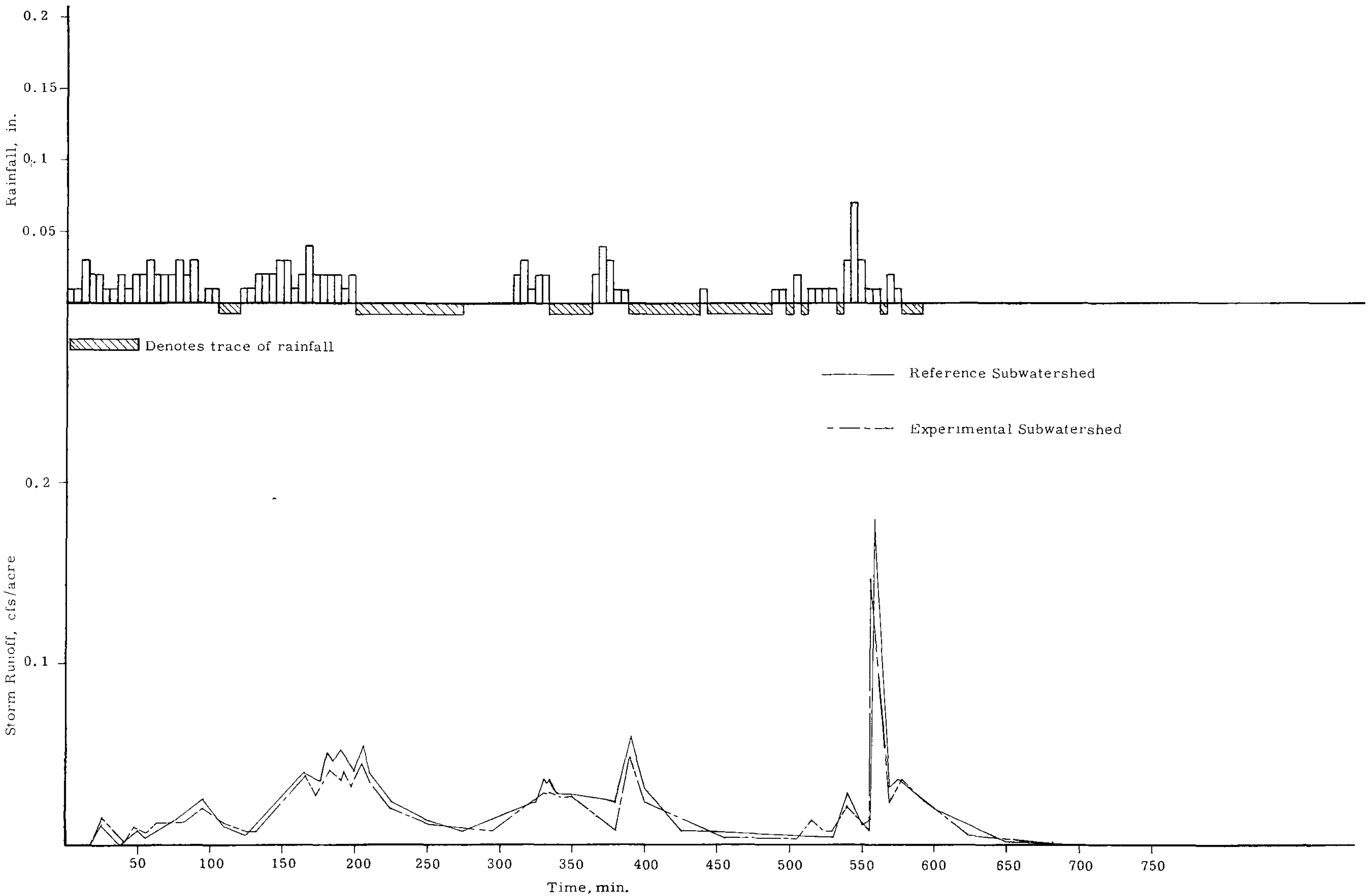

Figure 14. Storm Runoff Hydrograph for Storm of April 13, 1972

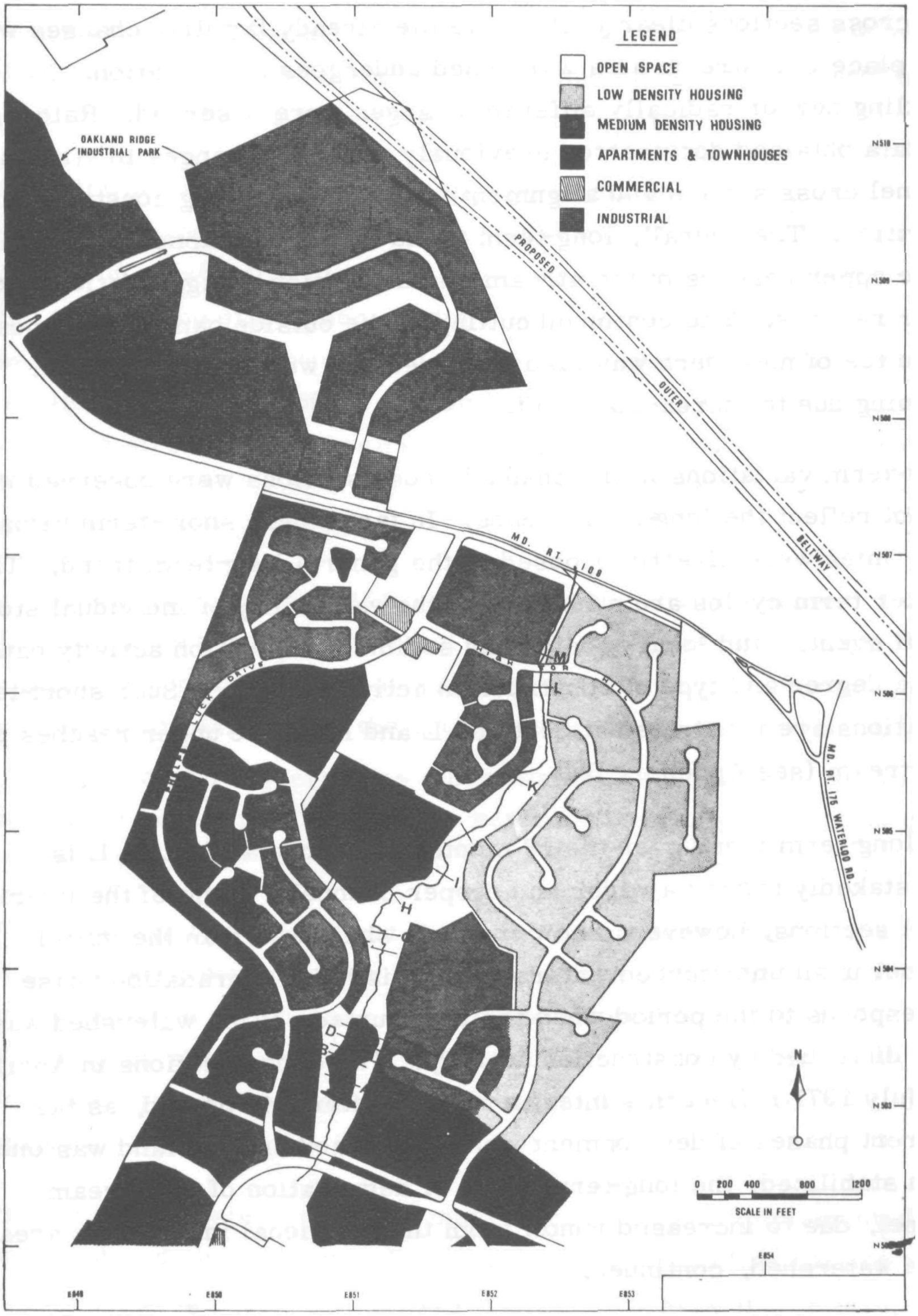

Figure 15. Map of Demonstration Area with Stream Channel Cross Section Locations

The cross sections clearly illustrate the already familiar changes which take place in a stream as a watershed undergoes urbanization. No startling new or radically different changes were observed. Rather, the data obtained documented previously reported changes in stream channel cross section and alignment which occur during construction activities. The overall, long-term trend is one of channel downcutting in the upper reaches of the stream and deposition or aggradation in the lower reaches. The continued cutting of the outside banks and deposition at the toe of meanders was also observed, as was general channel widening due to increased runoff.

Short-term variations in the channel cross sections were observed which did not reflect the long-term trends. In fact, these short-term variations sometimes were directly opposed to the general long-term trend. These shorter term cycles are a function of the variability of individual storm runoff events, and local erosion and sediment deposition activity caused by the degree and type of construction activity nearby. Such short-term variations are illustrated at Sections L and M on the upper reaches of the stream (see Appendix B).

The long-term trend over the 18 months of record at Section L is unmistakedly toward a wider and deeper channel. Some of the interim cross sections, however, show channels shallower than the initial channel in an undisturbed watershed. This brief aggradation phase corresponds to the period when the land surface of the watershed was most disturbed by construction activity. The cross sections in April and July 1971 reflect this interim trend. After this period, as the different phases of development were completed and the land was once again stabilized, the long-term cycle of degradation of the stream channel, due to increased runoff from the additional impervious area in the watershed, continued.

Section M also exhibited such a short-term variation in its general degrading trend. First, aggradation occurred as the land was denuded by local construction activity and erosion increased. Then, downcutting predominated as storm runoff increased upon completion of storm sewer construction. Stabilization of the channel at its final elevation and configuration was only accomplished through use of a concrete lining which connects into a culvert under High Tor Hill.

In the lower reaches of the stream, including Sections F, G, and M, the oftentimes excessive deposition can be attributed to both the greater amount of construction activity downstream as well as the general flattening of the streambed gradient downstream of Section I. In addition, the storm water retention pond and its accompaning forebay serve as excellent preservers of the stream bed bottom elevation in this area. All three stream gaging weirs and their accompanying downstream Fabriform® protection were also observed to function as excellent local grade control structures.

Section H, established at the bend of a rather sharp meander, further illustrates the natural process of channel realignment and cross section adjustment inherent in any stream whose watershed is undergoing drastic land use changes. Here, the outside (west bank) of the meander continues to actively erode as storm water flows increase due to the increased impervious area in the watershed and the installation of storm sewers.

From Section I to points upstream, the characteristic geomorphic process is one of degradation rather than aggradation of the channel bottom. This corresponds to an increase in the channel slope upstream of Section H. The steeper slope coupled with the increased storm water runoff from developed areas produces the consequent observed downcutting of the channel.

This study indicates that, on a macro scale the plan implemented for sediment and erosion control during development in this portion of the Village of Long Reach works very well. Little sediment is deposited downstream of the watershed under study due to the large combination storm water and sediment retention pond. More work needs to be done on a micro scale, i.e., upstream of the pond, however, if the stream channels in such areas are to be preserved in a natural state. Both comprehensive storm water management and local erosion control programs are needed to preserve the configuration of the stream channel and prevent future flooding problems. Although the stream channel studied may be quite small in comparison to channels in urban areas which presently cause problems, this study nevertheless dramatically illustrates the causes and effects which construction activity has on a previously undisturbed watershed.

Application of the EPA Storm Water Management Model

The EPA Storm Water Management Model is basically a tool developed to aid in predicting the amount of runoff and pollutants delivered from given rainfall events in a completely urban area. During the course of this project, three major runs of the Model were completed. A number of minor runs were also made as input deficiencies were found and corrected.

Because of the low degree of urbanization prevalent in the demonstration project watershed throughout the project and the discontinuous storm sewer system, the applicability of the Storm Water Management Model could not be fully tested. Nevertheless, actual field data was input into the model in order to try to discern its sensitivity to the various watershed parameters in small and largely undeveloped watersheds. The EXECUTIVE and RUNOFF Blocks were primarily used during these analyses. When a watershed parameter was not known or could not be measured to any great degree of accuracy, the program was left to choose its own built-in default values.

Reasonable results were obtained from the RUNOFF Block even with the low degree of urbanization present. Figures 16 and 17 show the hyetograph and the overland flow hydrograph for one of the subbasins in the experimental subwatershed for the storm of July 1 to July 2, 1971. The subbasin shown comprises 2.14 acres near the downstream terminus of the experimental subwatershed. Results such as shown are typical of those received and appear reasonable for the area.

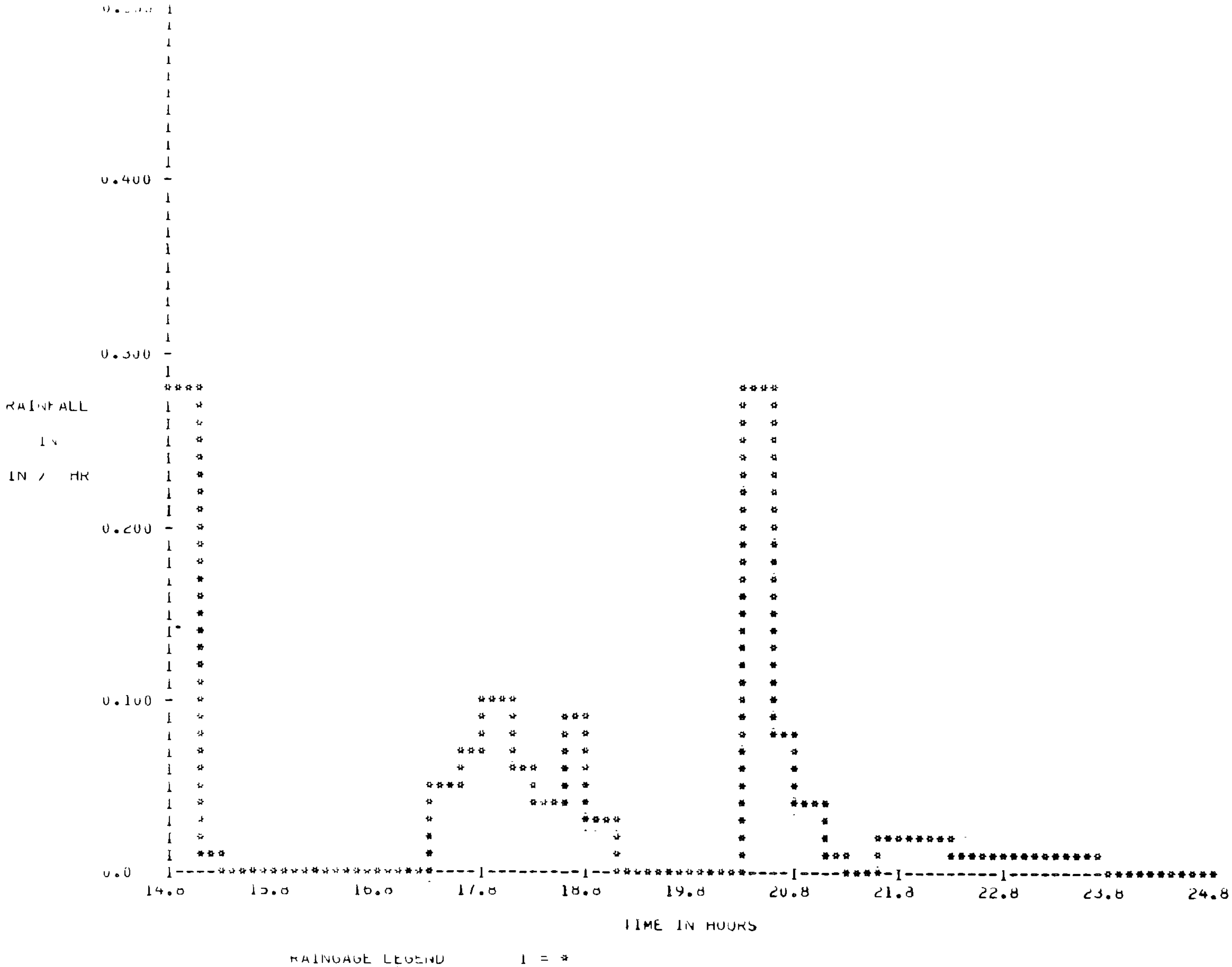

Figure 16. Computer Rainfall Hyetograph for Storm of July 1-2, 1971

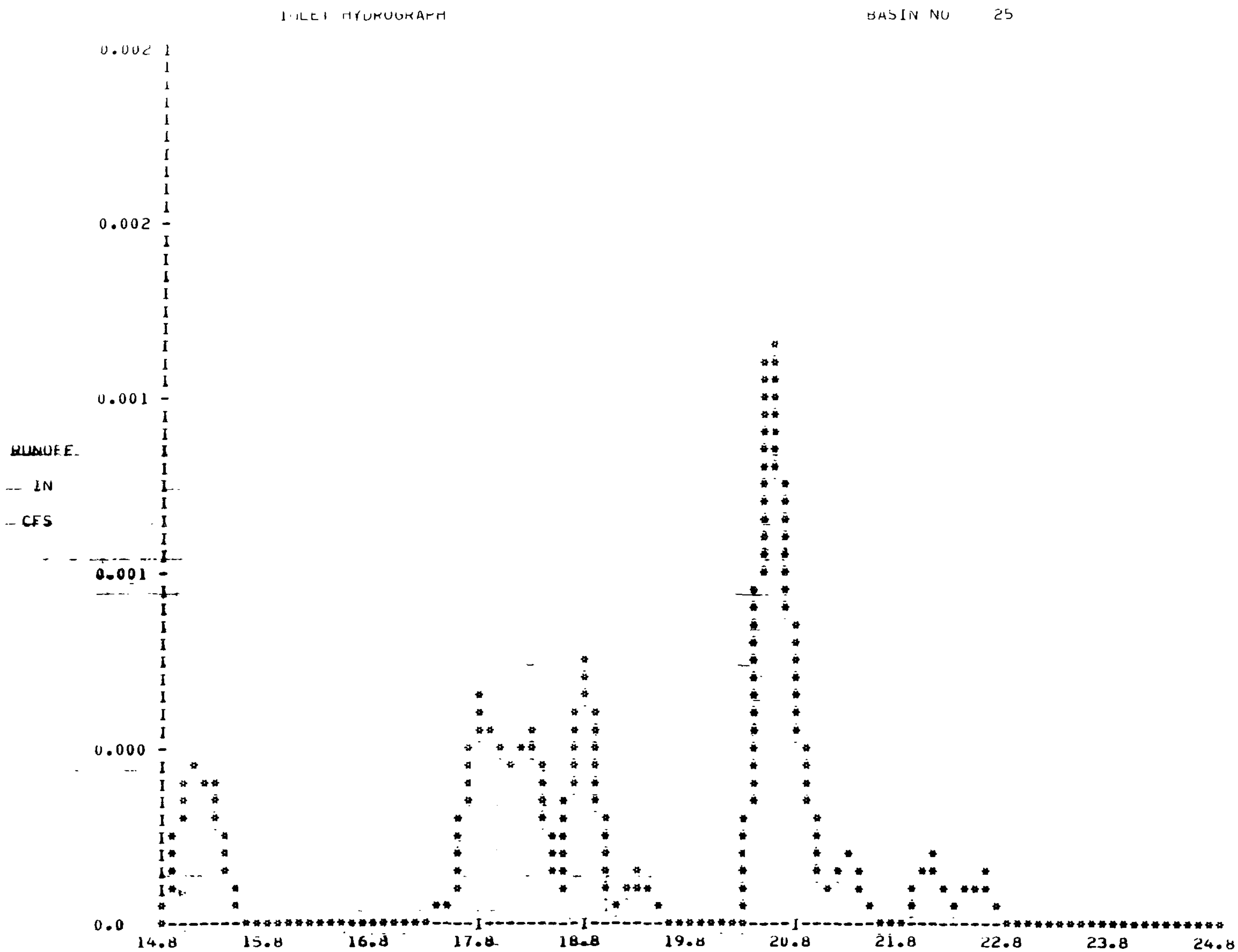

Figure 17. Computer Inlet Hydrograph for Storm of July 1-2, 1971

The TRANSPORT Block of the program was also studied for possible testing. However, the emptying of the storm sewers from the various subbasins directly into the natural stream channels made direct comparison with gaged data impossible in most cases. One computer run utilizing the TRANSPORT Block was attempted for the complete experimental subwatershed when no urbanization had yet been accomplished in the subwatershed. Some preliminary runoffs were obtained at selected points in the subwatershed; however, a complete comparison with actual gaging records at the terminus of the experimental subwatershed could not be done. The EPA Storm Water Management Model was used on very small watersheds, i.e., on the order of a few acres, and in a largely undeveloped area. Thus, a number of peculiarities were discovered which do not normally show up when the model is more suitably used on larger, completely urbanized areas. These include nonacceptance by the Model of zero percent imperviousness values in the input watershed data. This is easily corrected by inputting a very small number which is essentially zero, such as 0.01. Tabular printouts supplied in the RUNOFF Block for the computed quantity and quality parameters usually show zero (0) values for small watersheds. This is due to the fact that the parameters are formulated to be printed only to the hundredth decimal place and naturally, for small watersheds, most of these parameters are measured in very small quantities. This can be changed by simply changing the FORMAT specifications for RUNOFF Block output when small watersheds are being analyzed.

It is recommended that further trials of the EPA Storm Water Management Model be made when the project watershed is at a more extensive degree of development. This would require that adequate gaging records be kept and that construction activity be monitored on a continuous basis. However, it is anticipated that only the experimental subwatershed will be able to be extensively analyzed by the Model because of the discontinuous nature of the storm sewer system throughout the rest of the demonstration watershed. Use of the experimental subwatershed could thus provide a check only on the Model's accuracy for a small watershed in a low density housing area.

Stream Channel and Floodplain Ecology Studies

In this part of the demonstration project,the changes in the ecology of the stream channel and floodplain associated with urbanization were monitored. This monitoring was accomplished by periodic visits to a number of observation sites located throughout the watershed, including points along the main stream channel above the storage pond, points within the storage pond and its forebay, and one point along the main stream channel below the pond.

At each of these points observations were made of the physical appearance and any noticeable changes in the floodplain and stream channel were recorded. Changes in or loss of arboreal species, vegetative cover, and aquatic species were noted. These studies were designed to be of a qualitative nature and were to document the presence of common indicators or nuisance species which accompany degradation of water quality or increasing unsuitability of the environment. The diversity of species was used as a relative indicator of the health of the stream and pond system.

The initial survey was conducted in July of 1970 at the start of the demonstration program. It was a cursory survey without sample collection, count, or analysis and was intended to establish a rudimentary baseline to which subsequent surveys could be compared. The surveys of June and September 1971, May and November 1972, were more formal. The initial survey was conducted by one investigator and the subsequent four were conducted by another, equally well qualified scientist.

Following is a listing prepared from the initial survey of the fauna found on the undersides of small stones and boulders that were abundantly present in the shallow rapids of the streams. Indicators of clean water include:

(1) Tube building caddis fly larvae
(2) Net building caddis fly larvae
(3) Mayfly nymphs

(4) Planaria

(5) Crayfish

(6) Hellgrammites

(7) Snails and snail egg masses

In addition, leeches were observed associated with mud deposits and chironomus midge larvae were found on some slimy surfaces. The chironomus midge larvae usually increase with increased organic pollution.

Brown and tan colored diatom films are indicators of clean water and were observed on stones. A rise in the phosphate content of the water would be indicated by the presence of coppery blue-green algal films on the rocks. Water striders, diving beetles, and water boatmen were observed on films in the water. Rusty colored diatom films were found on aquatic grasses and plants.

Horsefly larvae, dragonfly larvae, and bloodworms are mud dwelling organisms and were observed at various locations. The horsefly larvae were found associated with both clean and rich muds. The dragonfly larvae were usually associated with clean muds, while the bloodworms were noted where there was heavy organic pollution.

Four forms of floating algae were observed. Filamentous green algae (Spirogyra) and Hydrodictyon inhabited the pond and are indicators of clean water. Stigeoclonium, also a clean water indicator, was found in the flowing water.

For purposes of identification in the four subsequent surveys, UPPER STREAM shall refer to the northerly upper branch which is located in the reference subwatershed (Figure 2). The easterly branch was not surveyed. LOWER STREAM shall refer to that portion of the stream from the intersection of the two upper branches to the forebay. POND shall refer to the storm retention pond. SPILLWAY STREAM shall refer to the outflow below the dam.

Not all stations were sampled every time in precisely the same fashion. For example, conditions fluctuated so widely at stations along the lower stream that different locations, over approximately 50 meters, were selected on each occasion. The pond transect was not run in exactly the same line or identical distance since a boat was not used each time, nor were the marking rods always present.

While certain physical and chemical parameters were monitored at the time of each survey, there was no attempt to run complete chemical analyses.

As a result of these and other inequalities, data presented here are primarily qualitative. On the other hand, the structure of certain biotic associations, even the presence (or absence) of specific life-forms, does much to indicate the state of health of an aquatic ecosystem.

At the time the primary stream and pond were seen in the second study, serious degradation had already set in. What few normal biota were found occurred only in the upper reaches of the Upper Stream, but these too disappeared prior to the third and fourth surveys.

A conclusion, which will be reiterated later, is that when the stream-banks have been stabilized, reducing excessive transport of particulate matter, the stream— even with an increase in carrying capacity —has the potential of becoming well-colonized by a variety of lotic organisms. The association of these organisms, or species composition, would indicate the general health, or lack of health, of the stream. But with a thoroughly unstable stream bed (as now exists) that is subject to scouring, excessive sedimentation and flushing rates that may increase by a factor of ten, there are no opportunities for indicator organisms of any sort to become established. Some of the same conditions prevail in the pond as well, but here the biota are already well established. When fine particulate materials and colloids depart, the pond has an excellent chance of becoming a productive and attractive body of water.

Note: Organisms in the following sections are rated by relative abundance as abundant, very common, common, uncommon, rare, based on counts made in both field and laboratory. There was no attempt to relate large, visible forms to microscopic organisms in this scale.

Stream. The stream has suffered continuous degradation over the period it has been observed. It was very nearly abiotic at the last survey. Early in the study, the Upper Stream retained vestiges of its original plant and animal associations, but now it is almost indistinguishable from the severely damaged Lower Stream. The condition of both streams is due almost entirely to a lack of stability, with accompanying sedimentation and abrasive particle transport. Originally it supported a normal coastal plain association of organisms: aquatic, marsh, and moist bank plants, and animals characteristic of both saturated soil and open flowing waters, riffles, and pools. While some of the more mobile animal organisms are still present along the stream banks (red-backed salamander, grass frog) or within the substrate (oligochaetes), little remains of the once-flourishing aquatic insect population, liverworts, mosses, fluviatile algae, rooted aquatics, or even diatom films. In one stretch of over 100 meters, only a single damaged rooted aquatic (Typha) was found in the last survey (November 1972).

Despite severe instability, dissolved oxygen values have consistently appeared favorable. Nutrient load, which could result in eutrophication in a stable stream bed, has not appeared marked at the time of sampling, although it undoubtedly occurs with flush-off from new lawns.

While the Lower Stream was nearly destitute of any significant life-forms at the beginning of the survey, the Upper Stream at first still retained a few that are characteristic of the region. Typical of neuston in such streams was the small, broad-shouldered water strider (Rhagovelia) congregating near small riffle areas. Since their food consists of smaller aquatic insects, worms, and other invertebrates, either on or below the surface, it is assumed there were sufficient quantities of these to sustain the water strider population.

A few small fishes appeared at some distance and were not collected; they resembled dace. The most apparent vertebrates were grass frogs (Rana pipiens) along the banks, and juvenile salamanders (Plethodon sp.) under stones in quiet reaches of the stream. Motile epifaunal forms consisted of isopods (Asellus sp.) which were common, and an occasional crayfish (Orconectes virilis). Mud chimneys were found in associated wet floodplain areas, indicating the chimney crayfish (Cambarus diogenes). The motile insects included stonefly nymphs (unidentified) which were common, mayfly nymphs and subimagoes: a total of three species of immature mayflies, one of which (Potamanthus sp.) was very common.

