Supporting Documents

Att3_IG1_ARB_Workplan_9of10 includes the following:

Project No.	Project Name	Supporting Documentation Included	Notes
13	Lower Cosumnes River Floodplain Restoration Project	Lower Cosumnes River Floodplain Restoration Project Preliminary 10% Design	The 10% Design submittal for the proposed project has been included.
14	OHWD / Rancho Murieta Groundwater Recharge Project	Planning and Implementation of Groundwater Storage and Recovery Systems International (Journal of Water Resources & Arid Environments)	This paper analyzed the use of infiltration basins as a groundwater recharge element and identified three possible recharge site locations, including the area of the proposed project.
		Anderson Airport Well Test Hole Drilling Results and Proposed Well Design	This document evaluated ground conditions for well drilling in the area of the proposed project.

Lower Cosumnes River Floodplain Restoration Project Preliminary 10% Design

US-CA-1-30
LOWER COSUMNES RIVER FLOODPLAIN RESTORATION PROJECT

DUCKS UNLIMITED

DUCKS UNLIMITED, INC.
WESTERN REGIONAL OFFICE
3074 GOLD CANAL DRIVE
RANCHO CORDOVA, CA. 95670-6116
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SHEET INDEX

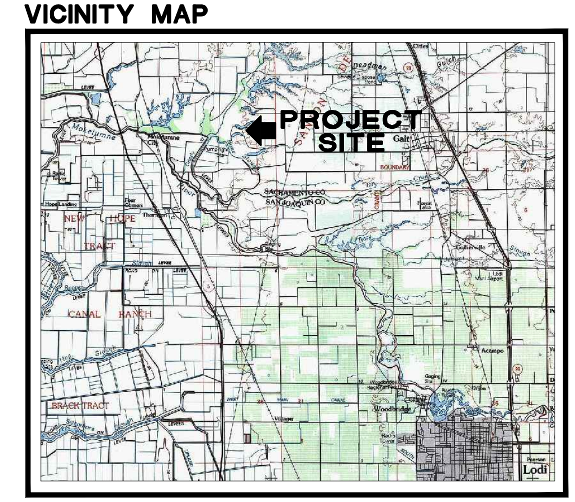
ABBREVIATIONS

AC	ACRE	NTS	NOT TO SCALE
CAP	CORRUGATED ALUMINUM PIPE	OC	ON CENTER
CC	CENTER TO CENTER	OD	OUTSIDE DIAMETER
CL	CENTERLINE	PP	POWER POLE
CMP	CORRUGATED METAL PIPE	PSI	POUNDS PER SQUARE INCH
CMPA	CORRUGATED METAL ARCH PIPE	PVC	POLYVINYL CHLORIDE
CONC	CONCRETE	R	RIGHT
DIA	DIAMETER	RD	ROAD
Dp	PIPE DIAMETER	REF	REFERENCE DIMENSION
Dr	RISER DIAMETER	REQD	REQUIRED
DU	DUCKS UNLIMITED, INC.	S	SOUTH
E	EAST	SCH	SCHEDULE
EG	EXISTING GROUND	SF	SQUARE FEET
EL	ELEVATION	SP	SPECIAL
EX	EXISTING	SY	SQUARE YARD
FB	FLASHBOARD	STA	STATION
FL	FLOWLINE	TBD	TO BE DETERMINED BY ENGINEER
FT	FOOT, FEET	TE	TOP ELEVATION
FTG	FITTING, FOOTING	TOL	TOP OF LEVEE
GA	GAUGE	TYP	TYPICAL
H	HEIGHT	USA	UNDERGROUND SERVICE ALERT
HDPE	HIGH-DENSITY POLYETHYLENE	VLV	VALVE
ID	INSIDE DIAMETER	W	WIDTH
IE	INVERT ELEVATION	W	WEST (WHERE APPLICABLE)
IN	INCH, INCHES	W/	WITH
L	LENGTH, LEFT	WCS	WATER CONTROL STRUCTURE
LBF	POUNDS-FORCE	WS	WATER SURFACE
LF	LINEAR FEET	WSEL	WATER SURFACE ELEVATION
MAX	MAXIMUM	WWF	WELDED WIRE FABRIC
MIN	MINIMUM		
MISC	MISCELLANEOUS		
N	NORTH		

SURVEY POINT DESCRIPTORS

CTBM	Bench Mark (permanent)	RDSH	Road Shoulder	SDPT	Storm Drain, Pipe Top
CTBT	Bench Mark (temporary)	RDSN	Road Sign	SSCO	Sanitary Sewer, Cleanout
CTCP	Survey Control Point (permanent)	RDST	Road, Painted Stripe	SSMH	Sanitary Sewer, Manhole
CTCT	Survey Control Point (temporary)	RDTC	Road, Top Back of Curb	SSPI	Sanitary Sewer, Pipe Invert
DIFL	Ditch Flowline	RDTO	Road, Toe of Slope	SSSV	Sanitary Sewer, Service
DIGB	Ditch Grade Break	RDTP	Road, Top of Slope	TEGY	Telephone, Guy Wire to Pole
DITO	Ditch Toe	RDTW	Road, Top Back of Walk	TEOH	Telephone, Overhead
DITP	Ditch Top	TFBL	Building	TERI	Telephone, Riser
SWFL	Swale Flowline	TFBR	Brush	TESN	Telephone, Warning Sign
SWGB	Swale Grade Break	TFCO	Concrete (pad, slab, etc.)	TETP	Telephone, Pole
SWTO	Swale Toe	TFGB	Grade Break	TEUG	Telephone, Underground
SWTP	Swale Top	TFGS	Ground Shot	WTFH	Water Fire Hydrant
IRCO	Irrigation Concrete Pad	TFRK	Rock Or Rocky Area Boundary	WTHW	Water High Water
IRCP	Irrigation Control Panel	TFTO	Grade Break at Toe	WTMT	Water Meter
IRPI	Irrigation Pipe Invert	TFTP	Grade Break at Top	WTPI	Water Pipe
IRPM	Irrigation Pump	TFTL	Tree line	WTPM	Water Pump
IRPT	Irrigation Pipe Top	TFTR	Tree	WTVL	Water Valve
IRVL	Irrigation Valve	TFVP	Vernal Pool Edge	WTWL	Water Well
IRWL	Irrigation Well	ELBX	Electric, Box or Pullbox	WAEW	Edge of Water
FNAP	Fence Angle Point	ELGY	Electric, Guy Wire to Pole	WAHW	High Water Mark
FNCR	Fence Corner	ELOH	Electric, Overhead	WAUW	Under Water Ground Shot
FNGT	Fence Gate	ELMT	Electric, Meter	WAWS	Water Surface
FNLN	Fence Line	ELPP	Electric, Power Pole	WCFL	Water Control Structure, Flowline/Invert at Structure
LVCL	Levee Centerline	ELSN	Electric, Warning Sign		
LVGB	Levee Grade Break	ELTR	Electric, Transformer	WCHW	Water Control Structure, Headwall
LVTO	Levee Toe of Slope	ELTW	Electric, Tower	WCPI	Water Control Structure, Pipe Invert at Outlet
LVTP	Levee Top of Slope	ELUG	Electric, Underground		
RDCL	Road, Centerline	ELVT	Electric, Vault	WCPT	Water Control Structure, Pipe Top at Outlet
RDED	Road, Edge of Dirt Road	NGMT	Natural Gas, Meter		
RDEG	Road, Edge of Gravel Road	NGPI	Natural Gas, Pipe	WCST	Water Control Structure, Top of Structure
RDEP	Road, Edge of Paved Road	NGSN	Natural Gas, Warning Sign		
RDFC	Road, Face of Curb	NGVL	Natural Gas, Valve	WCWW	Water Control Structure, Wing Wall
RDFL	Road, Gutter Flowline	SDMH	Storm Drain, Manhole		
RDGB	Road Grade Break	SDPI	Storm Drain, Pipe Invert		

VICINITY MAP



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SURVEY DATUM

HORIZONTAL AND VERTICAL CONTROL OPUS SOLUTION – coordinates are State Plane 0403 California Zone 3 in US feet [NAD83]. They were established f[illegible]m [illegible]e GR[illegible] Elli[illegible]id w[illegible] i[illegible]ormatio[illegible] from [illegible]e Trimble R-8 receivers on July 10 & 11, 2008, calibrated to an OPUS posi[illegible] and s[illegible]nt [illegible]o N[illegible] for s[illegible]lu[illegible] [illegible]he vertical [illegible]ntrol came from the same solution using Geoid03 in the NAVD88. T[illegible] full OP[illegible] so[illegible]tio[illegible] r[illegible]rt [illegible]s [illegible]n file a[illegible] the W[illegible] engineering department in Rancho Cordova, California.

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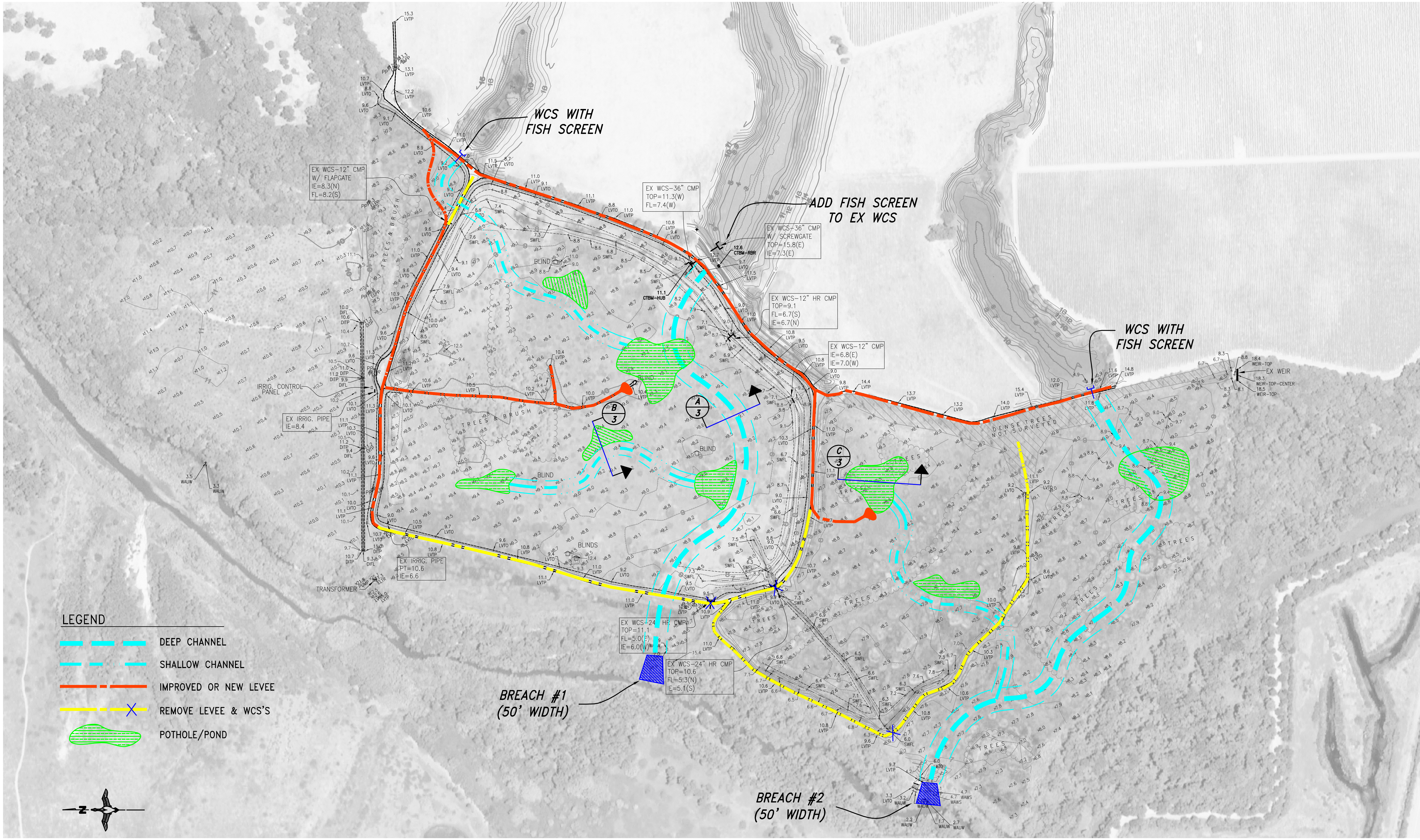

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LOWER COSUMNES RIVER RESTORATION PROJECT CONCEPT PLAN

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DRAWN BY: JS
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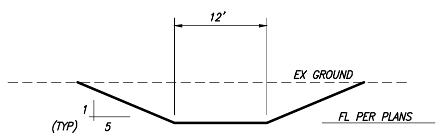
CHECKED BY:

DATE: 10.08.09
SHEET NO. 2 OF 3
APPROVED BY: JDM
APPROVED BY:



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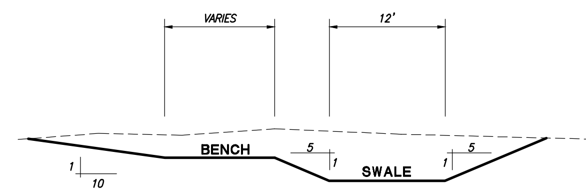

