SITE PLANNING ELEMENTS FOR AGGREGATE MINING OPERATIONS[1]

by
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Abstract. Aggregate mining is an urban land use. As a result the industry faces opposition from an increasing number of people and a greater number of competing land uses. In response to this conflict the industry must, if it wishes to remain near its market, become a more compatible part of the areas within which it operates. Companies must demonstrate they can improve the appearance of operational areas, decrease the impact of processing and earth moving activities on surrounding lands, and create stable and productive lands upon completion of mining. This paper presents the concept that through the site planning process, these objectives can be realized and that mining can shape new and productive environments as a natural and integral part of its earth moving activities. Five basic components of the site plan for an aggregate mining operation are discussed. The first component is the context of the proposed mine site. The site is reviewed in relation to its immediate and long term impacts on the regional setting with respect to land use policies, development trends, aggregate markets, access, and environmental issues. The second component is surface conditions. This is essentially an audit of the land, water, vegetation, and atmospheric conditions to determine how they might present problems or opportunities in the site planning process. The third component is subsurface conditions. The ultimate land form will be determined by the deposit structure and characteristics of materials within the deposit. This information is essential for executing the full mining and development potential of any given site. The fourth component is the mining operation. Earth moving equipment and operations are the means by which new environments are created. When mining operations are not considered in the land shaping process, proposed land forms cannot be created according to plan. The fifth component involves the synthesis of previous components into a cohesive and organized extraction and land shaping program. This component will be guided by four objectives: 1) site the processing plant and mining operations to minimize dust, noise, and visual impacts on surrounding lands; 2) maximize access to the aggregates; 3) maximize use of equipment and earth materials in shaping new lands; and 4) create stable, productive, and attractive lands through the mining process.

Key Words: aggregate mining; site planning; land shaping.

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Introduction

Over two billion tons of aggregate are produced per year (Tepordei 1992), making the construction aggregate industry one of the largest segments of the entire mining industry. It is also one of the few mining industries that operates in every state. Significantly, a unique aspect of the aggregate mining industry is that it is primarily an urban land use. That is to say, extraction of stone, sand, and gravel occur primarily within or at the fringe of more populated parts of the country. This urban proximity is influenced by two factors.

1. The primary market for aggregate exists within or near cities where there is a concentration of construction in terms of both maintenance of the infrastructure and the expansion of uses and facilities.

2. Aggregate is a bulky product that is relatively inexpensive to produce but expensive to transport. F.O.B. plant prices range from $2.37 to $5.51 per ton (Tepordei 1992). Trucking, which is the primary mode of transportation, can more than double the product price for every additional twenty mile hauling distance (Envicom 1979).

These factors are magnates that draw aggregate industries to populated areas. The result is, the industry faces growing opposition from an increasing number of people and from a greater number of competing land uses. This opposition is nurtured, in part, by negative images born of the industry's past and current insensitive land use practices. For the aggregate industry, this negative image is accented by high exposure, as it strives to continue operations in increasingly populated areas.

Citizens object to the presence of mining in their community because mining is considered a locally undesirable land use that reduces land values, discourages quality development, and creates unusable land (Bauer, Dec. 1991). However, in their opposition, citizens do not address the negative economic and environmental consequences of prohibiting mining within or near urban areas. Opposition does not reduce aggregate consumption. Elimination of aggregate mining within or near urban areas forces companies to find and process aggregates at greater distances from the market, thus increasing both the cost of the product and the impact on the environment due to greater hauling distances, more fuel consumption, and increased wear of highways (Envicom 1979).

It is often contended that mining is incompatible with urban land uses and with urban landscape. A review of site conditions and general appearances of mine areas indicate the average mining company is not sensitive to the impact of their activity on the surrounding landscape. On the other hand, a significant number of examples showing sensitive siting of mine operations and facilities, and effective development of mined-out sites into other uses exist throughout the United States and Canada (Bauer. Apr. 1991). These examples demonstrate that, with some fore thought:

1. Mining operations and facilities can be sited to minimize potential negative impacts with present and future conditions surrounding the mine sites.

2. Productive and attractive lands can be created in mined-out sites as natural outcomes of the mining process.

Aggregates are essential to the maintenance and development of cities. Existing cases clearly demonstrate aggregate mining can be a compatible urban land use (Bauer, Apr. 1991). The issue, then, is not whether or not mining should be allowed, but rather how and under what terms mining should be conducted. The author visited numerous pits and quarries during the last three years. It was observed in every case where problems relating to the compatibility of operations with surrounding landscapes existed, the problem could have been avoided or minimized through a site planning process, initiated before the operation started.

For mining operations to continue as compatible and productive urban land use, communities and mining companies must address three basic issues.

1. Communities must protect reserves from urban encroachment and establish appropriate performance standards for each mining operation.

2. Mining companies must modify their activities in a way that illustrates a greater sensitivity to the environment and to fact that they will be surrounded by an increasing number of people over the life of the operation

3. Detailed site plans must be developed before mining operations are initiated to guide the siting of facilities as well earth moving activities throughout the course of the mining operation.

Site Planning

Site planning is the process of modifying the physical environment to support human activities (Lynch 1973). It is based upon an understanding of all factors that relate to and influence the characteristics and qualities of a particular space, as well as existing and proposed activities within that space. While basic elements of a site plan are similar in most projects, it is essential to recognize each site presents unique sets of conditions and relationships that need to be considered in the site planning process. In the case of mining, three conditions uncommon to most other projects exist. These are:

1. Mining is a major but transitory use for the site.

2. Mining results in a massive modification of the site, which creates special land shaping and land development problems, but also unique landscape qualities and development opportunities.

3. The earth moving activity that alters the original landscape is the same activity that can be used to create productive new landscapes.

Site Planning Concept for Mining Operations

Central to the issue of site planning for mining operations, is the concept that mining is the means of shaping new and productive environments. It recognizes that earth forming and earth moving are natural and integral parts of any mining operation, and only when mining operations are merged with land shaping operations can the fullest potential of a given site be realized (Bauer 1970).

Objectives for Mining Operations

Site planning objectives for mining operations relate to a wide range of environmental, production, aesthetics, land use, and economic issues and needs. The basic objectives are to:

1. Create a mine environment that is compatible with adjacent land uses.

2. Maximize the mining of aggregate resources.

3. Exploit unique deposit features created by the mining operation in the design of new landscapes.

4. Maximize the land building and land shaping opportunities presented by both the mining operation and the deposit.

5. Develop a coordinated and sequential program of mining, earth moving, and land shaping to assure that lands are prepared for development as mining progresses through the deposit.

