PLAN OF STUDY FOR EVALUATING THE EFFECTS OF LIGNITE MINING IN LOUISIANA ON WATER RESOURCES

Submitted by

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PART A

PLAN OF STUDY FOR EVALUATING THE EFFECTS OF LIGNITE MINING IN LOUISIANA ON WATER RESOURCES

INTRODUCTION

As the nationwide and worldwide shortages of energy become more apparent, and as the cost of energy rises, there is little doubt that lignite as found in northwestern Louisiana will assume a major role in energy production. Lignite is defined by the U.S. Bureau of Mines as "a soft porous and carbonaceous material that is the intermediate stage between peat and subbituminous coal." Lignite is also defined as the lowest grade of coal having a caloric value of less that 8,300 BTU's per pound. Lignite occurs chiefly in the Gulf Coast Province in the thick beds of the Wilcox group of formations of Texas, Arkansas, Louisiana, Mississippi and Alabama. Lignite also occurs to a lesser extent in the overlying beds of the Claiborne and Jackson groups. It is estimated that a total of 22 billion tons of lignite may be recoverable by surface mining in this area.

Louisiana's coal reserves are presently estimated at one billion tons which accounts for approximately seventeen percent of Louisiana's available energy.

Probable commercial lignite deposits in Louisiana are located in Desoto, Red River and Sabine Parishes. The Chemard Lake lignite lentil was found to have fairly constant thickness over a large area of south-east Desoto Parish with reservoir estimated at 546 million tons. Studies have also revealed that Sabine Parish contains at least 50 million tons of reserves. These lignites occur in the Wilcox group. Average proximate analysis of lignite from this area yielded the following characteristics:

also states that a shortage of housing and adequate public facilities and services will exist.

It is anticipated that one corporation, Phillips Coal Company, will soon initiate mining operations. This mining project includes an agreement with Cajun Electric Power Cooperative, Inc. (CEPCO) to purchase 150 million tons of lignite from Phillips from a deposit near the town of Armistead, Louisiana. This coal will be used to fuel two 540 megawatt steam electric generating units for 30 years. The first generating unit is planned to be operational in 1985, with the second project for a 1988 start-up.

The amount of lignite to be mined from this single operation is estimated to be equivalent to 300 million barrels of oil or two trillion cubic feet of natural gas and will supply the fuel to generate the power requirements for approximately 200,000 homes.

It can readily be seen that the lignite deposits in Louisiana are a valuable natural resource and that care must be used in the extraction of this resource. One major area of concern with regard to lignite mining operations is the overall impact on water resources in the mined areas. These impacts may include not only direct demands of the mining operations, but also indirect demands associated with industrial, urban and economic growth. The purpose of this effort was to identify the water related impacts associated with lignite mining and to define management tools and techniques which may be utilized in Louisiana. The following sections of this report will discuss both surface and ground water impacts of lignite mining operations and will address direct and indirect water demands. Regional water resource management techniques will also be addressed, along with predictive water resource models.

Water resources vary widely in regional and local patterns of availability. The supply is dependent upon topographic and meteorological conditions as they influence precipitation and evapotranspiration. Quantities of water stored are dependent to a large extent on the physical features of the earth and on the earth's geological structure. Surface waters are found nonuniformly distributed over the earth's surface. It is estimated that only about four percent of the United States land surface is occupied by fresh surface waters. These waters vary widely in quality, quantity, seasonal distribution and frequency of occurrence.

Ground water supplies are much more widely distributed than surface supplies. Nevertheless, strong local concentrations are found as a result of the variety of soils, rocks and geologic structures located underground.

The water related impacts of lignite mining, with regard to water supplies, can best be evaluated by addressing the direct demands associated with the anticipated mining operations themselves and the indirect demands. These indirect demands would include those prompted by new urban growth and associated industrial and economic expansion.

The direct demand of water supplies for lignite mining operations occurs in three areas. One is in the extraction and preparation of the lignite for transportation. A second is the actual transportation of the lignite, i.e., slurry pipeline. A third deals with auxiliary facility demands. It is a generally accepted fact that the maximum recovery of lignite deposits is accomplished utilizing surface mining techniques. Recovery efficiencies of 90 percent are often expected. Surface mining methods presently proposed in Louisiana will not require water in any significant amounts for extraction and preparation of lignite.

with this expansion will come significant demands on existing water supplies.

Water resources are developed primarily for urban water supply including industrial process demands, irrigation, power generation, flood control, recreation, pollution control, navigation and fish and wildlife conservation. Because it is important that our water resources be utilized to the fullest extent, a consideration of the multiple use of water is mandatory for all but the smallest projects.

In order to better define the anticipated impacts of lignite mining on water supplies due to indirect demands, it is necessary to briefly define the factors expected to influence those demands. Urban water supply and industrial process requirements will be the most significant in the lignite areas in the future. These requirements may be quite variable from region to region. A reliable estimate of the quantity of water required for municipal, industrial and agricultural uses in a region must be made before systems can be designed to transport, process or distribute these flows.

There have been a number of predictive methodologies developed in an effort to correctly estimate water consumption. These techniques attempt to account for such factors as climatic conditions, economic conditions, composition of the community or region, water pressure, costs of water and water quality. Based on these factors, it is safe to estimate that water consumption in lignite mining areas may be as high as 250 gallons per capita per day. This figure includes such things as associated industrial and commercial use and fire demand.

The sources of this demand will come from either surface water supplies or groundwater supplies. The surface water supply for a

The quality of precipitation is usually quite high, but once the precipitated water has penetrated the soil with its component minerals and rocks and flowed in streams contaminated by municipalities and industries, its quality may be seriously degraded by bacteria, organic matter, dissolved salts, acids, and possibly radioisotopes.

Drinking-water regulations prescribed by the EPA recommend that the total dissolved-solids content for human consumption should not exceed 500 millingrams (mg) per liter. The U.S. Geological Survey states that water containing more than about 2000 mg/l dissolved solids are generally unfit for long-term irrigation under average conditions.

Increased emphasis on the quality of our water resources comes in the face of increasing population, accelerated industrial activity, and large-scale pollution. Waste-abatement operations range from simple technical adjustments to the consideration of exceedingly complex social-political-economical-psychological problems. A complicating factor is that each pollution-abatement problem is different. In addition, the motivations for abatement programs are shifting from the pure health-hazard base in an inclusion of aesthetic valuations.

With these facts in mind, those factors which impact surface and ground water in lignite mined areas of northwest Louisiana were addressed. As was the case in water supply demands, water quality impacts on ground and surface waters are anticipated to be associated with two major areas of activity. Those areas are actual mining activities and associated urban and industrial expansion.

Ground water quality is influenced considerably by the quality of the source. Changes in source waters or degraded quality of normal supplies may seriously impair the quality of the ground water supply.

This intrusion may at times lead to draw down of the localized ground water table in order to efficiently extract lignite. This draw down is accomplished most often by pumping immediately adjacent to the active mine area. The pumped ground water is usually discharged to a surface watercouse outside of the active site. The actual impact is dependent upon not only the characteristics of the local ground water resource, but also upon the actual mining methods. Factors such as methods of land clearing, and overburden removal and lignite characteristics may all have an impact on the ground water resource.

Generally, this is an impact which must be addressed on a case by case basis. If surrounding areas presently utilize the ground water resource or its use is anticipated in the future, the direct impact of mining operations may prove to be significant. Some of the management techniques discussed in the next chapter are applicable to evaluation of this type of ground water impact. Presently, there appears to be some question as to the impact of lignite recovery in northwest Louisiana and further investigation is needed.

The main impacts of mining activities in the past has been on the quality of surface waters in and around the mining areas. These impacts are due primarily to two factors: sedimentation and acid mine drainage.

The most severe effect of lignite mining may be soil or sediment washed into streams from land disturbed by surface mining. Improperly managed surface-mined land and access roads have in some places led to the washing away of massive amounts of sediment. This sediment comes from piles of earth removed to expose the coal and from unreclaimed mine areas. It coats stream bottoms; fills stream channels; disrupts or destroys water, plant, and animal life; reduces the recreational value

4. Downdrain structures

5. Level spreaders

6. Grassed waterways

7. Outlet protection

8. Riprap

9. Check dams

10. Sediment basins

The second factor having a major impact on surface water quality in mining areas is acid mine drainage. The degree of water acidity caused by mine drainage in any location is based primarily on the area's geology. Where a stream passes over limestone, it develops a greater degree of alkalinity which provides a buffering action to help neutralize acid drainage from mined areas. Where streams do not come into contact with limestone but pass over other kinds of rock, such as sandstone, the water's alkalinity may remain low. The water will have little buffering capability so when acid drainage enters the stream it may push the acidity to critical levels. Acid stream conditions also increase the solubility of certain metals such as copper, nickel, and cadmium which even in minute concentrations may be harmful to water, plant, and animal life.

Acid drainage develops from mined areas when certain minerals in the soil are exposed to air and water. Acid drainage from strip mines can be controlled by properly burying acid-producing deposits or adding lime to neutralize them.

The intensity of acid mine drainage, and therefore its potential impact on surface water quality, is usually evaluated by measurement of various water quality parameters. The most common physical, chemical procedures may be used. These include placement of crushed limestone barriers in stream beds; addition of lime, soda ash or other neutralizing agents to streams; or construction of treatment facilities to neutralize mine water and remove precipitants.

