1996 AGRICULTURAL/WATER SUPPLY ENERGY EFFICIENCY INCENTIVE PROGRAM FIRST YEAR LOAD IMPACTS EVALUATION

STUDY No. 542

Prepared for

Southern California Edison

Prepared by

HDR Engineering, Inc.
Irvine, California

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SECTION 1 - INTRODUCTION

1.1 INTRODUCTION

The 1996 Agricultural and Water Supply Customers Energy Efficiency Incentive Program (AEEIP) was developed to encourage Southern California Edison (Edison) customers to use energy efficient processes, controls, and equipment. The 1996 AEEIP includes technical services and cash incentives to assist the customer to achieve energy savings. HDR Engineering, Inc., was retained by Edison to evaluate the first year energy and demand impacts of the energy efficiency measures installed under its 1996 AEEIP.

The objectives of study were to:

- provide an independent review and analysis of the measures installed; and
- estimate *ex-post* load impacts of the measures with respect to energy use.

These objectives were accomplished by performing the following tasks:

- review of the incentive coupons, pumping records, pump efficiency test data;
- develop on-site data collection and survey instruments;
- gather data through field measurements, observation, and interviews with on-site personnel;
- perform engineering analysis to determine load impacts.

The portions of this report to be completed by Edison are located in the individual site summaries in Section 4 - Pumping Measures. Additionally, Edison has made a separate in-house effort to improve how ex ante savings will be estimated for pumping applications in the future. The improvements, or "second ex antes", are included in this report for informational purposes, and have no bearing on the study's "official" gross savings realization rate.

The work for this report was performed in compliance with the Work Plan, which was developed by HDR as part of this project. The Work Plan and RFP are separate documents, and are not included in this report.

The analyses in this report are based on information obtained from field visits to all of the facilities, meetings and discussions with customer operations staff, review of existing pumping records and pump efficiency tests, performing new pump tests, and the use of standard hydraulic and energy equations and theories.

1.2 REPORT ORGANIZATION

The remainder of this report is organized as follows:

1.3 ACKNOWLEDGMENTS

HDR Engineering, Inc., wishes to thank the following Edison personnel for their assistance collecting data and coordinating and performing pump tests for the preparation of this study:

DATA COLLECTION
John Peterson
Paul Williams

PUMP TEST COORDINATION
Curtis DeWoody
John Hayball
Dan Johnson
Caroline Lee
Sheila Lee

PUMP TEST TECHNICIANS
Leo Atencio
Scott Hamilton
John Nasalroad
Harold Nielson

1.4 ABBREVIATIONS AND DEFINITIONS

ac-ft	-	acre-foot of water
AFY	-	acre-feet per year
avg	-	average
BS	-	booster station
calc	-	calculated or calculation
CCF	-	hundred cubic feet
cfs	-	cubic feet per second
DO	-	dissolved oxygen
DUOM	-	designated unit of measure (kWh/ac-ft)
ex-ante	-	condition before efficiency measure was installed
ex-post	-	condition after efficiency measure was installed
FLH	-	full load hours
ft	-	feet
gal	-	gallon
gpm	-	gallons per minute
HDR	-	HDR Engineering, Inc.
hp	-	horsepower
hrs	-	hours
Hz	-	cycles per second
kW	-	kilowatt
kWh	-	kilowatt hour
min	-	minute
MG	-	million gallons
mgd	-	million gallons per day
mo	-	month
no.	-	number
psi	-	pounds per square inch (pressure)
rpm	-	rotations per minute
SCE	-	Southern California Edison
SCADA	-	supervisory control and data acquisition
tdh	-	total dynamic head
VSD	-	variable speed drive
yr	-	year

SECTION 2 - RESULTS SUMMARY

2.1 OVERVIEW

The 1996 AEEIP measures studied in this report include 1) pumping improvements and 2) heating, ventilation, and air conditioning (HVAC) improvements. HDR performed the *ex-post* impact evaluations for the pumping measures only. The complete evaluations for these measures are documented in this report. An outside independent firm performed the *ex-post* impact evaluation for the HVAC measure. The summary and findings from that firm were provided to HDR by Edison, and are included in Appendix D.

Edison performed ex-ante load impact calculations for pumping and HVAC measures using their Measure Analysis Reporting System (MARS) program. As is explained in more depth in Section 3, engineer Paul Williams of the Edison Customer Solutions staff has identified a problem in the way that its major computer program for producing measure ex ante estimates, MARS, handles water pumping applications. During the study period, Mr. Williams has worked to develop an improvement to the CPUC-approved routine, and has provided revised estimates of the kWh savings and kWh savings/acre foot. This work used a minimum of additional empirical information beyond that used in original MARS estimates, and essentially corrected the way MARS handles head pressure. His work does not imply any change in the original MARS-generated ex antes (in terms of the realization rate for which Edison is accountable), but is included in this report to document the importance of future incorporation of changes in a future version of MARS. Essentially, then, Edison's "official" savings estimates, provided by the program tracking system, are supplemented by an informal intermediate set of estimates which more realistically respond to hydraulic lift. Note that Mr. Williams and HDR worked completely independently, as the former concentrated on improving how the original inputs are used, and HDR dealt with the empirical effort to produce ex post estimates.

2.2 PUMPING MEASURES

2.2.1 Measure Descriptions

The work by HDR for 1996 involved evaluation of 8 customers with 13 measures, total. For this report, each customer is considered a "site". Some sites had measures installed at several locations, or premises. Edison assigns premise numbers to each of its meters. In instances where a site had more than one meter (premise), the site numbers are given additional number suffixes (i.e. Site 3-1, Site 3-2, etc.). Sites that had only one measure do not have these suffixes. Additionally, sites that had only one meter, yet several measures installed, also do not have these suffixes. Complete descriptions of each site, location, and measure are included in Section 4. All data obtained as a part of the site investigation is included in the data for each site in Appendix B. The following Table A summarizes the sites and measures.

TABLE A
PUMPING MEASURE DESCRIPTIONS

MEASURE NO.	SITE NO.	MEASURE DESCRIPTION
1	1	Replace existing motor with new 100 hp motor with VSD
2	2	Replace existing pump and impeller assembly
3	3-1	Replace existing pump and motor with new 100 hp pump and motor
4	3-2	Replace existing pump and motor with new 100 hp pump and motor
5	3-3	Replace existing pump and motor with new 100 hp pump and motor
6	3-4	Replace existing pump and motor with new 125 hp pump and motor
7	4	Replace existing motor with new 250 hp motor with VSD
8	5	Replace existing pump and motor with new 40 hp pump and motor with VSD
9	6	Replace existing pump and motor with new 150 hp pump and motor with VSD
10	6	Replace existing pump and motor with new 75 hp pump and motor
11	7	Installation of new VSD on existing 150 hp motor
12	8-1	Installation of new 350 hp well pump and motor with VSD
13	8-2	Installation of new 350 hp well pump and motor with VSD

2.2.2 Load Impacts

The load impact analysis was conducted using site-specific information. Measures may be similar, however, each site is a unique system, and each site had different types of data available. For these reasons, various analysis methods for determining the energy demand, usage, and impacts were used. The analyses in this report are based on: data collected during field visits to all of the facilities and information obtained from meetings and discussions with customer operations staff; review of existing pumping records, billing statements and pump efficiency tests; performing and evaluating new pump tests; the use of standard hydraulic and energy equations and theories. Complete descriptions of each site and location, data available for that location, calculations, and assumptions are included in Section 4. Table B summarizes the gross load impacts for each measure.

TABLE B
PUMPING MEASURES GROSS LOAD IMPACTS

MEASURE	SITE	DESCRIPTION	EX-POST GROSS SAVINGS		
			DUOM kWh/ac-ft	kW (avg)	kWh/yr
1	1	100 hp motor w/VSD	225	0	169,526
2	2	new pump/impeller	69	10	39,141
3	3-1	100 hp pump/motor	168	46	148,403
4	3-2	100 hp pump/motor	153	44	181,713
5	3-3	100 hp pump/motor	241	43	172,609
6	3-4	125 hp pump/motor	162	73	230,038
7	4	250 hp motor w/ VSD	253	113	173,859
8	5	40 hp pump/motor/VSD	112	9	47,908
9	6	150 hp pump/motor/VSD	16	0	109,025
10	6	75 hp pump/motor	Combined with Measure 9		
11	7	VSD on 150 hp motor	**-421**	0	**-156,525**
12	8-1	350 hp pump/motor/VSD	16	29	131,817
13	8-2	350 hp pump/motor/VSD	20	48	139,467
TOTALS			N/A	415	1,386,981

The designated unit of measurement (DUOM) for this evaluation is the quantity of kWh per acre-foot of water. This represents the amount of electrical work required to move one acre-foot of water to its destination. For all the various sites, a wide range of DUOMs was obtained. This is due to the fact that the amount of head added to the water (i.e. pressure increase) is different for each system. In some cases the water pressure must only be increased a few psi, for example, a booster pump may have to only raise pressure by 40 psi to meet the system requirements. In other cases, a well pump may have to lift the water several hundred feet out of the ground (300 feet of lift equals 130 psi) , and supply a usable pressure of 80 psi, for a total of 210 psi. It is obvious that the kWh per acre-foot requirements for the well pump will be much higher than the booster pump.