Site Planning Elements for Mining Operations

Site planning is a problem solving process (Booth 1983). It involves a series of elements, with each element building on, overlapping, or occurring simultaneously with other elements. It involves a systematic integration of elements that lead to a clear definition of the problem, a delineation of the various issues, restraints, and opportunities, determination of a program, development of a solution, and description of a program that illustrates how the solution can be realized. There are five elements of a site planning program for a aggregate mining operation. The first four involve inventory and evaluation of data pertinent to the project. The last element involves preparation of a master mining and land shaping plan, based upon the synthesis of inventory and evaluation data.

Context: Evaluation of spatial relationships between the surrounding landscape and the mine site.

Surface Conditions: Evaluation of physical factors that can influence visual and environmental impacts of mining as well as long range development opportunities in the mined-out site.

Subsurface Conditions: Evaluation of the physical factors that can influence the nature, pattern, and feasibility of the mining operation, revegetation of the site, and the character of, and long range development opportunities for, the mined-out site.

Operational Conditions: Evaluation of elements, processes, and procedures of the mining operation in terms of how the operation impacts the surrounding environment, and how it can be used to reshape productive lands.

Synthesis (Master Plan): Preparation of programs, concepts, plans and procedures that integrate the operational elements into the site to minimize impacts on the landscape during mining, that organizes the extractive process to shape productive lands in the mined-out site as an integral part of mining operation, and that exploits the unique characteristics the mined-out deposit to create an attractive landscape.

Context

The region within which a proposed aggregate mine site is to be located is one of the first and most significant elements of a site plan. It has economic, aesthetic, environmental, as well as land use implications. Ideally the evaluation of the region, or the context within which mining will occur, should begin as part of the site selection process to determine the feasibility of a project and to develop strategies for the preparation of the site plan and permitting process.

1. Population projections provide a bases for determining future demands for aggregate. They are also indicators of possible populations increases in the immediate vicinity of the mine site over a particular time period.

2. Comprehensive plans and land use policies are used to assess patterns of growth and development. Indicators include direction of utility expansion programs, proposed highway routes, road improvements and interchanges, land use and land zoning maps, and land use policies related to open space, environmental issues, and growth. Another indicator may include the quality of the landscape that may attract or discourage development. This data is useful in assessing future market needs, and particularly, in assessing possible land use conflicts associated with potential developments in the immediate vicinity of the aggregate site. Strategies can be incorporated into the site plan to avoid or minimize these anticipated conflicts before they occur.

3. Transportation systems are evaluated from two points of view. One is to assess potential land development activity, the other is to assess the conflicts and opportunities to deliver aggregate to the consumer. Of particular interest, is the need to determine

truck routing to minimize conflicts with the community, especially the residential community.

Surface Conditions

Although the surface will be drastically altered by the mining operation, consideration must be given to existing physical characteristics of the site. This data is useful in assessing the potential visual exposure of the mine operation, the possible limits of mining, desirable access points, and various environmental constraints. It is equally important to extend the assessment to adjacent lands to determine the relationship of these lands to the project site and to assess existing and potential areas of conflict. The character of the site and its relationship to the adjacent lands can influence such things as entrance location and design, siting of the processing plant, direction of mining, screening requirements, extent of mining, and various environmental design requirements.

1. Existing terrain and vegetation are delineated to assess the potential for screening both the processing plant and the actual mining activity throughout the life of the mining operation. Areas exposed to adjacent lands typically require alternative site design solutions. It should be noted that terrain and earth berms are effective sound barriers, while both terrain and vegetation can be used to block views of an area. Another advantage of vegetation screens is that they can be use as wind barriers to control dust. Thus, in an effort to minimize the impact of mining on adjacent lands, existing terrain and vegetation can be used to influence the location of facilities and the pattern of excavation.

2. Surface drainage relates to several different drainage conditions. These include off-site drainage into the site, site drainage off the site, flood plains, flood ways, streams, natural bodies of water, and wetlands. These conditions will influence the permitting processes, the pattern and extent of mining, the location of the processing plant, and site design details such as sedimentation control, water discharge, and mitigation of disturbed areas. Data about these conditions should be detailed and delineated on site maps (Fig. 1).

3. Access to the site is of major concern. Five factors are considered in identifying potential access points into the site. First, is sight distance for trucks entering the site or exiting the site on to a public road. Second, is the classification and condition of the road. Third, is access to highway routes presenting least conflict with the public. Fourth, an entrance that does not expose the processing plant and mine site to the public. Fifth, an entrance that has a suitable grade for loaded trucks exiting the site.

4. Regulation of aggregate operations is typically within the jurisdiction of the local agencies. Height restrictions on the processing plant, excavation setbacks from property lines, slopes, landscape planting requirements, and screening are common local restrictions. These, along with state and federal regulations must be assessed and incorporated into the site design process.

Subsurface Conditions

The ultimate land form of reshaped mine sites is influenced by the deposit structure and by the quantity and characteristics of the material within the deposit. A detailed assessment of deposit characteristics, and the recording of that data in a graphic format is essential for executing the full mining and development potential of any given site. This assessment should provide images of that deposit structure as it would appear totally mined-out, because it is the base from which the final land form will be emerge. It should also delineate the type and quantity of available overburden material that can be used to build new land forms. To use an artistic analogy, the deposit is the pedestal upon which to place a piece of sculpture; the earth materials are the clay used in creating that sculpture piece.