The factors affecting surface and ground water impacts in lignite mining areas due to urban and industrial expansion deal primarily with surface water quality. The deterioration of ground water quality in this case would most probably be due to injection of waste streams into the ground water table. This is obviously not an acceptable disposal technique and is not anticipated to ever occur in northwest Louisiana.

The impacts associated with rapid urban and industrial expansion on surface water quality can be significant. Many studies have shown that urbanization can cause an increase in flooding and drastic changes in water quality. Larger floods increase the risk of property damage and injury to residents. The deterioration in water quality causes increased costs of water processing and wastewater treatment and limits contact recreation along a water course. Flood alleviation measures, such as channelization or enlargement of sewers, are expensive and often only represent stop-gap measures.

Urbanization brings with it changes in land use, at times severely disrupting the natural landscape, replacing it with impervious surfaces and redistributing the land surface flows.

In general, sources of pollutants may be classified into two categories: point source or nonpoint source. An example of a point source would be the outlet into a river of a municipal wastewater treatment system or an industry directly discharging effluent into a river. The point of origin of these pollutants may easily be observed and identified.

1. Establish planning boundaries
2. Perform a water quality assessment and propose water quality segment classifications for area streams.
3. Compile discharger, demographic, and land use inventories and projects.
4. Perform a nonpoint source assessment.
5. Review water quality standards.
6. Develop total maximum daily loads of pollutants.
7. Review or propose point source load allocations.
8. Identify municipal waste treatment system needs.
9. Evaluate industrial waste treatment system needs.
10. State nonpoint source control needs
11. Outline residual wastes and land disposal needs.
12. Assess urban and industrial stormwater treatment system needs.
13. Project target abatement dates.
14. Establish regulatory programs.
15. Identify management agencies.
16. Perform an environmental, social, and economic impact assessment of the proposed plan.
17. Evaluate various point source planning options including regionalization of wastewater treatment plants, new construction and upgrading of existing facilities.

Completion and implementation of these activities, together with strict enforcement of state water quality criteria and evaluation of the cumulative impact of any water related activity, will serve to alleviate point source pollution problems.

1. Nonstructural or source control options which attempt to reduce the amount of pollutants washed off a drainage area.
2. Structural or discharge control options which attempt to treat stormwater runoff at the point of discharge into a receiving stream.

Source control management addresses measures currently available for minimizing pollution from urban runoff before it enters a combined or storm sewer system or a receiving stream. Some of these measures may be increased street cleaning, erosion control, and chemical and material handling and storage controls. Structural control options may consist of a number of best management practices including detention devices, buffer zones, weir structures, use of porous materials for paving, etc. Structural controls may also include physical/chemical treatment processes involving chemical addition, clarification and filtration. These processes might include dissolved air flotation, microscreening, disinfection or swirl concentrator.

It can be seen from the various water related impacts and the numerous methods and technologies available to alleviate those impacts, that regional water resource management is needed. The techniques may be applied to northwest Louisiana and are discussed in the next section of this report.

surface effects of underground mines are also regulated. Minimum performance standards are specified. In addition to requiring the use of appropriate measures to minimize erosion (such as diversion of runoff from the mined area) and the formation of acid water (such as timely coverage of acid-producing spoil), the regulations require that all drainage from disturbed areas, with the exception of areas containing only diversion ditches, sedimentation ponds, or access roads, be passed through properly designed and operated treatment ponds so that the effluent meets stringent limitations for suspended solids, pH, and other parameters prior to discharge to receiving streams. In passing this legislation, Congress intended the states to assume primary jurisdiction over the regulation of coal mining and reclamation operations on non-Federal and non-Indian lands.

As might be expected from legislation that in one way or the other affects the entire Nation, SMCRA and its accompanying regulations are highly controversial, with views ranging from lofty praise to severe criticism. The mining industry fears that the regulations will put a severe financial burden upon many of the smaller operators. They fear that they will be forced out of business, thereby creating high unemployment in coal mining areas and possibly affecting the Nation's supply of coal and production of energy.

Environmental groups generally support the regulations, but some believe various requirements are not stringent enough to assure adequate environmental protection. Many members of the general public fear that the regulations are inflationary. The Office of Surface Mining (OSM), which has primary responsibility for assuring implementation of most of the programs established by SMCRA, has analyzed these and related confor the landowner, the SCS may decrease their share to as low as 60 percent. The maximum area that can be reclaimed under the program is 320 acres per landowner.

In framing this legislation, Congress anticipated many problems that could arise in compliance with the stringent regulations. One such problem is the small operators who often do not employ the professional personnel needed for compliance with the regulations. Technical assistance will be available to them under OSM's Small Operator Assistance Program. OSM has worked with several other agencies to develop additional small-operator assistance programs. In response, TVA has developed a special program to purchase coal from and provide technical assistance to small operators.

In the spring of 1979, TVA signed an agreement with Roane State Community College at Harriman, Tennessee, to provide small mine operators and mine consultants in east Tennessee with a better understanding of requirements of the 1977 law through educational programs. Similar agreements were reached in September 1979 with the University of Kentucky's Institute for Mining and Minerals Research for operators in eastern Kentucky; Walker State Technical College in Alabama; Mountain Empire Community College, Southwest Virginia Community College, and the Virginia Division of Mined Land Reclamation in Virginia.

The programs will cover such subject areas as water quality monitoring sediment basin construction, blasting techniques and certification, drainage control, mine management, and mine law.

Inspections of each mining and reclamation operation are required of the regulatory authority on a monthly (a <u>partial</u> inspection) and quarterly (a <u>complete</u> inspection) basis to determine compliance. If

WATER QUALITY MODELS WITH APPLICATION TO WATER RELATED IMPACTS OF LIGNITE MINING

This section of the report presents a review of available water quality models which could be used to study the impacts of the proposed lignite mining operations discussed earlier in the report. It was the objective of this review to identify a class of models that demonstrated the greatest potential for interfacing with the computerized data base currently under development by the Remote Sensing and Image Processing (RSIP) staff.

RSIP Computerized Data Base

The detailed capabilities of the RSIP computerized data base has been documented in Part B of this report. This section briefly discusses the system capabilities and limitations which are relevant to the model selection process. A clear understanding of the interaction between the digitized data base and the water modeling systems is necessary to select the appropriate models for interfacing. For the purposes of this discussion, three levels of interaction will be discussed.

Level I interaction:

Level I interaction (see Figure 1) with the RSIP computerized data base provides that a portion of the input data required by a water resource model be derived from the generalized data system. The data system has the capability of converting information normally available to the engineer from maps or areal photographs into one dimensional (river characteristics) and two dimensional assays (drainage basin characteristics) through a process called digitization (Ia). By digitizing several types of information for the same area a system of overlays for a study area can be developed. Utilizing similar techniques, a representation of three dimensional systems, such as lake or ground water reservoir, can be developed. If the system being analyzed were strictly linear in nature, only marginal benefits from the use of the computerized data base would result for Level I interaction. The computerized data base would function primarily as a data storage system (Ib) since most existing water models are well suited for the handling of one dimensional information. Data handling, however, becomes increasingly difficult when two or three dimensional characteristics are considered. This is particularly true when the overlay of several characteristics are required for the development of the input data required for a water resource model.

Almost universally, water models are not structured to accept study area characteristics directly. Characteristics such as slope or soil type (for the two dimensional case) are typically averaged or otherwise manipulated by the engineer prior to input to the model as coefficients or subbasin characteristics. Level I interaction will require two linkage packages. The first, which contains the data manipulation and overlay algorithms (Ic), will be required to create overlays from the more generalized data storage bank. The second, the conversion algorithms (Id), will convert the overlayed information into the specific coefficients or characteristics required by the water model (Ie). The water model, utilizing the input data from both the digitized data base (Ia through Id) and conventional input directly from the user, will conduct the required analysis and output in the normal fashion.

It is clear from the above overview of the Level I interaction that linkage of a water resource model with the digital data base will require

