APPENDIX I

REGIONAL EXAMPLE SHOWING BASELINE INFORMATION FOR GEOLOGY AND HYDROLOGY

MID-CONTINENT SITE

The number of locations at which site-specific baseline data for geology, overburden, surface water and ground water needs to be collected depends on many variables. Rather than presenting and attempting to rationalize minimum or maximum numbers and locations for surface-water stations, boreholes for overburden data, ground-water observation wells and frequency and duration of water sampling, we have included summaries of baseline information for geology and hydrology as it exists in planned or actual permits. We refer to these summaries as regional examples of baseline data requirements. In this context, regional can refer to hydrologic issues as may exist in one region but not all regions of the country and for which precise kinds and amounts of data are needed to establish, for example, the potential for acid mine drainage formation. Regional may also refer to differences in philosophy and technical approach to sampling and standards deemed acceptable for baseline geology and hydrology information from one state or region to another.

The three examples of baseline information collection from different regions of the country are presented in Appendices H, I, and J.

- The eastern permit example which is presented in Appendix H represents an area surface mine in a temperate humid region.
- The following mid-continent permit example represents an area lignite mine in temperate continental region.
- The western example which is presented in Appendix J summarizes an actual work plan for baseline data collection for an area mine in a semiarid region. The plan was developed by the operator in close cooperation with the RA. The work plan illustrates how the need for new ground- and surface-water stations and data collection was based on an evaluation of existing information from nearby mines.

The Mid-Continent Region (MCR) Mine example is an area lignite mine that is expected to encompass more than 20,000 acres over the projected life of the mine. The MCR Mine is located along the border of Leon, Limestone and Freestone Counties in Texas. Surface mining began in 1985 and is scheduled to continue until approximately the year 2018. The most recent permit action was a 1994 permit renewal including approximately 2580 new acres. The renewal involves a continuation of the mining operation from area A into area B utilizing a single dragline operation. In area C, a single dragline operation will continue, alternating between the north and south end of the pit. In area D, a bucket wheel excavator with an around-the-pit conveyor will be utilized in conjunction with a single dragline operation. Dewatering activities will continue as in previously permitted operations for areas A/B and C and in advance of the excavation in area D. In all areas, topsoil substitution is being requested.

The permit area is characterized by gently rolling hills dissected by dendritic drainage patterns. Surface elevations prior to mining ranged from about 550 feet on the divide between the Brazos and Trinity River Basins to about 350 feet along the east permit area at Alligator Creek. The surface water drainage divide separating the Brazos River Basin on the west and the Trinity River Basin on the east generally coincides with a massive sand channel which divides the permit area into west and east portions. See Figure I-1 for location of MCR and two other active mines, MCR 2 and MCR 3, in relation to major drainage features in the area.

The highest areas in the western portion are in the central area and result from the presence of erosion resistant remnants of iron-cemented sand and mud units capping relatively loose sand deposits. The lowest portion in the western area is in the vicinity of the Lambs Creek and Mine Creek tributaries of Lake Limestone. Surface drainage from the western portion of the Permit area is in a westerly direction toward Lake Limestone and the Navasota River. Principal tributaries are Lambs Creek and Mine Creek which drain to Lake Limestone. A small portion is drained by tributaries of Birch Creek which flows into the Navasota River downstream of Lake Limestone. The Navasota River flows into the Brazos River about 80 miles downstream of Lake Limestone.

The highest areas in the eastern portion are in the north area, also resulting from the presence of erosion resistant remnants of iron-cemented sand and mud units capping relatively loose sand deposits. The lowest portion in the east area is in the southeast where the tributaries draining the eastern Permit area flow into Alligator Creek. Surface drainage from the eastern portion of the permit area is in a southeasterly direction. Principal tributaries are Silver Creek, Rena Branch, the upper reaches of Buffalo Creek and several unnamed tributaries. All of this area drains to Alligator Creek which drains to the Trinity River about 25 miles downstream.

A. Geology

The permit area is in the Gulf Coast Basin, an extensive gulfward-dipping homocline. Locally, the region is broken by Tertiary fault systems, which reflect gulfward subsidence and moderate uplift to the west. The East Embayment, a structurally low area roughly parallel to the Sabine Uplift, extends to the northwestern corner of Leon County where surface and subsurface units dip and thicken toward the center of the Embayment. Domal structures, generally related to

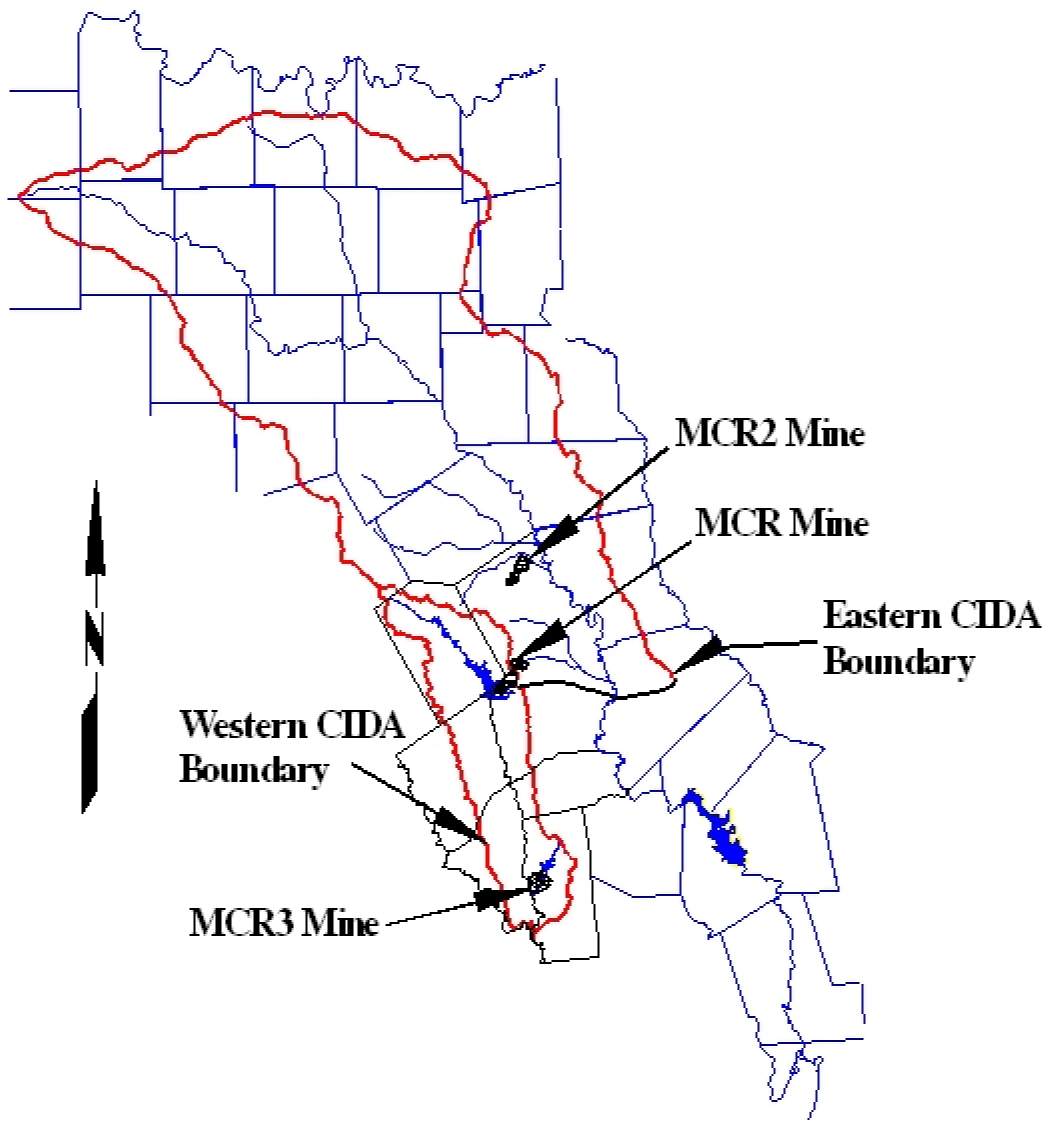

Figure I-1. Location of MCR and two other active mines, MCR 2 and MCR 3, in relation to major drainage features of the Navasota and Trinity River basins.

salt intrusions, are located along the axis of the Embayment. Over most of the permit area, the structural characteristics are generally consistent with the regional framework. Formations strike northeast to southwest and dip about 1^0 to the southeast (Gulfward). Structure mapping of the lignite seams reveals local undulations that depart from the regional dip and are thought to be the result of differential compaction of the sediments.