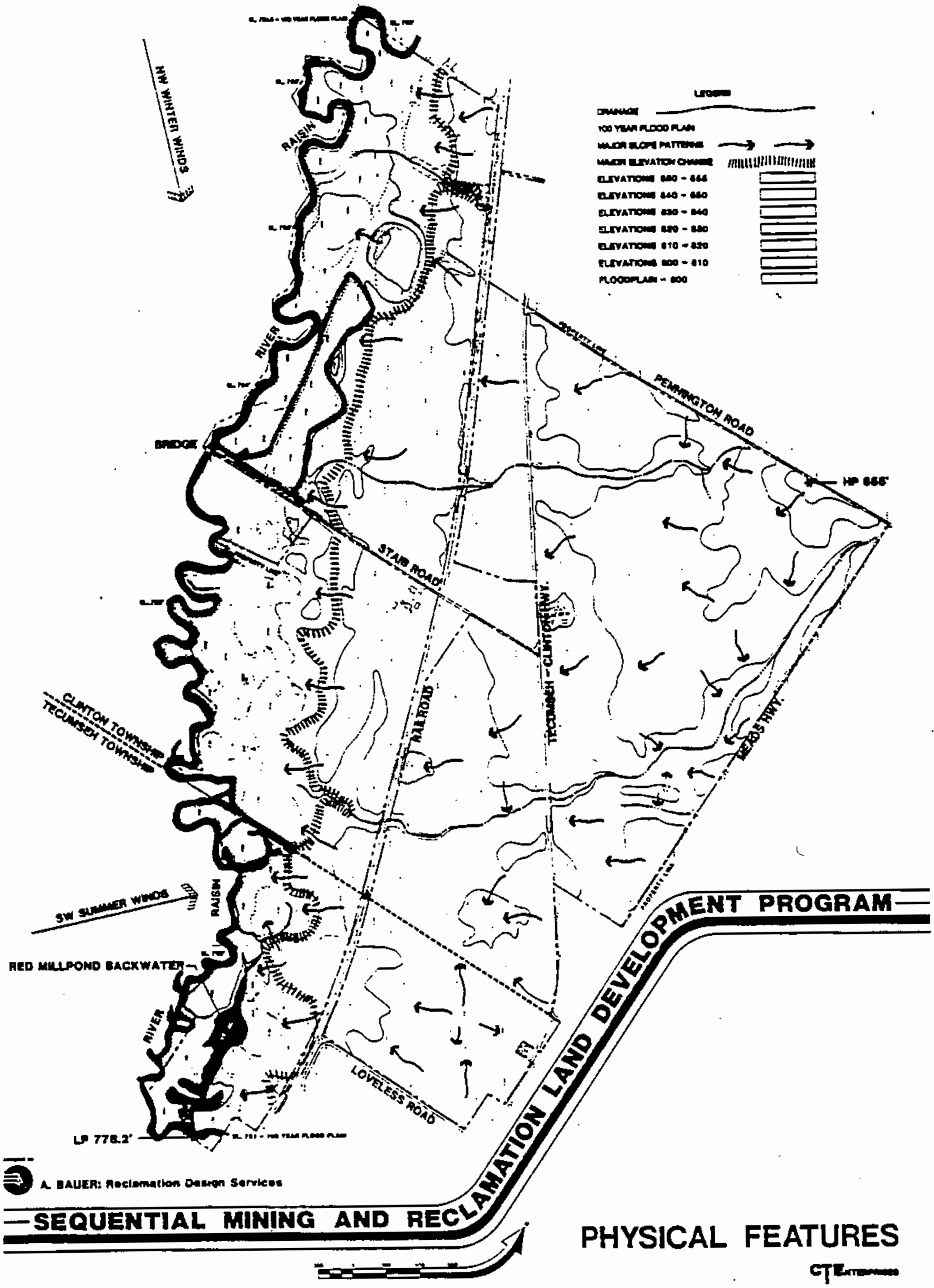


Figure 1. Illustrates an analysis of surface conditions, with arrows indicating slope patterns, dot-dashed line showing drainage ways, grey pattern identifying flood plane, and hashed lines indicating major change in elevations.

1. The deposit outline delineates the horizontal and vertical extent of a deposit. It is drawn from geologic data provided by deposit borings (Bourne and Bauer 1992). A map of the bottom and lateral limits of mining, sets the stage for the site planner to begin shaping the future landscape (Fig. 2).

2. Overburden, in the form of topsoil and subsoil, covers most deposits of stone, sand, and gravel in various depths. This material should be evaluated in terms of its characteristics, such as fertility, permeability, compaction, and erodibility; quantity, as relates to depth of topsoil and subsoil; and distribution, as relates to the location of material, by volume. This latter feature is important in terms trying to maximize land shaping opportunities and minimize earth hauling distances.

3. The ground water elevation, in relation to the deposit depth, will of course, indicate whether a mining operation will be a wet or dry excavation. In quarry operations, where this water table is typically lowered, additional studies related to impacts on the water elevation beyond the quarry site are essential. Ground water elevation data will influence the type of extractive operation that will be developed, the pattern of excavation, and the land development potential of a site (Fig. 3). Data about the depth of material below water is crucial in determining where to place overburden for land building.

Mining Operations

The mining operation is the vehicle by which new lands will be created. The challenge is to combine earth moving activities of mining with land forming requirements of the proposed landscape. Expanding on the artistic analogy cited above, the earth moving equipment is to the site planner, what the scalpel is to the artist. However, in combining both mining and land shaping activities, it is essential to note, the first order of business is to allow for efficient extraction of the aggregate. Land shaping activities must be conducted within the context of efficient mining activities. In addition, issues of visual and environmental impacts of the total mining operation must be considered for the entire life of the operation.

1. The processing plant is the front door of most mining operations. It is also the link with the pit or quarry. Data related to the impact of the plant on the surrounding area must be considered. This includes, area requirements, height of structures, material storage needs, dust control (plant and ground), noise control, water needs, and ancillary facilities. Equally important is an understanding of the relationships between the processing plant and the excavation area, and the processing plant and the entrance area. Each of these items are used as criteria in siting the processing plant.

2. Typically two types of earth handling equipment are considered. The first deals with the equipment used to extract stone, sand, and gravel and transport material to the processing plant. The second type involves equipment used to move overburden and other non-commercial material about the site. The type and character this equipment and its adaptability to land forming activities are critical factors in designing the proposed landscape.

Synthesis (Master Plan)

Design of the final configuration of the mine site should occur hand in glove with the design of the processing plant, the selection of various types of mining and earth moving equipment, and the programming of the mine operation. Preparation of a master plan involves synthesis of data collected about the context, surface, subsurface and operations, into a single program, a statement of objectives, and a series of plan documents that illustrates the conduct of an operation, and projected outcome. There are four major sets of master plan documents.