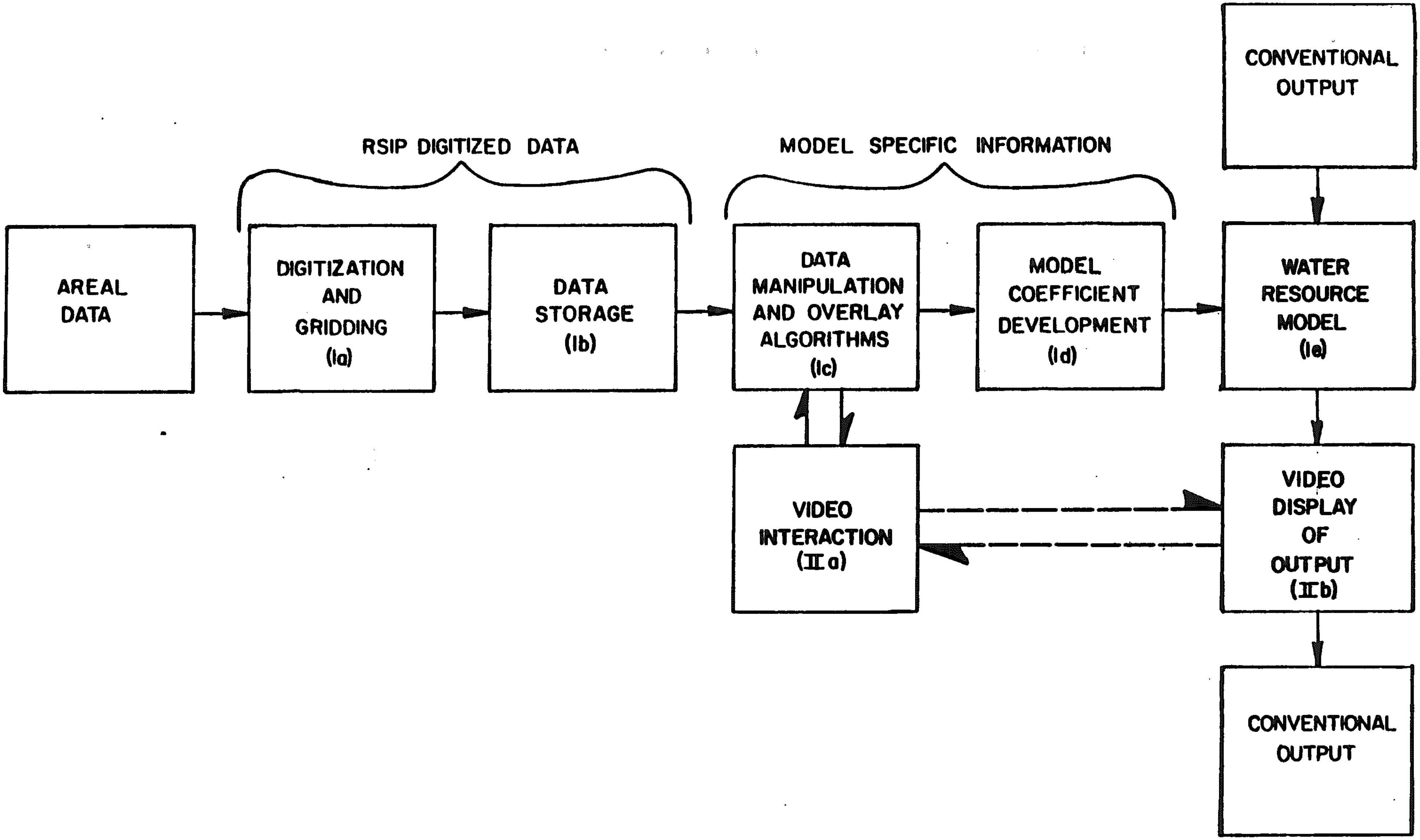


FIGURE 2: LEVEL 2 INTERACTION BETWEEN THE RSIP DATA BASE AND A WATER RESOURCE MODEL.

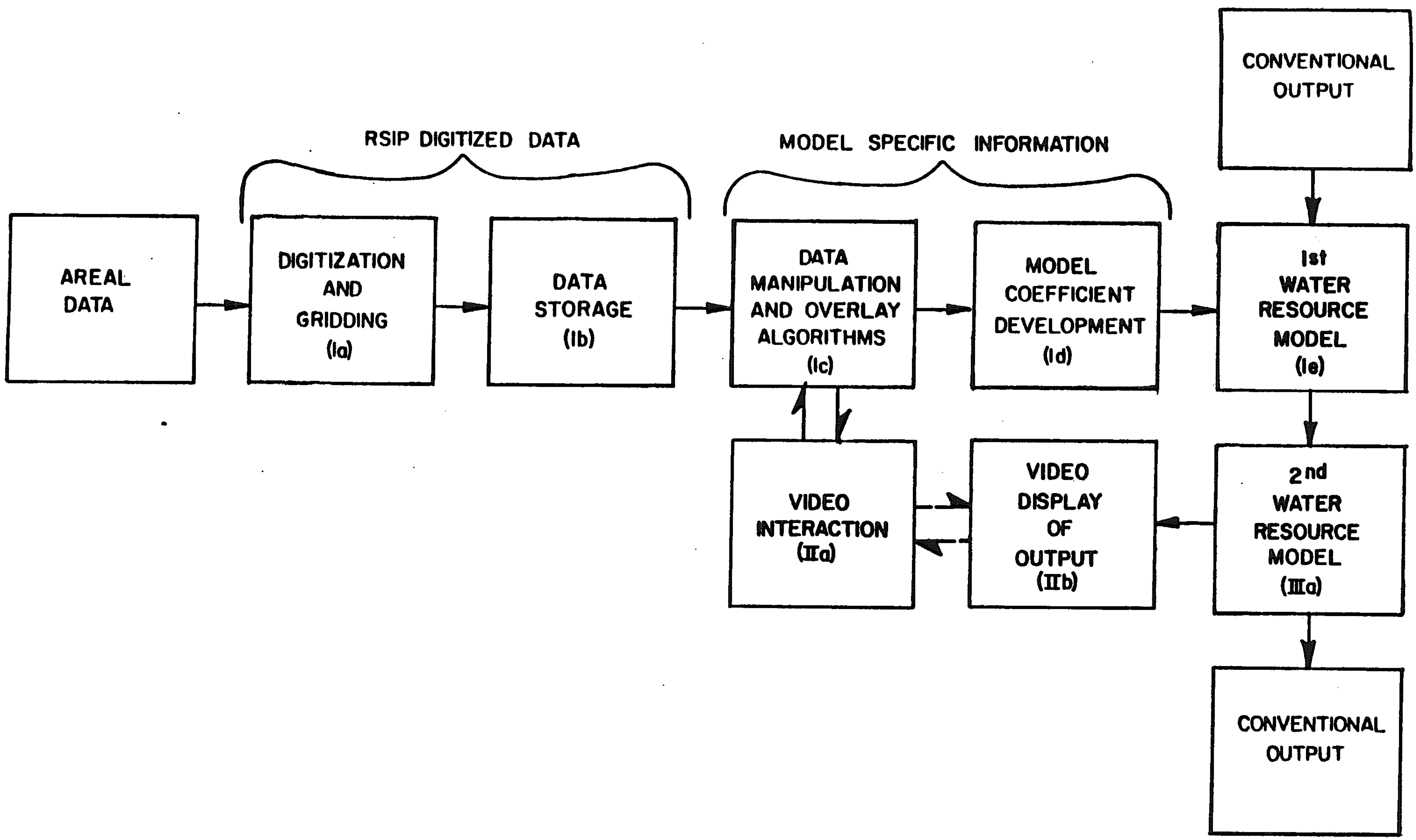


FIGURE 3 : LEVEL 3 INTERACTION BETWEEN THE RSIP DIGITIZED DATA BASE AND TWO WATER RESOURCE MODELS.

The flexibility of the RSIP system is such that a large number of models from each of the classifications could be successfully interfaced with the digitized data base. Optimum utilization of the system dictates that models linked with the system have regional application to water related problems throughout the State of Louisiana. This criteria implies that models ultimately selected for linkage to the digitized data base display a reasonable degree of flexibility so that they can be applied to analyze problems occurring in distinctly different study areas. Further the model should be of low to moderate complexity so that the group of potential users would not be severely limited by the availability of highly trained personnel which some modeling systems require for application. It is likely that the models selected would be used by state agencies for regulatory purposes. Such useage will require that the models employed are recognized as credible by the professional community. For this reason only models currently in wide use with proper program documentation were considered in the selection process.

For maximum benefit to be derived from the interactive Level II capabilities, it is necessary that the management alternative considered involve manipulation of the overlays resulting from the manipulation of data from the digitized data base rather than alteration of data derived from the supplementary conventional data input. The best example of an areal category that lends itself to manipulation as part of management alternatives is land use.

A major consideration also involved in the selection process relates to the need for development of specific linkage routines (Id) for successful interface between the digitized data base and the selected water resource model. It is highly desirable to select a classification of models that

WATER RESOURCE MODELS

Table 1 lists the six major water resource model classifications which were considered in the survey of model classifications. The model classifications are determined on the basis of the principle objectives for which the models were developed. These objectives in turn have historically led to the development of classes of models with similar characteristics. Within a classification there remains a wide variety of models. These individual models differ from others in their classification in their theoretical basis, solution routines, data requirements, resolution and output. These differences reflect the resources and needs of the user group, as well as regional variations in the factors essential to solving water resource problems. A brief discussion of each of the classifications follows.

Hydrologic models:

This classification of models is used to investigate quantitative aspects of water supply problems. The most sophisticated of these models stochastically simulate precipitation and runoff events in order to examine storage and distribution capabilities on a seasonal basis. Other modeling systems are typically deterministic in nature and consider only certain aspects of the water supply problem or employ simplifying assumptions to reduce their complexity. These models are widely employed as management tools in the development of water supplies for communities that are experiencing growth.

Typically hydrologic models represent a coupling of hydrologic data that is largely two dimensional in nature with distribution networks that are principally of one dimensional character. A large part of the data base could be incorporated into the digitized data base for Level I interaction. This data would be in the form of land use, slopes, soil types, and meterologic overlays. Unfortunately, the full benefit from Level II interactions would not be realized with these models since the management alternatives which are most frequently considered are found in the storage and distribution networks. These alternatives most frequently include the analysis of required storage capabilities such as reservoir capacities that would permit adequate supplies during drought periods. Considering these alternatives typically involves alteration of point data. Little benefit would be realized from Level II interaction as compared to conventional analysis techniques. The potential for Level III interaction is considered as poor to moderate since most of the models have been developed with narrow objectives in mind. They have been only rarely linked with models from other classifications.