Attached (sessile) or infanual life-forms included one ectoproct bryozoan colony (Plumatella sp.), several species of caddis fly larvae (Limnephilus Neophylax) that were common, several bettle larvae (Hydropsyche?), and a variety of midge, or chironomid, larvae that were common.

Films of sessile and other diatoms coated many of the larger protruding pebbles. Scrapings revealed both filamentous and nonfilamentous green algae; in two spots there was appreciable blue-green algal growth (Oscillatoria) strongly suggesting local enrichment that dissipated downstream quickly enough to not allow further growth.

In September 1971, in two low-velocity pools, chironomid midge larvae (unidentified green variety) were common on stout submerged logs. In the substrate were rare nematodes and aquatic oligochaetes.

A soft yellow, apparently bacterial, slime streamed out from twigs and pebbles in tufts. Diatoms on exposed surfaces were rare, but among the bacterial filaments small phytoflagellates were common. An occasional larger euglenoid appeared as well. There were a few small ciliates, a few large ciliates (Loxodes), and hypotrichs ranged from few to common. This association, found over much of the stream, was strongly indicative of a polluted condition and was borne out by the presence of scavenging gastrotrichs, scavenging midge larvae, and diatoms that appeared to be Nitzschia.

By May 1972, nearly all of the above organisms were absent from the Upper Stream as well as the Lower Stream. The broad-shouldered water striders were still present in reduced numbers, since they theoretically are agile enough to avoid dangerous situations and capable of seeking minor shelter. Of the truly aquatic animals, only a few caddis fly larvae were found surviving in their heavily-constructed cases. All of the soft-bodied forms had disappeared, as had the algae. In most cases, protruding stones, if they could be found, were scoured clean even of diatoms.

Marginal vegetation along the banks was also severely affected. Much of this had been apparent during the second survey when it was noticed that the floodplain now reached beyond zones that would normally support golden club, skunk cabbage, and cinnamon fern (remnants of all were seen) into sassafras, greenbrier, beech, and oak regions. What degrees of survival or transition might have occurred cannot now be determined, since much of the region has been altered by construction. The larger trees have been left, but whether their root systems will tolerate repeated high water levels is conjectural.

While it is difficult to generalize about the entire stream, in November 1972 it possessed all of the following characteristics in the reaches of the Lower Stream: heavy sedimentation of large abrasive particles that lacked any degree of sphericity, banks that were deeply cut below previous levels, often severely undercut with large chunks washing into meanders; meander deposits consisting both of natural gravel and crushed rock from construction; much debris consisting of brush, leaves, plastic sheeting, etc.; some evidence of iron bacteria in lateral rivulets; no signs of established aquatic vegetation; slight opalescence and some foam in pools. The only animal organisms collected were two aquatic oligochaetes.

In short, the stream at present is very nearly abiotic, at least of macrobiota and large microbiota (bacterial cultures were not attempted). Nevertheless, with proper effort and sufficient time, a stream of this size, with no major pollutant contributions, should recover. It would appear that the greatest problem facing the reestablishment of life in the stream bed is the control of excessive runoff and sedimentation.

Pond. While the pond receives excessive quantitites of sediment from stream and bank drainage, is often totally opaque due to suspended or colloidal particles, and is blanketed with thick bottom deposits, at no time during this survey has it failed to support life, often of an unexpected variety and abundance. To date, most of the biota is composed of small, easily-overlooked organisms. They are, nevertheless, of considerable biological significance. Major trauma, such as hydraulic dredging and lowering of water level, flood rise and major sediment transport, probable enrichment from surrounding lawns and planting, have, at most, only temporarily delayed the expected stages of aquatic succession.

It is far from a balanced pond community. For example, the benthic community, normally so important to the exchange of nutrients and nitrification, is almost completely absent due to the suffocating effects of clay-sized particles that carpet the bottom more than 1 m. thick. Such pioneer rooted emergents as have been seen around the pond margins on one survey, often are found destroyed on the subsequent trip. The opacity of the water prevents primary production by algae or spermatophytes more than a few centimeters deep. Clearing is remarkably slow due to the minute size of suspended particles.

Nevertheless, the littoral zone is biologically very active, and the plankton populations have not only shown continued growth, but a truly remarkable increase in variety, which must be construed as a tentative approach to health. When sediment levels fall and the water clears, when organic detritus builds upon the substrate of clay, the nucleus of biota already present will allow growth and production toward a mature pond.

Early in the sampling (June 1971), many of the plankters still dominating were already present, although plankton diversity was not so great as today. Phytoflagellates were uncommon, blue-green algae (Oscillatoria) rare, and one diatom (Pinnularia) was common to abundant. One ciliate (Dileptus) was rare, but the rotifers were abundant in toto, although at the species level, only one (Asplanchna) was common. Others (Keratella, Polyarthra, Noteus, and Cephalodella) occurred more sporadically. The predaceous midge larva (Corethra) was a surprising find, since it usually occurs in lakes, not ponds. Of planktonic crustaceans, only Diaptomus and its nauplius larvae appeared; both were common.

In September 1971, after a long summer growing season, the pond harbored a wide variety of aquatic and migrant organisms. The water, while still tan with clay particles, had a greenish cast that was not entirely borne out by its plankton populations, described shortly. Black ducks were seen feeding along the shoreline; tadpoles (Rana clamitans?) were common in the shallows, as were small diving beetles (Haliplus). A few rooted emergent seed plants (Scirpus, one Typha) had appeared along the shoreline, and a single frond of crisp-leaf pondweed (Potamogeton natans) was collected with a dip net. A few small patches of filamentous green algae floated at the surface at the lower end of the pond, but there was no obvious bloom.

Plankton tows yielded a wide variety and huge populations at this period. Algal indicators of water quality were somewhat contradictory, with filamentous blue-greens (Oscillatoria) very abundant, euglenoids (Euglena) common, both being indicative of organic enrichment or pollution, but Ankistrodesmus falcatus var. acicularis, a green unicell characteristic of clean water, abundant as well. The filamentous green alga, Spirogyra, was common, and the desmid Closterium, rare. There were several species of small phytomonads, possible indicators of pollution, and on-the-spot microscopy revealed a high count of active bacilli. Diatoms were represented mostly by Pinnularia, generally recognized as a clean water form; it was common. Fragillaria was present, but uncommon; Diatoma was common, although only toward the lower end of the pond.

Among the zooplankton, filter-feeding protozoans and rotifers dominated. Vorticella monilata occurred commonly on surfaces along the shoreline, while another ciliate protozoan (Dileptus) was common in plankton hauls. Rotifers in toto were abundant, indvidual species ranging from common to abundant (Keratella, Euchlanis, Dicranophorus, Polyarthra, Synchaeta --not in order of relative abundance). A few other ciliates (Urocentrum turbo) and rotifers (Monommata) were seen, but only rarely.

Copepod crustacean nauplius larvae were abundant, as were adults of one species (Diaptomus), while another adult (Canthocamptus) was uncommon. A predaceous midge larva (Corethra) was present in the plankton, but curiously one of its staple types of food, the entire group of cladoceran crustacea, appeared to be totally absent (see text for November 1972).

By mid-May 1972, after a period of winter quiescence, a wide plankton diversity continued unabated. Most notable was the presence of enormous numbers of algal primary producers, notably a slender green desmid (Ankistrodesmus falcatus var. acicularis) which is recognized as an indicator of clean water. An indicator to the contrary, Euglena, was seen but rarely. Diatoms in toto and separately were abundant, all of which species seen are associated with biologically clean water. While most of the diatoms were planktonic, some were associated with three species of filamentous green algae that flourished in shallow water along the western shoreline. The dominant green filament was of a Ulothrix-type, but an unfamiliar variety. Attached to this were such diatoms as Gomphonema and Navicula, while planktonic diatoms included Diatoma, Fragillaria, Meridion, Tabellaria, Surirella, and Navicula. Fragillaria was abundant, Navicula and Gomphonema common. The only desmid other than Ankistrodesmus (the most abundant organism present) was a rare Cosmarium.

Other than several unidentified ostracods and a few very small Kurzia-type cladocerans, the zooplankton was almost absent. On the other hand, bottom samples and culling through the algal masses yielded nematodes, chironomid midge larvae, dragonfly nymphs (the large Anax), Hydra oligactis, unidentified damselfly nymphs, gastropod molluscs (Physa), aquatic oligochaetes, a larval salamander (Plethodon sp.), and several fishfly larvae (Chauliodes).

The final pond survey was conducted in mid-November 1972. The water was totally opaque due to an extraordinarily heavy load of clay-sized and colloidal particles. The substrate was slippery, dense, and almost completely impenetrable by infaunal animals or root systems. The west bank was cut over but not eroded, while the east bank had been graded, seeded, but left with bare earth along the shoreline. There was no evidence of rooted aquatic emergent plants on either shore, although the island appeared well vegetated and possessed some emergents, a possible stock source for natural dispersal. Dissolved oxygen levels were somewhat lower than usual at the surface (9.75 ppm); nevertheless the plankton community was flourishing.

From fragments along the shore, it appeared that blue flag and water hemlock had grown recently somewhere along the pond margin. In the water, several extensive masses of filamentous green alga (Spirogyra) supported an extensive community of life-forms. Earlier filamentous greens noted on previous surveys seemed to have been succeeded by Spirogyra. Its filaments were not heavily fouled, as had been the case with Ulothrix earlier, although there was some evidence of clusters of one type of diatom (Navicula) attaching. Ciliate protozoans (Vorticella sp.) were attached, but little else. Interspersed in the algal masses were a few smaller primary producers, notably desmids and some free-living diatoms (Gyrosigma).

One rotifer (Notommata copeus) was common, as were ovigerous copepod crustaceans (Cyclops). Among the larger animal life-forms, two or three species of myfly nymph (one was Bactis), one gastropod mollusc (Physa), one damselfly nymph, a black chironomid midge larva, and a waterboatman (Corixa), all approached being common. Semiaquatic oligochaete worms were present in the saturated littoral, but not in the substrate which seemed abiotic.

The plankton community on this date was characterized by an explosion of cladoceran crustaceans which in previous surveys had been nearly absent. All cladocerans were common, some abundant, especially a small, two-eyed species that remains unidentified. Others included Bosmina sp., Bosmina longirostris, Daphnia, Ophryoxus, Alonella nana, Chydorus, and Macrothrix; an unusually wide variety for one order of Crustacea. Among the copepod crustaceans, Diaptomus was still abundant, and another unidentified form was present, but uncommon. Hydra oligactis was collected with the plankton, but either came from the surface film or from the algal masses close to shore. This coelenterate was almost common. In every case it was found to have eaten several cladocerans, but no copepods.

The only other crustaceans present were two species of ostracods, both unidentified, one large form being common. Nauplius larvae of the copepods were, of course, common.

Rotifer populations were sparse, with only Keratella showing up repeatedly, therefore abundant. Ciliate protozoans were uncommon, with only the motile form of Vorticella appearing more than a few times; it was still uncommon, however. Single sightings were made of a large unidentified ciliate and a small nonphotosynthetic flagellate. Several rhabdocoel flatworms were collected, but not identifed. The euglenoid Phacus was the only suggestion of unclean water, but it was rare and therefore not indicative.

The Spillway Stream is a stream seriously affected by many of the same conditions present in the upper watershed area, but unlike that region has shown somewhat greater stability with small populations of fluviatile plants and lotic fauna.

SUMMARY STATEMENT

As noted earlier, the lotic environment of the stream is all but destroyed. Its present condition is due almost entirely to a lack of stability, with accompanying heavy sedimentation and abrasive particle transport. Originally it supported a fairly normal coastal plain association of organisms, including aquatic and marsh plants, and animals characteristic of both saturated soil and open flowing waters, riffle and pool. While some of the more mobile fauna (salamanders, oligochaete worms) are still present along the stream banks or within the coarse substrate, little remains of the once-flourishing aquatic insect population, liverworts, mosses, fluviatile algae, and rooted aquatic plants.

Should the banks of the stream be stabilized in the future by new vegetation, the runoff of organic compounds discouraged, and storm water management measures taken to reduce the volume of periodic surges, the stream could recover a measure of its former condition. It is unlikely, however, that stream bank, pool, and riffle diversity will ever be as great again, primarily because of efforts needed to manage a simplifed and controlled watershed.

The lentic environment of the pond, while affected, at times severely so and still reduced in environmental opportunities, nevertheless gives the impression of an ecosystem showing rapid trends toward a natural succession of life-forms. This succession is delayed, however, by sediment that continues to escape the forebay, descending to carpet the substrate or creating an opacity that denies light penetration, thereby limiting the photic zone close to the shoreline and to a depth of only a few centimeters. So long as this occurs, primary production is impossible in all but the shallowest littoral regions. The substrate itself, a thick blanket built from precipitating clay-sized particles, denies entrance or penetration by burrowing infaunal forms which, through their activities, create turnover and prevent consolidation of sediment, inhibits root development, and is unattractive to the highly selective epifaunal forms that normally would browse across such a wide expanse. In short, the benthic community still is not established, and at no time have cores or bottom-grabs yielded anything other than an occasional epifaunal life-form, usually an immature aquatic insect.

The pond's main problem of excessive sedimentation is accompanied by a slight degree of eutrophication. This was not serious on the sampling dates, although at times it may have been, or may be in the future. What is especially striking in the biological samples obtained during the various surveys over an extended period of time is the gradual establishment of a healthy, diversified plankton population which is sensitive to, and reflects, physico-chemical parameters as well as biological interactions. This augers well for the eventual successful development of a diversified biotic community including tracheophyte plants and vertebrate animals, but only if the particle load can be reduced.

Without control measures, it is difficult to project what the eventual outcome will be, especially if the stream and forebay continue to contribute massive quantities of sediment into the pond with every rain. Certainly the role of benthos in turnover, in decomposition, in the production of nutrients, is an important one to the continued succession of a pond community. Presumably the nutrient requirements of phytoplankton are currently being met by the occasional flushing from seeded areas of applied fertilizers, but as the bordering plots and lawns are still new and only recently under cultivation, the results have not been marked among the photosynthetic algae.

When construction is complete and the area has become stabilized, the pond should be cleaned once more. When cleaning is complete, shrubs and trees should be established around the pond. Rooted aquatic littoral plants can then take hold, their deciduous leaf-fall soon resulting in a loose carpet of organic detritus, encouraging invasion by organisms to greater depths and more extensive areas than now occurs along the substrate.

The banks of the pond on the east side were raw at the time of the last survey with no natural vegetation between what appears to be a flood level and new lawns. It is essential to encourage the planting of moist soil shrubs (button-bush, etc.) and trees (willows, etc.) as well as the natural growth of rooted emergent and floating-leaf aquatic plants (arrowhead, loosestrife, spatterdock, etc. . A zone of such emergents and floating-leaf plants should be allowed along both shorelines to provide shelter, feeding stations, and breeding opportunities to a wide variety of aquatic organisms. A desirable result would be at least one focal point in a food web: pond fishes of the sunfish and bass type. Some fishes have entered the pond on their own accord (eels) and others have been released there (blue gills, pumpkin-seed, white crappies, large mouth bass) but this survey failed to find evidence of them. The pond as yet does not appear suitable for maintaining a sustained population.

Once littoral zones of vegetation are established, the fauna, from protozoan to vertebrate, will follow; nearly every pond animal also has its preferred zone of activity determined by plant community. With an increase in rooted vegetation near the head of the pond, close to the forebay (if it can survive there), its screening action presumably could cause an increase in the precipitation of inorganic particulate matter, to a certain degree clearing the water. Generally, heavily vegetated ponds are clearer than those without rooted aquatic vegetation.

The west bank of the pond still has not been laid bare, but seems to have been mowed repeatedly and also is destitute of natural shoreline vegetation with the exception of a few pioneering aquatic grasses (rush, sedge). The island, on the other hand, appears largely unaltered from earlier visits and could provide a nucleus of shelter for such fishes, reptiles, amphibians, and aquatic invertebrates as now exist in the pond, as well as a source of residual breeding populations, the production of eggs, seeds, and spores. While plans are underway to open the island by means of a bridge, it is hoped that its natural vegetation will only be slightly altered, and that subsequent development and planting of the island be conducive to maintaining it as a miniature natural preserve. A few hardy trees and shrubs would greatly add to both its permanence and its function in the pond ecosystem.

Given time, care, and the proper continuing ecological attention, Hittman Pond could become an extraordinarily attractive and productive resource to the community.

Methods used in the course of these ecological studies included:

1. Field observations made *in situ.*
2. Collections: studied fresh when possible; otherwise preserved for analysis in the laboratory.
3. Hydrology:
   - Temperature
   - pH
   - Dissolved oxygen
   - Forel-Ule color scale
   - Transparency (Secchi disk; colorimeter)
4. Biology:
   - Ekman dredge
   - Peterson dredge
   - .25 m plankton net + centrifugation
   - Dip net
   - Minnow net
   - .5 m^2 sampler
   - Coring device
   - Sediment sampler
   - Stream sampler
   - Fouling plates
   - Foerst bottle
   - Herbarium press

5. Laboratory:

- Microcentrifuge
- Near-ultra centrifuge for nannoplankton
- Leitz Labolux phase contrast microscope
- B&L Greenough stereo for scanning
- Counting chambers (S-R)
- Culture chambers, controlled environment chamber, incubator
- Herbarium
- Leitz-Nikon photomicroscope

6. References:

- Library of 60+ standard limnological texts
- Reprint collection in limnology

SECTION VII

SEDIMENT AND WATER QUALITY STUDIES

The success of a sediment pollution control program depends not only on trapping waterborne sediment in suitable devices, but also on the ultimate disposal of the material in such a way that it will not cause subsequent pollution by reentry into streams. The major portion of this section of the demonstration program was devoted to evaluating, testing, and demonstrating alternative techniques and practices for sediment removal, handling, drying, conditioning, and disposal.

ENTRAPMENT

The primary facility for entrapping sediment from storm water runoff in the project watershed was the storm water retention pond discussed in Section V. In order to reduce the quantity of sediment being transported into the pond and to help facilitate sediment removal, an engineered forebay was designed and constructed. The criteria and rational used to design the forebay are presented in Appendix C. In essence, an engineered forebay is a settling basin located at the junction of a stream with a pond and separated from the pond proper by a submersed weir or dam. A forebay serves as an entrapment device for both bed load and suspended sediments.

The final forebay design that was incorporated with the storm water retention pond is shown in Figure 18. The forebay surface area is approximately 9000 ft^2 and is arranged in a trapezoidal shape with the wide end adjacent to the pond. The pond and forebay are separated by a submerged dam whose elevation is about one foot below the normal pond elevation. The length of the submersed dam (maximum forebay width) is approximately 100 feet. The depth of the forebay adjacent to the dam is about five feet. The forebay length is about 175 feet and the side walls have a nominal 4 to 1 slope.

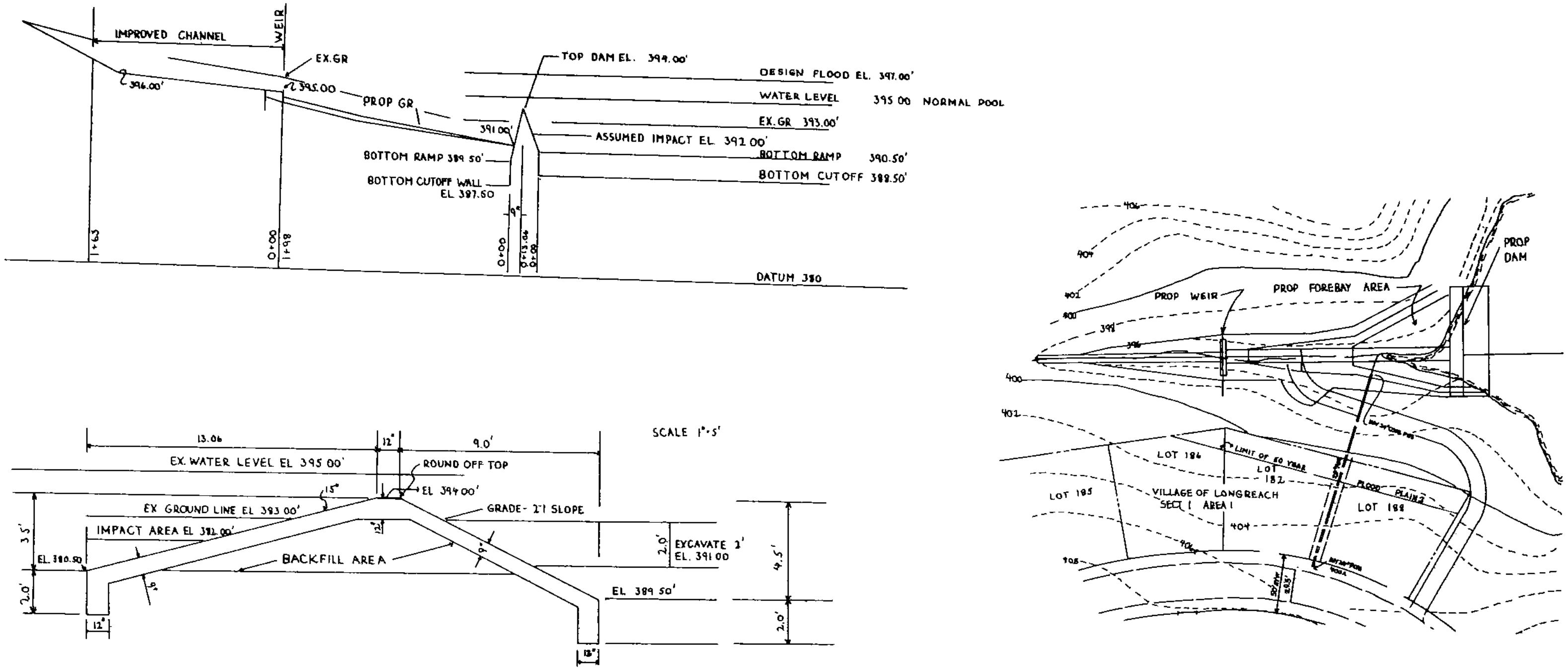

Figure 18. Forebay Design

Attempts were made to compile simultaneous water quality data from Station 3 and water quality and flow data from Station 4 in order to develop information on the trap efficiency of the combined forebay and pond as a function of overflow rate. The water quality data from Station 4 which could be directly related to the other data were extremely limited and no overall correlation could be derived. From limited observations at selected storm overflow conditions, the actual trap efficiencies (82 to 86 percent removal of suspended solids) were generally higher than one would predict on a theoretical basis (70 to 75 percent) for the same flow conditions. It is estimated that the overall trap efficiency of the forebay and pond over the demonstration period was in excess of 95 percent, including bedload.

REMOVAL

Several techniques for removing sediment from the storm water retention pond and forebay were evaluated. Primary consideration was given to evaluating which method of combination of methods would accomplish efficient and economical sediment removal, while minimizing surrounding site disturbance. The alternative approaches selected for detailed evaluation were:

1. Conventional dragline
2. Underwater scoop with a long reach
3. Conventional hydraulic dredge with a pipeline to the disposal area
4. Conventional hydraulic dredge to forebay
5. Submerged roads
6. Special on-site dewatering facilities
7. Combined scoop/dredge

A summary evaluation of these alternatives is presented in Appendix D. The techniques finally selected for demonstrating sediment removal were conventional dragline, underwater scoop with a long reach, and utilization of the forebay as a sediment holding and dewatering area prior to hauling away by conventional dump truck. The principal of the underwater scoop is shown in Appendix D.

By including the forebay dam, it was possible to isolate the forebay area by lowering the pond level and diverting the base stream flow. Once isolated, the forebay contents could be partially dewatered in place by batchwise decanting without disrupting the pond shoreline. The employment of an underwater scoop to bring pond sediments into the forebay necessitated special requirements in the forebay dam design and construction such that it could withstand the impact forces of the scoop bucket.

Sediment removal operations were begun on May 1, 1972 and were completed on the 19th of May. Five days were required to clean the forebay, seven days were spent removing pond sediments, and the remaining six days were idle due to rain or weakends. A total of approximately 700 yd^3 of sediment were removed from the forebay and 1300 yd^3 from the pond.

The first operation was the construction of a stream diversion channel around the forebay to the pond. The stream flow was thus routed directly to the pond which enabled the forebay to be separated from the stream to pond system. Water was then decanted from the forebay leaving relatively dry sediment materials.

Sediment was removed from the forebay by conventional dragline and loaded directly onto conventional dump trucks. Figure 19 illustrates the conventional drag line-dump truck operation. The drag line operation proved to be time-consuming and inefficient because the bucket frequently spilled sediment material before it could be loaded.

After sediments from the forebay had been removed, the drag line bucket was replaced with the long reach sediment scoop arrangement shown in Figure 20. Sediment from the pond was then scooped into the forebay and then loaded by backhoe onto dump trucks. The arrangement of scooping sediment into the forebay and simultaneous removal from the forebay and loading by backhoe resulted in the most efficient sediment removal technique that was demonstrated.

Figure 19. Conventional Dragline - Dump Truck Operation

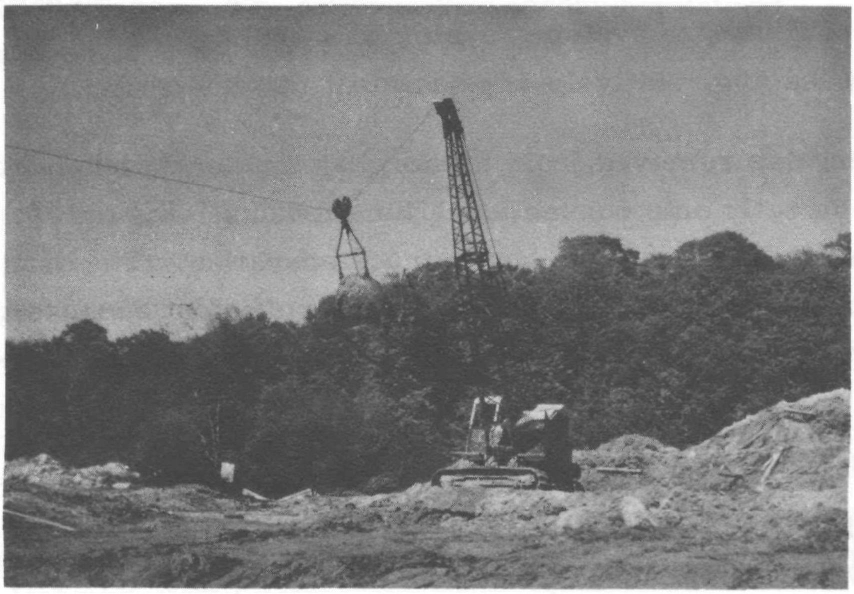

Figure 20. Long Reach Scoop Arrangement

It is worthy of notation in this document that a new machine, designed specifically to remove sediment from small lakes and ponds, has become commercially available since final arrangements for sediment removal were made for this demonstration. The device, called the MUDCAT, is currently (June 1973) being evaluated on another EPA sponsored project.

Sediment Removal Costs

The equipment operation costs associated with removing and transporting sediment one and a half miles by dump truck to the disposal site are presented in Table 7. The D-8 caterpiller was used solely as a deadman during the cable supported underwater scoop operations. If a less expensive deadman arrangement had been employed, the cost per yard would be reduced from $3.80 to about $3.00.

