Fort Huachuca Groundwater Modeling Study

Scope of Work, Cost and Time Estimate

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1. Purpose of Proposed Groundwater Modeling Studies: Engineering Service Request No. EY-FY85-M085, dated 1 March 1985, from Military Design section to Hydrologic Engineering Section identifies the following specific tasks pertaining to Fort Huachuca Groundwater supply:

a. Prepare a Scope of Work for a comprehensive groundwater modeling study for Fort Huachuca;

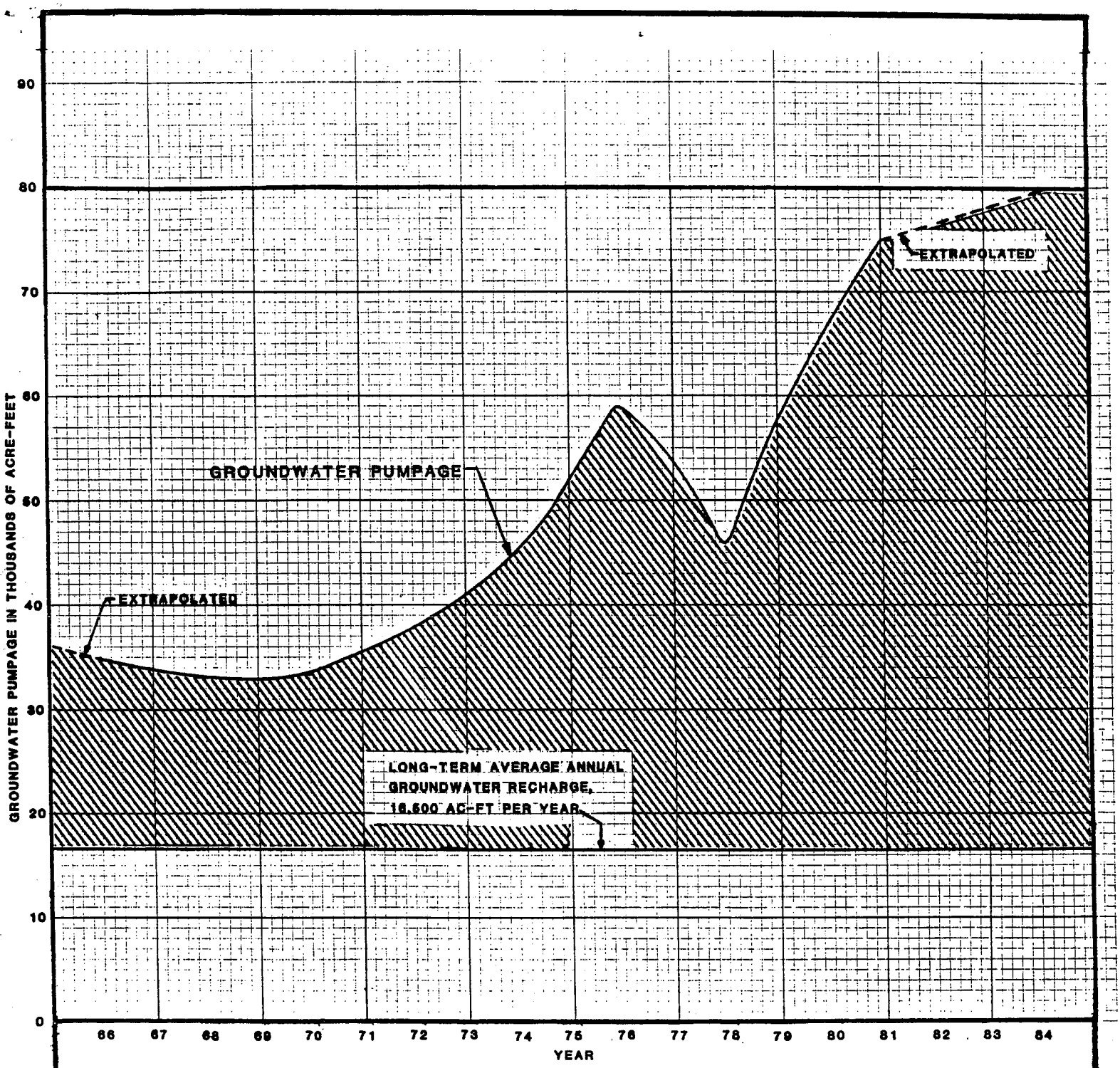
b. A time schedule for completion of work;

c. Cost estimate to perform the work; and

d. Provide Design Branch with three (3) copies of above items.