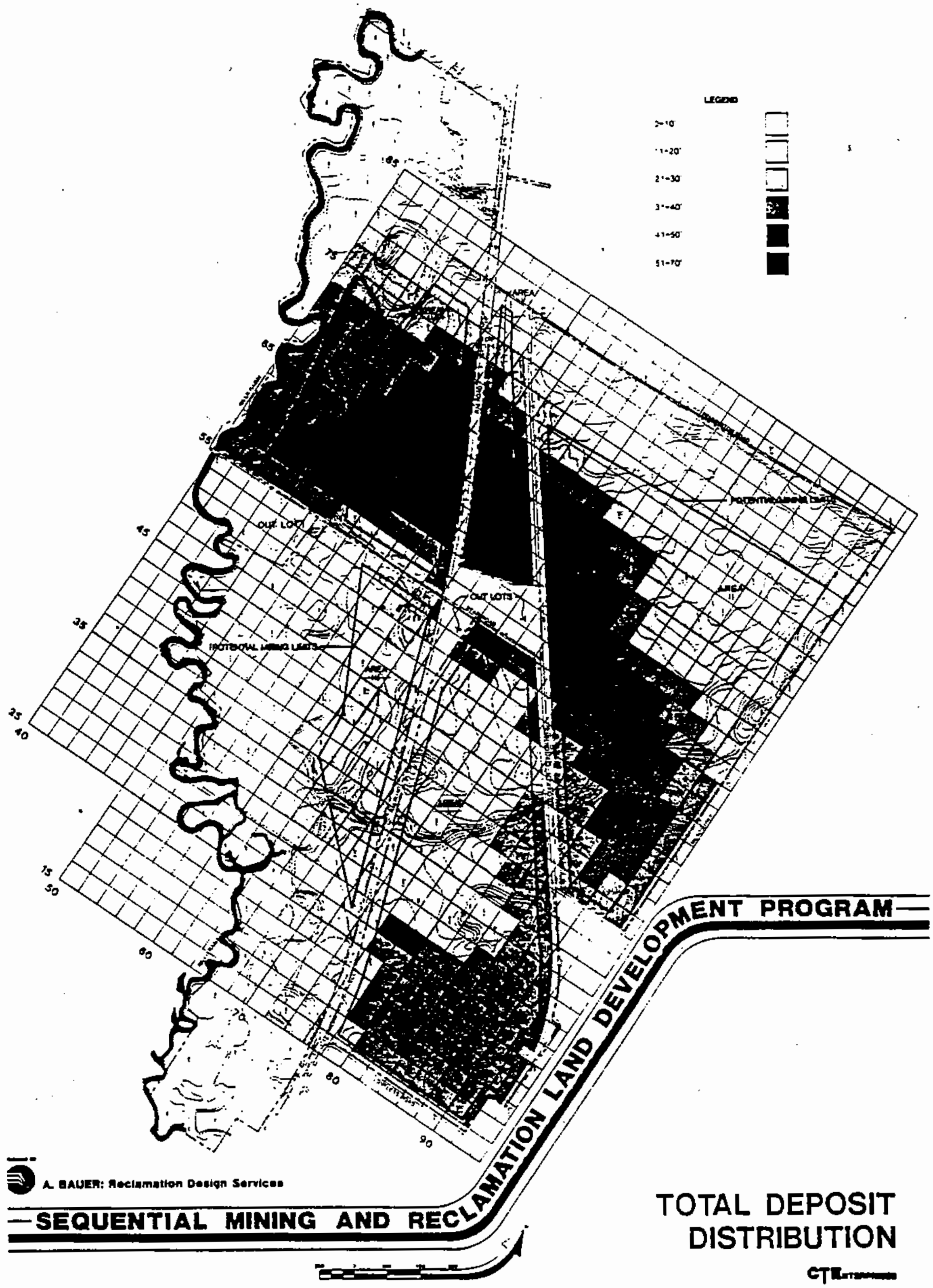


Figure 2. Demonstrates aggregate deposit depths, with the darkest pattern being 51 to 70 feet deep and the lightest pattern being less than 10 feet.