A final consideration in the selection process is the value to be realized from the application of a hydrologic model to the lignite mining test case. Since the water requirements of strip mining are of a minimal nature, it is anticipated that the proposed mining operations will not directly impact local water supplies through demand. Industrial and urban expansion associated with the new mining operations may in some cases require development of new water supplies. A review of the currently proposed sites (see Chapter 2) has not indicated water supplies will limit growth near the new mines. The development of modeling capabilities for the analysis of water supply problems associated with lignite mining operations appears to be of marginal benefit at this time. This conclusion is drawn from an overview perspective of a number of potential lignite mining sites. When a specific study area for Phase II of this study is selected it should be reevaluated for the specific case.

impacts of management alternatives. For example, the two most widely recognized runoff models, SWMM and STORM have been successfully interfaced with stream models such as RECIEV III and QUAL II. In terms of compatibility with the RSIP digitized data base, the runoff models show excellent potential for all three levels of interaction.

The impact of runoff quality upon the receiving streams in the vicinity of the proposed lignite mining operations has been identified in Chapter II as an area of concern. Although the effects of the mining operations themselves have in most cases been throughly investigated, indirect effects resulting from associated land use changes generally have not. Alteration of land use patterns through industrial or urban expansion associated with the new lignite mining operations will have a significant impact on runoff quality. This may result in development of dissolved oxygen deficits in receiving streams if excessive BOD loading results or in development of eutrophication problems in downstream reservoirs if excessive nutrient loading results. A high value is therefore associated with the analysis of alterations in runoff quality that may result from growth associated with new lignite mining operations.

Stream models:

Stream models were developed primarily for the analysis of the effects of wastewater discharges (point sources) upon the quality of rivers and streams. The parameters most commonly considered in the quality analysis included dissolved oxygen, BOD, coliform bacteria, nutrients and algal biomass. The models analyze systems of a one dimensional character. Stream systems are typically represented by a network of headwaters and mainstream reaches. Inputs are typically of a point

As stated before, the proposed lignite mining operations may indirectly have adverse effects on stream quality. Since the mining operations themselves and other new point discharges of wastes resulting from domestic and industrial expansion will be subject to critical review under the NPDES regulations, the impact is more likely to occur through diffuse sources. Concerns relative to stream quality would therefore be best addressed through analysis of changes in runoff quality with eventual input of the results of this analysis into a linked stream model.

Reservoir models:

Reservoir models were developed almost exclusively for the analysis of eutrophication problems in natural lakes and manmade reservoirs. As a group the reservoir models tend to be more complex than other modeling classifications. This complexity results from the need to consider many physical, chemical and biological phenomenons simultaneously in a three dimensional format. The physical considerations include advection and diffusion processes, aeration processes, heat budgets, stratification phenomenon, and meteorologic considerations. Chemical processes include the kinetics of nutrient cycles, oxygen demand, and benthic-water columns interactions. Biological considerations are normally restricted to the consideration of algal kinetics. These kinetics are, however, intricately dependent upon the chemical and physical considerations. The three dimensional character of reservoir models results from the need to consider the variation of the various parameters with depth throughout the entire reservoir area.

It appears that little benefit would be realized from the development of Level I interaction alone. The principal difficulty here is that the type of data required for reservoir modeling is of a very the present time none of the sites reviewed appear to present a threat to major reservoir systems such as Toledo Bend.

Ground water models:

Ground water models were developed to assist in the management of ground water systems utilized for water supply purposes. Many of the models were initially developed to determine pumping rates that could be maintained under a given set of recharge conditions. Models currently available usually include at least limited capabilities of modeling ground water quality. The ground water models are similar to the reservoir models in that they usually display a three dimensional structure. Some of the less complex systems are principally two dimensional in nature.

Compatibility of ground water models with Level I interaction is rated as moderate. The geologic information that is necessary for application of these models is often available in a mapped format. Significant benefit would therefore be realized if this information is available in the digitized data base. However, the ground water models suffer from some of the same drawbacks as the reservoir models. These similarities include model complexity, specific data requirements and a three dimensional format. For these reasons Level I interactions are viewed as only a moderate advantage. Level II interaction would benefit the calibration/ verification processes but would be only of moderate benefit for the examination of alternatives because the data manipulation would still be compatible with conventional input capabilities. The potential for interfacing at the Level III appears also to be limited. The ground water models are not normally linked directly with models of other classifications. The potential for Level III interaction is therefore rated as poor.

can have a significant effect upon flood hazards. Alterations of drainage patterns also can have a direct effect. The need for analysis of the impact of the operations on the flooding problem is rated moderate to high for the general case. A more exact determination requires a review of site specific information.

Recommendations

The review of the compatibility of the various modeling classifications with the RSIP digitized data base is summarized in Table 2. It is apparent from this summary that the modeling classification which shows the greatest potential for Phase II of this study is the runoff modeling category. This category can be used to assess an impact area relevant to the lignite mining case study. The runoff models also show excellent potential for development of interfacing for all three levels of interaction. The runoff models are developed from data that is usually available in a mapped format. This two dimensional nature of the input data makes the runoff models particularly attractive for Level I and Level II interaction. Level III interaction is assured since the runoff models have already been modified on a number of occasions to interface with stream models. Two other classifications, the hydrologic and flood routing models, show almost as great a potential for development at the Level I and Level II interactions as the runoff models. This high potential for interfacing principally reflects the two dimensional nature of input data. These models show no potential for Level III developments and have only moderate relevance to lignite mining in the general case. The hydrologic and flood routing models are therefore recommended as secondary choices for Phase II of this study. The only other modeling classification that warrants serious consideration for Phase II of this study is the ground water category. Development of interfacing capabilities for the ground water models would be considerably more difficult and would not benefit potential users as much as the recommended categories. The ground water models are not recommended for use in Phase II unless the selection of a study area warrants it. This modeling category would warrant consideration after more experience has been gained from application of the models based upon data derived from a two dimensional format.

Topographic data (elevation contours) are either available on standard USGS topographic maps or in digital format from the National Cartographic Information Center (NCIC). These tapes are very expensive (approx. $10-15) and are available for the entire State of Louisiana. Apparently, five-foot contours were derived from 1:250,000 topographic maps and the one-foot contours were linearly extrapolated from the map derived contours. Computer programs accompany these tapes which allowed us to derive percent slope and aspect (direction of slope). These data if shown to be acceptable are invaluable considering that they are already digitized.

Detailed water resources information was apparently last acquired in 1963. General water resources information from gauging stations recording stream flow, and quality are published every year in a USGS water data report entitled "Water Resources Data for Louisiana". This information can be obtained from the USGS on computer tapes, but this is tabular not mapped data. The following water resources data for the lignite area are available from the USGS:

Surface Water (Drainage basin characteristics in latitude and longitude format)

1. Daily discharge
    a. Machine readable image of daily discharge
    b. Statistical analysis (i.e., mean, standard deviation, frequency/duration)
2. Stages (elevations - stream slope)
3. Miscellaneous measurements (water quality)
4. Results of analysis and product format
    a. Statistics

interest to the state archeologist, he will let you know if the area has any sites which must be avoided. Road maps of the entire lignite area are available from the State Department of Transportation and Development.

Through conversations with the Office of Conservation, Louisiana Department of Natural Resources, a lot of data are available from the Philips Coal Company which has the lease on the land where the first major lignite mine will go into operation this year. This information should be made available to the public in the middle of April when the final permit mining application is submitted.

High quality, color infrared, 1979 aerial photographs (9 x 9 inch transparencies at a scale of approximately 1:125,000) have been acquired and cataloged for the entire lignite mining area. Lower altitude, NASA derived, color infrared transparencies (December 1979) at a scale of about 1:60,000 have also been acquired. Four channel multispectial scanner data were also acquired where these second set of photographs were acquired. These digital scanner data have a resolution of approximately 5 by 6 meters on the ground. These data will be invaluable in that they document premining land cover/use data for eventual input into the GIS. Numerous seasonal Landsat satellite images exist for the area since 1972. These multispectral data are at a resolution of 1.1 acres and can provide nearly continuous land use activities in the area over the last nine to ten years. A recent (1979) georeferenced Landsat scene has been ordered and will be classified into various land use class and input to the GIS.

Still more and more data is being compiled as a specific model is being chosen and other agencies get involved and notify us as to the availability of their data.

