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ENVIRONMENTAL IMPACT OF RIVERBANK REVETMENT,(U)

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ENVIRONMENTAL IMPACT OF RIVERBANK REVETMENT

prepared for

The U. S. Army Corps of Engineers

Louisville District

by

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David E. Stein

University of Louisville

May, 1975

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This study addresses the technical economic, and environmental feasibility of common bank revetment techniques and reviews existing environmental impact assessment methodologies and their pertinence to assessment of bank revetment projects.

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ABSTRACT

In this study, which addresses the technical, economic, and environmental feasibility of common bank revetment techniques, a review of existing environmental impact assessment methodologies and their pertinence to assessment of bank revetment projects has been presented. This review of assessment procedures along with visual evaluation of various revetment projects, provided the basis for the establishment of an assessment procedure to be utilized in bank revetment projects.

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CHAPTER I

INTRODUCTION

Alluvial rivers have benefited mankind in a variety of ways. Since early times, rivers have been utilized for travel and trade. From their fertile floodplains man has fed and clothed himself. Rivers were, and still are, major arteries of commerce. Early alluvial rivers provided trade routes which could be navigated with little or no improvement. As cultivation and settlement of the floodplains occurred, concern for agricultural, industrial, and residential developments evolved. Not only were these concerns occassionally damaged by flooding, but the meandering rivers were often destroying productive areas through bank erosion.

It is desireable to minimize bank caving in all rivers since eroded materials returned to the river may form bars that obstruct navigation or cause additional bank erosion endangering both public and private developments. The regulation and control of alluvial rivers requires that these water systems be partially stabilized and held to a minimum length consistant with the demands for navigation.

One means of channel stabilization in alluvial rivers incorporates bank revetment which may be defined as any protection which directly protects the river bank slope by providing a continuous protective cover. Although bank revetments provide only localized protection, they can generally be justified to prevent the undermining of levees, the destruction of valuable land, and the deterioration of natural channels. Numerous materials have been utilized for revetment type protection, including: hand-placed or dumped riprap, gravel, portland cement, asphalt, lumber, metal, and various combinations of these.

Several major factors play a role in revetment technique selection, including: technical feasibility, cost, and environmental effects. Environmental effects have often emerged as a deciding factor since the implementation of the National Environmental Policy Act of 1969 (NEPA). Bank revetment projects now require the preparation of impact statements since they fall under the guidelines established by NEPA. Preparation of an impact statement for a bank revetment project is not a simple task. The one major drawback with regard to the impact assessment of revetment projects is the cost of the environmental study. Although bank revetments are usually significantly less expensive than many major projects (such as the construction of dams or power plants), bank revetment impact studies require the review of all the environmental parameters considered in the review of costlier projects. Consequently, an assessment procedure must be devised which simplifies the evaluation of bank revetment impact assessments, thereby reducing the cost of such studies.

Before such an impact procedure can be developed, visual evaluation on various revetment projects must take place to develop a basic understanding of the environmental parameters affected by various types of channel stabilization. Possible alternatives which exist with regard to the development of impact assessment procedures specific to bank revetment projects include the utilization or revision of an existing methodology, or the development of a new procedure based on a review of existing impact assessment methods.

The purpose of this study, which was funded by the Louisville District, U. S. Army Corps of Engineers, was to evaluate the various revetment procedures currently utilized as to their technical and economic feasibility and their environmental effects. An optimum model for the environmental impact assessment of river bank revetment was also to be established.

CHAPTER 2

BANK REVETMENT TECHNIQUES

2.1 NEED FOR BANK PROTECTION

As the bank of rivers are erodible, it is necessary to provide protective measures to halt this erosion when required. In the absence of defences against bank cutting, settlement and urbanization which resulted from the transportation and fertile land provided by the river, may be destroyed by direct attack of the water.

Protection of banks along navigable waterways in the United States is a form of engineering art rather than an applied science. Bank stabilization works are generally chosen on the basis of subjective judgement instead of sound engineering practice. This is due in part to the lack of direction in selection of bank protection techniques and to poor communication between responsible engineering agencies. The principle objectives of channel stabilization are a fixation of the bank to prevent removal of the alluvial soil, and the preservation of developments thereon.

Various methods have been utilized to prevent bank erosion along alluvial rivers, one of these methods being revetment. Revetment protection provides for direct continuous protection of the bank surface preventing bank cutting. In order to best evaluate revetment techniques three different types of study are necessary. These areas of study include: technical feasibility, economic feasibility, and environmental impact.

The determination of technical feasibility involved the analysis of six criteria (1): durability, strength, flexibility, permeability and filtering properties, weight and anchorage, and placement condition and methods. While not all of these criteria are disernable in each revetment technique, each plays a role in determining technical feasibility.

The economic study involved assessing the material and in place cost of each method used in bank revetment. While data was often unavailable for some methods and there were inconsistancies in units (lot, yd^3, ft^2, etc.), every effort was made to determine the ft^2 (m^2) cost of each method after establishing an average depth of placement for each method.

The environmental analysis of revetment techniques, as presented in Chapter 3, involved the evaluation of a set of established environmental parameters. These parameters, which were established by an interdisciplinary environmental team from the Louisville District Corps of Engineers, include environmental concerns within the ecological and physical environments and also aesthetics. While socio-economic parameters also play an important role in environmental assessment, they were deleted in this study due to their site dependency.

2.2 RIPRAP REVETMENT TECHNIQUES

The conventional stone riprap revetment is the most widely used bank protection technique. In this study, riprap revetment techniques included any type of bank protection formed by unconnected pieces of material. Four types of riprap have been assesed. They include:

conventional stone riprap, ceramic riprap, soil blocks, and indurated low-grade rock.

Riprap revetment techniques are very permeable due to void space between the unconnected pieces. While a synthetic filter blanket, or layer of dumped gravel, is often needed to prevent leaching of the fines, no internal drainage is required. Another desirable feature of riprap techniques is their ability to settle and fill minor holes and otherwise adjust themselves to irregularities in the subgrade. The stability of riprap revetments tend to increase with the size of the individual pieces, making possible any desired degree of protection.

2.2.1 Conventional Stone Riprap

One of the most widely used, and most satisfactory forms of bank protection consists of placing a loose rock facing on the bank slope. This type of protection can be either dumped or hand placed depending on the site conditions and degree of protection desired. Hand placement tends to provide better gradation.

Much research has gone into the study of more effective means of bank protection. The effectiveness of a procedure has in general been found to increase as the cost increases. However, stone riprap is one major exception. Due to the availability of quarried stone in the Louisville, Kentucky area, the initial cost of this type revetment represents a much smaller investment than other methods which meet the same design requirements.

2.2.2 Ceramic Riprap

There are two types of commercially available ceramic which could be utilized to form riprap. These are: vitrified clay masonary units and poreen. These materials have the same general properties of conventional riprap including flexibility and permeability but they are each inherently different.

Vitrified clay masonary units (common clay brick and tile) have been found to be too light in weight to provide adequate stability. Because sufficient weight is needed in the individual pieces for adequate revetment protection, several units would have to be bound together to form mats increasing the production cost of this method considerably.

Poreen, a ceramic material which has a higher density and higher strength than normal vitrified clay masonary units, could be manufactured in sufficient size and with interlocking features to allow units to be placed directly on the slope. While these interlocking features provide a good continuous protective cover, some migration of foundation material would probably occur without a filter blanket. The interlocking blocks would have to be hand placed on the bank to provide the protection for which they were designed. Poreen could also be fabricated into mats, as were the vitrified clay units.

The use of ceramic units such as common clay brick and tile or poreen would be technically feasible; however, the production costs associated with this method is excessive and the standards for finished products are hard to meet.

Another form of ceramic riprap (crude glass riprap) formed by melting sand is another alternative to conventional riprap, but the present methods and equipment used in production have not been adequately tested and proven. This method forms balls or blocks of riprap rather than placing a layer or mat on the bank surface. From the few studies that have been conducted with glass riprap, it is believed that it is quite brittle and has the tendency to form shrinkage cracks which cause it to break apart.

2.2.3 Stabilized Soil Blocks

Consideration has been given to the feasibility of using materials to stabilize the natural soils existing at or near the revetment site and forming the soil into blocks suitable for use as riprap. Cement, asphalt, and chemicals have been considered as stabilizing agents.

Soil cement blocks as well as sacks filled with soil cement have been used as artificial riprap. The normal procedure utilized in making soil cement consists of either breaking up hardened soil cement slabs, or casting individual blocks. The preferred method is casting of individual blocks. Soil cement blocks have the lowest material cost of any type of artificial riprap. However, more economical construction methods must be developed. Curing methods, cement contents, durability, and methods for manufacturing individual pieces should be reviewed.

Cationic asphalt emulsion in soil stabilized blocks could produce riprap which is slightly less expensive than soil cement but more expensive than quarried stone. The thickness of the protection required for this method, durability, and filter requirements, need further study to determine the full economic feasibility of this method. Asphalt-sulfur hot mix blocks are some what more expensive, but they offer a shorter cooling time and ease of handling. Raw material costs are rather high in this method. Asphalt stabilized soil blocks are flexible when new, whose properties gives them the tendency to mold to one another. This tendency to bind together provides added resistance to erosion and increases the filtering properties.

Chemically stabilized soil blocks have been researched a great deal within the past 30 to 40 years. Some of the various agents harden very quickly, which eliminates the problem of storage. However, there is no known chemical which will provide adequate strength in soil blocks at a competitive price.

2.2.4 Rock Induration

Rock induration is simply the stabilization of weak, low quality rock which has insufficient strength and durability to be used as riprap. Methods of rock induration include surface coatings, electro-chemical stabilization, and thermal stabilization. These methods do not appear technically feasible because the standards for finished products are too hard to achieve. There have been very few recent developments in this area and the expense of these methods do not warrant further consideration of their use for bank protection.

Sandbags have been utilized sparingly as a type of riprap protection, but usually only in emergency situations when no other material was available. No information as to their cost or technical feasibility was available.

2.3 MATTRESS TECHNIQUES

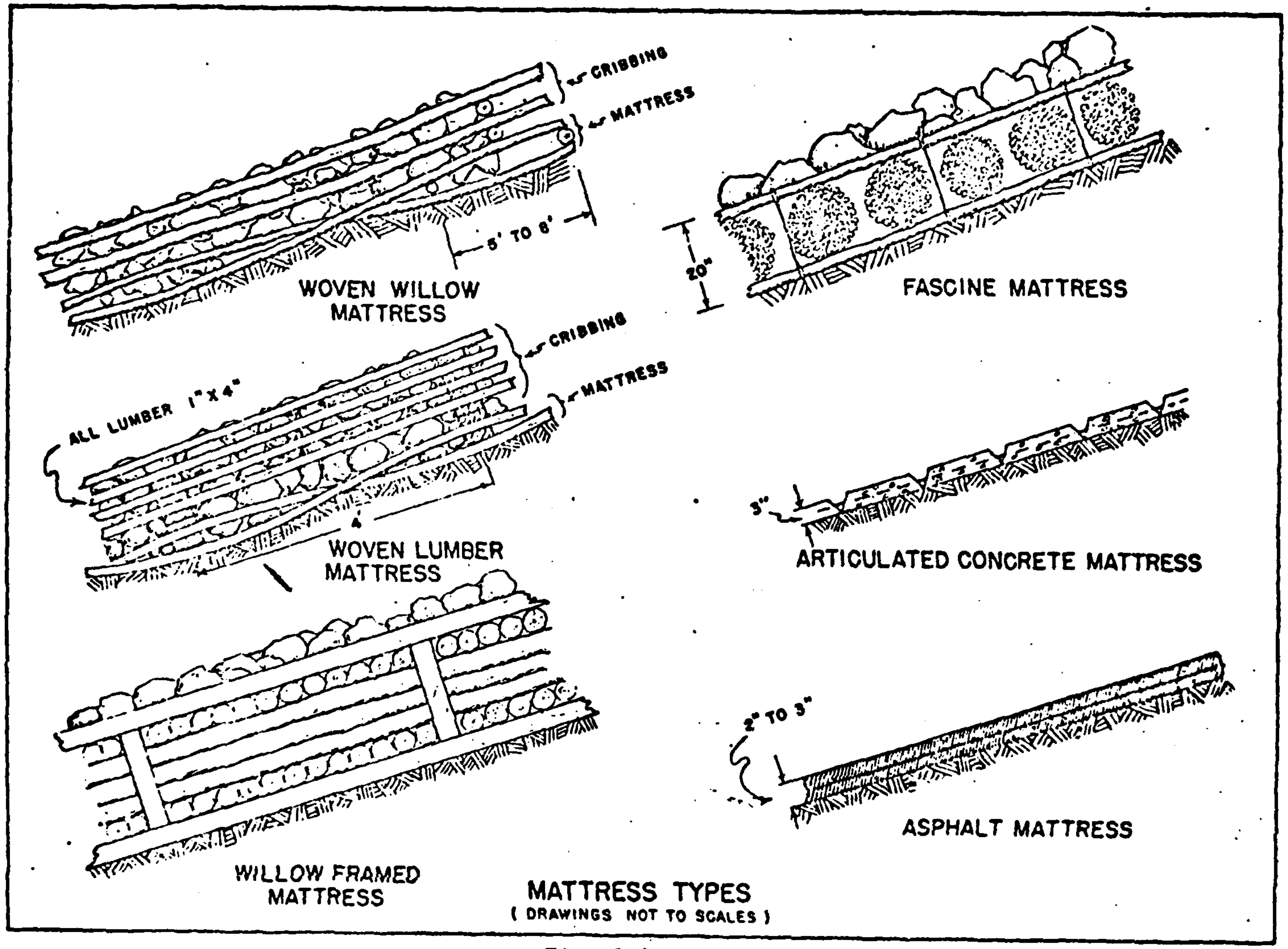
Mattress revetment techniques consist of those methods of bank protection which provide a continuous covering for the bank by means of an interwoven system of individual components. The components which are incorporated in the mattress system, may be concrete, ceramic, asphalt, quarried stone, timber, old auto tires, or various other types of material. The components are usually woven together by means of wire, but cloth is sometimes used both by itself and as the binding material for the individual pieces.

The components which make up the weight and mass of the mattress system are usually considered rigid. The binding materials give the system its flexibility. Mattress revetments are usually fabricated in large sections and sunk against the underwater bank. For the most part, mattress revetment applications have been limited to subaqueous bank protection. The permeability of a mattress type revetment is much like that of riprap. The voids between the interconnecting pieces allows for sufficient drainage and in most cases mattresses require a filter blanket to retain the soil. The strength and durability of a mattress revetment depends mainly on the material used to fabricate the mattress. While mattress revetments are flexible to some degree, the continuity of this type of revetment limits the flexibility somewhat. The large sections of a mattress revetment usually provide the weight needed to stabilize the system. Constraints in the fabrication of mattress revetments consist of time, labor costs, and lack of availability of materials.

2.3.1 Articulated Concrete Mattresses

The articulated concrete mattress (see Figure 2.1) is fabricated on launching barges from precast units 25 ft. (7.5 m) long and 4 ft. (1.2 m) wide. These precast units consist of 20 concrete blocks, 3 in. (7.2 cm) thick, 4 ft. (1.2 m) wide, and 14 in. (35.6 cm) long, connected together by corrosion resistant wire. The individual blocks are separated by one inch and have two strands of reinforcing wire running their width. The reinforcing wire is continuous in each direction in order to facilitate fabrication of the units into a mattress. The final mattress is approximately 90 ft. (27 m) wide. The fabrication and launching of the mattress is a continuous operation after each row of precast units is fastened to the preceding row. The launching barge moves away from the bank to allow most of the row to slide into the water making room for fabrication the next extension. This process is repeated until the desired length of mattress is completed.

The concrete revetment mattress is durable, flexible, permeable,



MATTRESS TYPES
(DRAWINGS NOT TO SCALES)

Fig. 2.1

and has sufficient strength and weight. The one disadvantage is the lack of adequate filtering. The foundation materials have a tendency to be sucked out through the intricies in the mattress. This method of protecting the banks is not economically feasible for all, but the largest sites. The articulated concrete mattress requires the initial construction of a $4,000,000 plant to precast the system before it can be launched.

2.3.2 Ceramic Mattresses

As stated in Section 2.2.2, the only technically feasible way for ceramic material to meet the weight requirements of revetment type protection is to bind the individual units into mats. These fabricated ceramic mats could be launched just as the articulated concrete mattress was and would have approximately the same properties as the concrete mattress. The only difference would be in the weights of the separate systems. The ceramic mat would be somewhat lighter and would have the tendency to move when subject to severe current action. The cost of the ceramic mattress would be reduced by barge fabrication and launching, but the cost would still be slightly higher than quarried stone.

2.3.3 Asphalt Mattresses

The reinforced asphalt mattress (see Figure 2.1) was used extensively along the lower Mississippi River from 1934 to 1943. In

1943, the articulated concrete mattress replaced the asphalt mattress due to the many short comings involved in its fabrication and placement. The asphalt mattress required a specialized and costly plant for its manufacture and placement. The asphalt mattress could be placed only when the river was low and currents in excess of normal were major problems.

2.3.4 Timber Mattresses

A number of types of timber mattresses have been developed and utilized to some extent for bank revetment. Timber mattresses have been known to possess long lives, if continually submerged. However, when they are exposed to the air they deteriorate rapidly, particularly where they are subjected to intermittent submergence and exposure.

The woven willow mattress (see Figure 2.1) consisted of willow brush woven around willow poles, reinforced with wire and iron rods. This type of mattress was contructed on barges, launched and sunk into place with ballast. The woven willow mattress lacked flexibility and it was so permeable the soil on the banks was washed out through the strands.

The framed willow mattress (see Figure 2.1) was fabricated by constructing upper and lower frames of timbers and securing willow poles between them. This type of mattress was erected on the bank and when completed floated and sunk into place by rock ballast. This type of mattress was found to be durable and was effective if properly placed.

The willow facine mattress (see Figure 2.1) consists of tightly bound bundles of willows fastened together to form a continuous mat. This method was also constructed on the bank and sunk into place. The mattress is heavy, and special equipment was required to fabricate and place it. Because of the labor involved in this method, it was very expensive to implement.

The woven lumber mattress is a development of the woven willow type mattress and was used where lumber could be procured at a relatively low cost.

2.3.5 Synthetic Mattresses

Synthetics have been used by themselves in individual sheets, and also to form cloth revetment mattresses which have pockets in which concrete or sand could be injected to stabilize and sink the material. Synthetic material has the greatest potential for economical bank protection. There are many materials available, but nylon has been most widely used in bank protection. Nylon is not resistant to deterioration from sunlight when used above the low water level. Although acrylics are more resistant to the sun, they are not as strong as nylon. It is believed that synthetics, when used in the form of sand or concrete filled mattresses, will provide bank protection greater than that of the articulated concrete mattress in terms of filtering, flexibility, and anchoring. Reservations have been expressed in the use of a single layer or synthetic material for bank protection, due to the anchoring problems and also the effective life of the material.

2.3.6 Other Mattress Techniques

Gabions, which are essentially riprap enclosed in a wire basket, is one method of bank revetment which has recently received much attention. Gabions cost approximately 50 percent more by volume than graded riprap. However, evidence shows that a large reduction in volume can be obtained with gabions because of the bulkiness and their ability to be used with soil anchors.

Another mattress type revetment method which has been found satisfactory by the Soil Conservation Service is a net of auto tires wired together and partially filled with concrete. This method is known to be durable and flexible, and when used in conjunction with a filter blanket prevents leeching of the fines. Weight can be added in this method if more stabilization is required by simply increasing the concrete content of the tires.

2.4 MONOLITHIC REVETMENT TECHNIQUES

Monolithic bank revetment techniques involve covering the slope with an impermeable layer. The methods described here cover not only pavement protection techniques such as concrete or asphalt, but also stabilization of the soil layer itself by means of chemicals or thermal stabilization.

Monolithic revetment techniques provide a continuing, non flexible, and impermeable protective covering. In most cases, monolithic protection has been limited to use on the upper banks (above normal pool levels) of streams and rivers, due to the drainage problems it creates. The impermeable layer tends to cause a buildup of hydrostatic pressure behind the revetment as the water level in the river or stream drops and water behind the revetment can not escape. Even though weep holes are usually provided to reduce the pressures, ruptures often occur.

2.4.1 Soil Cement Paving

Soil cement has proven reliable in earth dam protection, but this technique needs further investigation to determine if a thinner protective layer will be effective and economical on a river bank. One problem associated with the soil cement is the placement techniques required to provide reliable protection. Soil cement must be compacted to provide this protection and after compaction, it must be undisturbed for a few days. Another problem that is inherent in most paving revetment techniques is the rigidity. Soil cement does not have sufficient flexibility to conform to slight changes in the slope which may occur after it is placed.

2.4.2 Asphalt Paving

Asphalt has been used to some extent for upper bank paving. Unlike soil cement, asphalt is more flexible and conforms to minor changes of the slope. Asphalt can be applied to the bank by either spreading or spraying, and various mixtures have been tested as to their effectiveness.

Asphalt is available in three basic forms; pure asphalt, cut back asphalt, and asphalt emulsions. Pure asphalt heated above its melting point and mixed with soil or aggregate is most commonly used for uncompacted upper bank pavement. Cutback asphalt consist of pure asphalt dissolved in volatile solvents. Cutback asphalt can be applied warm or cold to dry aggregate and will harden as the solvent evaporates. Asphalt emulsion is asphalt which has been mixed with water and an emulsifying agent to form a suspension of asphalt globules. Emulsions can be mixed with agregate and will harden upon the evaporation of water.

Emulsified asphalts have an advantage over hot mix asphalts, because they can be used at lower temperatures. They also have an advantage over cutback asphalts because there are no flammable solvents to evaporate. Asphalt emulsions are slow to harden though and they do not adhere well to the aggregate. This adherence problem has been eliminated though by the development of a cationic asphalt emulsion which adheres well to most mineral aggregate.

Spreading the asphalt has been found to be far less costly than spraying because of the available equipment.

Appearance is one disadvantage to using asphalt in a residentially developed area. The material does not blend well with the land water interface, and for the most part has limited its use to undeveloped areas. Permeability is another limiting factor in the use of asphalt. No reliable method has been found to provide adequate drainage and without this drainage, rupture failure is likely.

2.4.3 Other Monolithic Revetment Techniques

Metal sheeting and chemical and thermal stabilization have been considered for use in bank revetment. Chemical soil stabilization and metal sheeting are considered far too costly when compared to other techniques. The basic material costs of these methods are not likely to drop, which keep them from being a common means of soil stabilization. The equipment for thermal stabilization has not been refined to the point where it can provide consistant and reliable results.

2.5 DISCUSSION OF REVETMENT ALTERNATIVES

Approximately 80 to 90 percent of the bank protection constructed by the Corps has been quarried stone with steel or timber drift barriers. Protection by vegetation is second to stone revetment as the most utilized means of controlling bank erosion. Other methods have included channel improvement, grouted stone or gravel revetments, gravel revetments, asphalt revetments, wooden bulkheads, pile dikes, and stone groins. Pile dikes and treated timber bulkheads are suitable for protecting short lengths of bank where space is minimal. Experience with grouted stone and asphalt revetments indicate that they are more costly than quarried stone and less durable.. Gravel revetments are suitable for temporary protection only, as they require repair after every major flood. Maintenance costs for grouted or asphalt revetments have been found to be higher than for quarried stone because rigid revetments do not adjust to damage as well as quarried stone does. For streams with large drainage areas (25-50 square miles), satisfactory bank protection has been obtained by simple slope reduction but this requires expensive land acquisition.

The methods now under consideration for bank protection by the Louisville District, U. S. Army Corps of Engineers include: the conventional stone riprap revetment; gabions; a net of auto tires wired together; partially filled with concrete; concrete mats similar to those used on the lower Mississippi; spoiling dredged soil against banks and planting trees to contain the soil; filter cloth covered with bedding material (graded stone), then covered with chain link fence or wire mats held in place by steel posts; channel cutoffs to relieve cutting tendencies in bends; sheet piling and rock placed in front of the piling (114).

Of these methods, only two seem unfeasible and these could be used in remote emergency cases. The use of concrete mats would require construction of a $4,000,000 plant near each site making it economically unfeasible at all but the largest sites. Channel cutoffs would require tremendous amounts of both time and money and would probably have adverse environmental effects. There have also been some reservations expressed as to the effectiveness of filter cloth covered with bedding material.

Some nonstructural measures now being considered by the Louisville District to control slope erosion include: public notice to barge lines to avoid problem areas; purchase of additional land in the vicinity of navigation projects; aerial photo inspection to evaluate caving problems; and changes in the operation of tainter gates to relieve forces on caving banks at navigation projects.