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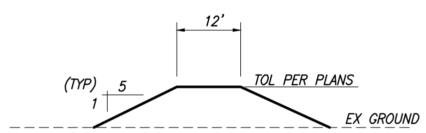

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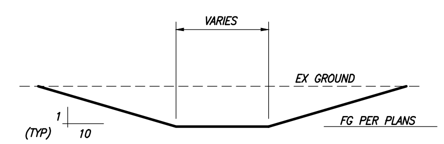

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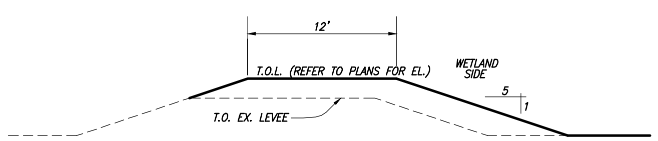

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		SURVEYED BY: JM	
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DATE: 10.08.09	SHEET NO. 3 OF 3	APPROVED BY: JDM	APPROVED BY:

Planning and Implementation of Groundwater Storage and Recovery Systems International (Journal of Water Resources & Arid Environments)

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Planning and Implementation of Groundwater Storage and Recovery Systems

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Abstract: The main objectives of all Groundwater Storage and Recovery (GSR) projects are to recharge, store and recover all or a portion of recharged source water. The groundwater recharge element of the system can be achieved by different direct methods, including infiltration basins, vadose zone wells, injection wells, dual-use wells that both inject and recover water, or a combination thereof. In-lieu recharge, which is the replacement of pumped groundwater with surface water supplies, is considered an effective indirect recharge method. The initial planning to develop a GSR project is driven by source water characteristics and amount, available aquifer storage and land for recharge facilities. The development of the GSR project is multi-phase effort that includes:

Phase1: Hydrologic Characterization of Potential Sites and Site Selection
Phase 2: GSR Facility Design and Construction
Phase 3: Operation, Maintenance and Monitoring
Phase 4: Project Evaluation and Improvement

GSR systems have a long successful history in California, mainly in the southern part of the state. Robertson-Bryan, Inc. (RBI) has developed a phase-based plan for a recharge pilot project in south Sacramento County, California, USA. Historic contour maps of the area show a significant drawdown at the center of the basin as a result of increased pumping. The initial phase of this project is underway and preliminary investigations revealed a great potential for the success of the recharge project.

Key words: Groundwater Storage and Recovery % Infiltration Basins % Injection wells % In-lieu recharge % Phase-based Plan

INTRODUCTION

The increasing demand for water in the United States and other countries produced the realization that the vast underground reservoirs formed by aquifers are invaluable water supply sources, as well as water storage facilities [1]. Developing scientifically based strategies for sustainable use of our groundwater resources is essential in addressing growing demands of an increasing population and to prepare for the effects of climate change. One of the strategies that have been used and proved to be successful in mitigating depletion of natural groundwater reserves is the development of Groundwater Storage and Recovery (GSR) projects. GSR is a simple concept, in which surface water or recycled water is stored in subsurface permeable aquifers when water is plentiful and extracted during times of peak demand or drought. The main operations of all GSR projects are recharge, storage and recovery of all or a portion of source water recharged. The groundwater recharge element of the system can be achieved by different direct methods, including infiltration basins, vadose zone wells, injection wells, dual-use wells that both inject and recover water, or a combination thereof. In-lieu recharges-the replacement of pumped groundwater with surface water supplies-is considered an effective indirect recharge method.

Communities throughout the world are developing underground storage capacity to meet their growing water demands. In 2004, Topper *et al.* reported that artificial recharge was being “used in at least 32 states in the U.S. and at least 26 countries worldwide.” Many of these projects are implemented by state and local jurisdictions. GSR systems have a long and successful history in California, where artificial recharge of alluvial aquifers with storm runoff by use of spreading basins

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began about the turn of the century and was a widespread practice by the 1930s, mainly in the southern part of the state [2].

Groundwater supports nearly 95 percent of all water demands in south Sacramento County. In the last four decades, groundwater levels in wells in the area have generally declined between 3 and 15 meters (10 and 50 feet). The average annual decline in water levels in the basin is 0.3 meters (1 foot). Historic contour maps of the south basin show an increase in the size of the cone of depression at the center of the basin as a result of increased pumping. Therefore, to protect the health and viability of this vital resource, interested stakeholders have come together to develop a management strategy for the groundwater resources in the area. In 2006, six stakeholders in the South Sacramento Basin entered into an agreement to produce a South Sacramento County Groundwater Management Plan. The common interest of these partners is to meet future water demand through comprehensive planning and collaboration with other stakeholders-including local, state and federal agencies-and with local academic institutions and residents in the area. One of the primary objectives of this planning process is to implement conjunctive use of groundwater and surface water. This includes planning for development of groundwater recharge projects in the area. Robertson-Bryan, Inc. (RBI) has developed a phase-based plan for a GSR project in south Sacramento County, California, USA, using recharge basins as the recharge method. The purpose of developing this phase-based plan is to provide a practical investigative planning approach for developing artificial recharge projects, which will allow agencies in south Sacramento County to pursue technically and fiscally sound recharge projects.

Development and Implementation of Gsr Projects: The initial planning to develop a GSR project is driven by source water characteristics (timing and amount) and available aquifer storage and land for recharge facilities. The study describes a four-phase process for development and implementation of the *recharge basins GSR* projects. This multi-phase approach allows agencies and stakeholders to cost effectively manage the project budget. These phases are:

Phase 1: Hydrologic Characterization of Potential Sites and Site Selection
Phase 2: GSR Facility Design and Construction
Phase 3: Operation, Maintenance and Monitoring
Phase 4: Project Evaluation and Improvement

The focus of this paper is on Phase 1, which provides the process and procedures for evaluating potential recharge locations for the Project. Subsequent phases are addressed more generally because specific design, operation, monitoring and project documentation depend on Phase 1 findings.

Phase 1: Hydrologic Characterization of Potential Sites and Site Selection: The objective of this phase is to hydraulically characterize potential recharge sites in specific basins to determine if any are appropriate for GSR projects. Site characterization should address the following questions:

- Are infiltration rates of the near-surface layers (within 3 meters (10 feet) of surface) sufficiently high for the project needs?
- Do lateral extensive low-permeability layers exist within the shallow vadose zone?
- What are the hydrologic properties of the predominant layer type?
- What is the potential for recovery?

Accordingly, at the end of this phase and by answering these questions, the detailed design criteria of the project facilities will be determined, project construction outlines will be laid, management and operation procedures will be formulated and a monitoring plan will be decided. An important outcome of this phase is a detailed project budget. The ensuing sections of this paper describe the field and modeling evaluations and the information that will be produced. These evaluations will be phased to include:

Hydrology and Hydrogeology Data Assembly: Available regional baseline basin data should be assembled and analyzed to determine potential initial recharge sites. These data should include basin hydrogeology and well logs; regional and local groundwater levels and groundwater contour maps; land use and land parcel availability for recharge projects; soil maps of the basin; hydrology data, including rainfall and evapotranspiration; surface water supply; water rights and pumping test results; and water quality data for the surface water source and the aquifer.

Near Surface Hydraulic Evaluations: The following field investigations are designed to determine the infiltration capacity and hydraulic conductivity of the top 3 meters (10 feet) of the soil profile.

- Backhoe Test Pits

Backhoe test pits allow visual observation of the soil horizons and overall soil conditions both horizontally and vertically. An extensive number of test pit observations can be made across a site at a relatively low cost and in a short time period. Soil samples from test pits should undergo laboratory testing to determine particle size distribution and soil permeability. At each test pit, the following conditions should be noted with depth measurements described as depth below the ground surface:

- Soil horizons (upper and lower boundary),
- Soil texture and color at each horizon,
- Color patterns (mottling) and observed depth,
- Observation of bores or roots (size, depth) and
- Near surface hardpan or limiting layers (clay layers).

The number of test pits varies depending on site conditions. In general, for infiltration basins, multiple test pits should be evenly distributed at the rate of 5 to 8 test pits per site. Additional tests should be conducted if local conditions indicate significant variability in soil types. Similarly, uniform site conditions indicate that fewer tests are required.

Particle Size Distribution Analysis: Sieve analysis of particle size distribution from soil samples collected during test pit excavations allows estimation of soil permeability and normalized infiltration. The sieve analysis uses a graded series of wire screens [3].

The gradation data yields the percentage of fines (percent passing the number 200 sieve (0.075 mm)). Soils with higher percentage of fines indicate a higher percentage of clay materials, which makes the soil unsuitable for recharge basins. The effective grain size D_{10} (diameter for which only 10 percent of the sample particles are finer), will be determined and used to estimate the saturated hydraulic conductivity using the Hazen formula:

$$K = C\,(D_{10})^2 \qquad (1)$$

Where:

K = Hydraulic conductivity (cm/sec)
C = A constant and unit conversion factor that varies from 1.0 to 1.5
D_{10} = Effective grain size diameter (mm)

Spreading basin approximate maximum infiltration rate q_A can be calculated using the following equation:

$$qA = (k)\,(A) \qquad (2)$$

Where:
q_A = infiltration rate
A = The total infiltration area of the soil interface

This equation is acceptable for estimation purposes, as studies have shown that under ponding, the long-term vertical infiltration rate of a soil usually approaches a steady value equal to the saturated hydraulic conductivity.

Double-ring Infiltrometer Test: Infiltration is the major process that affects groundwater recharge. A double-ring infiltrometer is the instrument most often used for measuring infiltration rates in the field. These tests sharpen estimates made for sites selected from the sieve analysis. A double-ring infiltrometer consists of two metal cylinders with the inner and outer cylinder diameter of 30.5-61.0 centimeters (12-24 inches), respectively [4]. Both rings are driven partially into the soil about 5 to 10 centimeters (2 to 4 inches) and filled with water. The rate at which the water moves into the soil is measured. The infiltration rate is determined as the amount of water that penetrates the soil per surface area over time. The infiltration rate becomes constant when the soil becomes saturated. The double-ring infiltrometer minimizes the error associated with the single-ring method because the water levels in the outer ring forces vertical infiltration of water in the inner ring. The ASTM standard D3385, the standard test method for infiltration rate of soils in field using a double-ring infiltrometer, describes a procedure for measuring infiltration rate with a double-ring infiltrometer.

Small-scale Infiltration Basins: Small infiltration basins are usually 9-by-9-meter (30 by 30 feet) basins with a depth of 1 to 2 meters (3 to 7 feet). To measure infiltration rates, the same principles and equations as cylinder infiltrometer can be applied. The water level is raised until it reaches operational depth, then the depth of water in the basin is measured over time to observe the ability of the basin to drain. Backhoe trenches (2 meters (7 feet) deep, 1 meter (3 feet) wide) are dug perpendicular or parallel to the basin sidewall to determine lateral spreading. The advantage of this method is that it provides a large-scale determination of infiltration rate and hydraulic conductivity.

Mid-depth and Deep Hydrogeologic Characterization: Borehole exploration is used to ensure that the hydrogeology of the deeper strata (below 3 meters) to depths of about 35-85 meters (115-280 feet), or to water level, is conducive to recharge operations and to estimate hydraulic parameters of deeper layers. This exploration will:

C Determine underground stratigraphy and lithiological formations and

C Identify presence of low-permeability layers that could result in perching and impede recharge to deeper aquifer levels.

On average, one to two test boreholes should be drilled on sites with expected relatively uniform lithology in accordance with the standards set out below. Boreholes are drilled using one of these drilling methods: air rotary drilling, cable tool drilling, or mud rotary drilling [5]. If clay layers are either minimal or extensive, further borehole exploration is not needed. For boreholes less than 85 meters (280 feet) deep, sampling of drilling cuttings will be taken at 1.5 meters (5 feet) depth intervals or at every change in formation material [6]. Samples would be evaluated and described in a driller's sampling log.

Boring logs include the location, depths, geotechnical data and sample description for each material identified in the borehole (Figure 1). Description and identification of soils and classification of soils are in accordance with ASTM standards or any other appropriate geologic standards. Borehole location should be based on the groundwater gradient in the area.

Three boreholes should be drilled-one in the center of the potential recharge basin site, one up-gradient and one down-gradient of the recharge basin. The exact location of boreholes should be determined based on site location.

The first borehole in the middle of the recharge basin will determine if further exploration should be eliminated because of extensive clay layers.

Geophysical logging can be used to supplement borehole logging to aid in interpreting the borehole logging. Gamma logging can be useful to confirm specific subsurface geologic conditions (permeability) if standard methods are inconclusive.