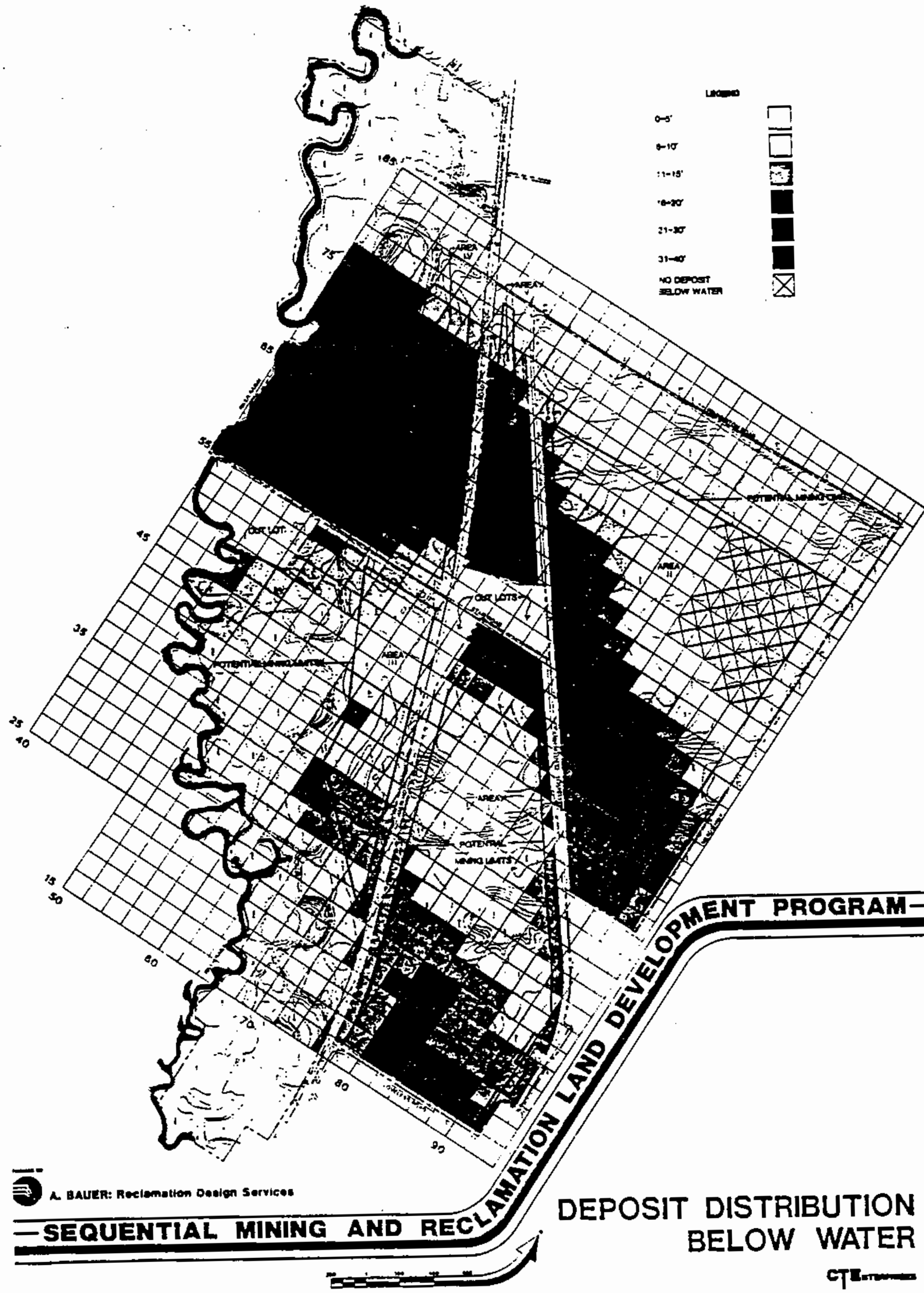


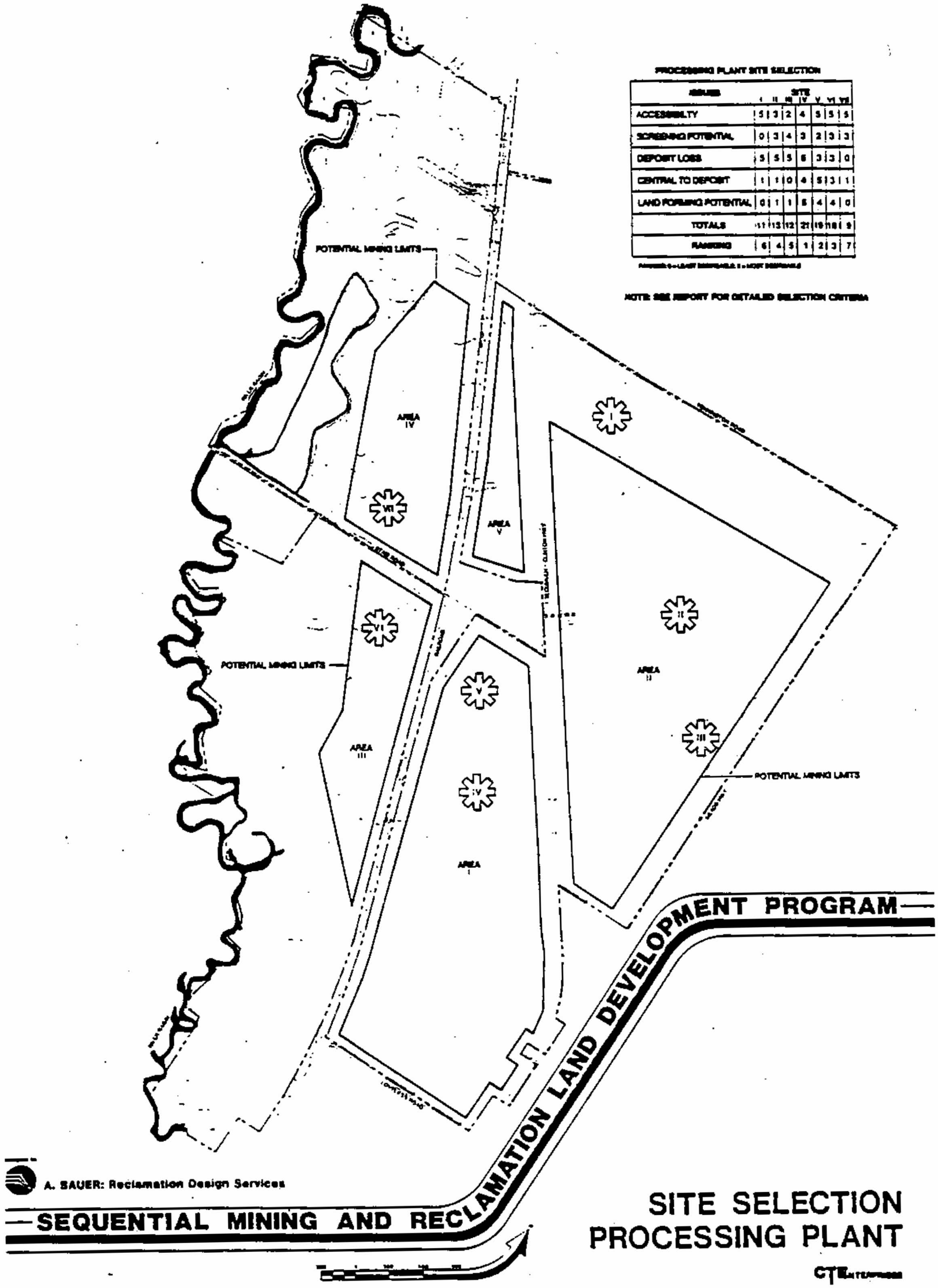
Figure 3. The depth of deposit below water table illustrates water depths by the tone of black. The darkest tone indicates aggregate reserves of 30 to 40 feet below water. The lightest tone indicates less then six feet of aggregate below water. This information is used to determine where to place overburden to build the greatest amount of land in the mined-out areas.

1. While some processing plants are portable, or semi-portable, plants for most large scale operations are permanent structures. Location of these plants is crucial to both the mining operation and to the long term impact of the facility on the adjacent lands. Primary criteria in selecting a site include: relationship to the mass of reserves held in the deposit; access to public roads; and visual and audio impacts on adjacent land. In Figure 4, a series of potential locations, marked by the asterisks, were evaluated, based upon a specific set of criteria. Working in collaboration with the geologist and operations people, location IV was selected as the best site. One criterion used in siting these plants availability of natural screening offered by existing terrain and wooded areas. When these features offer limited screening opportunities, alternative methods can be used. These include building earth berms, where needed, with overburden from the site, and/or install various types of trees and shrubs to create vegetation screens. Another effective approach that can be used in some circumstances, is to locate the processing in the excavated pit, below the surrounding landscape. The site selected in Figure 4 was an open field. The solution to screening the plant from the surrounding lands is shown in Figures 5 and 6. A combination of placing the plant in the pit, twenty feet below grade, and adding ten to fifteen berms with trees and shrubs, demonstrates an effective way of eliminating a potential visual and audio conflict with neighboring residence. In this example, because of the elevation relationship of surrounding land to the proposed mine site, the conflict could not have been resolved without coordinated planning efforts initiated before mining began.

2. To the extent possible, the entire mine area should be screened from the public. However, in many situations mine activity may not be exposed for several years. Through the development of a long range screening program, that includes taking advantage of natural screens in siting the processing plant and in directing the pattern of mining, a very cost effective screening program can be developed. Where instant screens are needed earth berms and large trees and shrubs need to be installed. But, where mine areas will not be exposed for several years, inexpensive seedlings of a wide variety of species can be planted and allowed to grow into effective screens by the time any potential conflict occurs.

3. Three factors should be taken into account in the design of aggregate operational procedures. They include: efficient mining production as relates to the type of extractive equipment used; coordination of the excavation, deposit conditions, and proposed land shaping activities; and the visual and audio impact of the operations on adjacent lands. Figure 7 illustrates a portion of a coordinated and phased mining and land shaping plan. With initial excavation efforts, the overburden is placed in strategic areas to screen operations. Aggregate is mined by a dredge which operates at water table, fifteen to twenty feet below natural grade, thus reducing the visual and audio impact of the operation on the neighbors. Mining is then directed at initiating excavation in those areas of the deposit where the land shaping and land development potential is the greatest. This opens areas for placement of overburden that will be removed from subsequent disturbed portions of the site, thus avoiding double handling of earth. In this particular project, land areas are expanded into those shallow excavated water areas, which permits maximum development of land with available overburden.

4. It is a fundamental premise in a sequential mining and land shaping project, that the final land form will be a reflection of both the deposit characteristics and the earth moving equipment (Bourne and Bauer 1992). Opportunities for development are unlimited. No use can be excluded from the list of potential uses for the mined-out site. The primary land shaping requisite is that the shaped lands be stable and be of appropriate slope and dimension to accommodate the



ISSUES	SITE I	II	III	IV	V	VI	VII
ACCESSIBILITY	5	3	2	4	5	5	5
SCREENING POTENTIAL	0	3	4	3	2	3	3
DEPOSIT LOSS	5	5	5	6	3	3	0
CENTRAL TO DEPOSIT	1	1	0	4	5	3	1
LAND FORMING POTENTIAL	0	1	1	5	4	4	0
TOTALS	11	13	12	21	19	18	9
RANKING	6	4	5	1	2	3	7

Figure 4. This figure indicates possible locations for the proposed processing plant. Using a specific set of criteria, site number IV in Area I was selected.