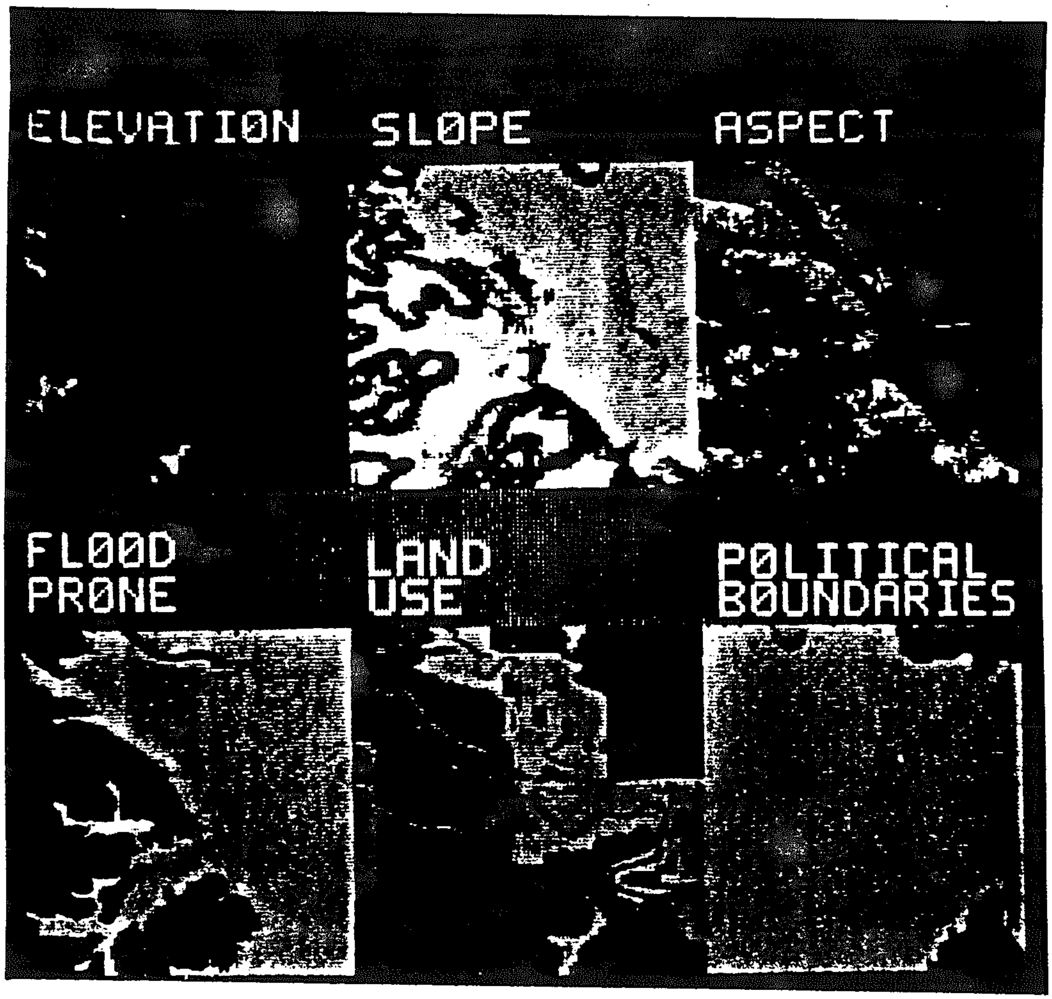


Figure 4. Composite of elevation, slope, aspect, flood prone areas, land use, and parish boundaries.

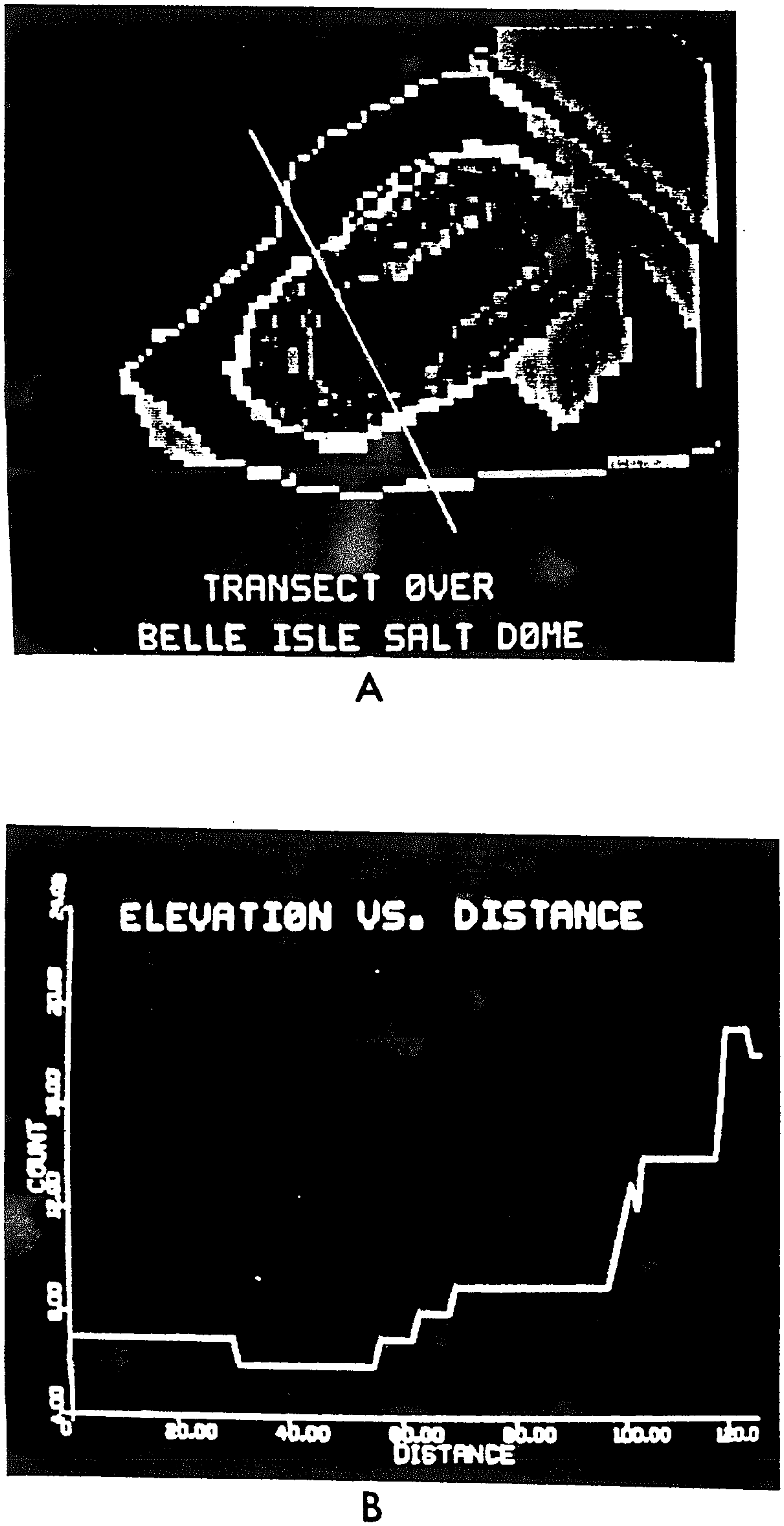


Figure 5. Example of transect capability across an elevation map of a salt dome (A) and an example elevation vs. distance plot (B).

The capability to enter point data such as stream guages was also incorporated into the GIS (Figure 6A). It was determined that during various permitting activities, that user agencies would have to determine data from around a particular area or point. Figure 6B shows a circle with a predetermined radius. This circle could represent a restriction that a certain type of land use (i.e., water body) or habitat could not be within so many meters of a particular site. Table 3 is an automatic computer-generated plot telling the investigator the type of classes within the circle, how many times it occurred, the percentage of each class, and its area in square miles and hectares.

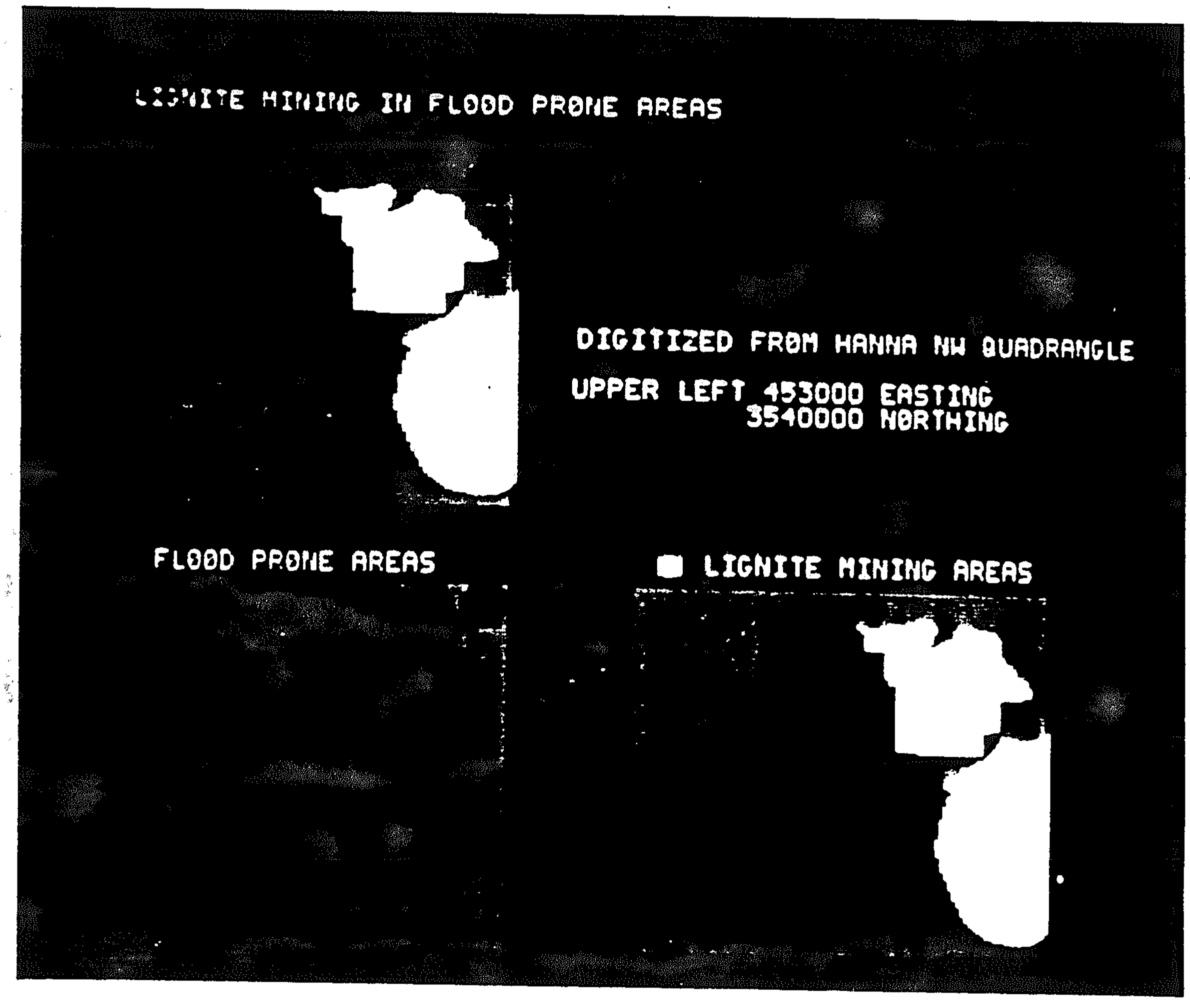
The user can call up and view any map that is in the GIS and he can perform certain functions on each data set. Another capability of the GIS is to combine or overlay the maps. Figure 7 shows a flood prone map (7A) and a land use map (7B). If the user would like to see what land use is in the flood prone areas, the computer produces Figure 7C which is a map of land use in the flood plain. Acreage of each class can also be derived from Figure 7C if necessary. Figure 8 shows a flood prone map (8A) and a map of mine boundaries (8B). The user combined these maps (8C) to see if the mines would need to be engineered to prevent flooding. The answer was yes. The first mines are apparently located in the 100 year flood plain.

