PRESENTATION TO

1992 REGIONAL PHOSPHATE CONFERENCE

SEPTEMBER 24 AND 25, 1992

TABLE OF CONTENTS

LIST OF FIGURES

LOCATION AND ABANDONMENT OF WELLS IN MINED-OUT AND RECLAIMED TERRAIN

Richard C. Fountain, Marc V. Hurst, David J. Brown
Richard C. Fountain and Associates

ABSTRACT

The proposed expansion of the IMC Fertilizer, Inc. New Wales Operations' gypsum stack necessitated an accurate inventory of wells that might be hydraulically influenced by the proposed expansion. Richard C. Fountain and Associates undertook the task of locating all of the wells that penetrate beyond the Surficial Aquifer System in a study area consisting of the proposed gypsum stack expansion area, the existing gypsum stack, and the peripheral area within approximately 2,000 feet of the existing and proposed gypsum stack areas. The review of written and graphic records on well construction in this area, interviews with individuals knowledgeable on wells constructed in the area, the review of numerous vintages of historical aerial photography of the area ranging from 1947 until project commencement in mid-1986, and field reconnaissance to locate existing wells and suspected well sites which were later investigated by various geophysical techniques made up the initial phases of the study.

Physically located wells were surveyed; however, it was not practical to physically locate wells that were deeply buried in mined-out areas. Their locations were determined through examination of historical survey records or by

photogrammetry. A total of 109 wells of different types that penetrate the subsurface beyond the Surficial Aquifer System were located within the boundaries of the study area. Their coordinates were determined by surveying or by photogrammetry.

All of the wells will be abandoned by various methods to regulatory agency standards.

LOCATION AND ABANDONMENT OF WELLS IN MINED-OUT AND RECLAIMED TERRAIN

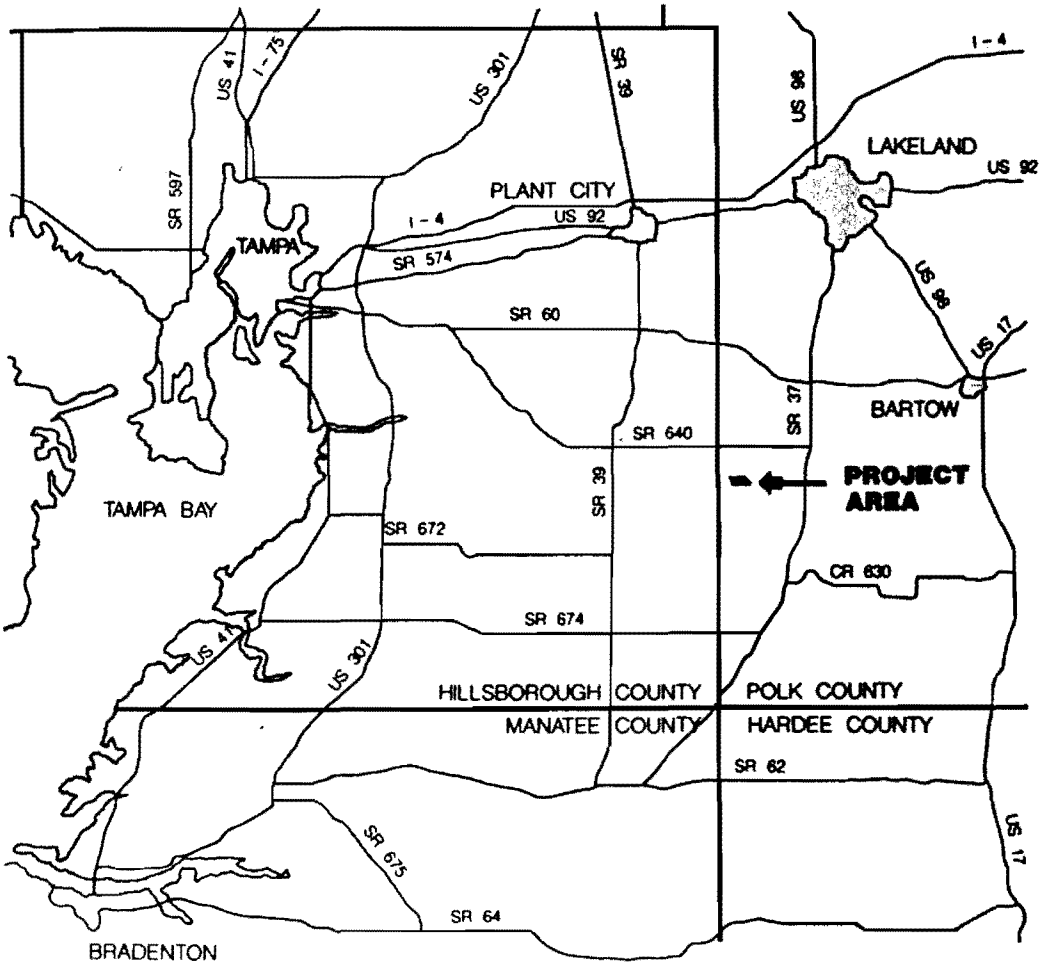
Richard C. Fountain, Marc V. Hurst, David J. Brown
Richard C. Fountain and Associates

INTRODUCTION

The proposed expansion of the IMC Fertilizer, Inc., New Wales Operations' gypsum stack necessitated an accurate inventory of wells that might be hydraulically influenced by the proposed expansion. The firm of Richard C. Fountain and Associates undertook the task of locating all of the wells that penetrate beyond the Surficial Aquifer System in a study area consisting of the proposed gypsum stack expansion area, the existing gypsum stack, and the peripheral area within approximately 2000 feet of the existing and proposed gypsum stack areas. The study area lies within Sections 4, 5, and 6, Township 31 South, Range 23 East; Sections 31, 32, and 33, Township 30 South, Range 23 East; and the south one-half of Section 30, Township 30 South, Range 23 East. Figure 1 shows the location of the study area.

A large number of the wells in the study area are classified by the Florida Department of Environmental Regulation as Class V, Group 2, drainage or recharge wells. In addition, sealing water wells used in the phosphate matrix and tailings transport systems, production wells, domestic wells and ground water observation wells were found. Many