TABLE 7. POND AND FOREBAY SEDIMENT REMOVAL COSTS

Equipment Items	Dollar Cost/hr	Hours of Operation	Total Cost
1. Front end loader and operator	24.00	21	$ 504
2. One yard bucket backhold	40.00	28	1,120
3. Crane and one yard bucket	35.00	84	2,940
4. D-8 caterpillar	35.00	49	1,715
5. Five-10 yard dump trucks	16.50	84	1,386
			$ 7,665

DRYING

Several methods were considered for effective drying of sediment. These included the use of both chemical and physical methods to enhance the rate of drainage and drying.

A wide variety of chemical conditioners, including Dow A21, Hercufloc 6217, Hercufloc 6175, and Dow N17, were tested under laboratory conditions for their effect on sediment drainability. The test results indicated that, in general, chemical conditioners would be impractical under field conditions. A description of the laboratory sediment studies is presented in Appendix E.

Physical methods of sediment dewatering proved to be reasonably effective and practical. The physical techniques investigated included the use of the forebay as a partial draining device during pond cleaning, sand drying beds, grass filter strips, and surface scarification of disposed sediment to enhance drying.

Sand drying beds were effective in aiding both coarse and fine textured sediment dewatering by downward drainage. Increased dewatering rates were most notable with the coarse grained materials. In general, the finer the sediment material, the less marked was the increased dewatering rate. These results were to be expected.

The establishment of a grass filter strip around the sediment disposal area provided an effective means of capturing solids that would normally have been carried away with the sediment drain water. The filter strip also helped to retard erosion around the disposal site.

Sediment surface scarification was effective in aiding the immediate drying to a depth of approximately one foot. This effect was most evident with the fine grained materials.

Utilization of the forebay as a partial draining device during pond cleaning was difficult to evaluate under field conditions because a number of springs fed directly into the forebay. The absence of sediment leakage from the dump trucks during transport to the disposal site indicated that prolonged forebay dewatering was unnecessary.

CONDITIONING AND DISPOSAL

Field studies were conducted to determine the feasibility of manipulating sediment in order to acquire a material with improved characteristics. The details of these studies are presented in Appendix F.

Several low cost and usually available materials were tested for their effectiveness as sediment conditioners. These included digested sewage sludge, fly ash, woodchips, high magnesium lime, and 10-10-10 fertilizer.

These following materials were applied to four demonstration drying beds in the following amounts:

Digested sludge (40% solids)	5 lbs/sq ft
Woodchips	4 lbs/sq ft
Fly ash	5 lbs/sq ft
Lime	0.4 lbs/sq ft
Fertilizer	0.4 lbs/sq ft

Each drying bed was divided into four plots. Each plot measured 7 feet by 13 feet. Conditioning materials were mixed in with the top six inches of sediment. Kentucky 31 Tall Fescue grass seed was then sown and the following response parameters were observed:

1. Germination period
2. Density and coverage
3. Quality of plants

The following general observations were noted:

1. Grass seed germination occured first on plots containing digested sewage treatment plant sludge.
2. Plots containing fly ash germinated two weeks later than control plots.
3. Areas containing woodchips had stunted and sparse grass growth.
4. Grass coverage and density was greatest on the fertilizer and sewage sludge plots.
5. Plant response on plots treated with lime was similar to the control plots.

6. Plots treated with lime experienced dense rapid grass growth during the first few weeks. Signs of nutrient deficiency became apparent during the second month of growth.

WATER QUALITY

A base flow sampling and analysis program was conducted during the demonstration period to determine the background water quality prior to watershed development and what changes, if any, occurred during development. Base flow water samples were periodically taken upstream of the forebay, at the forebay, and downstream of the pond by automatic and hand sampling techniques. Water samples used for base flow analyses were always collected after several days without rain.

The parameters used to describe water quality were turbidity, suspended solids, pH, total alkalinity, total hardness, chloride content, nitrite and nitrate content, total phosphate content, and chemical oxygen demand (COD). Over the term of the demonstration period, the following base flow water quality observations were made:

1. Little difference in quality was noted between pond influent and effluent samples.
2. Turbidity and suspended solids measurements increased.
3. Alkalinity, hardness, and chloride measurements remained about the same.
4. Nitrite, nitrate, and total phosphate measurements increased significantly.

Table 8 presents average water quality values during the beginning, middle, and end of the demonstration period.

TABLE 8. AVERAGE WATER QUALITY DURING BASE FLOW CONDITIONS

Period	Water Quality Parameters								
	Turbidity (JTU)	S.S. (mg/ℓ)	pH	Total Alkalinity (mg/ℓ)	Total Hardness (mg/ℓ)	Cl^- (mg/ℓ)	NO_2 & NO_3 (mg/ℓ)	PO_4 (mg/ℓ)	COD (mg/ℓ)
Beginning of Project	8	11	7.2	24	18	8	0.2	<0.1	24
Middle of Project	10	15	7.4	21	14	8	0.8	0.2	25
End of Project	14	18	7.3	23	16	7	1.2	0.3	26

SECTION VIII

REFERENCES

1. Guidelines for Erosion and Sediment Control Planning and Implementation, Water Resources Administration, State of Maryland and Hittman Associates, Inc., for EPA, EPA Report No. EPA-R2-72-015, August 1972.

2. Young, Robert L., "Above Lake Needwood," presented at Winter Meeting, Interstate Commission on the Potomac River Basin, Fredericksburg, Virginia, February 29, 1968.

3. Storm Water Management Model, Metcalf & Eddy, Inc., University of Florida, and Water Resources Engineers, Inc., for EPA, 4 Volumes, EPA Report Nos., 11024DOC07/71, 11024DOC08/71, 11024DOC09/71, and 11024DOC10/71.

SECTION IX

APPENDICES

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APPENDIX A

STORMWATER MANAGEMENT POND HYDROLOGIC DATA

Included herein are the basic hydrologic and meteorologic data used for the stormwater retention pond analyses.

TABLE A-1. POND PEAK FLOW PERFORMANCE: INITIAL LEVEL AT NORMAL RISER ELEVATION

Date of Storm	Total Rainfall (in.)	Duration of Storm (min.)	Approximate Return Interval of Storm (yr.)	Peak Inflow (CFS) (Station #3)	Peak Outflow (CFS) (Station #4)	Time Between Peak Inflow & Outflow (min.)	Remarks
5/12-5/13/71	1.92	630	<1	42.2	120	40	
5/15-5/16/71	1.21	840	<1	11.6	12.6	10	
5/30/71	0.95	555	<1	4.9	4.4	90	
5/30-5/31/71	1.05	345	<1	10.8	18.0	180	
7/1/71	0.43	105	<1	7.7	3.1	65	
7/1/71	0.50	135	<1	19.0	10.0	70	
8/3-8/4/71	0.62	345	<1	5.0	2.2	190	
8/4-8/5/71	0.68	540	<1	13.8	3.8	25	
9/11/71	0.63	105	<1	54.0	13.6	90	
9/12/71	0.28	120	<1	22.0	2.7	75	
9/12-9/13/71	0.93	195	<1	49.3	21.2	100	
10/9-10/10/71	1.93	1080	<1	27.5	90.0	30	
11/24-11/25/71	2.80	870	<1	37.5	142	25	Emergency Spillway Flowed
11/29/71	0.75	360	<1	9.2	9.2	90	
12/6-12/7/71	0.98	1005	<1	8.7	4.5	*	
1/2/72	0.65	750	<1	2.9	2.2	60	
1/4-1/5/72	0.55	1080	<1	3.2	3.0	135	
1/9/72	0.53	600	<1	4.2	3.0	150	
2/12-2/13/72	1.38	675	<1	14.0	16.3	110	
4/16/72	0.78	185	<1	31.0	9.2	105	
4/17/72	0.08	55	<1	4.3	3.5	180	

*Data not available

TABLE A-2. FULL POND PERFORMANCE CHARACTERISTICS DATA BANK

Total Rainfall (in.)	Duration of Storm (min.)	Average Intensity (in/hr)	Peak Inflow (CFS)	Time Between Peak Inflow & Outflow (min.)	% Difference in Peak Outflow vs. Inflow (%)	Peak Throughflow (%)
0.08	55	0.087	4.3	180	-19	81
0.28	120	0.140	22.0	75	-88	12
0.43	105	0.246	3.1	65	-60	40
0.50	135	0.222	19.0	70	-47	53
0.53	600	0.053	4.2	150	-29	71
0.55	1080	0.031	3.2	135	-6	94
0.62	345	0.108	5.0	190	-56	44
0.63	105	0.360	54.0	90	-75	25
0.65	750	0.052	2.9	60	-24	76
0.68	540	0.076	13.8	25	-72	28
0.75	360	0.125	9.2	90	0	100
0.78	185	0.252	31.0	105	-70	30
0.93	195	0.286	49.3	100	-57	43
0.95	555	0.096	4.9	90	-10	90
0.98	1005	0.058	8.7	*	-49	52
1.05	345	0.183	10.8	180	+67	167
1.21	840	0.086	11.6	10	+9	109
1.38	675	0.123	14.0	110	+16	116
1.92	630	0.183	42.2	40	+184	284
1.93	1080	0.107	27.5	30	+227	327
2.80	870	0.193	37.5	25	+278	379

*Data not available

TABLE A-3. POND PEAK FLOW PERFORMANCE: WATER LEVEL BELOW NORMAL RISER ELEVATION AT START OF STORM

Date of Storm	Total Rainfall (in.)	Duration of Storm (min.)	Approximate Return Interval of Storm (yr.)	Peak Inflow (CFS) (Station #3)	Peak Outflow (CFS) (Station #4)	% Difference in Peak Outflow vs. Inflow (%)	Peak Throughflow (%)	Time Between Peak Inflow & Outflow (min.)	Initial Pond Level (Ft. Below Normal Riser Elevation)	Remarks
7/29-7/30/71	0.81	480	<1	3.4	3.2	-6	94	25	1/4	Drawdown valve open full during storm
7/30/71	0.25	135	<1	4.0	*	*	*	*	1-3/4	
8/11/71	0.62	180	<1	7.9	0.21	-97	3	15	3	Same rainfall event-two distinct flow peaks
				2.4	0.12	-95	5	10		
8/19/71	2.10	180	1-2	150	3.2	-98	2	75	1-3/4	Same rainfall event-two distinct flow peaks
				34.0	5.6	-84	16	115		
8/26-8/27/71	4.15	1380	2-5	134	232	+73	173	145	1	Emergency spillway flowed
9/11/71	3.28	480	1-2	235	183	-22	78	175	2-1/4	Emergency spillway flowed
9/17/71	1.25	60	1-2	127	3.2	-98	3	15	2-1/4	
10/1/71	0.10	60	<1	2.1	*	*	*	*	2-1/2	
10/2/71	0.70	510	<1	25.1	0.51	-98	2	60	2-1/2	
10/23-10/24/71	0.85	1005	<1	3.0	0.13	-96	4	60	1	Same rainfall event-three distinct flow peaks
				2.4	0.16	-93	7	75		
				2.2	0.11	-95	5	70		
10/25-10/26/71	1.70	1080	<1	10.0	4.8	-52	48	80	1/2	Same rainfall event-two distinct flow peaks
				33.5	39.2	+17	117	35		
11/3/71	0.50	395	<1	4.5	0.05	-99	1	15	2	Same rainfall event-two distinct flow peaks
				6.0	0.21	-96	4	45		
4/13/72	0.82	245	<1	14.8	0.32	-98	2	-75**	2-1/4	
4/13/72	0.73	285	<1	31.6	1.8	-94	6	85	3/4	
5/4/72	0.60	240	<1	54.5	2.2	-96	4	5	2-1/2	Drawdown valve open 10% during storm
5/19-5/20/72	1.13	765	<1	10.5	0.27	-97	3	85	4	

*No distinct peak recorded at station #4.

**Station #4 peaked before station #3.

APPENDIX B

SELECTED STREAM CHANNEL SECTIONS

Included herein are the surveyed stream channel cross sections F through M used in reference to the stream channel morphology section of this report.