All of the previously discussed methods under consideration for use in bank revetment by the Corps are quite adequate. As previously stated, approximately 80 to 90 percent of the bank protection constructed in the Louisville District has been done with quarried stone. Because of its permanence and low cost in relation to other materials, quarried stone seems the obvious choice for future revetments. It seems in lieu of this fact that the most economical approach to slope protection would be finding a strong economical replacement for the standard quarried stone revetment. Available replacements for quarried stone include soil cement blocks, asphalt soil blocks, crude glass riprap, and ceramic riprap. Economic and durability studies should be focused at evaluating each artificial riprap method. Of the methods discussed earlier in this report, most are still only in experimental stages and are not applicable to the specific problems of the Louisville District. Their applications have been limited to specific problems and a complete evaluation of the function of a specific type of revetment is not possible. Economic analyses of various revetment techniques presented in Tables 2-1, 2-2, and 2-3 are incomplete and approximate. In place and material costs were estimated as close as available information allowed.

TABLE 2-1

RIPRAP REVETMENT TECHNIQUES

Material	Application	Estimated Cost Materials per square foot[1]	Estimated In Place Cost per square foot[2]	Remarks
Quarried Stone	10 in. thick layer dumped stone	$ .50	$1.00	Presently being used.
Ceramics				
Commercial Brick	10 by 10 foot mats, 4" thick	$2.75	$3.25	Individual bricks are too light for dumped riprap.
Commercial Tile	10 by 10 foot mats, 4" thick	$2.00	$2.50	Individual tile are too light for dumped riprap.
Poreen	10 by 10 foot mats, 3" thick	$1.75	$2.40	Too expensive for dumped riprap. 60 to 70 lb. pieces with interlocking features.
	12" by 24" blocks - hand placed	$1.70	$3.90	
Melted Sand	Crude glass heated in air-suspension kiln			Technical feasibility uncertain.

TABLE 2-1 (continued)

RIPRAP REVETMENT TECHNIQUES

Material	Application	Estimated Cost Materials per square foot[1]	Estimated In Place Cost per square foot[2]	Remarks
Stabilized Soil Blocks				
Soil Cement	4 ton per square - dumped	$1.50	$1.88	Based on a 50% size of 70 lbs.
Hot-mix Asphalt	4 ton per square - dumped	$2.50[3]	$2.90	Based on a 50% size of 125 lbs.
	5 in. layer of hand placed blocks	$1.50	$3.50	50 pounds per square foot.
Cationic Emulsion Asphalt	4 ton per square - dumped	$2.15[3]	$2.50	Based on a 50% size of 125 lbs.
	5 in. layer of hand placed blocks	$1.25	$3.25	50 pounds per square foot.
Asphalt-Sulphur	4 ton per square - dumped	$2.05[3]	$2.40	Based on a 50% size of 125 lbs.
	5 in. layer of hand placed blocks	$1.20	$3.20	50 pounds per square foot.

Notes:
1. Includes all material costs and cost of producing hot pressed blocks and stabilized soil blocks.
2. Includes all anticipated costs except grading of the bank, the cost of a filter blanket, and the contractor's profit.
3. Cost not proportional to hand placed blocks due to forming and production rate.

TABLE 2-2

MATTRESS REVETMENT TECHNIQUES

Material	Placement Method	Estimated Material Cost per sq. ft.	Estimated In Place Cost per sq. ft.
Articulated Concrete Mattress	Barge	$1.00	$2.00
Commercial Ceramic Mattress	Barge	$1.00[1]	
Poreen Matresses	Barge	$1.25[1]	
Synthetic Sheeting Mattress	Barge or Roll		
Synthetic Fabric Mattress	Barge or Roll	$1.10	$1.70
Synthetic Sheeting or Fabric	Roll	$ .75[2]	$1.00
Prefabricated Asphalt Mattress	Barge or Roll	$2.00[3]	$3.00
Gabions	Built in place		

Notes: 1. Transportation costs of ceramic materials are uncertain
2. Single thickness of synthetic material only.
3. Total cost of fabricating 5 inch thick mattress with reinforcement.

TABLE 2-3

MONOLITHIC REVETMENT TECHNIQUES

Material	Application Method	Estimated Raw Materials Cost per sq. ft.	Estimated In Place Cost per sq. ft.	Remarks
Asphalt-hot mix	Premixed and spread	$ .15	$1.20	
Soil Cement (Regular)	Premixed, spread, and compacted	$ .20	$1.10	
Soil Cement (Regular)	Mixed and compacted in place	$ .20	$1.10	
Cationic Asphalt Emulsion	Premixed and spread		$1.35	
Cationic Asphalt Emulsion	Premixed and sprayed		$2.35	Technical feasibility uncertain
Cationic Asphalt Emulsion	Sprayed		$2.10	Technical feasibility uncertain
Thermal (Fuel Oil)	Melted in Place	$ .30[1]		Technical feasibility uncertain
Thermal	Premelted in Kiln	$ .15[1]		Technical feasibility uncertain

Notes: 1. Fuel Oil Cost.

CHAPTER 3

EVALUATION OF ENVIRONMENTAL

IMPACTS OF BANK REVETMENT

3.1 PURPOSE AND REQUIREMENTS OF EVALUATION PROCEDURE

In order to select a method for evaluating the environmental impact of a bank revetment project, it was necessary to determine which environmental parameters would be beneficially or detrimentally affected by bank revetment procedures. Determination of both specific and general environmental parameters impacted in bank revetment projects was accomplished by field reconnaissance and visual evaluations of various revetment projects in the Louisville District of the U. S. Army Corps of Engineers. In addition to visual evaluations, various Environmental Impact Statements pertaining to bank revetment projects were consulted to determine the impact evaluation systems presently in use, what parameters were utilized in each impact evaluation, and the environmental impact on each parameter. Both field surveys and literature reviews of various Environmental Impact Statements on bank revetment projects were important in determining those parameters to be discussed in an environmental assessment of bank revetment. The field survey was also useful in evaluating long term environmental effects, long term reliability of specific revetment techniques, and long term maintenance and upgrading costs.

The field evaluation program was initiated with an environmental impact assessment matrix developed by the Louisville District Corps of Engineers (see Figure 3.1) as the basis for the evaluation. Due to time and monetary constraints, it was impossible to rate all parameters

ENVIRONMENTAL IMPACT ASSESSMENT MATRIX

		ECOLOGICAL ENVIRONMENT (250)				PHYSICAL ENVIRONMENTAL QUALITY (400)						SOCIO-ECONOMIC FACTORS (250)							AESTHETICS (100)			
		AQUATIC FLORA (60)	TERRESTRIAL FLORA (60)	AQUATIC FAUNA (65)	TERRESTRIAL FAUNA (65)	WATER QUALITY (100)	LAND QUALITY (75)	AIR QUALITY (75)	HYDROLOGY (50)	GEOLOGY (50)	NOISE LEVELS (50)	LAND USE (50)	ECONOMIC DEVELOPMENT (50)	ARCHAEOLOGY (30)	HISTORY (30)	RECREATION (30)	TRANSPORTATION (30)	CULTURAL FEATURES (30)	PHYSICAL FACTORS (40)	SPATIAL COMPOSITION (20)	MAN-MADE OBJECTS (20)	UNIQUENESS (20)
POSITIVE ENVIRONMENTAL QUALITY	+5																					
	+4																					
	+3																					
	+2																					
	+1																					
	0																					
	-1																					
	-2																					
NEGATIVE ENVIRONMENTAL QUALITY	-3																					
	-4																					
	-5																					
	RED FLAG																					

Fig. 3.1

Environmental Assessment Matrix - Louisville District Corp of Engineers in the matrix i.e. water quality, aquatic flora, etc. Therefore, individual evaluations involved only those parameters which could be visually evaluated, required short personal interviews, or necessitated research of the literature. Included in each project report, together with a discussion and evaluation of various environmental parameters, was the history of the project and the geographic setting of the revetment site.

The following is a basic outline of each field project report:

I. Project History

- A. Causes of erosion
- B. Authority for starting project
- C. Description of work
- D. Monetary expense

II. Geographic Setting

- A. Location with respect to various landmarks
- B. Description of surrounding terrain

III. Environmental Qualities of the Project Area

- A. Ecological environment
  1. Terrestrial flora (general description)
- B. Physical environment
  1. Land quality (visual evaluation)
  2. Hydrology-flow in relation to reveted bank
  3. Geology
     a. soil description

b. soil properties

c. structural features

C. Socio-economic factors (general description)

1. Land use

2. Economic developments

3. Archaeology sites (if present)

4. Historical sites (if present)

5. Recreational uses (if present)

6. Transportation facilities (if present)

a. water facilities

b. land facilities

D. Aesthetics

1. Aesthetic characteristics of the area

2. Aesthetic characteristics of revetment in relation to land - water interface

IV. Environmental Impact of the Project

A. Null alternative - what would occur (effects on each environmental parameter)

B. Project implemented - what has occured since the implementation of the project (effects on each environmental parameter)

Each project was evaluated as objectively as possible. Although any system utilized to evaluate and compare environmental impacts is subjective to some extent. As much factual information as possible, (including personal interviews) was utilized to form the basis of opinions.

3.2 NEWBURGH BANK REVETMENT

Project History

The Corps of Engineers was directed first by the 1970 Flood Control Act and later by the 1974 Water Resources Development Act as part of the new Newburgh Lock and Dam project, to complete bank revetment work along approximately 1.1 mi. (1.8 km.) of the Ohio River at Newburgh, Indiana to protect public and private facilities endangered by caving banks. The remedial work on this revetment began in July, 1957 at a federal cost of $18,200. Additional work performed in May, 1970 was limited to locations where Corps of Engineers inspections indicated bank conditions were most critical. This May, 1970 work required the full use of the $50,000 monetary limit allocated. The project as it now stands as completed in April, 1974 at a federal cost of approximately $1,700,000 and involved the acquisition of land, slight slope reduction, the placing of a dumped gravel filter blanket, and the final placement of a 2 ft. (0.6 m.) thickness of 150 lbs. (68 kg.) maximum weight limestone comprising approximately 37,500 yd.^{3} (28,500 m.^{3}) (see Figure 3.2).

The revetment design took into account both seasonal and permanent changes in Ohio River pool level at Newburgh. The seasonal pool changes at Newburgh are caused by alternate periods of flooding

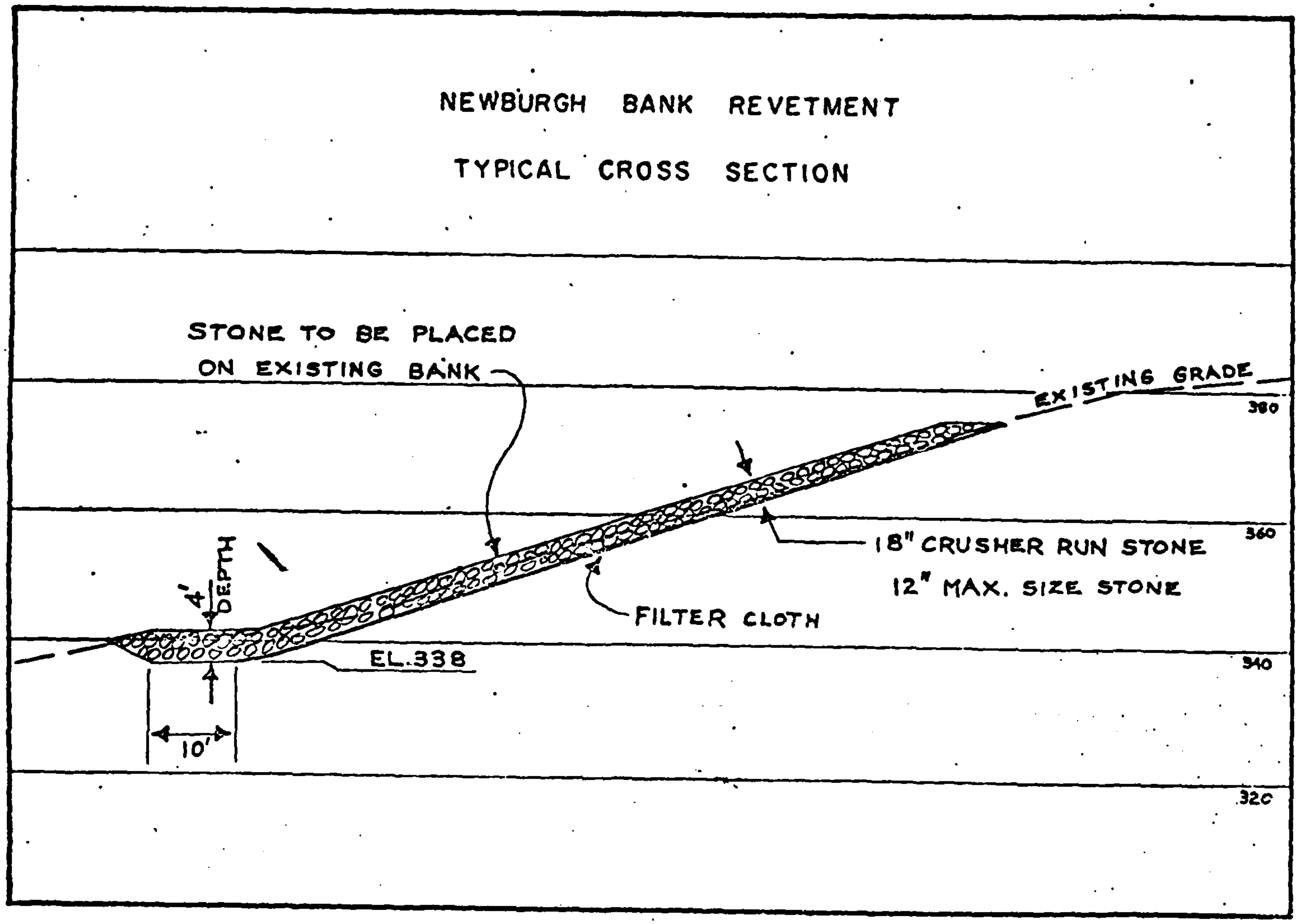

NEWBURGH BANK REVETMENT
TYPICAL CROSS SECTION
STONE TO BE PLACED
ON EXISTING BANK
EXISTING GRADE
380
360
340
320
18" CRUSHER RUN STONE
12" MAX. SIZE STONE
FILTER CLOTH
EL.338
4'
DEPTH
10'

Fig. 3.2

and drought. A permanent increase in pool level at Newburgh has resulted because of the two new dams recently constructed, upstream (Newburgh Lock and Dam) and downstream (Uniontown Lock and Dam) from the revetment site. The predominate cause of erosion in this area has been the concentration of flow released toward the project area from Dam 47 during periods of high water. Another contributing factor to erosion problems in the project area is the turbulence caused by tow boats locking through Dam 47. These conditions have been remedied by the removal of Lock and Dam 47, and the rerouting of the tows to a new channel, which has been dredged in midstream.

Geographic Setting

The site of the revetment project is located on the north (Indiana) bank of the Ohio River at the town of Newburgh, in Warrick County, Indiana, just downstream from the existing Lock and Dam 47 and the new Newburgh Lock and Dam under construction (see Figure 3. 3). The terrain of the surrounding area ranges from level to steeply sloping. The bottom lands near the Ohio River are relatively level. The area near the river valley contains some hills which are dissected by many tributary streams of the Ohio River.

Environmental Qualities of the Project Area

Ecological

The project site contains terrestrial vegetation ranging from a few large, scattered trees dotting the upper bank to a dense brush and

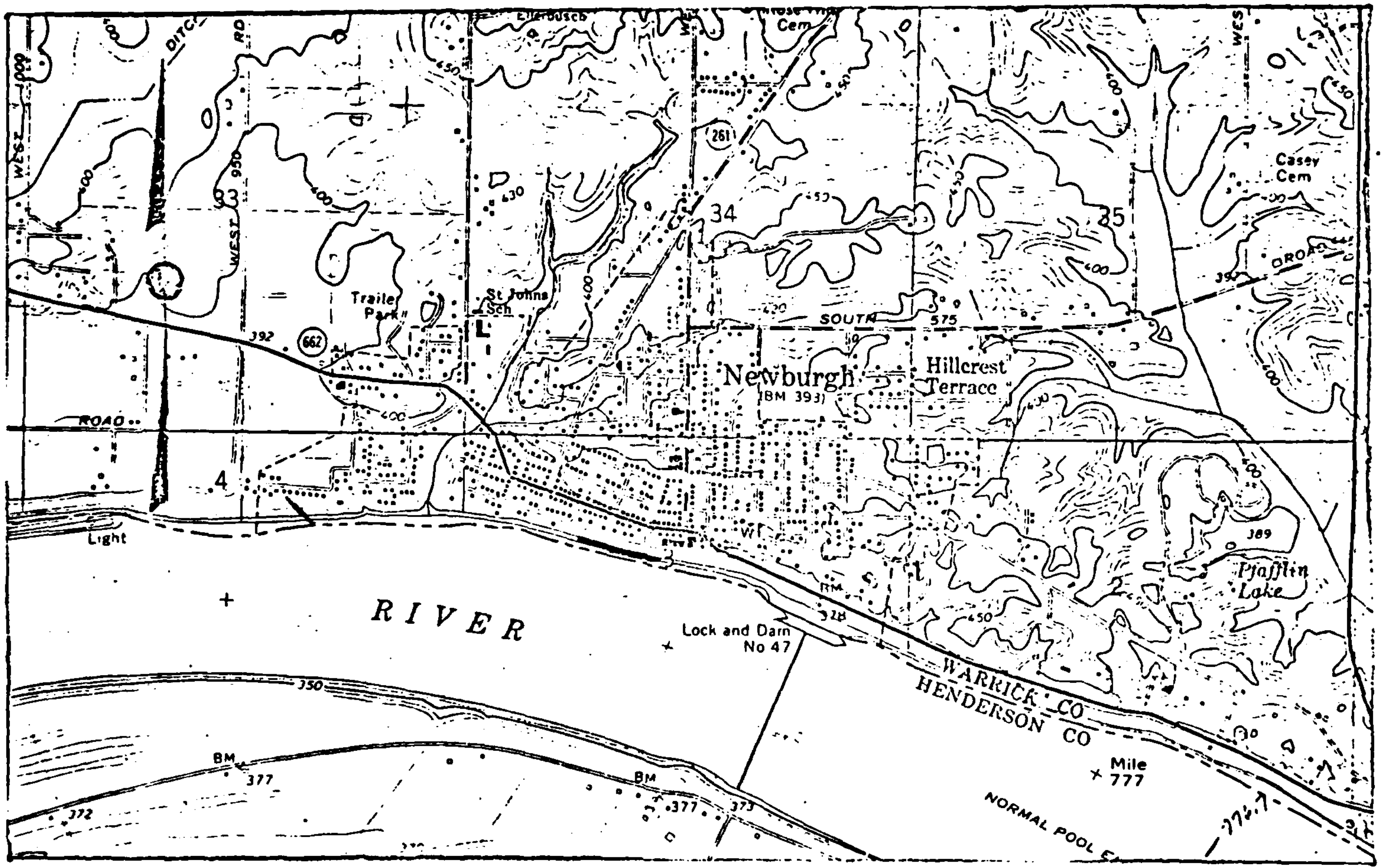


Fig. 3.3 - Location Map, Newburgh Bank Revetment (Ref. 74)

grass cover at the head and toe of the revetment. Since the project's completion in April, 1974, the revetment area has experienced some vegetative growth through the voids in the riprap. The relative newness of the revetment, the inability for vegetation to take hold in such a short time period, and the fluctuating water levels have left the lower portion of the bank almost void of vegetation.

Physical

The soil at the project site consists of a thick heavy layer of silt deposited over glacial alluvium at depths below 5-6 ft. (1.5-1.8 m). These soil materials along the riverbank are deep and typically well drained. The surface soils which formed in loess are unstable when wet and are susceptible to high degree of erosion. During construction activities, loess is cut on a vertical slope to prevent erosion by surface runoff and receding flood waters, but the vertical slopes at Newburgh were undesirable and are still susceptible to erosion from wave and current action and receding flood waters. A physical barrier to water action was a necessity at Newburgh.

Socio-Economic

The land area located between Water Street and the river consists of gradually sloping river bank. Only a small portion of land located at the downstream and/or toe of the revetment is used for residential purposes. The north side of Water Street at the upstream end or head of the revetment is commercialized. Approximately two blocks in this area are lined with retail businesses such as restaurants, antique shops, gift shops, and other similar businesses. Those buildings at the head of the revetment are in a poor state of repair. The downstream end of the revetment area to the north of Water Street is lined with private residential homes. Many of these structures are restorations of the early Newburgh riverfront settlements and some are still being re-habilitated.

Much of the economic growth in Newburgh has occured within the past fifteen years. While much of the northern portion of the Newburgh area is still rural farmland, the southern portion has the appearance of a modern suburbia with many new subdivisions, a few small shopping centers, and all of the other conveniences of modern living. The central business district of Newburgh lies approximately one block north of the revetment site. This area is a collection of many older restored homes from a former river settlement. Many of these dwellings are still private homes, but some have been converted into business establishments. A substantial population in Newburgh occured in the early 1960's, because of its proximity to Evansville, Indiana and the expanding job market there. Although Newburgh is of a rural nature it had adequate transportation arteries to provide for this growth. The Newburgh area itself has very little industrialization other than the new Alcoa plant located just upstream from the project.

The history of the area lies mainly in the restored old rivertown homes and their heritages. Most of these homes are located within a few blocks of the revetment site. Recreation is quite limited but there are many boating enthusiasts who use the Newburgh waterfront for pleasure boating and skiing. Transportation which was directly effected by the project's implementation includes, Water Street which runs along the top of the reveted slope and its side arteries which extend back one block to the main highway (state route 662). Water Street was in danger of caving if the project had not been implemented.

Aesthetics

Rennovation and restoration of many of the older structures in the Newburgh riverfront area has greatly increased the aesthetic character of the area. The entire riverfront area has been enhanced by a return to the original river town atmosphere.

Environmental Impact of the Project

Null Alternative

The consequences of the null alternative or "letting nature take its course" instead of following through with the riprap revetment at Newburgh would have resulted in many detrimental long term implications. There would have been continued erosion of the river bank if no protective measures were taken. Instability of the slope would have endangered persons in the area using the bank as a recreational, residential, or commercial area. The socio-economic impact of river bank failure would have been detrimental because of the destruction of a revitalized area which includes commercial establishments as well as a number of homes of considerable age and value. Continued collapse of the river bank would have represented severe degredation of the land along the Newburgh shore. There would also have been the possibility of severe buildups of sedimentation in the stream, deposits in the main channel restricting flow and river traffic in the area. There would have been direct destruction of vegetation in the project area if the bank was continually allowed to collapse. Lack of bank protection would have caused aesthetic degredation of the entire riverfront area at Newburgh. Although there would be no economic loss to the town of Newburgh due to construction costs, there would be severe economic losses if the bank had continued to erode.

Project Implemented

The use of riprap has virtually eliminated the erosional problem in the project area. Although the revetment has increased the land use potential in the riverfront area, no new developments have taken place. The riprap has made the project site more visually appealing from both the land and the water viewpoints.

Although the revetment itself is not aesthetically pleasing in the sense that the natural surroundings are invaded by foreign material, the revetment is more aesthetically pleasing than an eroded shoreline. The bank now offers a feeling of security and future stability.

The cultural and social interests impacted by this project, such as the rehabilitated residential homes and businesses along Water Street, have all received the benefit of both economic and personal security. The river is no longer endangering the physical and mental well being of residents in the area. This project is also beneficial to those who are involved in community development, in that planning can be undertaken with some degree of assurance of future conditions.

Since the revetment has decreased the friction at the land water interface, which in turn increases velocity, there is a possibility of further erosion down stream from the project area. The use of riprap is an added plus in this respect since it has voids which help to dissipate energy.

3.3 CANNELTON BANK REVETMENT

Project History

The Corps of Engineers completed approximately 5,290 ft. (1590 m.) of riprap bank revetment in 1967 in conjunction with the construction of the Cannelton Lock and Dam. This revetment was constructed to protect the bank adjacent to the locking facilities from erosional problems caused by turbulence and wave action from boats locking through the dam. All of the land involved in this revetment project was acquired under provisions involved in the construction of the lock and dam. The cost of the Cannelton revetment was approximately $315,700 and involved cutting the slope back to 2:1 and placing a dumped gravel filter blanket, and approximately 45,100 yd.^{3} (34,280 m^3) of a 2 ft. (.6 m.) thickness of 150.3 (68kg.) maximum weight limestone over the filter.

Geographic Setting

The Cannelton revetment project is located on the north (Indiana) bank of the Ohio River at both the upstream and downstream entrances to the Cannelton Locks in Perry County, Indiana (see Figure 3.4). The locks are approximately 2 miles upstream from the Lincoln Trail Toll Bridge which crosses the Ohio River between Cannelton, Indiana and Hawesville, Kentucky. Most of the area adjacent to the project site consists of steeply sloping knobs with some exposed vertical cliffs. Though most of the terrain in the area is relatively high. The area along the river bank is fairly level, but still well above the river's normal pool elevation. There are several streams which empty into the Ohio River in close proximity to the revetment site, cutting through the knobs in the immediate area.