This document delineates the Scope of Work, cost, and time estimate for conducting comprehensive groundwater modeling studies for Fort Huachuca Military Reservation. These studies will be designed to evaluate present groundwater conditions and those anticipated in the foreseeable future in the context of proposed withdrawals and diversions from the subject groundwater basin. The site-specific study results can also be used for establishing the basis of the various interim protests, if administrative and/or legal proceedings are held on various protests currently pending with the Arizona Department of Water Resources. The purpose of these predictive modeling efforts will be to forecast spatial and temporal changes in the movement of water within the basin. Means of replenishing the groundwater resource will be given high priority to ensure the availability of long-term sustainable water supply to meet requirements of base. The scope of the investigation, reflected in the cost and time estimate, would be to evaluate all available reports, data, information, and results of proposed modeling studies in an attempt to reach a supportable conclusion.

2. Overview of Present Groundwater Conditions: Every groundwater resource system is dynamic in nature; it responds in quantity (as well as quality), although slowly, to natural phenomena such as droughts. Developed groundwater systems are subject to both seasonal changes and long-term trends. Nevertheless, a groundwater reservoir commonly has the potential of providing a dependable source of supply due to its large reserves. However, a prolonged pumpage from a groundwater reserve well in excess of its renewable yield may result in the situation known as groundwater mining. In fact, preliminary results of water balance analysis indicate that the aquifers underlying the upper San Pedro Basin are currently being subjected to a hydraulic stress far exceeding the optimal yield of the basin. For instance, during water years 1966 through 1981, for which records are available, the basin has experienced, on the average, groundwater withdrawals of the order of 45,000 acre-feet per annum whereas the long-term average annual groundwater recharge for the entire basin is estimated to be approximately 16,500 acre-feet. See figure 1 for a graphical display of groundwater withdrawals and long-term average annual recharge for the basin. Moreover (unpublished) records further indicate that during the water years 1981 through 1984, groundwater extractions have exceeded 75,000 acre-feet per annum. This water balance analysis indicates not only unequivocal, continuous depletion of groundwater reserves ("mining!")



AQUIFER OVERDRAFT

COMPARISON OF GROUNDWATER WITHDRAWALS VS. AVERAGE ANNUAL RECHARGE

UPPER SAN PEDRO BASIN

U. S. ARMY ENGINEER DISTRICT LOS ANGELES, CORPS OF ENGINEERS

during the past 30 years but also possible, associated undesirable consequences such as excessive pumping costs (which will further escalate in the years ahead), increased depletion of streamflow by induced infiltration (capture of rejected recharge), intrusion of water of undesirable quality as well as land subsidence.

Furthermore, the major water production wells for the post and Sierra Vista, about 15 in number, are all clustered in an area near the main gate of the post and can be contained in a circle of about 3 miles in diameter. The high concentration of wells in this locality has resulted in a substantial lowering of the water table under the wells. The current static water level below ground surface under the Fort's major well field is approximately 510 feet and has been continuously declining at a rate of about 4 feet per annum. A review of available data also indicates that the aquifers tapped by the Fort Huachuca well field, Sierra Vista, housing developments around Sierra Vista, and the proposed withdrawal areas in the vicinity of Hereford, Arizona are hydraulically continuous. Because of this hydraulic continuity, any pumping of wells and/or diversions of water from the San Pedro River at the various sites will cause drawdowns over a relatively large area, eventually causing interference with the existing Fort Huachuca and Sierra Vista well drawdown fields. Mutual interference from the pumping of wells in the upper San Pedro Basin has been deduced by aquifer tests and confirmed by long-term water level measurements in the area.

Preliminary calculations also indicate that due to mutual interference and extension of the cones of depression resulting from a combination of various withdrawals and diversions, existing and those proposed by the Tenneco West, Inc., and Southland Utilities Company of Tucson, Arizona, existing wells may have to be pumped from deeper depths and run the risk of eventually running dry due to limited opportunity of groundwater recharge and replenishment in the basin. As indicated earlier, Fort Huachuca Installation's records indicate that the depth to the water level under the existing well field at Fort Huachuca currently averages about 510 feet and water level is continuously declining.

It is thus obvious that annual replenishment of the groundwater system in the Fort Huachuca area is greatly exceeded by the pumpage to meet the water demands of growing urban communities and irrigated agriculture. Consequently, under conditions of continuous groundwater mining an ultimate shortage of groundwater is possible, and indeed, inevitable. These preliminary findings have been discussed with the personnel of the Facilities Engineering Directorate at Fort Huachuca during the past few months.