Output products can either be the color prints as taken by a 35 mm camera off the color display or a grey map (computer plot) at any desired scale (Figure 9).

Again, these examples clearly demonstrate the potential capabilities of GIS using actual data from the area to be mined for lignite. More direction is needed from the various user agencies to further develop this system into an operational tool.

Table 3. Automatic computer printout of data derived from the point/ circle technique. Can also be used for any other outlined area (i.e., drainage basin, mine site).

	OCCUR.	PCT.	SQ. MI.	HECT.
CLASS 1	432	40	4.0	16.0
CLASS 2	10	1	0.1	0.4
CLASS 3	95	7	1.0	4.0
CLASS 4	7	1	0.1	0.4
CLASS 5	135	15	1.2	4.8
CLASS 6	91	7	1.0	4.0
CLASS 7	72	6	0.8	3.2
CLASS 8	35	3	0.3	2.4
CLASS 9	89	7	1.0	4.0
CLASS 10	370	36	3.0	12.0
CLASS 11	21	2	0.2	0.8



A

B

C

Figure 8. Example of overlay technique, where flood prone areas (A) are overlayed onto plant/mine boundaries (B) to produce a map of facilities in the flood plain (C).

SOME POTENTIAL USES OF A GIS

The following are potential uses for the developed GIS determined through conversations with various user researchers and agency personnel. They, however, do not in any way represent all possible uses.

1. Modeling of various water quality and quantity parameters and interactive viewing and analysis of results.
2. Checking accuracy of model by comparing the model output with actual stream characteristics which are retrieved from the GIS.
3. Quick information retrieval of all surface and ground water information and plotted at any scale to produce overlays for other mapped data.
4. Location of streams and other water bodies with reference to such mapped data as population, land use, rainfall, and mines.
5. Classification of impacted areas during floods.
6. Change detection of any feature where historical maps, photographs, or other data exist.
7. Location of restricted areas through use of overlays that follow certain laws or guidelines.
8. Use for predictive regional planning purposes (i.e., water requirements, changes in land use, sites for disposal facilities).
9. Help locate sampling sites (i.e., stream gauges or model input data-runoff from forested land).
10. Drainage pattern characteristics of an area (i.e., slope, aspect, basin boundary, area and/or land use) and associated stream discharge characteristics.

SUMMARY

As has been stated previously, there are several potentially harmful consequences associated with lignite strip mining operations on surface and ground water supplies of northwest Louisiana. Studies have indicated a tremendous resource potential of lignite in Louisiana. It is estimated that over one billion tons of recoverable lignite exists in Louisiana, which represents approximately 17 percent of the State's known energy reserves. It is anticipated, by the Surface Mining Division of the Office of Conservation, that five lignite surface mining permits will be requested during 1981. Of these, the proposed Oxbow lignite surface mine to be developed by Phillips Coal Company appears to be the one most appropriate for impact studies.

The Oxbow mine will supply fuel to power two 540 megawatt stream-electric generating units which comprise a project proposed by Cajun Electric Power Cooperative, Inc. The proposed mine-mouth power plant is to be located approximately two miles west of Armistead, Louisiana. It is estimated that 150 million tons of lignite are expected to be mined from the Oxbow lignite deposit over a 30-year period.

Some of the most critical limitations on mineral resource development today are related to the effects of mining of water resources. Regulatory agencies and the mining industry are faced with the problems of controlling stream and aquifer pollution, waste disposal, transport of solids by water, leaching of ores and tailing, and water supplies. These problems are not limited to the mining operation itself, but also include those resulting from associated industrial and urban growth.

Increased public concern for the effects of mining operations on the environment, including streams, reservoirs, and ground water aquifers, impacts. By utilizing the proper management tools, i.e. computer models, data can be generated dealing with direct, associated and cumulative impacts of lignite mining activities.

This project has successfully 1) established data requirements needed to study the impact of lignite mining on water resources, 2) evaluated and developed a GIS for merging such data, and 3) evaluated various models that could be used to predict various environmental impacts on Louisiana's valuable water resources.

RECOMMENDATIONS

With regard to evaluating effects of lignite mining in Louisiana on water resources, there is a need to apply the management approaches identified in this project. These management approaches will assist in evaluating the effects on water resources in northwest Louisiana of lignite mining operations through application of a water resource model. It is recommended that the application of a management tool be two-fold. The first step would be to select an appropriate modeling system that would address specific areas of concern and properly interface with the digitized data base being developed. The second step would be to actually apply the selected technique to an active mining area. This will provide a practical demonstration for the selected management tool together with the digitized data base.

It is apparent that the modeling classification which shows the greatest potential for Phase II of this study is the runoff modeling category. This category can be used to assess an impact area relevant to the lignite mining case study. The runoff models also show excellent potential for development of interfacing for all three levels of interaction. This two dimensional nature of the input data makes the runoff

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APPENDIX A

RELATED LEGAL ASPECTS

Numerous federal laws and state programs deal in some way with ground water protection or management.

Existing Federal Ground Water Protection Efforts

The Clean Water Act (CWA). Although there are specific references to ground water in the Clean Water Act, problems in interpretation and enforcement, and lack of resources, have deferred action that would affect ground water. Nevertheless, some provisions of CWA have increased ground water protection. The water quality management program required by Section 208 has served as a catalyst for the development of state ground water management programs. Grants to the states for pollution control programs provided under Section 106 and the creation of coordination mechanisms such as State/EPA agreements have strengthened state abilities in ground water protection.

Safe Drinking Water Act (SDWA). Several provisions of the SDWA relate to ground water protection: One program establishes a minimum standard for injection well design and operation and state program requirements and is intended to protect only ground waters that are current or potential sources of drinking water.

Sole-Source Aquifer Protection Program. Section 1424(e) of the Safe Drinking Water Act protects recharge zones from the federally funded projects that might contaminate them. Non-federally funded projects are not regulated.

The Resource Conservation and Recovery Act (RCRA) of 1976. This Act provides for control of the land disposal of municipal waste and the generation, treatment, storage, and disposal of hazardous waste. EPA

APPENDIX B

EVALUATION AND DEVELOPMENT OF A GIS

A part of this project involved the evaluation and development of a system for processing geographic or map data that would be useful in the management of water resources. In the development of such a system it was felt that the system should be capable of processing a wide variety of pertinent data including point source, map, aircraft and satellite data. The Remote Sensing and Image Processing Laboratory (RSIP) had a basic system for image processing that could be expanded to incorporate the needed functions for processing the additional data. This part of the study focused upon ways to implement the needed expansion. First let us rate the components of our present system.

The system software for the 8/32 computer includes the Dynamic OS/32 MT5 operating system and OS/32 MTM Multi-Terminal Monitor. Dynamic OS/32 MT supports a multiprogramming environment. When used in association with the Multi-Terminal Monitor (OS/32 MTM), it provides for a maximum of 16 concurrent on-line program development terminals. Figure 1 shows the system.

Let us now relate this system to the required functions for geographic data processing.

1. Line Drawing Entry: This will be input using the Talos Digitizer and Camera-Scanning System. The Talos Model 648 Cybergraph converts the physical position of a Pen or Cursor or an activated Digitizer Surface into a digital output. The activated surface on the model 648 is 48 x 36 inches. The Cybergraph system has a resolution of over 1000 points per inch.

2. Annotation Data: This will be input using the CRT's.

3. Image Data: The primary input medium will be the magnetic tape units. Satellite data or airplane data can be supplied in this format.