GENERAL SITE LOCATION



FLORIDA MAP KEY

N

0 10

SCALE IN MILES

GENERAL SITE LOCATION

GYP STACK EXPANSION

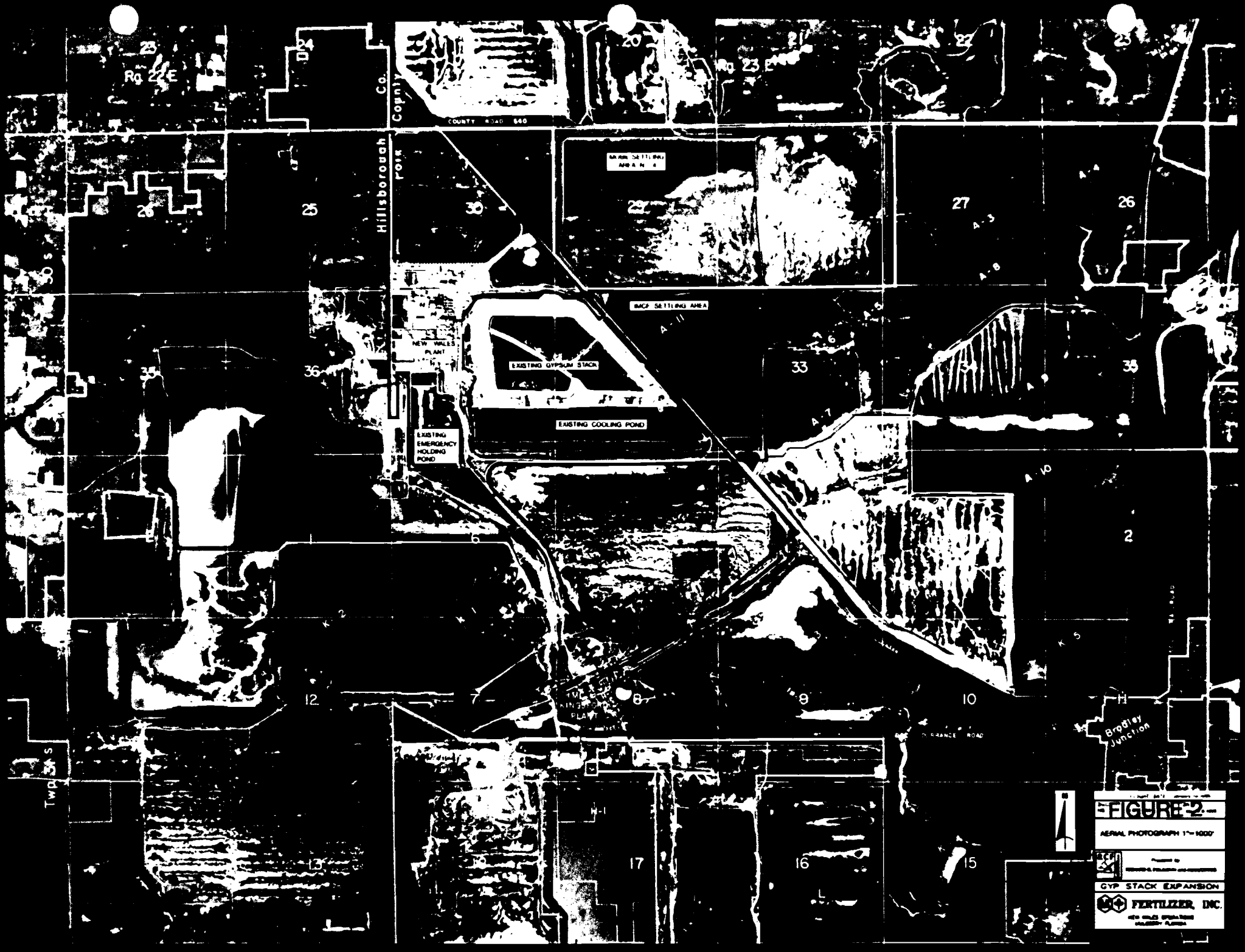
FERTILIZER, INC.

FIGURE 1

wells in the study area had been abandoned, mined out, or buried due to mining activities (Figure 2).

Initially, written records were reviewed and cross-checked to establish a list of wells to be located. The mine and contract personnel who were involved with construction, maintenance, and sampling of the wells were interviewed for their knowledge of any undocumented wells. Numerous vintages of historical aerial photography ranging from 1947 until the commencement of this project, in mid-1986, were examined in detail for photographic evidence of well construction sites. Field reconnaissance was conducted to locate existing wells and suspected well sites were investigated by various geophysical techniques and were excavated in order to locate wells that had been buried under shallow cover by mining activity. Physically located wells were surveyed. It was not practical to physically locate wells that were deeply buried in mined-out areas. Their coordinates were determined through an examination of historic survey records or by photogrammetry.

A total of 78 recharge, 19 sealing water, 5 production, 2 domestic, and 5 observation wells that penetrate the subsurface beyond the Surficial Aquifer System were located in the study area. Their coordinates were determined by surveying or by photogrammetry.


Rg 22E
Hillsborough County
COUNTY ROAD 640
MAIN SETTLING AREA N-4
MAIN SETTLING AREA
EXISTING GYPSUM STACK
EXISTING COOLING POND
NEW WELLS PLANT
EXISTING EMERGENCY HOLDING POND
NEW WELLS PLANT
Twp 32S
Bradley Junction
FIGURE 2
AERIAL PHOTOGRAPH 1"=1000'
GYP STACK EXPANSION
FERTILIZER, INC.

REVIEW OF RECORDS

Initially, written records were reviewed and cross-checked in order to establish a list of wells to be located and their respective construction characteristics. IMCF records were searched for well construction permits, abandonment permits, purchase order records, correspondence, memos related to well construction, surveyors' notes, consumptive use permits, miscellaneous maps, and various vintages of aerial photographs. The files of Burnett Contracting and Drilling Company, the primary drilling contractor, were researched for well permits, invoices, and drillers' reports. The preliminary well listing was cross-checked against the permit listing of the Southwest Florida Water Management District.

In August of 1986, a review of the files of Kucera South, Inc. was begun. Historic aerial photographs were examined for evidence of well construction sites. Suspect sites were noted for further investigation.

In October of 1986, a set of field notes from an IMCF survey of wells, completed in September of 1977, was located. The survey was found to contain coordinates of 35 recharge wells located within the study area. An additional survey

field note dated December 7, 1977, was located in IMCF's files that gave the location of one additional recharge well relative to a previously surveyed well.

Additional information was received from IMCF Minerals in January and February, 1988. A number of maps, permits, and memos pertaining to well locations were forwarded to our office for evaluation. One permit indicated the existence of a sealing water well, and a memo indicated the existence of a redrilled recharge well.

A retired IMCF employee who had been intimately involved with recharge well installation was interviewed in February, 1988. He confirmed the existence of several recharge wells and was able to confirm our approximate locations for two sealing water wells, and to indicate a possible location for a domestic water well.

In March, 1988, additional information was received from IMCF Minerals. A 1977 vintage aerial photograph was clearly marked with the locations of several recharge wells, all of which had been mined out before the expansion project began. The location of one other recharge well also was indicated. By using existing wells that were marked on the aerial as reference points, the coordinates of other recharge wells were determined. The coordinates of one recharge well had

previously been determined from the 1977 IMCF survey note and was determined to be accurate.

IMCF Minerals drillers were interviewed in the field. They confirmed our identifications of various recharge wells and other wells. Their detailed description of one well location corresponded with a previously unexplained mud pit location imaged in historic aerial photographs.

Additional information was received from IMCF Minerals. The mud pit locations of two recharge wells were found imaged in a historic aerial photograph allowing determination of the wells' coordinates by photogrammetric methods.

In November, 1988, our firm conducted an organized thorough search of the IMCF archives of the Production Services Department. No indication of any previously undiscovered well was found.

Historic aerial photographs from the files of IMCF, New Wales Operations, were reviewed for well location data. An aerial photograph, dated March 15, 1976, was found to contain an image of the mud pit that was used in the construction of an early recharge well.

In May, 1989, an aerial photograph, dated August 11, 1977, was received from IMCF Minerals. A mud pit image was noted at one of the suspected locations that was indicated on an August 1, 1977, blueline that had previously been our best location data for the well. Other aerial photographs, dated September 30, 1977, and November 15, 1977, were received from Kucera South, Inc. They also showed the mud pit location.

The original copy of the FDER Well Completion Report for one well was received from IMCF Minerals. The completion date, 10/11/77, was very similar to the drilling contractor's license number, 1011. In our opinion the blank for completion date was confused with the blank for the drilling contractor's license number.

Copies of permit data for this well were received from SWFWMD. The SWFWMD copy of the well completion report was identical to the copy received from IMCF Minerals, except for the completion date. A completion date of 12/21/77 was indicated on the SWFWMD copy. Based on the later completion date, a search was made for later vintages of aerial photography. Photographs dated December 23, 1977, January 31, 1978, February 28, 1978, March 1, 1978, and April 1, 1978, were received from Kucera South, Inc. The mud pit had been filled and the site leveled by December 23, 1977. The area had been mined by May, 1978. No evidence of well construction in the

area was found in any of the aerial photographs taken after the December 21, 1977, completion date indicated on the SWFWMD copy of the completion report.

The final list of wells includes 78 recharge, 19 sealing water, 5 production, 2 domestic, and 5 observation wells in the study area that penetrate the subsurface beyond the Surficial Aquifer System.

FIELD RECONNAISSANCE

Initial field reconnaissance was conducted in August and September of 1986 to locate, in the field, physical evidence for existing wells and physical evidence of abandoned or destroyed wells in and adjacent to the expansion area. Twenty-four recharge, 14 sealing water, 4 production, 1 domestic, and 4 observation wells were physically located. In addition, shallow excavation of suspected well sites revealed 1 sealing water and 4 recharge wells. During field reconnaissance, 1 observation and 21 recharge wells in and adjacent to the study area were flagged with markers for identification by aerial photogrammetric methods.