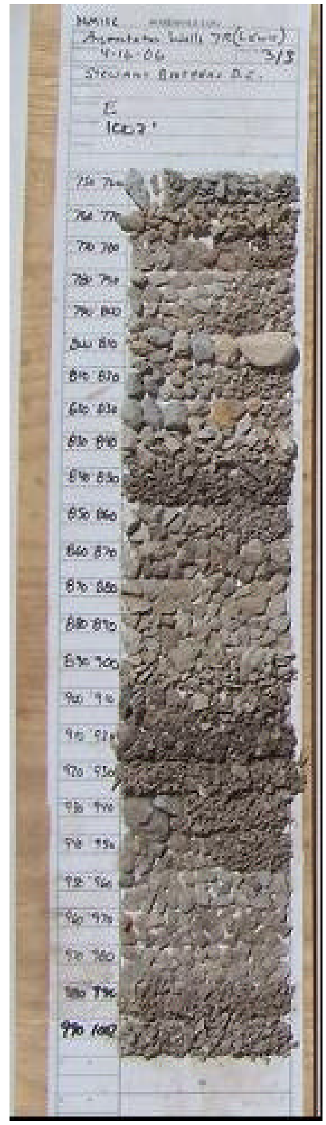

Fig. 1: Example of borehole geologic logging

Water Quality: Sampling both potential source water and groundwater will document baseline concentrations, determine geochemistry of source water and aquifer water; and determine the future impact of the recharge water on the groundwater to avoid any degradation that might result from the GSR project. Sampling results can be used as an indicator of the arrival of the source water to the aquifer, especially if there is different geochemistry between the two.

Source water samples should be collected on a quarterly basis from surface water source. Groundwater samples should be collected from boreholes and other wells in the area. Water quality of groundwater should be compared to recharge source water. These samples can be analyzed for dissolved solids, total and dissolved inorganic constituents, nutrients, organic and volatile organic compounds, radio nuclides and bacteria.

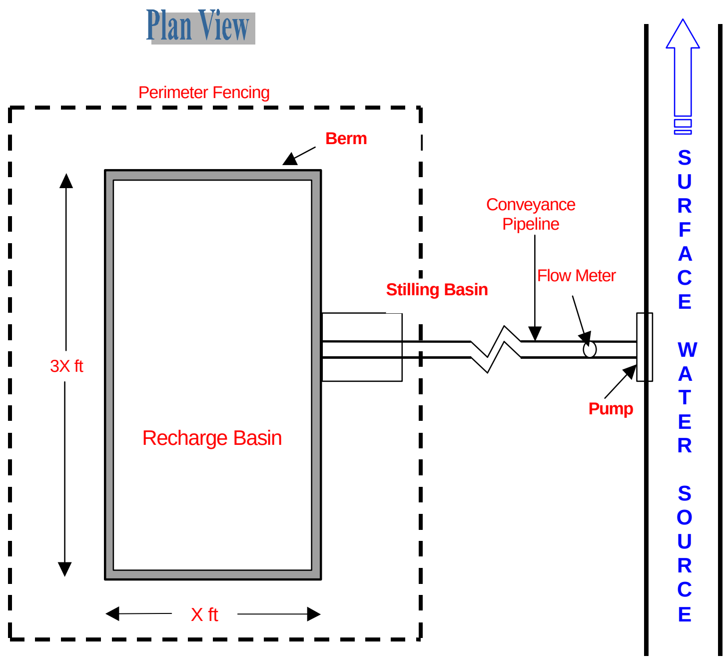

Fig. 2: Schematic Layout of a Typical Recharge Basin

Modeling of Groundwater Level Responses to Recharge Operations: The dynamics and effects of potential recharge operations on groundwater levels at each potential site should be analyzed using simple steady-state reverse drawdown equations or groundwater mounding equations [7]. The complexity of the model assumptions and type of model will depend on the data acquired during the field investigations for each site.

These models will be applied to facilitate quick but reliable analysis of multiple scenarios for recharge operations. The local hydraulic parameters and data collected from each site in previous stages, such as infiltration rate, depth to groundwater table and aquifer parameters will be used to develop these models.

Phase 2: Gsr Facility Design and Construction: GSR facilities are structures that provide for the effective recharge into and recovery of surface water from a local aquifer. Recharge facilities typically include water treatment unit or stilling basins, recharge or infiltration basins and conveyance facilities. Most basins are earthen structures designed to hold water and allow it to infiltrate into the underlying aquifer over a period of time. Therefore, recharge basins do not maintain a permanent pool of water and need a constant input of water supplied through a conveyance facility. Figure 2 provides a generalized schematic of the layout of recharge facilities.

Because recharge basins are susceptible to high failure rates due to clogging by sediments, pretreatment of water is necessary to remove suspended solids before the water enters the basin. Therefore, a water treatment plant or a stilling basin should be established to provide for the removal of suspended solids as part of the recharge facility design. A stilling basin is designed to allow sediment to settle out before the water is put into the spreading basin.

A typical recharge basin (Figure 2) should be graded as flat as possible, having a length-to-width ratio of 3:1, or greater, to provide uniform ponding and infiltration across the basin floor. For public safety and for easier maintenance access, the side slopes of the basin should be 3:1.

A recharge facility requires a constant supply of water that must be conveyed from its source or delivery point. The exact configuration of the conveyance facility required to move water from the source to the recharge facility will depend on the location of the recommended recharge site. If the recharge site is close to the surface water source, water transfer could be by gravity feed from the source to the recharge facility.

If the site is further from the source water, conveyance may require the use of pumps to draw water from the source. The type and number of pumps will be chosen based on the lift between the water surface elevation at the source and the discharge point into the stilling basin. The length of the pipeline or canal to convey the water depends on the location of the recharge facility. A magnetic flow meter should be attached near the discharge point at the recharge basin to measure the inflow.

Water recovery is typically accomplished through wells; however, some GSR systems utilize natural discharge of groundwater to a stream as a virtual means of recovery.

Phase 3: Operation, Maintenance and Monitoring: Operation of the recharge facility will entail management of water into the recharge facility and out of the recovery wells. The operation depends on the quantity and availability of the source water and the infiltration capacity of the facility. On the other hand, recovery can take place on a regular cycle, such as the annual dry season, or it may simply be part of the long-term plan, such as for future development or drought protection.

Maintenance generally consists of routine maintenance of equipment and removal of clogging materials from the recharge facility, which is the most crucial maintenance effort. If sediment accumulates, surface soils will become clogged and the basin will cease to operate as designed. Sediment should be removed by scraping and ripping to rejuvenate infiltration rates only when the surface is dry and “mud-cracked.” Light-weight equipment should be used to minimize soil compaction during maintenance activities

The monitoring element of a project includes recharge basin monitoring of inflow and infiltration, which will govern water management and monitoring of local and regional aquifer to measure changes in groundwater levels, quality and gradients resulting from the GSR operations. Monitoring of groundwater levels locally and regionally is crucial in determining the fate of the recharge water and hence the success of GSR project.

Recharge basin monitoring includes monitoring all elements needed to estimate the water balance of the basin, such as surface water diversion, evaporation, rainfall and water level in the basin. This is very crucial in the operation and management of the facility.

Local shallow aquifer monitoring is performed by utilizing monitoring wells or piezometers. Such monitoring wells and piezometers could be placed in some of the boreholes drilled during the site evaluation process in order to reduce costs. Following well development, pressure transducers and data loggers should be installed in each of the newly installed monitoring wells. For monitoring the regional aquifer and based on the need to determine directions of water movement in the area, shallow wells near the project site should be identified to obtain historic, current and future water level data measurements.

Source water samples should be collected on a monthly basis from the surface water or recycled water source. Groundwater samples should be collected from boreholes before the start of the recharge activities and from piezometers during the operation of the recharge facility. Water quality of groundwater should be compared to recharge source water. Sampling frequency should be at least once every month. These samples should be analyzed for dissolved solids, total and dissolved inorganic constituents, nutrients, organic and volatile organic compounds, radio nuclides and bacteria.

Phase 4: Project Evaluation and Improvement: This task will determine whether the GSR project is effectively meeting the program objectives and will enable project managers to evaluate and improve the performance of the project. In order to achieve that, monitoring data should be regularly collected and reported. Such reporting will enable the project managers to evaluate the performance of the project and to determine what to fix, what type if expansion is needed and how to improve project performance.

Potential for Gsr Projects in South Sacramento County: RBI has developed a phase-based plan for a recharge pilot project in south Sacramento County, California, USA. The South Basin is bounded by the Cosumnes River on the north and west and Dry Creek on the south, which is the boundary with San Joaquin County, as seen in Figure 3.

RBI collected, assembled and analyzed available regional basin data to determine potential initial recharge sites. These data include basin hydrogeology and well logs; regional and local groundwater levels and groundwater contour maps; land use and land parcel availability for recharge projects; basin soil maps; hydrology data, including rainfall and evapotranspiration; surface water supply; water rights and pumping test results; and water quality data for the surface water source and the aquifer

Based on the findings from the data analysis, groundwater is the major supply source for nearly all agricultural, residential and municipal users in southern Sacramento County. Annual precipitation in

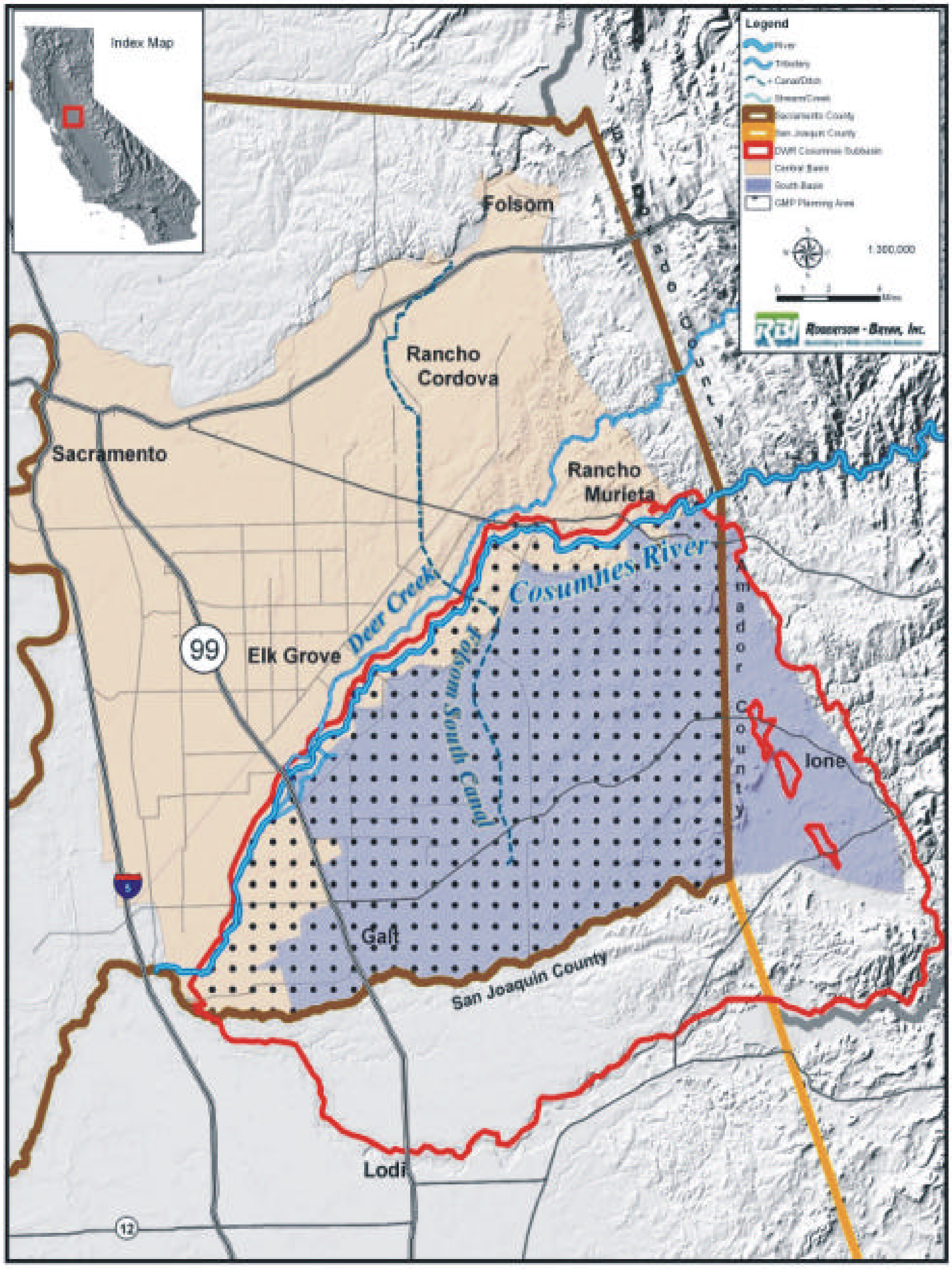

Fig. 3: Area of South Sacramento County Basin

the South Basin ranges from approximately 381 millimeters (15 inches) on the west to about 560 millimeters (22 inches) on the east [8]. Winter storms between November and March account for about 80 percent of the annual precipitation in the basin. Flows on the Cosumnes River are unregulated and result primarily from winter storms and limited seasonal snow melt. The Cosumnes River is the major source of surface flow to the south area and is generally considered to be a major source of groundwater recharge for the South basins. The hydrology and use of the Cosumnes River have changed substantially over time. The river was the major source of water diversions for agriculture in the late 1800s prior to groundwater well technology becoming available and affordable.