Environmental Qualities of the Project Area

Ecological

The revetment site is nearly void of vegetation except for a few instances of tall grass which have grown through the voids in the rip-rap. The lack of vegetation at the site can possibly be accounted for because of the recent placement of the riprap, fluctuating water levels,

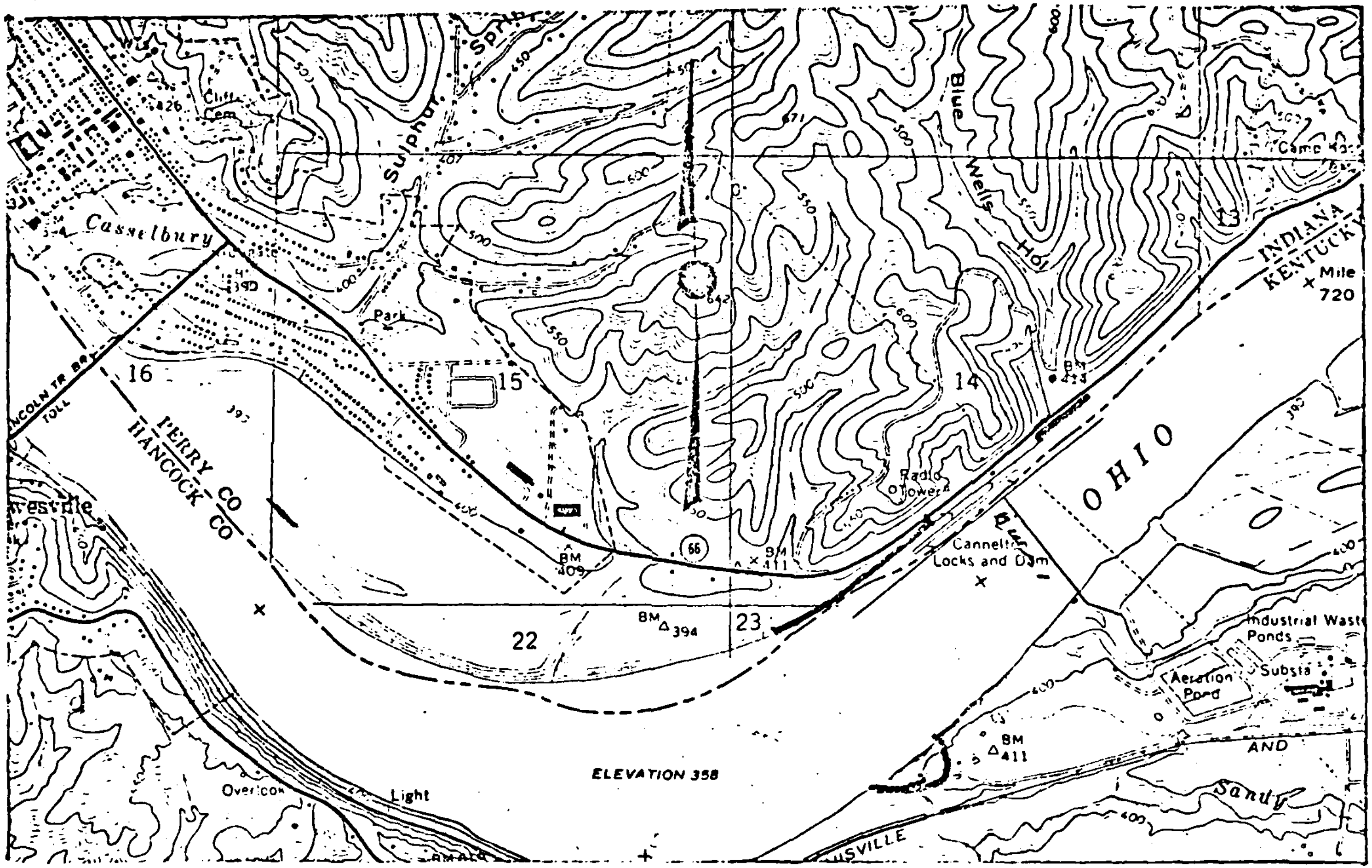


Fig. 3.4 - Location Map, Cannelton Bank Revetment (Ref. 75)

and wave action caused by boats locking through the dam, extremely close to the reveted area.

Physical

The soil at the site consists of deep, well drained silt loam deposited over mixed alluvium at depths below 5 ft. (1.5 m). The subsoil has good stability and is easily compacted when it is used for embankment purposes. The subsoil also has a low permeability and good resistance to piping failures when compacted. Unlike the subsoil, the substratum has poor stability and compaction potential, moderate permeability, and poor resistance to piping. The potential for erosion in this area was significant, due to the permeability and weak shearing *resistance of the soil, eddy currents from barges, and fluctuations* in water levels. A revetment was needed in this instance which would dissipate the energy of the waves and also allow drainage. This revetment would need to resist undermining as well as blow out from internal buildup of hydrostatic pressure.

Socio-Economic

Land use in the project area is devoted mainly to woodlands and the location of U. S. Highway 66 which runs along the Indiana shore within 100 yards of the reveted bank. The revetment was specifically designed to protect this main southern Indiana transportation artery from failure by undermining. Just north of the dam site the Corps of

Engineers has constructed an observation center and park on the rock bluff overlooking the dam. There is also a radio transmission tower located on this knob. There are no homes on the Indiana shore within 0.5 mi. (0.8 km.) of the project.

Aesthetics

This revetment has very little effect on the aesthetic values of the immediate area. Though the riprap is protecting the bank from erosion and blends well with the surrounding environment, there is a minimal amount of people who come in direct visual contact with the revetment.

Environmental Impact of the Project

Null Alternative

The environmental effects of the null alternative at Cannelton would invoke many detrimental involvements other than just the erosion of the bank itself. Erosion would deter vegetation within close proximity of the eroded area. The quality of land would be detrimentally impacted because it would no longer be suitable for any purpose. River hydrology would be unchanged and uninhibited if no measures were taken to retard the flow directed at the bank. Geology, another physical factor, would also be endangered if the bank were left to erode indifinitely. Both the soil and structural features would be eventually destroyed.

The land use potential of the immediate area would be minimal if the bank were left unprotected. The economic development of the area would also be negatively effected if the null alternative were implemented. Continued erosion of the bank would eventually result in the channel having to be dredged, which would slow river traffic and transportation of marketable goods. There would be little or no effect on history in the area if this alternative were chosen, because there are no significant historical landmarks in the area. Recreation itself would be only slightly impacted by channel degradation. Recreation activities in the project area are related primarily to the Ohio River. Although the eroded bank would be aesthetically unsightly under the null alternative, the river's recreational characteristics would be uneffected by aesthetic degradation. The transportation facilities would be the most endangered element of the socio-economic environment. U. S. Highway 66 which runs parallel to the Ohio River, passes within one hundred yards of the revetment. This transportation artery connects many towns all along the Ohio River in southwestern Indiana. There are no significant cultural features in the area which would be effected by the null alternative.

Aesthetically the erosion of the bank would be displeasing, but only a minimal number of people come into direct visual contact with the site.

Project Implemented

The revetment appears to have eliminated potential problems in the project area. Little vegetative growth has occured in the reveted area to date, however, the land environment is stable. The river flow directed at the bank in the project area has been counteracted by the use of a riprap revetment which lends itself to a more stable physical environment. The geological qualities of the area are no longer in any danger of water action.

Land use potential in the immediate area has increased but at the present time there are no new developments in the area other than Corp projects. Economic development has had little impact from stabilization of the bank at the dam site. The dam itself, though, is a major influence on economic growth of the entire river system. No historical sites have been destroyed or protected by the stabilization of the river banks. Though the dam has increased the recreational uses of the river, the bank revetment is not solely responsible for this increased use. The transportation artery which runs parallel to the reveted bank has received needed protection from the riprap revetment which benefits the entire area by making it more accessible. There are no significant cultural impacts resulting from the implementation of this project.

Aesthically the revetment has made the site more visually appealing than an eroded bank. Although the materials used in the revetment invade the uniformity of the natural surroundings, the reveted bank offers a settled or stable feeling.

3.4 BRAZIL BANK REVETMENT

Project History

The Brazil Indiana Waterworks Reservoir revetment was completed in 1932 with funds from the Works Project Administration, a federal agency set up during the depression to create jobs. The type of revetment utilized at Brazil is a system of flat rectangular vetrified clay tiles embedded in the bank. Before the reservoir was converted for use as a water supply facility, it had been a sand and gravel pit. The reservoir has since been abandoned as a water supply source, when it was found that much of the city's wastewater was fed directly into it. The reservoir is now used as an emergency water source and swimming.

Geographic Setting

The revetment project is located on the southern edge of the former water works reservoir just east of state Highway 340 in western Brazil, Indiana (Figure 3.5). Brazil is approximately 60 miles west of Indianapolis on U. S. Highway 40. The surrounding terrain is relatively level except where strip mines have cut into the landscape. Brazil is a small town of approximately 8, 500 people in a predominate coal mining region in west central Indiana. The area is dotted with small farms, strip mines, and brick kilns.

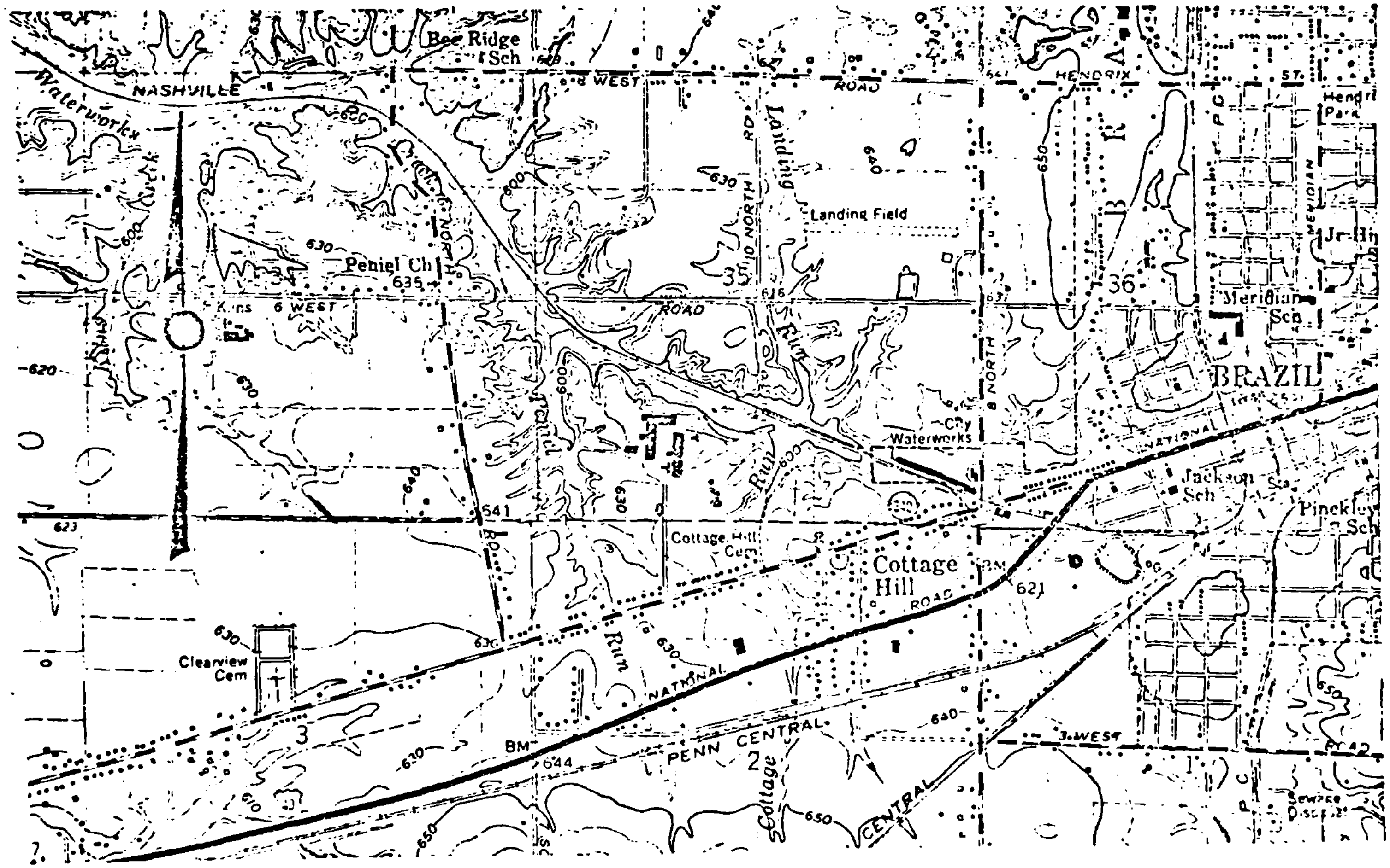


Fig. 3.5 - Location Map, Brazil Bank Revetment (Ref.77).

Environmental Qualities of the Project Area

Ecological

The Brazil revetment site has a variety of terrestrial vegetation, including many types and sizes of trees, scattered brush ranging in density, and grass. The revetment itself has experienced extensive vegetative growth (both trees and grass cover) within and around the spacing between the clay tiles. Reasons for significant vegetative growth within the revetment are the slight water level fluctuations which occur in the reservoir, and the age of the revetment. These small variances in water level allow the flora more time to become rooted, thereby making them more effective against inundation and wave action.

Physical

The soil at the Brazil revetment site consists of a silt loam alluvium deposited over layers of sand and gravel. This soil possesses moderate permeability, and is deep and well drained. This type soil is not normally eroded in an embankment setting, unless the water level extends over the reservoir banks and suddenly drops, or if water remains on top of the embankment without draining off.

Socio-Economic

Land on the southern side of the reservoir where the revetment project is sited is lined with private residential homes directly adjacent to the reservoir. Many homes here are rather large and elegant pre World War I era. The one house on the northern edge of the reservoir, which faces the revetment, is a small farm house in a poor state of repair and could be considered an eyesore. There is a east-west public road disecting the reservoir. The reveted portion of the bank lies in the western sector of this division. The reservoir itself is in poor shape of maintenance, with old tires and debris littering the area. The old pumping house is now being used for an asphalt batch plant, which also adds to the dissonance of the reservoir with the surrounding area.

Aesthetics

Homes along state Highway 340, adjacent to the revetment, are in good repair, many having been restored to their original turn of the century condition. The atmosphere of the entire area has been added to by the upkeep and restoration of all the homes both old and new in this area.

Environmental Impact of the Project

Null Alternative

The null alternative at Brazil would have had unfavorable effects on land and people in the immediate area, as well as people who used the water supply before the revetment was completed. Erosion would have destroyed a significant portion of the vegetative growth in the project area. The quality of the land would have been physically and economically degraded making it unfit for residential or agricultural use. The hydrology of the reservoir itself would have been unchanged, by not altering the flow. The soil on the bank though, would eventually have filled the reservoir, thereby eliminating the use of the reservoir as a water supply facility.

Further development of land in the area would have been inhibited by letting the reservoir stabilize itself. The owners of previously developed land would be insecure and the owners of undeveloped land would not want to risk their money on further development in the project area.

The economic development of the entire area would have been in jeopardy if the bank were left to erode, because the city would eventually have been forced to find a new water supply facility before further growth could occur. The unprotected bank would have little effect on the area's history because most of the development here occurred just prior to the time of the revetment. The erosion of the bank would not have effected recreational development in the project area. Transportation facilities would have been uneffected by further erosion because the roads bordering the revetment are either far enough away for it to have no effect, or not in the path of the eroding bank.

Aesthetically, the erosion would not have been in harmony with the surrounding environment either physically or emotionally. The degradation of the area would have had detrimental effects on the lives of people in the immediate area, as well as outsiders who considered this area as a potential home.

Project Implemented

The clay tile revetment has eliminated any further erosion in the reservoir. The revetment has also preserved and enhanced the vegetative growth at the site. The site has vegetation both through and around the revetment and the earth colored tiles blend well with the surroundings.

The land development at the site has since been completed, but the banks are now stable and protected. The flow in the reservoir has been altered but no further erosion was created by diverting the flow from this one bank. The ceasing of the soil erosion has created a stable physical environment.

Land use potential was increased when the reservoir was stabilized in 1932, but knowledge of the development sequence was unobtainable. Economic development potential was also increased with the stabilizing of the water supply source. No historical points were either preserved or destroyed by this bank revetment. The stabilizing of the water supply reservoir bank enabled the preservation of the swimming hole created when the reservoir was moved to a different location. The transportation facilities of the area have been uneffected by the revetment.

Aesthically, the revetment is more physically and emotionally pleasing than an eroded bank, though the materials used in the revetment are foreign to the natural setting. The revetment now gives the property owners at the site a sense of security.

3.5 NEW HARMONY BRIDGE BANK REVETMENT

Project History

The New Harmony Bridge Bank Stabilization Project dates back between 1941 and 1955, when the White County Illinois Bridge Commission acquired the bridge. Large expenditures were made during this period by both local interests and federal government to maintain this important river crossing. Remedial work at the New Harmony Bridge consisted of emergency riprap revetment on the Illinois bank at the west approach to the bridge to arrest and prevent further bank caving which would endanger the bridge foundation. This remedial work was accomplished at a total cost of $257,000 of which $120,000 was supplied by the federal government and $137,000 was supplied by the Bridge Commission. Further work at the New Harmony Bridge started in July, 1957 with the construction of a cutoff channel. This channel was designed to decrease the velocity and the amount of water directed at the bridge structure, which had since destroyed the previous revetment work. The cutoff channel was completed in February, 1958 at a cost of approximately $298,000 which was borne by the Federal Government. The remaining work at New Harmony was completed in 1971 at an estimated cost of $1,061,000 of which $962,000 was provided by the United States and $99,000 by local interests.

This final phase of the project consisted of enlargement of the existing cutoff channel, riprap revetment on the west bank of the widened channel, and the building of a dike at the north end of the old channel. The dike was intended to slow the channel velocity to the point where only seepage would occur through the dike, to keep the retired channel active with the environment. The enlargement and revetment of the existing cutoff also decreased the velocity downstream which could possibly prevent future erosional problems. Future work at the New Harmony Bridge will consist of periodic observation to insure permanence of the initial measures and any further stabilization work necessary.

Geographic Setting

The revetment project is located on the western bank of the Wabash River at and above the New Harmony Bridge in Posey County, Indiana and White County, Illinois (see Figure 3. 6). The bridge carries U. S. Highway 460, an important east-west traffic route in the federal highway system. This bridge across the Wabash River provides the only highway crossing of the river for a distance of 70 river miles (113 km) below Mount Carmel, Illinois. The terrain of the entire area on both the Indiana and Illinois banks consists of nearly level bottomland.

Environmental Qualities of the Project Site

Ecological

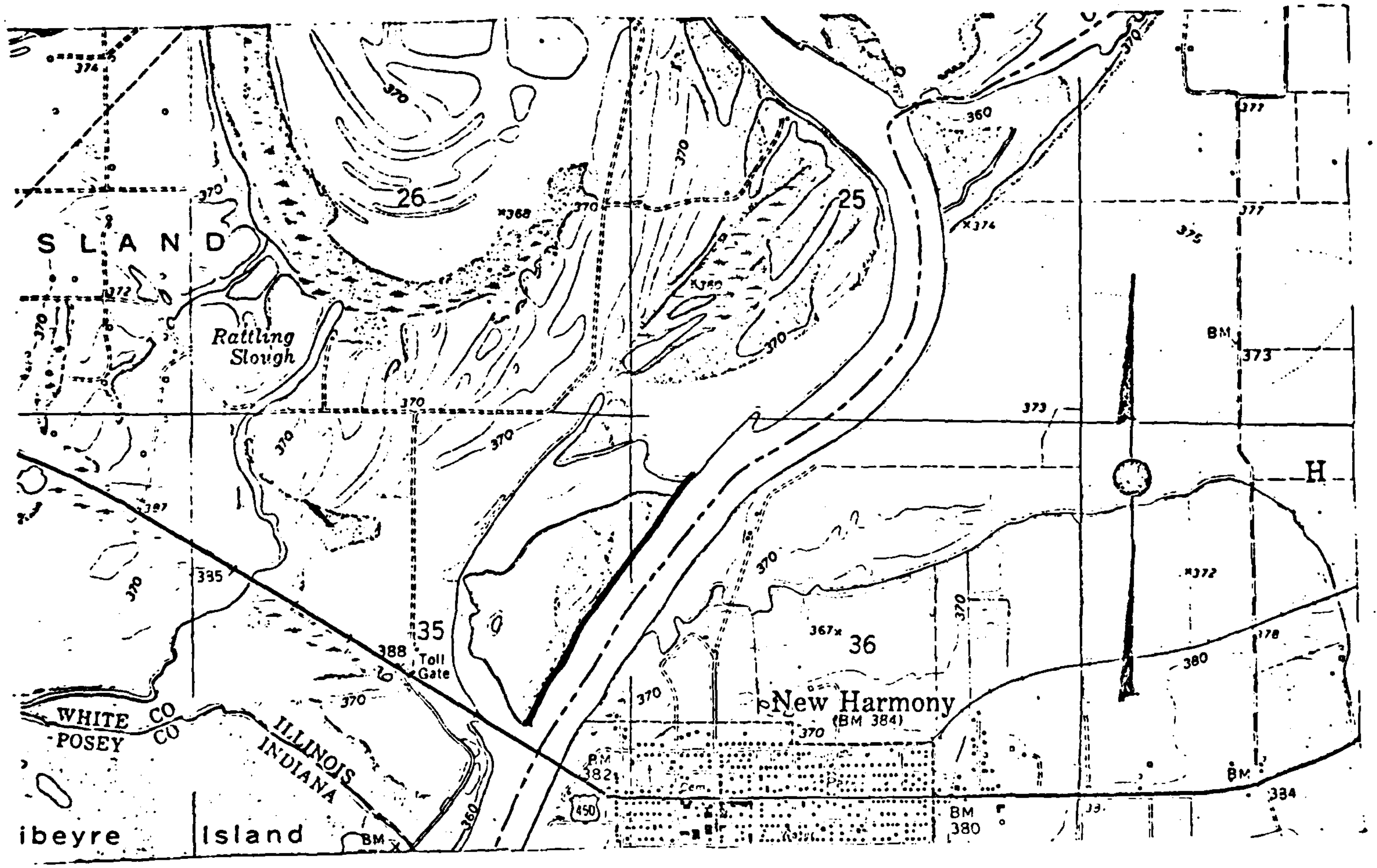


Fig. 3.6 - Location Map, New Harmony Bank Revetment (Ref. 86)

The island on which the revetment work is located is covered with a dense forest of trees and brush. The only parts of the island not overgrown include the access road through the center of the island, the eastern edge of the island which was cleared for channel enlargement and revetment, and the revetment itself. These areas have not been covered by vegetation as yet because of the recent placement of the revetment and channel widening, and the time required for vegetative growth. The area through the old channel itself is lined with trees and is almost inaccessible due to the dense brush cover on both the island and the old river bank.

Physical

The soil at the site consists of a thick heavy layer of silt loam to light silt clay deposited over alluvium. The soils are deep, well drained and moderately permeable. When used on embankments the subsoil possesses good stability. When compacted, the subsoil also has a low permeability on compaction and good resistance to piping. The substratum is unstable when compacted and has poor resistance to piping. Erosional tendencies were quite a problem here because of the soil properties, the swift current in the river, and fluctuating water levels.

Socio-Economic

Land use in the vicinity of the revetment is composed entirely of farmland on the Illinois side of the river with a few active and inactive oil wells dotting the landscape. On the Indiana side of the river a baseball park is located just north of the bridge and a boat ramp is located just south of it.

The entire town of New Harmony, Indiana derives much of its income from the tourist trade. New Harmony is an old Rappite communal settlement with many of the former buildings restored to their original condition. Many small shops selling handmade goods and antiques are scattered throughout the town.

Recreational uses of the area consist of boating, hunting, and various other recreational activities associated with the park located just north of the Indiana approach to the bridge and the boat launch just south of the bridge. The island created by the cutoff channel is a large source of game and many duck blinds are located along the Illinois bank.

Transportation systems played a major role in the development of this bank stabilization project. With U. S. Highway 460 serving traffic crossing the Wabash River for a distance of 70 river mi. (113 km) below Mount Carmel, it was necessary that this river crossing be secured to insure economic growth of the surrounding area.

Aesthetics

Rehabilitation of many old Rappite settlement structures has increased the aesthetic character of the area. The town has taken on the atmosphere of the former settlement both physically and emotionally. The quiet slow pace of an earlier time is still present.

Environmental Impact of the Project

Null Alternative

The effect of no direct intervention at the New Harmony Bridge site would have many unfavorable consequences. Continued erosion of the bank would have inhibited any terrestrial vegetation on the effected bank and would also have jeopardized any vegetation in the immediate area. The land quality would have been adversely effected because of the soil erosion and effects the erosion would have had on further land quality and development. River hydrology would not have been changed, if no alteration occurred in the flow itself. Geology of the project area would have been placed in danger if no alteration of stream flow had taken place and erosion had continued.