In February, 1987, 28 recharge wells, 14 sealing water wells, 1 observation well, and 8 ground control targets for aerial photography were surveyed and/or field checked by the civil engineering firm of I. F. Rooks & Associates, Inc. Surveyed coordinates of the wells and ground control targets were tied into the New Wales Grid Coordinate System. In order to complete the search for existing, unmined wells and to check the accuracy of coordinates established by I. F. Rooks & Associates, Inc., the firm of Alderman Land Surveys, Inc. was employed to retrace the 1977 IMCF survey of recharge wells. In the process, 4 additional recharge wells and 2 additional

sealing water wells were physically located within the expansion area.

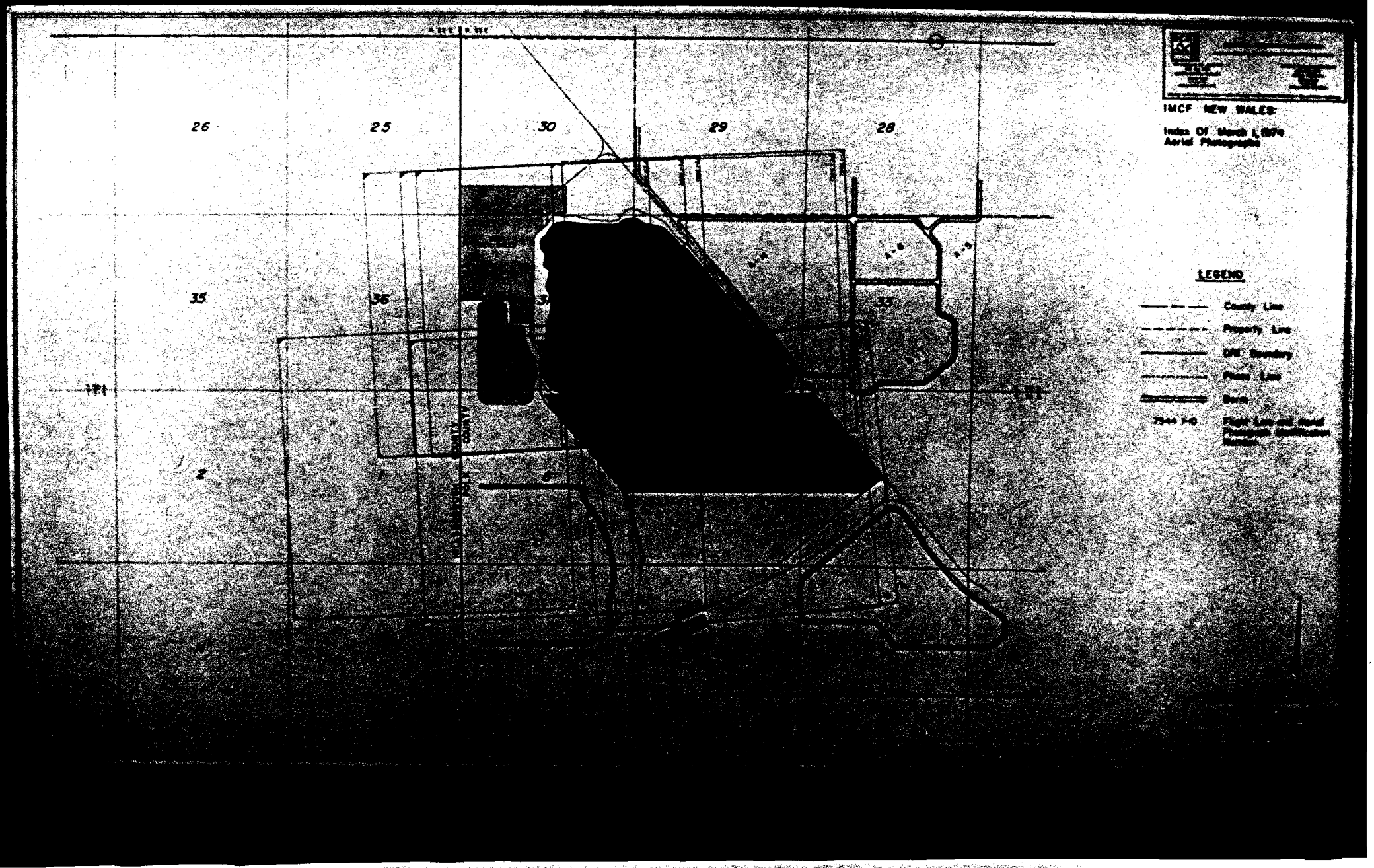
Coordinates of wells surveyed by various parties were compared in order to ascertain the relative accuracies of the individual traverses. It was found that coordinates surveyed by I. F. Rooks & Associates, Inc. were in close agreement with coordinates generated by Alderman Land Surveys, Inc. Their coordinates differed by a maximum of approximately 1.5 feet. Coordinates derived from the 1977 IMCF survey, a traverse not intended to result in high precision coordinates, were found to differ from those coordinates generated by I. F. Rooks & Associates, Inc. and Alderman Land Surveys, Inc. by a maximum of 10 feet.

In order to maintain the highest degree of consistency, it was decided to use I. F. Rooks & Associates, Inc. survey data as the preferred source of well coordinates since they had surveyed the ground control targets for rectification of the aerial photography. Survey data generated by Alderman Land Surveys, Inc. were used to locate those wells that were not surveyed by I. F. Rooks & Associates, Inc. The 1977 IMCF survey was utilized only for those wells that could not be surveyed by I. F. Rooks & Associates, Inc. or Alderman Land Surveys, Inc.

PHOTOGRAMMETRY

In August and September of 1986, Kucera South, Inc. produced six rectified aerial photographs at a horizontal scale of 1 inch equals 200 feet covering the study area. Standard photogrammetric techniques were used to rectify the aerial photography using the established ground control targets. Negatives of two 1972 vintage and four 1974 vintage aerial photographs (Figure 3) of the area from the files of Kucera South, Inc. were enlarged and prints rectified to the scale of the 1986 aerial photography using surveyed control points and physical features, such as railroad switches, electrical power substations, and similar identifiable objects, which were present throughout the 14-year time span.

Coordinates of wells that were generated from 1972 vintage aerial photography using a stereo plotter were received from Kucera South, Inc. It was determined that these coordinates were more accurate than coordinates derived without use of the stereo plotter. In addition, coordinates were generated by Kucera South, Inc. for well locations from the 1974 vintage photography by overlaying the 1974 images on the 1972 vintage photography.


IMCF NEW WALES
Index Of Mosaic Of
Aerial Photographs
LEGEND
County Line
Property Line
Flight Line
Base
26
25
30
29
28
35
36
33
2

Targets were placed in the field for a test to simulate the 1972 vintage photography. I. F. Rooks & Associates, Inc. surveyed the target locations that had not been previously determined. Aerial photographs were produced by Kucera South, Inc. to duplicate 1972 coverage as closely as possible.

Kucera International, Inc. began work on two coordinate system models based on the 1972 vintage photography. One model used three surveyed locations for control and the other model used six control points. Coordinates were determined for various locations imaged in the 1972 vintage photography using a stereo plotter. The coordinates were adjusted by the process of analytical bridging of control across the overlapping series of photographs. The coordinates were further adjusted to correct for curvature of the earth and for atmospheric refraction.

Kucera International, Inc. then developed two coordinate system models based on the 1989 vintage photography. These models were designed to duplicate the work done on the 1972 vintage photography. Two models were made to evaluate the differences in accuracy to be expected if three points were used to control the model instead of six.

When partial results of the coordinate system modeling based on the 1972 vintage photography were received from Kucera International, Inc., the results showed that the difference in accuracy between models, based on three or on six control points, was negligible. It was decided to use the 1972 model based on three control points as a base for derivation of coordinates from other vintages of photography that did not have sufficient overlap between successive photographs in a series or sufficient surveyable control points. By using the model based on three control points, three additional points with surveyed coordinates would be available for use as checkpoints to evaluate the accuracy of the coordinate system model. Careful evaluation of the accuracy of the modeling of the 1972 photography was important because coordinates derived from other vintages of photography would be based upon it.