In spite of the seasonal recovery of groundwater levels during the non-irrigation season, the groundwater levels in the center of the basin outside the influence of the Cosumnes River have generally declined between 3

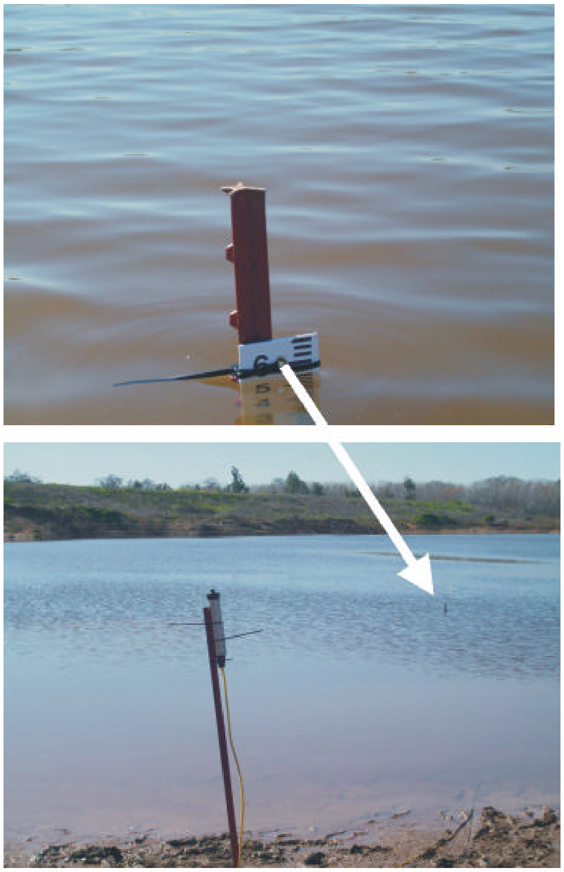

Fig. 4: March 12, 2009

Fig. 5. March 17, 2009

and 15 Meters (10 and 50 feet) over the past 50 years. Recent groundwater contour maps illustrate that the location of the regional cone of depression has shifted toward the center of the basin and increased in size. It is concluded that groundwater levels in the South Basin have generally declined throughout the basin with more severe depressions occurring near the communities of Galt and Elk Grove.

As water demand increases in the area in the future and with the lack of consistent surface water supply, groundwater levels are expected to further decline, leading to adverse economic and ecological impacts. This fact has led local agencies in the area to seriously consider groundwater artificial recharge projects. In addition to that, construction of new water conveyance facilities by Sacramento County and other agencies will provide the necessary means to transfer South County surface water entitlement on the American River. This water entitlement of 15,000 acre-feet per year, which historically has not been utilized due to the lack of conveyance facilities, can be used as a potential source of recharge in the area.

One of the geologic formations that contain groundwater in the South Basin is the Floodplain Formation, which is a younger alluvium layer that includes recent sediments deposited along the channels of active streams and consists of unconsolidated silt, fine-to-medium grained sand and gravel. The maximum thickness of this layer is 35 meters (100 feet), with a specific yield ranging from 6 percent to 12 percent. The sand and gravel zones in this layer are highly permeable and yield significant quantities of water to wells.

Based on hydrologic and hydrogeologic data collected and analyzed, RBI suggested three potential recharge sites within the floodplain formation. In addition, RBI contacted land owners of these sites and they expressed great interest in participating in a pilot GSR project in the area. Those sites are close to existing surface water conveyance routes such as rivers, creeks and canals.

Small Scale Infiltration Test: As a result of a short rise in the Cosumnes River stage in February 2009, water filled one of the potential sites, a mining pit on a property

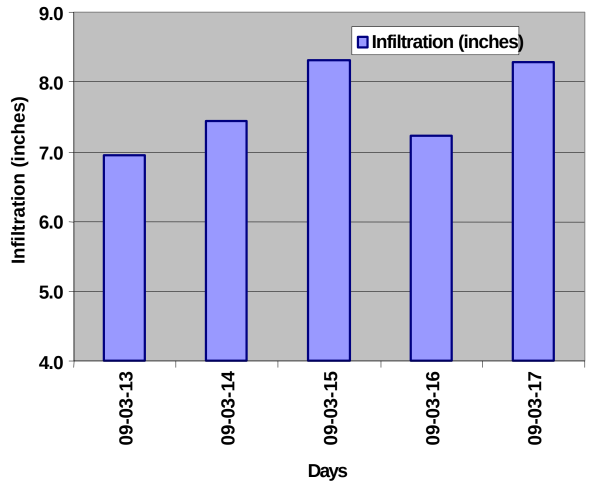

Fig. 6: Observed infiltration rates in recharge site, March 12-17, 2009

adjacent to the Cosumnes River. Two weeks after the event on March 10, RBI staff toured the site and observed water inflow and outflow. Water inflow had virtually stopped and there was no outflow. As a result of the visit, RBI undertook the task of monitoring the water infiltration at the site. The site has an area of approximately 4 hectares (10 acres) and a depth of about 4 meters (13 feet). The topsoil layers had been removed as part of the gravel mining operation, exposing sand strata with high infiltration rates.

RBI staff installed two staff gages on March 12, including a data logger, to record water levels at ½-hour increments (Figure 4). At that time, all inflow had ceased and no outflow was observed. On March 17, RBI staff retrieved the data and gages noting the decline in water levels as seen in Figure 5.

RBI gathered evaporation and rain data from the state Climate Irrigation Management and Information System for the entire period of the test. The findings of this test are:

- The water level dropped 104 centimeters (41 inches) during the five-day measurement period.
- The daily average rate of infiltration, after adjusting for evaporation and rainfall, was 19.3 centimeters (7.6 inches) per day as shown in Figure 6.
- The neighboring pit, which is about 4.6 - 6.1 meters (15-20 feet) deeper, showed no signs of pooled water as a result of lateral flow.

RBI staff concluded that removal of the topsoil layers exposed sand strata that produced relatively high rates of infiltration. Infiltration at his site appears to have been vertical, indicating little if any restriction to long-term success. Because the test started 15 days after the flooding of the site, it allowed infiltration rates to stabilize before the start of the test. This was confirmed by the test results which showed a stable infiltration rate with no erratic changes. RBI recommends small-scale testing of the other sites suggested, including bore holes to better assure the fate of the infiltrated water.

CONCLUSIONS

This study outlines the procedures of implementing specific test procedures, operational measures and a monitoring program. The implementation plan was developed as a generic plan for *recharge basins GSR* projects to serve needs of diverse agencies and wide range of stakeholders and can be slightly adapted and implemented in any location. The plan for the GSR project will allow local stakeholders to determine long-term viability of recharge activities. The multi-phase approach recommended in the study allows agencies and stakeholders to resourcefully fund the project and cost effectively manage the budget for the project, especially under current economic hardship faced by many agencies. RBI has developed a phase-based plan for a recharge pilot project in south Sacramento County, California, USA. Historic contour maps of the area showed a significant drawdown at the center of the basin as a result of increased pumping. The initial phase of this project is underway and preliminary investigations revealed a great potential for the recharge project success in this area.

ACKNOWLEDGEMENT

The authors are grateful to Mr. Stuart Robertson and Ms. Joan McHale for their valuable comments and edits.

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Anderson Airport Well Test Hole Drilling Results and Proposed Well Design

EATON DRILLING CO., INC.

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POST OFFICE BOX 975
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CONVENTIONAL & REVERSE CIRCULATION WATER WELL DRILLING
DOMESTIC • AGRICULTURAL • INDUSTRIAL
TEST HOLES • MONITOR WELLS

June 21, 1994

Rancho Murieta Community Services District
14670 Cantova Way
P.O. Box 1050
Rancho Murieta, California 95683

Attn. R. Lee Lawrence - District Superintendant

Re: Well Drilling - Contract No. 94-02: Test Hole Drilling Results and Proposed Well Design
Job# 6496 M - Rancho Murieta Community Services

Dear Mr. Lawrence,

The test hole procedures have been completed at the proposed well site located approximately 1 mile west of the main runway at the Rancho Murieta Airport. Following is a summary of the test hole drilling events, a description of the proposed well, and an outline of any changes in the construction costs based on the original bid and changes in the originally proposed well design.

After receiving the final approval to begin drilling on Wednesday, June 8, 1994 a 6-5/8 inch exploratory borehole (test hole) was drilled to 390 feet. Overall, the formations encountered above approximately 380 feet varied from brittle blue clays, sandy blue to gray clays with sand streaks, to sandy clay with gravel. Some organic material (wood) was also encountered. Please refer to the descriptive log attached for a detailed description of the lithology.

At approximately 380 feet a very hard formation believed to be basement was encountered. At 390 feet it was decided to cease test hole drilling operations. After conducting an electric log survey on June 9, 1994 the test hole was abandoned by placing cement from the bottom to the top of the borehole.

The electric logging survey, in conjunction with the descriptive log, cuttings samples, and sieve analysis of selected samples indicates a potential production zone located between approximately 230 feet and 330 feet. This formation (believed to be the Valley Spring / Ione Formation) has proven to be very unpredictable with regards to the overall production capabilities and yield. Sieve analysis and visual inspection of the samples shows sandy clays with interbedded gravel streaks.

The proposed well design enclosed is dictated by conservative expectations of the selected production zone. It is suggested to construct a well which draws water from the production zone through an outer casing. The proposed well would be constructed with 12-inch blank (unperforated) casing from the surface to 340 feet, with an outer 16-inch louvered casing placed from 240 to 330 feet. Slots or "windows" would be cut in the 12-inch casing at approximately 328 feet to allow water into the lower 12-inch portion of the well after flowing through the 16-inch louvered casing.

This type of well construction has proven to be very effective in preventing "falling water" conditions caused by drawing the pumping water level below screened portions of the well. Essentially, a well constructed as proposed would allow for pump settings as deep as 330 feet without sacrificing overall well efficiencies due to "falling water" or limited perforation intervals. It is expected that even with a very low yield, the well would produce the minimum required 500 gallons per minute if the pump could be set to 330 feet.

Sieve analysis of the formation indicates that a graded 6x12 gravel pack in conjunction with a 0.050 slot width would effectively control sand production. Also, an 80 foot cement sanitary seal is suggested (as indicated in the bid specs) to eliminate the possibility of surface contaminants from entering the well via the graveled annulus space.

It is suggested to install the louvered casing rather than the wire wound screen in this type of well construction. The louvered casing will not hinder the production capabilities of the well based on anticipated pumping rates and the selected gravel pack.

Additional options concerning the well design include the addition of an intermediate cement seal which may enhance the performance of the well, however will render the gravel fill pipe useless unless it is extended to below the intermediate seal (approximately 210 feet). Also well development and swabbing procedures are slightly different than as outlined in the specifications due to the outer casing design. Essentially, it is not possible to jet the perforations therefore this step is eliminated, however the well is bailed and airlifted.

Following is an outline of the costs to construct the well as proposed using the unit costs listed in the contract. Due to the nature of the proposed well design, it was necessary to add some items not included in the original bid proposal. I have also included the additional costs for these items.

NO.	BID ITEM	QUAN-TITY	UNIT PRICE	AMOUNT
1	Base Bid, 500' well complete	LS		$77,836.50
2	Price/foot between 350'-600'	-110	$57.40	($6,314.00)
3	Surface Seal	80	$21.82	as spec'd
4	Overbore Backfill	30	$5.00	$150.00
5	Addition/reduction 350'-650'	-160	$80.56	($12,889.60)
6	Unperforated casing	-80	$14.49	($1,159.20)
7	Wire wound SS well screen	80	$119.07	as spec'd
8	Graveling pipe	90	$5.43	as spec'd
9	Louvered well screen	LS	($6,124.56)	($6,124.56)
10	Louvered steel well casing	10	$42.51	$425.10
11	Setting test pump	100	$12.50	$1,250.00
12	Development and testing	40hrs	$110.00	as spec'd
13	Abandoning test hole	390	$3.00	n/a
14	6" dia. test hole	390	$9.81	n/a
	TOTAL BID:			$53,174.24
Additional Items to Construct Well As Proposed:				
15	28" Borehole	360	$5.75	$2,070.00
16	Additional gravel material	280	$3.00	$840.00
17	16" Louvered steel well casing	90	$20.82	$1,873.80
18	2" Vent tube	240	$2.50	$600.00
19	Additional cement material	80	$4.50	$360.00
	TOTAL ADDITIONAL COSTS:			$5,743.80
TOTAL JOB COST AS PROPOSED:				$58,918.04

Please find enclosed in this document, the interpretation of test hole logs and data by Dennis Nakamoto C.E.G., a well profile showing a diagram of the proposed well design, a descriptive log of the lithology, a field copy of the electric log survey, and sieve analysis sheets of selected samples

If there are any further questions, please call me at 662-6795.

Sincerely,

Bill Brewster

BB/wlb

HELMICK + LERNER
ENGINEERING AND ENVIRONMENTAL SERVICES

3750 Auburn Blvd., Suite A
Sacramento, CA 95821

Telephone: (916) 485-7222
FAX: (916) 485-8098

24 June 1994

Mr. Bill Brewster
Eaton Drilling Company, Inc.
P.O. Box 975
Woodland, California

Subject: Interpretation of Test Hole Logs
Rancho Murieta Water District
Rancho Murieta, California
HLI 11701

Dear Mr. Brewster:

This letter transmits the results of our review of information from your drilling and logging activities conducted for the Rancho Murieta Water District. Information reviewed consisted of drillers logs, downhole geophysical survey results, sieve analysis of selected samples, and the proposed well design which were provided by Eaton Drilling Company, Inc. This information was augmented by hydrogeologic information published by the United States Geological Survey[1] (USGS) and the California Department of Water Resources[2]. We have also visited the test hole location and inspected samples of drill cutting collected from the test hole.