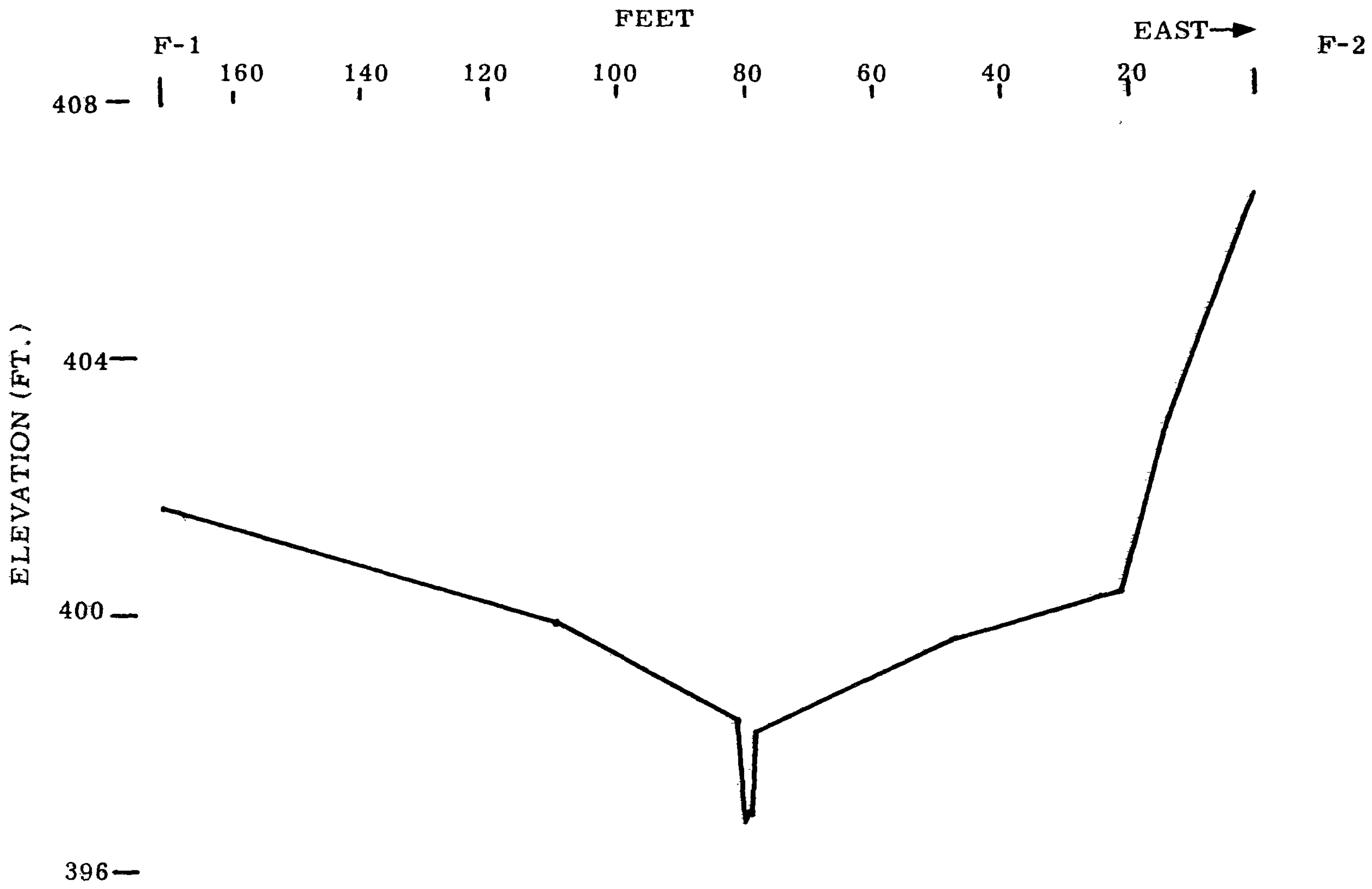

Figure B-1. Section F (Stream)
10/22/70

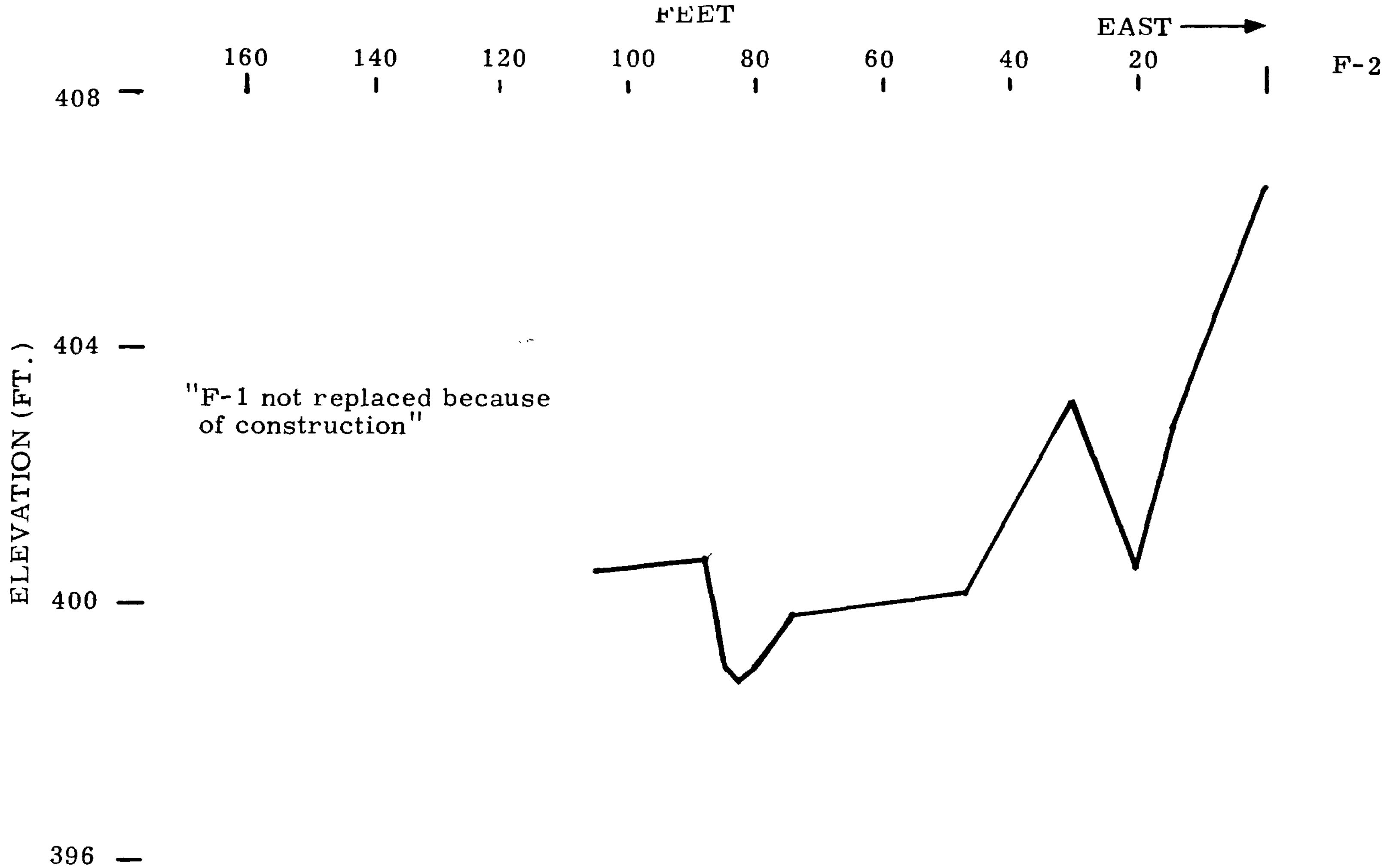

Figure B-2. Section F (Stream)
4/27/72

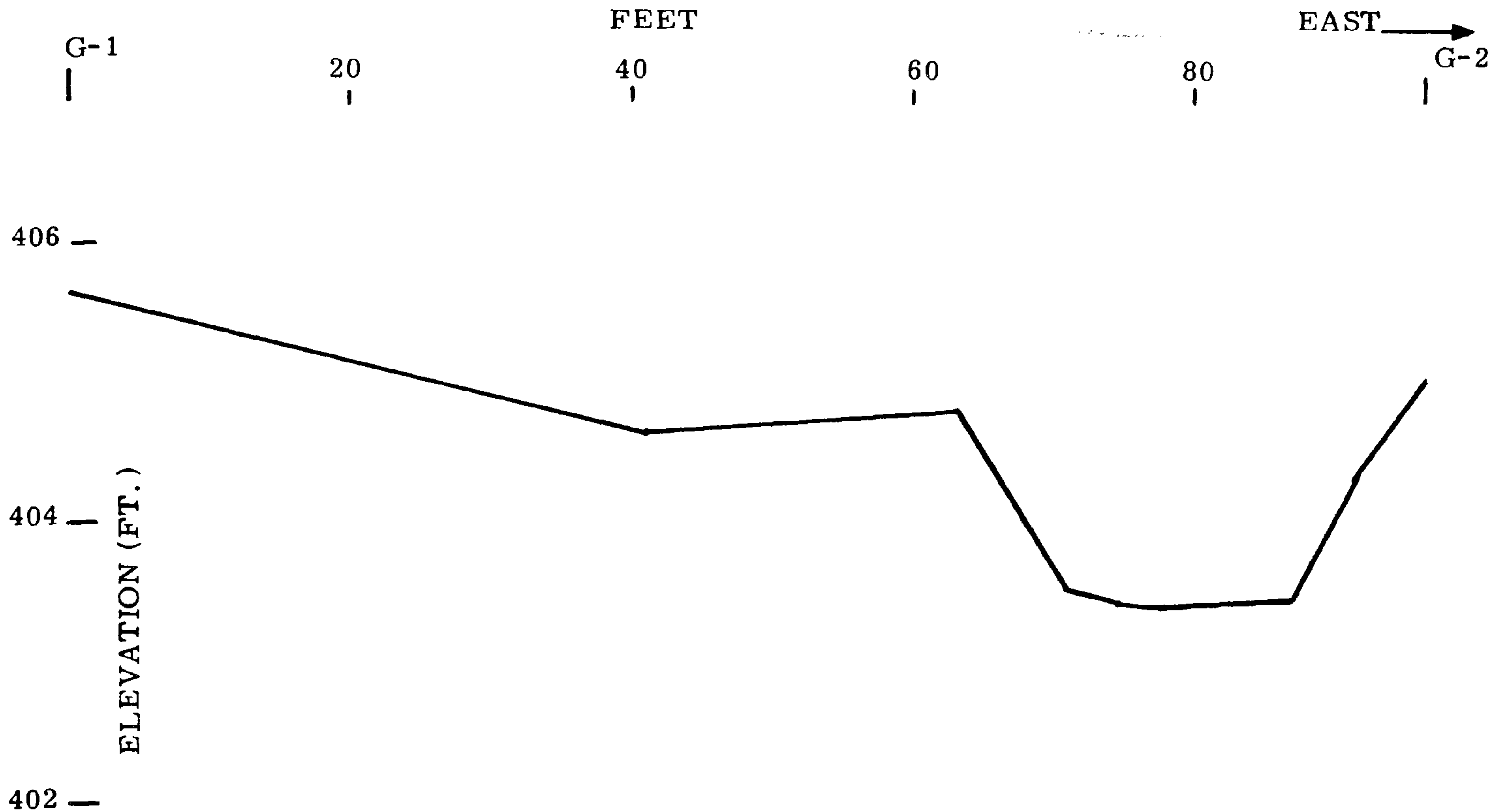

Figure B-3. Section G (Stream)
4/27/72

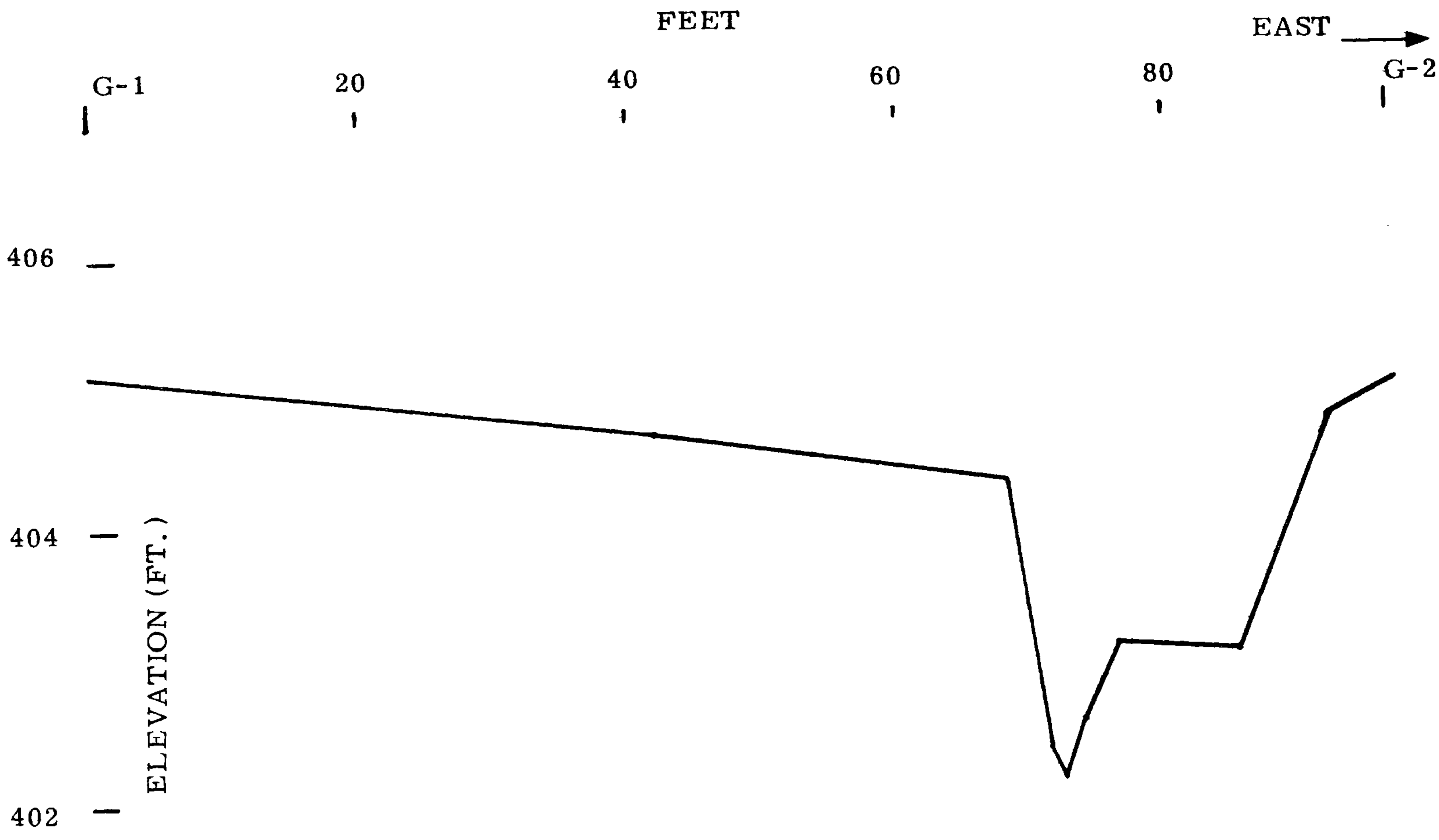

Figure B-4. Section G (Stream)
10/22/70

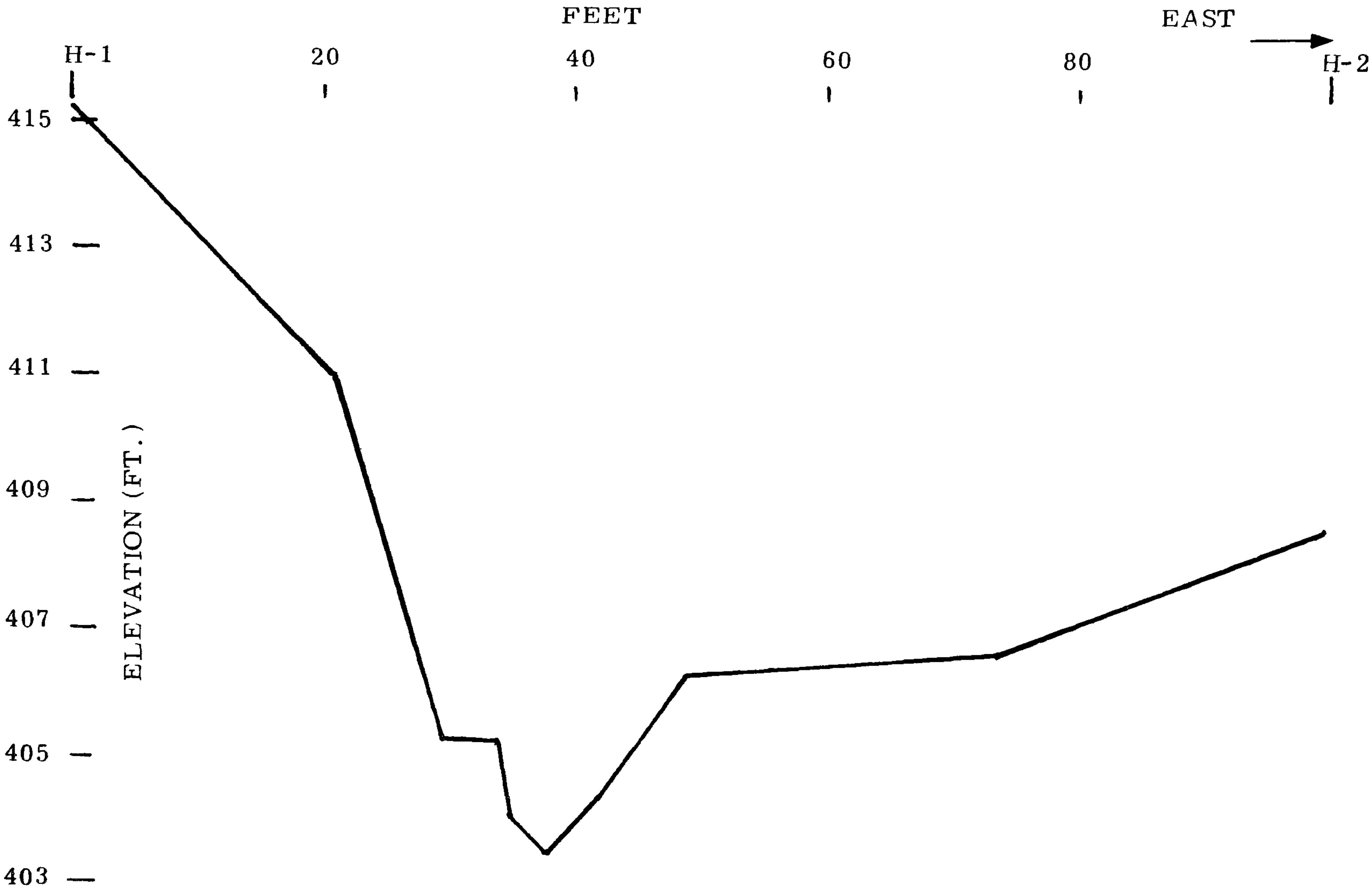

Figure B-5. Section H (Stream)
10/22/70

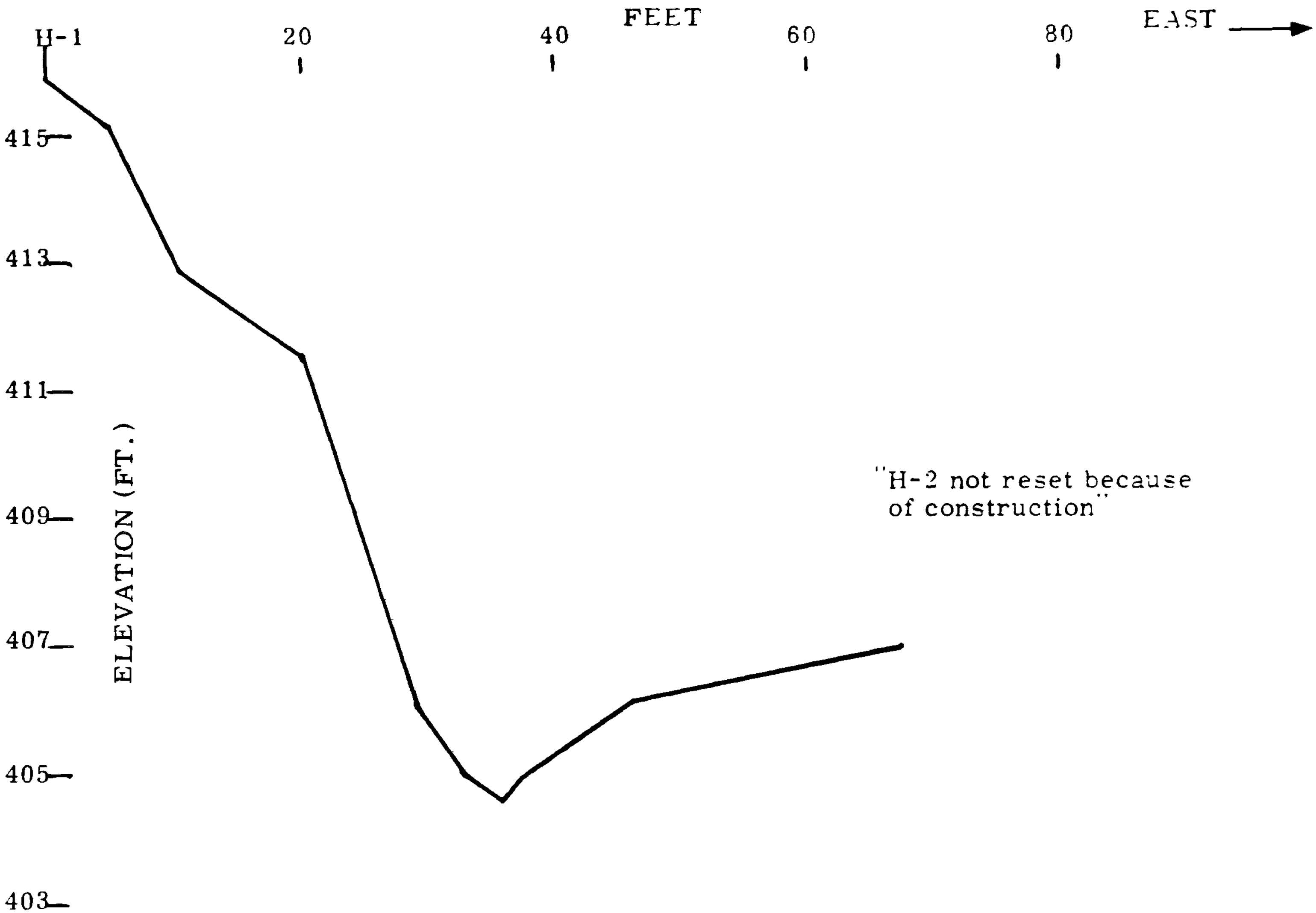

Figure B-6 Section H (Stream)
4/27/72

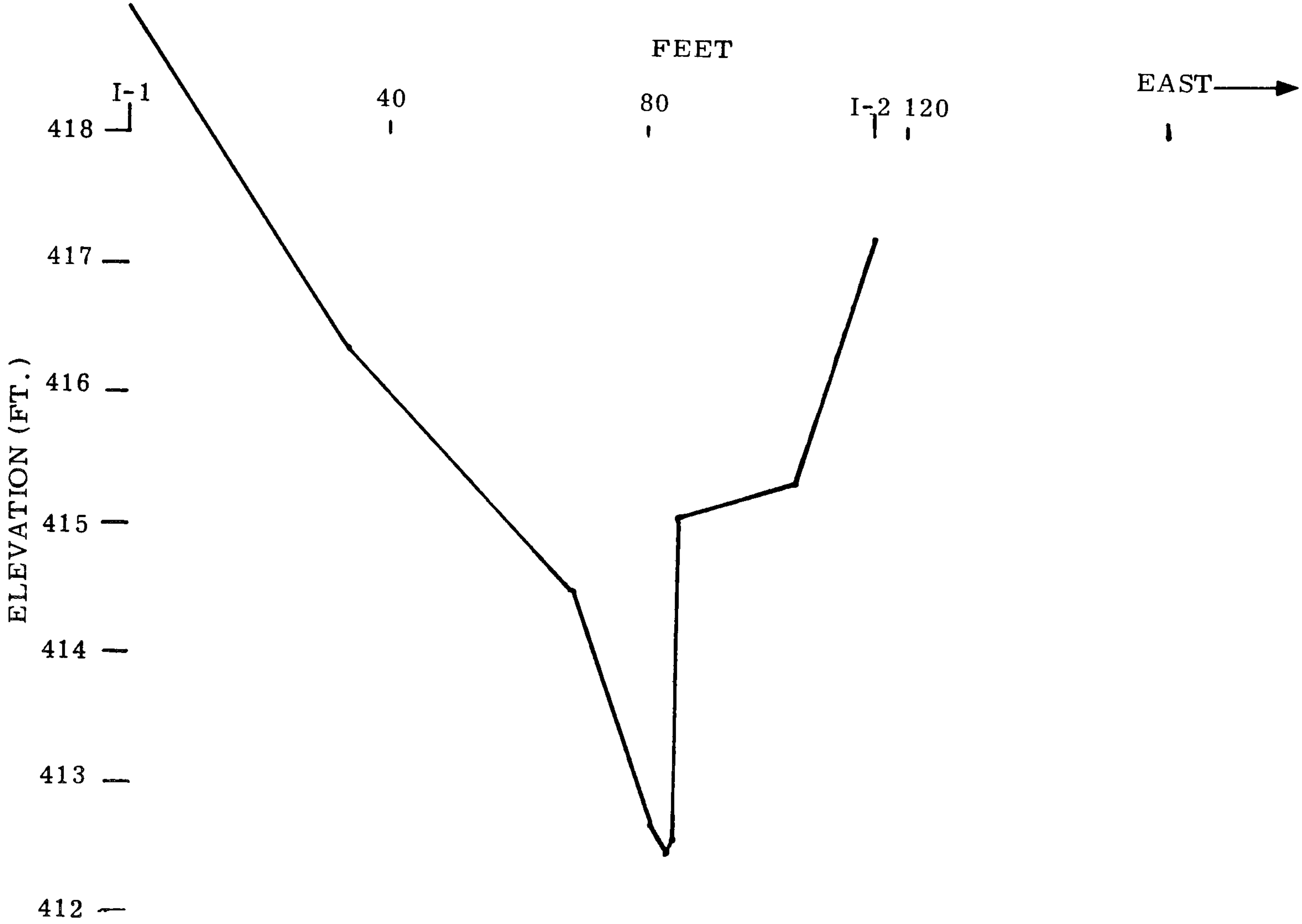