The permit area lies in the proximity of two systems of faults. The Mexia-Talco Fault system is located to the northwest and trends north-northeast. (Baker and others, 1963; Fogg and Kreitler, 1982; and Jackson, 1982). The Mexia-Talco Fault Zone is a series of echelon faults that coincide with the updip limits of the underlying Jurassic Louann Salt (Kreitler and others, 1980). Jackson (1982) agrees that the location of the Mexia-Talco Fault Zone was controlled by the updip limit of the Louann Salt and also suggests that it was partly controlled by Triassic rift faults. Thinning of the Louann Salt over the Sabine Uplift indicates that it was probably a positive feature before Louann Salt deposition and has remained so throughout geologic time (Kreitler and other, 1980). The Mexia-Talco Fault, which commonly dips from 45^0 to 65^0 with displacement up to 1000 feet at the top of Cretaceous, forms a graben complex.

The Elkhart-Jarvis-Mount Enterprise Fault System lies to the east and trends east. Keritler and others, (1980) also suggest that the Elkhart-Mount Enterprise Fault System was a structurally elevated relict shelf edge on the Gulf Coast Basin. The formations in the Wilcox Group generally strike northeast. The regional dip ranges from about 50 to 100 feet per mile, increasing to the southeast (Behout and others, 1976).

Geologic units of particular hydrogeologic importance at the permit area are the Upper Calvert Bluff Formation of the Wilcox Group and the overlaying Carrizo Sand of the Claiborne Group. The primary surface sediments mapped at the permit area are the Carrizo Formation and the Wilcox Group of Eocene Age. Alluvial deposits associated with recent drainage systems are also present. Geologic units relevant to the current investigation include: Quaternary alluvium and terrace deposits and the formations of the Wilcox Group.

The Calvert Bluff Formation of the Wilcox Group and the Carrizo and Reklaw Formations of the Claiborne Group are the principal geologic units which crop out within and immediately adjacent to the MCR Mine area. Minor exposures of Quaternary alluvium deposits occur along stream valleys in the area, but these deposits are very thin and discontinuous. These alluvial deposits occur to a greater extent along the major river valleys and tributaries of the Navasota River to the south and west and the Trinity River to the east and north.

The upper part of the Calvert Bluff Formation crops out in about half of the surface area of the MCR Mine. The Calvert Bluff occupies mainly the lower elevations of the northwestern portion of the mine area, giving way to the generally greater relief, higher elevation sand hills of the Carrizo Formation in the southeastern area of the mine. As much as 300 feet of upper Calvert Bluff section is observed in the deeper grid holes drilled in the MCR Mine area. Kaiser and Black (1978) interpreted the depositional setting of the Calvert Bluff Formation as the transition zone between the lower alluvial plain and the upper delta plain.

The Calvert Bluff Formation consists of the following sediment types as observed in continuous cores CC-1 through CC-20: gray to dark gray to olive gray silty clays, occasionally containing thin laminae of silt or silty sand; dark gray to dark grayish brown carbonaceous and lignitic clays, with varying amounts of silt, carbonaceous material (carbonaceous plant fragments and remains, and lignite laminae) and pyrite; gray to dark gray silts with varying amounts of clay, sand and carbonaceous material; very fine-to fine-grained silty sands with varying amounts of clay, sand and carbonaceous material; very fine- to fine-grained silty sands with varying amounts of clay; fine- to medium-grained clean sands with varying amounts of silt. Accessory minerals present include limonite, pyrite, various opaque (dark) minerals, muscovite mica, glauconite, and gypsum. Lignite and carbonaceous fragments are also commonly found. Moderately to highly indurated, iron-cemented silts and sands with ferruginous concretions occur in the oxidized zone in many parts of the area. Pyrite occurs as irregularly shaped modules and disseminated grains in sediments and as nodules, fracture-fill, veins, and disseminated grains within lignite seams. The pyrite is typically found within the reduced zone. Occasionally beds of sand or silt with siliceous or calcareous cement are present.

The Carrizo Sand crops out over about a third of the surface area of the MCR Mine. Carrizo outcrops occupy slightly higher elevations than outcrops of the Calvert Bluff, as evidenced by the increase in average elevation from the northwestern to the southwestern parts of the permit area (downdip). The Carrizo exists as moderately steep sand hills in its outcrop area, either in the form of continuous ridges or isolated hilltops. The Carrizo reaches a maximum thickness of about 120 feet in the permit area and is generally about 80 to 100 feet thick.

1. Data Collection Activities For Geology and Overburden

The geology description is based on data collected through grid drilling, continuous coring, and laboratory analysis of overburden, interburden, and underburden stratigraphic intervals. Grid drilling and logging began in the late 1970's and continued as necessary, through the present. An approximate chronology of continuous core collection is summarized in Table I-1 below.

Table I-1. Chronology of Core Collection

Mine Area	1986	1987	1989	1991	Total
A	3	5	5	6	19
C	3	6	4	2	15
D	3	8	8	3	22
Total	9	19	17	11	56

The cores were described in the field by a geologist and analyzed for a variety of physical and chemical parameters of interest in mining reclamation. The core descriptions along with geophysical logs of core holes were used to map the subsurface geology. Geologic descriptions of selected physical and chemical characteristics were included in the permit application.

Grid drilling and geophysical logging at the MCR Mine began in the late 1970's and has continued through the present. For this permit renewal application about 1,437 grid hole logs plus the information from 56 continuous cores were the basis for the characterization of the geology and oxidized zone within the MCR Mine.

Grid holes are normally drilled and logged about 10 to 20 feet below the deepest minable lignite seam. The grid holes were drilled under the supervision of an qualified geologist who logged the samples. A combination of natural gamma, gamma-gamma density, caliper and single point resistivity logs were run in each hole.

a. Core Drilling

Continuous cores were collected at 56 sites within the MCR Mine for the purpose of (1) characterizing the physical and chemical properties of strata down to and including the strata directly below the deepest minable coal seam, and (2) identifying the oxidized zone.

Coring was conducted with Failing 1250 and Failing 1500 hydraulic rotary rigs (using a Failing CFD-1B, mud rotary, drilling rig). Due to poor access and wet conditions some cores were completed with an Ardco buggy rig. Core locations were stalked and surveyed before the coring program.

Typically, after moving to a core location, a pilot hole was drilled 10 feet below the expected depth of the core and geophysically logged. A suite of logs including natural gamma, gamma-gamma density, resistivity and caliper were run in the pilot hole. Geophysical logging was performed by a private Geophysical Company.