The test hole is located adjacent to the Consumnes River, surrounded by cultivated fields and lies approximately 1-mile south of the Rancho Murieta Airport. The USGS maps for this area indicate that the Laguna Formation is exposed in the vicinity of the test hole; however, cultivating activities have significantly altered the ground surface and prohibit verifying the presence of the Laguna Formation. The test hole was terminated at a depth of 390, which is 11 feet below the contact between sediments and crystalline rock which refused drilling progress. Inspection of crystalline rock samples collected indicated that the rock is best correlated to metamorphosed volcanoclastic rocks of the Logtown Ridge/Gopher Hill Vocanics formations.

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[1]Olmsted, Franklin H. and Davis, George H. "Geologic Features and Ground Water Storage Capacity of the Sacramento Valley, California". U. S. Geological Survey, Water Supply Paper 1497. 1961

[2]California Department of Water Resources. "Evaluation of Ground Water Resources: Sacramento County". Bulletin 118-3. 1974

During drilling, cutting samples were collected at an interval of 10 feet, or at noted changes in underlying stratum. Following drilling, a suite of downhole geophysical surveys, comprised of spontaneous potential, 16-/64-inch normal resistivity, and point resistance were conducted and the test hole was subsequently abandoned by backfilling with cement grout. Review of the geophysical logs identified contacts between five geologic formations and three potential water-bearing strata.

The spontaneous potential log indicates that five formation contacts were penetrated at depths of 80 feet, 130 feet, 195 feet, and 376 feet. These results, combined with interpretations of drill cuttings, suggest that the stratigraphic column penetrated by the test hole is comprised of the following:

Depth Interval	Geologic Formation
0 - 80	Laguna Formation
80 - 130	Mehrten Formation
130 - 195	Valley Springs Formation
195 - 376	Ione Formation
376 - ?	Logtown Ridge/Gopher Hill Volcanics Formation

Normal resistivity and point resistance logs indicate that three potential water-bearing intervals of significant thickness were penetrated by the test hole. The shallowest interval begins at a depth shallower than 40 feet and extends to a depth of 48 feet. The second interval begins at a depth of 82 feet and extends to a depth of 114 feet. The third interval begins at a depth of 210 and extends to a depth of 324 feet. Ranking of these intervals, based on thickness, magnitude of the electrical resistivity response, and stratigraphic position, from greatest potential yield to least potential yield is listed below with the aquifer material and correlated geologic formation.

Rank	Interval	Driller's Log	Geologic Formation
1	210 - 324 feet	Gravel with Clay and Sandy Clay	Ione
2	82 - 114 feet	Sand with Streaks of Blue Clay	Mehrten
3	<40 - 48 feet	Gravel with Brown Clay	Laguna

The number 1 ranked interval consists of 114 feet of saturated thickness interpreted to lie within the Ione Formation. The Ione Formation is noted to yield brackish water at some foothill locations (Olmsted, 1961). However, review of the spontaneous potential log indicates that water within the 210- to 324-foot interval is likely to be fresh. The limited groundwater quality for the vicinity of the test hole which was reviewed confirms that fresh water is likely present; however, this assumption can not be confirmed without further testing. Published specific capacity for water wells penetrating the Ione Formation ranges from 2 to 8 gallons per minute per foot drawdown (Olmsted, 1961, Bulletin 118-3). If drawdown due to pumping equaled the saturated thickness (114 feet), the maximum expected well yield would be between 228 and 912 gallons per minute.

The number 2 ranked interval consists of 32 feet of saturated thickness interpreted to lie within the Mehrten Formation. The Mehrten Formation is noted to yield high quality water at most locations within the Sacramento Valley (Bulletin 118-3). However, specific yield for wells penetrating the Mehrten Formation at locations near the foothills region are reported to vary from 2 to 100 gallons per minute per foot drawdown (Olmsted, 1961). If drawdown due to pumping equaled the saturated thickness (32 feet), the maximum expected well yield would be between 64 and 3,200 gallons per minute.

State of California water well standards prohibit the pumping of groundwater from depths less than 50 feet into drinking water supply wells. Thus, the number 3 ranked interval cannot be considered feasible for a source of water.

The maximum well yields calculated above are based on the overpumping of the well such that dewatering of the aquifer in the immediately vicinity of the well occurs. Since this condition is not desirable, it must be recognized that the actual sustainable well yield will be significantly less than the above stated flow rates. The only accurate method for determining yield from a well is to conduct a long term pumping test.

Since the two identified aquifers are separated by 96 feet of nonaquifer strata, the proposed well design should address potential entrained air problems which may arise due to cascading water from the upper aquifer during periods of pumping. This would eliminate pump cavitation problems and allow for maximum drawdown.

Should you have any questions regarding this letter, please call us at your earliest convenience.

Sincerely yours,

HELMICK & LERNER INC.

Dennis B. Nakamoto, C.E.G. 1353
Senior Geologist

REGISTERED GEOLOGIST
DENNIS B. NAKAMOTO
No. EG 1353
CERTIFIED ENGINEERING GEOLOGIST
STATE OF CALIFORNIA

EATON DRILLING CO., INC.

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WOODLAND, CA 95695
PHONE (916) 662-6795

CONVENTIONAL AND REVERSE CIRCULATION WATER WELL DRILLING
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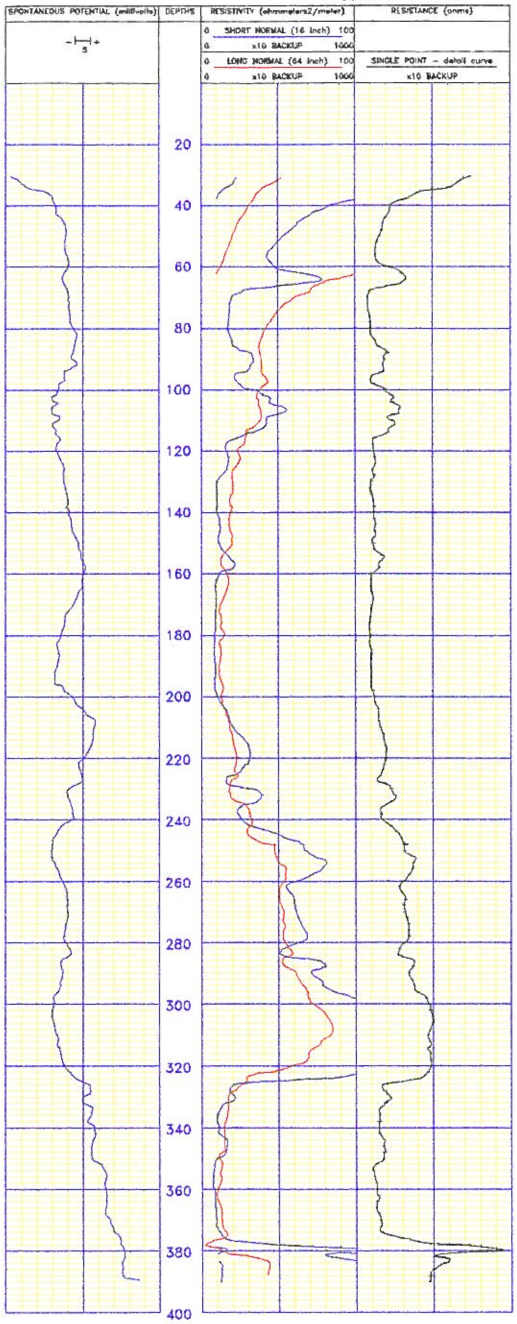
TEST HOLE * MONITOR WELL

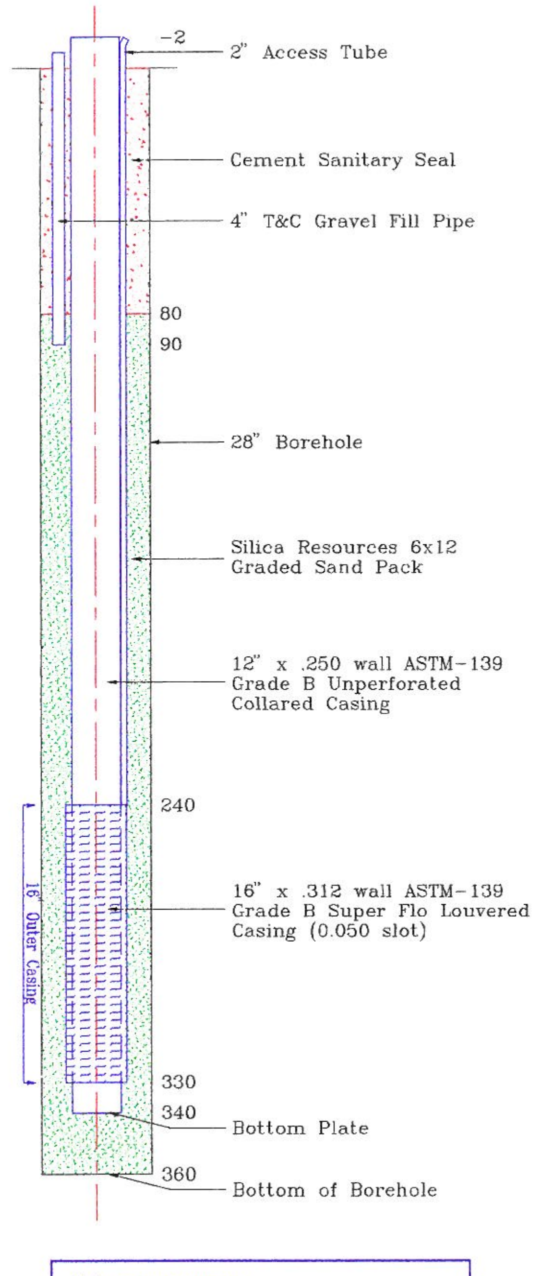
Customer Rancho Murieta	
Job Number 6496	Date 6/9/94
Location opx 1mi W of main run-way at Rancho Murieta	

APN 73-180-15	County Sacramento
T.R.S 7N 8E s4	Elev.
Water n/a PPM	Mud n/a PPM

* Logged by Wellenco



Well Profile
Job# 6496 M



Materials Summary	
12" x .250 wall Blank Casing	342'
16" x .312 wall Louvered Casing	90'
2" Access Tube	240'
4" Gravel Fill Tube	90'
6x12 Graded Sand Pack	280'
Cement Sanitary Seal	80'

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Rancho Murieta
Job# 6496 Ag
Descriptive Log
June 9, 1994

0 - 2	*Top Soil*
2 - 27	*Sand and Gravel*
27 - 34	*Tan Sandy Clay*
34 - 68	*Brittle Blue Clay with Brown Clay and Gravel*
68 - 85	*Gravel and Sand with Brittle Blue Clay*
85 - 115	*Sand with Streaks of Brittle Blue Clay*
115 - 125	*Dark Brown to Black Silty Clay*
125 - 142	*Blue/Gray Clay*
142 - 160	*Brittle Blue Clay with Sand Streaks*
160 - 204	*Silty Brittle Blue Clay*
204 - 245	*Sandy Silty Blue Clay*
245 - 260	*Shaley Gravel with Blue Clay*
260 - 264	*Silts (stratified)*
264 - 285	*Sandy Blue Clay with Wood*
285 - 328	*Sandy Clays with Gravel*
328 - 350	*Dark Brown to Black Clay with Wood*
350 - 375	*Sandy Blue/Gray Clay with Brittle Blue Clay*
375 - 379	*Hard Brittle Clay*
379 - 390	*Bed Rock (Shale)*

EATON DRILLING CO., INC.
REVERSE & ROTARY WELL DRILLING

TELEPHONE
(916) 662-6795

20 W. KENTUCKY AVE.
WOODLAND, CA 95695

SAND ANALYSIS
(FINE)