The 1972 vintage photography was closely examined for additional features that could be surveyed and used as checkpoints for evaluation of the accuracy of the 1972 coordinate system modeling. Four points, represented in the photography by railroad switch poles and foundation corners, were located. Their coordinates were surveyed by I.F. Rooks & Associates, Inc. Independently, Kucera International, Inc. reset the 1972 coordinate system model based on three control points and determined coordinates for the four new check-points.

Kucera International, Inc. completed their coordinate system modeling of the 1972 vintage and of the 1989 vintage photography in late July and early August, 1989. The results of the two 1989 coordinate system models confirmed that the accuracy of a model based on three control points is negligibly different from a model based on six control points.

Coordinates for wells imaged in vintages of photography other than 1972 were determined by Richard C. Fountain and Associates. Coordinates modeled from the 1972 vintage photography were used to control the other vintages of photography by an overlaying procedure that made use of the 1972 vintage photography and a gridded transparent overlay.

Five documented wells could not be located physically or photographically. Coordinates of three of these wells were included in the 1977 IMCF survey of recharge wells. One well was located using a 1977 IMCF survey note, and the fifth well, a production well, was located from coordinates given on an engineering drawing of the New Wales Plant.

ACCURACY OF LOCATIONS

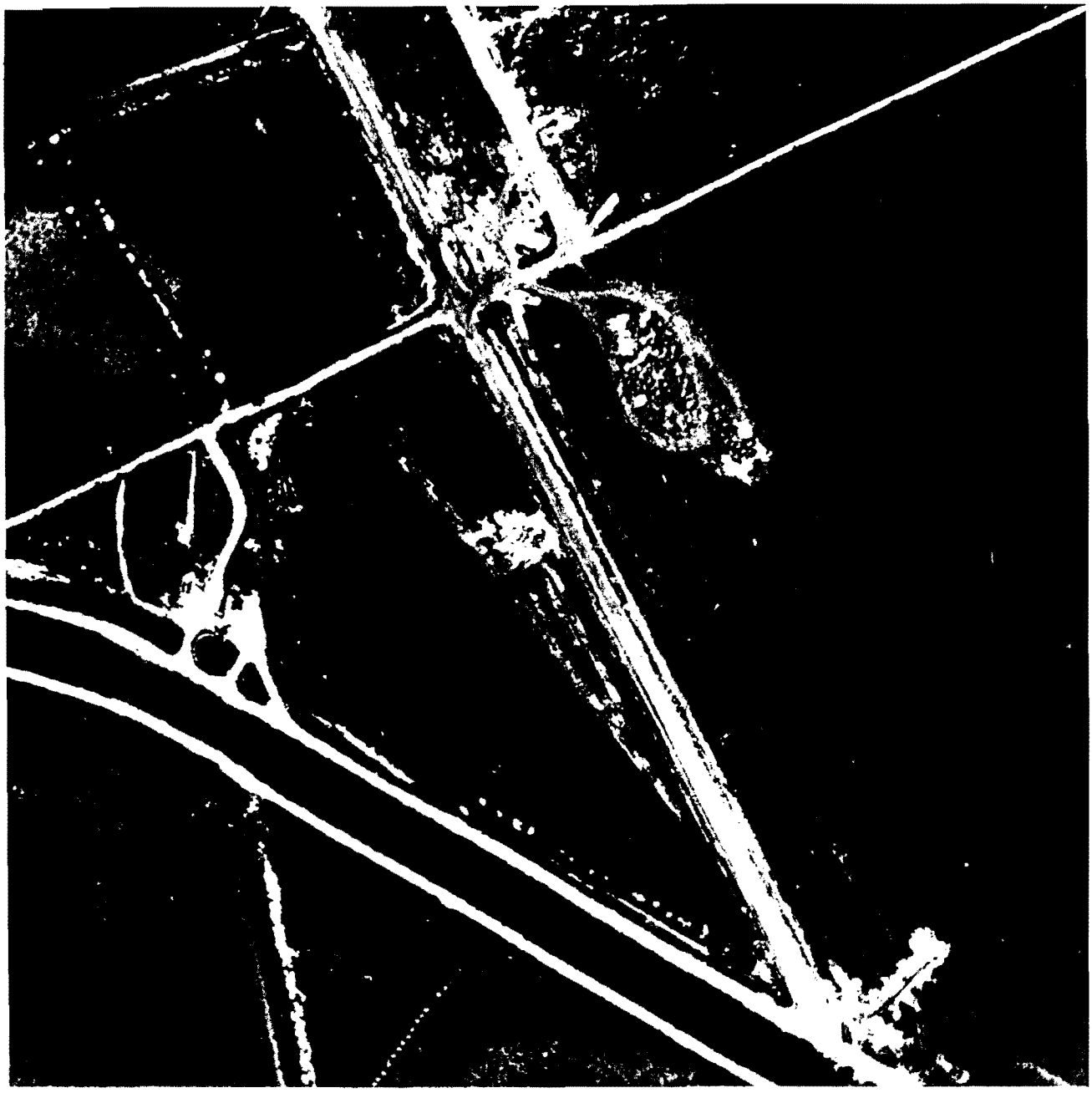
The coordinates of wells located for this project were derived by surveying or by photogrammetric methods. Coordinates were surveyed for those wells that could be physically found. Coordinates for some well locations that could not be physically found were noted in a 1977 IMCF survey. Coordinates of one well location were calculated from the unreduced field notes from the 1977 IMCF survey. Coordinates of one well location were found on an engineering drawing of the New Wales Plant site. Coordinates for the other wells that could not be physically found and for which historic survey records could not be found were derived by photogrammetric methods. Those well locations that could be precisely pinpointed in an overlapping series of aerial photographs with appropriate ground control were coordinatized by state-of-the-art photogrammetric techniques. The other well locations that could not be precisely pinpointed or that were not found in aerial photographs with sufficient overlap were coordinatized by less sophisticated photogrammetric methods. The location accuracies of the coordinates are dependent upon the methods by which they were generated.

Those well locations for which surveyed coordinates could not be generated or found were coordinatized by

photogrammetric methods. An overlapping series of aerial photographs taken in 1972 was found to contain images of well locations that had been targeted prior to the date of the photography (Figure 4). Kucera International used their stereo plotter to produce a three-dimensional coordinate system model of the well locations that had been targeted for the 1972 vintage photography. Coordinates of some of the targeted well locations had been surveyed in connection with this project. Those coordinates were used to control the coordinate system modeling. The technique of analytical bridging was used to distribute control through the entire series of overlapping photographs. These state-of-the-art photogrammetric techniques virtually eliminated the effects of photographic distortion from the modeled coordinates. The modeled coordinates were also corrected for distortions related to the earth's curvature and to effects of atmospheric refraction. Those modeled points that also had been surveyed, but not used to control the model, were used as checkpoints to evaluate the accuracy of the modeled coordinates. The location accuracy of coordinates derived from the 1972 model is a function of the accuracy of the 1972 model and of the survey accuracy of the coordinates used to control the model.

The well locations that could not be surveyed or coordinatized by state-of-the-art photogrammetric techniques were coordinatized by scaling relative to coordinates