After completion, the pilot hole was plugged according to the procedure specified by the RA, and the rig was moved about ten feet to begin the continuous core. The initial 10 to 15 feet of continuous core were collected with Shelby tubes and mechanically extruded. The remainder of the core, to a depth of 10 to 20 feet below the base of the deepest minable coal seam was obtained with a 4 3/4 inch diameter, ten-foot long, Christiansen core barrel with a 3-inch diameter, split-inner barrel or continuous barrel.

After a single core run, the inner barrel was removed and opened. The core was shaved (cleaned of drilling mud), measured, and percent recovery was calculated. Major lithological contacts were identified and measured before the core was transferred from the inner barrel to a PVC core trough. The core was then described by a geologist. Field analysis of the core included description of texture (grain size), color (Munsell color chart), dominant and subordinate lithology, roundness and sorting of grains, matrix quality and composition, major and accessory minerals, cementation, and sedimentary structures.

b. Overburden Sample Compositing

Core sample intervals for laboratory chemical and physical analysis were chosen in the field using lithologic character and geophysical log signature. Individual sample intervals varied from less than one foot to about ten feet, averaging about four feet. After intervals were chosen and described, representative samples were placed in plastic bags, sealed and delivered for laboratory analysis. Laboratory analytical methods for each parameter and the laboratory reports are discussed below.

After completion of the core, the drilling rig was moved. The hole was geophysically logged (using the same suite of logs as for the pilot holes) and plugged according to the procedure specified by the RA. The overall core recovery for the 56 cores was 90 percent or greater for each core including the re-cored intervals.

c. Laboratory Analysis

A number of tests were performed in the laboratory on samples of the overburden material collected during the coring program. The procedures used for the individual tests identified below were listed in the permit application. The tests were for overburden materials in general and for native soils or units proposed for soil substitution. The parameters included:

pH
electrical conductivity (EC)
Calcium (Ca)
Magnesium (Mg)
Potassium (K)
Sodium (Na)
Sodium adsorption ratio calculated (SAR),
Bicarbonate (HCO_3)
Carbonate (CO_3)
Chloride (Cl)
Sulfate (SO_4),
Cation Exchange Capacity (CEC)
Exchangeable bases calculation
Extractable bases
Texture/classification
Exchangeable Aluminum (Exch Al)
Base saturation percent (BS %)
Available nitrate (NO_3-N)
Available phorphorus (P)
Available potassium (K)
Available trace elements (copper, iron, manganese and zinc)
Exchangeable acidity (EA)
Pyritic sulfur
Potential acidity calculation (PA),
Neutralization potential (NP)
Inorganic carbonates (IC)
Acid base accounting calculation
Arsenic (As)
Boron (B)
Cadmium (Cd)
Chromium (Cr)
Copper (Cu)
Lead (Pb)
Manganese (Mn)
Molybdenum (Mo)
Nickel (Ni)
Selenium (Se)
Zinc (Zn).

d. Data Presentation

The data were presented in a series of tables for each core hole that listed parameter values, sample interval, and laboratory number. For example, a core from location 640/270 CC1 showed the total depth was 212 feet and 43 samples were collected, an average of one sample for every five feet. The actual sample interval ranged from as little as one foot to as much as 11 feet. In this example, each of the 43 samples included analyses of sand, silt and clay fraction and texture, pH, NP, Total S, CEC, Inorganic CO_3, Pyritic sulfur, Pot acidity, Exch acidity, A/B, CEC, EC, Ca, Mg, K, Na, SAR, Avail P, Avail K, Cd, Se, and values for total As, B, Tot Cd, Cr, Cu, Mn, Ni, Pb, Se, Zn, U and V.

Summary diagrams of selected physical and chemical characteristics were prepared for the 56 continuous cores within the MCR Mine. In addition to the geophysical logs, the diagrams include: a lithologic column based on the geologist's field description, sample number and interval, textural data, Soil Conservation Service (Natural Resources Conservation Service) soil textural classification, pH, EC, percent pyritic sulfur, NP, and an identified stratigraphic unit.

The geophysical logs are used to correlate physical and chemical characteristics of the different sedimentary units as the tool is slowly brought up from the bottom of the core hole to ground surface. The logs consisted of natural gamma ray, gamma-gamma density and single point resistivity.

B. Surface-Water Baseline Data

1. Lakes and Impoundments

USGS 7.5 minute topographic maps depicting pre-mine conditions of the area were examined to identify the locations of surface water bodies. In addition, Leon, Limestone, and Freestone County maps from the Department of Highways and Public Transportation provided information on surface impoundments constructed since 1964.

Lake Limestone, a 225,400 acre foot capacity reservoir, is located adjacent to the western boundary of the area. The lake is impounded by a dam on the Navasto River in Robertson, Limestone, and Leon Counties. The purpose of Lake Limestone is to "conserve and develop the water resources of the upper Navasto River in order to provide dependable water supplies to meet municipal, domestic, industrial and agricultural needs in the area of the upper Navasto watershed and in the lower Brazos Basin and adjoining coastal areas downstream of the project. The most urgent immediate need is for water for cooling of steam-electric generating facilities to be built in the upper Navasto watershed, where extensive deposits of lignite will be utilized to replace dwindling gas and oil supplies as a source of fuel for production of electric energy" (U.S. Corps of Engineers, 1976).

The total drainage area of Lake Limestone is about 674 square miles. The only major impoundments within the drainage area are Lake Mexia on the Navasto River about 100 river miles upstream of the Sterling C. Robertson Dam, and Lake Springfield downstream of Lake Mexia. The total drainage area above Lake Mexia and Lake Springfield are about 198 and 238 square miles, respectively. Lake Mexia impounds 10,000 acre-feet and is used as a source of water supply for the City of Mexia and the Mexia State Park.

There are over 400 naturally occurring or man-made ponds found throughout the area. Surface areas of these ponds range from about 0.1 acre to 30 acres, with water depths ranging from a few inches in some naturally swampy areas to more than ten feet in some of the larger man-made impoundments.

The majority of man-made ponds are located in headwater areas, gullies at lower topographic elevations, or excavations at the base of hillsides. Many of the man-made ponds are constructed utilizing earthen embankments. Many of the ponds on tributaries of named streams are constructed in series. Natural ponds are found in low swampy areas along streams and creeks and in isolated depressions scattered throughout the area. The normal substrate in these natural ponds is usually a sandy mud.

With the exception of those impoundments constructed for the oil and gas activities and sedimentation ponds associated with the current active mining, most ponds are used for hunting, fishing and livestock watering.

2. Seeps and Springs

The available literature identifies several springs located near the area (Brune, 1981). Ground-water discharge furnishes water to both the Navasto River and Trinity River Basins. In the outcrop of the aquifer, the water generally moves from higher elevations toward the lower elevations of the creeks and rivers.

3. Area C Streamflow Investigations

Baseline surface-water data was obtained from USGS records and a monitoring program to collect hydrologic data for the MCR Mine established in October 1986. Data collection activities for this hydrologic investigation included the installation of 14 crest gauge stream monitor stations and installation of one continuous recording stream monitoring station with companion rain gauge. Nine of the 14 stations were in watersheds unaffected by mining. The remaining five stations were located in watersheds in which some portion was disturbed by active mining during the monitoring period or had some portion in a reclaimed condition. Photographs of these stations were included in the permit application.

Monthly sampling of the surface water and instantaneous stream stage measurements were made at the 14 stream monitor stations in addition to three locations on Lake Limestone. One-time surface-water sampling was conducted at 20 pond locations located in or adjacent to the area. Photographs of the one-time monitoring stations were included in the permit application.