4. Interactive Editing: The CRT's and the Comtal Interactive Color Display will be used for this task.

5. Archival Storage: The disc drive and magnetic tape devices are available for archival storage.

6. Interactive Analysis: This can be conveniently performed with the Comtal Interactive Color Display. The Comtal has some image processing capability built into the display as well as a graphic overlay feature. The graphic overlay represents a bit plane of solid state memory. Data from this bit plane can be retrieved and overlaid on the digital image as the image is displayed.

7. Image Analysis: A basic image processing system has been implemented. The system implemented has been designed for ease of user operation, ease of integrating new modules and transportability to other systems. The image analysis system can be decomposed into two components, the kernal system and the application modules. The entire system is written in FORTRAN. A part of the system is resident at all times but most of the modules are resident only when a particular application requires them.

a. Kernal System

The kernal system maintains system subfiles and data files. It enables the user to easily access and maintain files. The subsystems central file stores all support information required. The subsystem control file is an index file which stores all non-imagery and applications support information required. The actual information in each

Georeferencing

8. Hard Copy Output: The Varian Statos printer/plotter is a high-speed raster scan device which prints information by sequentially scanning a linear array of styli along a fixed writing head and stepping the paper by an increment equal to the styli separation. These two operations, scanning and stepping are repeated as often as necessary to produce a matrix of dots which represents graphic data and alphanumeric characters.

Before considering the expansion of the existing system it is worth noting that substantial development is being conducted on geographic data processing systems. Many of these groups have been contacted to keep informed of their activities. The existing systems are all different with varying degrees of development and sophistication. They do, in general, have the following characteristics.

1. Commercial systems are better documented and more user oriented.

2. Commercial systems are expensive to buy and usually licensed to one specific user and therefore cannot be transported to other agencies without renegotiating the contract.

3. The source code is not always available to the user with commercial systems. Hence they cannot be expanded.

4. Systems developed at government or university laboratories are meant to be used on the laboratory system and may not be documented or easily transported.

5. Systems developed at government laboratories are available at very little cost but the developers may not provide much help in transporting the system.

WES (Waterways Experiment Station System)

Prior to examining the WES system, reviews of available literature describing the system was conducted. The available literature was sparse and consisted mostly of reports describing usage of the system rather than program documentation. It was discovered in the course of the work that documentation was not available, except program source listings, and it was extremely difficult to identify necessary programs. Personnel at WES were very helpful and such a situation often occurs in similar situations.

Available literature indicated capabilities for processing linear data which we did not discover to be the case. Linear data would be used to represent roads or stream boundaries. A block diagram showing the total structure of the system is shown in Figure 2 (the structure is taken from WES literature).

Spatial or map data may be represented as either polygon or grid. The polygon structure is composed of a sequence of arcs with connecting nodes and attribute information which allows the software package to reconstruct the parent map. The grid structure is a two-dimensional matrix of cells which contain the attribute information for the geographic location bounded by each cell. Each structure has advantages and disadvantages. The most desired capability, would be to analyze and convert data to either form at will.

The WES system handles the grid structure exclusively. Much available data of interest to us, such as satellite and aircraft, are also in grid form. Hence the grid structure is appropriate for our uses.

Several visits to WES were conducted and the following programs were selected for implementation.

TALOS - written by RSIP to perform digitizing.

DGPLT - plots the digitized data to exact map size for error checking.

FACGRD - grids digitized data.

SSPLMVD - plots gridded data.

PRIMMAST - creates geographic data base.

EXTENDER - enlarges geographic data base.

GROW - places attribute information in data base.

DBRE - overlay written by RSIP to convert data base information to ELAS format.

In order to allow one to digitize map data Talos was written by RSIP personnel to collect in the computer the digital point data. DGPLT, a WES program, was converted to our system and is used to plot the digital data in map size to compare with the original map. FACGRD is a WES program that was converted to our system and is used to grid the digital data. The output at the grid stage is block data at some resolution such as 200 meter or 100 meter according to user requirements. The finer the resolution the more expensive the storage and computer processing will be. The data at this time is in UTM coordinates. The program PRIMMAST creates a geographic data base. The data at this point is put on a disc file where the spatial are recorded in UTM coordinates. The program GROW places the attribute information associated with the map in the data base. Attributes are properties associated with each pixel or grid point on the map. Example attributes might be land cover such as water, urban etc. Once a basic data base is created one may want to add additional maps to the data base. These may be maps of a different type e.g. flood plain maps or else maps of an

Upper left UTM: 464000E and 3547000N
Lower right UTM: 470000E and 3542000N

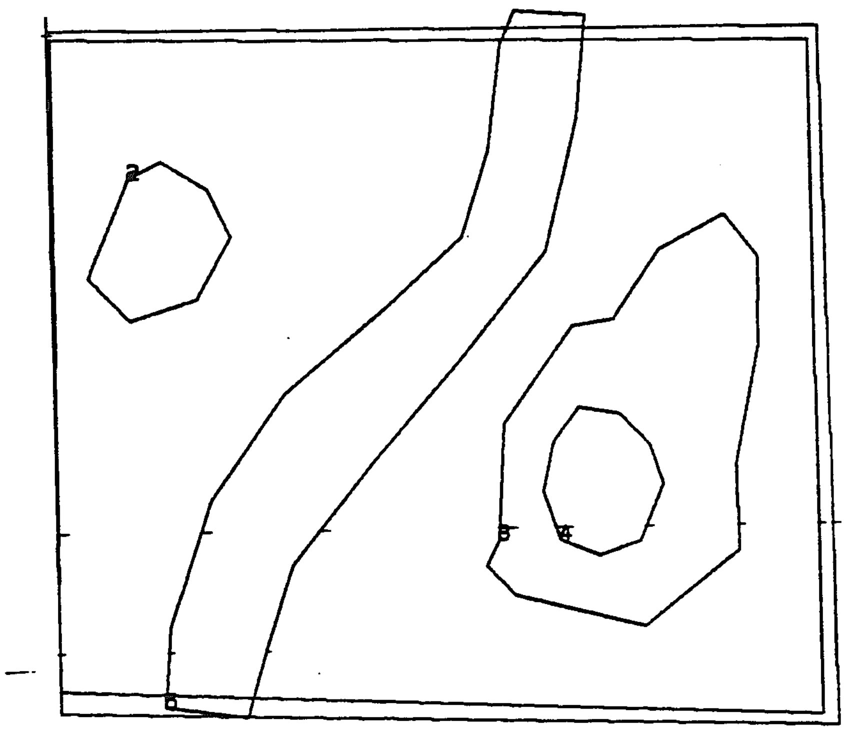

Figure 3. Output after input map has been digitized.