Figure B-7. Section I (Stream)
10/22/70

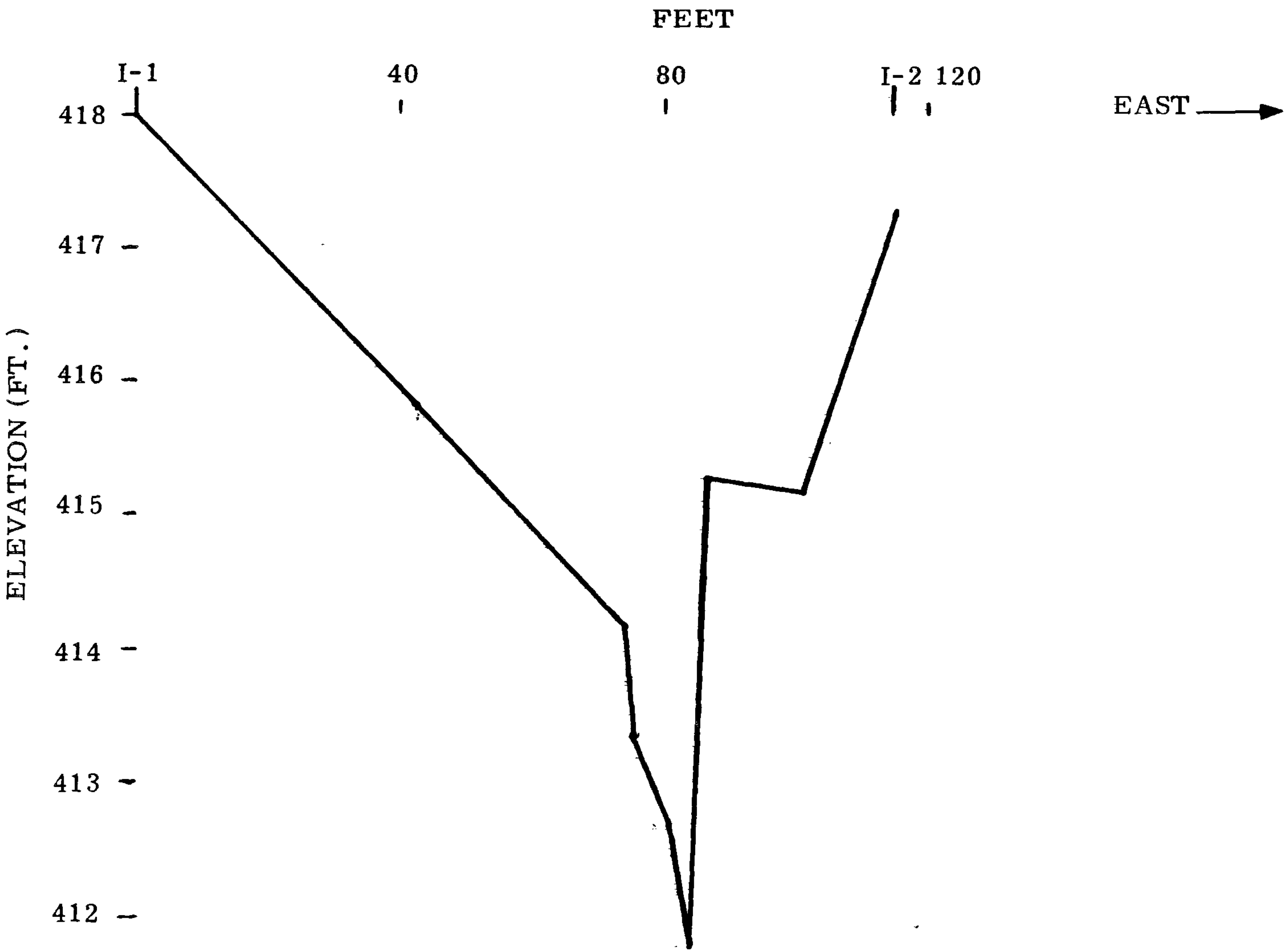

Figure B-8. Section I (Stream)
4/27/72

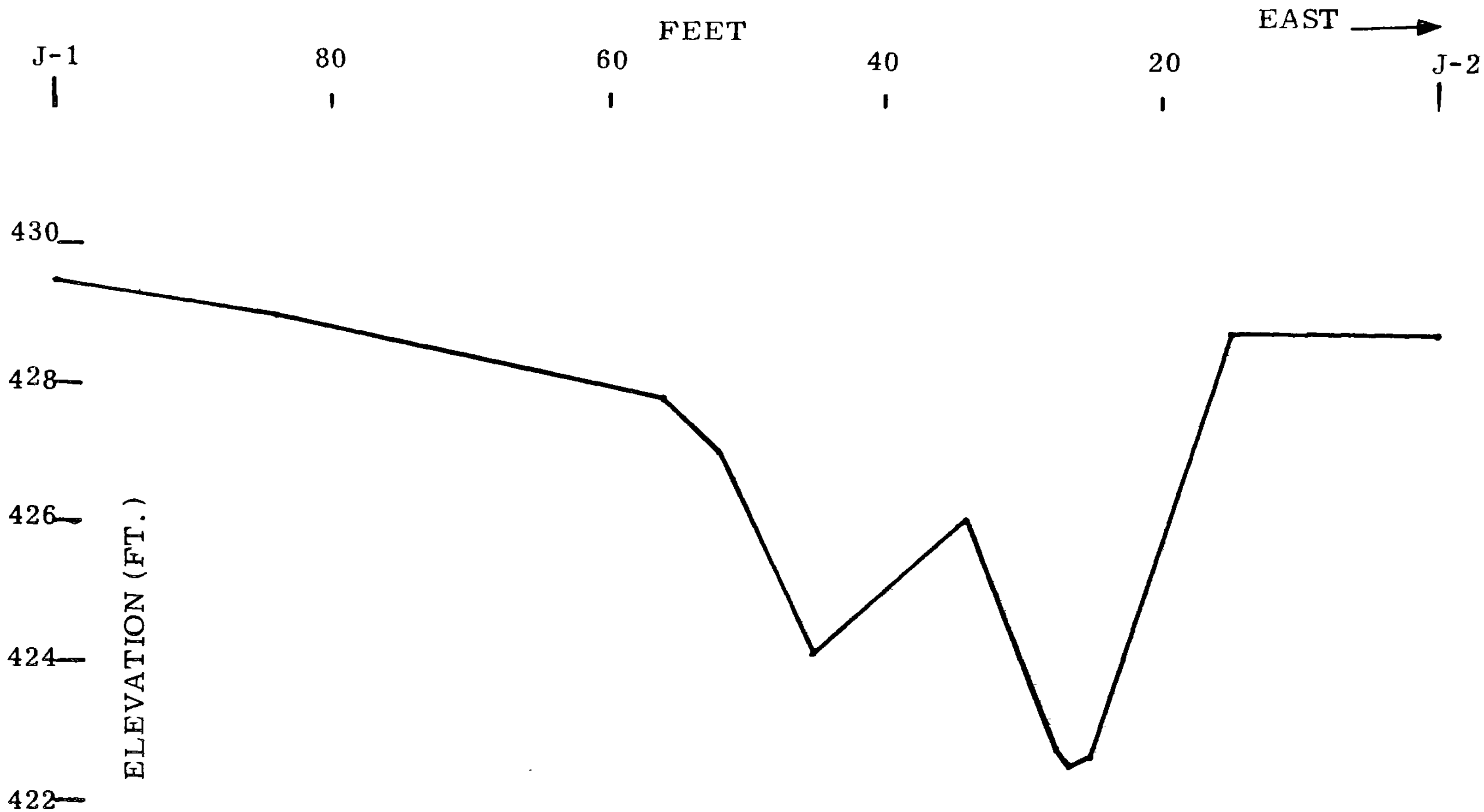

Figure B-9. Section J (Stream)
10/22/70

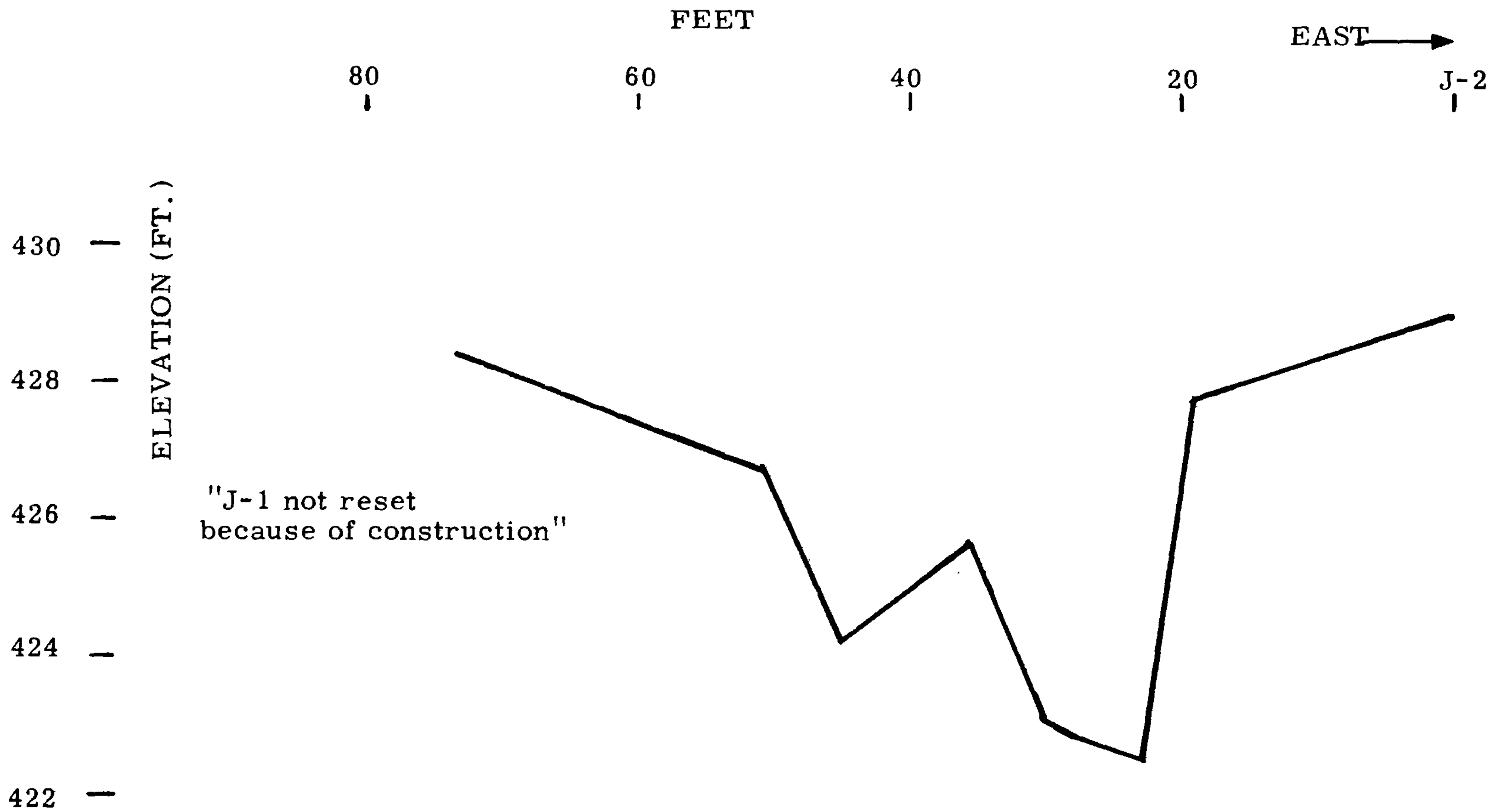

Figure 10. Section J (Stream)
4/27/72

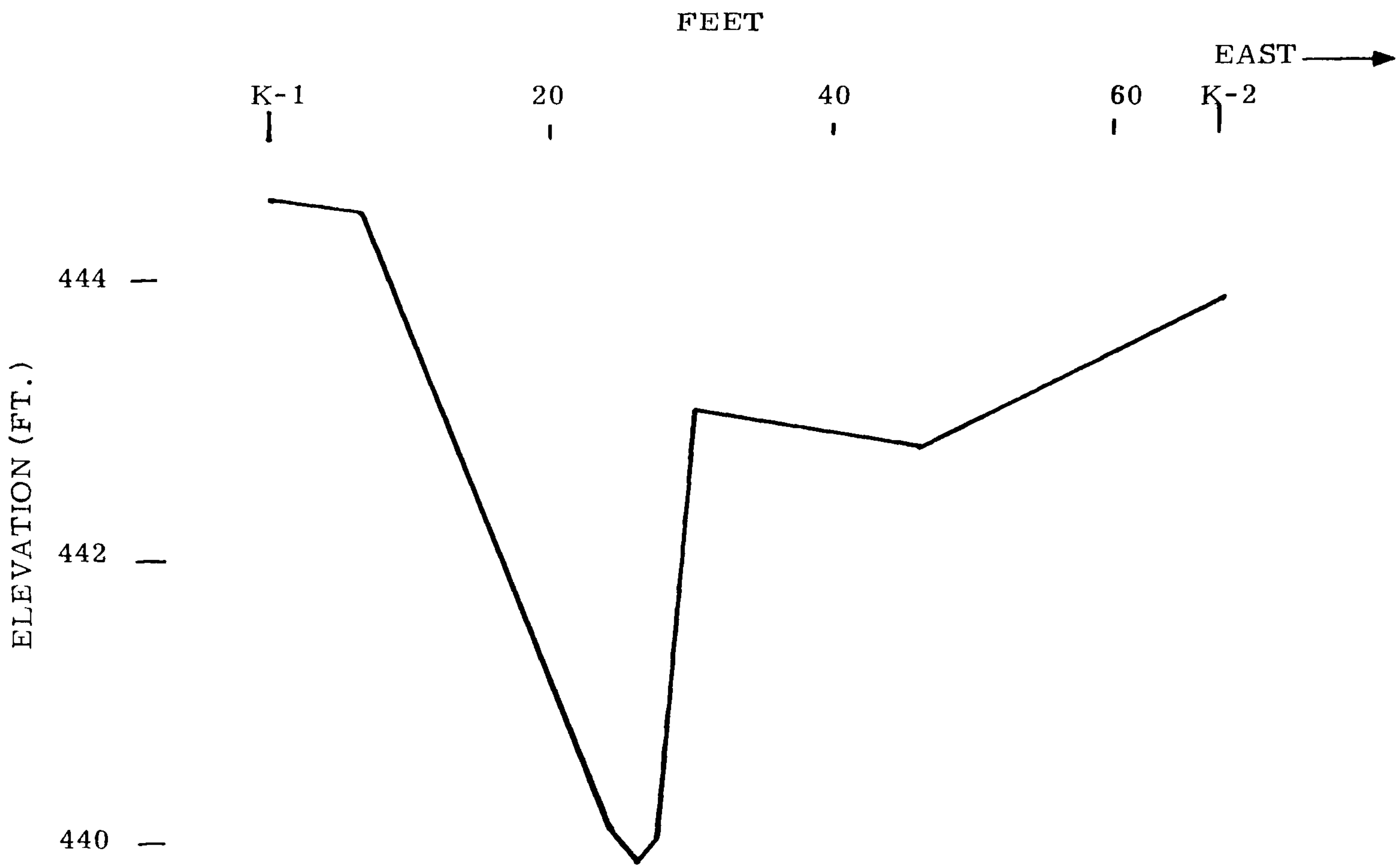

Figure B-11. Section K (Stream)
10/22/70

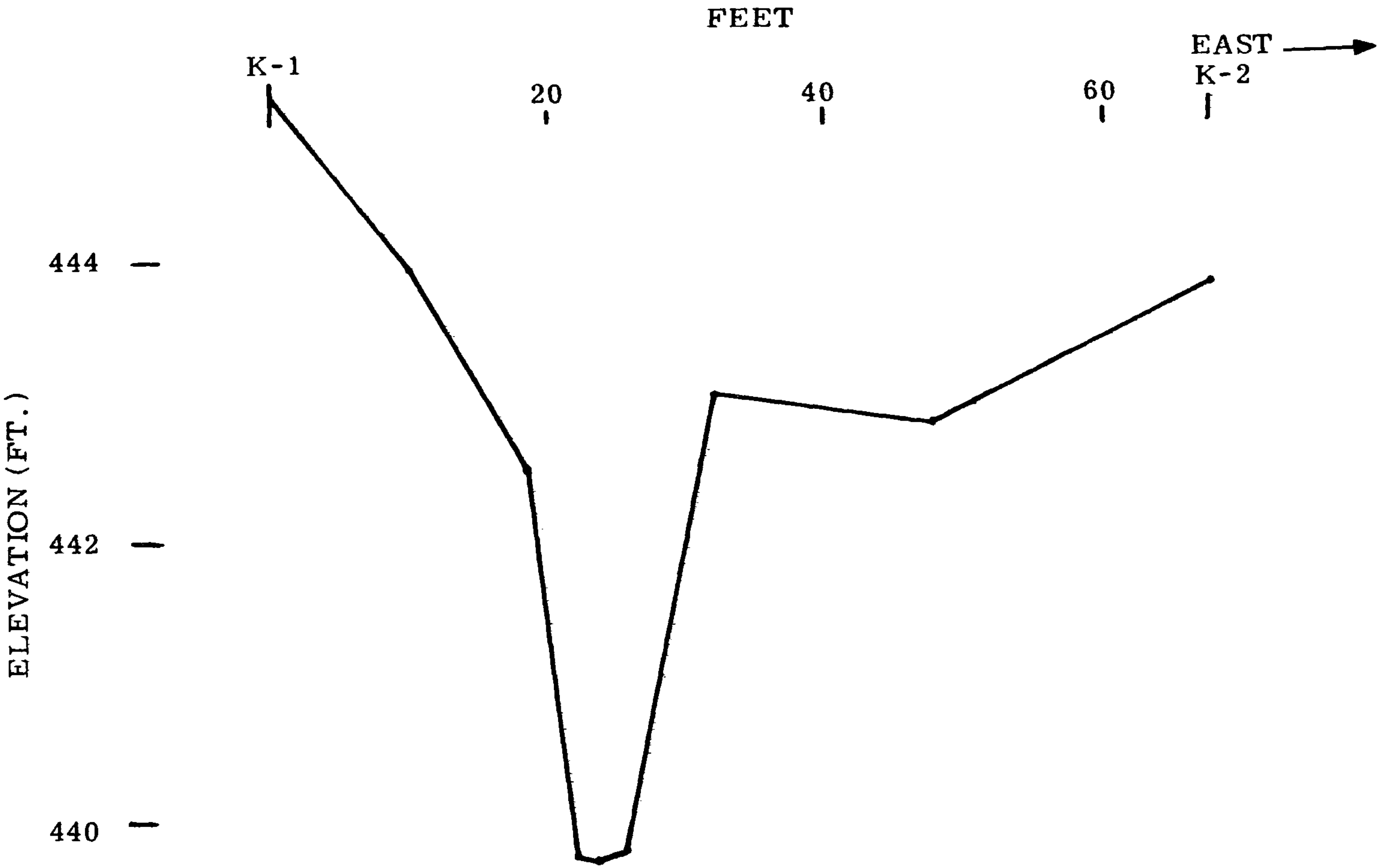

Figure B-12. Section K (Stream)
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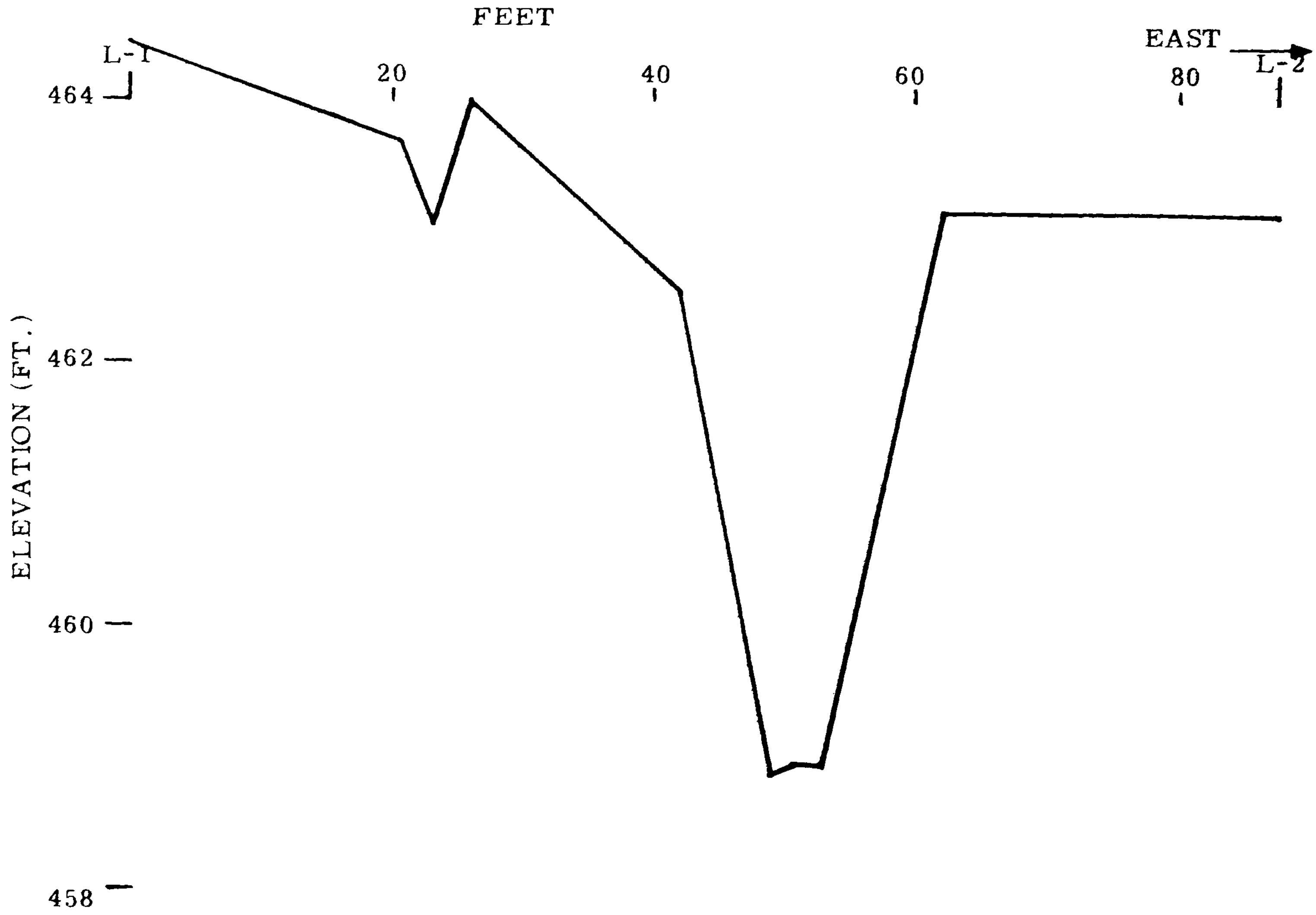