The potential uses of the land effected by no action at the site, would have been far reaching and detrimental. Though most of the land effected by the project is of an agricultural nature and already lies within the flood plain of the Wabash River. The null alternative could possible have caused total washing away of this land and left the population with no land, or land unfit and unsafe for any use. The continued erosion of the land and the bridge structure could have led to a slow-down or complete destruction of the economic growth of the area because not only the land would be unuseful, but the increased economics of transporting materials by another route would have led people away from the area. The tourist trade in New Harmony would also have suffered because people would no longer need to pass through this city when crossing the Wabash River. Recreational facilities would have been endangered if no action were taken to alleviate the caving banks. Most of the recreational facilities lie within the reach of the river and boating, hunting, and park facilities would have been eliminated if erosion had continued. Transportation would have been the major Socio-Economic factors effected by continued erosion. Highway is a major factor in both physical and economic growth of the area. The cultural features of the present or past inhabitants would have been in little danger if no action was taken to halt the erosion, other than the degradation of land and its associated uses along the river banks.

The aesthetics of the area would have been only slightly degraded in that most of the aesthetic character of the area is associated with the town of New Harmony, and its rehabilitation and the town is not close enough to the project itself to be directly effected. The aesthetic character and uniformity of the river bank and bridge structure would have been severly degraded and this would have eventually led to degradation of the town itself.

Project Implemented

The revetment project has minimized the erosional hazards and the concurrent problems at the New Harmony Bridge Project site. The vegetative growth in the area is nearly stable except on land that has continuous water level fluctuations. The flow previously directed at the bridge structure has been channelized away and the old channel filled with impervious material to help stabilize the physical and ecological environment of the retired channel. The quality of the land and the geology of the area is no longer in danger of water action other than the periodic seasonal flooding of the land unprotected by levels.

Land use of the area has neither increased nor decreased since the stabilization project, but the protection of the bridge between Indiana and Illinois could have some long term benefits on the potential land uses which have not yet surfaced in the area. Economic development of the area has neither increased or decreased since the project's implementation but the stabilization of economic growth more than makes-up for the loss that would have incurred had no steps been taken to eliminate erosion. No historical points have been directly effected by the project, but the indirect protection to the town of New Harmony in the way of security has provided historic and personal protection. Though the project was implemented after the completion of recreational facilities just above and below the east approach to the bridge (Indiana side), and the project itself is not protecting these locations, the revetment has increased the recreational uses of the Illinois bank. The project is protecting game and at the same time providing a hunting area for local sportsmen. The protection of transportation in the area (U. S. Highway 460) has also resulted in a positive impact on many other environmental factors, such as the benefits by economic development and land use. By protecting the transportation system, the area's lifeline, the potential of land use, and economic development have both been beneficially impacted.

Aesthetically, the riprap revetment has invaded the natural setting of the area but the aesthetic appeal of an eroded bank is much less than that of a protected bank even if the material is foreign to the site. The aesthetic character of the town has been indirectly protected in that people now feel more secure in knowing that their economic future is protected.

3.6 ROCKPORT BANK REVETMENT

Project History

The Rockport, Indiana bank revetment project provided for the repair and protection of a segment of caving bank which was endangering a city street lying between a rock bluff and the Ohio River. After receiving the assurance of local cooperation from the Rockport, Indiana city officials, the project was undertaken by the Corp of Engineers. The project was completed in 1960 at a federal cost of $25,900, and involved the placing of a 9 in. (23 cm) gravel filter blanket and final placement of an 18 in. (46 cm) thickness of dumped riprap over a length of 1400 ft. (420 m). In 1969 the city of Rockport again requested assistance for repair of an adjacent segment of caving bank which is endangering the same city street. A report on this new work was prepared in 1970 and is still under review. The main reason for the erosion hazard at Rockport is the concentration of flow directed at the bank from a large bend in the Ohio River just upstream from Rockport.

Geographic Setting

The Rockport revetment project is located on the north (Indiana) bank of the Ohio River at the City of Rockport, in Spencer County, Indiana (see Figure 3. 7). Rockport lies in the Newburgh pool between the newly constructed Newburgh and Cannelton Dams. The terrain of the surrounding area ranges from steeply sloping hills to nearly level bottomland. The area at the revetment site is on a steep slope and much of the development in the area lies on a steep sandstone rock bluff which overlooks the project site. The areas just upstream and downstream from the revetment both lie in the flat level bottom lands of the Ohio River.

Environmental Qualities of the Project Area

Ecological

The Rockport revetment site has extensive terrestrial vegetation ranging from a few scattered trees on both the upper and lower banks to a dense tall grass cover on the upper bank, and scattered grass cover in patches throughout the remaining portion of the revetment.

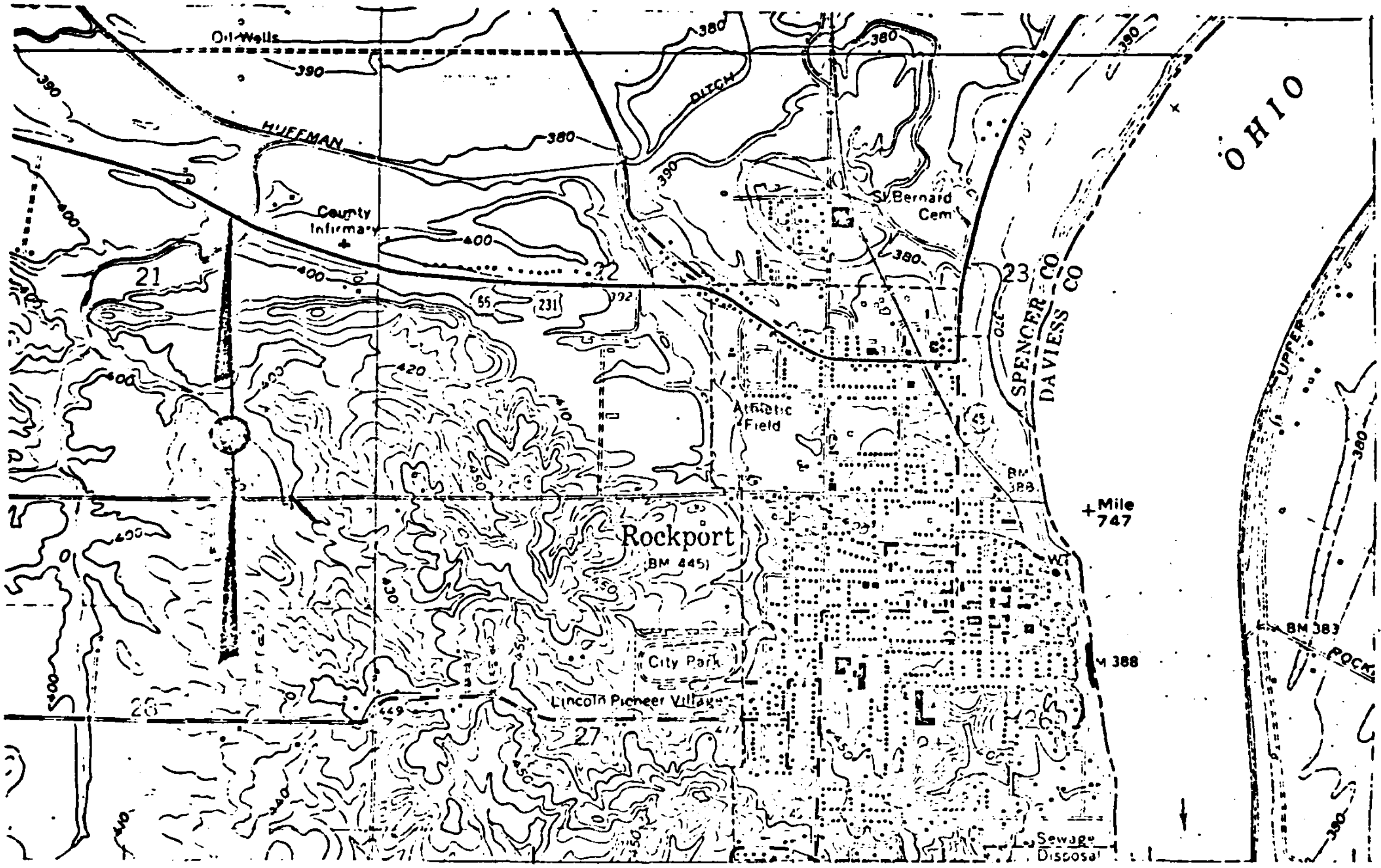


Fig. 3.7 - Location Map, Rockport Bank Revetment (Ref. 79)

Many of the trees on the lower bank have their roots exposed due to undermining of the soil in this area. The revetment has been in place a sufficient amount of time for the vegetation in the area to become rooted, thereby contributing to the stability of the slope.

Physical

The soil at the project site consists of a very steep silt loam which generally occupies the short bluffs between the nearly level alluvial soil and gentle slopes. The surface soils which have formed in loess are unstable when wet and are susceptible to high rate of runoff which is a definite erosion hazard. The silt loam at the site is approximately 3 ft. (.9 m) thick and overlies a thick heavy silty material which is deep and well drained. The permeability of the soil made the use of a permeable revetment necessary because of the drawdown, which occurs when there is a sudden drop in water level. This sudden drop in water level causes a pressure buildup behind an impermeable revetment which could result in a rupture.

Socio-Economic

Land between the city street and the river affected by erosion at the project site consists of a steep sloping river bank. A small portion of land downstream from the revetment is used for residential purposes. There are four cottages located on the upper level river bank, approximately one block downstream from the project site.

On the west side of the street, which parallels the revetment, is a steep sandstone rock bluff with carved steps extending to a protected hollowed overlook. This rock bluff is the setting for a park commemorating the first settlement of Rockport. There is also a Lincoln Memorial marker at the downstream end of the revetment, commemorating the Lincoln Heritage Trail.

The city of Rockport is rather small and scenic with most of the city being situated on top of a knob which overlooks the river valley. Some homes are located on the bluff which overlooks the city. The historical sites effected by the erosion of the bank include the first settlement site of Rockport, and the Lincoln Heritage Trail. Both of these sites are immediately adjacent to the project site.

Recreation in the project area consists of the use of the park directly across from the revetment and the river itself. There are no other sites in the immediate area which are directly affected by erosion potential.

The only transportation facility affected by the project is the street which runs parallel to the revetment between the rock bluff and the river. This is not an artery of major concern other than the fact that the street provides access to the park. The houses at the downstream end of the revetment would be accessible from two other side streets if this street were removed.

Aesthetics

The preservation of the park and the Lincoln Trail is in keeping with the aesthetic character of the natural river setting. Although the revetment has been accomplished with dumped scrap concrete fill rather than stone riprap, the setting at the riverfront is still quite scenic. The area could have been given a more pleasing appearance by the use of a uniform and consistant means of revetment.

Environmental Impact of the Project

Null Alternative

The null alternative at Rockport would have impacted on a long term basis, many parameters previously discussed. Continued erosion of the bank would have voided any vegetation previously growing there and would have detered any further vegetative growth as a result of the unstable conditions. The quality of land in terms of appearance and soil properties would have been degraded to the point where it would no longer be usable. River flow, though left in its natural state, would continue the destruction of the land unless it was inhibited by physical means. The geology of the area would change considerably if erosion continued over an extended period of time. The sandstone rock bluff opposite the river bank would be attacked by the erosional forces of the river. The bluff consists of a loosely cemented, easily weathered sandstone and shows extensive signs of wear. This bluff is actually part of the knob on which the city of Rockport stands.

The socio-economic impact of bank collapse would have been detrimental in both long and short term effects on land use, economic development, history, recreation, and transportation in the immediate vicinity of the now reveted area. Land use potential would have been decreased due to appearance, safety features, soil properties, and agricultural capabilities of the eroded land. Economic development would have decreased in the immediate area for much the same reasons land potential would be expected to decrease. The risk involved in developing this unprotected land would have increased as erosion continued. The history of the immediate vivinity would have deteriated with further erosion, because of the destruction of the first settlement site of Rockport and the Lincoln Heritage Trail. The history of Rockport in general would have been endangered if erosion were allowed to continue. The recreational uses of the park opposite the revetment would have been destroyed if no changes were made in haulting erosion. A minor transportation facility (the street paralleling the revetment and the river) would have been destroyed if no protective measures are taken to deter erosion.

Continued instability of the bank would have caused continued degradation to the aesthetic characteristics of the vicinity, in that the ecological, physical, and socio-economic environments would have been physically damaged. The damage accrued by the environment in the project area would have been discordant with the qualities of the adjacent unaffected areas.

Project Implemented

The riprap revetment project implemented at Rockport has virtually eliminated the erosion resulting from the flow of the Ohio River directed at the bank opposite the city street. Though the vegetative growth associated with the reveted area has not increased tremendously since the placement of riprap, the environment has been stabilized to the extent that vegetative growth adjacent to, and incorporated in the revetment has been preserved. The land quality in the immediate vicinity of the revetment has not improved since the use of the riprap stabilization techniques, but the land quality has been stabilized through revetment.

This means there is a better land quality now that the revetment is complete, than if no action had been taken and erosion were allowed to continue. The geology of the area, in the sense of soils along the river banks and the adjacent associated rock, has been preserved by the use of a physical means of retaining the bank. River flow, associated with the reveted area has been checked by the use of riprap stabilization procedures, but this poses little effect on the hydrologic system.

Land use potential in the area of the revetment has increased slightly since the implementation of the project. The revetment has caused no new developments along the banks of the Ohio River, but land for potential development exists and is protected from erosion. Economic development in the vicinity has also not increased since the project was realized, but again there exists potential for development associated with the now stable physical environment. The revetment procedure has preserved the historical points of interest in the area immediately adjacent to the project site and has also preserved the general historic nature of Rockport, by eliminating future erosion in the area. Recreational uses of the park and the river are still evident and are further enhanced by the stabilization of the land. Transportation in the area, (the city street which parallels the project) is protected from further damage by the stabilization of the bank.

The aesthetic character of the immediate area has been enhanced in the sense that it is now protected and secure from erosion. The type of protection that was used though is not physically appealing in that it has no continuity with the natural surroundings and it is not uniform or consistant. The revetment was supposedly done in limestone riprap, but it appears that the contractor incorporated some scrap concrete fill along with the limestone.

3.7 CLOVERPORT BANK REVETMENT

Project History

Annual fluctuations of the Ohio River have caused erosion of the bank at Cloverport, Kentucky. This localized erosion of the Cloverport bank was endangering approximately 600 ft. (180 m) of U. S. Highway 60. The work done on this project was begun under authority of Section 14 of the Flood Control Act of 1946, which provides for the construction of emergency bank protection works to prevent flood damage to highways, bridge approaches, and other public works. The project, when completed in August, 1973 at a federal cost of $19,600, involved the filling and shaping of the natural bank, the placing of a dumped gravel filter blanket, and the final placement of an 18 in. (46 cm) thickness or 26 lb. (11.7 kg) maximum weight limestone comprising some 1,400 tons (1,270 mg) and extending 325 ft. (98 m). The Cloverport revetment project was designed to withstand water level fluctuations caused by flooding, and the building of the new Cannelton Dam approximately 9 mi. (14.5 km) downstream which caused a rise in pool level at Cloverport.

Geographic Setting

The Cloverport revetment site lies approximately 25 ft. (7.5 m) north of U. S. Highway 60 where the highway parallels the Ohio River as it passes through the city of Cloverport (see Figure 3.8). Cloverport's terrain ranges from steep slopes to fairly level plains. The area just west of the city is steep and hilly. The city itself has some variance in elevation but generally lies on a level portion of the river terrace. The river bank from the revetment site continuing downstream

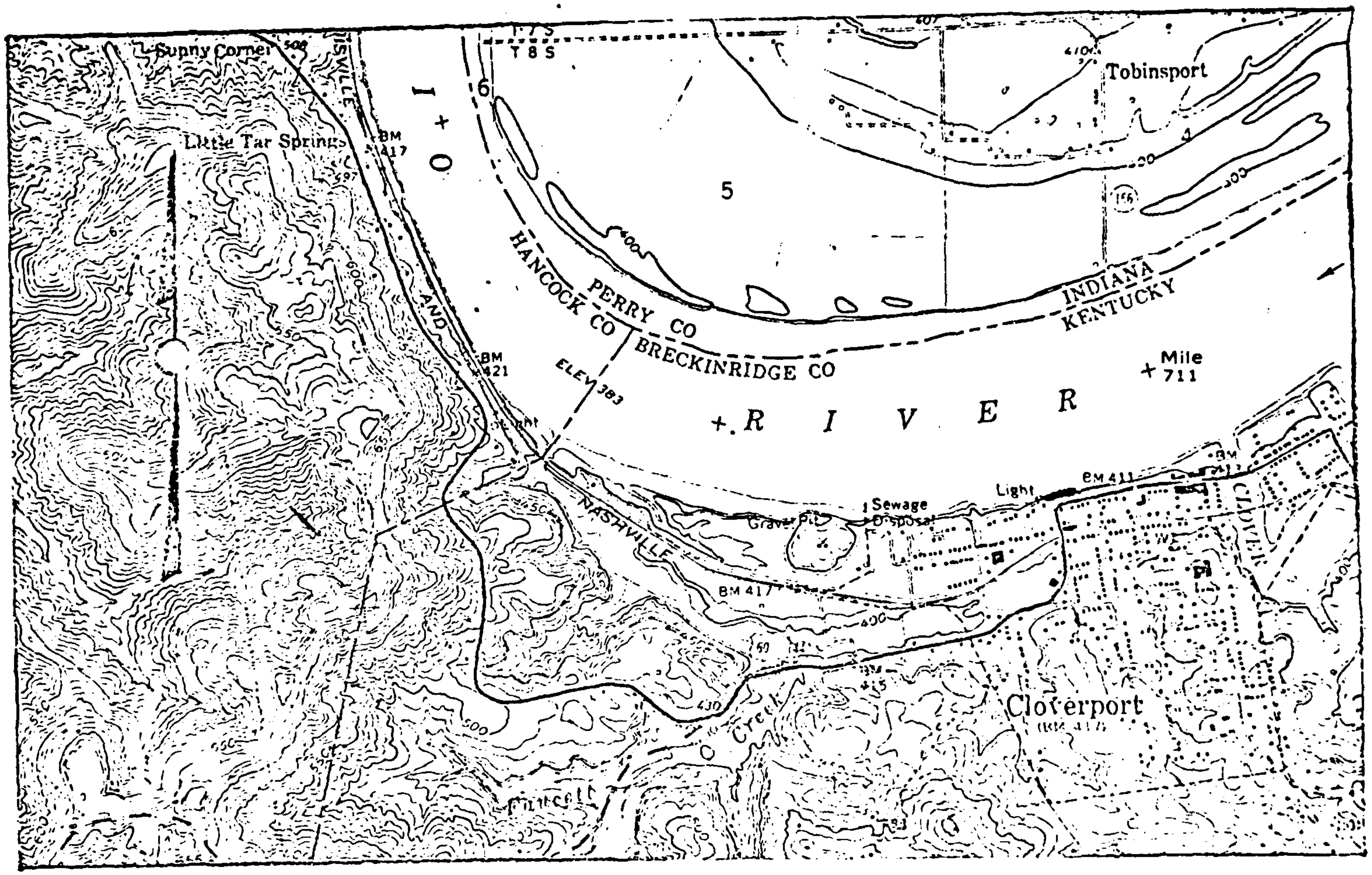


Fig. 3.8 - Location Map, Cloverport Bank Revetment (Ref. 82)

to a local sand and gravel pit is fairly steep, and there is no terracing of the slope. Upstream from the revetment site the slope at the land water interface is steep, but the land appears terraced.

Environmental Qualities of the Project Area

Ecological

The area in the immediate vicinity of the bank stabilization project possesses a variety of vegetative covers, but most of the area has a short grass covering. Both east and west of the protected bank, there is tall wild grass and a few small trees at the perimeter of the stone protection. There has been no vegetative growth on the revetment itself since its completion in August, 1973. This lack of cover on the reveted area can be attributed to the recent placement of the stone protection and the fluctuations in water level at the site.

Physical

The soil at the project site is a deep well drained silt loam deposited over thick unconsolidated alluvial stream deposits. These soils are unstable when subjected to water and provide very little resistance to erosion. These soils are quite permeable and have a tendency to retain water, which further increases their erosion hazard. The permeability of the soil at the project site necessitated a soil stabilization method which provided drainage to relieve hydostatic pressure buildup, and still maintained good erosion resistance.

Socio-Economic

The land between the highway and the river is composed mainly of a steep sloping river bank. The area to the east or upstream end of the revetment along the lower terrace of the river contains a small roadside park. North of the revetment is U. S. Highway 60 along which is located well preserved older homes in addition to relatively new modern homes. At the turn in U. S. Highway 60, directly opposite the reveted area, is a gas station which is the only commercial development in close proximity to the project.

Transportation protection was the basic reason for the Cloverport bank stabilization project. U. S. Highway 60 which passes with 25 ft. of the project is a major artery in the federal highway system, serving both central and western Kentucky. Highway 60 extends from Louisville, Kentucky and serves all of the cities westward along the Ohio River until it reaches Cairo, Illinois. This major transportation facility had to be protected to insure safe and adequate transportation, as well as continued economic growth of the entire state along the reaches of the Ohio River.

Aesthetics

The preservation of older homes in the area of the Cloverport revetment, as well as the newer modern structures, has preserved the Aesthetic character of the immediate area. The area is now more secure and visually pleasing than the eroded bank.

Environmental Impact of the Project

Null Alternative

Continued erosion of the river bank at Cloverport would have induced many serious problems associated with the previsouly related environmental qualities. No effort to halt erosion would have resulted in the destruction of all vegetation in the immediate area of the bank collapse, endangered any vegetation in the surrounding area, and hindered any further growth due to unstable conditions. The land quality at the site would have been destroyed if erosion were not halted. The soil properties, if erosion had occured, would have been significantly altered, making the land unusable. River flow patterns would not have been altered by letting nature take its course. The initial erosional problems were caused by water level fluctuations.

Land use in the vicinity of the revetment would have been negatively affected by further land degradation, because most of the land was previously developed before erosion occured and these developments would be in danger. Economic development would have received a set back if erosion continued, not only in the immediate area, but also in all areas served by U. S. Highway 60 because of its great importance to the transportation industry of central and western Kentucky. Recreation could possibly have been damaged if erosion continued in this area, not only because of possible damage to th park upstream from the eroded bank, but also because of possible damage to the recreation potential of the river. Transportation would have borne the impact on socio-economic due to the possible failure of U. S. Highway 60, which would have necessitated its rebuilding to insure adequate transportation facilities for the area.

The aesthetic impact of doing nothing to deter erosion would have been damaging to the physical environment as well as the emotions of the residents in the project area. The eroded bank would have presented a discordant picture because of the discontinuity with the surrounding environment.

Project Implemented

The revetment while eliminating the erosion at Cloverport, has also contained the damages incurred by the environmental qualities of the area. The vegetation in the area of the project now has a stable environment in which to grow even though vegetative growth has not occured on the revetment to date (1975). The land quality, while not actually improving, has stabilized and is better now than if no changes were made. The flow of the river has not been noticable altered by the riprap revetment.

Land use has not been appreciably increased by the bank stabilization methods used because most of the land around the site is either steep sloping river bank or was previously developed. Land development has been stabilized by halting erosion. Economic development has not noticably increased in the area because of bank revetment, but the intangible effect on this socio-economic factor would only be realized if the bank eroded.

Recreational uses of the area have likewise not grown at any significant rate because of the increased stability, however, the potential for future use is evident. Transportation facilities in the area have shown no increased use but by creating a stable physical environment the benefits of transportation will be realized in time by the increased economic development and land use of areas served by U. S. Highway 60.

The aesthetic benefits register immediately, but are often taken for granted. The area now has a stable environment, secured physically by the riprap, and emotionally by the sense of well being received by the residents of the area. The reveted bank, though foreign to the surroundings, has more appeal than an eroded slope. The use of riprap has caused an accumulation of debris on the lower portion of the bank due to water fluctuations and the debris in the river.

3.8 COOPER LEVEE BANK REVETMENT

Project History

The Cooper Levee bank stabilization is a project undertaken by local interests to stabilize a portion of levee under attack by water action. Cooper Levee itself is an addendum to Levee Unit - 5, which is a Corp of Engineers project located along the Wabash River in Gibson and Posey Counties, Indiana. The stabilization method used at Cooper Levee involved the random placement of old car bodies and various other junked objects. The carbodies were apparently rolled haphazardly off the steep river bank. The age of the revetment is unknown, but the cars have collected large amounts of sediments and some are nearly covered.

Geographic Setting

The Cooper Levee revetment site is located on the Indiana bank of the Wabash River in Gibson County, Indiana. The revetment site is approximately 5 miles north of Griffin, Indiana at the Schuh Bend of the Wabash River (see Figure 3.9). The terrain of the area is nearly all bottomland well within the flood plain of the river. The only variances in elevation occur at streams where the land elevations drop and the levees where elevations increase.