The preliminary findings were also discussed with Mr. Tom Anderson of USGS Tucson office; their major finding, based on a hydrologic analysis of the Upper San Pedro Basin, is that as a result of existing withdrawals from groundwater reservoir, the base flow is pretty well depleted, groundwater mining is currently taking place and that any additional stress on the groundwater resource will further accelerate the declining of water table in the area. There seems to be general concurrence between the two agencies' findings.

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These preliminary findings are tentative and can only be verified with the aid of more sophisticated two-or-three-dimensional analytical/numerical modeling techniques than were used in the various investigations thus far.

3. Objectives of Proposed Investigation and Modeling Strategy: A hydrogeological investigation is essential to the formulation and evaluation of a comprehensive groundwater resource system. The objective of the proposed investigation is to quantify the extent of any adverse impact on the Fort Huachuca Military Reservation groundwater supply resulting from several notices of application to appropriate water in the general vicinity of the Fort. Results of site-specific investigation may be needed to establish the basis for the various interim protests, if administrative and/or legal proceedings are held on various protests.

The areal extent and detail of the investigation will depend upon the dimensions of the groundwater basin, the complexity of the hydrogeologic characteristics of underlying aquifers as well as upon the present and prospective uses of the groundwater resources.

The proposed hydrogeologic investigation will be designed to yield requisite information on the following:

a. The study approach will address long-term installation needs and alternatives to solve those needs;

b. Well-documented figures for present usage and estimates for long-term potential water supply requirements; these will be coordinated with the personnel of Engineering Facilities Directorate at Fort Huachuca;

c. The geologic structure of the underlying aquifers and the boundaries of the groundwater basin;

d. The nature and hydraulic characteristics of the subsurface formations;

e. Groundwater levels, directions, and rates of groundwater flow;

f. Identify the inputs which have the most effect on the model's prediction. Since drawdown is of primary interest, these (inputs) will be the aquifer parameters as well as postulated incremental pumpage and recharge rates. Special efforts will, therefore, be devoted to the collection, retrieval, and analysis of data needed to estimate these parameters;

g. Analyze the reliability of the conceptual model and the adequacy of flow-component definition; and

h. Evaluate the relative importance of various model conditions pertinent to each hydrologic setting. A comprehensive evaluation and comparison of various alternatives and/or scenarious will be considered an integral part of this investigation. Sensitivity of model results to the generalization of values of hydraulic properties will receive special emphasis.

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A steady-state regional calibration will initially be carried out. Inasmuch as reliance solely on localized pump test analyses when estimating spatially-averaged model inputs may lead to gross prediction errors, pump test results will be used to constrain a regional calibration. The hydrologic system defined with the steady-state model will then be analyzed, using a transient simulation subject to physically realistic boundary conditions.

Attempts will be made to simulate historical as well as existing groundwater conditions in the basin. This will facilitate evaluation of model's performance by comparing its potentiometric head predictions with available measurements. As indicated earlier, sensitivity analysis will be considered an integral part of the proposed modeling studies to determine the sensitivity of drawdown to uncertainty in the model parameters. This is especially important in that the values of the various aquifer parameters cannot be known exactly.

The calibrated and verified model will thus provide a reliable predictive tool for site evaluation; it is probably the only way to evaluate simultaneously the effect of all significant parameters on potentiometric levels in conjunction with several alternative policies/scenarios pertaining to several groundwater resource management strategies.

4. Selection of Model: The proposed modeling study will be designed to simulate and analyze site-specific conditions; the model would also enable prediction of general trends in water level declines and the generalized interbasin and intrabasin response to basin-wide stress phenomena. The modeling study will produce a quantitative definition of the complex hydrologic system and evaluate the sensitivity of the model to changes in major input factors.