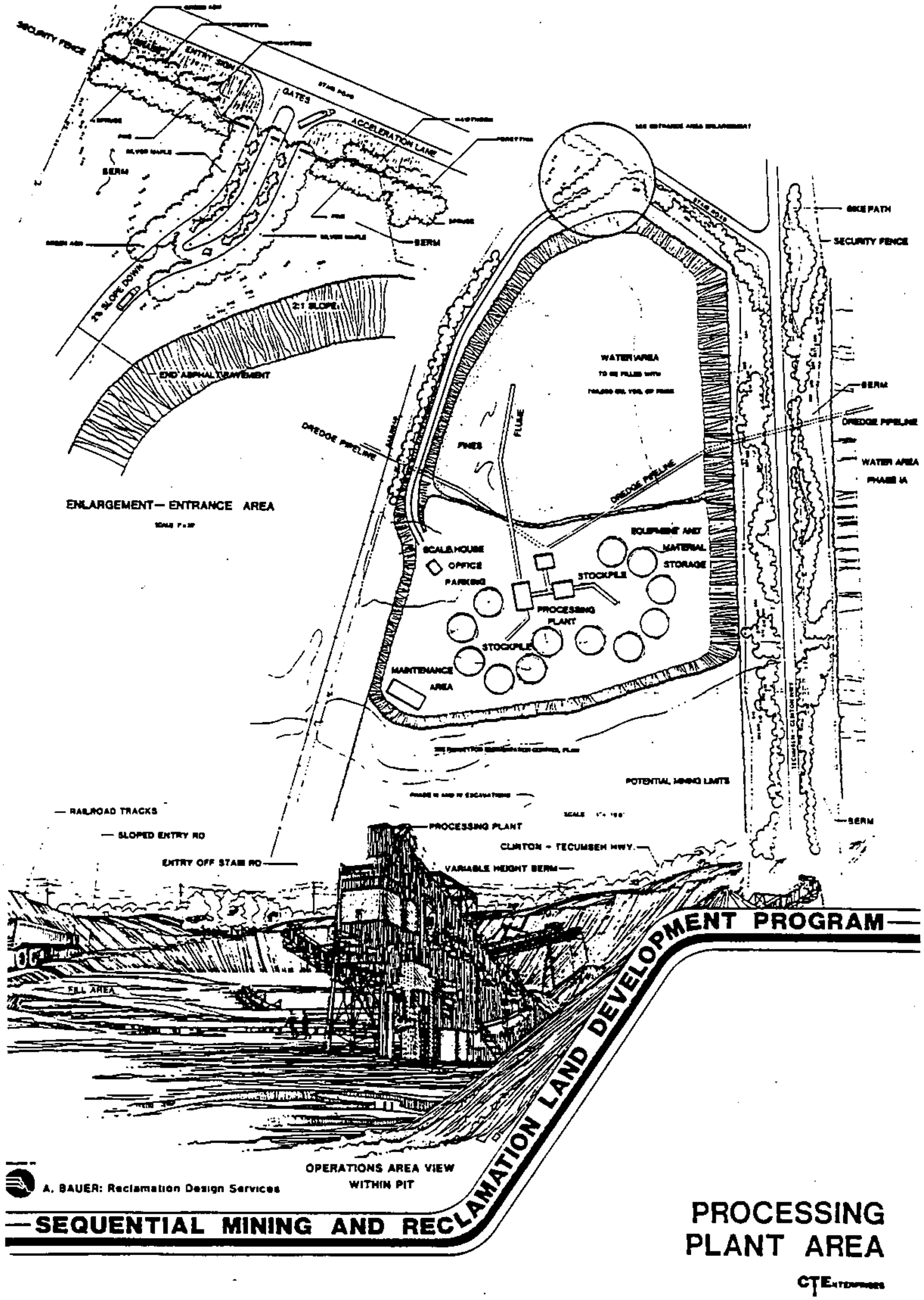


Figure 5. This is a site plan and sketch of the proposed processing plant. Specific consideration is given to screening the operation from neighbors.