Environmental Qualities of the Project Area

Ecological

The project area possesses terrestrial vegetation along the bank in the area of the revetment. The vegetation on the bank includes both large and small trees and tall grass. The top of Cooper Levee is lined with trees. Some of the trees closer to the river have exposed roots due to the undermining of the slope.

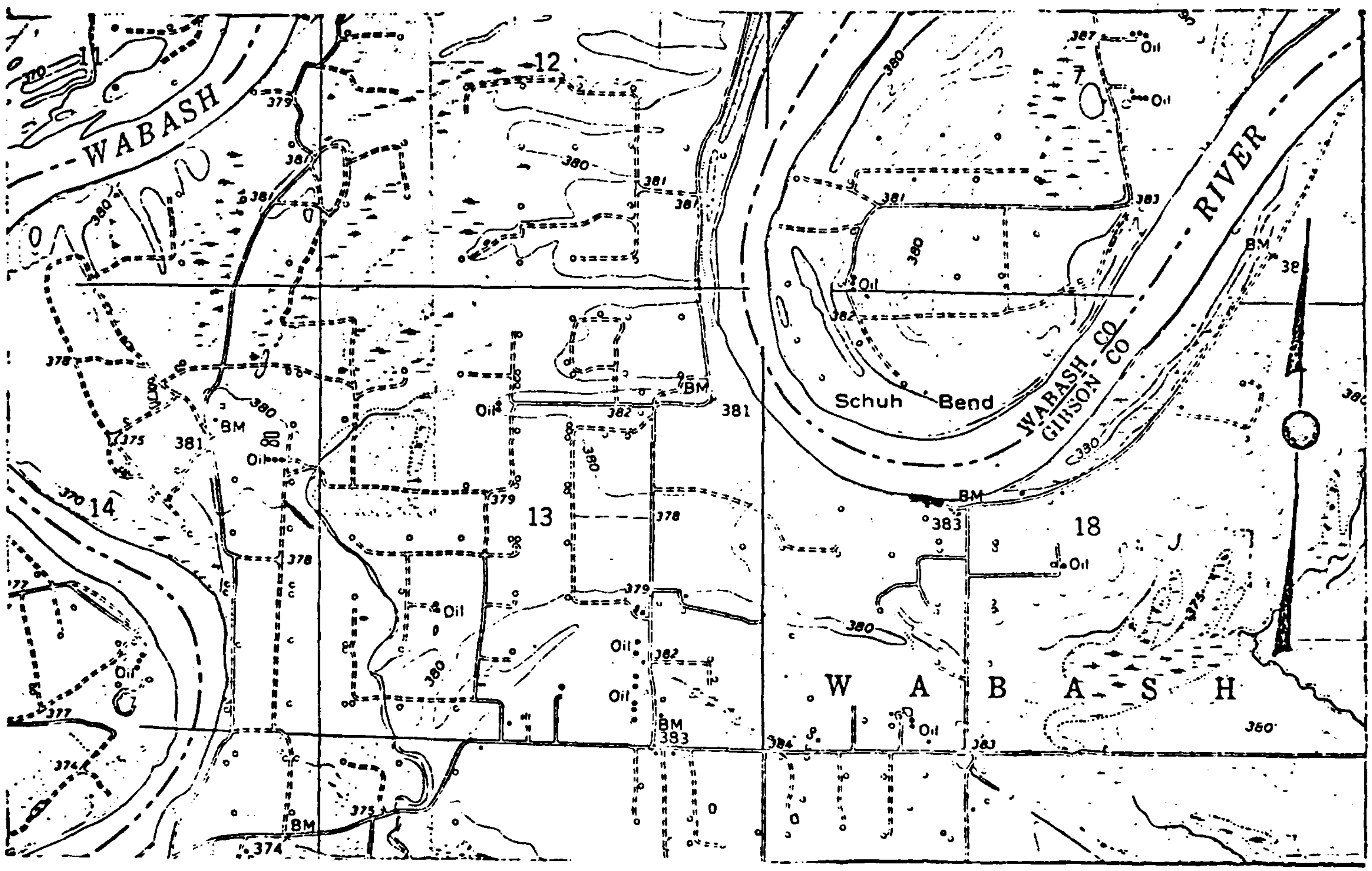


Fig. 3.9 - Location Map, Cooper Levee Bank Revetment (Ref. 84)

Physical

The soil at the site is a deep, well drained silt loam overlying consolidated sand and gravel deposits. The silt loam topsoil is not normally affected by overflow because of its elevation above the flats, but it is easily eroded when subjected to flooding and river currents. This soil type is light in weight and is usually found nearer a channel than heavier soil. This light weight and nearness to channel currents add to erosion potential.

Socio-Economic

Land around the levee is generally considered agricultural although there are many dry and operational oil well scattered throughout surrounding fields. Just opposite the revetment is an old dilapidated farmhouse which is still occupied. There is a hand pump for water less than 10 ft. (3 m) from the edge of the river. This house is the only residence within one mile of the car body revetment.

The economic development of the area consists mainly of farming and oil well operations. There are no public or private commercial facilities affected by the protection of the levee.

There are no historical sites in the area of the project and recreational uses of the river in the area by anyone, but canoeists is limited because of the swift currents, and rapids just downstream of the project area. There are no transportation facilities affected by the project other than the dirt roads to the oil pumping facilities, but these roads are not close enough to the bank collapse to be considered in danger.

Aesthetics

The aesthetic character of the area lies only in the natural picture of the river and the scenic beauty of the undeveloped land. This picture is marred by the oil wells and the revetment with its old car bodies.

Environmental Impact of the Project

Null Alternative

The environmental impact of not placing the old car bodies to protect Cooper Levee from eroding would have many major and minor effects on the local environment. The effect on the vegetative growth along the river bank would have been negative because of the unstable bank conditions and the inability for vegetation to exist along the eroded bank. Continued erosion would have jeopardized more vegetation as the slope failure moved inland. The quality of land would have been degraded if no protective measures were taken, because the land would no longer be fit for any useful purpose. River hydrology would have been unaltered by the null alternative, however, the effects on the physical environment would have been more severe than the effects on other environmental qualities if flow were altered by a physical barrier. If the levee continued to erode the soil properties and the agricultural potential of the land behind the levee would be ruined.

Land use and economic development would definitely suffer if no remedial action were taken. The agricultural users as well as the oil companies would have to move from the land if no flood protection was provided.

The aesthetics of the car bodies dumped into the river, and the oil wells scattered throughout the area are not very pleasing. However, the eroded bank would be even less appealing in both a physical and emotional sense. The levee would be eventually destroyed, leaving the land unprotected.

Project Implemented

The dumping of the old car bodies has minimized erosional hazzards and associated detrimental environmental impact at the project site. While halting the land erosion the car bodies have also been collecting sediments which is adding more land for vegetative growth. Land quality has not increased since the revetment but the land used for agricultural purposes have been stabilized. Though river flow has been altered by the use of these sediment collection traps, the positive impacts of stabilizing the physical environment far exceeds possible damages to the ecological environment and aesthetics.

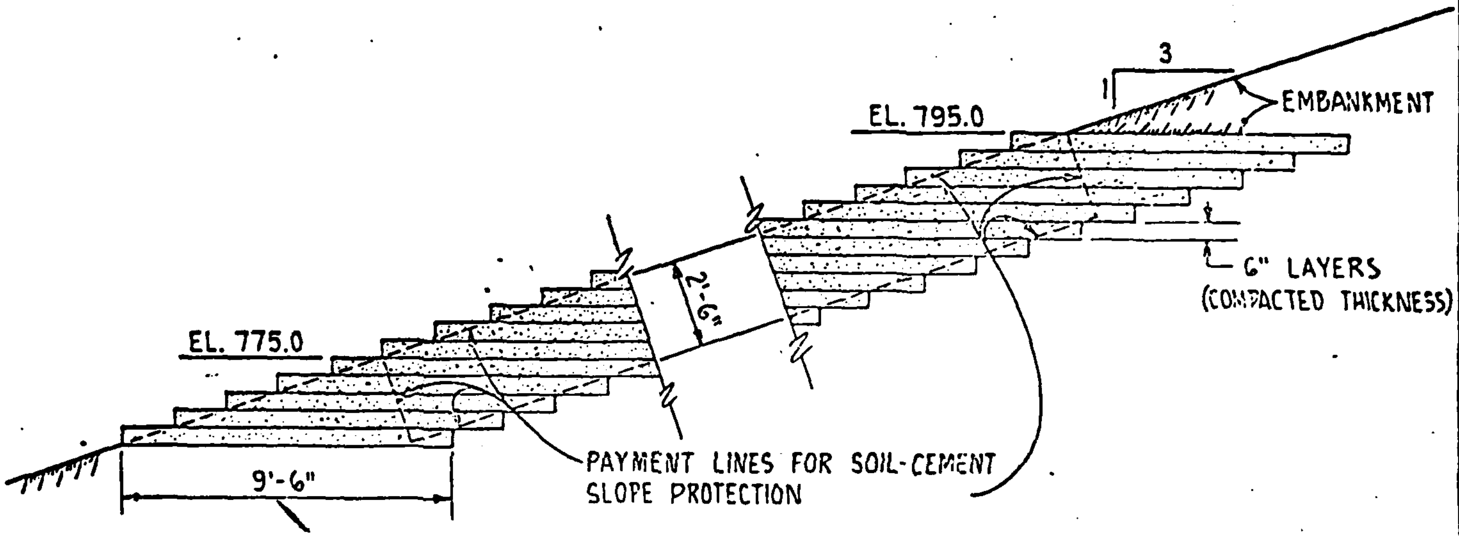
Land use and economic development of the area has remained constant since the action to halt erosion was taken. The land users and developers are now more secure because of the stability of the land in the project area. History, recreation, and transportation features of the area have been unchanged by the implementation or this revetment.

The aesthetic character of the natural environment has been severely degraded by use of the old car bodies to complete this revetment. The project is totally discordaint with the natural qualities and has no place, even though the revetment is not under public scrutiny.

3.9 EAGLE CREEK DAM REVETMENT

Project History

The Eagle Creek revetment is not actually a revetment in the sense that revetments are protective measures used to halt previous erosion. The stabilization at Eagle Creek Dam is actually a preventative measure incorporated in the initial construction of the dam to deter erosion. The dam with stabilization measures was completed in 1969. The stabilization technique utilized on the dam face was a soil cement mixture consisting of a 9 to 1 soil-cement ratio. The placement of the soil cement was accomplished by rolling the mixture out in layers 9.5 ft. (2.9 m) wide, .5 ft. (.2 m) high as the earth fill was rolled to increase the height of the dam (see Figure 3.10). The soil cement extends approximately 17 ft. from top to bottom on a 45 degree slope, 5 ft. (1.5 m) of which is covered by water during normal pool. The revetment runs the entire length of the dam face,



TYPICAL SECTION
SOIL-CEMENT SLOPE PROTECTION
UPSTREAM FACE OF DAM

Fig. 3.10

4,200 ft. (1260 m), and has a thickness of approximately 2.5 ft. (.75 m).

The planning for the dam was initiated following diastrous floods on Eagle Creek in 1956, 1957, and 1958. The reservoir is operated for flood control, pollution abatement, and water supply.

Geographic Setting

The dam is located about ten miles north-west of the center of Indianapolis, Indiana in line with 38th Street extended to Eagle Creek (see Figure 3.11). It will be located a few hundred feet above where Interstate No. 74 crosses Eagle Creek. The flood control reservoir extends upstream to above Traders Point, a distance of approximately 8 mi. (13 km) above the dam. The land in the immediate vicinity of the dam ranges from nearly level on the eastern edge of the reservoir to a steep slope on the western side. The land all along the shore of the reservoir is severely eroded because of water level fluctuations which develop when controlling floodwaters.

Environmental Qualities of the Project Area

Ecological

The vegetative growth at the reservoir is quite variable both up and down stream from the dam. The vegetation on the dam face itself is thick regularly kept grass cover from the high water mark on the dam face to the top of the dam. There is no vegetation on the soil cement slope. The soil cement is impermeable and has the consistency

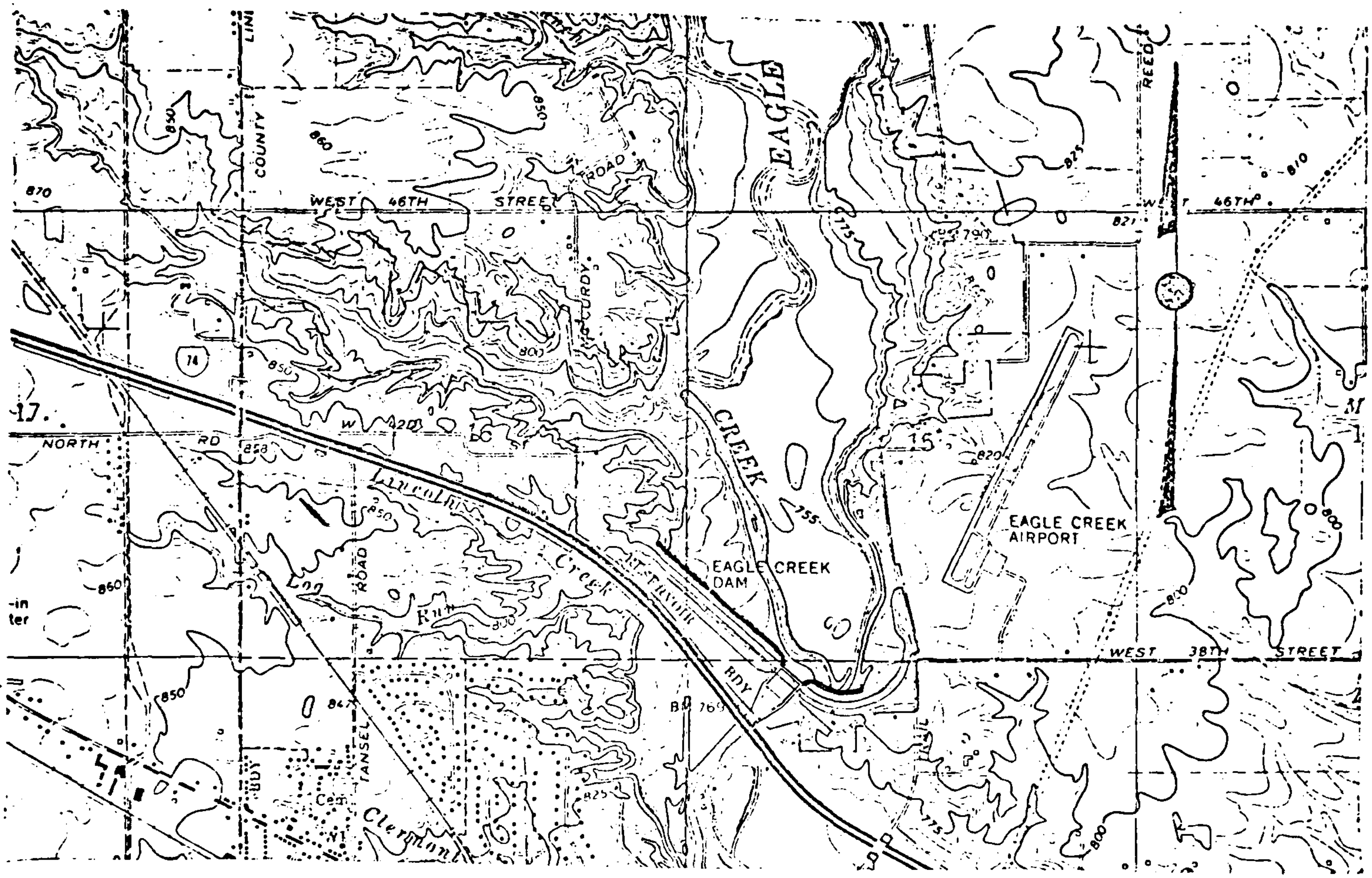


Fig. 3.11 - Location Map, Eagle Creek Dam Bank Revetment (Ref. 88)

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ENVIRONMENTAL IMPACT OF RIVERBANK REVETMENT,(U)

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of rock. Vegetative growth along the shore of the reservoir is usually limited due to the erosion continually taking place in the area.

Physical

The soil on the protected slope is not of a uniform nature because of its withdrawal from many soil types of the surrounding area. The soils in the dam are well compacted due to placement compacting techniques and overburden pressure. The compaction has decreased the permeability of the soil in the dam to only minimal amounts. The soil cement is used to protect the dam face from erosion as well as maintain the impermeability of the soil.

Socio-Economic

The entire Eagle Creek Reservoir area is in the initial stages of housing development. Most of the homes in the area have been completed since work on the reservoir project began. The new homes, as well as the old, could be considered exclusive full time residences. There is a small airport just northeast of the dam which will handle small planes. On the eastern edge of the reveted area there is a naval avionics testing area. The entire reservoir area is a game preserve and no hunting is permitted. Most of the developed areas at Eagle Creek are some distance from the erosion occuring around the reservoir perimeter and appear in little danger at the present.

The historical points of interests in the area of the dam are the two Eli Lilly Mansions on the downstream side of the dam. These homes are now occupied by the parks superintendant of Indianapolis and the manager of Eagle Creek Reservoir.

Recreational uses of the area rely heavily on the reservoir for boating, fishing, and various other water related activities. There are also park and picnic facilities throughout the area for public use.

Transportation facilities in the immediate area consist of a road which runs along the crest of the dam and Interstate 74, which crosses Eagle Creek a few hundred feet downstream from the dam. These are important facilities not only from a transportation viewpoint, but also for economic reasons. Interstate 74 provides transportation for all of central Indiana and the road crossing the dam is a useful access to all points within the park.

Aesthetic

The aesthetic character of the area takes into account many of the environmental qualities. The natural beauty of the reservoir, dam, and the park, along with the historical sites and various economic developments make the area a pleasing aesthetic picture.

Environmental Impact of the Project

Null Alternative

The environmental impact of not preventing the erosion on the face of the dam would have many detrimental effects. The erosion would not only damage the environmental qualities of the immediate area, but also of the area which depends on the reservoir for flood control, water supply, and pollution abatement. Erosion of the dam face would have little effect on the vegetation on the dam itself, but long term erosion could damage the structure of the dam. This could adversely affect vegetative growth downstream. The land quality of the lower reaches of Eagle Creek would be in danger if the reservoir were not contained and flooding eliminated. If the dam face had no physical protective barrier there would be no resistance to water level fluctuations and water currents caused by storms.

The land use and economic development both around the reservoir and downstream along Eagle Creek would be in danger if the dam were undermined. While the land downstream would be in continual danger of flooding and erosion, the developments around the reservoir would be in danger of being left without the use of the reservoir and its scenic beauty. The scenic beauty was specifically the reason behind developing this area.

The history and transportation factors associated with this area would be unaffected by erosion at the face of the dam.

Recreation facilities associated with Eagle Creek Reservoir would be rendered useless if the dam face were eroded to the point where the dam no longer held water.

The aesthetic character of the reservoir and the surrounding area would be ruined if nothing was done to prevent undermining.

The natural beauty of the area would be eventually left stranded without the aesthetic character and qualities of the water which make the site more visually appealing and more marketable.

Before erosion damaged the structure of the dam, thereby causing detrimental impacts to the area which depends on the reservoir for flood control, water supply, and pollution abatement, remedial measures would be most likely initiated to prevent the full impact of the null alternative being felt. These measures would be beneficial to parameters of the ecological, physical, and socio-economic environment as well as to aesthetics. Though now more difficult to install than if done as part of the initial project, these remedial measures would considerably increase the cost of maintaining the dam and reservoir.

Project Implemented

The use of soil cement on the dam face has ended the erosion hazard and with it many negative effects on the environmental qualities of the area. The soil cement stabilization technique has changed all the environmental factors associated with the site; increasing their value in most cases. The one factor which was not increased by the soil cement stabilization method was the vegetation at the site. Though the project is protecting vegetation above the water level of the reservoir, vegetation cannot grow on or through the revetment itself. The soil cement has no voids and has the consistance of concrete.

The land around the perimeter of the reservoir is still subject to the erosional hazards associated with water level fluctuations within the reservoir. Land quality downstream from the dam site is protected from flooding through the stabilization of the dam face. The fundamental reason for the development of the reservoir was to protect land along Eagle Creek from floodwaters. The hydrology of the reservoir though altered has not been changed enough by the implementation of the soil cement dam face to damage the hydrologic flow pattern. Geology of the area has been significantly protected downstream from the dam. Now no further damage will occur to lands previously subject to flood damage before the dam was constructed.

Land use in the area has not increased specifically because of the stabilization of the dam face. Land use and economic development have increased due to the dam itself and the soil cement stabilization technique plays a role in stabilizing the dam. History of the area has received some protection from the revetment in that the two Eli Lilly Mansions behind the dam are indirectly protected by the impermeable dam face. Recreation in the area also benefited significantly from the building of the dam and reservoir development. Again the stabilization technique utilized on the dam face is indirectly protecting this important environmental resource. Transportation in the area is not positively effected by the stabilization of the dam because there would actually be little effect on transportation in the immediate area if the dam were not protected.

The major impact affected by the stabilization of the dam is the aesthetic character of the reservoir itself and all of the environmental qualities related to the reservoir, including historic sites, economic development, and recreational land. All these factors are indirectly made more aesthetically appealing by the stabilization of the dam and thereby the stabilization of the reservoir. The aesthetic appearance of the dam face itself in relation to the land water interface is quite natural. The soil cement has the appearance of natural soil both in color and slope retention. This type of stabilization method requires less maintenance than the conventional riprap stabilization in that there is no weeding or debris cleanup required. The soil cement with no apparent voids does not allow vegetation to grow and the relatively smooth slope and surface of soil cement permits debris to recede as the water level does. This type of stabilization (soil-cement) could possibly be utilized for other purposes such as boat ramps or roads, further increasing it environmental suitability.

3.10 MOUNT VERNON BANK REVETMENT

Project History

The Mount Vernon, Indiana bank revetment is being placed in conjunction with the building of a new river port, the Southwind Maratime Centre. This project is being developed by the Indiana Port Commission. The bank erosion control measures at the site are now complete, but the project itself is still in its initial stages. A dumped riprap technique was utilized at the site and involved the placing of an initial dumped gravel filter blanket and the final placement of 250 lb. (113 kg) maximum weight limestone. The revetment work is a safety precaution to prevent detrimental wave and current action associated with large cargo boats, barges, and the river itself, and from destroying the land. The riprap is intended to provide protection from the construction barges during the construction phase of the port, and will also prevent erosion from the river traffic after the port is in use.

Geographic Setting

The Southwind Maratime Centre is located approximately 1.2 mi. (1.9 km) southeast of the central business district of Mount Vernon, Indiana along the north (Indiana) bank of the Ohio River (see Figure 3.12). The port was constructed around a natural river inlet. Before construction began on the port, the land in the area was flat fertile river bottom farmland. Most of the surrounding area is flat agricultural land. Since work on the port began, much filling and grading has taken place to raise the elevation of the land around the opening to the port. This filling and grading has removed all traces of the former natural terrain and vegetation.

Environmental Qualities of the Project Area

Ecological

The land at the port affected by the riprap stabilization is void

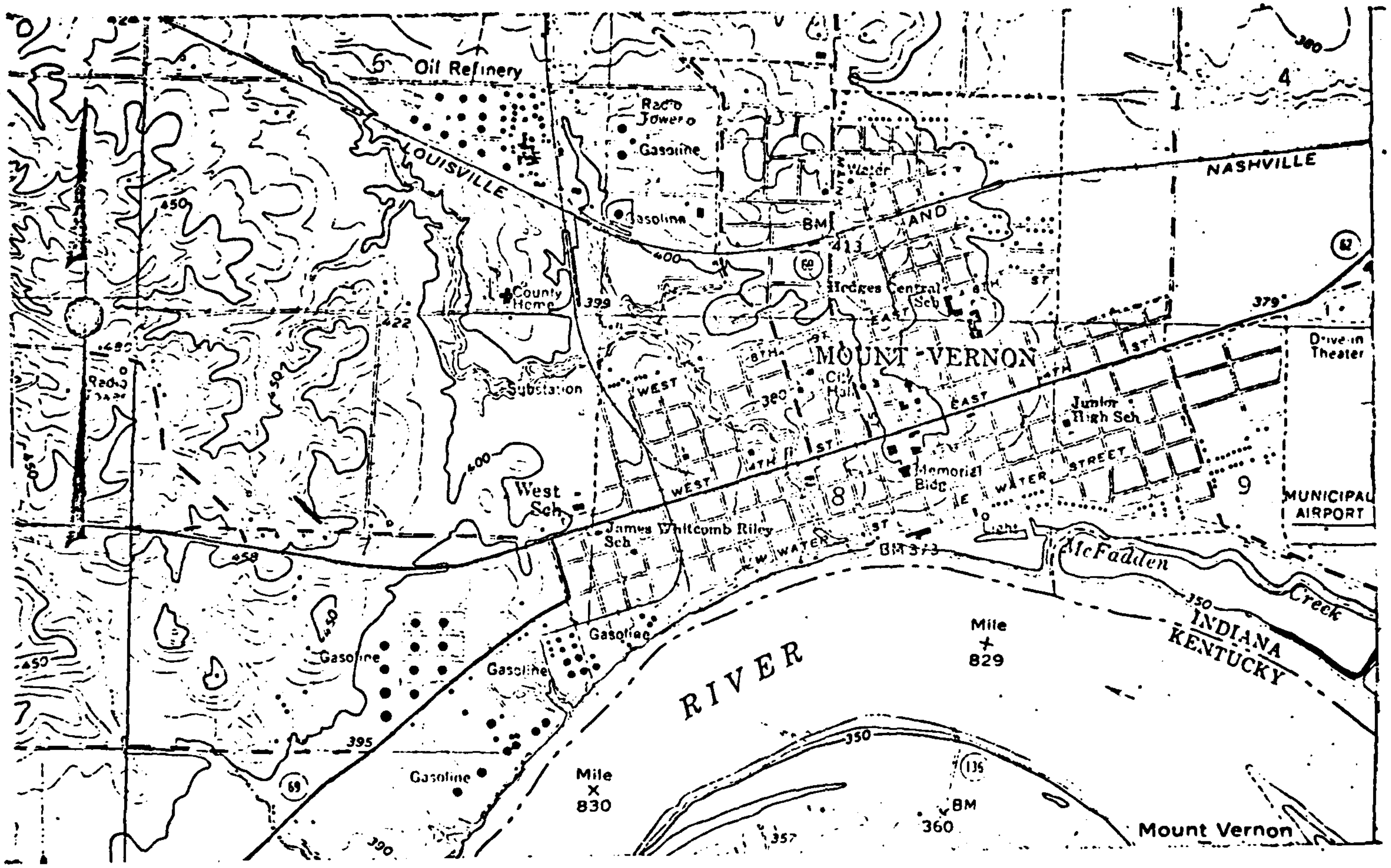


Fig. 3.12 - Location Map, Mount Vernon Bank Revetment (Ref. 89)

of natural vegetation at the present time. The area will be seeded after completion of the entire project, including the riprapped banks. Vegetation along the banks will provide more complete protection from erosion.