2.3 HVAC MEASURES

2.3.1 Measure Descriptions

The HVAC measures included one site with 3 measures. Detailed measure descriptions and *ex-post* calculations for the HVAC measures are included in Appendix D. The following Table C summarizes the sites and measures.

TABLE C
HVAC MEASURE DESCRIPTIONS

MEASURE NO.	MEASURE DESCRIPTION
1	Install VSDs on 2- 50 Hp chilled water pumps, change operating hours
2	Install VSDs on 2-25 Hp cooling tower fans, change operating hours
3	Reduction in operating hours of 4- 100 Hp supply air fans

2.3.2 Load Impacts

The gross load impacts are summarized in Table D.

HVAC MEASURES GROSS LOAD IMPACTS

MEASURE	DESCRIPTION	EX-POST GROSS SAVINGS	
		kW (avg)	kWh/yr
1	VSDs on 2-50 hp pumps	20	129,761
2	VSDs on 2-25 hp fans	0	66,936
3	Change run time hours of 4- 100 hp fans	0	901,411
TOTALS		20	1,098,108

2.4 SUMMARY TABLES

The following tables contain the gross load impacts and the net load impacts for all measures studied in this report.

SCE 1996 AEEI Program Energy Impacts

GROSS LOAD IMPACTS

SITE	DESCRIPTION	EX-ANTE 1			EX-ANTE 2			EX-POST			
		kWh	kWh/ac-ft	kW	kWh	kWh/ac-ft	kW	kWh	ac-ft	kWh/ac-ft	kW
1	100 hp vsd	350,911	394	0	104,339	118	0	169,526	755	224	0
2	New Pump	14,367	N/A	0		N/A		39,141	566	69	10
3-1	Pressure Change	227,391	236	0		N/A		148,403	884	168	46
3-2	Pressure Change	258,490	226	0		N/A		181,713	1,189	153	44
3-3	Pressure Change	255,589	213	0		N/A		172,609	717	241	43
3-4	Pressure Change	140,326	245	0		N/A		230,038	1,418	163	73
4	250 hp vsd	958,322	784	0	440,687	393	0	173,859	686	254	113
5	40 hp vsd	101,738	186	0	42,105	78	0	47,908	426	113	9
6*	150 hp vsd and 75 hp pump	290,653	102	0	117,651	41	0	109,025	6,799	16	-44
7**	150 hp vsd	278,070	412	0	50,175	35	0	-156,525	371	-421	2
8-1	350 hp vsd	793,885	345	0	196,406	85	0	131,817	3,919	34	29
8-2	350 hp vsd	793,885	328	0	278,272	115	0	139,467	2,890	48	48
TOTALS			3,471					1,386,981	20,620		373

* Ex-ante calculations for 150 hp VSD only; ex-post calculations are for 150 hp vsd and motor and 75 hp motor.

** Facility at site is deteriorating and is in urgent need of rehabilitation.

Edison's Claimed Gross Savings (MWh): **Pumping**			3,678	
Edison's Ex post Gross Savings (MWh): **Pumping**			1,387	
Gross Realization Rate: **Pumping**	0.38			
Ex ante kWh/ac-ft	500			
Ex post kWh/ft	67			
Gross Realization Rate/DUOM	0.13			
Edison's Claimed Gross Savings (MWh): **HVAC**			1,026	
Edison's Ex post Gross Savings (MWh): **HVAC**			716	
Gross Realization Rate: **HVAC**	0.7			
Ex ante savings per DUOM	0.36			
Ex post Load Impact per DUOM	0.003			
Gross Realization Rate/DUOM (kWh/sq-ft)		0.008		
Edison's Claimed Total Program Gross Savings (MWh):				4,737
Edison's Ex post Total Program Gross Savings (MWh):				2,136
Total Program Gross Realization Rate		0.45		

SCE 1996 AEEI Program Energy Impacts

NET LOAD IMPACTS

SITE	DESCRIPTION	NET TO GROSS	kWh SAVED	kWh/ac-ft REDUCED	kW REDUCED
1	100 hp vsd	0.75	127,145	168	0
2	New Pump	0.75	29,356	52	8
3-1	Pressure Change	0.75	111,302	126	35
3-2	Pressure Change	0.75	136,285	115	33
3-3	Pressure Change	0.75	129,457	181	32
3-4	Pressure Change	0.75	172,529	122	55
4	250 hp vsd	0.75	130,394	191	85
5	40 hp vsd	0.75	35,931	85	7
6*	150 hp vsd and	0.75	81,769	12	-33
	75 hp pump				
7**	150 hp vsd	0.75	-117,394	-316	2
8-1	350 hp vsd	0.75	98,863	26	22
8-2	350 hp vsd	0.75	104,600	36	36
TOTALS			1,040,236	797	280

*	Ex-ante calculations were for 150 hp VSD only; Ex-post calculations were for 150 hp vsd and motor and 75 hp motor.		
**	Facility at site is deteriorating and is in urgent need of rehabilitation.		
Edison's Claimed Net Savings (MWh): **Pumping**			3,274
Edison's Ex post Net Savings (MWh): **Pumping**			1,040
Net Realization Rate: **Pumping**		0.31	
Net Realization Rate/DUOM (kWh/ac-ft)			0.3
Edison's Claimed Net Savings (MWh): **HVAC**			913
Edison's Ex post Net Savings (MWh): **HVAC**			537
Gross Realization Rate: **HVAC**		0.58	
Gross Realization Rate/DUOM (kWh/sq-ft)			
Edison's Claimed Total Program Net Savings (MWh):			4,216
Edison's Ex post Total Program Net Savings (MWh):			1,599
Total Program Net Realization Rate		0.38	

SECTION 3 - GENERAL METHODOLOGY

3.1 OVERVIEW

HDR's role in this project was to provide an independent review and analysis of the measures installed in conjunction with the 1996 program year AEEIP by estimating the *ex-post* impacts of the measures with respect to energy use. HDR's evaluations are based on actual field data collected since the installation of the measures, and data available from Edison and the systems owners and operators. HDR's *ex-post* impacts will be compared to the *ex-ante* load impacts estimated by Edison, which were generated using their computer analysis program.

3.2 DESCRIPTION OF THE APPROACH - SCE

Edison's approach to modification of ex-antes for ASD's is described by Mr. Paul Williams as follows. Note that two critical factors, hydraulic lift and the extent of very low flow rates included in Edison's MARS 2.2 program, receive attention in this work. Mr. Williams discusses the issues and the resolutions which are intended for incorporation in the next version of MARS:

1996 water pumping ASD (Adjustable Speed Drive) energy saving calculations have been revised to (1) account for the minimum water system pressure head the pump must overcome before water can start to flow and (2) adjust minimum flows to not be less then 50% of design.

A typical well pump must develop a minimum pressure head that has two components: lift and discharge. The first component is the pressure required to lift water from the well bottom to the surface. The second part is the discharge pressure required to overcome the pressure of the distribution system it is pumping into, open a check value, and start to flow water.

In the case of a booster pump application, the minimum pressure head is the discharge pressure less the suction pressure.

These minimum pressure heads, in either well pump or booster situations, cause the system pressure curve to be higher at lower flow rates than the 1996 ASD calculation assumed. The *raised system curve, the pressure the pump must overcome before water can flow, requires the pump to use more energy than the 1996 ASD calculation estimated at partial flow rates and therefore overestimated energy savings.*

The 1996 base case hours of operation at low flows was modified slightly by reallocation of very low speed hours. All flow hours below 50% were added to the revised calculation 50% category (in MARS, a bin ranging from flow rates 50-59.9 of maximum). This is based on the ASD design assumption that pump speeds and flows should not be reduced to below 50% of the pump design point

ASD Energy savings were recalculated using a revised ASD calculation method taking into account system pressure at reduced flows and no low flows less then 50%. Assuming the system pressure was determined from a) information with the original rebate coupon papers, b) pump test data, c) a pump curve obtained from the customer, or d) other information provided by the customer.

In Section 4, each site-specific analysis includes a brief review of Mr. Williams' "revised ex-ante" calculations. Almost without exception, these calculations are substantially smaller than the original, official ex-ante savings that were filed by Edison. They are generally of the same approximate magnitude, when normalized on acre footage, as the ex-post findings from HDR (which are based on the production circumstances actually observed in the impact year, rather than the assumptions and inputs used by MARS). The revised ex-ante calculations include modifications of <u>both</u> the "base" and "measure" case consumption.