The selection of the mathematical model will be predicated on the following considerations:

a. The model should have the capability of describing the total system in quantitative terms, along with simultaneous consideration of inter-relationships between components of the system and hydraulic stresses on the hydrologic system;

b. The numerical model will be two-or three-dimensional and preferably employ a finite element formulation; this should offer a distinct advantage, compared to finite difference method, when modeling irregular boundaries and relatively localized areas of large hydraulic stresses such as those encountered within the subject basin;

c. The chosen model should be well-documented and the majority of the available data should be in a format compatible with model input requirements;

d. The model should be able to handle quantitatively, both in spatial and temporal contexts, conjunctive surface water-groundwater interrelationships, including stream recharge, as well as artificial recharge from existing and/or proposed basins;

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e. The model should provide the capability for the study of effectiveness of groundwater replenishment programs, strategies and basin management plans in conjunction with various alternatives;

f. The model should assist in determining sensitivity of underlying assumptions and approximations in both modeling techniques and input data;

g. The model should be capable of simulating groundwater flow in a confined (artesian) aquifer, an unconfined (watertable) aquifer or a combination of the two such as those encountered in the upper San Pedro Basin; and

h. The model should be able to handle heterogeneous and anisotropic conditions - an important consideration in the simulation of a hydrogeologically complex basin such as the one under consideration here.

These features and capabilities would enable consideration of a realistic representation of a complex hydrogeologic system. The main benefit in using such a comprehensive numerical model is that most, if not all of the relevant processes and their interactions can be simultaneously investigated with sufficient accuracy at a large number of discrete points.

5. Data Collection: All data pertinent to the study will be collected and collated. All previous studies and data sources will be reviewed to identify sources of information. Information to be collected will include:

a. Aquifer characteristics, namely transmissivity, storage coefficient, and infiltration rate;

b. Vertical leakage (leakance coefficient of aquitards) separating the underlying aquifers - this information is needed to establish the degree of hydraulic communication between the various aquifers underlying the subject basin;

c. Historical pumpage records;

d. The effect of existing and proposed developments (withdrawals and/or diversions) on recharge and discharge conditions;

e. The lateral extent of each aquifer and the hydraulic nature of its boundaries;

f. Potentiometric maps;

g. Maps of soils, vegetation and topography, aerial photographs, etc., if available;

h. Porosity of underlying aquifers; and

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i. Historical records of groundwater recharge, discharge, and evapotranspiration in the basin; data on stream-aquifer connection will receive particular emphasis.

As much as possible, only existing information will be utilized for the modeling study; no data collection will be made other than observations made during the site visit.

6. Modeling Results: Simulations with the calibrated conceptual model, reflecting added hydraulic stress due to anticipated withdrawals/diversions, will aid in evaluating groundwater resources of the basin. The results of the modeling efforts should greatly assist the decision makers in permitting/refusing any additional groundwater extractions and/or surface water diversions in the general vicinity of Fort Huachuca installation. The proposed modeling studies can also be directed toward possible mitigation of significant adverse impacts, if any. Accordingly, the quantity of percolation and groundwater recharge/replenishment can be increased by installation of appropriately designed spreading basins in the Fort Huachuca Military Reservation. Modeling studies proposed herein should considerably aid in the siting, design, and operation of the spreading basins, if needed.

More specifically, recommended modeling efforts would result in:

a. Development of potentiometric maps for present and anticipated future conditions, reflecting added hydraulic stress due to proposed diversions/withdrawals;

b. Increased knowledge about the behavior of the groundwater basin which would aid in evaluating the effectiveness of multiple managment plans and alternatives on the basin's water resources in spatial and temporal contexts;

c. Determination of sensitivity of assumptions in both modeling techniques and input data; and

d. Help design monitoring and surveillance programs, if required.

7. Cost and Time Estimates: These modeling studies would be carried out in-house next fiscal year within the Hydrologic Engineering Section, should adequate manpower be available. Otherwise, they would be contracted out to a competent Architect-Engineer (A-E) with expertise in groundwater modeling who will work under close supervision of HES's designated Project Manager. Study duration would be 1 fiscal year and hired labor funds of $36,000 would be required to do the modeling study and provide a documentation report. The following table provides a breakdown of tasks/subtasks and corresponding cost.

Task/Subtask Description	Cost
1. Review previous work; identify data gaps, delineate groundwater basin boundaries.	$ 2,000
2. Data collection, compilation, and analysis	3,500

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3. Evaluation of effect of major geological structures on groundwater movement.	1,500
4. Assessment of impact of proposed groundwater withdrawals on existing water supply systems; computation of safe yeild of the basin.	3,500
5. Model calibration; Sensitivity Analysis-Parametric Evaluation.	3,500
6. Generation of alternative solutions consistent with management strategies.	5,500
7. Analysis of results, including evaluation of mutual interference between wells.	2,000
8. Documentation report.	4,000
9. Travel, field visits.	2,000
10. Drafting, clerical, typing, etc.	2,000
11. Review/coordination.	2,500
Subtotal (items 1 through 11)	$32,000
Contract Administration	4,000
Total	$36,000

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