Physical

Due to the tremendous amount of filling and grading at the site, the soil is not homogeneous in type or properties. The soils at the port are well compacted and have only slight permeability due to the high degree of compaction. Riprap is used as a stabilization measure to prevent erosion and not to prevent water infiltration.

Socio-Economic

The land area around the new port development is devoted mainly to agriculture. The Mount Vernon Municipal Airport is located just outside the northwest corner of the project site. There are only a few homes in the immediate vicinity of the new port, most of which are widely scattered farm houses.

Recreational uses of the area are associated mainly with the Ohio River. The river is used for all types of water related recreation. Transportation affected by the port include both water and land facilities. The Ohio River which passes the port will receive both the benefits and the losses associated with increased river traffic. The road which parallels the river and runs past the north perimeter of the new port will also receive increased traffic because of the new jobs created and the transportation of goods to and from the port.

Aesthetics

The aesthetic character of the area lies basically in the rural nature of Mount Vernon and the surrounding countryside. The small town of Mount Vernon is enhanced by small specialty shops, vast expanses of farmland, and casual atmosphere of the entire area.

Environmental Impact of the Project

Null Alternative

The environmental impacts resulting from not preventing erosion at the *Southwind Maratime Centre* would include many long range detrimental effects on the ecological, physical, and socio-economic characteristics of the area. There would be no effect on vegetation growth at the project site at the present if no preventative action were taken, because there is no vegetation that is under attack. The land quality at the site would be severely effected by erosion in that the land would be unsuitable for future vegetative growth if there was no action taken to halt erosion. The hydrology of the area would be unaltered by the null alternative, however, the land would be subject to continual surface and subsurface water currents if the existing flow pattern was not changed.

The land use in the area of the port facilities would be eventually destroyed both physically and in terms of safety if erosion went unaltered. If bank collapse did occur remedial measures to halt the erosion would most likely take place. These remedial measures would involve revetment of the bank to prevent further erosion and possible dredging of the channel if the erosion was severe. In the long run the null alternative would increase the cost of the project by necessitating secondary stabilization of the bank and dredging of the channel. Remedial measures to halt erosion would be necessary to prevent damage to economic developments present due to the implementation of the port project. The remedial measures would also prevent degradation of other environmental qualities. The aesthetics features of the area at present would be neither preserved nor destroyed by the null alternative. The aesthetic character of the area surrounding the site is being detrimentally invaded by a physical feature not coherent with the surrounding environment.

Project Implemented

The use of riprap to control erosion at the Southwind Maratime Centre has virtually eliminated erosional possibilities at the port from construction activities as well as from increased river traffic. Vegetation will be unaffected by the stabilization technique because there is actually no vegetation to be affected until the project develops further.

Land quality at the site will be preserved by the prevention of erosion in that there would now be a stable physical environment in which the ecological environment could exist in a controlled manner. The hydrology of the river currents would be altered by the use of stabilization methods, but again this would lead to a more stable physical environment.

Land use in relation to port facilities would be preserved by controlling erosion and stabilizing the port area. This land stabilization would also enhance the possibilities of continued economic development. The recreation uses of the river would be preserved in their present state. Increased recreational uses of the river would be doubtful due to the volume of heavy river traffic. Transportation uses of the river would be preserved and very likely increased by detering erosion at the port.

The aesthetic character of the area with the building of the port will eventually be changed. At the present it is impossible to determine to what degree this change will occur and how much the stabilizing of the port will affect this change.

3.11 FALLS OF THE OHIO BANK REVETMENT

Project History

The revetment project located just below the Falls of the Ohio was authorized and completed in 1965 by the Louisville District Corp of Engineers. The revetment involved the aquisition of land, placing of a dumped gravel filter blanket and the final placement of an 18 in.

(46 gm) thickness of 200 lb. (90 kg) maximum weight quarry run limestone riprap, comprising approximately 6,500 cu. yd. (4900 m^3). This project was accomplished at a cost of $70,140. At the present time approximately 1000 ft. (300 m) of the initial 2138 ft. (640 m) protected have eroded away. This partial failure of the revetment is due to the unusual river currents generated by the water flowing through the hydroelectric plant at the McAlpine Lock and Dam.

Geographic Setting

The revetment work is located on the north (Indiana) bank of the Ohio River approximately 1 mi. (1.6 km) downstream from the Falls of the Ohio historic geologic site in Clarksville, Indiana (see Figure 3.13). The revetment parallels Harrison Avenue and lies directly across from the McAlpine hydroelectric generating plant. The terrain in the immediate area varies widely from site to site. To the north and east of the revetment, the land rises in a gentle slope and then levels off. To the west or downstream from the revetment, the land is fairly level and remains that way until it reaches Silver Creek further downstream.

Environmental Qualities of the Project Area

Ecological

The terrestrial vegetation at the Falls of the Ohio revetment ranges from tall grass along the upper bank to a cover of small

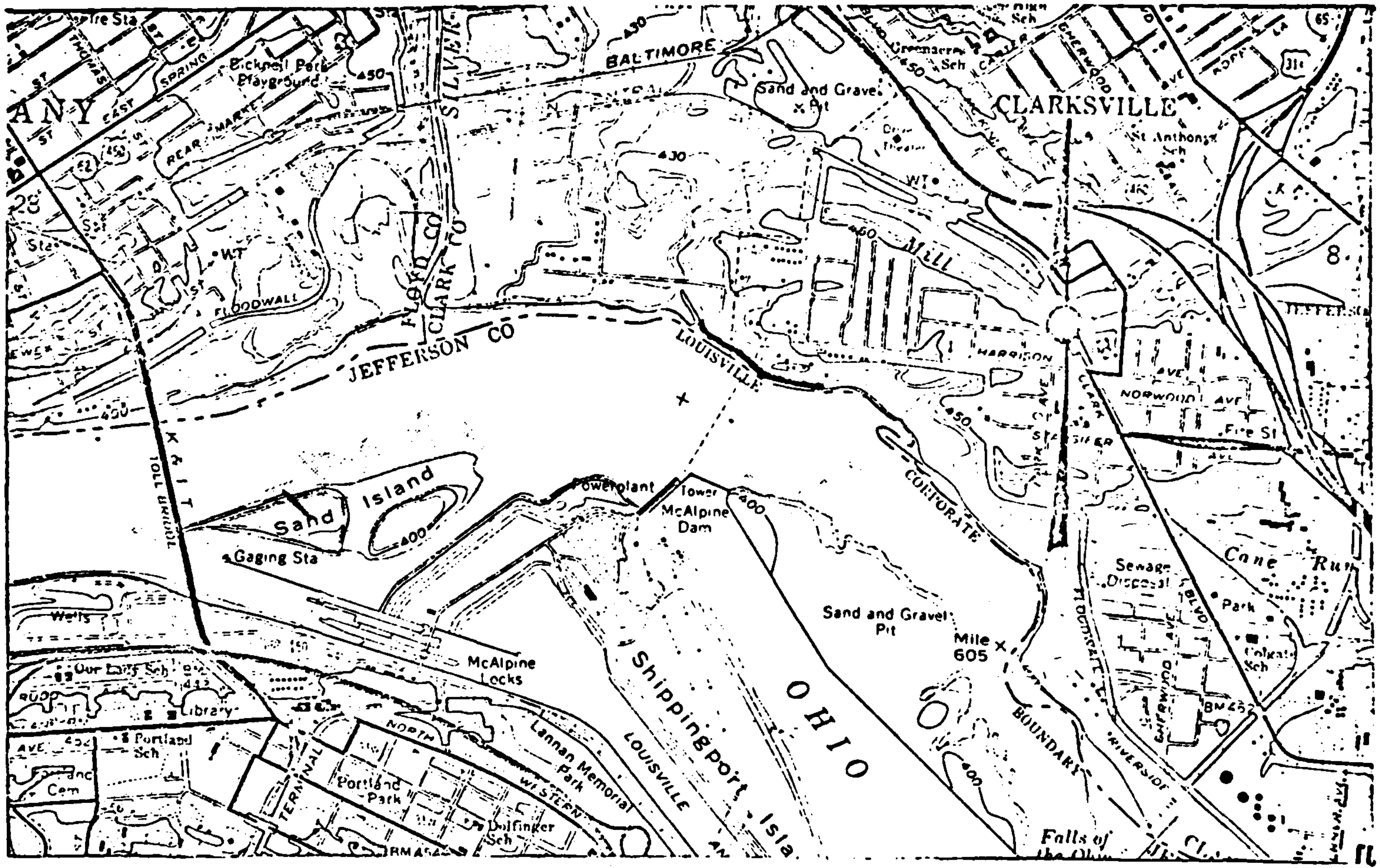


Fig. 3.13 - Location Map, Falls of the Ohio Bank Revetment (Ref. 90)

trees along the upstream or impact portion of the reveted bank. There is very little grass growing within the revetment itself due to the swift currents associated with the falls and dam and also the local fluctuations in the water level. From the revetment failure downstream to Silver Creek the Ohio River bank is nearly void of any vegetation.

Physical

The soil at the project site is a deep well drained silt loam deposited over mixed alluvium. Though the soil is subject to frequent flooding, it is fairly stable when compacted and has a low to moderate permeability. The soil is subject to piping because of water infilteration and the low permeability of the soil. The soil has a good resistance to shear failures. A revetment was needed here that was strong enough to resist direct current action, yet permeable to prevent pressure buildups and piping failures.

Socio-Economic

The land adjacent to and protected by the revetment is developed and used for both residential and agricultural purposes. The housing near the upper end or head of the revetment consists of both small farms and an ultramodern river front development. The land at the lower or downstream end of the revetment is nearly all agricultural and the homes are all rather small and apparently uncared for. There is a landfill further downstream which borders Silver Creek and has a few small shantys surrounding it. This area is not protected by the revetment but is also under attack by erosion. Harrison Avenue, which borders the caving bank, is in danger of collapse at other locations along the bank.

The only historic site in the area is the Falls of the Ohio Geologic Dig upstream from the revetment and there are no recreational facilities which would be endangered by further erosion.

Transportation associated with the bank stabilization project consists only of Harrison Avenue, which runs along the perimeter of the erosion. At one site, Harrison Avenue is now barricaded because of a large bank failure which collapsed part of the road.

Aesthetics

The aesthetic factors influenced by the possibilities of either stabilizing the slope or letting nature take its course are associated mainly with the natural beauty of the land-water interface. The aesthetic feeling of security or insecurity is also present to the residents of the immediate area and all others utilizing the area.

Environmental Impact of the Project

Null Alternative

The environmental impact of no intervention to halt the erosion in this area is evident because there is a portion of this bank which has continued to erode. This continuing erosion has had detrimental impacts on the ecological, physical, and socio-economic environments of the entire area adjacent to the site.

The vegetation along the caving bank was completely destroyed when the bank fell into the river and much of the land was washed away. If further erosion occured only more vegetation would be destroyed.

The degradation of land in the project area will also continue with further erosion. Nearby agricultural land will soon be under attack if erosion control measures are not taken. River hydrology will be unaltered if no preventative measures are utilized, but it is evident that by not altering erosional currents the bank will continue to move inland. The soils along the bank, in some areas, have already been destroyed and the soil further inland is now in jeopardy.

Though the land use where erosion has already occured is only marred by the loss of a portion of a road, further erosion could endanger both the agricultural and residential developments along the river bank in this area. The history associated with the Falls of the Ohio Geologic Dig will be unchanged by further erosion in this area because it is upstream from the site and it is not subject to the direct current flowing from the hydroelectric plant. Transportation is effected by the erosion at the site but the value of this transportation is limited because all of the traffic using this road can be rerouted around the cave-in without much delay.

The aesthetic beauty of the bank has already been destroyed at one portion because of the failure which has occured. Though the riprap revetment is not a true part of the natural surroundings, it is more appealing than an eroded bank. If no action is taken to halt the erosion, the aesthetic beauty of the entire land water interface will be destroyed. This erosion will also destroy the sense of aesthetic security achieved by the initial stabilization of the bank.

Project Implemented

It is clear that further action must be initiated to halt the erosion in the area of Harrison Avenue. If further measures are taken, vegetation will possible begin to grow on the stabilized bank. This action must be taken soon or the damage will be hard to reverse without tremendous expense.

The land quality at the site will be stabilized if revetment work is completed, to allow for vegetative growth and development. The hydrology will be changed by altering the currents from the dam, but care must be taken in stabilizing the bank to insure that the currents are not merely directed further downstream. If erosion occured further downstream, an even larger section of Harrison Avenue would be endangered. The soils would not be subject to the direct effect of the water if a protective revetment was utilized to dissipate the force directed at the bank.

Land use and economic development potential would be enhanced by the stabilization of the physical environment. Transportation could be rerouted onto Harrison Avenue if the bank were stabilized, but the increased use of the land area and the transportation facilities would only be slight. The area is not in a good location for new development because of the aesthetic appearance of the land itself and existing developments.

The aesthetic character of the area could only be enhanced by protective measures. Currently, the aesthetic qualities of the land surrounding the site are limited. However, stabilization of the waterfront will make the environment more desirable and useful, enabling the land environment to take on some of the aesthetic characteristics of the land water interface.

3.12 BEARGRASS CREEK BANK REVETMENT

Project History

The Beargrass Creek revetment is actually a retaining wall built to hold back a dirt fill at the site of a new condominium development. The bank stabilization was accomplished by the construction of a gabion wall, a heavy guage wire basket containing riprap. The gabions are tied together to form a uniform flexible barrier against water currents, and yet still provide drainage without the use of filter material. This bank stabilization was completed in July 1973, and was constructed by two seventeen year old boys. The gabions were designed so that silt and vines would hold the wall in place by the time the wire eventually corrodes away. This retaining wall was constructed under the authority of Jefferson County government.

Geographic Setting

The retaining structure is located along the south fork of Beargrass Creek in Jefferson County, Kentucky at the northwest corner of the intersection of Hikes Lane and Beargrass Creek (see Figure 3.14). The land in the vicinity of the stabilization structure consists of nearly all level recontoured, residentially developed land.

Environmental Qualities of the Project Area

Ecological

The terrestrial vegetation at the site is fairly uniform and consists mainly of grass which runs along the plain below the retaining wall, and the bank opposite the structure. At the present there is no vegetation on top of the bank which the wall is supporting or anywhere within the voids of the gabion structure.

Physical

The soil along Beargrass Creek, at the intersection of Hikes Lane and the creek consists of a thick well drained layer of silt loam. The soil is subject to periodic flooding, but water damage can be reduced by surface sloping to increase runoff and the usage of subsurface tile drainage. The soil in the project area is fairly permeable

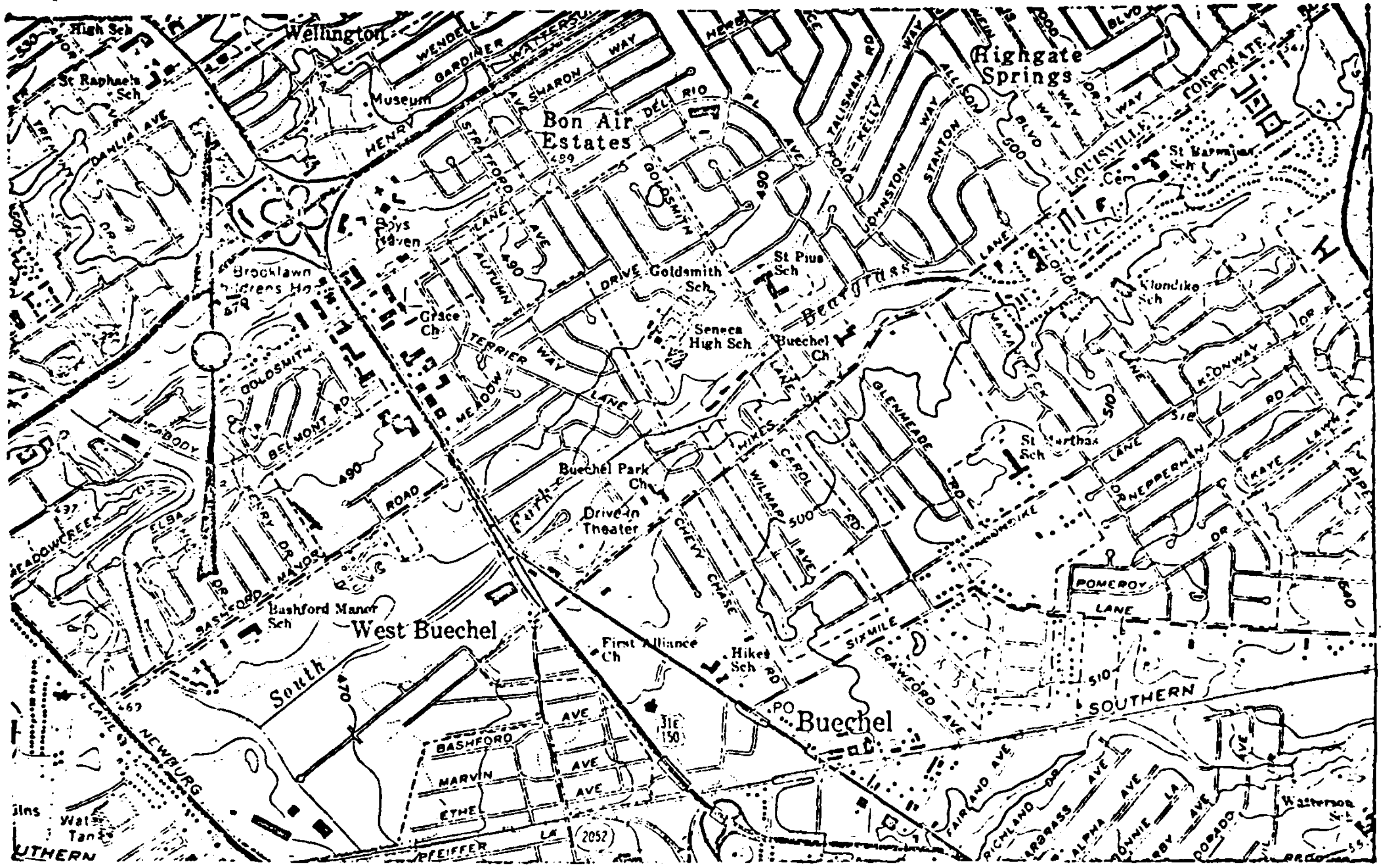


Fig. 3.14 - Location Map, Beargrass Creek Bank Revetment (Ref. 92)

when compacted and there would be little danger of rupture if an impermeable stabilization procedure were utilized.

Socio-Economic

The area on both sides of Beargrass Creek at Hikes Lane is utilized for residential purposes. Most of the homes in the area are within subdivision developments. The gabion retaining wall was used specifically to protect new condominiums. The wall will prevent the fill from eroding away, thereby preventing the stream bed from filling with sediments. There are no historic sites in the vicinity of this stabilization project and there are also no recreational activities associated with the land or the creek in the immediate area. Transportation in the area consists only of Hikes Lane which passes over Beargrass Creek just north of the project site.

Aesthetics

The aesthetic characteristics of the area are associated basically with the new housing developments in this area, and the natural beauty of the creek and the adjacent land.

Environmental Impact of the Project

Null Alternative

The effects of letting nature take its original course in this case could have a variety of alternative impacts on the environment in the immediate area. The creek was not actually eroding the banks along this section, but after the dirt fill was placed for the condominium development, the possibilities of erosion increased.

The height of the fill, the vertical cut which was made at the creek bank, and the soil properties, along with swift currents in the creek during periods of high water, have significantly increased erosion potential.

A protective structure would not be necessary to protect present vegetation at the project site because the site is presently void of vegetation. The only endangered vegetative growth will be the growth along the upper bank in the newly developed area when it is seeded.

Land quality would decline without some form of bank stabilization because the soil would be unfit for vegetative growth or any other use. The hydrology of the area would be unchanged under the null alternative, however, this flow is the primary reason behind the erosion. The geology of the area in terms of soil and soil erosion would be destroyed, and eventually deposited downstream if no revetment action was taken.

New developments at the site would be jeopardized by not protecting the banks, because of the possible cutting away of the bank and the eventual undermining of the foundations of the new condominiums. Historical sites, recreational uses of the area, and transportation facilities would not be influenced by continued bank erosion.

The aesthetic appearance of both the creek and the new residential developments would be detrimentally impacted if erosion took place.

The natural setting of the creek could eventually be clogged with sediments and the appearance of the eroded bank would deter potential buyers making present owners insecure.

Project Implemented

The use of gabion baskets as a retaining wall has eliminated possible erosion along the creek bank. The retaining structure, by providing physical protection, has increased the possibility of vegetation along the upper bank which will soon be seeded land on the upper bank.

Land quality along the upper bank has been benefically impacted by stabilizing the bank, giving rise to a possible increase in vegetation in this area. Hydrology has not been altered in terms of changing the direction of flow but the structure has decreased erosional possibilities initiated by water action. Geology and soil structure along the bank has been preserved and the danger of future erosion is limited.

Land use and economic development at the site have improved since the gabion wall was placed. The basic reason behind the placing of the structure was to provide a substantial base for the development of three story condominiums. History, recreation, and transportation have neither been limited in their use nor increased in their potential uses by the local stabilization of the creek bank. The project was only placed to limit localized erosion problems.

The aesthetic character of the land and water in the project area has significantly increased as compared to the character of an unprotected bank. Although a gradual seeded slope would have been more conducive to the natural environment, the natural slope would have been potentially dangerous in terms of erosion. Erosion would have damaged the aesthetic beauty of both the land-water interface and the new development at the site.

3.13 ANALYSIS OF ENVIRONMENTAL IMPACTS

In most cases the null alternative approach to bank erosion problems would lead to catostrophic failure. Therefore, it could be generally concluded that responsible parties would take preventative action to halt total failure before it occurred. Such preventative action could take the form of halting erosion with revetment techniques or stopping the source of the erosional force. In either case, where humans and their environment combine to form a social system which is endangered by bank erosion, it is necessary to protect these social resources.

The null alternative approach and the project implemented approach were presented for each bank revetment field evaluation since these are the two extremes. In each revetment case study, the longer the protection of social resources is delayed, the greater the cost of protection becomes. Many people feel that bank erosion should be prevented before erosion occurs. However, predictive techniques utilized to detect bank erosion have not been refined to the point where they are either economically feasible or accurate enough to predict erosional problems along extended sections of river bank. Thus, protection of the eroded bank at the first sign of erosion is usually the first available alternative.

This investigation included a visual evaluation of bank revetment projects in the Louisville, Kentucky and Vicksburg, Mississippi areas; and a review of Environmental Impact Statements from the Louisville, Kentucky; St. Louis, Missouri; Vicksburg, Mississippi; New Orleans, Louisiana; and Portland, Oregon Districts of the U. S. Army Corps of Engineers. From these studies it was concluded that the impact parameters which appeared to be most important with regard to revetment projects were those which affect aesthetics, emotions, or feelings. Aesthetics is in fact directly affected by impacts on ecological, physical, and socio-economic parameters. Erosion of the soil detracts from the aesthetic quality of an area similar to the loss of vegetation or recreational facilities. Aesthetics is in fact the social implications brought about by alterations of the ecological, physical, and socio-economic environments.