3.3 DESCRIPTION OF THE APPROACH - HDR

This section describes the approach and tasks used to conduct the site-specific engineering analysis for the 1996 AEEIP.

3.3.1 Gather and Evaluate Available Data

All available existing data regarding the energy use of the system were obtained. Edison provided historical pump tests, account billing data, and the incentive program coupon data.

The historical pump tests provide valuable information on the operation of the system. These pump tests provide a "snapshot" of the pumping capacity and energy use and demand. Typically, the tests obtained were for the system prior to installation of the measures. In some instances, there were pump tests before and after the measures were installed. Having pump tests for both before and after the measure was installed provides a good comparison of the system before and after the change. Additionally, it is easy to see significant system changes with both tests. Changes in the system, such as discharge pressure and water pumping level, are noted and assist in correctly evaluating the impacts. Where no pump tests had been performed since the installation of the measure, HDR coordinated with Edison to have a pump test performed at the time of the site visit.

It should be noted that the billing data that was supplied by Edison was typically not used for HDR's calculations. The billing data was useful in supplementing and verifying data obtained from the customers regarding:

1. When the pump was out of service for the measure to be installed.
2. Which months have the highest and lowest demands (i.e. quantity pumped).
3. Typical run times for constant speed pumps (where data was not available from customer, and where only one pump was on the meter).
4. Maximum kW demand, where no ex-ante pump test data were available.

In some cases the billing data was used as a check to verify that the calculations were of the right magnitude, especially where no pump test or limited site data was available.

The coupon data contained Edison's *ex-ante* estimates of load impact. It must also be noted that the coupon data was provided to HDR for an explanation of each measure that was installed.

3.3.2 Develop Site Evaluation Plan

The available data was reviewed to determine what additional data would need to be gathered at the site to perform the load impact calculations. A questionnaire (survey instrument) was developed which was used a guide for data collection at the site. A copy of this questionnaire is included in Appendix C.

3.3.3 Conduct Field Investigation at Each Site

The purpose of the field investigation was to get acquainted with the actual physical system and the system operation. Data collected at the site included all available data on the questionnaire, as well as additional notes on the system and it's operation. Discussions with the operators were valuable in finding typical pump run times and speeds, flow rates, seasonal variations, increase/decrease in use or production, problems with the system that may not be apparent, changes since the last pump test, and changes since the measure was installed.

Other critical data requested from the customers was quantity of water pumped for a period of time. In some cases, customers had annual quantities, and in other cases, monthly quantities were obtained. Additionally, recorded pump run time hours were requested which, where possible, were used to estimate or verify the quantities pumped.

At some sites, a pump test by an Edison pump test technician was scheduled at the time of the site visit. This provided the most accurate, up to date information on the system. Copies of the pump test were obtained from the technician at the site. All data obtained for each of the sites are included in the data for each site in Appendix B.

3.3.4 Conduct Site-Specific Analysis and Estimate Energy and Demand Impacts

After the data collection and site investigation had been performed, the data was evaluated to determine the load impact of the installed measures. The analyses in this report are based on information obtained from field visits to all of the facilities, meetings and discussions with customer operations staff, review of existing pumping records and pump efficiency tests and performing new pump tests. Engineering analysis and calculations were performed using these data, and the use of standard hydraulic and energy equations and theories.

It must be noted that each site had its own peculiarities, and not all data was available for every site. Some sites had very limited records, limited measurable site data, and/or no available data. In some instances, the data was not accessible from the customer. For instances where data was limited or insufficient, assumptions of pump use were made based on typical values for similar systems. Additionally, in some cases, data was estimated using empirical formulas and standard engineering calculations.

Typically, a one-year period of ex-post analysis was selected to determine the load impact, with calculations showing monthly totals. HDR attempted to select a period where billing records appeared consistent. As mentioned earlier, the billing records provide information of pump non-operation periods. Since the measures were installed at various times of the year in 1996, some of the time periods are different. In some cases, an annual quantity pumped was the only record available, in which case, monthly calculations and data breakdown were irrelevant, and only annual data is provided.

Because of the difference in available data, one particular strategy for determining the impact was not possible for all measures. Typically, the evaluations show the monthly data in 2 scenarios, one assuming the measure was not installed, and one assuming the measure was installed, for the same length time period. This method assures that the calculations for before and after the measures were installed are based on the same pumping conditions, same water demand, same seasonal fluctuations, etc., except where these conditions changed as part of the measure (for example, discharge pressure change).

SECTION 4 - PUMPING MEASURES

4.1 INTRODUCTION

The initial work by HDR involved evaluation of 8 customers with agricultural accounts. A total of 13 measures related to water pumping were evaluated. Each customer is considered a "site". Sites 3, 6, and 8 had more than one measure installed. Site 3 had measures installed at 4 locations, site 8 had measures installed at 2 locations. Site 6 had 2 measures installed at the same location. Table A summarizes the measures described in detail in this section.

TABLE A

MEASURE NO.	SITE NO.	MEASURE DESCRIPTION
1	1	Replace existing motor with new 100 hp motor with VSD
2	2	Replace existing pump and impeller assembly
3	3-1	Replace existing pump and motor with new 100 hp pump and motor
4	3-2	Replace existing pump and motor with new 100 hp pump and motor
5	3-3	Replace existing pump and motor with new 100 hp pump and motor
6	3-4	Replace existing pump and motor with new 125 hp pump and motor
7	4	Replace existing motor with new 250 hp motor with VSD
8	5	Replace existing pump and motor with new 40 hp pump and motor with VSD
9	6	Replace existing pump and motor with new 150 hp pump and motor with VSD
10	6	Replace existing pump and motor with new 75 hp pump and motor
11	7	Installation of new VSD on existing 150 hp motor
12	8-1	Installation of new 350 hp well pump and motor with VSD
13	8-2	Installation of new 350 hp well pump and motor with VSD

Analysis for Site No. 1

Description Of Measure

Installation of new 100 hp motor with a variable speed drive (VSD) on an existing vertical turbine well pump.

System Description

The installation of a new 100 HP premium efficiency motor with VSD was completed at this site in September, 1996. The new motor replaced an older constant speed 100 hp motor.

The pump control is set to maintain system pressure and fill a storage reservoir. There are also other sources of water that pump into this system. These other sources affect the pumping operation of this well when they are operating by increasing the system pressure. The system pressure varies depending on the level of water in the reservoir, and which sources of supply are operating. Typically, the system pressure is in the range of 60-85 psi. The pump flow rate varies as the motor speed and system pressure varies to meet the system demands.

With the VSD, the pump can operate efficiently through a range of flow rates, based on the instantaneous demands. When the motor operates at a reduced speed, energy savings is achieved because of the reduced energy requirement to the motor. Additionally, the new motor has an efficiency of approximately 94%. Older motors typically have efficiencies ranging from 88-90%.

SCE Methodology and Findings

Review of 1996 ASD calculation:

- MARS version 2.2 run of August 15, 1996 used for original SCE ex ante ASD savings calculation.
- The MARS calculation did not adjust for the static water head pressure that the pump must overcome before water can start to flow.

Revised ASD calculation used these changes:

- Used Edison August 8, 1997 pump test data because it had two test points at constant speed operation.
- Used pump curve supplied by customer August 19, 1997 to determine head and that pump efficiency drops by 10% at 50% flow point.
- The base case was modified slightly by reallocation of low speed hours. All the MARS pumping hours for flows below 50% were added to the revised calculation 50% category (50-59.9 %t of full). This is based on the assumption that pump speeds and flows should not be below 50% of the pump design point.
- Used a water ASD calculation program that adjusts energy consumption to account for static water head pressure that the pump must overcome before water can start to flow. Static head was 288.2 feet.

Savings from 1996 Mars calculation = 350,911 kWh/year.
Savings from revised water ASD calculation = 104,339 kWh/year.
Reduction of 1996 Mars savings = 246,572 kWh/year.
Reduction of 1996 Mars savings, by percent = 70 %.

Annual average energy consumption per acre-foot of water used:
1996 base case = 697 kWh/AF
1996 ASD case = 301 kWh/AF
Revised base case = 588 kWh/AF
Revised ASD case = 470 kWh/AF

See Appendix F-1 for (1) customer-supplied pump curve, (2) August 1996 MARS output, (3) August 1997 pump test data.

HDR Methodology and Findings

Data Collection and Sources

HDR staff visited the site on August 15, 1997. The purpose of the visit was to operate the pump at various speeds and determine the kW loads at those speeds. Additionally, information regarding the typical operation of the pump was needed.

The pump was operated at various speeds from 100% to approximately 80% of full speed. An SCE pump test technician was present and performed a pump test on the well pump during the site visit. Since the pump is affected by the operation of other pumping facilities, the other facilities were shut down during the pump test.