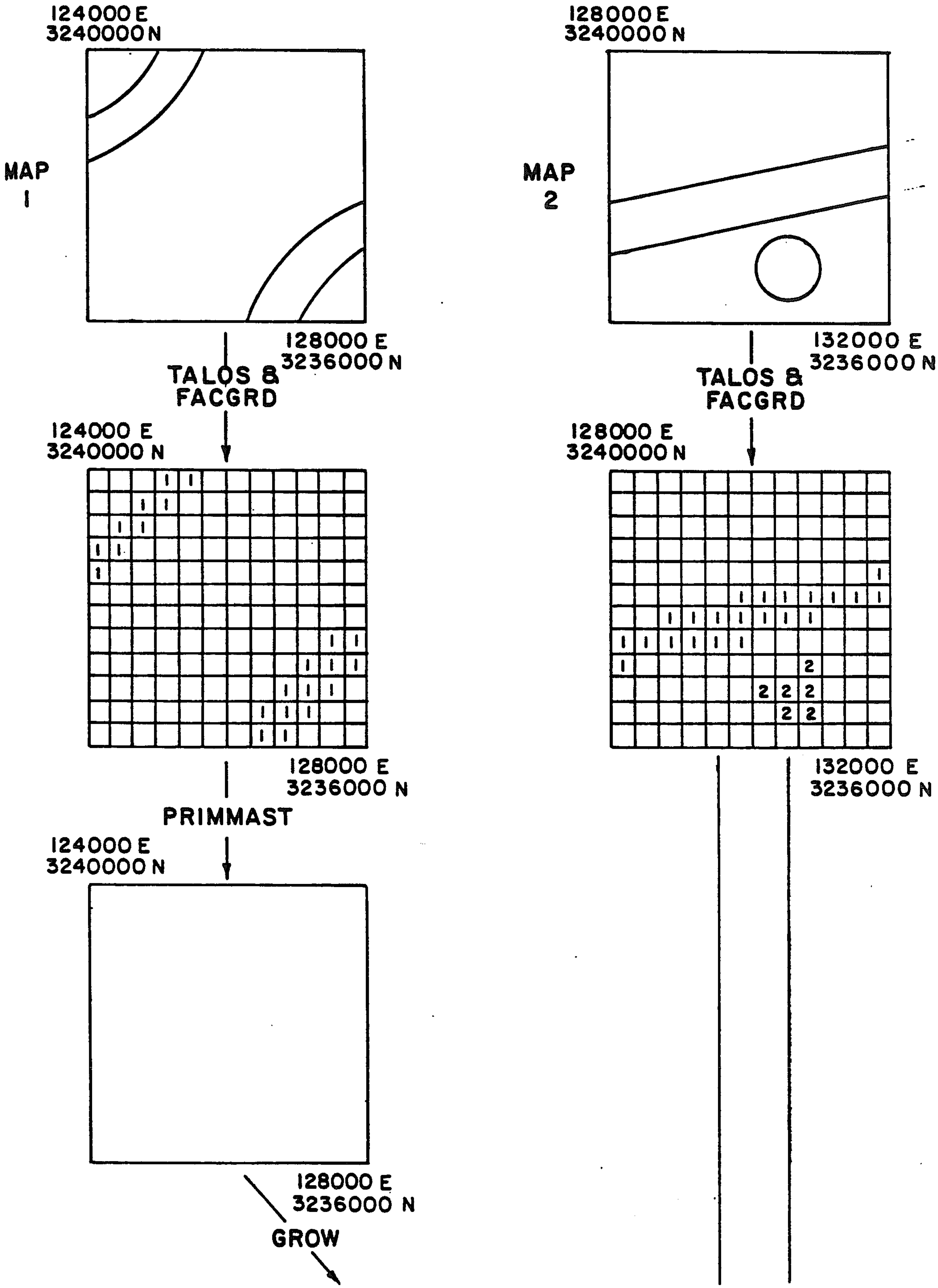

FIGURE 6. INTERACTION OF PROGRAMS TO ENLARGE THE DATA BASE

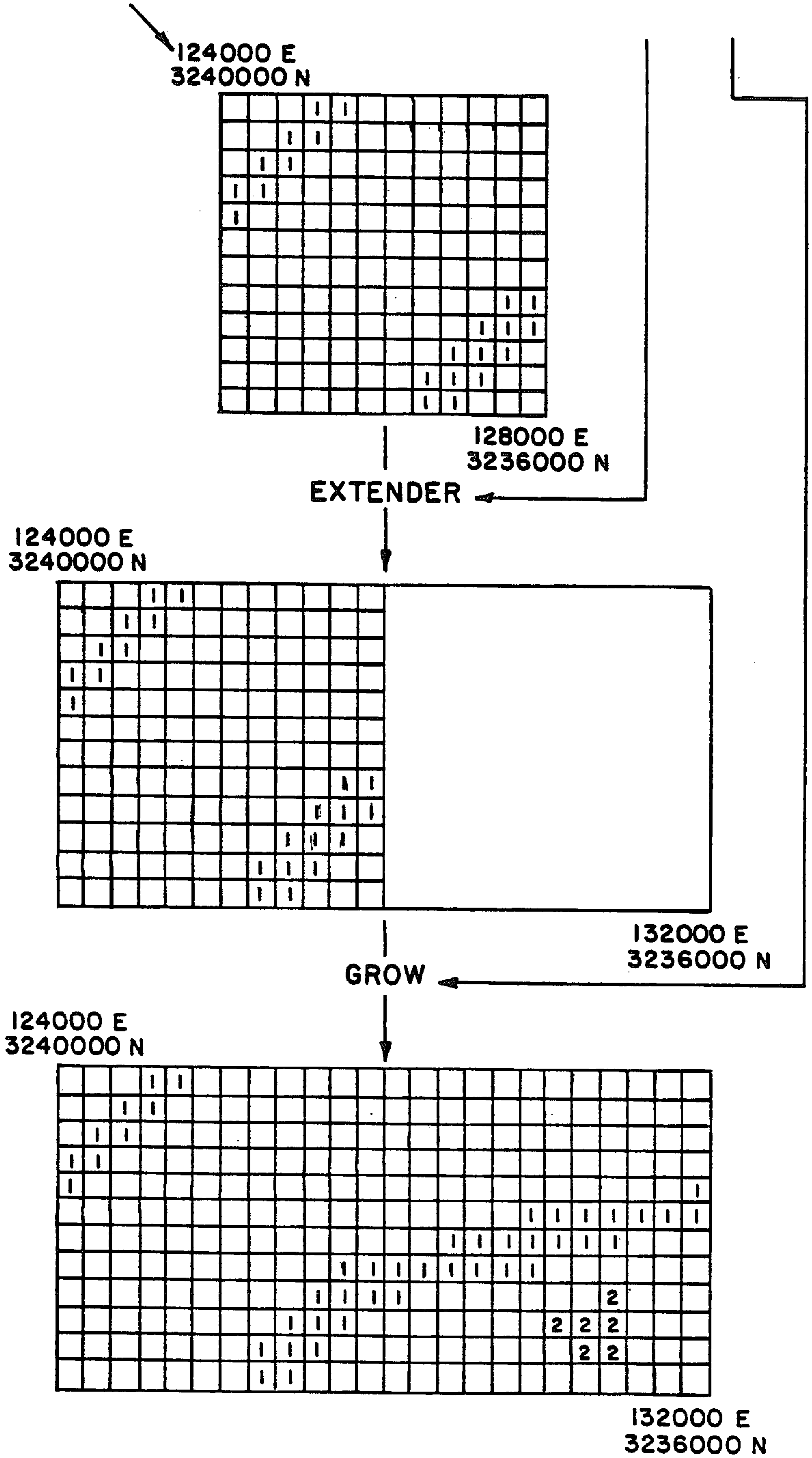

FIGURE 6. (Continued)

U.S. Fish and Wildlife Service System (MOSS)

The MOSS software is currently in use at U.S. Fish and Wildlife Service Fort Collins, Colorado. A CDC-CYBER computer is being used. MOSS is just one of the six components of the Western Energy and Land Use Team (WELUT) system. This system is called EIDA, for Ecological Information Data Analysis. The system has various implementations on Univac and Data General Eclipse computers. The system MOSS is programed in FORTRAN and can be implemented on other machines.

Let us now consider the MOSS system. MOSS has six subsystems:

1. User subsystem for graphic terminal interaction.
2. User language processor subsystem.
3. Data base management subsystem.
4. Data analysis subsystem.
5. Data display subsystem.
6. Data input interface subsystem.

MOSS map data is stored in two types of files. A master file is the type which cannot be modified by a MOSS user. This type of file has a hierarchial directory with each map being indentified by: name, category, subject, item, and legend. A master file contains data in polygon form. The other type of file, work file, can be user modified. It can contain data in either polygon or grid (cell) form.

MOSS Commands

MOSS commands can be divided into five functional groups:

1. General Purpose.
   a. Determine geographic coordinates UTM at any point on the screen.

d. Compute distance between two points by shortest line or by shortest path.

e. Transform data sampled in an irregular pattern to a regular grid.

f. Find union or intersection of maps.

g. Frequency tables.

h. Compute variance, standard deviation, range, mean, lengths, frequency, historgrams, charts, etc.

5. Display.

a. Output map to graphic display terminal, plotter, or line printer.

b. Adjust map scale.

c. Cross hatch shading.

d. Symbol plots.

e. Grid overlay.

f. 3-D historgrams for elevation data.

g. Convert polygon to vector map for display.

h. Generate legends and labels.

As can be seen the MOSS system has extensive capabilities. Many of them parallel or else can be easily added to our existing ELAS system. It is also a large system with possible unforeseen difficulties in implementation unless the hardware is for the system is purchased also which needlessly adds to expenses. A brief comparison of the WES and MOSS software is given in Table 1.

The Wetlands Analytical Mapping System (WAMS), has been considered by the RSIP lab as a possible alternative digitizing package. We have never seen WAMS in operation and draw our conclusions from documentation.

8. WES: No editing capability.

MOSS: Editing capability.

9. WES: It's up££

MOSS: Unknown organization. About 90,000 lines of fortran code. 880 routines. Different parts of the system run on CDC, Eclipse, and Univac machines. Uses Tektronix, Calcomp, IIS and APPS. Uses 192 Mb disc.

10. WES: Merges with Elas. Can use all Elas capabilities.

MOSS: Includes an Elas-like system of its own.

11. WES: Not documented.

MOSS: Documented.

polations to determine data values for missing grids and three-dimensional display.

We are continuing to evaluate these and other software packages. One possible solution might be to upgrade the present WES system to include editing, reduce required memory and disk storage, and add the capability to outline point and linear features. Additional functions might also be programmed into the present ELAS system to more effectively answer GIS-oriented questions. Improvement of our present system has the advantage of maintaining continuity with our other data processing activities. For instance, Landsat data can be geographically referenced, classified to produce land use information and then automatically registered and overlayed with digitized data for analysis. We have requested the source code to MOSS and WAMS to determine whether desired functions may be added to WES/ELAS without implementing their entire systems.

APPENDIX C

MONITORING AND REGULATORY USES OF GIS

1. Use satellite imagery, aircraft imagery and computer system to:
   a. Monitor and record large scale changes in the lignite impacted area.
   b. Identify and map sediment discharges from surface mines.
   c. Identify, map, and compute for a given mine, the acreage of active pit, spoil ridges, final graded terrain, revegetated terrain, roads, power lines, sedimentation ponds and land cleared immediately in advance of the pit.
2. Use of GIS to:
   a. Digitize existing maps of surface mines showing roads, soils, historical land use, ground water, lignite isopachs and crop lines, premining terrain and postmining terrain, slurry walls, conveyor belts, drainage diversions, excess spoil piles, siltation ponds.
   b. Using appropriate selection criteria display and or plot any one or combination of the files identified in (a) above.
3. Use aerial photography to:
   a. Review historical land use over the past ten years in mine plan areas.
   b. Study mine plan areas during the permitting process.
   c. Identify lands unsuitable for mining such as Indian mounds.

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