AERIAL PHOTOGRAPH SHOWING TARGETED RECHARGE WELL

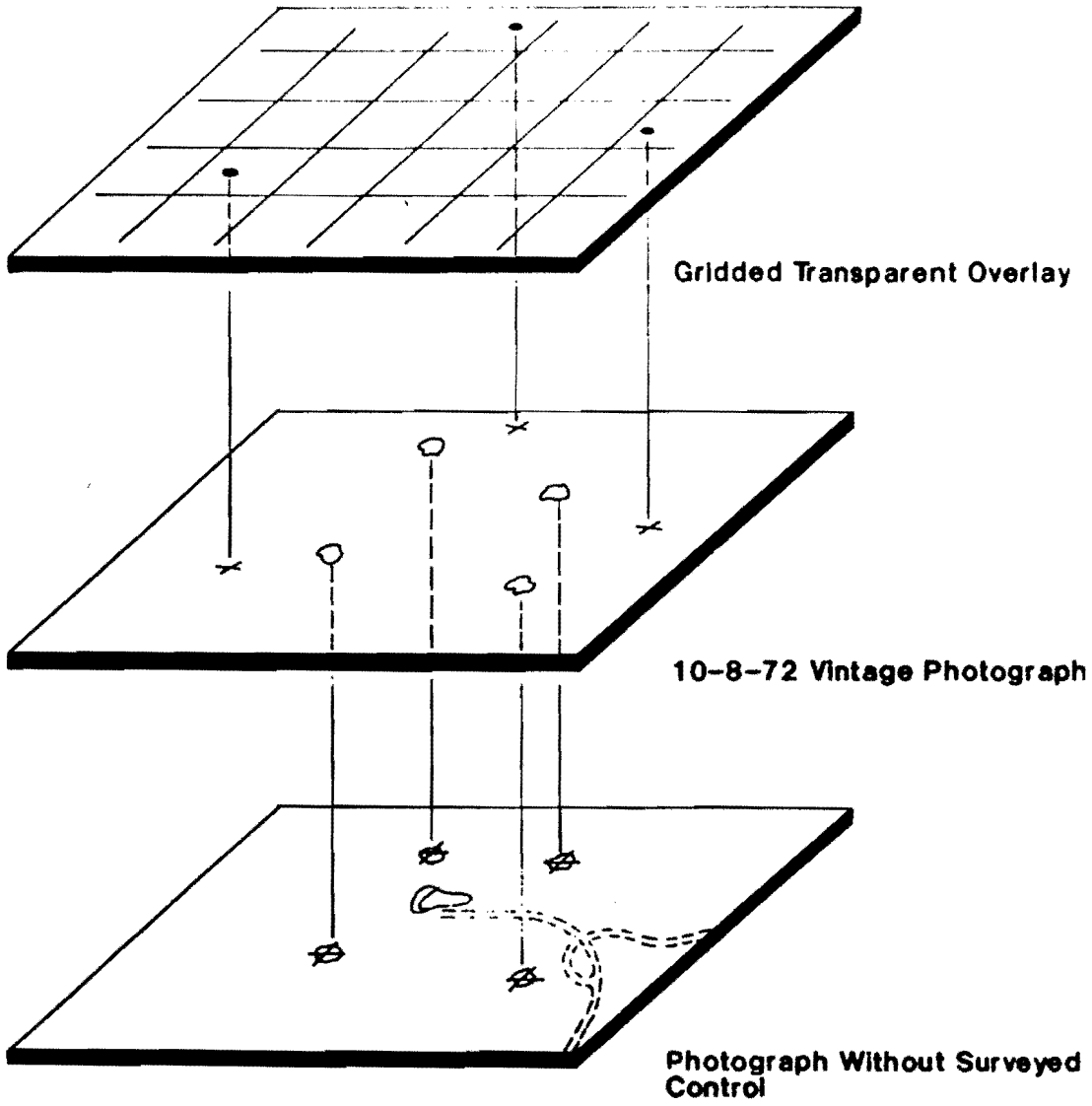


N

FIGURE 4

generated by the previously described methods. Most of the other coordinates were imaged in vintages of photography other than 1972. None of the other vintages of aerial photography contained enough precisely identifiable points with surveyed coordinates for use as control to allow scaling of coordinates directly from them. It was necessary to use the 1972 vintage photography to control the other vintages of photography by overlaying them on the 1972 photography.

Control from 1972 model coordinates was transferred to uncontrolled photographs by four steps. First, 1972 model coordinates were plotted on a transparent overlay that was gridded with the New Wales Grid Coordinate System at the same scale as the photography. Second, the grid was overlaid with the 1972 vintage photography and the plotted locations were aligned with corresponding target locations imaged in the 1972 vintage photography. Third, the uncontrolled photography was aligned with the 1972 vintage photography by using selected physical features, like small bushes or power poles, that could be positively identified in both photographs. Fourth, the well location, imaged in the uncontrolled photograph, was scaled relative to the grid. Figure 5 depicts the overlay method. Due to the inherent distortion of photographs, it is impossible to attain perfect alignment of the grid to the 1972 vintage photography or of the 1972 vintage photography to the uncontrolled photography. The degree of misalignment of



- coordinates of targets from 1972 stereo model plotted on transparent overlay
- targets in 1972 photograph
- corresponding physical features in 1972 photograph
- selected physical features near well location in photograph without surveyed control
- well location visible in photograph without surveyed control

NOT TO SCALE
Feb. 22, 1990

OVERLAY METHOD FOR TRANSFERRING CONTROL TO UNCONTROLLED PHOTOGRAPHY

FIGURE 5

each overlay was evaluated by measuring the distances between sets of corresponding alignment features.

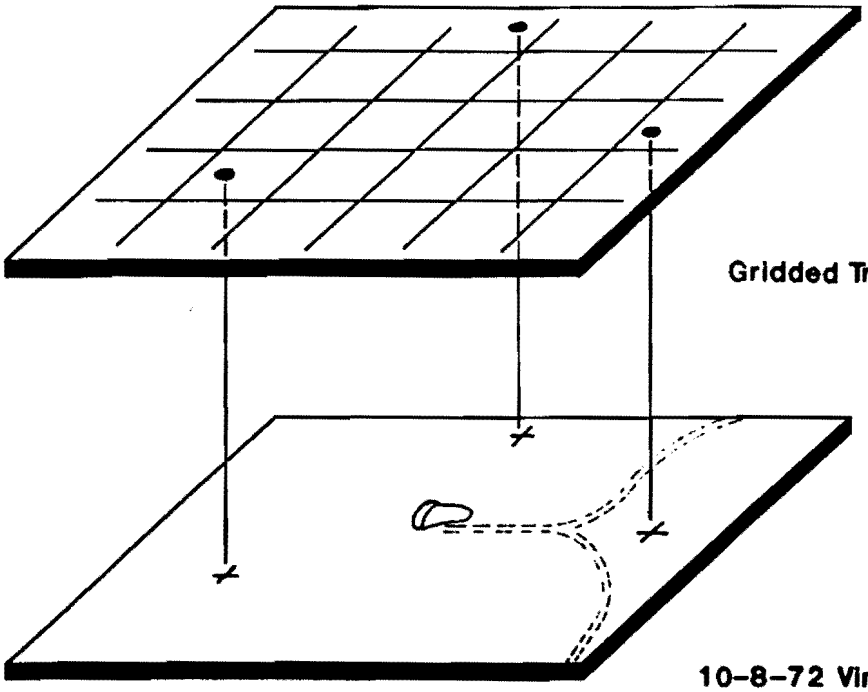
For each well location to be scaled, new photo and grid alignment points were selected and the overlays were realigned for optimum alignment in the vicinity of the subject well location. In general, photo and grid alignment errors are smallest for well locations near the centers of the photographs and largest for well locations near the edges of photographs.

The location accuracy of coordinates derived from vintages of photography other than 1972 by the above described overlay method is a function of several factors. Each factor represents the potential for inaccuracy that was introduced in each step of the process. The first factor is the accuracy of the survey used to control the 1972 coordinate system modeling. The second factor is the accuracy of the 1972 coordinate system model. The third factor is the accuracy with which coordinates from the 1972 vintage photography were plotted on the grid overlay. The fourth factor is the accuracy of the alignment of the grid overlay on the 1972 vintage photograph. The fifth factor is the accuracy of alignment of the uncontrolled photograph containing the image of the well location with the 1972 vintage photography. The sixth factor is the accuracy with which the well location can

be scaled relative to the grid. The seventh factor is the point identification accuracy of the features that identify the well in the uncontrolled photograph.

Two untargeted well locations imaged in the 1972 vintage photography could not be modeled. Coordinates for those locations were determined by an overlay method, similar to the method described above, using the grid overlay and the 1972 vintage photography. The accuracy of the coordinates generated by this method is a function of the same factors that were described above, except the factor representing misalignment of photographs. Only one photograph was used for this method. Figure 6 illustrates the overlay method for 1972 vintage photography.