From discussions with the water system operator at the site, information on pump run times and system operation was obtained. The operator indicated that the pump runs approximately 24 hours per day. Several months of water pumping and power consumption data (before and after VSD installation), pump curves, two previous pump tests (one before, one after VSD installation) were obtained from the owner. Information collected at the site, and subsequently, is in Appendix C.

Ex-Post Savings Methodology

The run time hours before and after the measure was installed are similar, however, pumping records indicate an increase in the water production after the measure was installed. This is likely due to the increase in efficiency allowing more water to be pumped in the same amount of time. The data in the attached table is actual recorded data from the owner, showing kWh per CCF (hundred cubic feet). The owner's data appears consistent with the SCE billing data, therefore, the owners data was used for the calculations of energy savings. Because the data available from the owner was considered more accurate than the standard equations and assumptions that have been used for other site summaries involving VSDs, it was used in place of the pump test data. The calculations in the table show the energy consumption for the pump operating with and without the VSD.

Assumptions for calculations with VSD

Since data was collected only for 2 complete months, and part of one additional month, this was extrapolated into 12 months using a simple direct ratio.

Assumptions for calculations with a constant speed pump

Since data was collected only for 3 months, this was extrapolated into 12 months using a simple direct ratio.

Using these assumptions, an approximation of actual annual energy used was calculated and is shown in Table 1-1. The calculations of annual energy saved are based on the water pumping requirement after the measure was installed. This may be an optimistic estimate of savings, since the quantity pumped increased. However, since this was actual water usage, we considered it a feasible estimate. If the water pumping requirement prior to installation of the measure was, the savings would have been much lower.

Summary of Calculated Savings

For a one year period with a water requirement of 754.8 acre-feet::

Estimated Energy Savings

CALCULATED CONSTANT SPEED		CALCULATED VSD		DIFFERENCE IN ENERGY USAGE	
kWh	kWh/ac-ft	kWh	kWh/ac-ft	kWh	kWh/ac-ft
542,110	718	372,584	494	169,526	224

Estimated Demand Savings

CONSTANT SPEED kW	VARIABLE SPEED kW	DIFFERENCE IN DEMAND kW
35-68	24-76	0

The kW values shown above were taken from actual pump tests performed at various flow conditions. Due to the increased water pumping requirements, it is assumed that there is no significant increase or decrease in demand. From the attached calculations, the energy savings due to the VSD installation is estimated to be 169,526 kWh annually, with a 224 kWh/ac-ft savings.

Description Of System Without Measure

Without the VSD, the pump would operate at a constant speed, regardless of the demand on the system. When pumps operate in this mode, they operate along a single pump curve. Typically, the design point of the pump is at a point on the curve where the pump is most efficient. When system demands fluctuate, the pump will move off the point of highest efficiency, decreasing the efficiency and thereby increasing energy demands. Since this pump operates in conjunction with other pumping systems, it would likely be operating off its design point much of the time without the VSD.

Site No. 1

TABLE 1-1													
	DATA FROM OWNER PUMPING RECORDS							CALCULATIONS			CALCULATIONS		
	YEAR	MONTH	CCF	HRS	kWh	GPM	kWh/CCF	ACRE-FEET	kWh/A-F		AVG. ANNUAL AC-FT	AVG. ANNUAL kWh/A-F	AVG. ANNUAL kWh
WITHOUT	1994	dec	22506	740	33600	379	1.49	51.7	650				
VSD	1995	sep	14270	704	27520	253	1.93	32.8	840		462.5	718.2	332,156
	1995	dec	13588	483	20720	350	1.52	31.2	664				
	ANNUAL		201,456					462.5					
WITH	1996	nov	9726	251	10080	482	0.96	22.3	451				
VSD	1997	may	38216	735	50040	648	0.76	87.7	570		754.8	493.6	372,584
	1997	aug*	34257	750	36098	980	1.05	78.6	459				
	ANNUAL		328,795					754.8					
NOTE: More water is being pumped after VSD installed.												224.6	
ANNUAL SAVINGS BASED ON PUMPING QUANTITY OF:						754.8	AC-FT		169,526	kWh			
ENERGY USAGE FOR SAME FLOW IF VSD WAS NOT INSTALLED:									542,110	kWh			

Analysis for Site No. 2

Description Of Measure

The booster pump was rehabilitated by installing a new pump/impeller assembly to increase the pump efficiency.

System Description

Rehabilitation of the pump was completed in November 1996. The pump pumps water to an elevated reservoir, and is controlled by the level sensor on the reservoir. The pump operates at a constant speed to fill the reservoir. The system discharge pressure is approximately 115 psi. The system operates at approximately the same capacity as before the measure was implemented. Pump test data before and after the change indicate the overall system efficiency increased from 53.6% to 62.7%. Energy savings are achieved because of the reduced energy requirement to operate the pump with the increased efficiency.

A standby gas powered pump at this station operates occasionally to meet system peaks. Additionally, two other booster pumps at this station pump water to a separate pressure zone.

SCE Methodology and Findings

Since there was no adjustable speed drive (ASD) pumping equipment installed at this site as part of Edison 1996 incentive program, there were no 1996 ASD calculations to review.

HDR Methodology and Findings

Data Collection and Sources

HDR staff visited the well site on September 11, 1997. The purpose of the visit was to look at the system set-up, discuss the use and seasonal variations in use, collect data on flow, pressure and energy use, and collect previous pump test data.

From discussions with the owner at the site, information on pump run times, flow rates, seasonal water demand variations and water quantity pumped was obtained. Information collected during the site visit, and subsequently, is in Appendix B.

Ex-Post Savings Methodology

Historical data showing pump run times was obtained and used to determine the pump operation. The pump test of the old pump shows a capacity of 890 gpm at 115 psi discharge pressure. The pump test of the new pump indicates a capacity of 817 gpm at 117 psi. The pump flow rates are nearly equal before and after the change, thus the number of run-time hours to deliver the required amount of water before and after the rehabilitation was assumed to be the same.

Because recent pump tests before and after installation of the new pump were available for this site, the data from these tests was used for the calculations. The difference in kW required is taken directly from the pump tests. SCE measures the kW input to the motor directly during the pump test. Pump run times were obtained from the owner. The total kWh is product of these two numbers. Table 2-1 shows the calculated kWh required if the old pump had been required to supply water to the system, and if the new pump had been required to provide the water. The difference in these two numbers is the estimated energy savings realized by the use of the higher efficiency pump.

This calculation is as follows:

kWh = kW X run time hours

The table also shows the gallons pumped per month. Gallons per minute is taken from the pump test data. Water pumped has also been shown in terms of acre-feet.

This calculations as follows:

Gallons = gpm X run time hours X (60 min./hour)

Summary of Calculated Savings

For the 12 month period from June 1996 to May 1997:

Estimated Energy Savings

CALCULATED OLD PUMP		CALCULATED NEW PUMP		DIFFERENCE IN ENERGY USAGE	
kWh	kWh/ac-ft	kWh	kWh/ac-ft	kWh	kWh/ac-ft
282,646	499	243,505	430	39,141	69

Estimated Demand Reduction

CALCULATED OLD PUMP kW	CALCULATED NEW PUMP kW	DIFFERENCE kW
75.1	64.7	10.4

The energy savings due to the higher efficiency pump installation is estimated to be 39,191 kWh annually, a 69 kWh/ac-ft savings, and a demand reduction of approximately 10 kW.

Description Of System Without Measure

Using the lower efficiency pump, the system would continue to operate at the increased energy usage and demand.

Site No. 2

TABLE 2-1

DATA FROM OWNER				CALCULATIONS		CALCULATIONS OLD PUMP		CALCULATIONS NEW PUMP			
YEAR	MONTH	RUN TIME (hours)	FLOW RATE (gpm)	GALLONS	ACRE-FEET	kW	CALC kWh	kW	CALC kWh	SAVINGS (kW)	SAVINGS (kWh)
1997	MAY	734.5	817	36,005,190	110.49	75.1	55,161	64.7	47,522	10.4	7,639
	APRIL	85.7	817	4,201,014	12.89	75.1	6,436	64.7	5,545	10.4	891
	MAR	218.5	817	10,710,870	32.87	75.1	16,409	64.7	14,137	10.4	2,272
	FEB	0	817	0	0.00	75.1	0	64.7	0	10.4	0
	JAN	39.9	817	1,955,898	6.00	75.1	2,996	64.7	2,582	10.4	415
1996	DEC	39.7	817	1,946,094	5.97	75.1	2,981	64.7	2,569	10.4	413
	NOV	306.4	817	15,019,728	46.09	75.1	23,011	64.7	19,824	10.4	3,187
	OCT	585	817	28,676,700	88.00	75.1	43,934	64.7	37,850	10.4	6,084
	SEP	380.1	817	18,632,502	57.18	75.1	28,546	64.7	24,592	10.4	3,953
	AUG	185	817	9,068,700	27.83	75.1	13,894	64.7	11,970	10.4	1,924
	JULY	505.1	817	24,760,002	75.98	75.1	37,933	64.7	32,680	10.4	5,253
	JUN	683.7	817	33,514,974	102.85	75.1	51,346	64.7	44,235	10.4	7,110
TOTALS				184,491,672	566		282,646		243,505		39,141
kWh/ac-ft							499		430		

Analysis for Site No. 3-1

Description Of Measure
Installation of a new pump and motor for low pressure irrigation system.