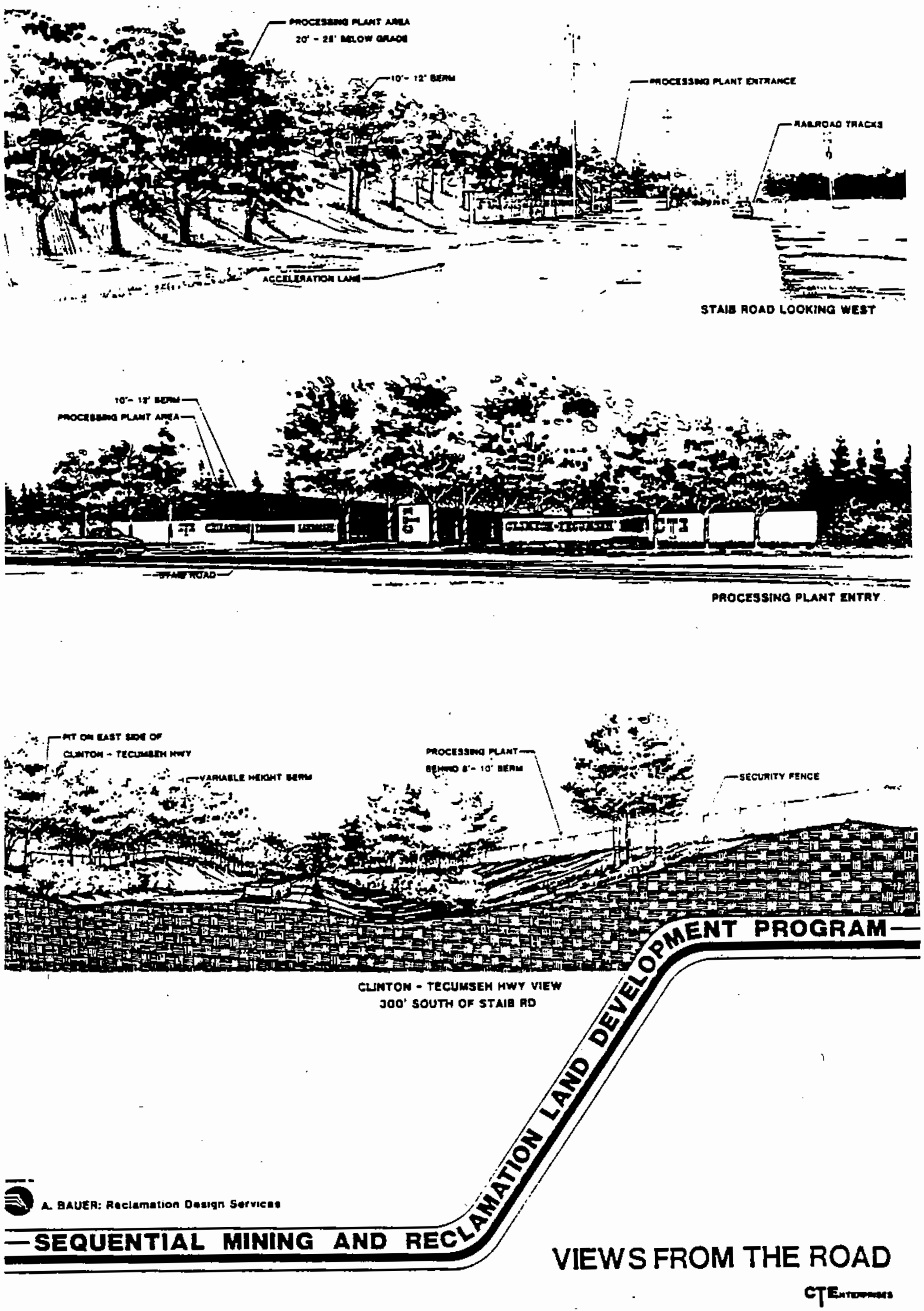


Figure 6. Illustrates various screening and landscaping ideas around the processing plant entry and around the pit.

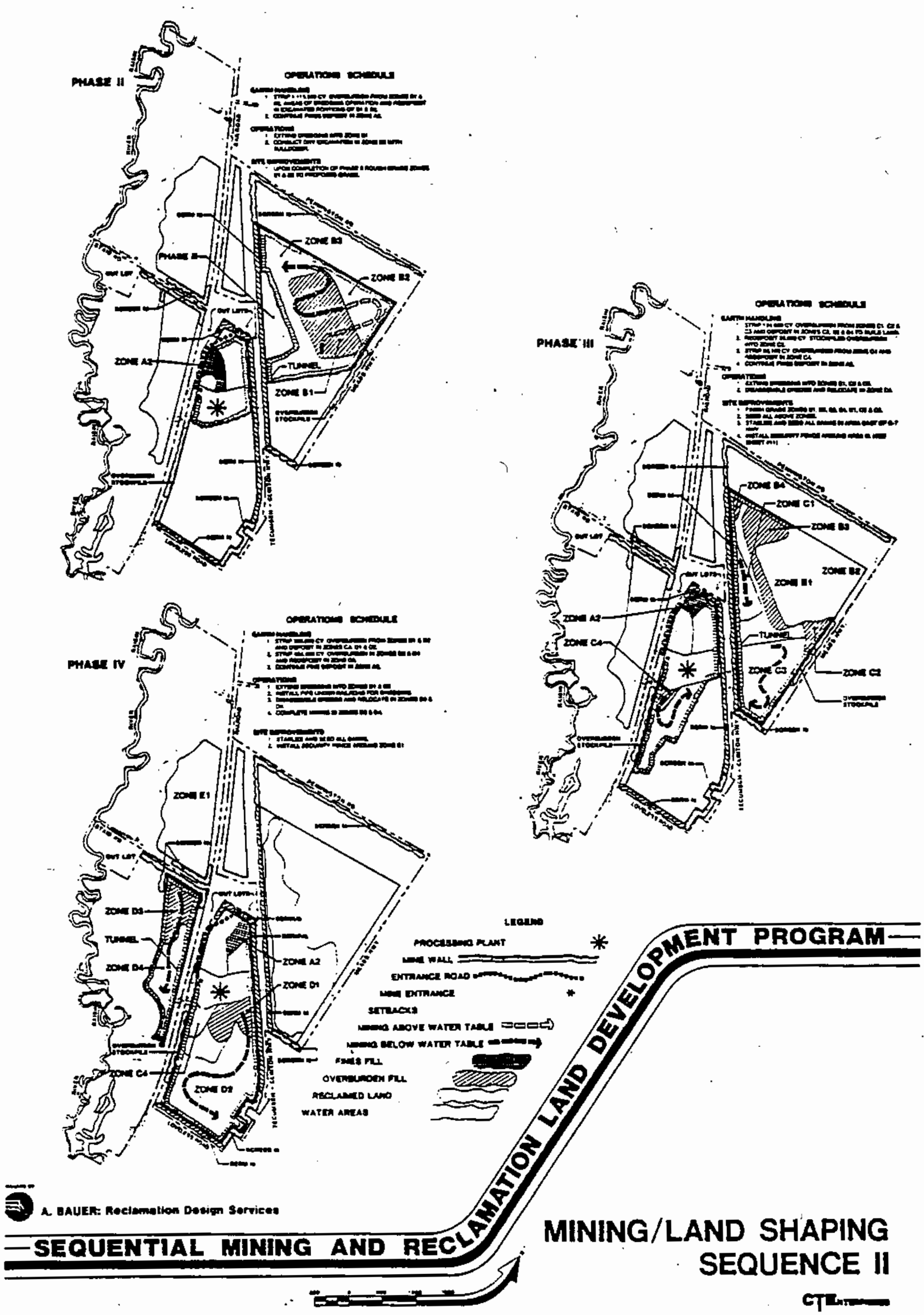


Figure 7. Illustrates three stages of a sequential mining and land shaping program. Aggregate excavation patterns are set to take advantage of the land shaping potential inherent in the deposit.

intended uses; whether it is a housing development or a wildlife area (Figs. 8 and 9).

Conclusion

To continue as an urban land user the aggregate producer must reevaluate its activity in the light of being surrounded by an ever increasing number of people. The industry must pursue a more sensitive and organized approach to mining, site improvement, environmental awareness, and land shaping. This can be achieved in the most cost effective and creative way, by integrating site improvement and land shaping activities with aggregate mining activities through the site planning process.