Figure B-13. Section L (Stream)
10/21/70

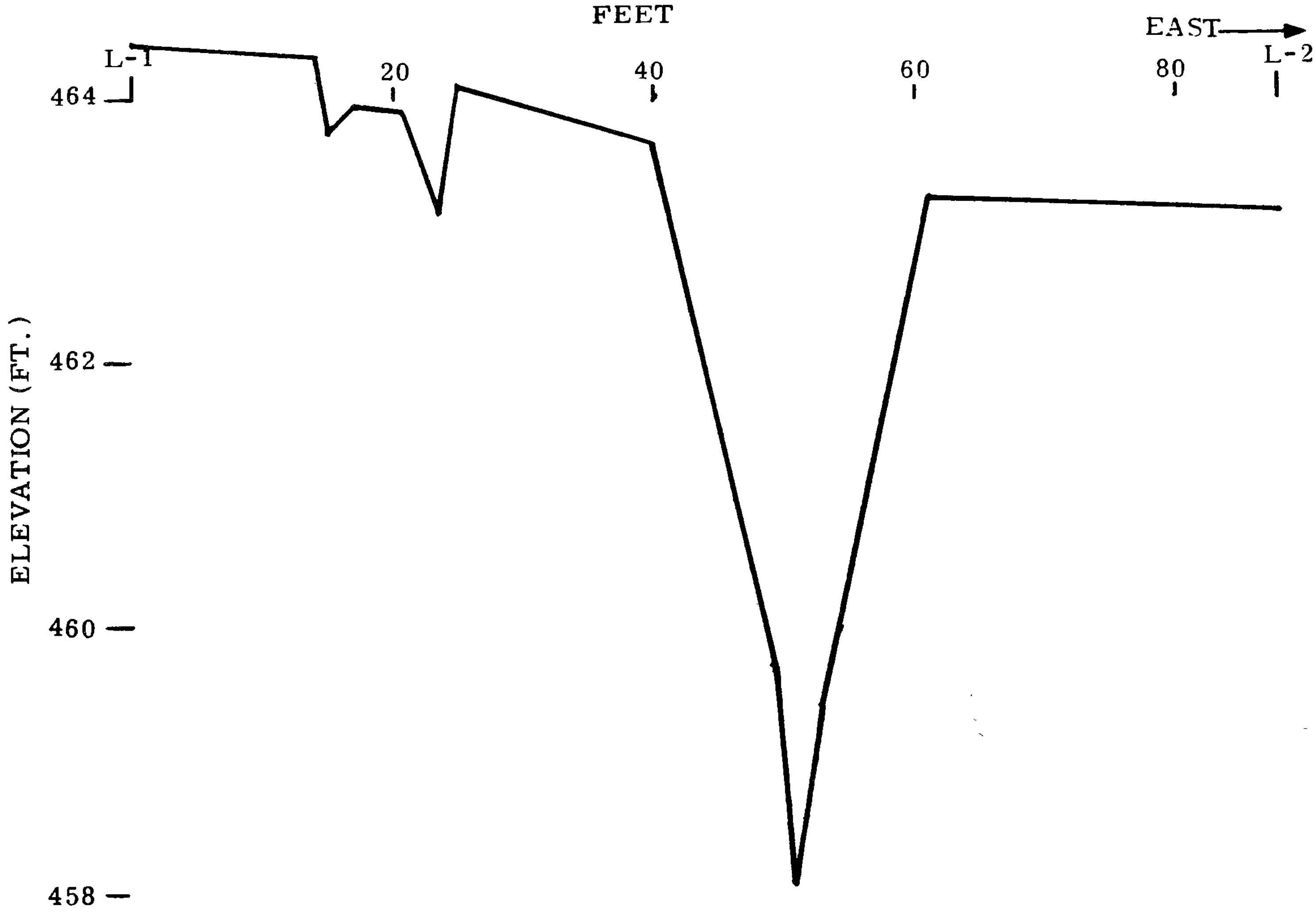


Figure B-14. Section L (Stream)
1/22/71

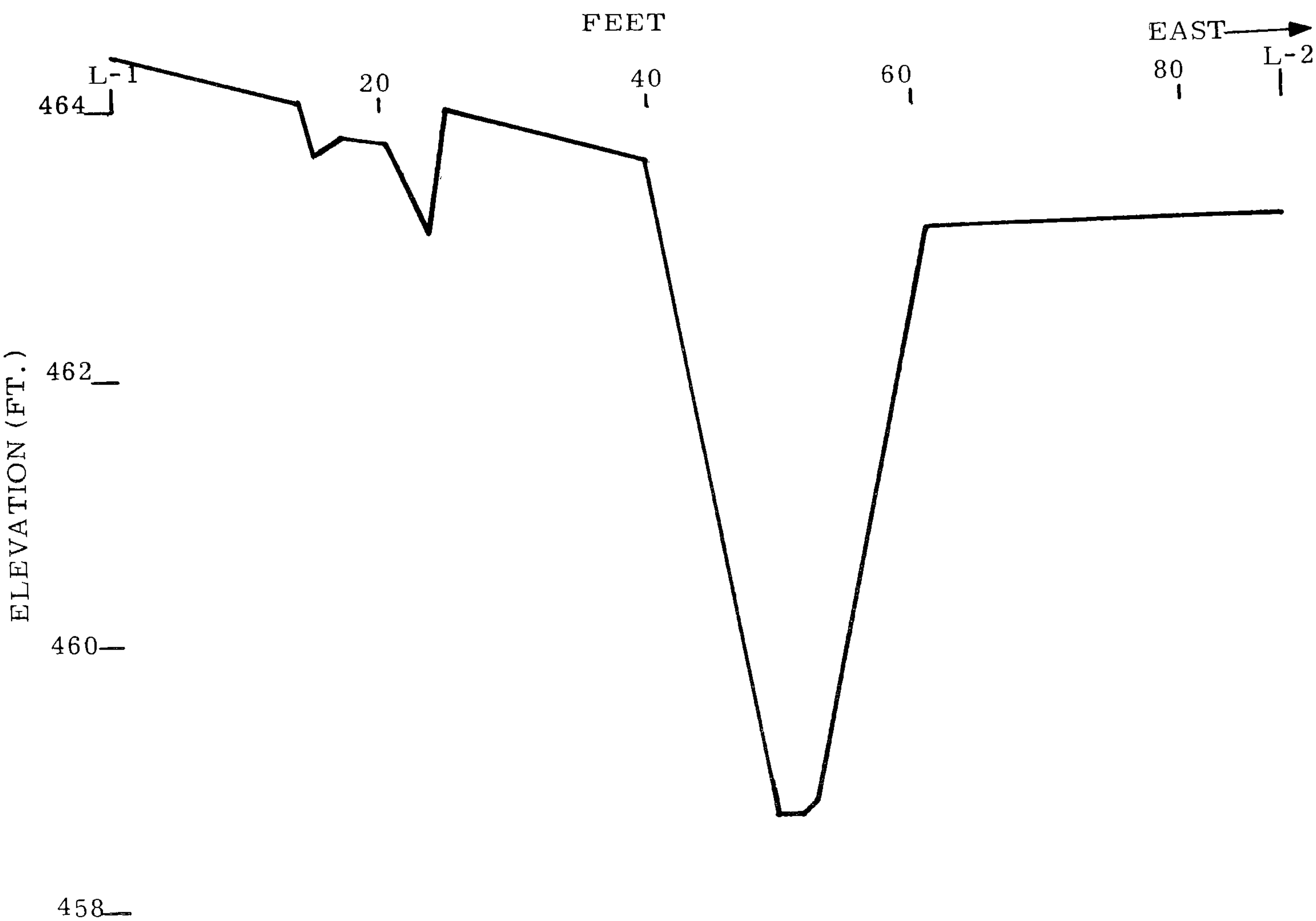


Figure B-15. Section L (Stream)
4/28/71

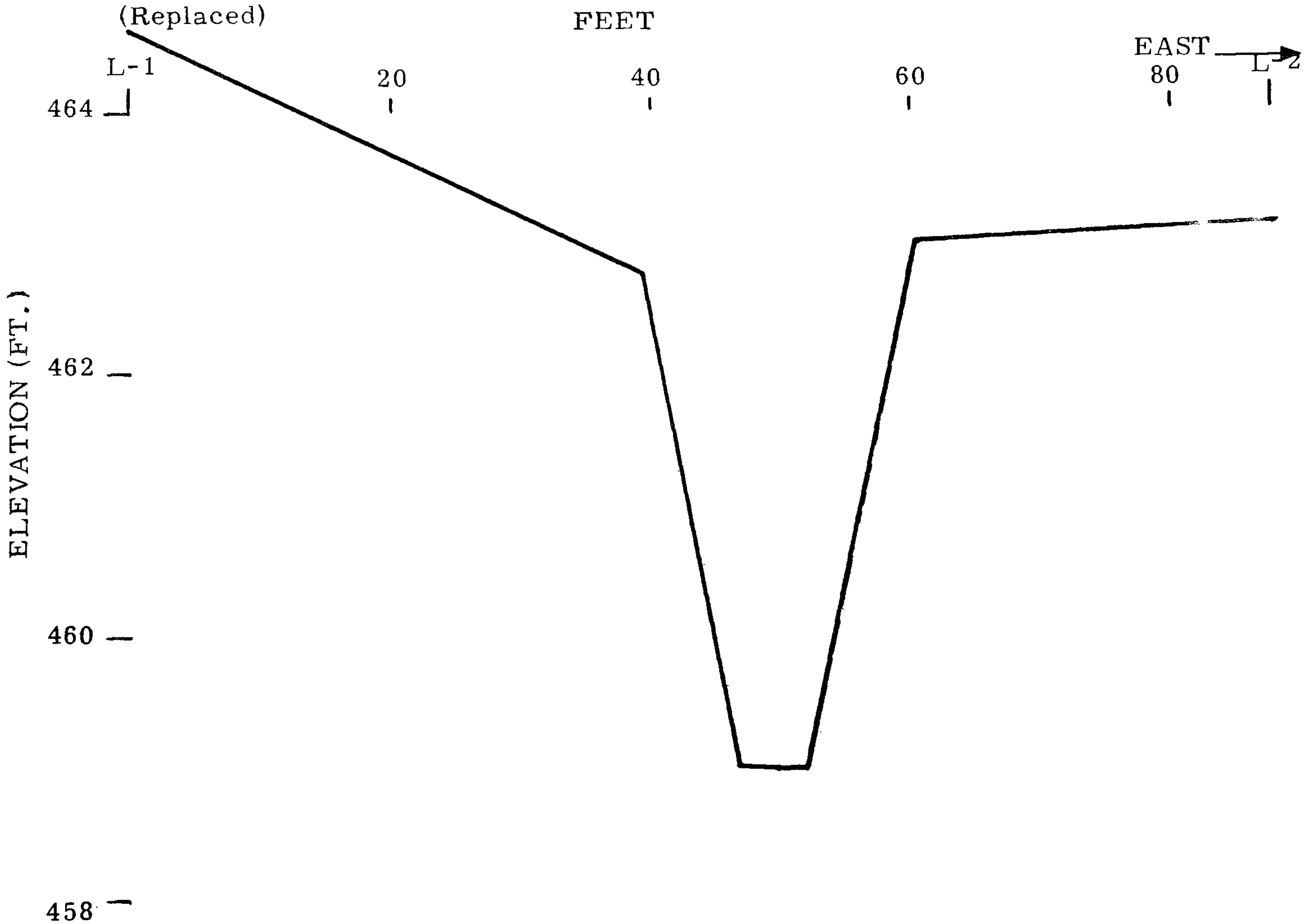


Figure 16. Section L (Stream)
7/26/71

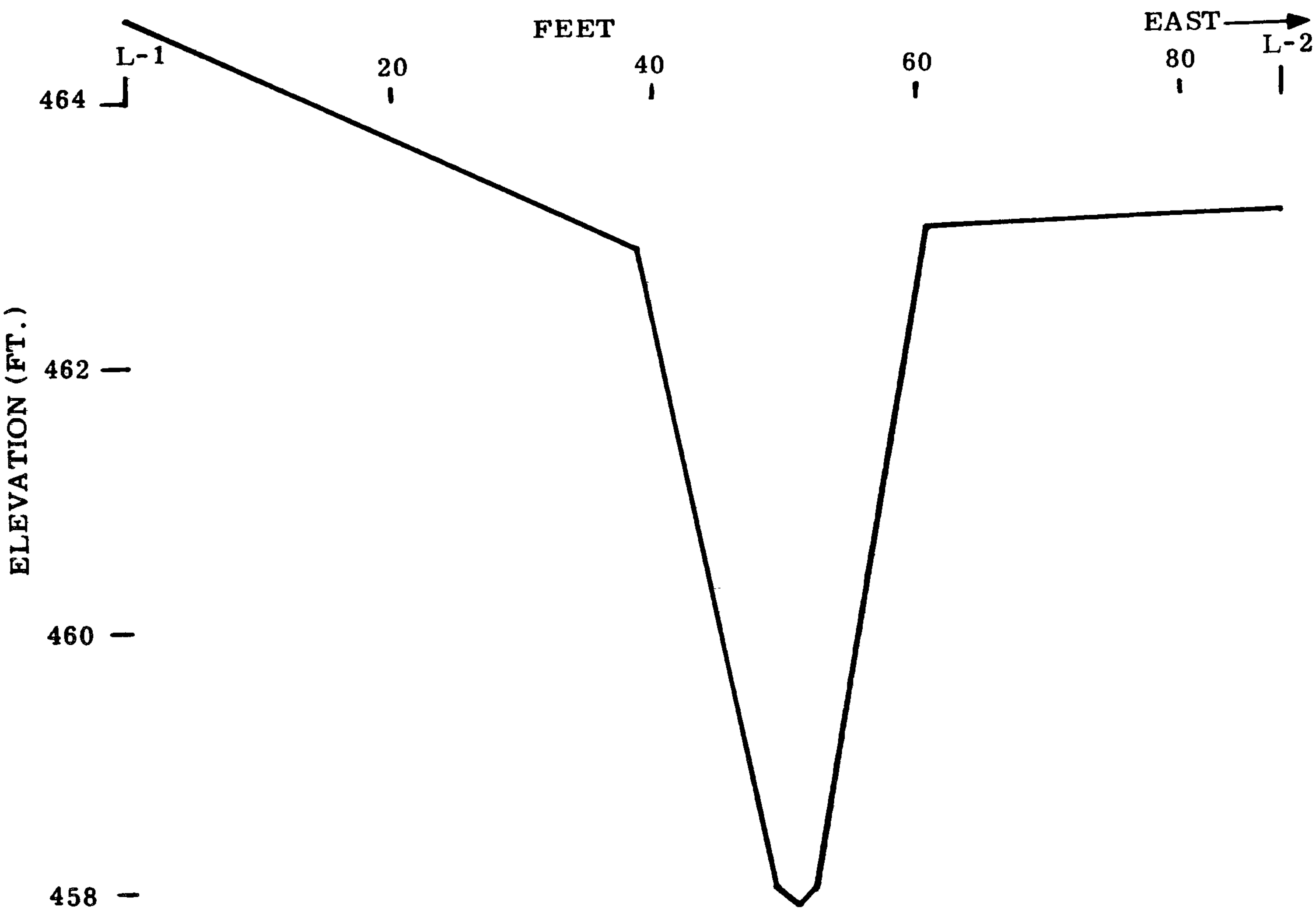


Figure B-17. Section L (Stream)
10/14/71

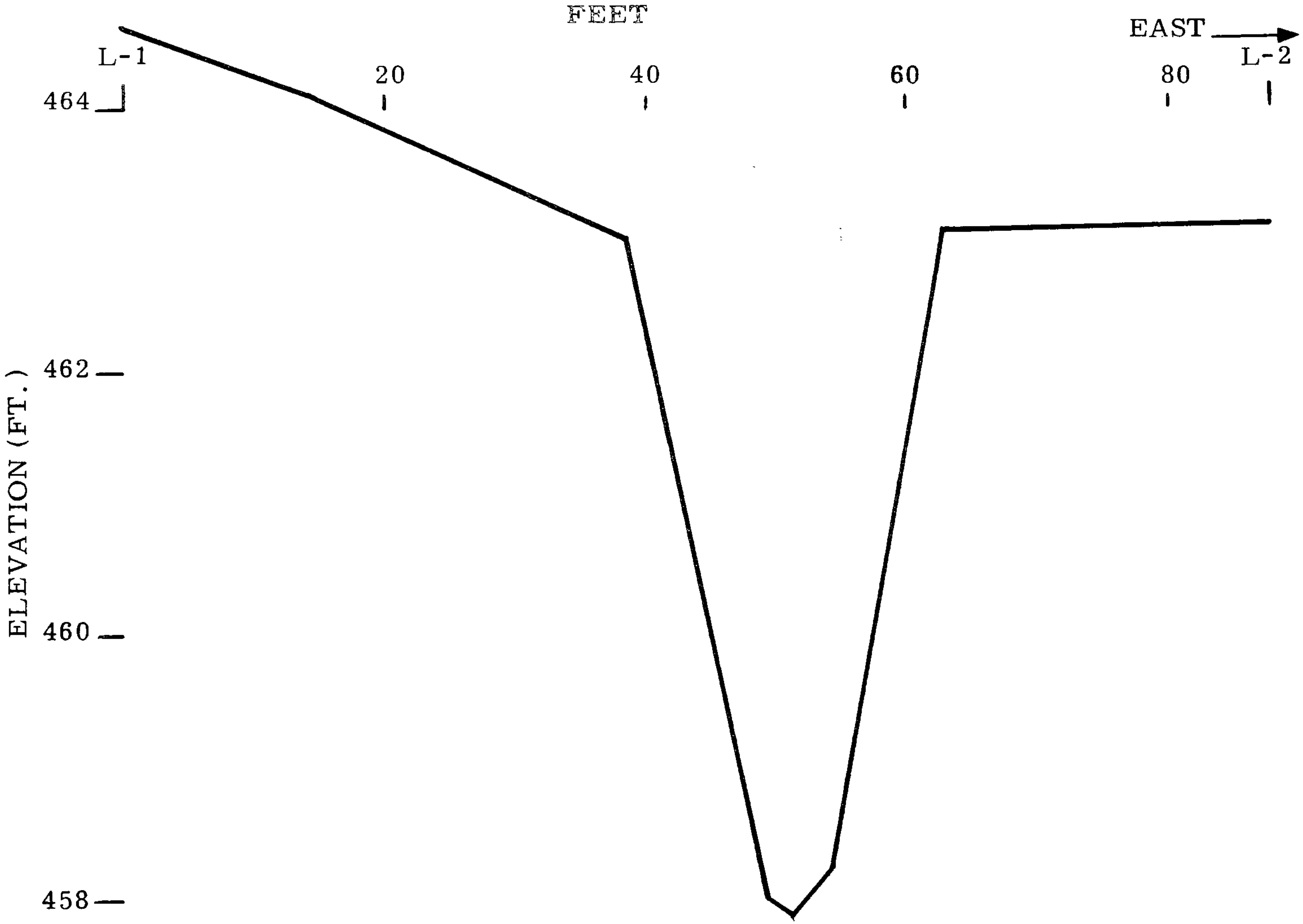


Figure B-18. Section L (Stream)
1/25/72

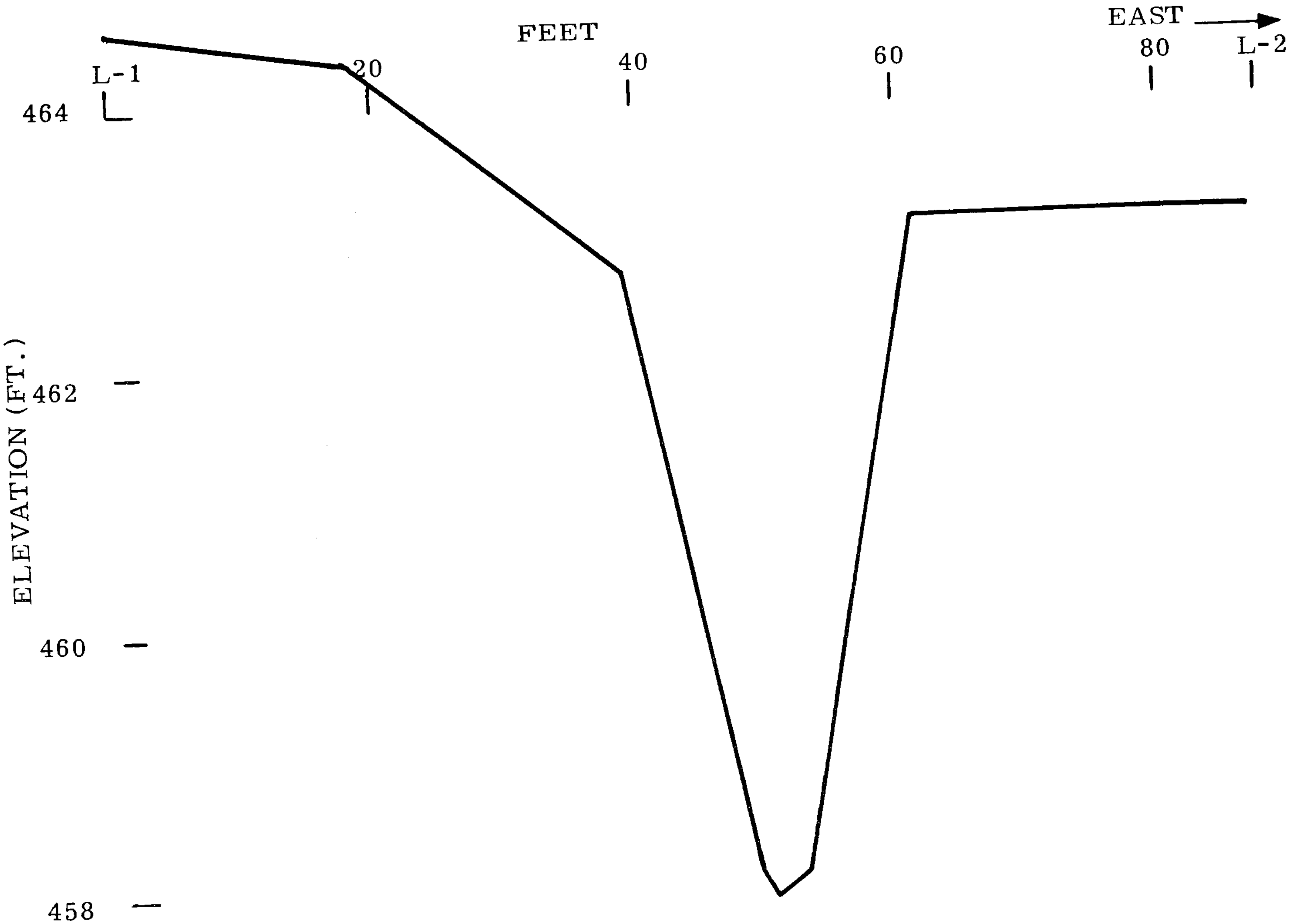


Figure B-19. Section L (Stream)
4/27/72

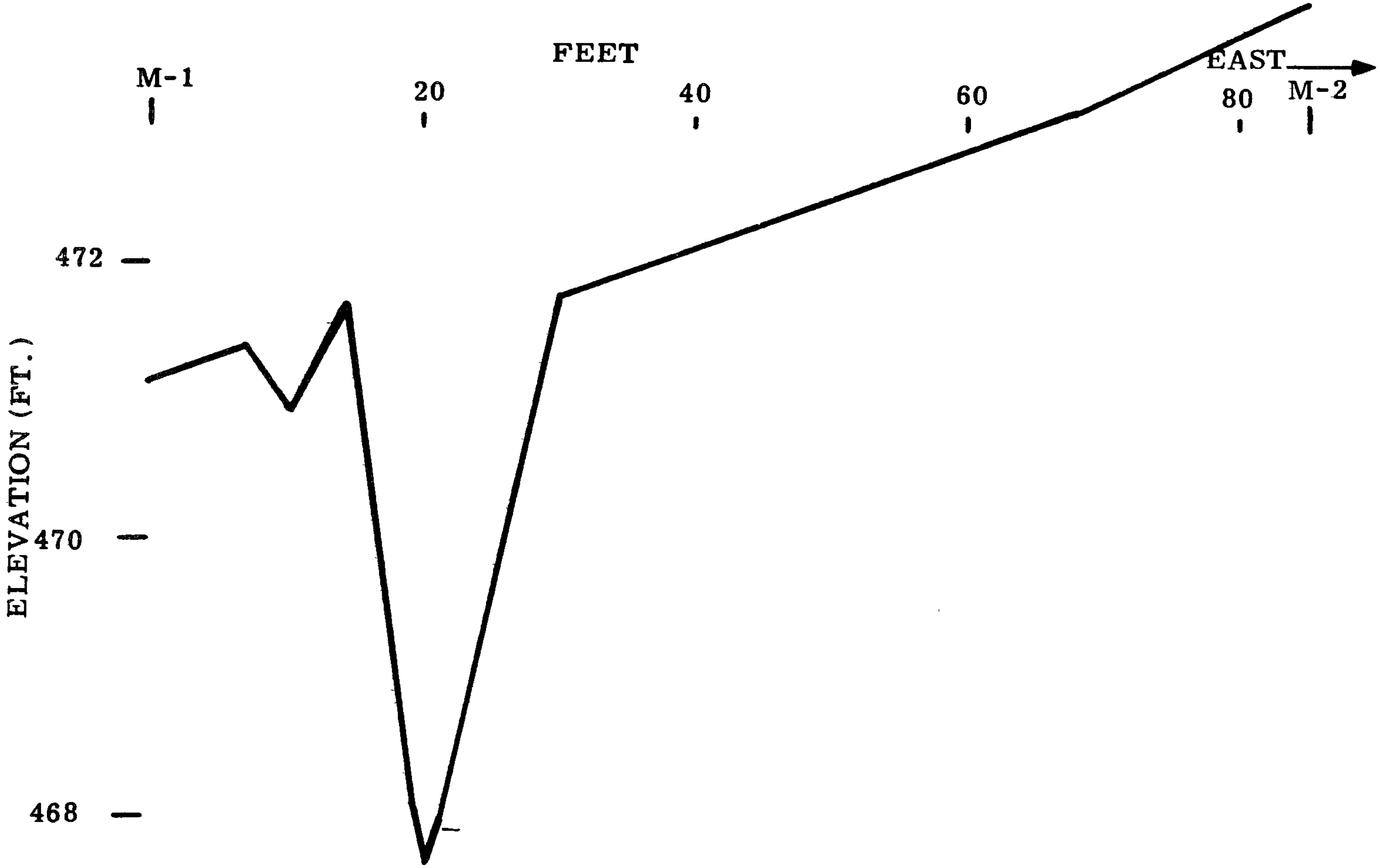


Figure B-20. Section M (Stream)
10/21/70

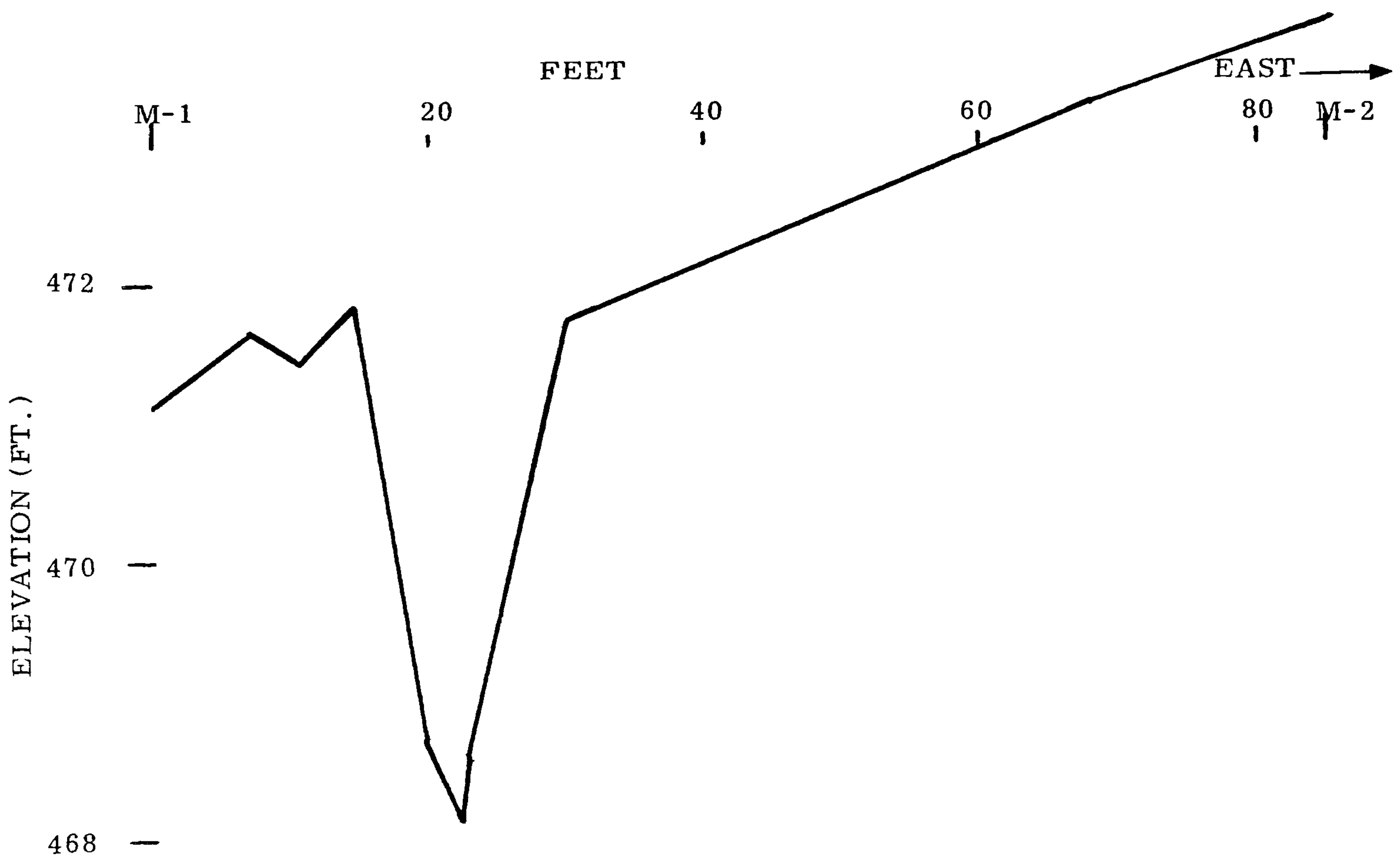


Figure B-21. Section M (Stream)
1/22/71

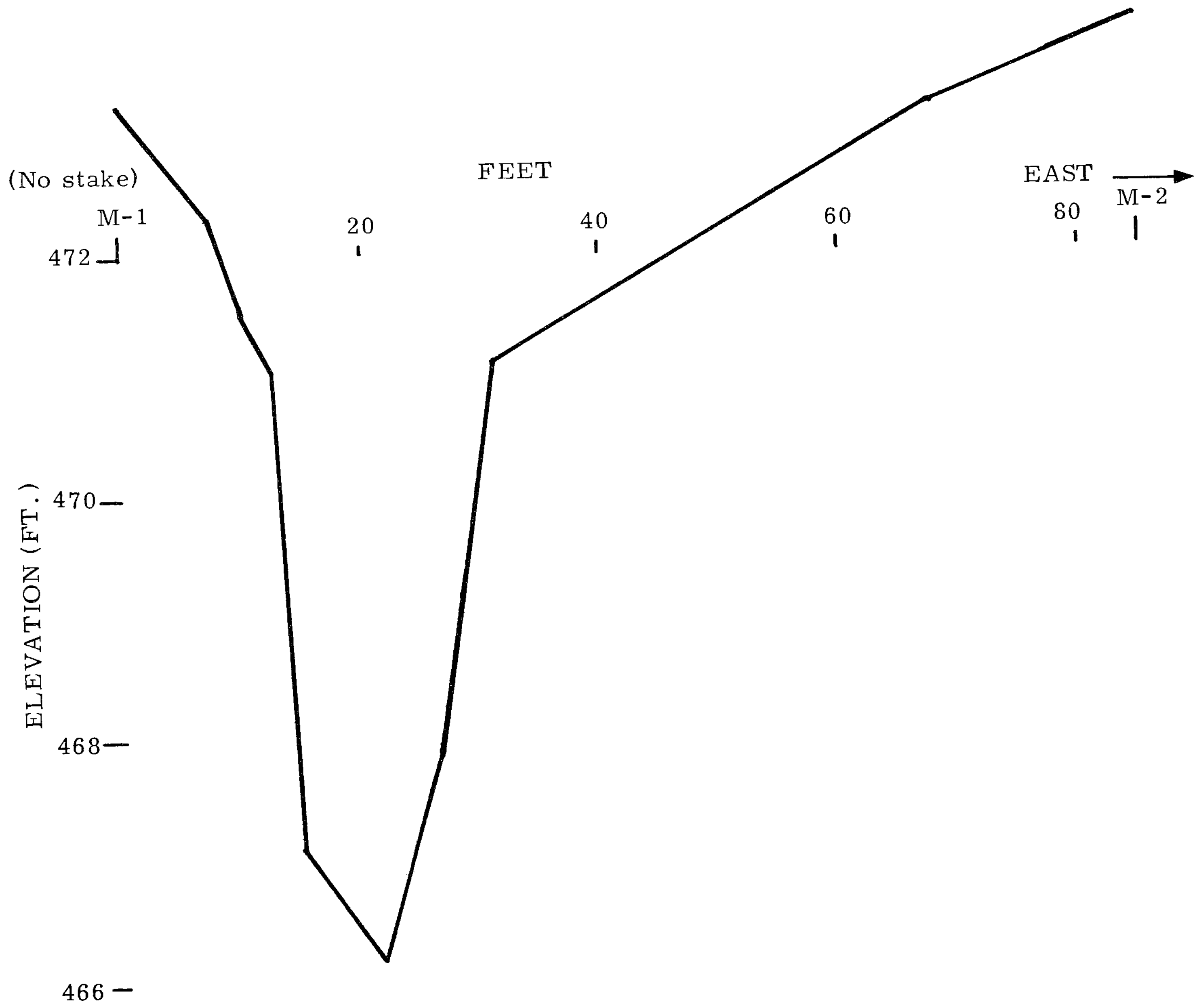


Figure B-22. Section M (Stream)
4/28/71

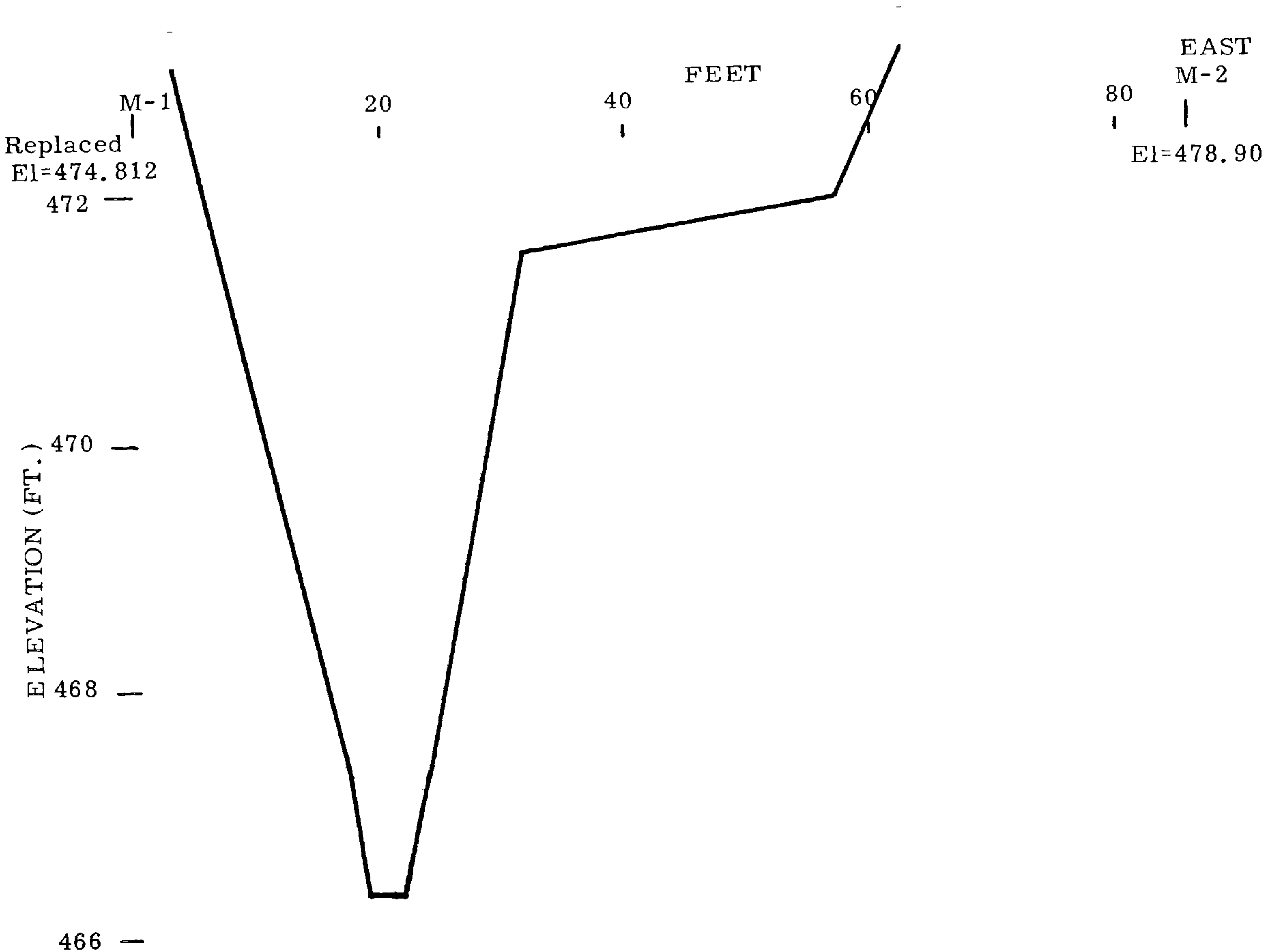


Figure B-23. Section M (Stream)
1/25/71

APPENDIX C

ENGINEERED FOREBAY DESIGN CRITERIA AND SEDIMENT ACCUMULATION

An engineered forebay is an appropriately sized settling basin, located at the confluence of a stream with a pond or lake. Its two principle functions are to capture suspended and bed load sediments that would normally be carried into the lake and to help facilitate sediment removal. Figure-18 depicts the forebay design employed in the demonstration project.

In discrete settling, the particle maintains its individuality and does not change in shape, size, or density during the settling process, as happens during flocculent settling. Naturally, settling suspended sediments are characterized by discrete settling.

A discrete particle will settle when the impelling force of gravity exceeds the inertial and viscous forces. The terminal settling velocity of a particle is defined by the relationship:

$$V = \frac{4g(\rho_s - \rho_\ell)D}{3C_d}$$

where:

ρ_s	=	specific gravity of the particle
ρ_ℓ	=	specific gravity of the liquid
V	=	terminal settling velocity of the particle
D	=	diameter of the particle
C_d	=	drag coefficient
g	=	gravitational constant (32 ft/sec^2)

The relationship used to describe the removal of discrete particles in an ideal settling tank assumes the particles entering the tank are uniformly distributed over the influent cross section and that a particle is considered removed when it hits the bottom of the tank. The settling velocity of a particle which settles through a distance equal to the effective depth of the tank during the theoretical detention period is described by:

$$V_o = \frac{Q}{A}$$

where:

Q	=	rate of flow through the tank
A	=	tank surface area

All particles having settling velocities greater than V_o will be completely removed, while particles with settling velocities less than V_o will be removed in the ratio of V/V_o.

Figure C-1 indicates a typical particle size profile for suspended sediments in the demonstration watershed. Assuming a specific gravity of 2.2 for the sediment and a 9000 sq ft forebay surface area, nominal sediment removals were calculated. Figure C-2 indicates the range of estimated sediment removals that would occur for varying flow rates using a forebay with a surface area of 9000 sq ft. For example, during a one year storm, the completed theoretical forebay entrapment efficiency is approximately 18 percent by total sediment weight.

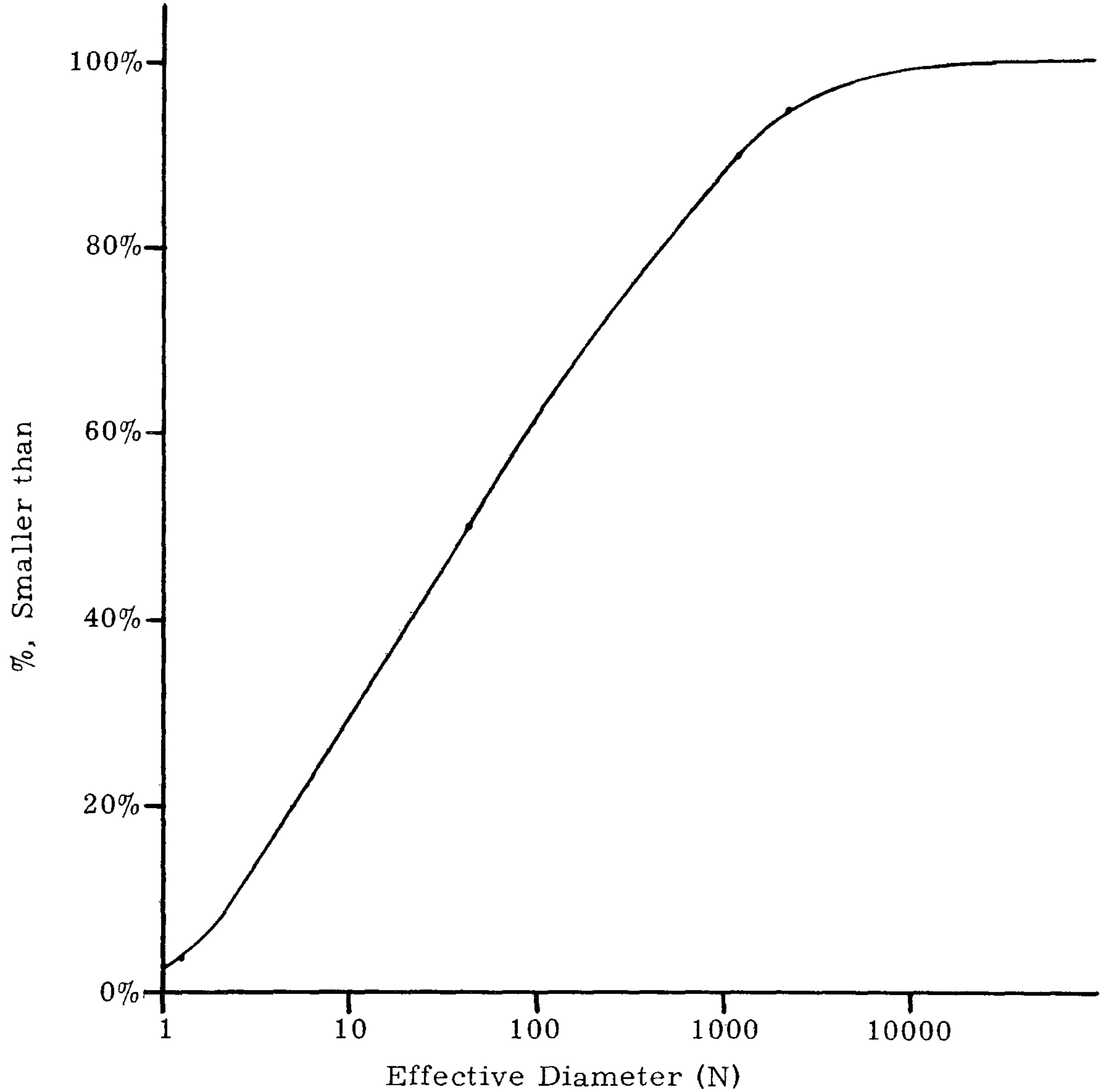


Figure C-1. Demonstration Pond Sediment Size Profile

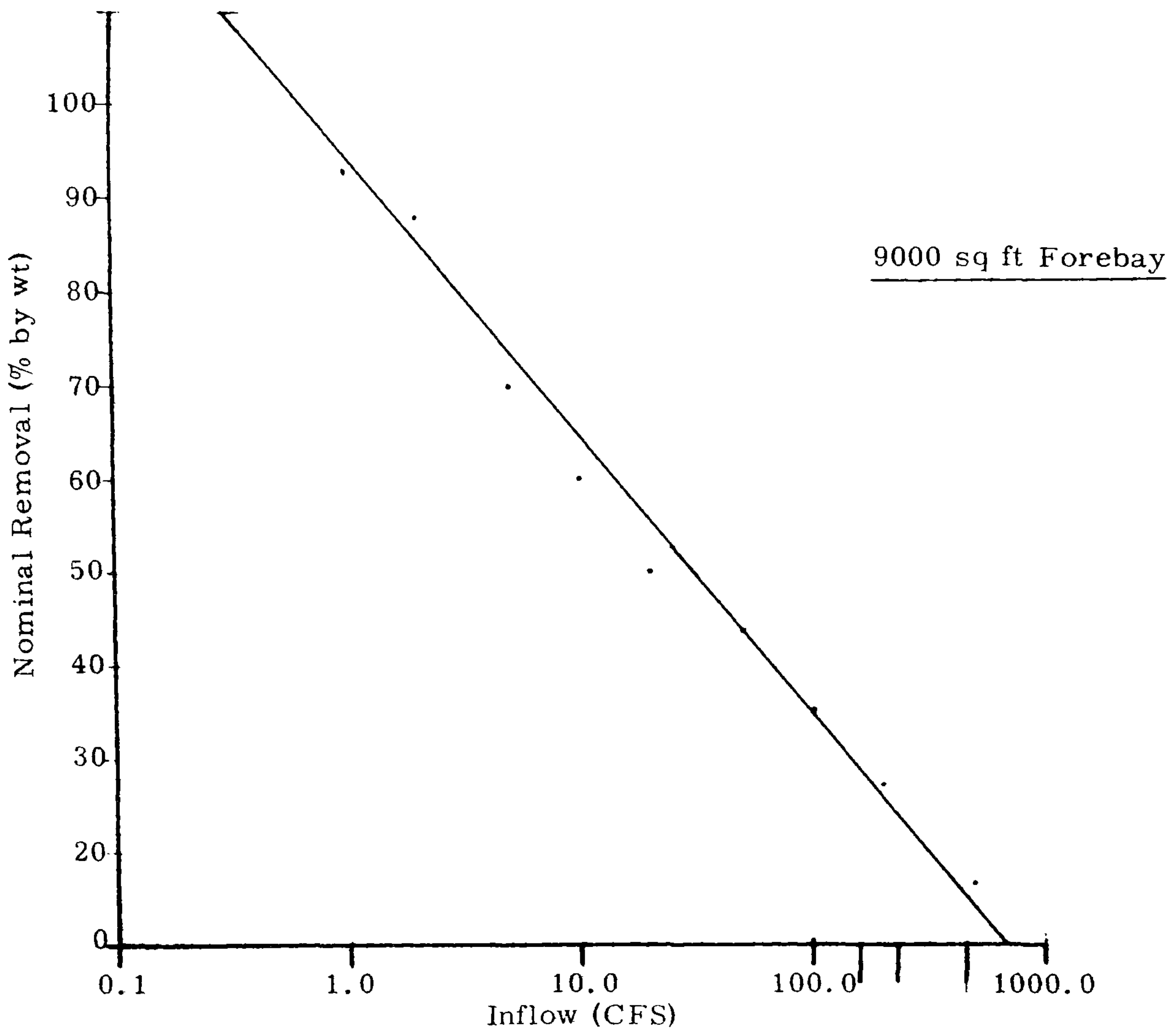


Figure C-2. Theoretical Forebay Sediment Removal Efficiencies

APPENDIX D

FEASIBILITY STUDY OF POND SEDIMENT REMOVAL TECHNIQUES

In order to ensure the success of the sediment and pollution control program, it was imperative that the material trapped in the pond be removed in a manner which will not allow significant amounts to return to surface waters. This, of course, had to be done at a reasonable cost and with minimum disruption to the surroundings, since the pond is in a park-like setting. Most techniques used today fail to meet all of the above requirements. Thus, new approaches had to be devised and/or evaluated along with existing techniques. However, because this project is not charged with developing new equipment, emphasis on the search for improved techniques was limited to the use of equipment already available. The following methods are discussed in this appendix:

1. Conventional dragline
2. Underwater scoops with a long reach
3. Hydraulic dredge with a pipeline to the disposal area
4. Hydraulic dredge to forebay
5. Submerged roads
6. Special on-site dewatering facilities
7. Combination scoop/dredge

Cost estimates have been based upon the maximum amount expected--about 9000 cubic yards at 30 percent solids. Since the forebay is assumed capable of removing one-third of the incoming material, pond cleaning techniques have been evaluated on a basis of 6000 cubic yards at 30 percent solids in place. Wherever possible, direct quotes from contactors and equipment suppliers were obtained.