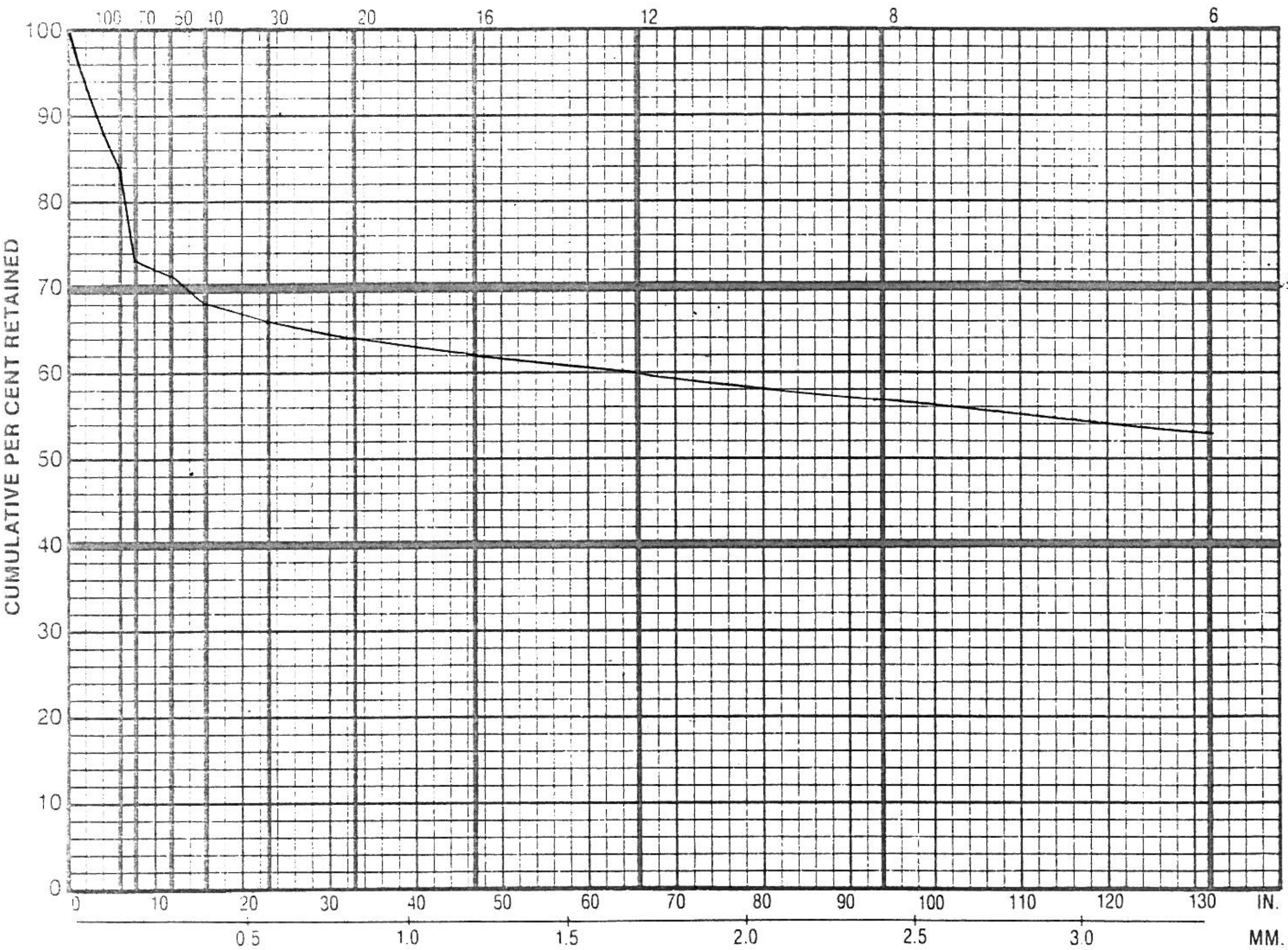
BY: Chris

Job Name Rancho Murieta Com. Services Job No. 6496-T Date 6/9/94

City ______ State ______ Zip ______

Driller ______ Phone ______

U.S. STANDARD SIEVE NUMBERS



SLOT OPENING AND GRAIN SIZE IN THOUSANDTHS OF AN INCH AND MM.

U.S. SIEVE NO.	SLOT OPENING IN	SLOT OPENING MM	SAMPLE DEPTHS G.	240'	250'	%
6	132	3.36	120			53
8	094	2.38	130			57
12	066	1.68	135			60
16	047	1.19	140			62
20	033	0.84	145			64
30	023	0.60	150			66
40	016	0.42	155			68
50	012	0.30	160			71
70	008	0.21	165			73
100	006	0.15	190			84
PaN			225			100

Comments Pea Gravel, Poorly Sorted, Non-Spherical & Angular. Trace of Brown Clay.

SCREEN RECOMMENDATIONS: DIAM. ______

SLOT	SETTING	LENGTH

EATON DRILLING CO., INC.
REVERSE & ROTARY WELL DRILLING

TELEPHONE
(916) 662-6795

20 W. KENTUCKY AVE.
WOODLAND, CA 95695

SAND ANALYSIS (FINE)

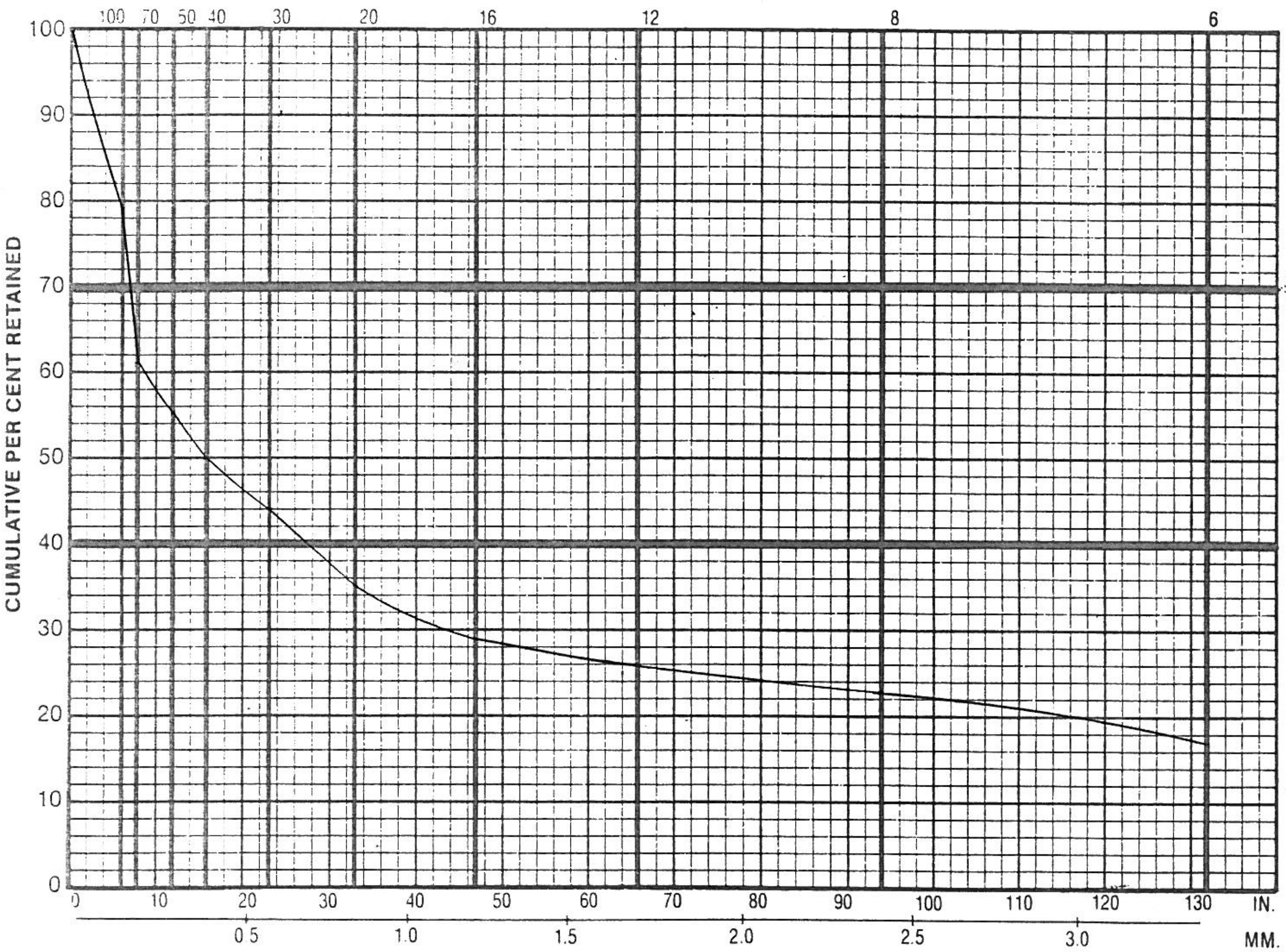
BY: Chris

Job Name Rancho Murieta Com. Services Job No. 6496-T Date 6/9/94

City ____ State ____ Zip ____

Driller ____ Phone ____

U.S. STANDARD SIEVE NUMBERS



SLOT OPENING AND GRAIN SIZE IN THOUSANDTHS OF AN INCH AND MM.

U.S. SIEVE NO.	SLOT OPENING IN.	SLOT OPENING MM	SAMPLE DEPTHS G.	250'	260'	%
6	132	3.36	30	↓	↓	17
8	094	2.38	40			23
12	066	1.68	45			26
16	047	1.19	50			29
20	033	0.84	60			35
30	023	0.60	75			44
40	016	0.42	85			50
50	012	0.30	95			55
70	008	0.21	105			61
100	006	0.15	135			79
PAN			170			100

Comments Pea Gravel, Poorly Sorted, Non-Spherical & Angular. Trace of Brown Clay.

SCREEN RECOMMENDATIONS: DIAM. ____

SLOT	SETTING	LENGTH

EATON DRILLING CO., INC.
REVERSE & ROTARY WELL DRILLING

TELEPHONE (916) 662-6795 | 20 W. KENTUCKY AVE. WOODLAND, CA 95695

SAND ANALYSIS (FINE)

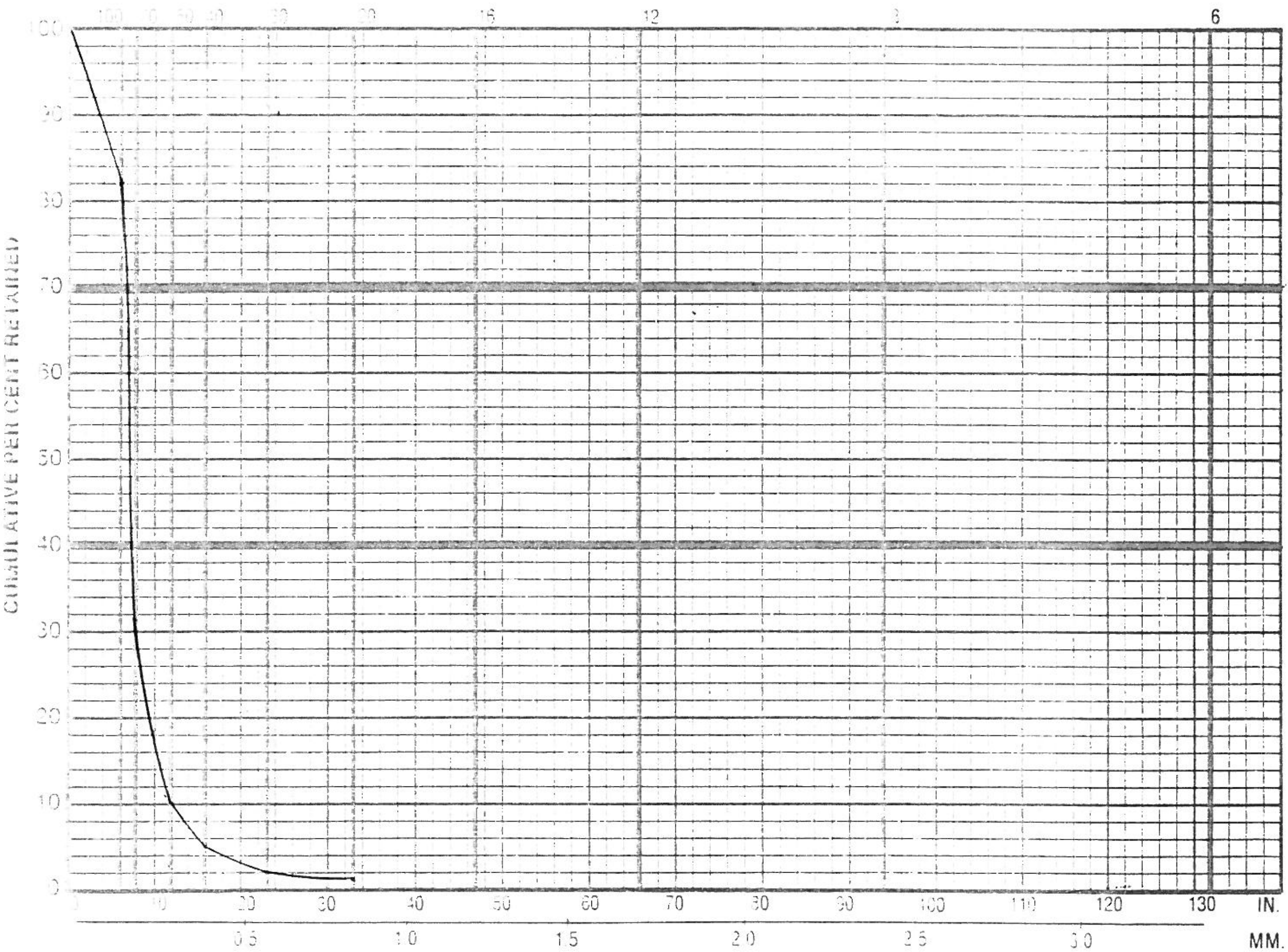
BY: Chris

Job Name Rancho Murieta Com. Services Job No. 6496-T Date 6/9/94

City ______ State ______ Zip ______

Driller ______ Phone ______

U.S. STANDARD SIEVE NUMBERS



SLOT OPENING AND GRAIN SIZE IN THOUSANDTHS OF AN INCH AND MM.