Most of the well locations that were scaled by the above described overlay methods were not precisely identified in the aerial photographs. We define "point identification accuracy" as the degree of precision with which a point can be identified in an aerial photograph. The exposed parts of a recharge well are too small to be resolved in aerial photographs at the 1" = 200' scale used for this project. Well locations were marked prior to photography in 1972 in order to accent each well's precise location in aerial photographs. Prior to photography, strips of material were arranged in the field in the shape of crosses radiating from each well



plotted coordinates from 1972 model

targets in 1972 photography corresponding with modeled coordinates

untargeted well location visible in 1972 photography

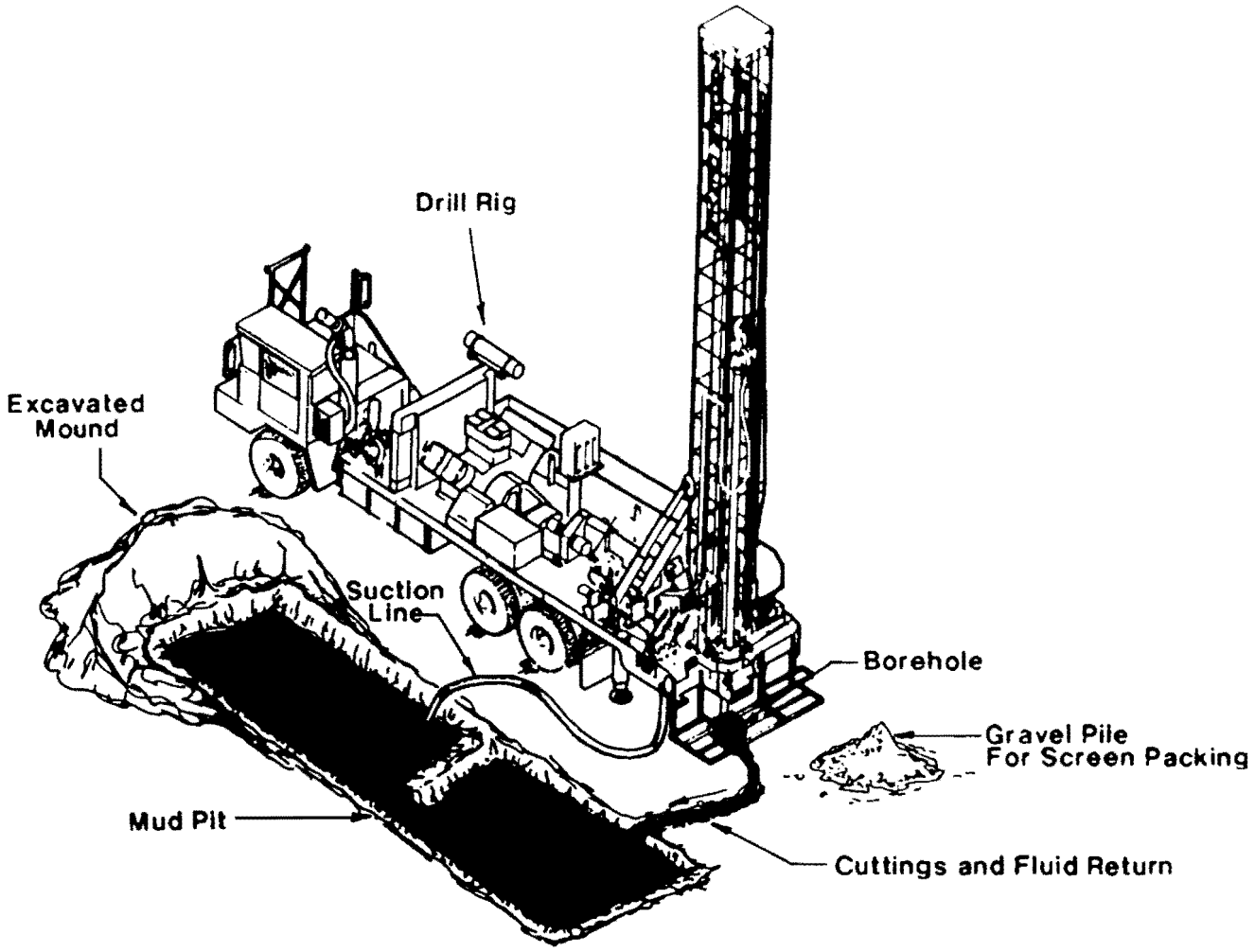
NOT TO SCALE
Feb. 22, 1990

OVERLAY FOR 1972 PHOTOGRAPHY

FIGURE 6

location. Photogrammetrists refer to such markers as targets. Since targets precisely pinpoint the locations of wells in aerial photographs, the point identification accuracy of the targeted well locations is approximately ±0.0 feet. Well locations that were not targeted prior to photography must be identified in the photographs by physical features associated with construction of the well, such as vegetational disturbances resulting from vehicular activity at the drilling site, mud pits, gravel piles, or pump and tank foundations.

Mud pits are small excavations used as reservoirs to contain drilling fluid which is referred to as "mud" by drillers. Drilling fluid is recirculated through the drill hole to cool and lubricate the drill bit and to wash rock cuttings out of the drill hole. Drilling fluid and cuttings flowing out from the drill hole are channeled along a shallow ditch into the mud pit where the cuttings settle out. Drilling fluid is then pumped by the drill rig from the mud pit through a suction hose, shown in Figure 7. The length of the suction hose limits the distance from the mud pit that a hole can be drilled. Equipment in use at the time when project wells were drilled limited the location of the drill hole to a maximum radius of 10 feet from the mud pit. The end of the mud pit where spoil was piled during excavation is unsuitable for drilling. The sides of a mud pit are unsuitable because of the bank instability and the possibility of a