DRAGLINE WITH CONVENTIONAL TRUCKS

The most commonly used method of cleaning ponds is the dragline. This method involves the use of a crane with a special dragline bucket. The crane is located on the bank of the pond. Through rapid rotation of the boom, the bucket is thrown into the pond. The dragline bucket is hauled in and the entrapped material is usually piled in windrows along the bank of the pond.

The reach of the dragline is quite limited – usually no more than 60 feet from the crane. A longer reach can be achieved if a long boom is used; however, this practice results in less efficient use of the dragline bucket. In addition, the long boom can present difficulties in transporting the dragline equipment to the pond site. Thus, the cost per yard removed of a dragline operation with a conventional boom is significantly lower than that with an extra long boom. Dragline sediment removal, therefore, is generally limited to removing the material near the shore line.

The usual method of dragline removal involves the piling of material along the banks (in windrows) as it is collected. This provides an opportunity for some dewatering. The solids are then transferred by loader or crane to regular dump trucks for transport to a disposal site. While piling in windrows aids in dewatering the sediment, the moisture content of the solids is usually great enough to cause leakage from regular truck bodies. It is estimated that air drying and dewatering in windrows would raise the solids content of the sediment from 30, as removed, to 40 percent after two days of dewatering.

The estimated cost of removing 6000 yd^3 from the pond was estimated to be approximately $12, 300. This does not include supervision, site cleanup, or a spotter at the dump location. Details of this estimate are given in Table D-1.

This technique must be considered a minimal effort because of the potential aesthetics problems that will result. Windrows of sediment

TABLE D-1. ESTIMATED COST FOR DRAGLINE OPERATION

Basis: 6000 yd^3 at 30% solids

A. Dragline

Approximate loading cycle for 1 yd^3 bucket* - 22 sec

Assume 50% efficiency in bucket

$\therefore$ 44 sec loading cycle

$$6000\ yd^3 \times \frac{44\ sec}{yd^3} \times \frac{hr}{3600\ sec} = 73.2\ hrs$$

Allowance for downtimes, equipment movement, etc. - 22.8 hrs

$\therefore$ Estimated equipment operating time = 96 hrs

Rental fee** - $100 (Inst.) + $22/hr (Incl. operator)

= 100 + 22 x 96 = $2200

If banks are not firm enough to support crane without pads, cost will be approximately doubled.*

$\therefore$ Assume dragline cost = $4400

B. Front-End Loader

1-3/4 yd^3 capacity - Assume same rate of operation as dragline

$\therefore$ 12 days

Rental*** (Incl. operator) = $45 + 18/hr

$\therefore$ 45 + 18 x 96 = $1775

C. Conventional Dump Trucks

6 yd^3 - traveling at 15 mph for 2 mile distance

Hauling cost estimated**** at $.60/$yd^3$ (Incl. operator)

6000 x $0.60 = $3600 x 1.25 (O.H. and profit) = $4500

6000/6 yd** = 1000 trips at 15 mph = 300 hrs

$\therefore$ use 4 trucks

TABLE D-1. ESTIMATED COST FOR DRAGLINE OPERATION (Continued)

Using 10T trucks, rental*** is $80/day (Incl. operator)

4 x 80 x 12 = $3840

∴ Assume $4500 as truck cost

D. Total Equipment Cost

Dragline	$ 4,400
Front-End Loader	1,775
Trucking	4,500
Subtotal	$10,675
Contingency (15%)	1,600
Total	$12,275 or $2.05/yd^3

E. Site Restoration Costs

Sod - 2 windrows 400 ft x 30 ft = 24,000 sq ft @$0.90/yd^2	= $2,160
Labor - 5 man-day @$40	= 200
Total Site Costs	$2,360

F. Total Cost

Equipment	$12,275
Site Restoration	2,360
	$14,635

*"Dodge Estimating Guide for Public Works Construction," McGraw Hill, p. 136, 1970.

**Cheasapeake Dredging Company, Baltimore, Maryland.

***Joseph J. Hock, Inc., Baltimore, Maryland

****"Building Construction Cost Data, 1969," Robert Snow Means Company, Inc., p. 10, 1969.

on the pond banks are sure to be a nuisance in the eyes of the nearby residents. Once the sediment has been removed, the area where the windrows were located will be unsightly so that a significant landscaping effort will be required to restore the area to an acceptable aesthetic level. One method would be to lay sod in all disrupted areas. Assuming windrows 400 feet long and 30 feet wide on each side of the pond, the sodding costs alone would be $2,160 ($.90 per square yard installed). In addition, about five days of labor at $40/day should be included for other cleanup work. Thus, the total site restoration work is estimated at $2,360. Seeding the area would, of course, be less expensive but the area would not regain its former aesthetic level or its ability to be used as a park for a period of time that could be measured in months.

In addition, the use of conventional dump trucks would result in the loss of significant amounts of sediment en route to the disposal area. This material would not only create a nuisance but would find its way back into nearby streams through storm water runoff.

In summary, dragline removal of sediment may be relatively inexpensive; however, severe aesthetic problems result that can only be remedied by expensive landscaping techniques. Total costs for removal of 6000 tons of wet solids transport to the drying beds, plus site cleanup are estimated at $14,635.

It must also be noted that this estimate contains the inherent assumption that all of the sediment can be removed by dragline. This, most likely, will not be true since the dragline can only reach about 60 feet from the shore. The pond is up to 250 feet wide. Thus, in the widest part of the pond large areas would not be reached. In order for sediment in these areas to be removed, it must slough or flow toward the shoreline area. This is not likely to occur to a significant extent.

CRANE OPERATED SCRAPERS

As mentioned in the previous section, one of the major drawbacks to draglines is the limited reach of the dragline bucket which limits the amount of material that can be removed. There are, however, variations of the dragline approach which are capable of scraping the entire bottom of the storm water retention pond. Several manufacturers produce special scoops which are hauled in by conventional cranes or winches but are returned by a cable attached to a "deadman" located some distance away. This arrangement can increase the effective reach of a scoop to over 1000 feet. The scoop operates in the same manner as a dragline bucket in that it scrapes the bottom and pulls the material in toward the crane. The material is then piled along the shore in windrows. One such approach involves the use of a conventional dragline crane and a scoop and deadman manufactured by Sauerman Brothers, Inc., of Bellwood, Illinois. A typical arrangement is shown in Figure D-1. Larger buckets and greater mobility can be achieved by using a boom support for the crane and a bulldozer for the tail anchor (Figure D-2). This evaluation is based upon the use of a 1-1/2 yard bucket with a conventional dragline crane. Table D-2 presents the estimates developed for two cases:

1. Case A scrape to a windrow along one bank, load conventional dump truck with a front-end loader and transport to disposal area.
2. Case B - scrape to forebay, allow to dewater, load conventional dump trucks, and transport to disposal area.

Estimated costs including site cleanup are as follows:

1. Case A – $13,150
2. Case B – $13,150

The lower cost of a scraper over the use of a conventic -al dragline is mainly due to the longer reach of the scraper. Thus, only one windrow is necessary using the scraper so that site restoration costs are

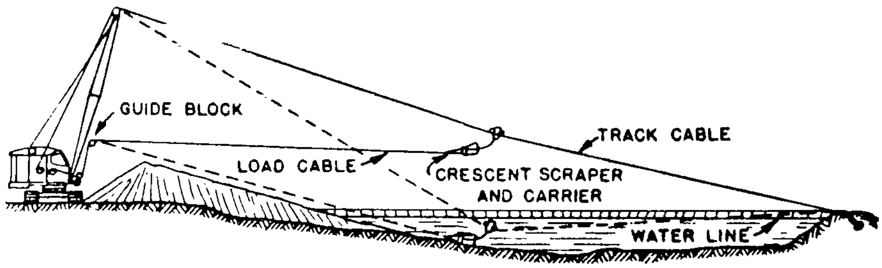


Figure D-1. Crane Operated Scraper, Typical Arrangement

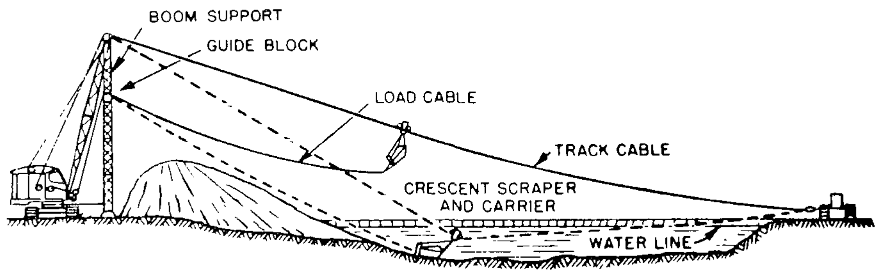


Figure D-2. Crane Operated Scraper, Alternate Arrangement

TABLE D-2. ESTIMATED COST FOR SAUERMAN SCRAPER

Basis: 6000 yards at 30% solids; 1-1/2 cubic yards scraper bucket; 100% of bucket volume utilized

Case A Scrap entire pond bottom to a windrow along one bank (approximately 200 feet average width). Load onto dump trucks from windrows.

(1) Equipment

(a) Crane and scraper complete

For 200 ft reach, loading cycle time***** = 90 sec

∴ Dragline crane and bucket will be used

$$6000 \text{ yd} \times \frac{1.5 \text{ min}}{1.5 \text{ yd}} \times \frac{\text{hr}}{60 \text{ min}} = 99 \text{ hr}$$

Add 36 hr for downtime, moving, etc.

∴ 135 hr total time - say 17 days

Rental fee for crane•

$100 + 22 x 135 = $2600

Rental for scraper*****

$360/mo x 2	= $ 720
Total	$3320

No allowance has been made for pads for the crane since it can be moved back from the pond edge.

(b) Front end loader•

17 days x 8 x $18 + $45 = $2400

(c) Dump trucks•

Same as for conventional dragline = $4500

TABLE D-2. ESTIMATED COST FOR SAUERMAN SCRAPER (Continued)

(d) Total equipment costs

Crane and scraper	\$3, 320
Front end loader	2, 400
Dump trucks	4, 500
	\$10, 220
Contingency 15%	1, 530
	\$11, 750

(2) Site Restoration

(a)	Sod - one windrow - 400 ft x30 ft @\$0.90/yd^2 (installed)	\$1, 200
(b)	Other - 5 man-days@\$40/day	200
(c)	Total site restoration	1, 400

(3) Total Case A Costs

Equipment	\$11, 750
Site Restoration	1, 400
	\$13, 150

Case B: Scrape to forebay (average distance - 300 ft) allow to dewater and load onto dump trucks.

(1) Equipment

(a) Crane and scraper

For 300 ft. reach, complete loading cycle time***** = 135 sec

$$6000 \times \frac{2.25 \text{ min}}{1.5 \text{ yd}} \times \frac{\text{hr}}{60 \text{ min}} = 150 \text{ hr}$$

Assume 24 hr downtime, etc. (less movement of deadman than in Case A)

∴ Total rental time = 174

TABLE D-2. ESTIMATED COST FOR SAUERMAN SCRAPER
(Continued)

	Crane rental•			
		$100 + 22 x 174	=	$ 3,900
	Scraper rental		=	720
				$ 4,620
(b)	Front end loader•			
		22 days x 8 x 18 + $45	=	3,200
(c)	Dump trucks•			
	Dewater in forebay. Assume 25 % reduction in volume of sediment			
		∴ 3/4 x $4500	=	3,380
(d)	Total equipment cost			
		Crane and scraper	=	4,620
		Front end loader	=	3,200
		Dump trucks	=	3,380
				$11,200
		Contingency 15%		700
				$12,900

(2)	Site Restoration			
	(a)	Sod - 10 ft x 50 ft = 500 ft^2 @$0.90/$yd^2$	=	$ 45
	(b)	Other - 5 man-days at $40/day	=	200
	(c)	Total site costs	=	245
(3)	Total Case B Costs			
		Equipment	=	$12,900
		Site Restoration	=	245
		Total		$13,145

*****Sauerman Brothers, Inc., Bellwood, Illinois, Technical Information

•See Table D-1.

proportionally reduced. While total estimated costs for Cases A and B are the same, there are some notable differences in the distribution of costs within each estimate: (1) Case B has lower site restoration costs since no windrows are formed; (2) trucking costs are lower in Case B since the sediment will be partially dewatered in the forebay; and (3) Case B required five more days to complete. Note that the cost of the forebay has not been included in this evaluation.

Attempts were made to prepare estimates using the Terra-Marine Scoop, a device similar to the Sauerman scraper except that the scoop is pulled by a truck mounted winch. However, at the time this evaluation was prepared, the manufacturer had not yet submitted the necessary cost and engineering data. It is estimated, however, that the cost of this scoop system will be about $\$1/yd^3$, or \$6000, for removal to the forebay. This would be comparable in cost and effectiveness to the Sauerman system.

HYDRAULIC DREDGE

Most large solids removal operations are accomplished by a hydraulic dredge with mechanical cutter teeth. Sediment is loosened by the mechanical teeth and swept up the intake pipe by hydraulic action. The discharge from the dredge pump is directed to a spoils area for subsequent dewatering. Because water is drawn into the intake pipe, dredging usually is a clean operation in the immediate vicinity of the intake pipe. On the other hand, proper disposal of the large quantities of water required to move the sediment often is quite difficult to accomplish.

Most floating dredges operate in a crab-like fashion. After the equipment has been assembled and floating pipe laid to a fixed shore spoils pipe system, the dredge drops a leg or spud to the bottom. The spud acts as a pivot point for the dredge which slowly swings in an arc as it removes sediment. Once the desired arc has been completed, a second spud is dropped and the first retracted so that the dredge swings back along a similar arc that is transposed forward. Periodically, new sections of floating pipe must be added as the dredge moves away from its starting point.

In order to assess the cost and level of effort associated with hydraulic dredging, the Mobile Dredging and Pumping Company of Exton, Pennsylvania was requested to prepare estimates for three separate cases given below. Pipeline transport to the disposal area was included in two cases. The possible location of the pipeline is shown in Figure D-3. At the time the estimate was requested, it was expected that only 2000 yards of material would be removed. While the expected volume has risen to 6000 yards, a new estimate was not prepared due to the high cost previously given.

1. <u>Case I</u>

Install pipeline and pumping stations for solids transport to sludge disposal area (distance - 10, 000 feet)

Clean pond once and remove pipe and pumping stations

Estimate sediment to be removed at 30% solids content	2000 $yards^3$
Approximate length of pond	700 feet
Width - maximum minimum	250 feet 10 feet
Water depth - maximum minimum	9 feet 0 feet
Maximum length floating pipeline	600 feet
Minimum length floating pipeline	0 feet
Maximum length of shore pipeline to disposal area	9400 feet
Approximate lift to disposal area	50 feet
Approximate sediment depth	0. 25 to 2 feet

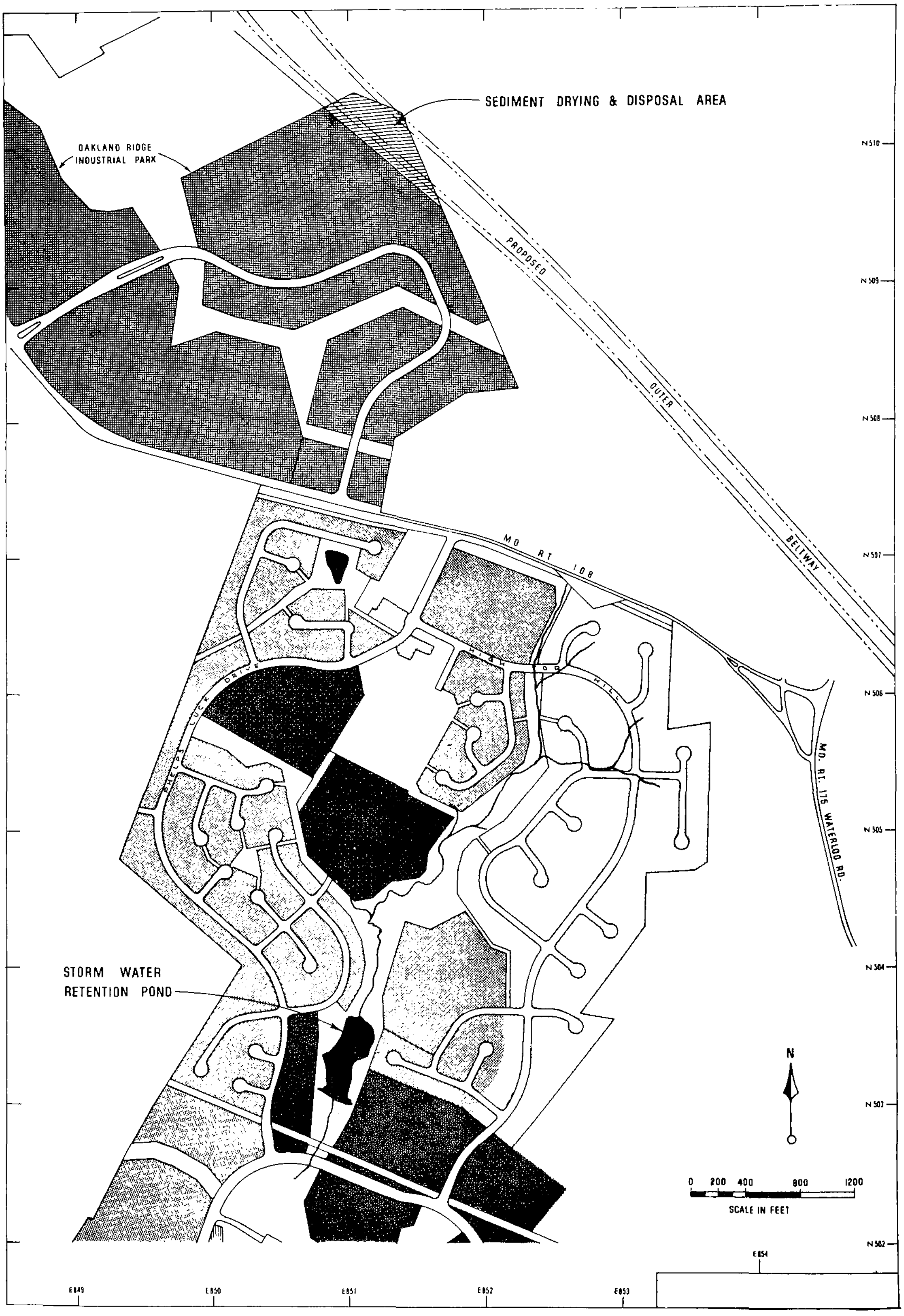


Figure D-1. Possible Location of Sediment Transport Pipeline

2. Case II

Install pipeline, etc., to sludge disposal area

Clean pond at the end of 1970, 1971, and 1972

Then, remove pipe and pumping stations

Estimated sediment to be removed (at 30% solids content)

1970	2,000 $yards^3$
1971	6,000
1972	2,200
	10,000

Pond dimensions and pipeline distances are the same as in Case I

Approximate sediment depth

1970	0.25 to 2 feet
1971	0.75 to 4 feet
1972	0.25 to 2 feet

3. Case III

Pump dredged material to forebay area

Clean pond once

Estimated sediment to be removed at 30% solids content- 2000 $yards^3$

Same pond dimensions, sediment depth, and floating pipeline lengths as in Case I

No shore pipeline used

The Mobile Dredging and Pumping Company has supplied the following estimates:

Case I	$ 52,280
Case II	136,840
Case III	31,100

Since the only difference between Cases I and III is that in Case I the sediment is pumped to the disposal area while in Case III it is pumped to the forebay, one can conclude that the cost of pumping sediment to the disposal area is about $20,000 on a one-time basis. This includes setup and removal of pipe and pumping stations, equipment rental, and operating labor. The dredging company further estimated an equipment mobilization cost for Case III of $3000. Thus, about $28,000 is estimated for actual dredging or about $14/yard.

This high unit cost is attributed by Mobile Dredging to the sensitivity of dredging costs to area covered rather than depth of sediment. Evidently, the major operating cost involves connecting new pipe as the dredge "walks" along the pond bottom. According to Mobile Dredging, the total cost would increase very little if the depth of sediment were greatly increased to say 6 to 10 feet since the movement of the dredge would be essentially the same as Case III, where the estimated sediment depth ranges from 0.25 to 2 feet for 2000 cubic yards at 30 percent solids. Thus, if sediment was allowed to build up to 0.75 to 6 feet (6000 cubic yards), the unit cost would be about $3.50-4 cubic yards. This is still appreciably more expensive than the previous cases considered.

Mobile Dredging estimated that about two months would be required to complete each dredging operation. The dredge is capable of covering about 3500 square feet per day. Note that in Case III, the cost of solids removal from the forebay and transportation to the disposal area is not included.

Mobile Dredging estimated the cost of the three cases on the basis of their smallest dredge which is a sizable piece of equipment. The dredge is 8 ft x 12.5 ft x 6 ft and has a 6 in. x 6 in. pump and is capable of dredging to a depth of 21 feet. A smaller dredge could probably perform as well for much lower cost; however, attempts to locate a small dredge to purchase or rent in the Baltimore-Washington area have been unsuccessful.

UNDERWATER ROADS

All of the removal methods discussed thus far involve either some disruption of the pond banks or removing solids to the forebay. The forebay will require fairly frequent cleaning so that the technique used should be as rapid and efficient as possible. One technique which has been suggested is the use of roads on the bottom of the forebay upon which front-end loaders or draglines could operate when the forebay is drained, an approach similar to the technique used at Lake Bancroft in Virginia. This would represent an efficient and fairly clean operation since: (1) the sediment would be subjected to minimal hauling; and (2) trucks would be loaded in the forebay. This approach has also been considered for cleaning the pond.

Consideration was given to the use of monolithic underwater concrete roads on which to operate sediment removal equipment. These would be formed and poured in place. However, this type of construction is not recommended for several reasons. The limiting condition for the design of an underwater road would have to assume that the underlying soil could subside or be eroded from under the slab. This would result in long unsupported lengths and would require that the road be designed as a long beam. Relatively thick reinforced sections would be needed; therefore, this is an expensive approach.

The road could also be designed as a series of relatively long slabs (10 to 20 feet) to limit the possible length of unsupported slabs. For this case, the maximum unsupported length would be determined by the area of the slab less the area required to support the weight of the slab plus equipment. This could still result in relatively long unsupported lengths and relatively costly construction. There is also the possibility that this type of construction could also become unusable; for example, if the undermining occurred at the ends or sides of the slabs allowing them to cant in relationship to each other.

For these reasons, the recommended construction for underwater roads should take the form of relatively small blocks. Small blocks will settle to conform to the bottom, have minimal unsupported lengths, and will reduce the possibility of becoming canted to the point that they cannot be used.

Small block underwater roads could be constructed using sectional forms and in place pours or by the use of precast blocks. The precast block concept is favored since the blocks will require reinforcement and assembly line fabrication using standard components will undoubtly be cheaper than field placement of reinforcing steel. Prestressing might also be desirable to reduce the thickness of the block.

The optimum size for the blocks involves several considerations. The area of each block must be adequate to support the weight of the most heavily loaded wheel of the equipment that will be operated on the road. Based on an allowable loading of two tons per square foot for the bottom of the pond and a maximum load of 10,000 pounds per wheel, the minimum area should be 2.5 square feet. Since the blocks will not be uniformly loaded, the area will have to be larger. With small blocks, the weight of the block will not be adequate to preclude tipping and some support will be required from the underlying soil. Also, the vacuum created by lifting the block will have to be relied upon to preclude tipping.

Unsuccessful attempts were made to obtain the design criteria for the perforated concrete blocks which have been extensively used in Europe for parking areas and roadways. In the absence of this information, the following design has been assumed. The blocks would be about 3 feet square with 16 - 5 inch holes on 8-inch centers leaving a web of 3 inches between holes and 3-1/2 inches on the edges. This will provide 6.8 square feet of bearing area. Based on a 10,000 pound load in the center and no ground support at the center, and using a simple reinforced beam analysis, the required thickness is 5.3 inches, say 6 inches. The weight of the block would be 500 pounds. With a prestressed block, the thickness could probably be reduced to 4 inches.

With a concentrated load on the edge of the block,the tipping moment would be about 3000 to 4000 foot-pounds. Under this condition, the righting moment of the block would be about 350 foot-pounds. However, the lifting of the outer edge would create a partial vacuum. A partial vacuum of about 4 to 5 psig would provide a sufficient force to resist tipping. Since the holes in the slab will provide good assurance of seating, only a severe undermining would cause the block to tip.

There is also a question as to whether the blocks should be used to form a full width surface or whether two rows can be used to provide tracks for the vehicles. This could reduce the number of blocks about a fourth, with extra blocks used at intersections and turns.

In addition to attempts to obtain design information on the blocks from European manufacturers, discussions were held with block fabricators for local production. For blocks as described above, an initial estimate of $2/square foot installed has been generated for preliminary purposes. Blocks could be used in both the forebay and the pond. The basic forebay design includes an underwater road adjacent and parallel to the forebay dam which intersects with a road down the length of the forebay approximately following the longitudinal axis. Total road length is estimated at 250 feet. Assuming a 12-foot wide road, approximately 3000 square feet of surface is involved. At $2/square foot, the approximate cost for a road system in the forebay would be $6000. This assumes that the roads are laid with a minimum of clearance between adjacent blocks.

The cost of a road system in the pond using the above block design is of significantly greater magnitude. If one assumes that the entire pond will be cleaned by dragline operating from the roads, approximately 1750 feet of roadway are required to place all of the pond within a 50-foot reach of the dragline. For a 12-foot wide roadway, approximately 21,000 square feet of road surface must be provided. Thus, a complete underwater roadway for the pond would cost about $42,000. This could be lowered if:

(1) The blocks were laid in two tracks instead of a "solid" roadway

(2) Roads were laid in the upper portion of the pond, where most of the deposition is expected to occur

With our limited current knowledge on the design, cost, and performance of the concrete block roadways, it would be inadvisable to recommend large scale road construction in the pond. A more reasonable approach would be to construct roads in the forebay, where the need is most critical, and to use the forebay roads as a test facility to evaluate their use in the pond.

Another approach that appears attractive is the use of precast reinforced concrete "logs" used in the construction of retaining walls. The logs, which are readily available as 5-1/2" x 5-1/2" x 48" blocks, could be arranged in an open mesh which is held together by cables passing through each log. Figure D-4 shows the proposed arrangement. Logs with holes in their sides would be strung on the cables which would be enclosed in the forebay or pond. After all the logs are installed, a steel backplate would be inserted and the cables would be tightened. When a wheeled vehicle traveled over the roadway, the mat would be somewhat flexible. According to Figure D-4, each linear foot of roadbed would require about seven square feet of block. At $2/square foot, the roadway would cost about $14/linear foot; thus, a roadway in the forebay would cost about $3500-$4000.