4. Continuous Streamflow Monitoring

A continuously recording stream gauging station was installed on Lambs Creek where it crosses the Renewal Area boundary. This station monitors a drainage area of about 3050 acres which is about 19 percent of the entire Lambs Creek drainage area. About 2540 acres of the monitored area is within the Renewal Area which is about 12 percent of the entire area.

a. Sampling Procedures

The discharge at the continuously recording station was measured on a monthly basis using the same methods as the crest gauge stations. These discharge measurements, in which the stage height at the time of measurement is recorded, were used to develop a rating curve for the station. The rating curve is based on limited low-flow data to define the preliminary relationship between stage height and flow. Hydraulic principles were used to further extrapolate the rating curves for gauge heights greater than those measured in the field. For the continuous stage station, the stage data was reduced to flows and the rating curve was then used with the electronically recorded time versus stage data to develop the preliminary continuous hydrograph (time versus discharge) for the station.

b. Recording Rain Gauge

A continuously recording rain gauge was installed upstream of the continuously recording stream monitoring station (SW-12) in the Lambs Creek watershed. The rain gauge consists of a tipping bucket gauge and an Omnidata DP101 Datapod Recorder. The gauge is mounted on a steel platform supported by a concrete anchored six-foot piece of five-inch O.D. steel pipe. Adjacent to the pipe's anchor is a wooden cellar in which a water-tight housing for the recorder is stored. The subterranean location of the data recorder was necessary to maintain a suitable operating temperature. Rainfall data was recorded at one-minute intervals.

5. Periodic Streamflow Monitoring

a. Description of Monitoring Stations

Fourteen crest gauge stream monitor stations were installed at various locations throughout the C Area. The locations of these stations were selected based on delineation of drainage basins within the area, site accessibility, channel shape and reach, and channel stability. The cross sections of the stream channels were surveyed at each of the crest gauge monitor stations by mine personnel. The watersheds monitored ranged in size from 27,700 acres to 523 acres. Plots of the stream cross sections for the 14 crest gauge monitor stations are provided in the permit, and the stage reference point for each station refers to the elevation of the bolt on the typical crest gauge installation.

Installation of the crest-gauge structure entailed the digging of a 6- to 10-inch diameter hole about three feet deep near the channel edge. A 5-foot section of 2-inch O.D. galvanized pipe with a 3-foot length of 2-inch O.D. threaded, galvanized anchor was placed in the hole followed by enough concrete around the anchor to reach ground level. A removable redwood measuring staff was placed inside the gauge pipe. A bolt through the pipe about 5 inches above ground level was used as a support for the measuring staff. Powered cork was placed inside the gauge pipe and a galvanized threaded cap was screwed on the top of the pipe to keep the staff in a fixed position. As flow occurs in the stream, the powdered cork rises to the stream stage and is deposited on the redwood staff. The crest gauge is read by noting the highest occurrence of cork on the staff, indicating the highest stream stage that has occurred since the last monitoring visit. The instantaneous stream stage occurring during a sampling visit could also be measured by one-tenth of a foot increments painted on the exterior of the gauge pipe.

b. Sampling Procedures

On a monthly basis, field personnel visited each station and measured the instantaneous discharges. At stations where the flow was low and somewhat controlled such as a pipe culvert, a stopwatch and bucket of known volume were used to measure the flow. Where flow or stream channel conditions made this method impractical, a velocity meter was used to measure stream velocity. Velocity and flow depth measurements were made with the velocity meter on one-foot wide increments along the stream channel cross section.

Velocity readings were taken at sixty percent of the flow depth to represent the average velocity. Based on the incremental width, velocity, and flow depth, the flow rate for each increment was accumulated to get the total flow rate for the stream. When wading into the stream was considered unsafe due to higher stages and velocities, the discharge was computed from a velocity measurement at the bank times the cross-sectional area of the stream. The depth which was measured at the point of velocity measurement was used to estimate the corresponding cross-sectional area from the stream cross-sections developed from surveying when the stream was dry. The instantaneous stage height of the stream was also measured, and the maximum crest stage since the last inspection was noted.

Streamflow information for the area is composed of monthly streamflow measurements. Monthly streamflow data at the area were collected. The streamflow data are composed of a measured flow rate and stage at the time of monitoring and a stage crest since the previous monitoring visit.

5. Regional USGS Stream Gauging Stations

There are no long-term historical gauging stations on the streams potentially impacted by mining. Therefore, a regional approach was also used to estimate runoff characteristics for a receiving stream. This approach involved the extrapolation of data from gauged watersheds influenced by similar hydrometerology and sharing similar physiographic, soil and vegetational characteristics as the receiving stream watersheds. The records of the USGS were reviewed for streamflow gauging stations in the vicinity of the area. The criteria used in the selection of stream gauge data for the regional streamflow characterization of the receiving streams are: first, the period of record of the historical data should be sufficiently long to include both wet and dry periods; secondly, the drainage area upstream of the gauge should be on the same order of magnitude in size as the receiving streams; and finally, the gauged data should not be influenced by large upstream regulations or diversions.

6. Surface-Water Quality

Water quality data were collected on a monthly basis from October 1987 through July 1988. Five stream monitoring stations received untreated and/or treated runoff from disturbed or active mine areas during the monitoring period. The water quality analyses of samples taken at these sites will not be discussed in terms of characterizing the baseline surface water quality conditions for the renewal area.

Monthly water samples were also taken at three Lake Limestone monitor stations. Water quality samples were collected at the monitoring stations to determine representative water quality. The water quality parameters of the samples include and exceed those specified in the Regulations. Temperature, pH, specific conductance and dissolved oxygen were also measured in the field.

The samples collected by the mine were prepared as follows. Each sample was divided into four subsamples which were prepared for laboratory analysis according to the parameters to be analyzed. One subsample was filtered through a 0.45 micron cellulose acetate filter using a positive pressure (peristaltic) pump and acidified with nitric acid. The other three subsamples were left unfiltered. Reagent grade nitric acid to one subsample and sulfuric acid was added to another subsample. The fourth subsample was not acidified. The sample bottles were labeled with the following information: date, sample identification, type of aliquot (e.g. filtered preserved with type acid) and the initials of the sample collector. The sample containers were then packed in ice and shipped to the laboratory within 24 hours of sample collection.

7. One-Time Water Quality Sampling

To more completely characterize the quality of surface water in the area, the sampling program included a one-time sampling of surface-water bodies. The sampling sites were selected based on the size of water body, land access, and location of the site in relation to the permit application. Sampling procedures were similar to those used to collect the monthly surface-water samples, as previously discussed.

C. Ground-Water Baseline Data

1. Water-Level Measurements

Ground-water levels have been monitored at the C Area since 1985 for the long term monitoring wells, unless the well was mined through or otherwise destroyed. Water levels were generally measured in those wells on a quarterly basis.

2. Water Sampling and Chemical Analyses

Ground water has been sampled from various wells at the C Area since 1986. Samples were usually obtained after pumping the well until at least three casing volumes of ground water had been removed and the water temperature, conductivity and pH had stabilized. Field filtration and preservation were done, if necessary, at the time of sampling. Sample bottles were labeled, put on ice, and delivered to the laboratory.

The ground-water chemistry parameters analyzed most frequently during the various field programs within area C were carbonate, bicarbonate, chloride, sulfate, calcium, magnesium, sodium, potassium, pH, conductivity, and total dissolved solids. Methods used to analyze these parameters, as well as methods used to analyze other ground-water chemistry parameters investigated at the mine were documented in the permit application. Results of the field and laboratory analyses for wells at the C Area are presented in the permit.