During the evaluation of the revetment sites in the Louisville area, it became apparent that the weighting of the various parameters on the impact matrix (see Figure 3.1) was subjective. A review of the New Harmony Revetment case revealed that the transportation parameter of socio-economic systems was the most important socio-economic parameter. However, the impact matrix did not weight it as the most critical parameter (see Figure 3.1).

A review of Environmental Impact Statements revealed that revetments exert impacts on the water, land, air, and noise parameters of the physical environment. Construction activities such as grading, filling, and placing of the revetment exert negative short-term impacts on the physical environment. In the case of water quality, the short-term impacts of increased turbidity during construction are offset by the fact that once the river bank is stabilized, rates of erosion diminish, and the reveted area undoubtedly contributes less turbidity to its adjacent water body than do unprotected eroding bank lines. Noise and air parameters will also be detrimentally affected during the construction phase of a revetment as a result of increased traffic loads and noise levels associated with construction. However, noise levels and air quality will revet to normal levels following construction activities. Land quality will be upgraded immediately upon project implementation by making the land more suitable for public and private use. The beneficial land quality impact will continue to increase as construction continues and then level off.

Aquatic flora, aquatic fauna, and terrestrial fauna, parameters of the ecological environment, have not received comprehensive attention. However, the U. S. Army Corps of Engineers, Waterways Experiment Station is coordinating a series of studies regarding these parameters. It is known that various revetment types may provide better wildlife habitats than others, due to noticable changes in the composition of the biota of the river. Different methods of revetment and their associated effects on the ecological environment will be the subject of one of these studies at the Waterways Experiment Station.

The evaluation of terrestrial vegetation impact at various revetment sites in the Louisville area indicates that the long-term impacts on vegetation is beneficial due to the stabilization of the physical environment. Various impact statements have drawn the same conclusion and also contend that construction tends to destroy existing vegetation prior to project implementation.

River hydrology has received very little discussion in relation to bank revetment impacts. Revetments tend to decrease channel width and in turn increase velocity which may cause further erosion downstream.

Geology has only been discussed in general terms in most impact statements. One exception is the E. I. S. on the Newburgh, Indiana Bank Protection Project, prepared by the Louisville District Corps of Engineers. Geology, and in particular soils, are of major importance in determining both the causes of erosion and the preventative measures needed to stabilize river banks. The most common type of river bank failure is a slough or falling in of material due to undercutting by water. Soil being weak, when subject to tension, yields to gravity and seeks a lower level once the bank is undercut. The best solution to such a failure is to flatten the bank slopes and provide some means to protect it from undercutting.

The parameters within the socio-economic environment, land use, economic development, archaeology, history, recreation, transportation, and cultural features are effected only if present in the project area. In most cases these parameters are beneficially impacted by implementation of a bank revetment project. The only detrimental effect which might occur to the socio-economic parameters would occur if one or more of the elements of the socio-economic environment had to be removed to implement the revetment project. The destruction of a historical site or landmark to cut back a slope and revet a bank would also constitute a detrimental impact.

Revetment Alternatives for the Louisville Area

The best methods of bank revetment, from a technical and economic standpoint, appear to be the conventional stone riprap revetment; gabions; and a net of auto tires wired together and partially filled with concrete. While all of these approaches provide adequate protection in terms of strength, flexibility, and permeability, durability or cost per year of each technique is still unknown.

It has already been shown that the initial cost of a gabion revetment is consistantly higher than a conventional riprap revetment, however, the relatively recent reintroduction of gabions has not enabled adequate economic surveys to be conducted to assess their long-term effectiveness. While it is known that gabions provide a continuous and uniform means of bank protection, it is believed that the uniformity and bulkness of this type of protection would provide easy retrieval of the system if failure did occur. In cases where bank failure is common place, retrieval could be an asset.

The environmental aspects of revetment projects previously discussed vary only slightly with revetment type or methodology. The most noticable difference between the environmental impact of revetment alternatives occur with regard to aesthetic factors. While it is clear that there are many viable methods of reveting a bank that will result in protection of the ecological, physical, and socio-economic environments, aesthetic impact depends on the method utilized. It should be noted that technical feasibility should be the first consideration in choosing a revetment technique. There is no advantage to a revetment procedure which is aesthetically pleasing if adequate protection is not provided. By initially evaluating technical feasibility a variety of viable methods can be chosen to protect an area. These alternatives then undergo further analysis by the evaluation of their economic and aesthetic impacts.

In evaluating the economic and aesthetic factors of various revetment alternatives, no preference should be given as to initial criteria consideration. Economics and aesthetics go hand in hand and should compliment each other. If a revetment approach is aesthetically pleasing but not economically feasible (or visa versa), another technique should be reviewed until an alternative is obtained which meets both criteria. Another factor regarding aesthetic acceptability is the location of the revetment in relation to a residential, industrial, or agricultural area. The agricultural and industrial areas would not require the same high degree of aesthetic appearance as would a residentially developed area.

Of the three revetment methods discussed, the most aesthetically pleasing are the conventional stone riprap and the gabions. While also providing good protection for eroding banks, the auto tire mattress is not as pleasing as other riprap or gabions since it does not blend consistantly with the surrounding environment.

CHAPTER 4

BANK REVETMENT ASSESSMENT METHODOLOGIES

4.1 EVALUATION OF IMPACT ASSESSMENT TECHNIQUES

With the diversity of environmental impact assessment methodologies currently available, it would seem pointless to develop another totally new methodology for the evaluation of bank revetment impacts. It is pertinent to define which existing impact evaluation procedures can be best applied to bank revetment projects. The impact procedure chosen could then be revised to fit the specific need and goals of bank revetment projects.

Before evaluating the various methodologies, a set of principles which define the assessment procedure should be evaluated. The impact assessment method selected must be capable of generating predictive processes, identifying resource functions, utilizing a systems approach, selecting criteria to be analyzed and employing impact assessment throughout the planning process (94). These principles should serve as a basis for the evaluation of existing techniques utilized in environmental impact assessment.

4.2 REVIEW OF IMPACT ASSESSMENT METHODOLOGIES

The Battelle environmental assessment methodology for water resources planning utilizes a quantitative approach to evaluate environmental impacts. A hierarchial structure (see Figure 4.1) is used in the Battelle system, to account for differerent levels of information used in the environmental evaluation. The most general

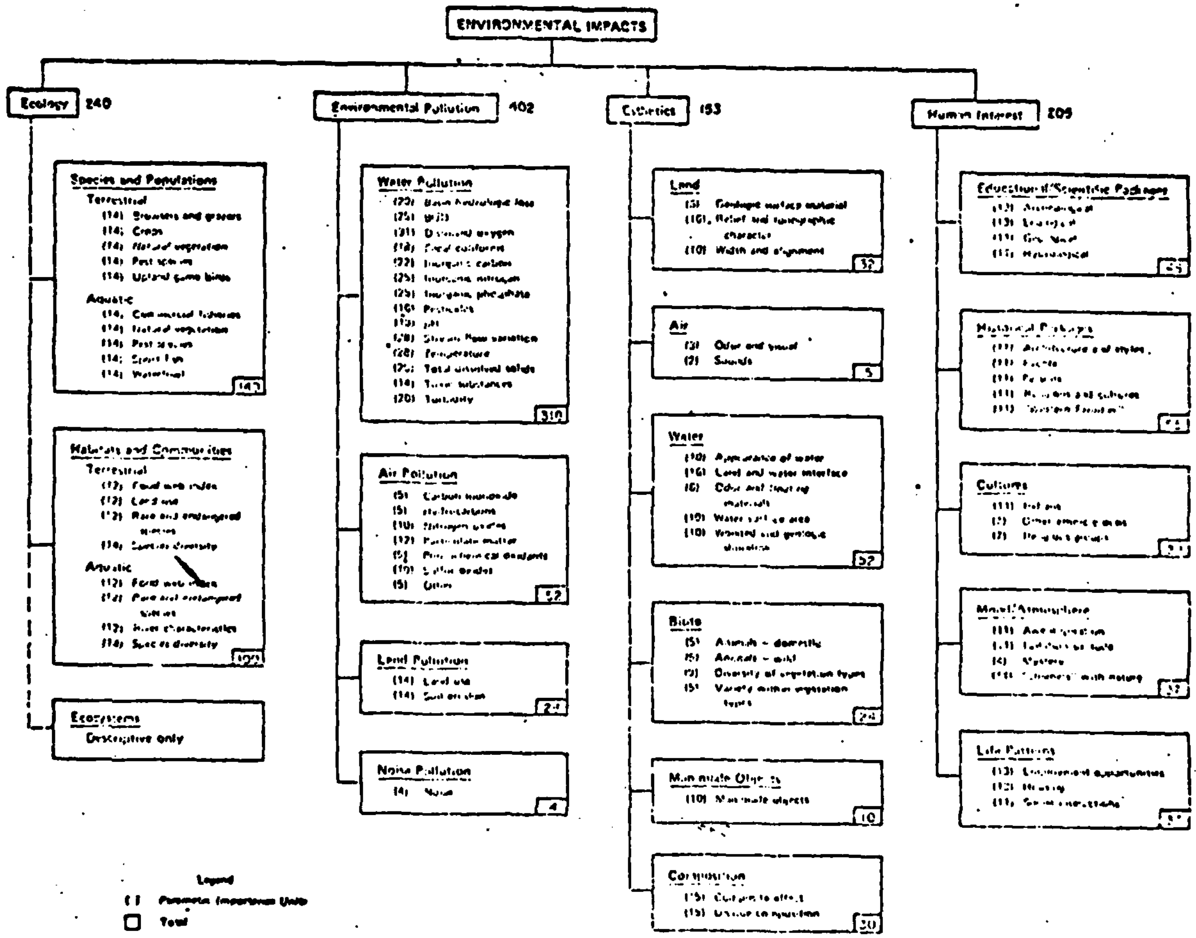


Fig. 4.1

Battelle's Environmental Evaluation System level, level 1, is divided into four categories: ecology, environmental pollution, aesthetics and human interest. These categories are subdivided into eighteen environmental components in level 2. In level 3, the system becomes even more specific with the subdivision of the components into 78 environmental parameters. Level 3 provides the key to the Battelle system because it is these individually weighted parameters that are measured to determine the environmental impact. The Battelle measurement technique consists of four steps:

1. Previously developed value functions transform parameter (e.g. feet, acres, mg/l) into "environmental quality values (EQ)".

2. The environmental parameters are weighted in proportion to their importance by an interdisciplinary team and expressed in terms of "parameter importance units (PIU)".

3. The PIU is multiplied by the EQ resulting in "environmental impact units (EIU)" for each parameter.

4. The EIU are summed for all 78 parameters, a high numerical result indicating beneficial environmental impact and a low result indicating environmental degradation.

The U. S. Geological Survey Matrix (see Figure 4. 2) for evaluating environmental impact was designed to serve as a preliminary guide or checklist for persons faced with preparing Environmental Impact Statements. The horizontal axis of the matrix lists 100 "proposed actions which may cause environmental impact"; the vertical axis lists 88 "existing characteristics and conditions of the environment which

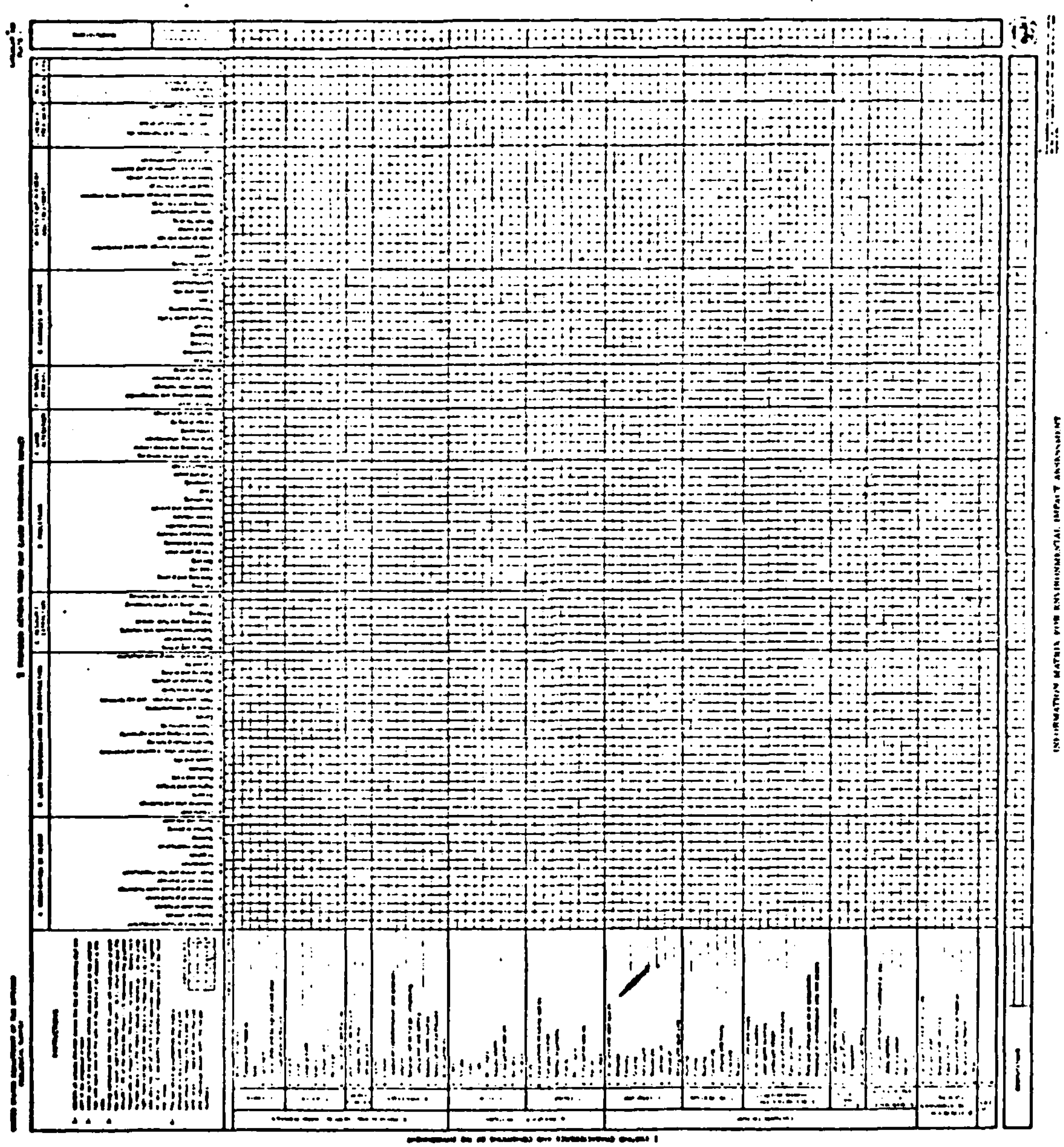


Fig. 4.2

U. S. Geological Survey Matrix

could possibly be impacted by the action". Though there is a possibility of 8800 interactions, only a few significant interactions will require comprehensive treatment. Those interactions which do not appear on the matrix but occur in a particular project can be added.

To use the USGS matrix for environmental analysis, each action involved in the project (horizontal axis) is checked. Under each action checked, a slash is placed at each intersection of environmental conditions (vertical axis) where an impact is probable. A number from 1 to 10 is placed above the slash to indicate impact magnitude and a number from 1 to 10 is placed below the slash to indicate the impact's relative importance, noting that 1 represents the lowest importance and 10 the highest. The matrix is then visually evaluated to determine which parameters are most beneficially or detrimentally impacted.

Another impact assessment approach which was developed by an interdisciplinary team from the Louisville District Corps of Engineers, and utilized in assessing the environmental impact of the Louisville Water Quality Management Plan, also incorporated a matrix approach to environmental assessment. This matrix approach relies on a numerical rating of 21 weighted parameters, which are subdivisions of four basic categories: ecological and physical environments, socio-economic factors, and aesthetics (see Figure 4. 3). The weightings of the individual parameters were established by an interdisciplinary team for water resource related projects. Each environmental parameter was rated from -5 to +5, a minus number indicating detrimental

ENVIRONMENTAL IMPACT ASSESSMENT MATRIX

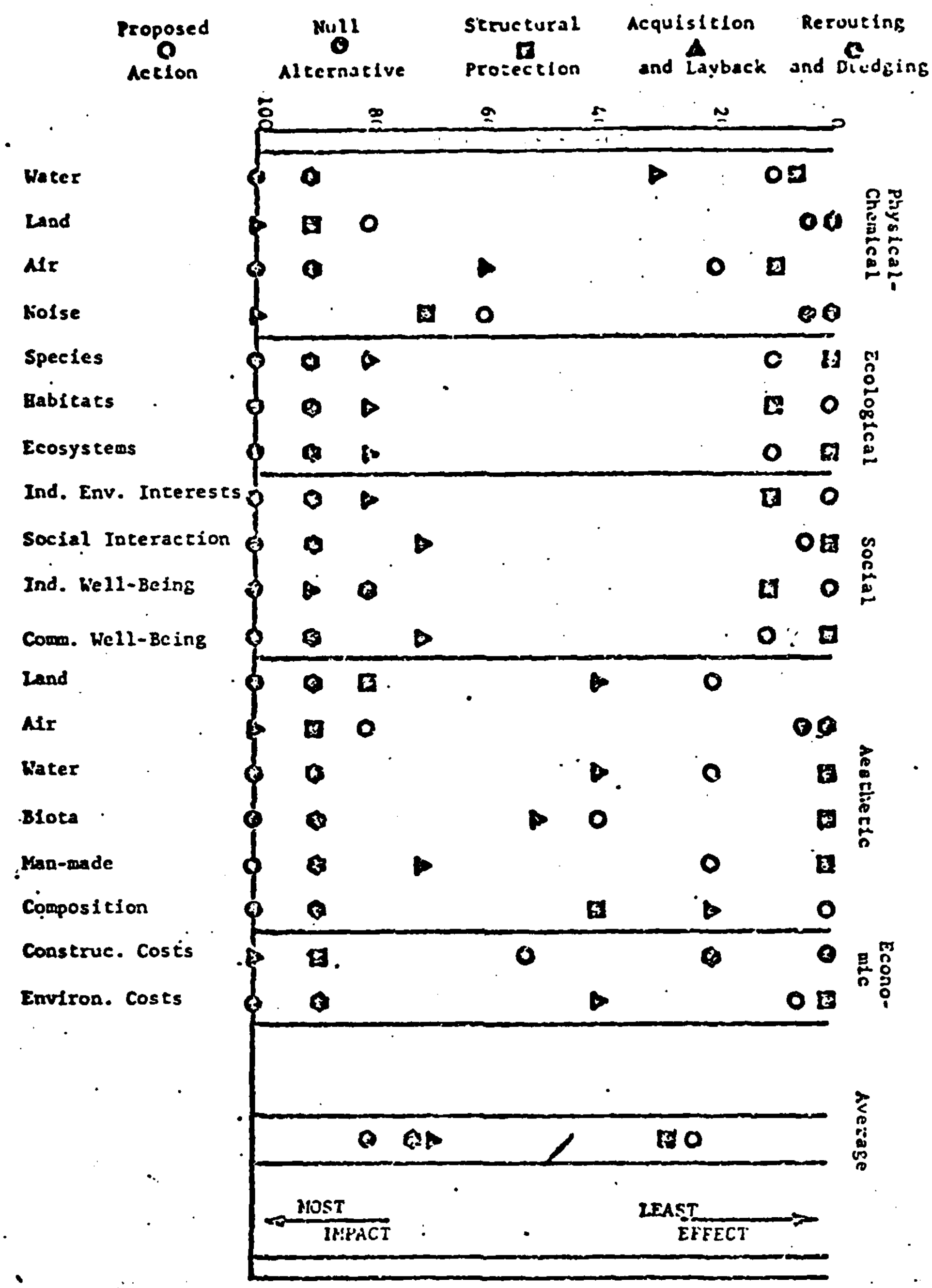
		ECOLOGICAL ENVIRONMENT (250)				PHYSICAL ENVIRONMENTAL QUALITY (400)						SOCIO-ECONOMIC FACTORS (250)							AESTHETICS (100)			
		AQUATIC FLORA (60)	TERRESTRIAL FLORA (60)	AQUATIC FAUNA (65)	TERRESTRIAL FAUNA (65)	WATER QUALITY (100)	LAND QUALITY (75)	AIR QUALITY (75)	HYDROLOGY (50)	GEOLOGY (50)	NOISE LEVELS (50)	LAND USE (50)	ECONOMIC DEVELOPMENT (50)	ARCHAEOLOGY (30)	HISTORY (30)	RECREATION (30)	TRANSPORTATION (30)	CULTURAL FEATURES (30)	PHYSICAL FACTORS (40)	SPATIAL COMPOSITION (20)	MAN-MADE OBJECTS (20)	UNIQUENESS (20)
POSITIVE ENVIRONMENTAL QUALITY	+5																					
	+4																					
	+3																					
	+2																					
	+1																					
	0																					
	-1																					
	-2																					
NEGATIVE ENVIRONMENTAL QUALITY	-3																					
	-4																					
	-5																					
	RED FLAG																					

Fig. 4.3

Environmental Assessment Matrix - Louisville District Corp of Engineers environmental impact and a positive number indicating beneficial environmental impact. The rating for each parameter is multiplied by its weighting to determine environmental impact factors. The environmental factors are then summed to arrive at an environmental quality rating (EQR).

A diagramatic assessment procedure utilized in Environmental Assessment Newburgh, Indiana Riverbank Protection Action provided for a "qualitative" comparison between the environmental impacts of alternative revetment procedures. This evaluation system used a hierarchial structure in which there were five primary categories: physical-chemical, ecological, social, aesthetic, and economic. These five categories were subdivided into 19 parameters (see Figure 4.4) which were evaluated on a percentage detrimental impact basis for each alternative, 0% being the least detrimental effect and 100% being the most detrimental impact. The various alternative actions were denoted by different symbols on the impact diagram. After each alternative action was evaluated for every parameter, the average percentage effect for each action was calculated and placed in the designated column on the chart. The "average" effect of each alternative was calculated assuming equal weighting of all parameters. This system provided ready access to the overall effects each alternative exerted on the environment.

There is a variety of other assessment procedures currently in use. Among these is the Atomic Energy Commission (AEC) approach



QUALITATIVE REPRESENTATION OF IMPACTS

Fig. 4.4

Diagramatic Evaluation of Alternatives

which was developed for impact assessment of nuclear power plant construction and operation. The AEC guidelines present various aspects of impact assessment development. However, specific parameters evaluated in the AEC approach were deemed inapplicable for bank revetment projects.

Other impact assessment methodologies currently in use include visual, numerical, and economic techniques, all of which can be adapted to the above procedures with minor modifications.

4.3 DEVELOPMENT OF AN ENVIRONMENTAL ASSESSMENT PROCEDURE FOR BANK REVETMENTS

The Battelle environmental assessment methodology for water resources planning presents a comprehensive, systematic, and replicable method for evaluation of environmental impacts. However, flexibility is not an integral characteristic of the Battelle system. The individual parameters within this system are evaluated on the basis of previously established weightings without consideration of differences in community and geographic settings. In addition, there is no choice of parameters to be studied in this system.

The U. S. Geological Survey Matrix does not evaluate the environment as a system (each parameter interacting with the other), but rather as a series of independent actions. This approach negates consideration of secondary and tertiary impacts. It is difficult to develop impact predictions using the USGS approach because the alternatives can only be evaluated on a parameter basis rather than a systematic basis. However, the USGS matrix provides the most complete and comprehensive checklist of environmental interactions and provides a good basis for the selection of criteria important to a specific project.

The matrix developed by the Louisville District Corps of Engineers was based on an approach similar to the Battelle system. However, the Corp's matrix allows more flexibility in the impact assessment process. In this system the parameters for each category have not been specified and may be chosen and weighted on the basis of the individual project. This system not only gives the user his choice of criteria, but also enables him to be more comprehensive in addressing important parameters. However, this approach becomes inflexible with regard to weightings of each component. These weightings can change from site to site, particularly in bank revetment projects. In some instances transportation may be the major concern or cause for implementation of a bank revetment project whereas at another site protection of recreational facilities may be the major priority.

The approach utilized in Environmental Assessment Newburgh, Indiana Riverbank Protection Action is flexible in the sense that the parameters for each component of the system have not be chosen and the system uses no weighting scale. In this instance the neglection of a weighting scale indicates that all parameters are to be assumed equally important. The use of percentages in rating environmental effects is technically qualitative, but rating on a basis from 1 to 100 is a quanitative evaluation. This approach also makes no attempt to delineate positive environmental effects on the impact diagram which would be helpful in presenting the project at public hearing.

It should be noted that bank revetments are far less expensive when compared to nuclear power plants and dams. A bank revetment project impacts fewer lives and is not nearly as far reaching as power plant or dam construction. However, a bank revetment assessment must address virtually the same parameters involved in an environmental analysis of much costlier projects. Therefore, an approach is needed which would provide for the pragmatic environmental impact assessment of bank revetment projects at a reasonable cost. Such an approach would be scaled down in scope from larger projects yet cover all environmental aspects.