System Description
Replacement of Well No. 1 pump and motor was completed in December 1996. The well supplies water to an above ground, center pivot irrigation system. A 100 hp motor replaced a 125 hp motor. The pump control is set up on a timer and operates to provide a preset water application rate in inches of water per acre. The pump operates at a constant speed and the system discharge pressure is approximately 10 psi. The previous system operated at approximately 55 psi. Energy savings are achieved because of the reduced energy requirement to operate the motor at the lower discharge pressure. Additionally, the low pressure system sprays a coarser spray (not a fine mist), and the sprinkler heads were placed lower to the ground. This allows more water to reach the ground because less water is lost from being blown off-site by wind, and less water is lost to evaporation. The reduced water loss also saves energy in a reduced amount of required pumping.

In addition to the well pump, the electrical service provides power to the well pump control panel and the eight 1/4 hp motors that cause the irrigation line to rotate in a circle.

SCE Methodology and Findings

Since there was no adjustable speed drive (ASD) pumping equipment installed at this site as part of Edison 1996 incentive program, there were no 1996 ASD calculations to review.

HDR Methodology and Findings

Data Collection and Sources
HDR staff visited the well site on October 20, 1997. The purpose of the visit was to look at the system set-up, discuss the use and seasonal variations in use, collect data on flow, pressure and energy use, and collect previous pump test data.

From discussions with the owner at the site, information on pump run times, settings, flow rates, seasonal water demand variations and water quantity pumped was obtained. Information collected during the site visit is in Appendix B.

Ex-Post Savings Methodology
Historical billing data was used to assist in determining the pump operation. The number of hours the pump operated at high pressure to meet the water pumping requirements is indicated by the monthly full load hours, as provided on the billing worksheets. Before the change, the pump capacity was approximately 1475 gpm (from a previous pump test). At the time of the visit, the flow gauge at the pump discharge read approximately 1600 gpm, though the owner said the pump normally pumps approximately 1400 gpm. The pump flow rates are nearly equal before and after the change, thus the number of run-time hours to deliver the required amount of water was assumed to be the same.

Actual energy billed is shown in Table 1. Also shown in this table is the calculated kW and kWh required if the high pressure pump had been required to supply water to the system, and if the low pressure pump had been required to provide the water. The difference in these two numbers is the estimated energy savings realized by the use of the low pressure system.

The calculations are as follows:

$$kW = \frac{(gpm)\ (total\ feet\ of\ head)}{(3960)\ (pump\ efficiency)} \times \frac{0.746}{(motor\ efficiency)}$$

$$kWh = \frac{(kW)\ (gallons\ pumped)}{(gpm)\ (60\ min/hour)}$$

Total feet of head equals the pumping water level (from pump tests) plus the discharge pressure in terms of feet of head (1 psi = 2.31 feet).

Pump efficiency and motor efficiency are estimated from pump and motor data, and previous pump tests. Typically, new motors have efficiencies of approximately 94%. Older models have efficiencies of 88-90%.

Gallons pumped is calculated by the average pumping rate (gpm) times the full load hours the pump ran during that billing cycle. Water pumped has also been shown in terms of acre-feet.

For example, from Table 1, for the month of May 1997:

$$kW = \frac{(1475\ gpm)\ ((136\ feet + (10\ psi \times 2.31))}{(3960)\ (0.74)} \times \frac{0.746}{0.94} = 62.7$$

$$kWh = \frac{(62.7\ kW)\ (28{,}143{,}000\ gallons)}{(1475\ gpm)\ (60\ min/hour)} = 19{,}941\ kWh$$

Summary of Calculated Savings

For the 12 month period from June 1996 to May 1997

Estimated Energy Savings

CALCULATED LOW PRESSURE		CALCULATED HIGH PRESSURE		DIFFERENCE IN ENERGY USAGE	
kWh	kWh/ac-ft	kWh	kWh/ac-ft	kWh	kWh/ac-ft
204,174	231	352,577	399	148,403	168

Estimated Demand Reduction

CALCULATED LOW PRESSURE kW	CALCULATED HIGH PRESSURE kW	DIFFERENCE HIGH - LOW kW
62.7	108.3	45.6

The energy savings due to the low pressure system installation is estimated to be 148,403 kWh annually, a 168 kWh/ac-ft savings, and a demand reduction of approximately 46 kW.

Description Of System Without Measure
Using the high pressure system, the pump would continue to operate at the increased energy usage and demand.

SITE No. 3-1

TABLE 3-1												
DATA FROM BILLING WORKSHEETS					CALCULATIONS		CALCULATIONS LOW PRESSURE		CALCULATIONS HIGH PRESSURE			
YEAR	MONTH	FULL LOAD HOURS	MAX KW	kWh FROM BILLING	GALLONS	ACRE-FEET	kW	CALC kWh	kW	CALC kWh	SAVINGS HIGH-LOW (kW)	SAVINGS HIGH-LOW (kWh)
1997	MAY	318	86	27,319	28,143,000	86.36	62.7	19,941	108.3	34,435	45.6	14,494
	APRIL	327	83	27,173	28,939,500	88.81	62.7	20,505	108.3	35,409	45.6	14,904
	MAR	400	75	29,984	35,400,000	108.63	62.7	25,083	108.3	43,314	45.6	18,231
	FEB	193	73	14,055	17,080,500	52.41	62.7	12,102	108.3	20,899	45.6	8,797
	JAN	0	0	0	0	0.00	62.7	0	108.3	0	45.6	0
1996	DEC	0	0	0	0	0.00	62.7	0	108.3	0	45.6	0
	NOV	1	112	160	88,500	0.27	62.7	63	108.3	108	45.6	46
	OCT	128	123	15,699	11,328,000	34.76	62.7	8,027	108.3	13,861	45.6	5,834
	SEP	420	122	51,253	37,170,000	114.06	62.7	26,337	108.3	45,480	45.6	19,143
	AUG	585	121	70,806	51,772,500	158.87	62.7	36,684	108.3	63,347	45.6	26,663
	JULY	575	121	69,602	50,887,500	156.16	62.7	36,057	108.3	62,264	45.6	26,208
	JUN	309	122	37,716	27,346,500	83.92	62.7	19,376	108.3	33,460	45.6	14,084
ANNUAL TOTALS				343,767	288,156,000	884		204,174		352,577		148,403
kWh/ac-ft								231		399		

Analysis for Site No. 3-2

Description Of Measure
Installation of a new pump and motor for low pressure irrigation system.

System Description
Replacement of Well No. 2 pump and motor was completed in December 1996. This well also supplies water to an above ground, center pivot irrigation system, very similar to the well at Site 3-1. In this case, a 100 hp motor replaced a 125 hp motor. The pump controls are also the same as site 3-1, however, the system discharge pressure is approximately 6-7 psi. The previous system operated at approximately 34 psi. Energy savings are achieved because of the reduced energy requirement to operate the motor at the lower discharge pressure. Additionally, the low pressure system sprays a coarser spray (not a fine mist), and the sprinkler heads were placed lower to the ground. This allows more water to reach the ground because less water is lost from being blown off-site by wind, and less water is lost to evaporation. The reduced water loss also saves energy in a reduced amount of required pumping.

This well produces air in the discharge, which could be heard while the pump was running. Air production generally reduces the efficiency of the pump system. However, it was not clear what was causing the development of the air.

In addition to the well pump, the electrical service provides power to the well pump control panel and the eight 1/4 hp motors that cause the irrigation line to rotate in a circle.

SCE Methodology and Findings

Since there was no adjustable speed drive (ASD) pumping equipment installed at this site as part of Edison 1996 incentive program, there were no 1996 ASD calculations to review.

HDR Methodology and Findings

Data Collection and Sources
HDR staff visited the well site on October 20, 1997. The purpose of the visit was to look at the system set-up, discuss the use and seasonal variations in use, collect data on flow, pressure and energy use, and collect previous pump test data.

From discussions with the owner at the site, information on pump run times, settings, flow rates, seasonal water demand variations and water quantity pumped was obtained. Information collected at the site is in Appendix B.