3. Hydrogeologic Testing

Aquifer tests have been conducted at 22 locations within area C. Test programs have included pump tests and slug tests. All pump tests were constant-discharge and recovery tests. The slug tests were performed by dropping a sand-filled section of PVC pipe into the water column of each well. Results of the aquifer and slug tests conducted and analyzed by the mine, as well as descriptions of the geologic units being tested, are summarized in the permit application. Results of other aquifer tests not analyzed by the mine are presented also in the permit application. Details concerning specific hydrologic testing at the mine are provided in the following section.

Twenty two aquifer tests have been included in the C area. Aquifer test summary sheets and selected graphical plots from tests analyzed by the mine are provided in the permit application. The mine has conducted and analyzed twelve aquifer tests in the C Area.

4. Water Well And Oil And Gas Well Inventories

In 1987 the MCR mine conducted a combined field investigation, literature review and records search in order to update the 1979 water well inventory that was submitted with the 1983-1989 mining permit application. In June and July of 1992 they conducted another literature review and records search to update the 1987 well inventory. In addition to field verification by Northwestern, the following sources were used to obtain information about water wells in and within one mile of the proposed permit area: State Water Commission, Mine Company, State Department of Health and the State Water Development Board.

The 1979 State Department of Health inventory identified 118 wells within one mile of the permit boundary; the 1987 update identified 146 additional wells; and the updates in 1992 identified another 44 wells. Well locations and the well inventory are included in the permit application.

5. Hydrogeology

Principal sources of shallow ground water in the region of the MCR Mine area C include the Newby Sand of the Reklaw Formation, the Carrizo Sand, and sand units in the upper portion of the Calvert Bluff Formation. Ground-water velocities and flow directions in these hydrogeologic units are highly variable across the area and are dependent in part on the geometry and hydraulic properties of water-bearing zones. The areal extent and thickness of sand units vary considerably over the area, and different degrees of interconnection exist between the sands. On a local scale, ground-water flow is likely to follow a more variable path than suggested by the general direction of flow indicated by water table and potentiometric contour maps.

Ground-water flow directions within the permit renewal area were evaluated on the basis of water level measurements taken in monitoring wells located throughout the mine area. The historical water level data are presented in the permit application. Three water level maps were constructed using data from the second quarter of 1992. Water level measurements from shallow monitoring wells were used together with a topographic map to construct a map of the approximate water table elevation for the unconfined overburden. Measurements from monitor wells completed in the overburden interval between the L4 and L6 lignite seams were used to construct a confined overburden (interburden) potentiometric map. Measurements from monitoring wells completed beneath the L6 seam were used to construct an underburden potentiometric map. A list of wells that were monitored and their zone of monitoring is provided in the permit application.

6. Hydraulic Properties

The hydraulic properties of the geologic units within the C area were estimated from monitor well data and the results of a series of aquifer tests of selected sand intervals. Aquifer tests were not performed in one geologic formation because it covers only a small part of the mine area. Construction Specifications and water level data for monitoring and test wells are presented in the permit application. Summaries of selected aquifer tests outlined below and selected data plots are presented in the permit application. A summary of the results of aquifer tests conducted and analyzed by the mine are presented in the permit application. Results of other aquifer tests not analyzed by the mine are summarized in the permit application.

7. Recharge Capacity

Recharge capacity is defined as the "ability of the soils and underlying materials to allow precipitation and runoff to infiltrate and reach the zone of saturation" (SRA Coal Mining Regulations, 1988).

The premining recharge capacity of the C area was estimated using the method of Thornthwaite and Mather (1957) as modified by the EPA (Fenn and others, 1975). This procedure uses empirically-derived equations and tables to estimate the amount of incident precipitation (on a monthly and annual basis) which may become direct surface runoff, evapotranspiration, and percolating soil water. The water that percolates below the root zone will either be discharged at seeps and springs or will become recharge water to the ground-water system.

The average annual precipitation in the C area is 38.4 inches per year (Section 779.131), with average monthly precipitation ranging from a high of 4.5 inches in April to a low of 2.0 inches in July (Larkin and Bomar, 1983).

The percent of incident precipitation which immediately becomes surface runoff was estimated using runoff coefficients presented by Chow (1964). Runoff coefficients are equal to the fraction of precipitation which becomes direct surface runoff. The coefficients are empirically derived and are based upon vegetation cover, soil type and slope conditions.

Runoff coefficients range from 0.08 for level sandy pastures in the summer, to 0.25 for loamy rolling woodland in the winter and spring.

Also required for the water balance equation was an estimate of the soil moisture retention capacity of the soil. The retention capacity is the product of the available water at field capacity and thickness in the root zone. The retention capacity of the soils at the C area was estimated from a table presented by Thornthwaite and Mather (1957) which is based on soil type and vegetation cover.

8. Ground-Water Quality

Chemical characteristics of ground water within the Permit Area C were evaluated on the basis of water samples collected from 59 monitor wells. Of these 59 wells, twenty-four of the wells are screened in the unconfined overburden (water table) aquifer, seventeen of the wells are screened in the confined overburden (interburden) aquifer, and eighteen of the wells are screened in the underburden aquifer. Copies of the laboratory data reports are included in the permit application.

The use of cation-anion electrical balances (charge-balance error) provides a check against errors in water analyses. The difference between the sum of the major cations and the sum of the major anions divided by the sum of the two values (in milliequivalents per liter) and multiplied by 100 is the cation-anion electrical balance, expressed as percent. Charge-balance errors in the range of 5 to 10 percent are generally considered the maximum limits for reliable data in scientific work.

9. Water Chemistry in the Overburden

Twenty-four wells completed in the overburden were sampled. The wells range in depth from 15 to 188 feet. The analytical results for the 24 samples were plotted on a trilinear, or Piper, diagram, a method for graphically illustrating chemical water types. The concentration of the dominant cations (calcium, magnesium, sodium and potassium) and anions (bicarbonate, carbonate, chloride, and sulfate) were converted to milliequivalents per liter, and the percentage of contribution of each chemical species for each group was plotted on the diagram. The trilinear plot of the 24 analyses illustrates that the ground water in the overburden is variable in character. The cation distribution indicates that the samples range in composition from sodium/potassium to predominantly mixed cation. There is a small percentage of the ground water that has a calcium cation classification. In the anion triangle, there is a tendency toward a chloride/bicarbonate type water to a mixed anion-type water. Sulfate type water dominates only one sample.

The concentrations of TDS in samples from the overburden ranges from 51 to 6722 mg/L, with a mean of 485 mg/L. Values of pH range from 4.0 to 7.1 units, with a mean of *5.6* units. The maximum concentrations of dissolved iron and manganese were 51 and 4 mg/L, respectively. Two wells have concentrations of TDS in excess of 1000 mg/L. The high TDS concentration is most likely due to the proximity of these wells to mined out areas, where TDS concentrations are commonly higher than ambient concentrations.

10. Water Chemistry in the Interburden

Seventeen wells completed in the interburden were sampled. The wells range in depth from 90 to 286 feet. A trilinear plot illustrates that the water of the interburden is primarily of a mixed cation type, with lesser amounts of calcium and sodium. In the anion triangle, waters are generally of a mixed anion to a bicarbonate type. A few wells plot in the sulfate and chloride portions of the diagram. In the diamond plot, the water falls in several different chemical domains, illustrating the variable nature of the interburden waters.

The concentration of TDS ranges from 72 to 976 mg/L, with a mean of 250 mg/L. Values of pH range from 5.1 to 7.0 units, with a mean of 6.0 units. The mean concentration for dissolved iron and manganese is 2.81 mg/L and 0.85 mg/L, respectively.

11. Water Chemistry in the Underburden

Nineteen wells completed in the underburden were sampled. The wells range in depth from 88 to 299 feet. Trilinear plots of the analyses illustrate that the underburden ground water ranges from a mixed cation to calcium type water. The dominant anion is bicarbonate/carbonate, with mixed anion type water comprising the majority of the rest of the water. A single sample plotted in each of the sulfate and chloride type corners.