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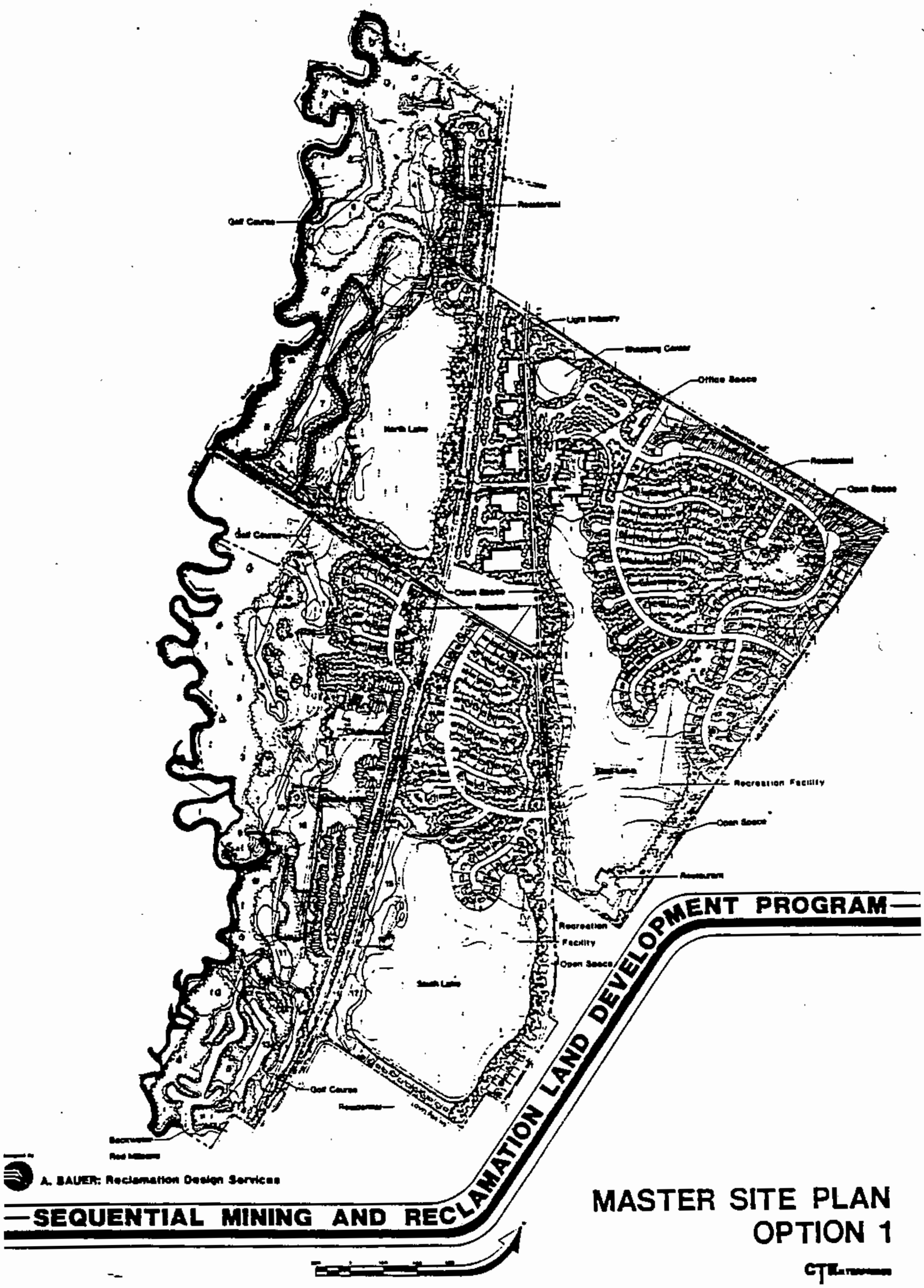

Figure 8. The master site plan of the proposed configuration and use the deposit when it is mined-out. The water areas and land forms reflect the deposit structure shown in figures 2 and 3.

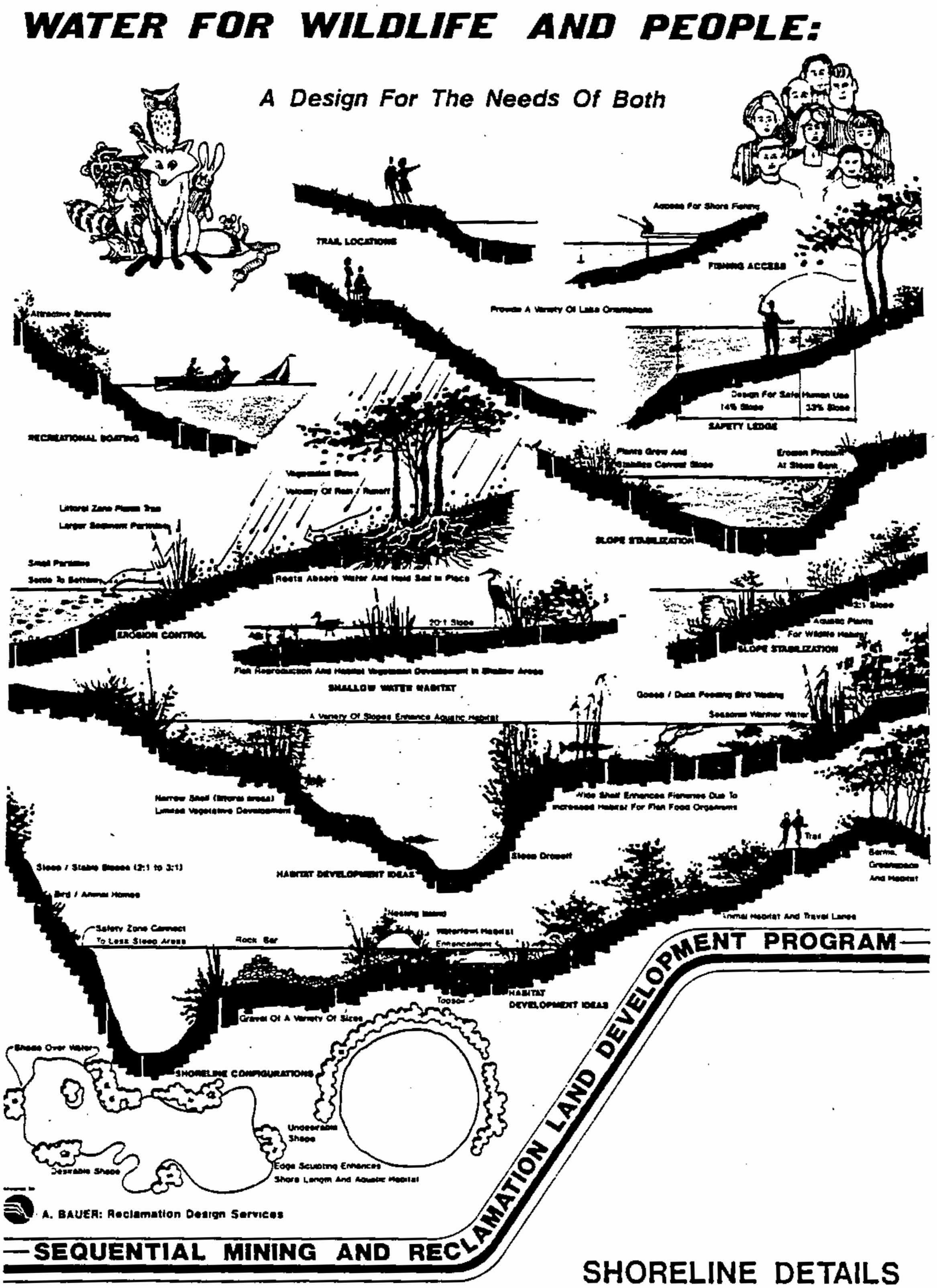

Figure 9. Illustrates various types of shoreline configurations that can be created by the land shaping operation.