Ex-Post Savings Methodology
Since historical billing data was not provided for this well, data from the pump test was used to assist in determining the pump operation. The pump consumed 485,188 kWh in the year prior to the last pump test (May 24, 1994), and pumped approximately 1189 acre-feet. The pumping rate during that test was 1,239 gpm, and the energy demand was 93 kW. The system operated at 34 psi discharge pressure with a pumping water level of 129 feet. This is considered the "high pressure" system.

At the time of the site visit ("low pressure" system), the pumping rate was approximately 1,050 gpm with a discharge pressure of 7 psi. Assuming the same annual irrigation requirement, and the same pumping water level at this flow rate, the low pressure system would consume only

301,993 kWh per year with an energy demand of approximately 49 kW. The calculation for this estimate is as follows.

Using the equations from Site 3-1, the difference between the high and low pressure systems would be:

kW = (kW for high pressure system) - (kW for low pressure system) =

$$kW = \frac{(gpm)\,(tdh)}{(3960)\,(pump\ eff.)}\ (high\ pressure) - \frac{(gpm)\,(tdh)}{(3960)\,(pump\ eff.)}\ (low\ pressure) =$$

$$kW = \frac{(1239\ gpm)\,(129\ feet + ((34\ psi) \times 2.31))}{(3960)\,(0.60)} \times \frac{0.746}{0.87} - \frac{(1050\ gpm)\,(129\ feet + ((7\ psi) \times 2.31))}{(3960)\,(0.65)} \times \frac{0.746}{0.90} = 92.8 - 49.1 = 43.7\ kW$$

and:

$$kWh = kW/gpm\ (high\ pressure) - kW/gpm\ (low\ pressure) \times \frac{(ac\text{-}ft \times 325{,}892\ gal/ac\text{-}ft)}{(60\ min/hour)} =$$

$$kWh = \frac{(92.8\ kW)}{(1239\ gpm)} - \frac{(49.1\ kW)}{(1050\ gpm)} \times \frac{(1189\ ac\text{-}ft \times 325{,}892\ gal/ac\text{-}ft)}{(60\ min/hour)} = 181{,}713\ kWh$$

Summary of Calculated Annual Savings

For a12 month period:

Estimated Energy Savings

CALCULATED LOW PRESSURE		CALCULATED HIGH PRESSURE		DIFFERENCE IN ENERGY USAGE	
kWh	kWh/ac-ft	kWh	kWh/ac-ft	kWh	kWh/ac-ft
301,993	254	483,705	407	181,713	153

Estimated Demand Reduction

CALCULATED LOW PRESSURE kW	CALCULATED HIGH PRESSURE kW	DIFFERENCE HIGH - LOW kW
49.1	93.1	44

Table 3-2 summarizes the data and calculations for these calculations. The energy savings due to the low pressure system installation is estimated to be 181,713 kWh annually, a 153 kWh/ac-ft savings, and a demand reduction of approximately 44 kW.

Description Of System Without Measure
Using the high pressure system, the pump would continue to operate at the increased energy usage and demand.

SITE No. 3-2

TABLE 3-2													
HIGH PRESSURE SYSTEM FROM PUMP TEST						HIGH PRESSURE SYSTEM CALCULATIONS			LOW PRESSURE SYSTEM CALCULATIONS				ANNUAL SAVINGS
YEAR	MONTH	Ac-Ft/yr	kW	gpm	kWh/yr	gal/yr	hr/yr	kWh/yr	gpm	kW	hr/yr	kWh/yr	kWh/yr
93/94	July-June	1189	93.1	1239	485124	3.87E+08	5212	483705	1050	49.1	6151	301993	181713
kWh/ac-ft								407				254	

Analysis for Site No. 3-3

Description Of Measure
Installation of a new pump and motor for low pressure irrigation system.

System Description
Replacement of Well No. 1 pump and motor was completed in December 1996. The well supplies water to an above ground, center pivot irrigation system. A 100 hp motor is at the site (same hp rating as before change). The pump controls are also the same as site 3-1, however, the system discharge pressure is approximately 5 psi. The previous system operated at approximately 45 psi. Energy savings are achieved because of the reduced energy requirement to operate the motor at the lower discharge pressure. Additionally, the low pressure system sprays a coarser spray (not a fine mist), and the sprinkler heads were placed lower to the ground. This allows more water to reach the ground because less water is lost from being blown off-site by wind, and less water is lost to evaporation. The reduced water loss also saves energy in a reduced amount of required pumping.

In addition to the well pump, the electrical service provides power to the well pump control panel and the eight 1/4 hp motors that cause the irrigation line to rotate in a circle.

SCE Methodology and Findings

Since there was no adjustable speed drive (ASD) pumping equipment installed at this site as part of Edison 1996 incentive program, there were no 1996 ASD calculations to review.

HDR Methodology and Findings

Data Collection and Sources
HDR staff visited the well site on October 20, 1997. The purpose of the visit was to look at the system set-up, discuss the use and seasonal variations in use, collect data on flow, pressure and energy use, and collect previous pump test data.

From discussions with the owner at the site, information on pump run times, settings, flow rates, seasonal water demand variations and water quantity pumped was obtained. Information collected at the site is in Appendix B.

Ex-Post Savings Methodology
The same methodology and calculations for determining ex-post savings was used for this site as was for Site 3-1. Historical billing data was used to assist in determining the pump operation. The number of hours the pump would have operated at low pressure to meet the water pumping requirements are based on the monthly full load hours, as provided on the billing worksheets. Before the change, the pump capacity was approximately 966 gpm (from a previous pump test). At the time of the visit, the pump was operating, however, the owner indicated that it typically pumps approximately 1000 gpm. The pump flow rates are nearly equal before and after the change, thus the number of run-time hours was assumed to be the same.

Actual energy billed is shown in Table 3-3. Also shown in this table is the calculated kW and kWh required if the high pressure pump had been required to supply water to the system, and if the low pressure pump had been required to provide the water. The difference in these two numbers is the estimated energy savings realized by the use of the low pressure system.

The calculations are as follows:

For the low pressure system, for the month of September 1996:

$$kW = \frac{(966\ gpm)\ ((119\ feet + (5\ psi \times 2.31))}{(3960)\ (0.75)} \times \frac{0.746}{0.94} = 33.7$$

$$kWh = \frac{(33.7\ kW)\ (20{,}459{,}880\ gallons)}{(966\ gpm)\ (60\ min/hour)} = 11{,}896\ kWh$$

Summary of Calculated Savings

Estimated Energy Savings

CALCULATED LOW PRESSURE		CALCULATED HIGH PRESSURE		DIFFERENCE IN ENERGY USAGE	
kWh	kWh/ac-ft	kWh	kWh/ac-ft	kWh	kWh/ac-ft
135,771	189	308,380	430	172,609	241

Estimated Demand Reduction

CALCULATED LOW PRESSURE kW	CALCULATED HIGH PRESSURE kW	DIFFERENCE HIGH - LOW kW
33.7	76.5	42.8

Based on flow quantities for the 12 month period from October 1995 to September 1996, the energy savings due to the low pressure system installation is estimated to be 172,609 kWh annually, a 241 kWh/ac-ft savings, and a demand reduction of approximately 43 kW. Since the water demand did not change significantly in the last few years, this data is considered valid for the first year after the installation of the measure.

Description Of System Without Measure

Using the high pressure system, the pump would continue to operate at the increased energy usage and demand.

SITE No. 3-3

TABLE 3-3												
DATA FROM BILLING WORKSHEETS					CALCULATIONS		CALCULATIONS LOW PRESSURE		CALCULATIONS HIGH PRESSURE			
YEAR	MONTH	FULL LOAD HOURS	MAX KW	kWh FROM BILLING	GALLONS	ACRE-FEET	kW	CALC kWh	kW	CALC kWh	SAVINGS HIGH-LOW (kW)	SAVINGS HIGH-LOW (kWh)
1996	SEP	353	90	31727	20,459,880	62.78	33.7	11,896	76.5	27,019	42.8	15123
	AUG	352	89	31327	20,401,920	62.61	33.7	11,862	76.5	26,942	42.8	15080
	JULY	387	90	34795	22,430,520	68.83	33.7	13,041	76.5	29,621	42.8	16580
	JUN	418	89	37207	24,227,280	74.35	33.7	14,086	76.5	31,994	42.8	17908
	MAY	621	90	55849	35,993,160	110.45	33.7	20,927	76.5	47,531	42.8	26605
	APRIL	520	91	47314	30,139,200	92.49	33.7	17,523	76.5	39,801	42.8	22278
	MAR	410	93	38162	23,763,600	72.92	33.7	13,816	76.5	31,381	42.8	17565
	FEB	164	91	14901	9,505,440	29.17	33.7	5,527	76.5	12,553	42.8	7026
	JAN	47	91	4308	2,724,120	8.36	33.7	1,584	76.5	3,597	42.8	2014
1995	DEC	0	0	0	0	0.00	33.7	0	76.5	0	42.8	0
	NOV	243	91	22116	14,084,280	43.22	33.7	8,189	76.5	18,599	42.8	10411
	OCT	514	91	46758	29,791,440	91.42	33.7	17,321	76.5	39,342	42.8	22021
TOTALS (Annual Savings)				364464	233,520,840	717		135771		308380		172608.91
kWh/ac-ft								189		430		

Analysis for Site No. 3-4

Description Of Measure
Installation of a new pump and motor for low pressure irrigation system.