The concentration of TDS ranges from 135 to 1807 mg/L, with a mean of 380 mg/L. The range of pH is from *5.7* to 7.4 units, with a mean of 6.6 units. The mean concentration of dissolved iron is 1.33 mg/L and of dissolved manganese is 0.88 mg/L. With the exception of one sample having a TDS concentration of 1807 mg/L, the water quality within the underburden is of relatively good quality.

12. Ground-Water Use Inside And Within One Mile Of The Permit Area C Boundary

Inventories of existing water wells were performed in 1979, 1987, and 1992 to document locations, uses, and other information for wells inside or within one mile of the Permit Renewal Boundary. The 1987 and 1992 surveys primarily included a file search of the State Water Commission records and a field verification (conducted by the mines). Available information for each well is presented in the permit application.

The breakdown of water use from the 308 wells reported in this inventory is as follows: domestic - 139 wells, industrial - 13 wells, irrigation/stock - 10 wells, abandoned - 12 wells, public supply - 11 wells, destroyed - 1 well, mixed use (domestic and irrigation/stock) - 46, and none or unknown use - 76 wells. A majority of all wells within one mile of the permit renewal boundary are completed to a depth greater than 200 feet, in the underburden.

D. Baseline Information For CHIA

Under the coal mining regulations, the RA is required to provide an assessment of the probable CHIA on surface- and ground-water systems by proposed and anticipated mining operations within a defined cumulative impact area (CIA). For purposes of permit approval, the development of a CHIA must be sufficient to determine whether or not these operations have been designed to prevent material damage to the hydrologic balance outside the permit area. This involves the assessment of the aggregate effects of existing and proposed surface-mining activities on the hydrologic environment within the affected watershed systems.

The effects of mining in the western part of the MCR Mine were included in the CHIA prepared for the mining revision application submitted for the MCR3 Mine IV; both mines are located within the Navasota River drainage basin. The CHIA presented herewith contains the assessments of the effects due to the proposed mining expansion in the western part of the MCR Mine. Also included in this new CHIA are the cumulative effects of projected mining in the eastern MCR Mine and the MCR2 Mine on surface-water uses within the Trinity River Basin. The effects on the ground-water resources adjacent to each mine also are assessed. Figure I-1 shows the extent of the drainage areas, part or all of which are referred to as the Cumulative Impact Drainage Areas (CIDA's) of the Navasota and Trinity River Basins. Included in Figure I-1 are the Water Commission stream segments for which water-quality standards have been determined.

1. Delineation of Cumulative Impact Area

a. Surface Water

The surface-water CIA may be described as that area over which existing and proposed mining activities may cause measurable changes in specified hydrological parameters. The mining activities of the CIA within the Navasota River drainage include all the MCR3 Mine areas and the western portion of the MCR Mine area (Figure I-2). The mining activities of the CIA within the Trinity River drainage include the eastern part of the MCR Mine plus the MCR2 Mine areas (Figure I-2).The geographical boundaries used to describe the surface-water CIA follow the drainage basins which encompass all the proposed operations and any existing mines. For this CHIA, the mining activities are located in the Navasota River and Trinity River drainage basins (Figure I-1). In order to accurately describe the potential effects of the mining activities on the surface-water system of each CIA, a separate CIDA has been delineated. This CIDA takes into account all the surface-water drainage areas that influence the CIA. The CIDA's (Figure I-1) follow the watershed boundaries of each drainage basin.The CIA within the Navasota CIDA includes the headwaters of the tributaries that drain the MCR Mine Area and flow into Lake Limestone (Figure I-2). The CIA is delineated along the natural stream channel of the Navasota River to just upstream of the tributaries draining the MCR3 Mine areas. At this point, the CIA encompasses the watershed associated with these tributaries of the Navasota River. This CIA includes all of the MCR3 Mine areas and about half of the MCR Mine area.

The downstream boundary of the CIA is located at the confluence of the Navasota and Brazos rivers. The total area of the CIA area is approximately 350 square miles.

The CIA for the eastern MCR and the MCR2 mine areas within the Trinity CIDA encompasses the areas draining both mines (Figure I-2). It includes part of the Tehuacana Creek downstream from the MCR2 Mine and along the Trinity River to the USGS gaging station near Crockett (No. 08065350). It also includes the area along Buffalo Creek downstream from the eastern MCR Mine area and along the Trinity River to the same USGS gauging station, the downstream boundary of the CIA, which consists of about 200 square miles. Both Tehuacana and Buffalo Creeks are tributaries to the Trinity River.

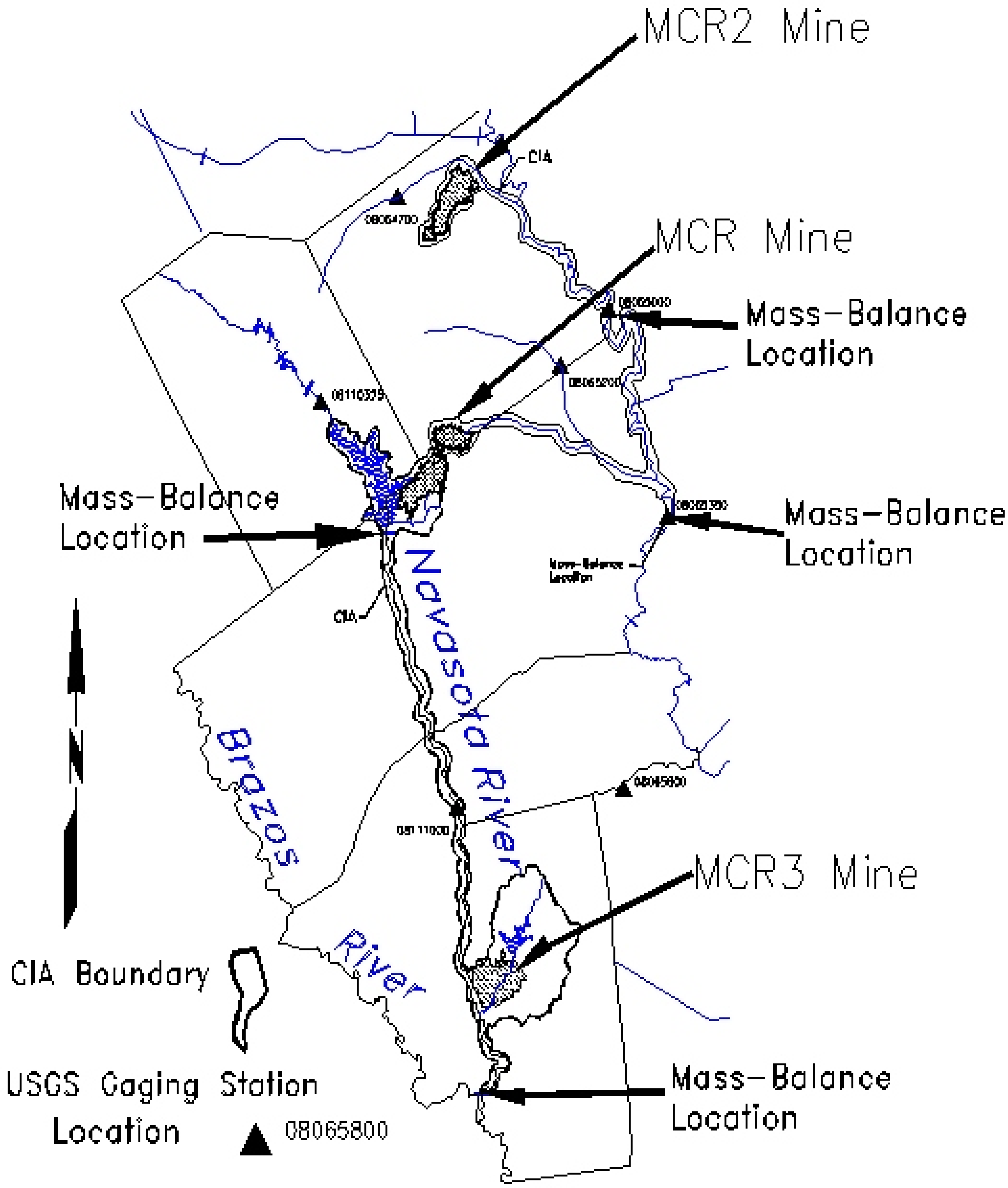

Figure I-2. The surface-water CIA and proposed mining activities within the Navasota River drainage