The best approach to optimizing the cost of a bank revetment impact assessment would be to simplify the assessment procedure. This would entail the careful selection and consideration of criteria to be given to all environmental parameters but evaluation comprehensiveness should vary fro each parameter depending on its relative importance to the overall project. Another procedure simplification would involve making the procedure more qualitative and less quanitative. This could only be accomplished by eliminating the rating system for each parameter so that it only depicted environmental "quality". Total elimination of the rating system would be the ideal situation, but determining which alternative to implement would be difficult without ratings since many revetment types might result in the same environmental quality (negative or positive) for each parameter. Therefore, a simplified rating system should be devised to measure variances in environmental quality.

Flexibility of impact assessment should be a major concern. To divide a system of categories into components and then weight each category and its individual components is largely subjective. There is no viable way to determine what components warrent more attention on a specific project until an initial field reconnaissance is completed. Weightings are useful in determining a factor for environmental quality rating, however these weightings should be standardized since they obviously vary from site to site. Therefore, the practice of weighting criteria to be studied should be a secondary consideration and accomplished only after the site has been visited.

Making the assessment procedure functional is another major priority. The assessment procedure must be useful to both the project planners and to those who must present the project in public hearings. Therefore, a system needs to be developed which will be readily interchangable between these two entities. A numerical rating system, while often suitable for internal project planning, often alienates outsiders. The rating of one parameter over another often generates public hostility.

The environmental assessment procedure which best meets the goals of bank revetment project assessment is the matrix developed by the Louisville District Corps of Engineers with minor revisions. The initial procedure developed by the Corps of Engineers has already established itself as being capable of developing predictive processes, useful in the identification of resource, functions, systematic, selective of criteria to be analyzed and beneficial in planning all phases of the project.

This approach is part of the predictive process in that after short and long term impacts have been established, it can be utilized as a basis for future planning. Like the Battelle system, this approach has an established set of categories, each of which can be divided into a specific yet unspecified number of parameters or resource functions. While these functions vary from site to site, each warrants individual attention. The ideal approach is not to determine how the functions act independently, but to evaluate their effects on the system. This brings the evaluator to the systems approach, which in short, evaluates resource functions on the basis of their impact on the system. The assessment procedure developed by the Corps of Engineers is definitely a study of systems, each parameter a subdivision of a component and each component a subdivision of a major category. This approach provides for interactions between parameters, components, and categories for an unlimited number of alternatives. Consequently, The parameters of one category may impact a parameter within a different category.

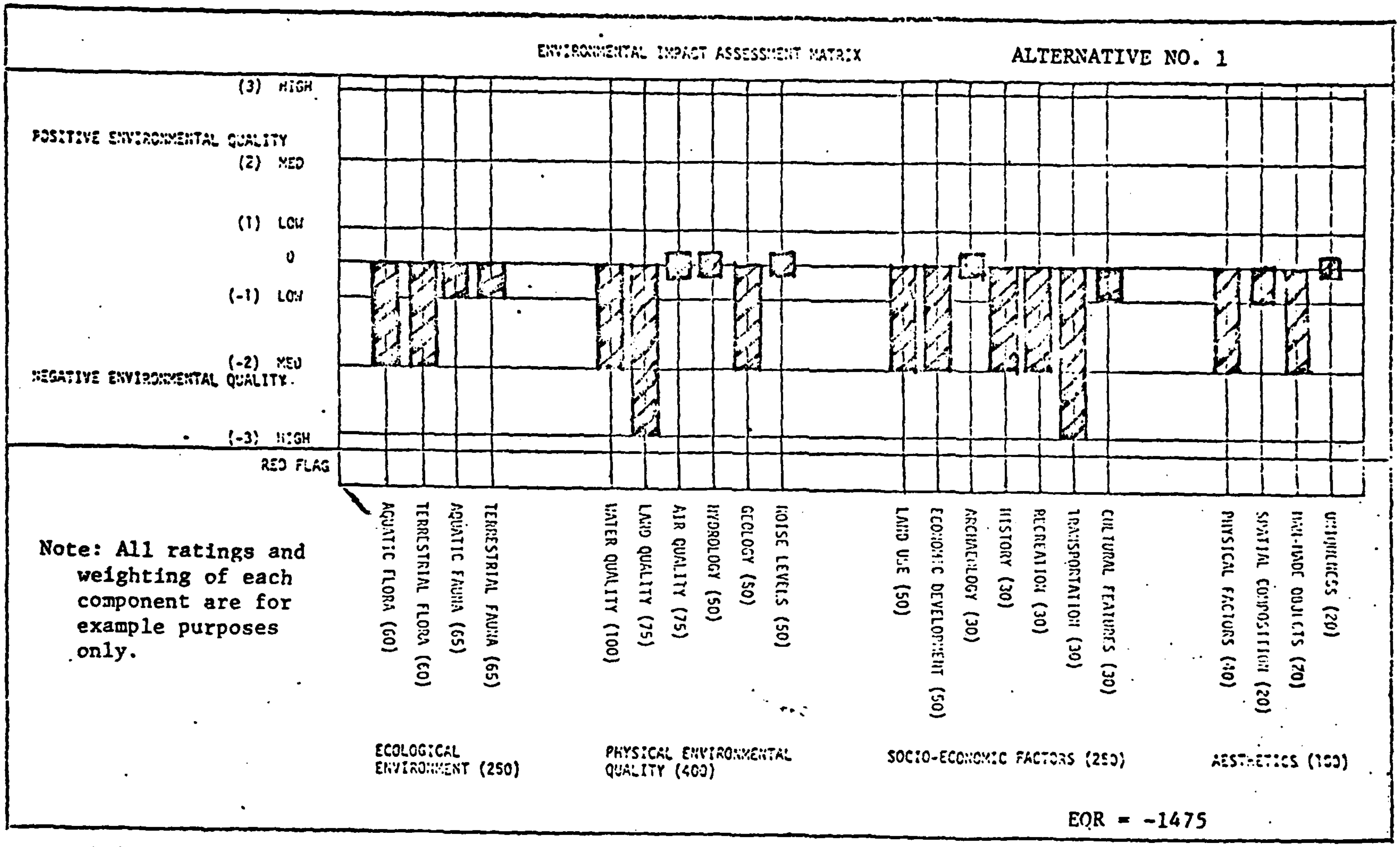
Selection of criteria, another principle necessary in establishing a viable impact methodology, has been carefully considered in this procedure. While a specific number and weighting of criteria is not presented each can easily be established for each assessment project. This approach of choosing criteria to be studied tends to make the procedure more flexible in that criteria can be chosen on the basis of preliminary investigations. Criteria can therefore be concentrated or directed at resource functions which are of major concern. Criteria can be established by using a checklist, literature on the project site, and field reconnaissance. As previously stated this procedure can be included as part of the planning process. By evaluating short and long term impacts for each alternative, this procedure can be utilized as a viable portion of the decision making process.

Alteration of the matrix developed by the Corp (see Figure 4.5) may encourage implementation of the established principles or impact assessment methodology. Altering the rating scale for each parameter so as to make it more qualitative can be accomplished by reducing the scale to six factor instead of the established eleven (-5 through +5), and applying the terms high, medium, and low quality (positive or negative) instead of numerical ratings. Numerical ratings can be applied to the scale making it a useful tool for planners since a rating of environmental quality can be determined for each alternative (see Figure 4.6 and 4.7). The rating system can be further simplified for use in public hearings, by eliminating the variable rating scale and expressing the impact of each

ENVIRONMENTAL IMPACT ASSESSMENT MATRIX

	ECOLOGICAL ENVIRONMENT				PHYSICAL ENVIRONMENTAL QUALITY						SOCIO-ECONOMIC FACTORS							AESTHETICS			
	AQUATIC FLORA	TERRESTRIAL FLORA	AQUATIC FAUNA	TERRESTRIAL FAUNA	WATER QUALITY	LAND QUALITY	AIR QUALITY	HYDROLOGY	GEOLOGY	NOISE LEVELS	LAND USE	ECONOMIC DEVELOPMENT	ARCHAEOLOGY	HISTORY	RECREATION	TRANSPORTATION	CULTURAL FEATURES	PHYSICAL FACTORS	SPATIAL COMPOSITION	MAN-MADE OBJECTS	UNIQUENESS
POSITIVE ENVIRONMENTAL QUALITY (3) HIGH																					
(2) MED																					
(1) LOW																					
0																					
NEGATIVE ENVIRONMENTAL QUALITY (-1) LOW																					
(-2) MED																					
(-3) HIGH																					
RED FLAG																					

Fig. 4.5 - Corp Matrix Revised for Environmental Assessment of Bank Revetments



Note: All ratings and weighting of each component are for example purposes only.

Fig. 4.6 - Sample Matrix: Internal Matrix Depicting Environmental Quality Rating (Alternative No. 1)

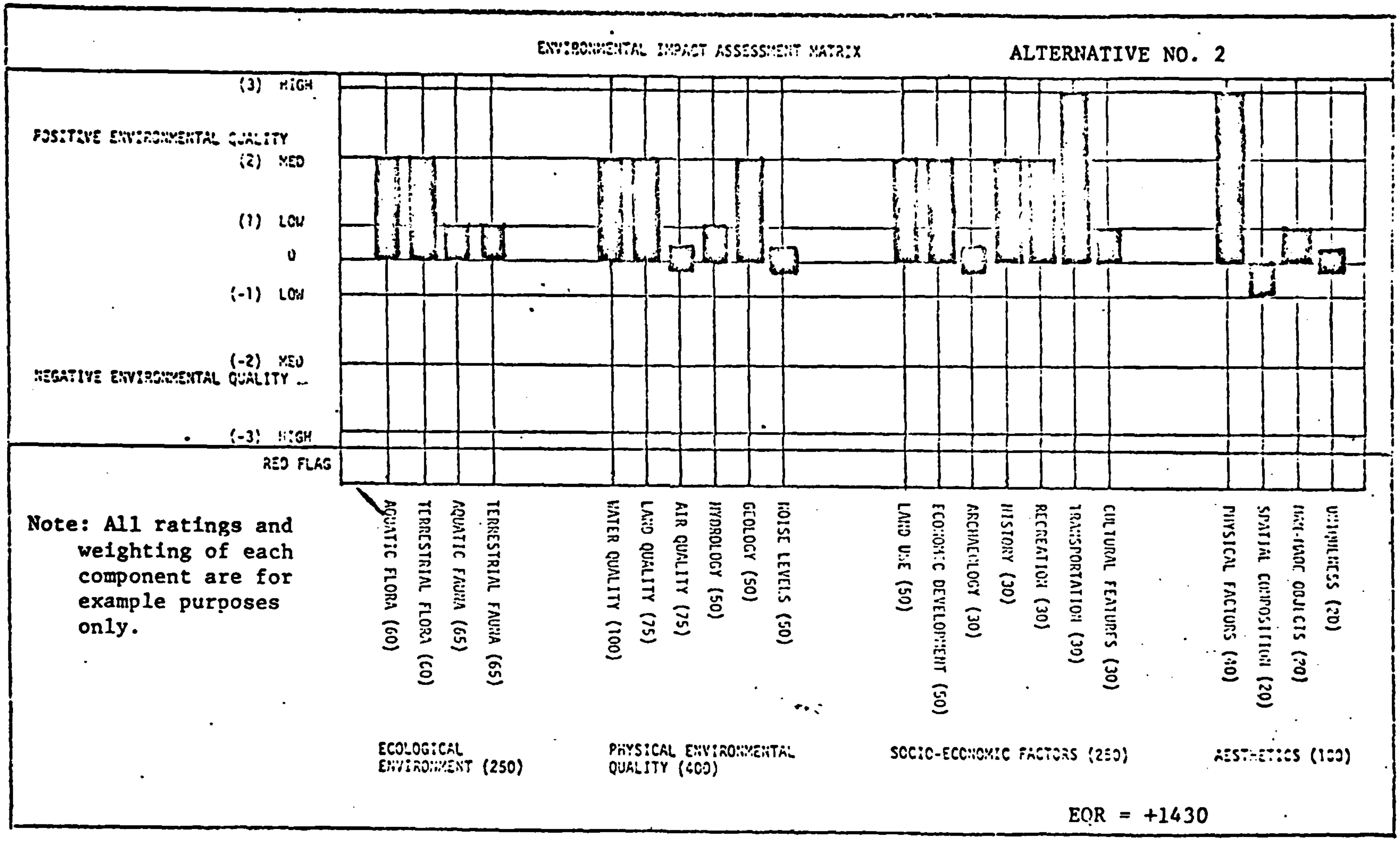


Fig. 4.7 - Sample Matrix: Internal Matrix Depicting Environmental Quality Rating (Alternative No. 2)

parameter as either positive or negative environmental impact. One approach to the elimination of the rating system would be to color code the system. This could often eliminate the controversy over numbers and methods of rating.

This approach has previously established a means of making the evaluation more comprehensive. By enabling the evaluating team to choose the criteria to be studied, efforts can be directed at parameters of the system which deserve more thorough investigation. This enables the cost of the environmental assessment to be reduced while at the same time providing a comprehensive review of all interactions. This system is already flexible in that it enables the user to choose criteria specific to the area under study. However, this flexibility can be increased by rating revetment projects with regard to community and geographic features. These ratings are useful in the planning process since they enable the environmental quality rating (EQR) to be established for the entire system. On the other hand, the system is ideal for use in public hearings if numerical ratings are expressed (see Figure 4.8).

The matrix may be presented at a hearing in a variety of ways without posing major technical problems or alienating any sector of the affected public. One method, utilizing the color approach, would be to mark each environmental component with a colored line; the width of the line denoting the importance of each component and the color denoting the environmental impact (see Figure 4.9). The height of the bars would no longer have to be established or defended under such an

ENVIRONMENTAL IMPACT ASSESSMENT MATRIX

	UNIQUENESS	AESTHETICS
	MAN-MADE OBJECTS	
	SPATIAL COMPOSITION	
	PHYSICAL FACTORS	
	CULTURAL FEATURES	SOCIO-ECONOMIC FACTORS
	TRANSPORTATION	
	RECREATION	
	HISTORY	
	ARCHAEOLOGY	
	ECONOMIC DEVELOPMENT	
	LAND USE	
	NOISE LEVELS	PHYSICAL ENVIRONMENTAL QUALITY
	GEOLOGY	
	HYDROLOGY	
	AIR QUALITY	
	LAND QUALITY	
	WATER QUALITY	
	TERRESTRIAL FAUNA	ECOLOGICAL ENVIRONMENT
	AQUATIC FAUNA	
	TERRESTRIAL FLORA	
	AQUATIC FLORA	

Fig. 4.8- Revised Matrix Altered for use in Public Hearing

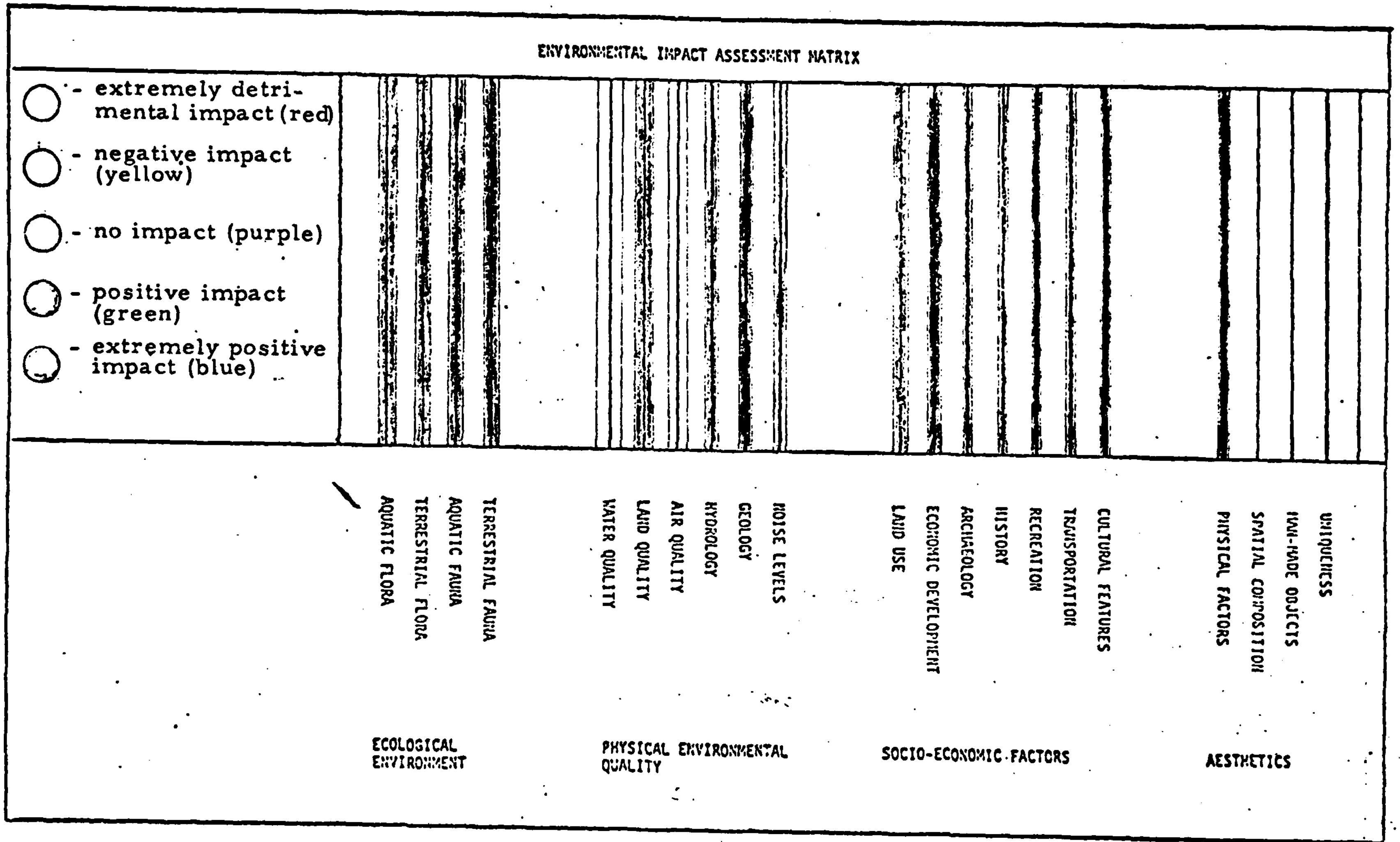


Fig. 4.9- Sample Matrix: Matrix for use in Public Hearing (Color Coded)

impact presentation since the variation in parameter importance would be represented by either the color or width of a color bar. This could be depicted and easily defended with visual aids such as slides and diagrams. This system could be utilized to present both the long and short term effects of each revetment alternative.

Another factor which is of major concern when evaluating alternatives, but was obviously eliminated in all but one of the assessment methodologies, is the variation in project bost with project alternatives. This is particularly important in bank revetment projects, where cost varies significantly with the technique utilized. Planners will benefit from the inclusion of a cost-effective analysis in the assessment study since the analysis presents yet another approach to alternative selection. In *cost-effective* analysis the EQR would be established by summation of the environmental impact factors (-3 to +3) times the component weightings. This rating would be divided by the cost effectiveness factor (CEF) - the cost of the revetment divided by its prospected life. The CEF relates a per year cost of the revetment which enables it to be compared against various revetment alternatives and their benefits. This method is in reality a form of cost-benefit ratio, but in this instance there is *no* monetary value placed on benefits. In this proposed cost effectiveness evaluation, the higher the numerical value obatained the more desireable the alternative from a cost-effectiveness viewpoint.

An interdisciplinary team is best suited for environmental impact assessment. However, in bank revetment projects, it is usually unfeasible to utilize an entire interdisciplinary team in a field survey of a project site. The best approach would utilize a minimum of two team members to visually evaluate, photograph, and gather preliminary data from the test site. These members could then weight each component and determine what parameters should be studied in-depth. A preliminary report would then be presented to the interdisciplinary team and the evaluation defended in the presence of the entire team. This evaluation could then be altered to take into account any discrepencies pointed out by team members. This approach to environmental assessment would significantly lower the cost of the evaluation yet still provide for replicable impact assessments.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

BANK REVETMENT PROCEDURES

Quarried stone, artificial riprap, "mattresses", and various forms of monolithic bank protection have been utilized in bank revetment projects. Riprap is currently the most widely used and satisfactory means of bank protection. This is due, in part, to the low cost of riprap in relation to other revetment materials together with its technical advantages, and its aesthetic acceptability.

Of the several types of artificial riprap considered technically feasible for use in bank protection, it appears that soil cement blocks, and asphalt stabilized soil blocks, have the greatest potential for replacing quarried stone. However, it appears that artifical riprap will not replace quarried stone for some time due to higher initial investment required to implement this technique and the availability of quarried stone in the Louisville District area.

None of the monolithic bank protection types reviewed appear to have significant potential at the present time when compared to uncompacted asphalt pavement. Some monolithic methods which do appear to possess potential include soil cement, synthetic elastomer sheets, and uncompacted asphalt pavement. At the present monolithic methods are restricted more by drainage than anything else.

Many materials have been utilized to fabricate mattresses for bank revetment, but the economics involved in fabricating and placing the mattresses preclude this method for all but the largest sites. A single layer of synthetic material has the greatest economic potential for this type protection, however, problems associated with deterioration and anchorage have not been alleviated.

ENVIRONMENTAL IMPACT OF BANK REVETMENT PROJECTS

Revetments exert impact on parameters within the ecological, physical, and socio-economic environments. The parameters which appeared to be most important with regard to the impact assessment of revetment projects were those which affect aesthetics. Short term impacts of implemented bank revetment projects are usually detrimental in nature. However, the negatively affected parameter in most cases will revert to normal levels or improve following construction activities. In general, the long term environmental impacts associated with revetment projects are beneficial in nature. However, both short-term and long-term impacts are largely dependent on the revetment technique utilized.

From the standpoint of material availability, technical advantages and environmental acceptability, quarried stone, gabions, and a mattress of auto tires wired together and partially filled with concrete appear to be the most viable revetment procedures in the Louisville area.

IMPACT ASSESSMENT OF BANK REVETMENT PROJECTS

Existing environmental impact assessment methodologies range from qualitative to quantitative and various schemes have been devised for presenting assessment results.

Bank revetment projects, which are usually small in terms of size and cost in relation to major projects such as dams and power plants, must address virtually the same parameters within the environmental assessment process. A simplified approach is needed for the impact assessment of bank revetments which will provide an inexpensive pragmatic environmental assessment.

In most cases it was found that assessment methodologies were too quantitative and inflexible and were unadaptable to the community and geographic setting. Five basic principles were found to be necessary for a good impact assessment methodology including: the generation of predictive processes; the identification of social resource functions; the utilization of a systems analysis; and the selection of criteria. Other assets which were found to be valuable to the establishment of a viable impact assessment methodology included: the interdisciplinary team approach; the economic analysis of various alternatives; and the adaptability of the assessment procedure to both internal planning processes and public hearings.

The impact assessment procedure selected (see Figure 4.5) to optimize the efficiency and results of environmental assessment of bank revetment is a minor revision of the matrix approach developed by the Louisville District, U. S. Army Corps of Engineers (see Figure 4.3).

The impact assessment matrix has divided the environment into four categories: ecological environment, physical environment, socio-economic environment, and aesthetics. The four categories are sub-divided into 21 parameters which are rated as to their high, medium, or low environmental quality (positive or negative). To utilize the matrix for internal planning, weightings can be given to the various parameters on the basis of their importance. These weightings can be used to establish a numerical environmental quality rating of the total project which is useful in comparing the environmental effects of project alternatives. A cost analysis was added to the procedure to enable the environmentally acceptable project alternatives to be evaluated in relation to their long term costs. This gives the planners another method of selecting the revetment technique to be implemented. The matrix can be further simplified by eliminating the rating scheme and use of the parameter weightings. This simplified matrix, when used with a visual presentation technique, would be a useful tool for presenting of the project in public hearings.

RECOMMENDATIONS FOR FUTURE RESEARCH

Every effort should be made to keep abreast of all new materials developed for bank revetment use and to keep up with new applications of previously developed methods. Further field reconnaissance should be initiated and case histories of projects reviewed to determine the long term effectiveness, maintenance, and upgrading costs required for each of the various methods of revetment. This program should be set up to evaluate each of the various types of bank revetment and if possible, the oldest of each type in existance. Overall river bank protection studies may well indicate that a more expensive method of revetment can be justified if failure and resulting maintenance costs can be reduced. While keeping abrest of revetment techniques, every effort should also be made to obtain data on the long and short term environmental effects of specific revetment procedures.

New approaches are continually being developed for environmental assessment. Attempts should be made not only to review these procedures and their adaptability to specific projects, but to develop new assessment procedures and open communication channels so these procedures can be reviewed and revised to the needs of specific projects.

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