System Description
The replacement of this well pump and motor was completed in December 1996. The well supplies water to an above ground, center pivot irrigation system. A 125 hp motor replaced a 150 hp motor. The pump control is set up on a timer and operates to provide a preset water application rate in inches of water per acre. The pump operates at a constant speed and the system discharge pressure is approximately 11 psi. The previous system operated at approximately 56 psi. Energy savings are achieved because of the reduced energy requirement to operate the motor at the lower discharge pressure. Additionally, the low pressure system sprays a coarser spray (not a fine mist), and the sprinkler heads were placed lower to the ground. This allows more water to reach the ground because less water is lost from being blown off-site by wind, and less water is lost to evaporation. The reduced water loss also saves energy in a reduced amount of required pumping.

In addition to the well pump, the electrical service provides power to the well pump control panel and the eight 1/4 hp motors that cause the irrigation line to rotate in a circle.

SCE Methodology and Findings

Since there was no adjustable speed drive (ASD) pumping equipment installed at this site as part of Edison 1996 incentive program, there were no 1996 ASD calculations to review.

HDR Methodology and Findings

Data Collection and Sources
HDR staff visited the well site on October 20, 1997. The purpose of the visit was to look at the system set-up, discuss the use and seasonal variations in use, collect data on flow, pressure and energy use, and collect previous pump test data.

From discussions with the owner at the site, information on pump run times, settings, flow rates, seasonal water demand variations and water quantity pumped was obtained. Information collected at the site is in Appendix B.

Ex-Post Savings Methodology
Historical billing data was used to assist in determining the pump operation. The number of hours the pump would have operated at low pressure to meet the water pumping requirements are based on the monthly full load hours, as provided on the billing worksheets. Before the change, the pump capacity was approximately 1769 gpm (from a previous pump test on May 30, 1995) and the energy demand was 128 kW. This is considered the "high pressure" system.

At the time of the visit, the flow gauge at the pump discharge read approximately 1300 gpm ("low pressure" system). Assuming the same irrigation requirement at this flow rate, the low pressure system would operate for more hours at a lower kW requirement of approximately 56 kW. The calculation for this estimate is shown in Table 3-4.

Actual energy billed during 1996 is shown in Table 3-4; this represents the energy consumption before the change, since the change occurred in December 1996. This year of flow data was used to estimate a complete year of energy savings, since it had water usage in almost every month. Also shown in this table is the calculated kW and kWh if the high pressure pump had been required to supply water to the system, and if the low pressure pump had been required to provide the water. The difference in these two numbers is the estimated energy savings realized by the use of the low pressure system.

The equations and calculations are similar to those used for Sites 3-1, 3-2, and 3-3.

Summary of Calculated Savings

Based on the same assumptions used for Sites 3-1, 3-2, and 3-3, the savings for the one-year period from January through December is:

Estimated Energy Savings

CALCULATED LOW PRESSURE		CALCULATED HIGH PRESSURE		DIFFERENCE IN ENERGY USAGE	
kWh	kWh/ac-ft	kWh	kWh/ac-ft	kWh	kWh/ac-ft
323,911	228	553,949	391	230,038	163

Estimated Demand Reduction

CALCULATED LOW PRESSURE kW	CALCULATED HIGH PRESSURE kW	DIFFERENCE HIGH - LOW kW
54.7	127.2	72.6

The energy savings due to the low pressure system installation is estimated to be 230,038 kWh and 163 kWh/ac-ft savings annually, with a demand reduction of approximately 73 kW.

Description Of System Without Measure
Using the high pressure system, the pump would continue to operate at the increased energy usage and demand.

SITE No. 3-4

TABLE 3-4												
DATA FROM BILLING WORKSHEETS					CALCULATIONS		CALCULATIONS LOW PRESSURE		CALCULATIONS HIGH PRESSURE			
YEAR	MONTH	FULL LOAD HOURS	MAX KW	kWh FROM BILLING	GALLONS	ACRE-FEET	kW	CALC kWh	kW	CALC kWh	SAVINGS HIGH-LOW (kW)	SAVINGS HIGH-LOW (kWh)
1996	DEC	0	0	0	0	0.00	54.7	0	127.2	0	72.6	0
	NOV	22	126	2772	2,335,080	7.17	54.7	1,637	127.2	2,799	72.6	1162
	OCT	628	128	80384	66,655,920	204.55	54.7	46,719	127.2	79,899	72.6	33180
	SEP	508	130	66040	53,919,120	165.46	54.7	37,792	127.2	64,632	72.6	26840
	AUG	504	130	65520	53,494,560	164.16	54.7	37,495	127.2	64,123	72.6	26628
	JULY	599	130	77870	63,577,860	195.10	54.7	44,562	127.2	76,209	72.6	31647
	JUN	661	131	86591	70,158,540	215.29	54.7	49,174	127.2	84,098	72.6	34923
	MAY	527	128	67456	55,935,780	171.65	54.7	39,206	127.2	67,049	72.6	27843
	APRIL	550	130	71500	58,377,000	179.14	54.7	40,917	127.2	69,975	72.6	29059
	MAR	136	130	17680	14,435,040	44.30	54.7	10,118	127.2	17,303	72.6	7185
	FEB	126	130	16380	13,373,640	41.04	54.7	9,374	127.2	16,031	72.6	6657
	JAN	93	130	12090	9,871,020	30.29	54.7	6,919	127.2	11,832	72.6	4914
ANNUAL TOTALS				564283	462,133,560	1,418		323911		553949		230038
kWh/ac-ft								228		391		

Analysis for Site No. 4

Description Of Measure
Installation of variable speed drive (VSD) on a 250 HP well pump.

System Description
Construction of a VSD on this well was completed in December, 1996. The pump was installed with a 250 HP VSD and premium efficiency motor. The pump control is manual from a remote control center. The pump flow rate varies as the motor speed varies, to fill the system reservoirs, and supplement additional pumping from this zone. With the VSD, the pump can operate efficiently through a range of flow rates, based on the instantaneous demands. When the motor operates at a reduced speed, energy savings is achieved because of the reduced energy requirement to the motor.

According to the system operator, the well was previously equipped with a temporary VSD, and prior to that a "soft start "starter.

SCE Methodology and Findings

Review of 1996 ASD calculation:
- MARS version 2.2 run of October 25, 1996 used for original SCE ex ante ASD calculation.
- The MARS calculation did not adjust for the static water head pressure that the pump must overcome before water can start to flow.

Revised ASD calculation used these changes:
- Used Edison July 29, 1997 pump test data because it listed a total head value. An earlier Edison November 19, 1996 test did not list a total head value with a sounder line and the customer air line was inoperative or missing.
- Used a pump curve supplied by customer to find pump curve shut off head point.
- The base case was modified slightly by reallocation of low speed hours. All the MARS pumping hours for flows below 50% were added to the revised calculation 50% (50-59 % of full) category. This is based on the assumption that pump speeds and flows should not be below 50% of the pump design point.
- Used a water ASD calculation program that adjusts energy consumption to account for static water head pressure that the pump must overcome before water can start to flow. Static head was 575.4 feet.

Savings from 1996 Mars calculation =	958,322 kWh/year.
Savings from revised water ASD calculation =	440,687 kWh/year.
Reduction of 1996 Mars savings =	517,635 kWh/year.
Reduction of 1996 Mars savings, by percent =	54 %.

Annual average energy consumption per acre-foot of water used:
1996 base case = 1,281 kWh/AF
1996 ASD case = 497 kWh/AF
Revised base case = 1,522 kWh/AF
Revised ASD case = 1,129 kWh/AF

See Appendix F-4 for (1) customer-supplied pump curve, (2) July 1997 pump test data, (3) November 1996 pump test data, (4) October 1996 (original) MARS output.

HDR Methodology and Findings

Data Collection and Sources

HDR staff visited the well site on July 29, 1997. The purpose of the visit was to operate the well pump at various speeds and determine the kW loads at those speeds. Additionally, information regarding the typical operation of the pump was needed. This information is used to estimate the amount of time the pump normally operates at reduced speeds, and what are the typical reduced speeds.

The pump was operated at various speeds from 100% to 70% of full speed. The pump was operating at a higher system pressure than usual because an interconnection with a system that operates at a higher pressure was open. The control panels at the site provided readings of percent of motor speed, frequency (hertz), amps, and flow rate (cfs).