b. Ground Water

In the lignite-mine areas within the Wilcox and Jackson-Yegua geologic systems, two different sets of physical limits must be identified to describe the appropriate ground-water CIA. One set involves the boundaries of the impacted aquifer systems in each mine area; this is normally derived from the applicants' Probable Hydrologic Consequences (PHC) analyses. (The areal aquifer impacts caused in all mines within a hydrologic system are accumulated in the preparation of the CHIA.) The other set consists of the limits to which the long-term ground-water contributions to stream baseflow in the reclaimed mined areas affect the downstream surface-water uses. The latter usually encompasses a much larger area than the former and thus becomes the principal basis for the ground-water CIA.

In all three mines (MCR3, MCR, and MCR2), the effects of the surface-mining activities on each area's aquifer systems are expected to be confined to areas within or in proximity to the permit boundaries. Long-term impacts associated with the spoils-area ground-water contributions to streamflow probably will be insignificant. However, analyses related to these items are completed in this CHIA to estimate the effects on ground-water users adjacent to the mines and on downstream surface-water users.

The only significant use of surface water downstream from the western MCR Mine area is at Lake Limestone (industrial cooling, public supply). Surface-water users downstream from the MCR3 Mine include industrial uses and an irrigation permit (645 acres) to divert Navasota River water about 24 miles downstream from the mine. In addition, some riparian-rights users for domestic, stock, and irrigation are located in the small Navasota River reach between the mine and its confluence with the Brazos River. The drainage area of the Navasota River above this confluence is 2211 square miles.

The uses of surface water downstream from the MCR2 Mine area are those located along the Trinity River reach between the mine and the USGS streamflow gauging station near Oakwood (No. 08065000, Figure I-2). Trinity River water is diverted for industrial uses near the mine and for minor irrigation and municipal uses along the entire reach. Uses of surface water downstream from the western MCR Mine area include minor irrigation, municipal, industrial, and domestic and stock riparian-rights uses along the Trinity River below the USGS streamflow station near Crockett (No. 08065350, Figure I-2). There are no known uses for Buffalo Creek effluent nor for the flow at Tehuacana Creek between the MCR2 Mine and the Trinity River.

For purposes of delineating the ground-water CIA's for this CHIA, the surface-water CIA's will suffice. However, the CIDA's for the Navasota and Trinity Rivers (Figure I-1) will be used in mass-balance calculations.

2. Baseline Hydrologic Conditions and Summary of Data Used

a. Surface Water

The CIDA for the western portion of the MCR Mine drains approximately 2,211 square miles of the Navasota River Basin. The CIDA for the eastern portion of the MCR Mine drains approximately 13,911 square miles of the Trinity River Basin. Surface-water records available for this area include USGS gauging stations and applicant baseline monitoring stations.

Within the MCR Mine area, several USGS gauging stations characterize the regional runoff attributes. Station 08110325 on the Navasota River above Lake Limestone has a drainage area of 239 square miles. Based on records collected from 1978 through 1991, the average discharge is 76,070 acre-feet per year for an annual unit runoff of 0.50 acre-feet per acre. The Tehuacana Creek gauge (USGS Station 08064700) is situated in the Trinity River basin near Streetman. It has a drainage area of 142 square miles and a unit area discharge of 0.67 acre-feet per acre averaged over 23 years of discharge data. The series of USGS stations along the two drainage basins indicate a wide range of runoff. The Upper Keechi Creek gauge has a long period of record with flow being measured from a basin which has no regulated flow. Average flow from the Upper Keechi Creek station was used in the mass-balance analysis to characterize the flow for the area. The Upper Keechi Creek station, USGS Station 08065200, located east of the MCR Mine and South of the MCR2 Mine, has a drainage area of 150 square miles, and an average flow of 52,890 acre-feet per year for a 29-year period of record, and a unit area discharge of 0.55 acre-feet per acre.

Baseline water-quality records from the MCR Mine area indicate average concentrations for total iron of 2.49 mg/L, total manganese of 0.51 mg/L, total suspended solids of 37 mg/L, total dissolved solids of 376 mg/L, and a pH of 6.9 standard units.

Water uses of concern downstream of the MCR Mine area include industrial (cooling purposes), public supply and recreation. All of these uses are in the immediate Lake Limestone area.

Within the MCR3 Mine area, USGS station 08111000 on the Navasota River near Bryan drains 1,454 square miles. During the water years 1961 through 1991, the average flow was 418,800 acre-feet per year for a unit discharge of 0.45 acre-feet per acre. The Bedias Creek near Madisonville (USGS Station 08065800) is located northeast of the MCR3 Mine areas. It has a drainage area of 321 square miles and an average unit area discharge of 0.705 acre-feet per acre during the period of 1967 through 1991.

Surface-water quality for the MCR3 Mine area indicates elevated constituent levels compared to the MCR Mine area. Baseline TDS values for the MCR3 stations averaged 421 mg/L (based on a flow-weighted average of TDS concentrations provided in MCR3 V baseline information; see Tables .129-10 and .129-11) and ranged from 183 mg/L to 837 mg/L. Total suspended solids average concentrations ranged from a trace to 140 mg/L. Average total iron concentrations ranged from 0.10 mg/L to 1.77 mg/L. Average total manganese concentrations ranged from 0.27 mg/L to 0.85 mg/L.

Downstream from the MCR3 Mine, water users include a water-use permit issued to a Municipal Power Agency. The intended use is for industrial purposes. Other uses in this area include some riparian rights for domestic, stock and irrigation uses.

Surface-water quality for the MCR2 Lignite Mine area indicates elevated constituent levels similar to those of the MCR Mine area. Baseline TDS values for the MCR2 stations averaged 324 mg/L and ranged from 76 mg/L to 814 mg/L. Total suspended solids average concentrations ranged from <5 mg/L to 131 mg/L for all stations. Average total iron concentrations ranged from 0.77 mg/L to 3.66 mg/L. The average for total manganese concentrations was 0.54 mg/L.

Downstream of the MCR2 Lignite Mine, a utilities electric company holds a water contract which authorizes the use of 20,000 acre-feet of water per year from the Trinity River. The intended use is for industrial purposes.

b. Ground Water

The main aquifers in the MCR Mine area are the sands within the Claiborne and Wilcox Groups of Eocene age. The fairly permeable Carrizo Sand of the Claiborne Group is part of the shallow overburden and varies from 0 to more than 100 feet in thickness. The Calvert Bluff of the Wilcox Group consists of the lignite-bearing formation that overall forms most of the less permeable overburden system (0-300 feet thick); however, this formation also contains some very permeable sand channels. The underburden consists of deeper Wilcox sediments that are several hundred feet thick, including the Simsboro Sand, a major aquifer in the regional area.