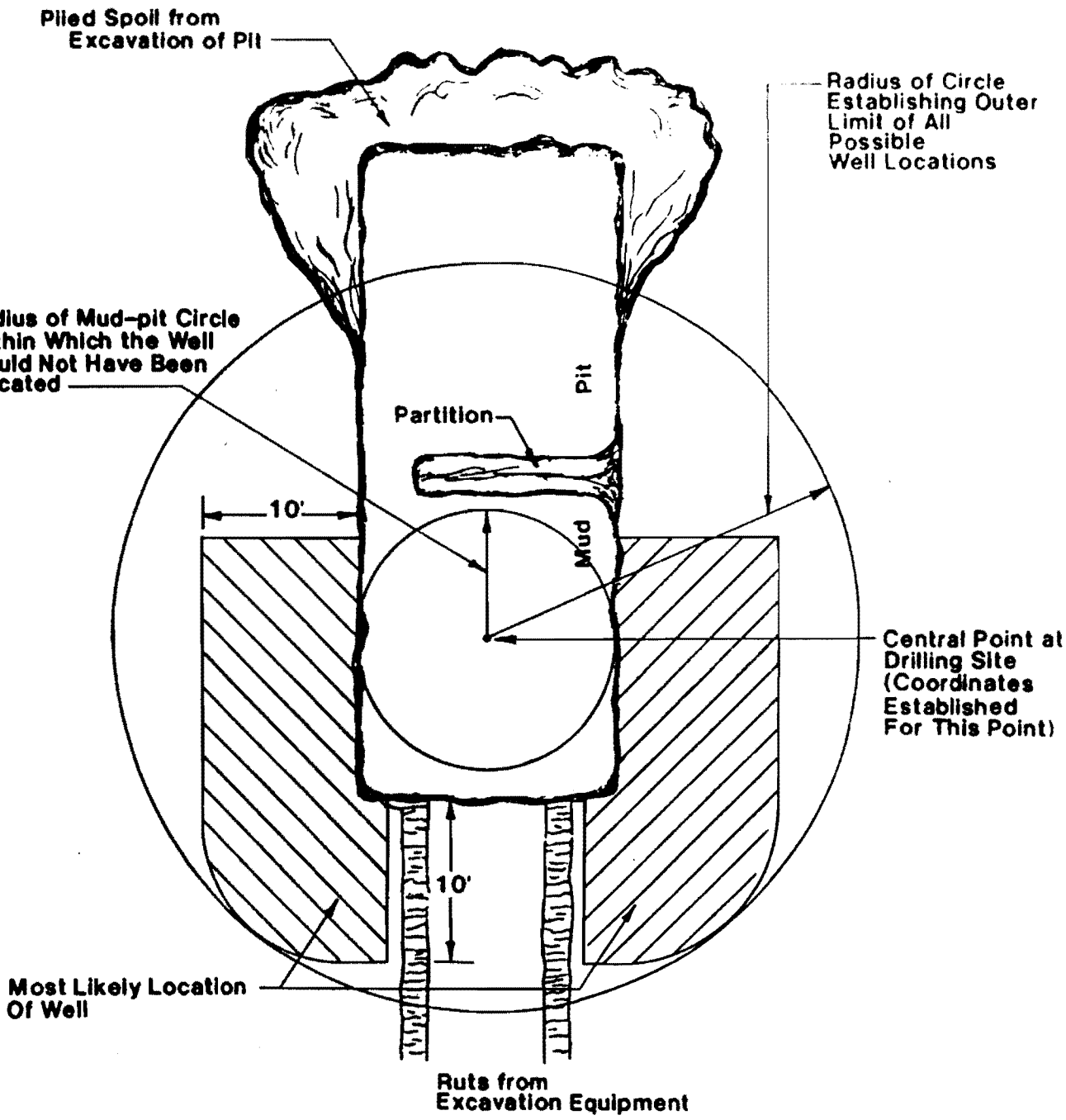
NOT TO SCALE
Feb. 22. 1990

SCHEMATIC OF DRILLING OPERATION
USED IN WELL INSTALLATION

FIGURE 7

collapse. Therefore, the possible well locations that are identified by a mud pit image are located within 10 feet of the mud pit corners on the rutted end of the mud pit, as shown in Figure 8. The central point of possible well locations indicated by a mud pit is centered ¼ of the long dimension of the mud pit from the rutted end of the pit. The well location coordinates given in this report that were derived by photogrammetric methods from mud pit locations indicate the central point of possible well locations. The point identification accuracy of each coordinate is dependent on the dimensions of the mud pit that was used to identify the well location.

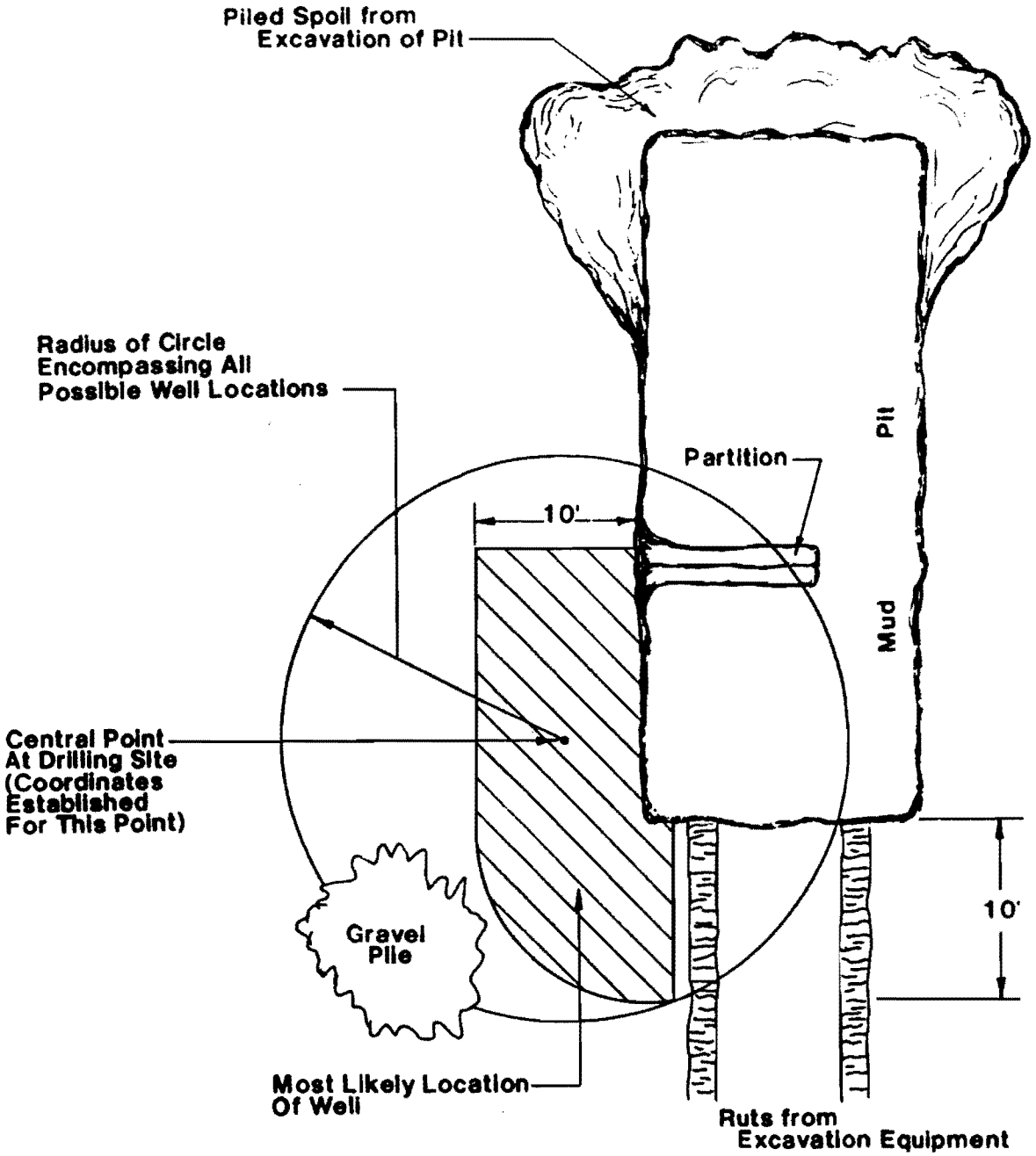
The presence of a pile of gravel adjacent to a mud pit improves the point identification accuracy by eliminating one side of the pit as a possible well location. Figure 9 shows the area of possible well locations that is identified by a mud pit with a gravel pile. Coordinates in this report that are based on mud pits with gravel pile locations indicate the central point of possible well locations that are shown in the figure. The point identification accuracy of each coordinate is dependent on the size of the mud pit. Figure 10 is an aerial photograph showing a well located by mud pit and gravel pile features.