U.S. SIEVE NO.	SLOT OPENING IN	SLOT OPENING MM	SAMPLE DEPTHS G.	240'	260'	%
6	.132	3.36	0	↓	↓	0
8	.094	2.38	0			0
12	.066	1.68	0			0
16	.047	1.19	0			0
20	.033	0.84	5			1
30	.023	0.60	10			2
40	.016	0.42	20			5
50	.012	0.30	35			10
70	.008	0.21	110			31
100	.006	0.15	290			82
Pan			350			100

Comments Sand.

SCREEN RECOMMENDATIONS. DIAM. ______

SLOT	SETTING	LENGTH

...CONSIDERATIONS ENTER INTO THE MAKING OF A GOOD WELL THAT WHILE WE BELIEVE SLOT SIZES FURNISHED OR RECOMMENDED ... TO BE CORRECT WE ASSUME NO RESPONSIBILITY FOR THE SUCCESS ... WELL.

EATON DRILLING CO., INC.
REVERSE & ROTARY WELL DRILLING
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20 W. KENTUCKY AVE. WOODLAND, CA 95695

SAND ANALYSIS (FINE)

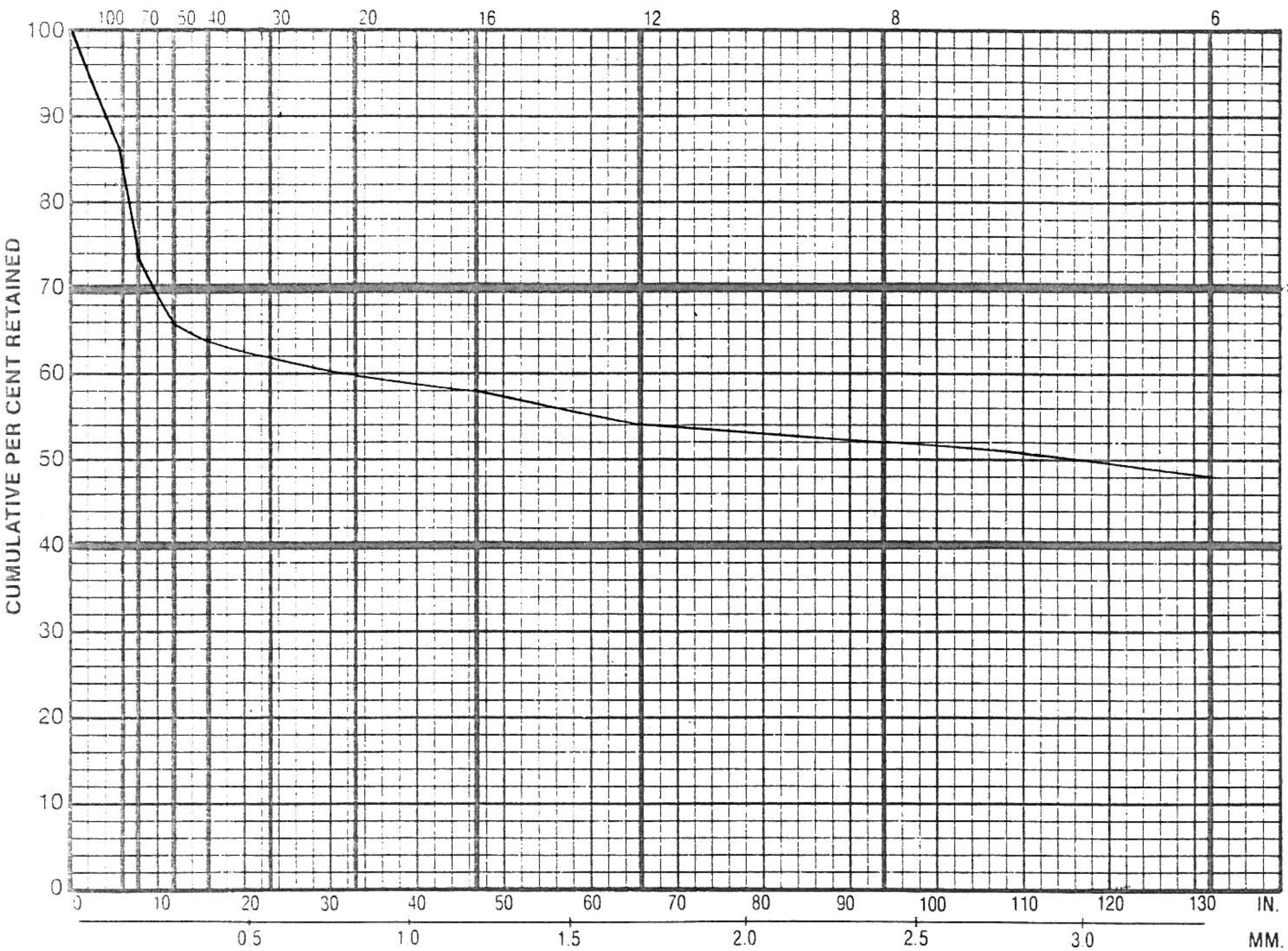
BY: Chris

Job Name Rancho Murieta Com. Services Job No. 6496-T Date 6/9/94

City ____ State ____ Zip ____

Driller ____ Phone ____

U.S. STANDARD SIEVE NUMBERS



SLOT OPENING AND GRAIN SIZE IN THOUSANDTHS OF AN INCH AND MM.

U.S. SIEVE NO.	SLOT OPENING IN.	SLOT OPENING MM	SAMPLE DEPTHS G.	280'	290'	%
6	132	3.36	120			48
8	094	2.38	130			52
12	066	1.68	135			54
16	047	1.19	145			58
20	033	0.84	150			60
30	023	0.60	155			62
40	016	0.42	160			64
50	012	0.30	165			66
70	008	0.21	185			74
100	006	0.15	215			86
Pan			250			100

Comments Pea Gravel, Poorly Sorted, Non-Spherical & Angular. Very little Brown Clay.

SCREEN RECOMMENDATIONS: DIAM. ____

SLOT	SETTING	LENGTH

EATON DRILLING CO., INC.
REVERSE & ROTARY WELL DRILLING

TELEPHONE (916) 662-6795 | 20 W. KENTUCKY AVE. WOODLAND, CA 95695

SAND ANALYSIS (FINE)

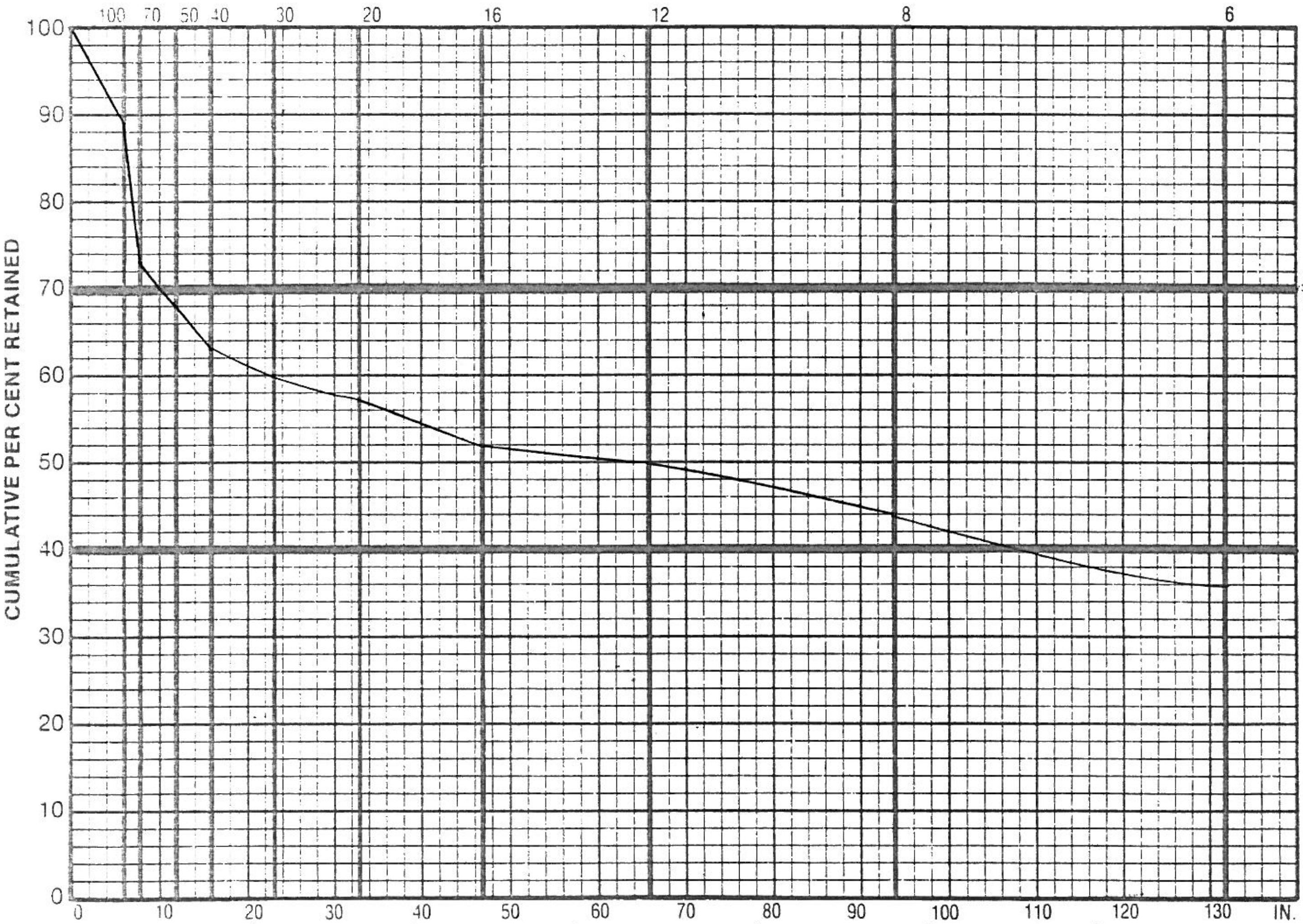
BY: Chris

Job Name Rancho Murieta Com. Services Job No. 6496-T Date 6/9/94

City ______ State ______ Zip ______

Driller ______ Phone ______

U.S. STANDARD SIEVE NUMBERS



SLOT OPENING AND GRAIN SIZE IN THOUSANDTHS OF AN INCH AND MM.

U.S. SIEVE NO	SLOT OPENING IN	SLOT OPENING MM	SAMPLE DEPTHS G.	290'	300'	%
6	.132	3.36	70	↓	↓	36
8	.094	2.38	85			44
12	.066	1.68	95			50
16	.047	1.19	100			52
20	.033	0.84	110			57
30	.023	0.60	115			60
40	.016	0.42	120			63
50	.012	0.30	130			68
70	.008	0.21	140			73
100	.006	0.15	170			89
Pan			190			100

Comments Pea Gravel, Very Poorly Sorted. Non-Spherical & Angular. Very little Brown Clay.

SCREEN RECOMMENDATIONS: DIAM. ______

SLOT	SETTING	LENGTH

EATON DRILLING CO., INC.
REVERSE & ROTARY WELL DRILLING

TELEPHONE (916) 662-6795 — 20 W. KENTUCKY AVE. WOODLAND, CA 95695

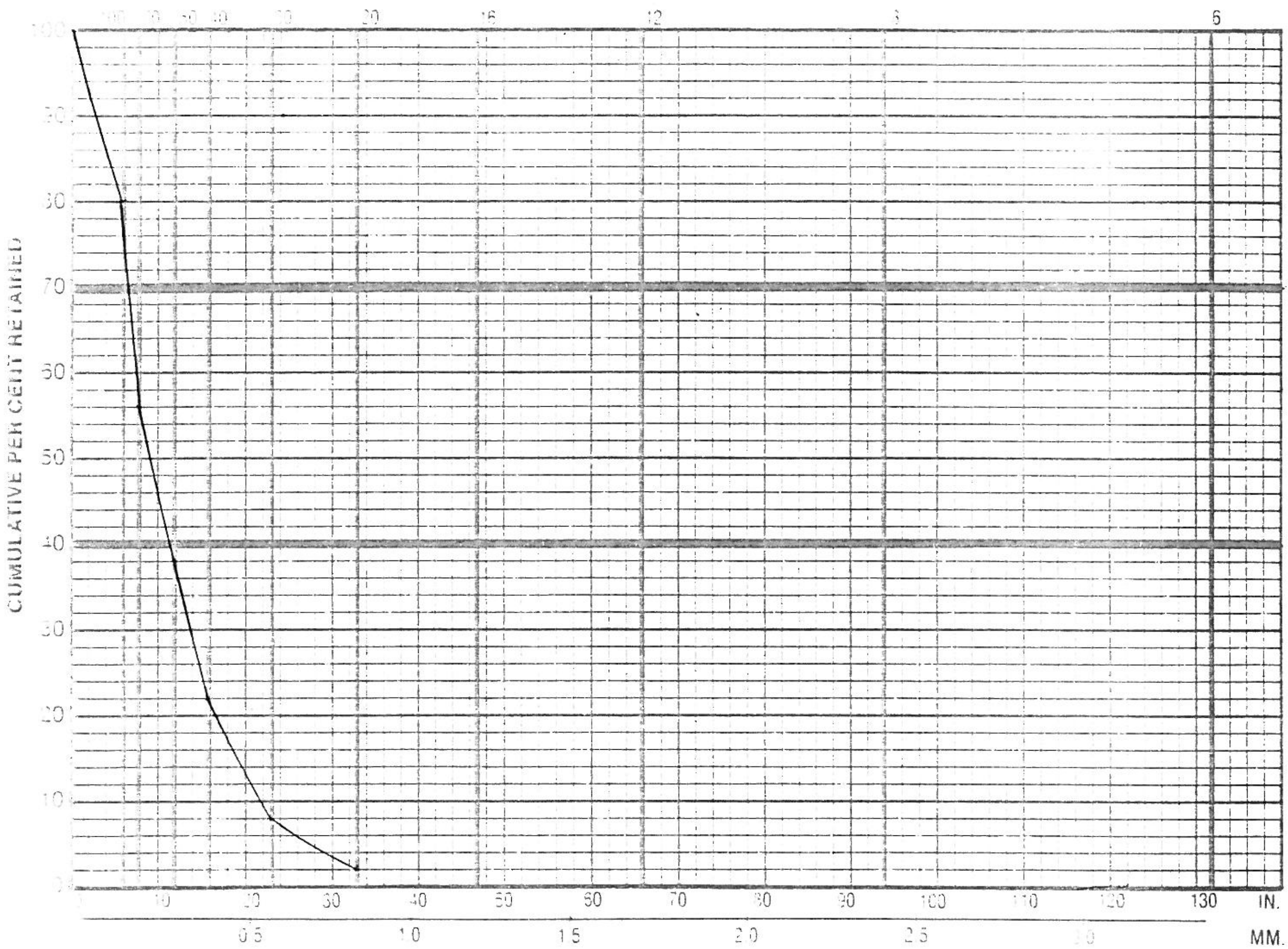
SAND ANALYSIS
(FINE)