Baseline ground-water information for the MCR Mine area is derived from 75 monitoring wells, 56 continuous cores, more than 1400 boreholes for geophysical logs, 22 aquifer tests and an inventory of more than 300 private wells. Fluctuations of aquifer head away from mining areas are small, whereas aquifer heads near mined areas have declined as much as 20 feet. The shallow water-table aquifer (Carrizo-Wilcox) contains water that varies from about 50 to more than 6000 mg/L in TDS, but the average is only about 485 mg/L. The confined Wilcox overburden contains water with a TDS content varying from 70-1000 mg/L, with an average of only 250 mg/L. The water in the confined Wilcox underburden has a TDS range of 135 to more than 1800 mg/L and an average of about 380. An average annual recharge of 2.7 inches was estimated to reach the water table, from where movement may be traced along the topographic relief. Movement in the confined Wilcox sands of the western mine area generally is eastward and southeastward along a regional gradient towards stream-valley lows within the Navasota River watershed. In the eastern area, movement is toward Buffalo Creek, a tributary of the Trinity River. About 60 percent of the inventoried private wells are used for domestic and stock purposes, and nearly 30 percent are in the category of wells that are unused, abandoned, destroyed, or the use is unknown; the rest are used for public supply, industrial, and irrigation needs.

Eight fine-grained sand units (aquifers) are identified within the Manning and Wellborn Formations of the Jackson Group, which is about 1600 feet thick in Grimes County and contains the lignite seams being mined in the MCR3 mine. Throughout each of the mine-block areas of the mine, the overburden strata consists of a pair of the sand units, interbedded with clay-silt lenses. Some of these sands may be as much as 100 feet thick, but most vary between 0 and 50 feet. The underburden system is similar, with one or two of the sand units making up the first permeable strata below the major lignite zones. Hydraulic conductivities of the sand-unit aquifers generally are less than 3 feet per day under predominantly confined conditions.

Baseline ground-water information for the existing MCR3 mine areas has been derived from more than 800 boreholes for geophysical logging, 22 aquifer tests, 24 continuous overburden cores, about 200 monitoring wells, and an inventory of more than 250 private wells. Ground-water movement in the identified sand units is generally southward (locally southeastward or southwestward) toward the MCR3 and Navasota River drainage areas. Recharge has been estimated to range from 1 to 6 inches per year over the outcrop area from an average annual rainfall of 39 inches. Average flow velocities within the overburden sand units range from 10 to 180 feet per year, but these can be much greater locally where hydraulic gradients are large. The chemical quality of the water in the sand units is quite variable, with pH values ranging from about 3 to 6, and TDS ranging from less than 500 to more than 8,000 mg/L with varying amounts of hydrogen sulfide gas. Most of the water is only marginally suitable for agricultural and industrial uses; some fresh water is used for domestic supplies.

The principal aquifers in the MCR2 Mine area are the sands within the lignite-bearing Calvert Bluff Formation of the Eocene Wilcox Group. Only the channel sands within this system have a significant transmissivity; most of these sands are found in the overburden material, which is 20 to 150 feet thick above the first of two lignite seams. Total saturated-sand thickness in the overburden varies from 0 to about 80 feet. The interburden between the two seams, plus the immediate underburden below the second seam, generally contain minor, thinly interbedded sand systems.

Baseline ground-water information for the MCR2 Mine is derived from more than 600 boreholes for geophysical logging, about 65 principal monitoring wells, 23 aquifer tests, 26 continuous overburden cores, and a private-well inventory of almost 140 wells. The total dissolved solids concentration of ground water in the unconfined overburden varies from slightly more than 100 to nearly 1800 mg/L, but the average is only slightly above 600 mg/L. The confined interburden and underburden ground water is generally lower in TDS content, varying from about 250 to slightly more than 1000 mg/L. Recharge to the water table is estimated to vary between 3 and 10 percent of the average annual rainfall of about 38 inches. Movement of the unconfined water in the overburden generally follows the topographic relief in the general direction westward and northward toward Tehuacana Creek, at velocities varying from 20 to about 300 feet per year. Movement in the confined interburden and underburden systems is more gradual and much slower, with velocities averaging about 12 feet per year. The direction of ground-water movement in the interburden is similar to that of the overburden; however, the underburden ground water moves eastward and northward toward the Trinity River and its alluvial system. Only about one-fourth of the inventoried private wells are active, and most of these are used for supplying domestic and stock needs.

3. Hydrologic Concerns

a. Surface Water

The principal hydrologic concerns, in relation to the probable impacts to surface water by the proposed surface-mining operations on the delineated CIA are as follows:

(1) Chemical changes in receiving streamflow

The chemical constituents found in the surface water flowing within and through the permit area may be affected by (1) exposure to new mineral surfaces due to spoil removal and replacement, (2) a change in the quantity of constituent loading on receiving streams in the CIA due to the change in amount of surface-water runoff from permit area, and (3) the chemically inferior contributions of the spoils ground water to the baseflow in the area.

(2) Physical changes in receiving streamflow.

The premine to postmine contour changes within the permit area drainage basins, and the introduction of impoundments and other surface-water control structures to the surface-water regime, may change the availability and quantity of surface water. Low flow, peak flow and the variations in flow through time from a specific precipitation event may be altered because of (1) changes in shape, slope, land cover, and soil type of watersheds in the permit area, (2) retention and detention of surface water in impoundments, (3) rerouting of overland flow, and (4) construction of stream channel diversions. Changes in TSS of receiving streams in the permit area should also be evaluated.

(3) Geomorphic changes within the CIA's drainage basins

The physical changes in the permit area may result in geomorphic instability of the drainage basins within the CIA. Changes in the amount of sediment produced from the premine, active-mine, and postmine conditions may affect the receiving stream's erosional or accretion capacity. Geomorphic changes may, in turn, result in additional physical changes in receiving streams or their watersheds.

2. Ground Water

The principal hydrologic concerns, in relation to the probable impacts to ground water by the surface-mining operations in these lignite mines, are as follows:

a. Aquifer-head drawdowns and declines

The water levels in private wells located within or outside the permit area may be drawn down by (1) pit inflow resulting from the removal of the shallow overburden material, (2) pumping wells drilled for dewatering the overburden in advance of mining, and (3) deep pumping wells drilled into the underburden to depressurize the aquifer in order to avoid mine-floor heave. All of these surface-mining activities will have the potential effect of reducing the availability of ground water to the private wells tapping the various aquifers in the area.

b. Physical changes in the reclaimed spoils areas

The removal of stratified overburden sediments and the replacement with mixed overburden material (spoils) will result in physical changes that affect resaturation and the ground-water flow regimen. Initially, porosity and the vertical permeability very likely will be greater than those during premine conditions, and the resaturation rates will be larger than the premine recharge rates. These parameters should decrease with compaction, and the resaturation also will decrease. The bulk transmissivity in the reclaimed spoils may be less than during premine conditions, which will bring about a different equilibrium of ground-water flow as resaturation takes place. This may result in different water-table gradients as well as local changes in the quantity and location of the natural discharge (springs, seeps) to surface drainage ways.

c. Chemical changes in the spoils ground water

Resaturation of the spoils area will create a system containing a more mineralized ground water than that which existed during premine conditions. This is due to the leaching of the fluffed overburden mix. The nature of the increases in the total dissolved solids, acidity, and toxic elements is critical to the eventual contributions of spoils ground water to adjacent aquifers and to springs and seeps. The quality of the well water that is withdrawn from these adjacent, as well as deeper, aquifers could be impaired. Surface water being used downstream from the reclaimed areas could be affected by the chemically inferior contributions of the spoils ground water to the base flow in the area.

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