NOT TO SCALE
Feb. 22, 1990

POSSIBLE WELL LOCATIONS AT DRILLING SITE IDENTIFIED BY A MUD PIT

FIGURE 8



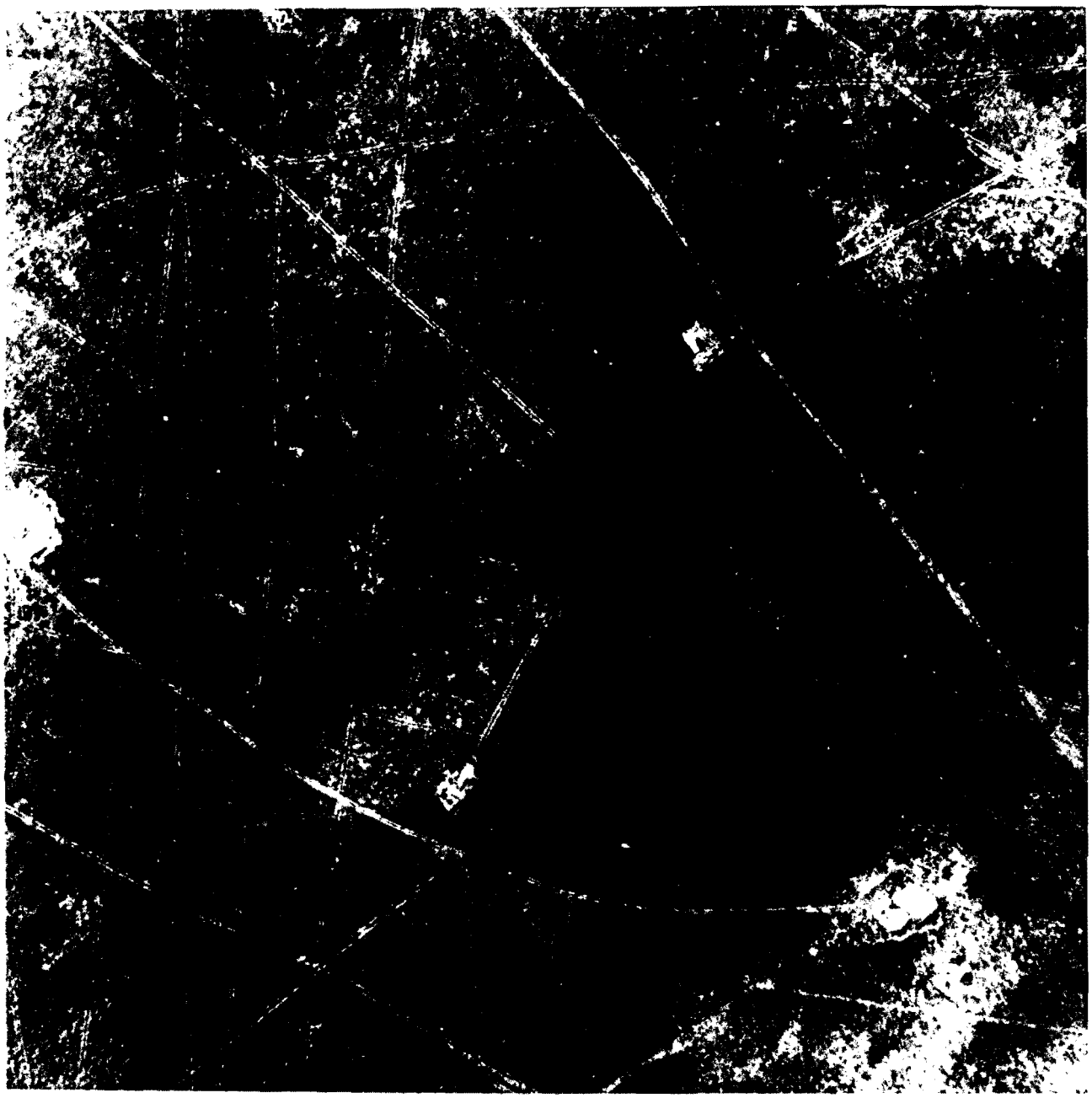
NOT TO SCALE
Feb. 22, 1990

Possible Well Locations at Drilling Site Identified By A Mud Pit with Gravel Pile

FIGURE 9

AERIAL PHOTOGRAPH SHOWING RECHARGE WELL LOCATION

DETERMINED BY MUD PIT AND GRAVEL PILE



N

FIGURE 10

Two well locations were identified in aerial photographs by operational drill rigs in place, i.e., with the boom erect. The exact locations of these wells are indicated as precisely as are targeted wells. The point identification accuracy of an operational drill rig is approximately ±0.0 feet.

After the completion of well construction, typically the mud pit is filled and the site is graded. Normally a disturbed area is the only remaining feature by which a well can be identified in aerial photography after the well is complete. The only generalization that can be drawn is that the well is located somewhere within the disturbance. The well location coordinates given in this report that were derived by photogrammetric methods from disturbed areas represent the centers of the disturbed areas. The point identification accuracy of a coordinate based on a disturbed area is equal to plus or minus the radius of a circle circumscribing the disturbed area.

One well was identified in photographs by a 3 X 3 foot concrete pad that was used as a foundation for a pressure tank. Tank pads are constructed immediately adjacent to the wells they serve. Since a tank pad can be built on any side of a well, a tank pad does not precisely identify the location of its associated well. The point identification accuracy of a 3 X 3 foot tank pad is ±3.0 feet from the center of the pad.

The accuracies of the locations are expressed as radii of circles of influence. The radius of each circle of influence was determined by the coordinate location technique used and the type of point that was located. Each radius was set sufficiently large to include the well with a very high degree of accuracy.

NON-EXISTENT WELLS

Four reported well numbers were found to be erroneous. These well numbers are referenced in various IMCF documents and maps, but no corresponding permit data, drillers' invoices, or water quality analyses could be found. No unidentified drilling sites, or vegetational disturbances large enough to mask drilling sites, was interpreted from any vintage of aerial photography that was examined, either at the locations shown in the IMCF documents or nearby. Neither the past nor contemporary IMCF mine superintendents, IMCF geologists, the primary drilling contractor, nor the construction contractor's supervisor had any recollection of wells at the four reported locations. In order to be certain, each of the reported sites and its vicinity was excavated to various depths below natural grade and scanned with a metal detector. All points where metal was detected were further excavated to find the source of the anomaly. Each site was further searched by Ardaman & Associates, Inc. by using a flux gate magnetometer and excavating each anomaly. No wells or indications of drilling activity, i.e., mud pits, gravel piles, or discarded drilling wastes, were found at any of the sites. How well numbers for non-existent wells originated is a matter of speculation, but the extraordinary investigative effort in the field, including exhaustive excavation, has demonstrated that these reported wells were never installed.

ABANDONMENT

A total of 18 wells in the DRI area had not been physically located before construction was begun. IMC Fertilizer, Inc. agreed to install soilcrete caps at "bedrock" level large enough in diameter to reliably cover each well in the DRI area that could not be physically located and abandoned to regulatory standards. Three methods were proposed to install the caps, by dewatered excavation, by overlapping augers, and by jet grouting. The method proposed for each well depended on the depth and diameter of the proposed cap. Wells that were physically located during construction of the caps were abandoned in a conventional manner by grouting from bottom to top with neat cement grout in lieu of capping.

The simplest capping method, the dewatered excavation method, consisted of dewatering the cast overburden fill above the "bedrock" in the mined areas and excavating to the depth of the proposed cap. One well was capped by this method. An airlift dewatering system was installed around the circumference of the area to be excavated. Conventional earth moving equipment was used to excavate the cast overburden material and to dig a form for the cap into the "bedrock". Soilcrete was pumped into the excavation to the desired depth with a

series of grout pumping trucks. After the grout was emplaced, the excavation was backfilled.

The overlapping auger method consisted of installing 6- to 9-foot diameter caissons in a close-spaced array to cover the area of influence of the well and emplacing soilcrete plugs through the caissons. Each caisson was vibrated into the ground at a carefully surveyed location. Then, the soil was removed from the caisson with a large auger. Soilcrete was tremied into the bottom, the caisson was removed from the ground before the soilcrete set up, and backfilled with spoil. When the primary array of soilcrete plugs had been emplaced, a secondary array of caissons was installed. The secondary caissons were surveyed so that they were centered on the spaces between the primary soilcrete plugs. By precisely positioning the caissons to install overlapping soilcrete plugs, it was possible to assure 100 percent coverage of the area of the well. Five wells were capped by the overlapping auger method.

The jet grouting method consisted of drilling a close-spaced array of drill holes to the depth where the cap was to be emplaced and forcing grout into each hole at high pressure. Four wells were capped by jet grouting.

Eight wells were physically located in the process of installing caps over them. Five were located in dewatered excavations. Three were found in caissons. In all eight cases capping was aborted and the wells were abandoned in the conventional manner, by tremie grouting with a drill rig.

The excavated wells were recognized by traces of their construction materials. Short intervals of casing or rusted iron flakes from decomposition of an iron casing identified some wells. Pea-sized quartz gravel, originally used in construction of the well's filter packs, was found in each well that was physically located during capping. The wells seeped pressurized water upwards from the upper Intermediate Aquifer System into the pit bottoms. The identity of each well was further verified by cleaning it out with a drill rig and checking diameter and depth measurements against construction records.

To abandon the wells that were physically located in dewatered excavations, a drill rig was driven down a ramp into the excavation. The wells were cleaned out to their originally constructed depth and abandoned by grouting with neat cement grout from bottom to top.

In caissons in which wells were physically located, observing appropriate safety precautions, men were lowered into the open hole. Typically, after preliminary confirmation that a well had been found, a temporary riser pipe was installed to extend the well to ground surface for return of drill cuttings. A drill rig was set up over the riser at ground level. The well was cleaned out so that local pressurized zones in the upper Intermediate Aquifer System could recharge down the well to deeper aquifers. With the pressure relieved, a permanent riser pipe was sealed into the surrounding natural materials. Each well was then tremie grouted through the riser pipe. After the abandonments were complete, the riser pipes were cut off near the bottom of each caisson and encased in a soilcrete plug for added protection. The caissons were backfilled and removed.