BY: Chris

Job Name: Rancho Murieta Com. Services — Job No. 6496-T — Date: 6/9/94

City: ____ State: ____ Zip: ____

Driller: ____ Phone: ____



U.S. SIEVE NO.	SLOT OPENING IN.	SLOT OPENING MM	SAMPLE DEPTHS G.	300'	320'	%
6	.132	3.35	∅	↓	↓	∅
8	.094	2.38	∅			∅
12	.066	1.68	∅			∅
16	.047	1.19	∅			∅
20	.033	0.84	10			2
30	.023	0.60	35			8
40	.016	0.42	90			22
50	.012	0.30	155			38
70	.008	0.21	230			56
100	.006	0.15	325			80
PAN			405			100

Comments: Sand

SCREEN RECOMMENDATIONS, DIAM. ____

SLOT	SETTING	LENGTH

[illegible] CONSIDERATIONS ENTER INTO THE MAKING OF A GOOD WELL THAT WHILE WE BELIEVE SLOT SIZES [illegible] RECOMMENDED [illegible] SAMPLES ARE CORRECT WE ASSUME NO RESPONSIBILITY FOR THE SUCCESSFUL [illegible]

EATON DRILLING CO., INC.
REVERSE & ROTARY WELL DRILLING

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20 W. KENTUCKY AVE. WOODLAND, CA 95695

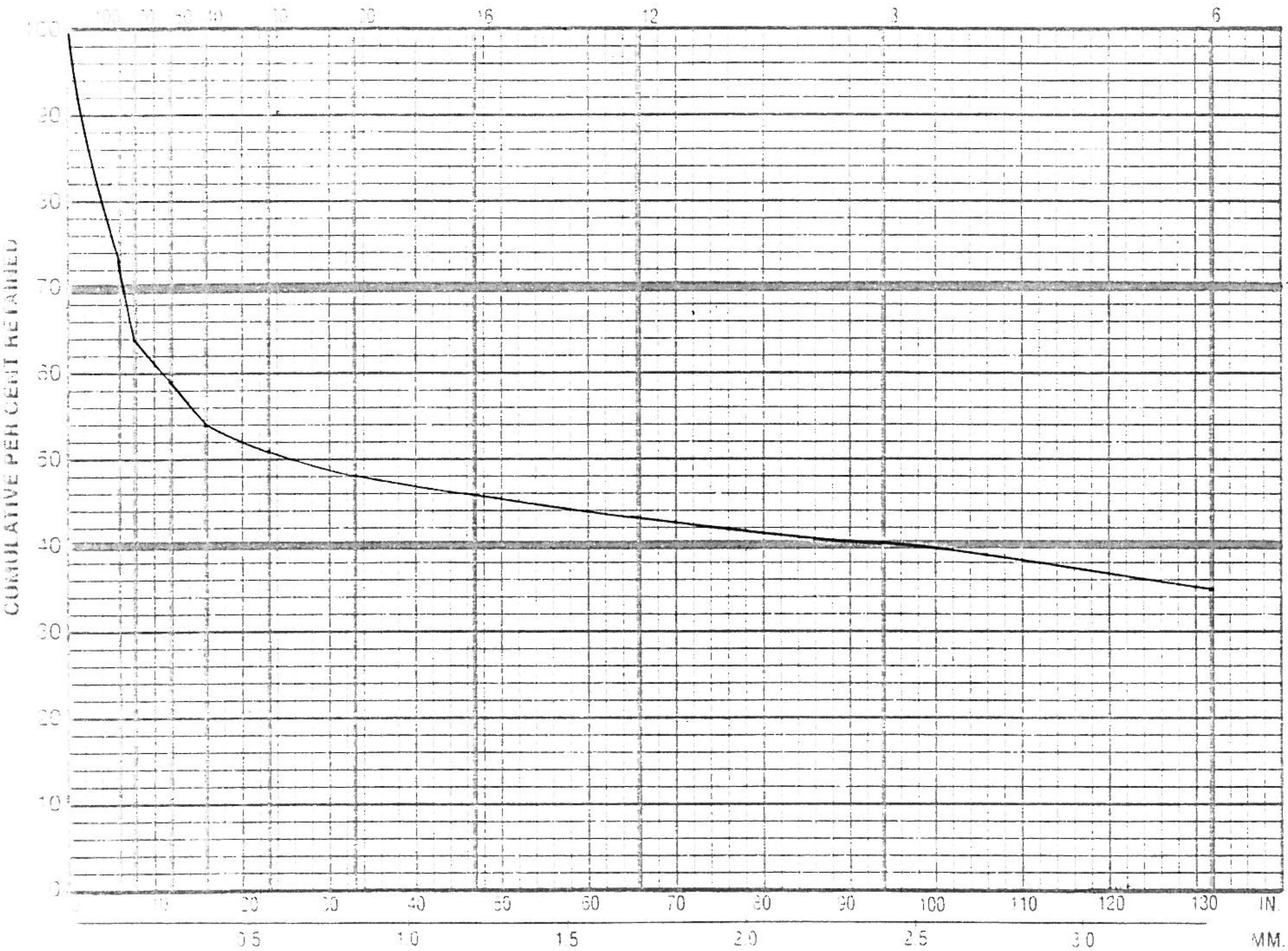
SAND ANALYSIS (FINE)

BY: Chris

Job Name Rancho Murieta Com. Services Job No. 6496-T Date 6/9/94

City ______ State ______ Zip ______

Driller ______ Phone ______



U.S. SIEVE NO.	SLOT OPENING IN	SLOT OPENING MM	SAMPLE DEPTHS G.	300'	310'	%
6	.132	3.36	65	↓	↓	35
8	.094	2.38	75			40
12	.066	1.68	80			43
16	.047	1.19	85			46
20	.033	0.84	90			48
30	.023	0.60	95			51
40	.016	0.42	100			54
50	.012	0.30	110			59
70	.008	0.21	120			64
100	.006	0.15	135			73
			185			100

Comments: Pea Gravel, Very Poorly Sorted. Non-Spherical & Angular. Blue Clay Present in Sample. Hard Clayd form.

SCREEN RECOMMENDATIONS: DIAM. ______

SLOT	SETTING	LENGTH

[illegible] CONSIDERATIONS ENTER INTO THE MAKING OF A GOOD WELL THAT WHILE WE BELIEVE SLOT SIZES FURNISHED OR RECOMMENDED [illegible] ARE CORRECT WE ASSUME NO RESPONSIBILITY FOR THE SUCCESSFUL OPERATION OF THE WELL.

EATON DRILLING CO., INC.
REVERSE & ROTARY WELL DRILLING

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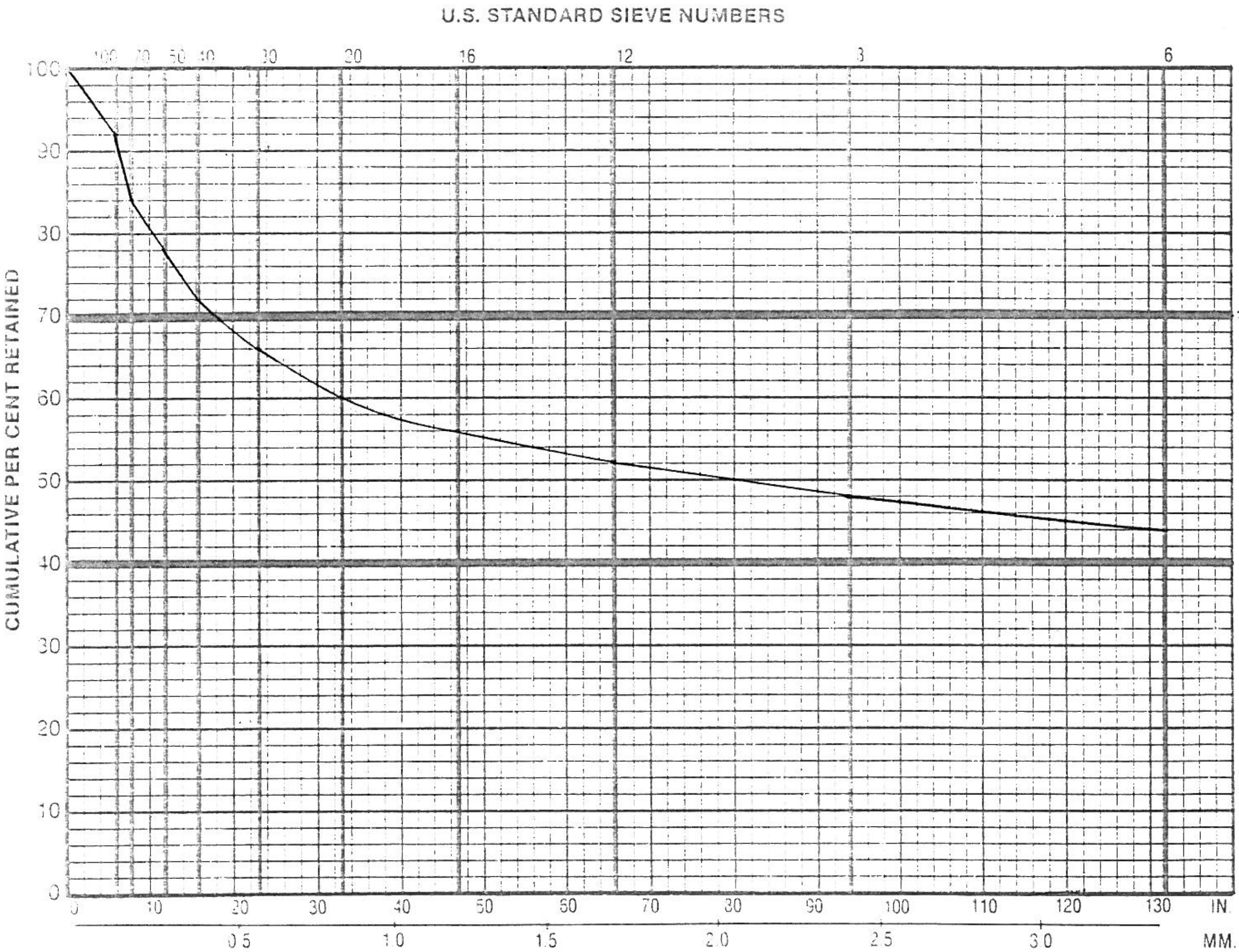
SAND ANALYSIS (FINE)

BY: Chris

Job Name: Rancho Murieta Com. Services Job No. 6496-T Date 6/9/94

City ____ State ____ Zip ____

Driller ____ Phone ____



SLOT OPENING AND GRAIN SIZE IN THOUSANDTHS OF AN INCH AND MM.

U.S. SIEVE NO.	SLOT OPENING IN.	SLOT OPENING MM	SAMPLE DEPTHS G.	310'	320'	%
6	.132	3.36	110	↓	↓	44
8	.094	2.38	120			48
12	.066	1.68	130			52
16	.047	1.19	140			56
20	.033	0.84	150			60
30	.023	0.60	165			66
40	.016	0.42	180			72
50	.012	0.30	195			78
70	.008	0.21	210			84
100	.006	0.15	230			92
PAN			250			100

Comments: Pea Gravel, Poorly Sorted. Non-Spherical & Angular. Trace of Brown Clay.

SCREEN RECOMMENDATIONS: DIAM. ____

SLOT	SETTING	LENGTH