SMALL PUMP/DREDGE

It has been noted that an appreciable amount of sediment is expected to be deposited in the forebay, where it could be easily removed after dewatering by loaders operating from "underwater" roads. It is also expected that most of the sediment in the pond proper will be located

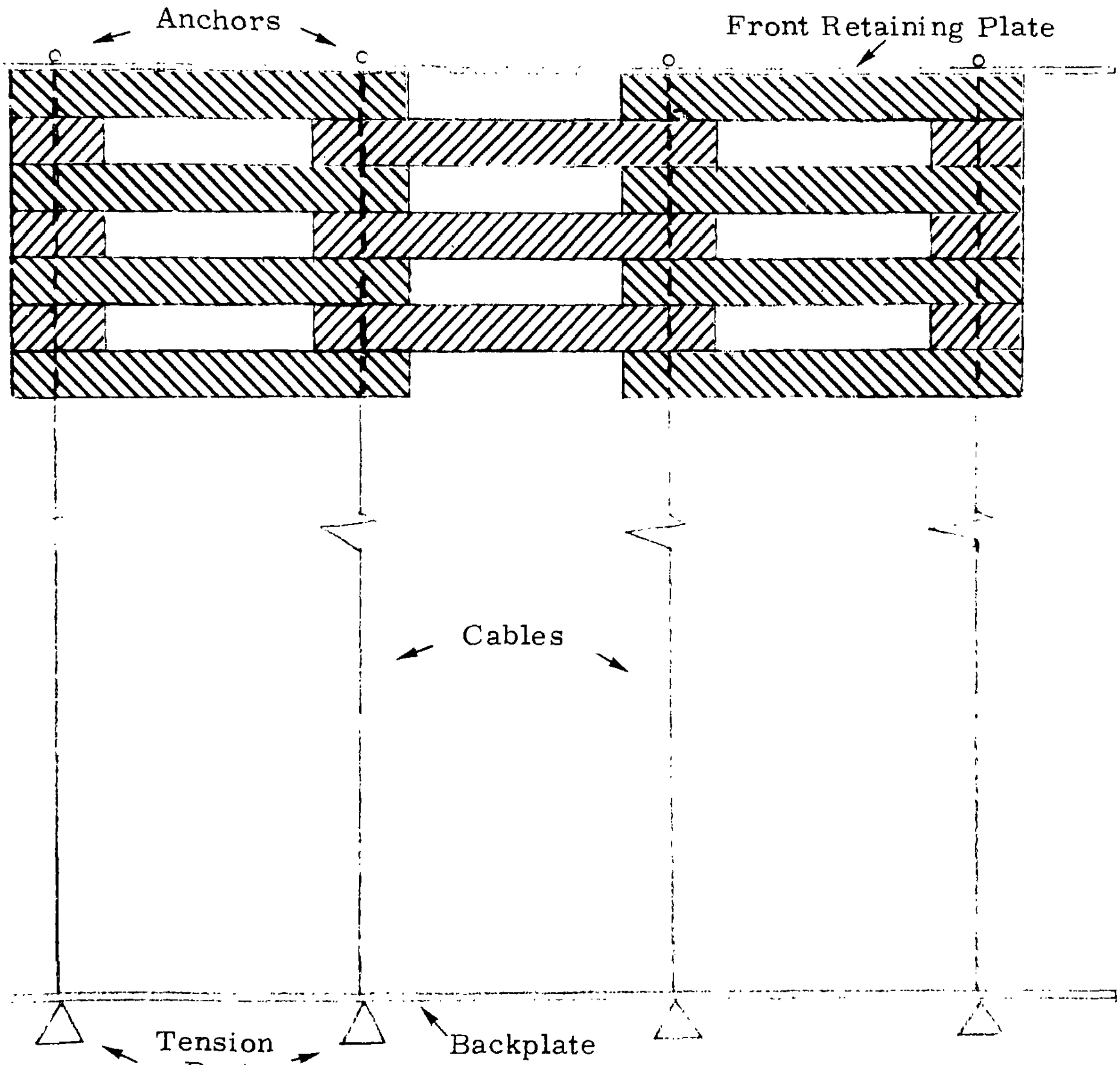


Figure D-4. Underwater Concrete "Log" Road at the upper end because of the relatively large surface area available. Thus, it may be possible to devise an economical method of periodically removing material from the upper end of the pond to the forebay, and thus minimizing the need for cleaning the entire pond. This function could be served by a small floating dredge that would pump to the forebay and would operate in the upper area of the pond. Because the forebay will be designed to remove almost all of the coarse material, most of the material in the pond should be of relatively small particle size. Thus, it should be possible to remove the sediment without the use of a mechanical cutting head such as that used by conventional dredges.

As mentioned in a previous section, small dredges are not available for rental. It should not be difficult, however, to assemble readily available components in a small equipment package that could be used to test the hypothesis that significant amounts of material could be pumped from the upper end of the pond without elaborate mechanical cutting equipment. The heart of this system will, of course, be the pump. Diaphragm pumps such as that manufactured by the Edson Corporation of New Bedford, Massachusetts, have been used for light duty dredging in boat yards and marinas. Their largest pump, 4" intake - 130 gpm, could be easily mounted on a raft. Flexible intake hoses would connect the pump to a rigid on-shore PVC pipeline leading to the forebay. The raft would be held in place by steel pipe "spuds" dropped from two corners. The intake probe would be guided manually by an operator aboard the raft. The package would, therefore, include a heavy duty gasline-powered diaphragm pump, flexible intake and discharge piping, a dredging probe, a raft, and several floats.

Approximate costs for assembling the equipment package and operation for four weeks are estimated at about $3500. This estimate must be considered preliminary in that little is known about the labor required to remove a given amount of sediment with this system; twenty man-days has been assumed.

APPENDIX E

LABORATORY SEDIMENT STUDIES

EFFECT OF CHEMICAL ADDITIVES

Five columns, each filled with three feet of sediment above one foot of filter sand and nine inches of gravel, were tested. The columns were treated with the following chemicals:

Column 1		Control
Column 2	Dow A21	250 ppm
Column 3	Hercufloc 6217	250 ppm
Column 4	Hercufloc 6175	250 ppm
Column 5	Dow N17	250 ppm

A filtration test was operated for three days and the amount of water drained was recorded. The test was abandoned at the end of the third day due to the unsatisfactory results. All chemical treatments failedto significantly improve drainability.

EFFECT OF SEDIMENT DEPTHS

Five columns each filled with nine inches gravel and 12 inches of filter sand were filled with the following amounts of sediment:

Column 1	6 inches
Column 2	12 inches
Column 3	18 inches
Column 4	24 inches
Column 5	36 inches

The water drained from each column was recorded. The test was conducted for 56 days. Results of the test are presented in Table E-1.

TABLE E-1. SEDIMENT DEWATER TEST BY VARYING DEPTH OF COLUMN

Unit No.			1		2		3		4		5	
Bed Depth			6 in.		1 ft		1 ft 6 in.		2 ft		3 ft	
Time	Reading	Days	ml H_2O Drained	% H_2O Remain*	ml H_2O Drained	% H_2O Remain*	ml H_2O Drained	% H_2O Remain*	ml H_2O Drained	% H_2O Remain*	ml H_2O Drained	% H_2O Remain*
6/15	14:30	0	0	100	0	100	0	100	0	100	0	100
6/16	9:00	0.77	40	75	70	78	50	89	75	83	90	90.4
6/17	9:30	1.80	75	53	110	65	125	73	130	79	150	84
6/18	9:45	2.80	95	41	145	54	155	66.5	165	67	200	79
6/21	9:00	5.77	122	24	179	43	207	55.5	233	61	270	71
6/22	9:30	6.77	129	19	188	40	220	52.5	247	60	288	69
6/25	9:30	9.77	142	11	207	34	250	46	286	54	335	64
6/28	14:00	13.00	150	5	230	26	280	40	316	49	374	60
6/30	10:00	14.80	150	5	238	24	292	37	331	47	394	58
7/8	14:00	23.00	154	3	257	18	348	25	388	37	468	50
7/12	13:30	27.00	155	2	262	16	366	21	415	33	493	47
7/15	15:00	30.00	155	2	267	14	376	19	432	30	515	45
7/20	15:00	35.00	155	2	268	14	388	16.5	452	27	554	41
7/29	11:00	43.80	156	1.4	273	12	401	14	470	25	618	34
8/11	15:30	56.00	---	----	275	--	418	----	480	--	672	--
Dewater Rate K_1 @t<3.5			0.1333		0.0875		0.0588		0.0500		0.0377	
Dewater Rate K_2 @t>3.5			0.0588		0.0281		0.0189		0.0124		0.0082	
Total Water W_0			500		1000		1500		2000		3000	
Total Drainable Water*			158		312		468		624		936	
Residue Water			340		688		1032		1376		2064	

*% Drainable Water Remaining at t Days.

*Determined Based on Column 1 Test.

VACUUM FILTRATION

Small samples of sediment (200 mℓ) were treated with various chemical additives ranging from zero to several thousand parts per million. The treated samples were filtered by a Buchner Funnel under a vacuum of 20 inches of mercury. The filtrate using Whitman #4 filter paper was measured at various intervals. The rate of filtration as measured by the fraction of the water drained was plotted on semilog graph paper. The efficiency of the filtration test was determined by the time required to remove 30 percent of the initial moisture. The efficiency of each test was compared with control tests under similar test conditions. The test results are summarized in Table E-2.

The chemical additives tested included three inorganic coagulants, 12 organic polymers supplied by Dow and Hercules, three combined organic and inorganic coagulants and four physical agents. The results indicated that up to 66 percent improvement of removal rate can be obtained; however, extremely high dosing rates must be applied.

TABLE E-2. VACUUM FILTRATION OF SEDIMENT SAMPLE

Additives Tested	Dosing Rate mg/ℓ	Time (min) Required to Remove 30% Moisture from Sample at Opt. Dosage: Control	Opt. Run	Improvement	Opt. Dosage
$Alk(SO_4)_2 12H_2O$	75-2800	60 min.	60 min.	0%	--
$FeCl_3 6H_2O$	50-3000	72 min.	39 min	46%	3000
$FeSO_4 7H_2O$	67-3120	75 min	60 min	20%	3120
Dow C_{31}	10-500	50 min	50 min	0%	--
Dow C_{32}	10-500	80 min	52 min	35%	500
Dow A_{21}	20-1000	83 min	28 min	66%	1000
Hercufloc 8586	5-150	75 min	57 min	37%	150
Hercufloc 6217	8-250	75 min	37 min	51%	250
Hercufloc 6175	8-250	70 min	40 min	43%	250
Hercufloc 8634	8-250	80 min	65 min	19%	250
Dow A_{22}	50-1500	90 min	40 min	56%	1500
Dow N_{11}	38-750	75 min	40 min	47%	750
Dow N_{12}	25-750	75 min	28 min	63%	750
Dow N_{17}	25-750	100 min	38 min	62%	750
Dow A_{23}	25-500	105 min	43 min	59%	500
$FeCl_3 6H_2O$* + Hercufloc 6217	50-400	85 min	53 min	38%	400
$FeCl_3 6H_2O$* + Hercufloc 6175	50-400	90 min	42 min	53%	400
$FeCl_3 6H_2O$* + Dow A_{23}	50-400	100 min	43 min	57%	400
Sand	5-40% Vol.	55 min	55 min	0%	--
Sawdust	2-20% Vol.	120 min	95 min	21%	20%
Incinerator Ash	5-40% Vol.	100 min	100 min	0%	--
Crushed Foam	5-30% Vol.	125 min	95 min	24%	30%

*$FeCl_3 6H_2O$ applied at 500 mg/ℓ

APPENDIX F

FIELD STUDIES FOR EVALUATION OF SEDIMENT DRYING, CONDITIONING, AND DISPOSAL

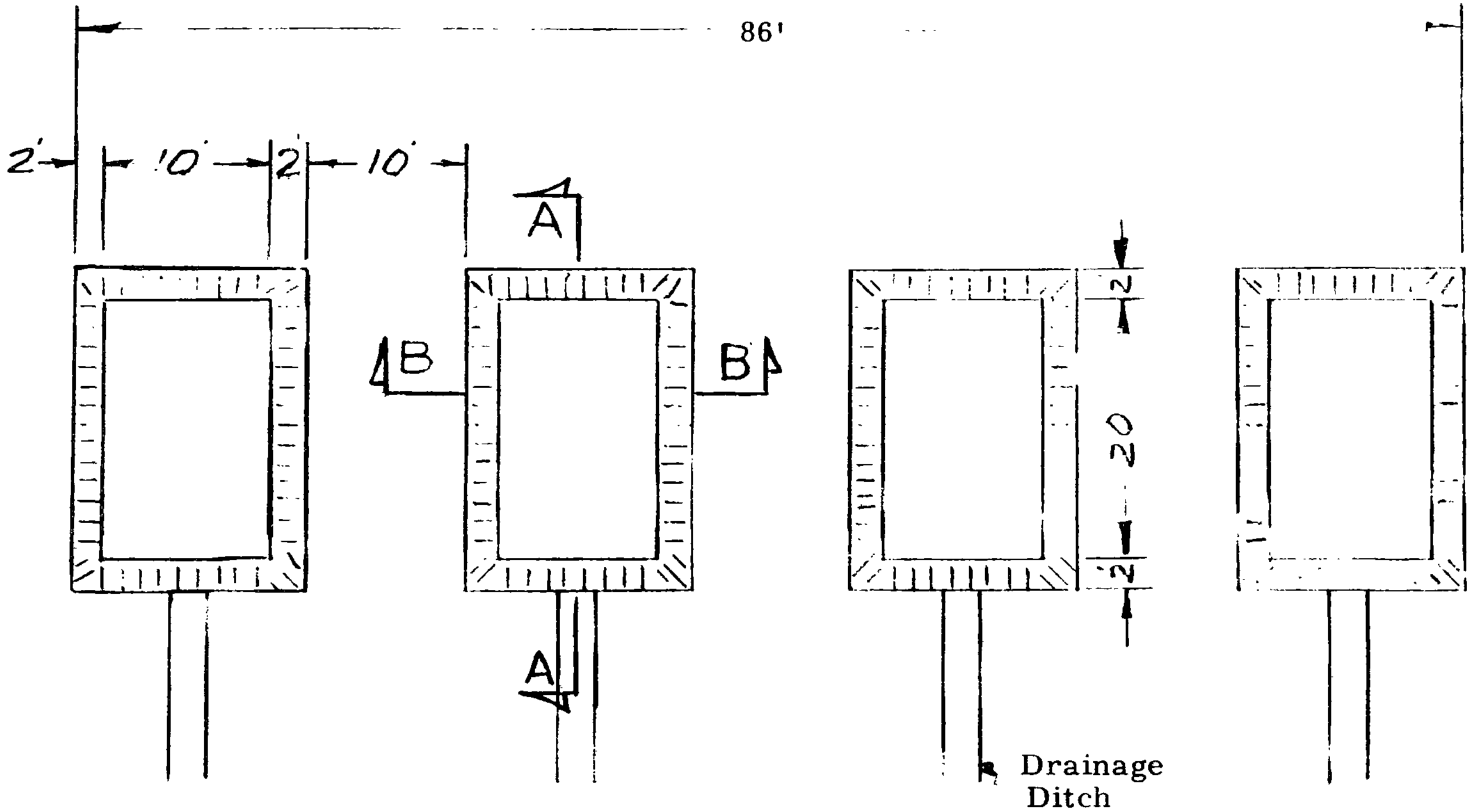
OBJECTIVES

The objectives of the field studies were:

1. To demonstrate and evaluate the use of sand and gravel drying bed bottoms
2. To demonstrate and evaluate mechanical/physical handling of drying sediment
3. To investigate various mixtures of sediment and other additives
4. To demonstrate the effectiveness of various mixtures on test grass plots

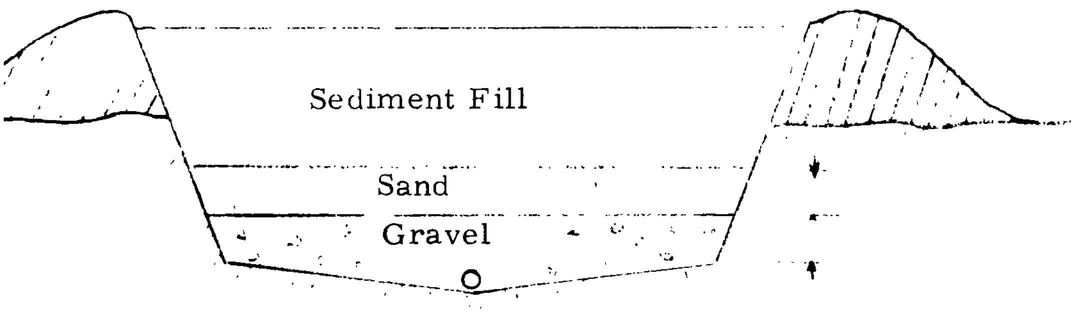
METHODOLOGY

Demonstration tests were conducted on four drying beds illustrated in Figure F-1. The beds had gravel and sand bottoms consisting of 12 inches of gravel (1/8 to 3/4inches) overlain by a 12-inch layer of sand (effective size 0.3 – 0.75 mm; uniformity coefficient not over 4.0). Provisions were made for carrying away water drained from the sediment. The drying beds were loaded directly from the trucks. Core samples were collected for moisture analysis; drained water samples were collected for physical and chemical analysis at various intervals. Sketches of the demonstration beds are shown in Figures F-2, F-3, and F-4. The drying beds were further divided into four plots each.



1" = 12'

Figure F-1. Demonstration Drying Beds - Plan View



1'' = 4'

Figure F-2. Section B-B, Demonstration Drying Beds

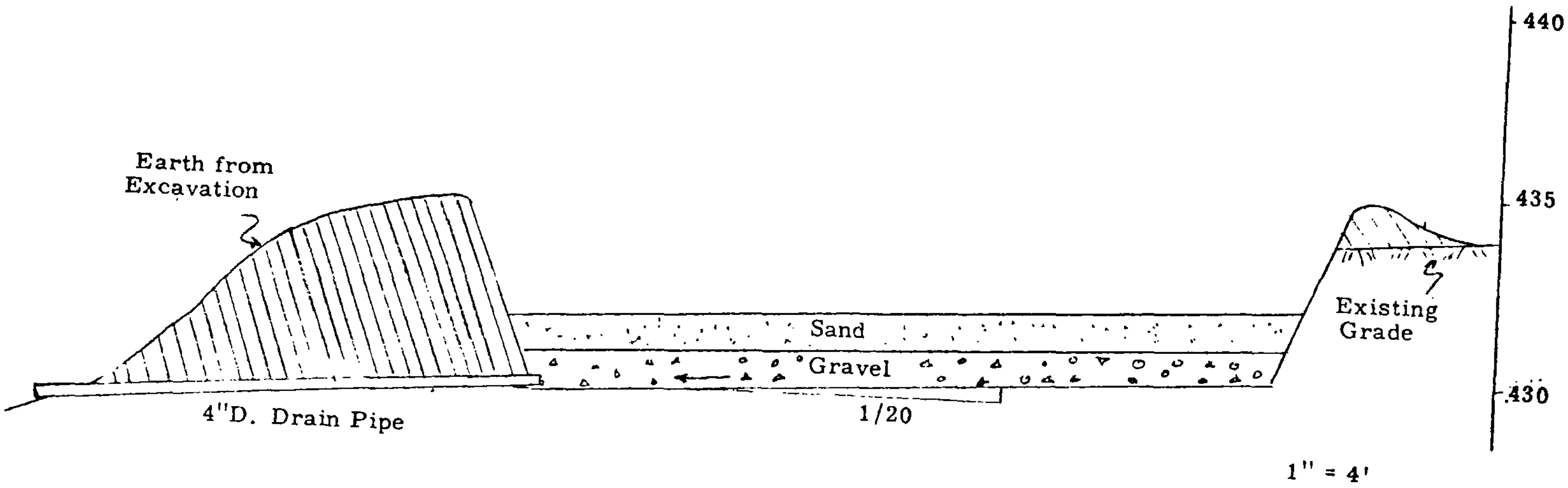


Figure F-3. Section A-A, Demonstration Drying Beds

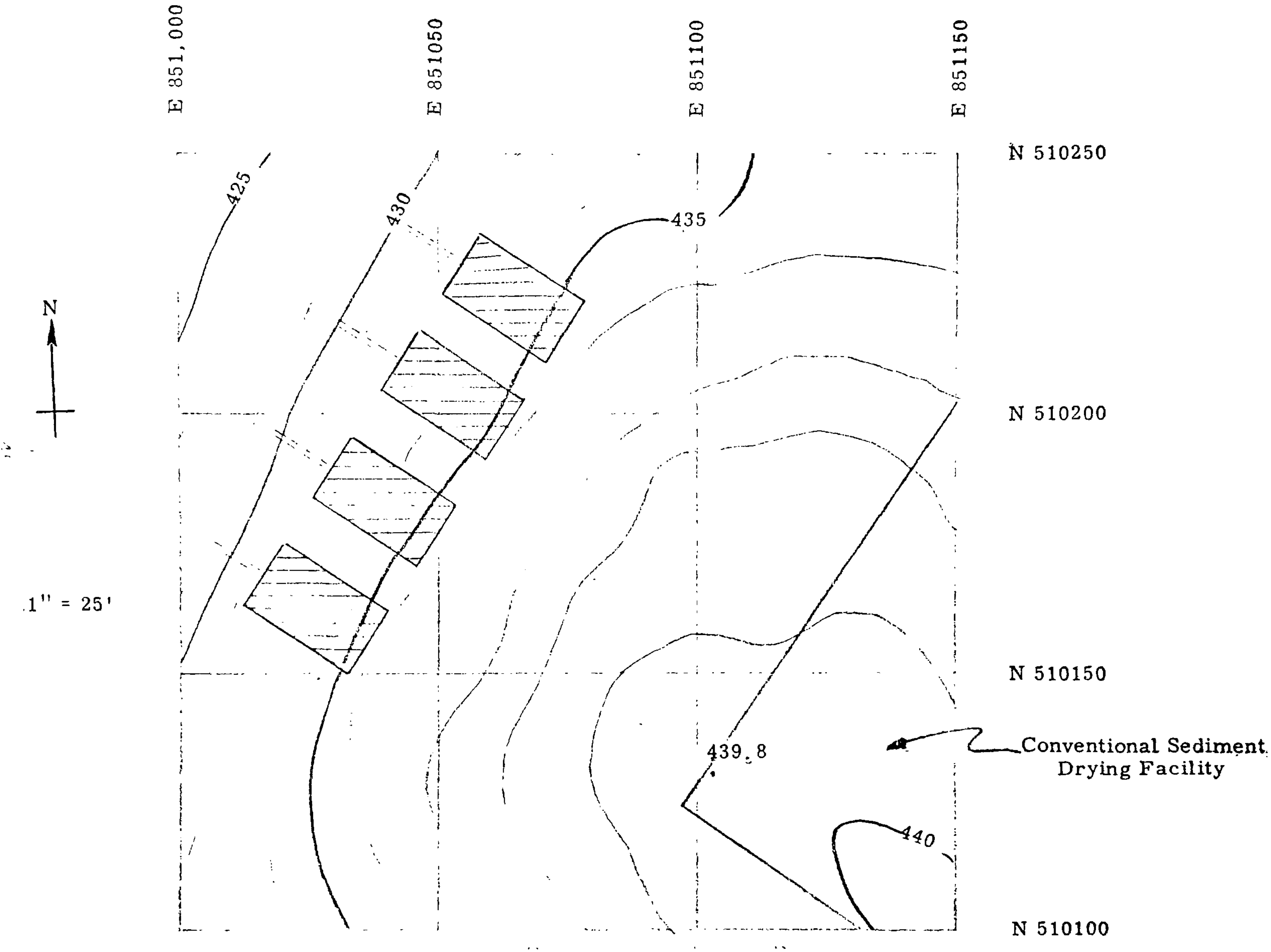


Figure F-4. Location of Demonstration Drying Beds

Several conditioning materials were added to the sediment according to the following pattern:

Bed 1	Bed 2
Plot 1 - Sludge	Plot 5 - Sludge
Plot 2 - Fly ash	Plot 6 - Fertilizer 10-10-10
Plot 3 - Woodchips	Plot 7 - Woodchips
Plot 4 - Control	Plot 8 - Control

Bed 3	Bed 4
Plot 9 - Fly ash	Plot 13 - Fly ash
Plot 10 - Sludge	Plot 14 - Fertilizer 10-10-10
Plot 11 - Control	Plot 15 - Control
Plot 12 - Lime	Plot 16 - Lime

Equal amounts of seed were sown in each plot. Observations were made over a period of eight weeks on plant behavior and sediment characteristics.

Application Rates of Additives

Sludge	-	5 lbs/sq ft
Fly ash	-	4 lbs/sq ft
Woodchips	-	5 lbs/sq ft
Lime	-	0.4 lbs/sq ft
Fertilizer	-	0.4 lbs/sq ft

Results and Discoveries

The parameters considered to be the main determinants in evaluation of the studies were:

(1) Germination period

(2) Plant cover and density

(3) Plant quality

(4) Drainage water quality

(5) Physical conditions of sediment upon application of conditioning material

(6) Drainability

Germination took place on most plots eight days after seeding except for fly ash plots where initial germination was observed after 12 days. The degree of coverage was greatest in the sludge plots, follwed by lime, control, fertilizer, and woodchips. Plant coverage in the fly ash plots was very sparse, but after another week coverage improved.

Plant quality was determined by the color of the leaves, the stability of the leaves, and the rate of growth. All the above factors were considered during the growth period. The color of the plants varied from dark green on the fertilizer and sludge plots to light green in the control plots of pond sediments. Forebay sediment control plots had better quality plants than pond sediments. Grass on fertilizer and sludge plots grew faster than the others, and plants on woodchip plots showed slowest growth. This can be attributed to the availability of nitrogen in sludge and fertilizer. The most prominent cause of deterioration in plant quality was nutrient deficiency. This was well evidenced in the control and woodchip plots.

The conclusions drawn from these studies are:

(1) Sediment,when properly mixed with both organic material and inorganic chemicals,supported vigorous plant growth.

(2) The drainability of fine sediment was improved by addition of organic material.

(3) The most effective additives tested were sludge, fertilizer, and fly ash.

(4) Unconditioned sediment plots showed signs of nutrient deficiency.

SELECTED WATER RESOURCES ABSTRACTS

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W

4. Title

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5. Report Date

6.

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7. Author(s) Becker, Burton C., Emerson, Dwight B, and Nawrocki, Michael A.

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Environmental Protection Agency report number, EPA-660/2-73-035, April 1974.

16. Abstract

During the period of this demonstration, a natural and agricultural region is being converted to an urban community. This project consists of (1) the implementation, demonstration, and evaluation of erosion control practices: (2) the construction, operation, and demonstration of the use of a stormwater retention pond for the control of stormwater pollution; and (3) the construction, operation, and maintenance of methods for handling, drying, conditioning, and disposing of sediment. In addition, a gaging and sampling program was conducted as part of this project to determine the effects of urbanization on the hydrology and water quality of natural areas. This project was conducted in the Village of Long Reach, Columbia, Maryland.

This report was submitted in fulfillment of Grant No. 15030 FMZ by the Water Resources Administration, State of Maryland, under the partial sponsorship of the Environmental Protection Agency. Work was completed as of June 1973.

17a. Descriptors *Aquatic environment, *Construction, *Demonstration Watersheds, *Erosion Control, *Rainfall-runoff relationship, *Sedimentation, *Urbanization, *Watershed, Biology, Channel morphology, control, costs, dam, ecology, forebays, gaging stations, hydraulics, hydrology, lentic environment, lotic environment, mathematical models, maintenance, monitoring, peak discharge, pond, revegetation runoff, suspended load, trees, turbidity, utilities, water quality, weirs.

17b. Identifiers

*Guidelines, *Columbia, Maryland, grade control, recycled glass, recycled sediment, return frequency, sediment basins, site evaluation, soil loss surveys, woodland development.

17c. COWRR Field & Group 02E, 02H, 02J, 04A, 04C, 04D, 05C 05D

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