Billing records were reviewed to determine periods of non-operation of the pump during the 12 month period investigated. Based on this information, the pump was not fully operational until July of 1996. Prior to that date, the pump operated at full load (197 kW) at least once during the billing cycle, but not for a significant number of hours.

From discussions with the water system operator at the site, information on pump run times, speeds, seasonal water demand variations and water quantity pumped was obtained. The operator indicated that the pump runs approximately 24 hours per day, and the normal speed is approximately 70% (or 42 Hz). The pump test technician, however, stated that his records indicate the pump usually operates at a higher speed (higher kW). Water quantities pumped for the period from April, 1996, to June, 1997, were collected. Information collected at the site is included in Appendix B.

Data supplied from Edison consisted of a previous pump test, billing worksheets, and the incentive coupon data.

Ex-Post Savings Methodology

Data collected at the site allowed us to calculate the kW demand and pumping rate (gpm) at various speeds. Additionally, monthly water production was used to calculate the average pumping rate per month. The calculations in the attached table show the energy consumption to produce the required quantity of water at reduced speed and at full speed. The Affinity Laws for centrifugal pumps were used for the calculations.

Assumptions for calculations with VSD

Since continuous recording of pump speed is not available, assumptions of average pump speed were made over one billing cycle based on the maximum kW for that cycle. The maximum kW is an indicator for the maximum speed that the pump operated at during that cycle, and is given on the Edison billing worksheets. For example, a maximum kW of 85 means that the pump ran at 76% speed for at least 15 minutes during that billing cycle. Since the pump operator indicated that the pump runs approximately 24 hours per day, this average flow was assumed to occur 24 hours per day.

The following affinity law for centrifugal pumps was used to determine the motor speed based on the kW demand from the billing sheets:

$$kW_1/kW_2 = ((N_1/N_2)^3$$

The maximum kW measured during the site visit was 195.5 kW (kW_1) with the pump operating at 100% speed (1785 rpm, N_1). N_2 is the calculated speed from the equation above. The resulting kW for these speeds are shown in Table 4-1.

The calculations for the pump with a VSD include a reduction factor for the flow rate calculation. This is due to the difference between actual field data and what the affinity laws predict. The factor varies with pump speed and is estimated by (rpm speed/100). For example, for April. 1997, the affinity law predicts 823 gpm for a pump speed of 1352 rpm, however, field data for a pump speed of 1348 rpm was 511 gpm. The predicted gpm was decreased by 1352/1785 (or 75.8 %) to assume a flow rate of 624 gpm. We believe this is reduction is reasonable for these calculations.

Assumptions for calculations with a constant speed pump.
To meet the same water pumping requirements, the calculations for comparison with a constant speed pump were made assuming the pump would operate at 100% of full speed. To meet the requirements, the constant speed pump would not have to operate 24 hours per day.

It should be noted that the owner occasionally supplements its well water supply with treated water from an interconnection with another system (Metropolitan Water District), which is at a higher pressure. At the time of this site visit and pump test, this interconnection was open. This difference was accounted for by using the variable speed calculations.

Using these assumptions, and the Affinity Laws, an approximation of actual energy used was calculated and is shown in Table 4-1. Also shown in this table is the calculated kW if the pump had been required to operate at full speed to deliver the same water requirement. The difference in these two figures is the estimated energy savings realized by the use of the VSD.

Summary of Calculated Savings

For the period from June 1996 to May 1997:

Estimated Energy Savings

CALCULATED CONSTANT SPEED		CALCULATED VSD		DIFFERENCE IN ENERGY USAGE	
kWh	kWh/ac-ft	kWh	kWh/ac-ft	kWh	kWh/ac-ft
670,030	977	496,171	723	173,859	254

Estimated Demand Reduction

ESTIMATED CONSTANT SPEED kW	ESTIMATED VSD kW	SAVINGS AVG kW
195.5	73-92	113

NOTE: The meter at the site records power use by lighting, control panels and hypochlorite generating system. Estimated kW and kWh shown above are for the pump motor only.

From the attached calculations, the energy savings due to the VSD installation is estimated to be 173,859 kWh and 254 kWh/ac-ft annually, and an average of 113 kW.

Description Of System Without Measure

Without the VSD, the pump would operate at a constant speed, regardless of the demand on the system. When pumps operate in this mode, they operate along a single pump curve. Typically, the design point of the pump is at a point on the curve where the pump is most efficient. When system demands fluctuate, the pump will move off the point of highest efficiency, decreasing the efficiency and thereby increasing energy demands.

SITE No. 4

TABLE 4-1

DATA FROM BILLING WORKSHEETS				FROM OWNER	CALCULATIONS W/ VSD					CALCULATIONS W/O VSD			
YEAR	MONTH	MAX KW	kWh FROM BILLING	ACRE-FEET PUMPED	SPEED rpm	% SPEED	gpm	kW	CALC kWh	FLOW gpm	CALC kWh	SAVINGS (kW)	SAVINGS (kWh)
1997	MAY	73	47080	57.2	1285	72.0	564	73	40237	1087	55877	113.5	15640
	APRIL	85	48880	55.9	1352	75.8	624	85	41376	1087	54617	101.5	13241
	MAR	85	43960	61.7	1352	75.8	624	85	45647	1087	60254	101.5	14607
	FEB	77	41920	50.7	1308	73.3	584	77	36305	1087	49528	109.5	13223
	JAN	77	31640	52.0	1308	73.3	584	77	37243	1087	50807	109.5	13565
1996	DEC	78	38800	35.1	1314	73.6	589	78	25214	1087	34249	108.5	9036
	NOV	79	74640	61.2	1320	73.9	594	79	44171	1087	59746	107.5	15575
	OCT	92	49260	64.6	1388	77.8	658	92	49047	1087	63057	94.5	14010
	SEP	77	48060	60.0	1308	73.3	584	77	42935	1087	58574	109.5	15638
	AUG	77	55860	62.3	1308	73.3	584	77	44582	1087	60820	109.5	16238
	JULY	77	50160	64.5	1308	73.3	584	77	46186	1087	63009	109.5	16822
	JUNE*	75	48620	60.9	1297	72.7	574	75	43228	1087	59492	111.5	16264
ANNUAL TOTALS			578880	685.9					496171		670030		173859
kWh/ac-ft									723		977		

Analysis for Site No. 5

Description Of Measure

Installation of new pump and 40 hp motor with a variable speed drive (VSD) on a vertical turbine booster pump.

System Description

The installation of a new pump and motor with VSD was completed at this site in December, 1996. The pump was installed with a 40 HP VSD and premium efficiency motor, replacing an older 40 hp motor. The pump control is preset to maintain a system pressure of 88 psi. The pump flow rate varies as the motor speed varies to meet the system demand. There is no storage in this system. With the VSD, the pump can operate efficiently through a range of flow rates, based on the instantaneous demands. When the motor operates at a reduced speed, energy savings is achieved because of the reduced energy requirement to the motor.

SCE Methodology and Findings

Review of 1996 ASD calculation:

- MARS version 2.2 run of October 10, 1996 for used for original SCE ex ante ASD calculation.
- The MARS calculation did not adjust for the static water head pressure that the pump must overcome before water can start to flow.

Revised ASD calculation used these changes:

- Used Edison's August 9, 1993 pump test data because it included two test points at constant speed operation.
- The base case was modified slightly by reallocation of low speed hours. All the MARS pumping hours for flows below 50% were added to the 50% (50-59% of full) category, based on the assumption that pump speeds and flows should not be below 50% of the pump design point.
- Used a water ASD calculation program that adjusts energy consumption to account for static water head pressure that the pump must overcome before water can start to flow. Static head was 197.5 feet.

Savings from 1996 Mars calculation =	101,738 kWh/year.
Savings from revised water ASD calculation =	42,105 kWh/year.
Reduction of 1996 Mars savings =	59,633 kWh/year.
Reduction of 1996 Mars savings, by percent =	59 %.

Annual average energy consumption per acre-foot of water used:
1996 base case = 391 kWh/AF
1996 ASD case = 205 kWh/AF
Revised base case = 454 kWh/AF
Revised ASD case = 376 kWh/AF

See Appendix F-5 for (1) October 1996 original MARS run, (2) August 1993 pump test data.

HDR Methodology and Findings

Data Collection and Sources

HDR staff visited the site on August 15, 1997. The purpose of the visit was to operate the pump at various speeds and determine the kW loads at those speeds. Additionally, information regarding the typical operation of the pump was needed. This information is used to estimate the amount of time the pump normally operates at reduced speeds, and what are the typical reduced speeds.

The pump was operated at various speeds from 100% to approximately 85% of full speed. Since the pump was actively serving system, minimal variations on pumping could be performed so as not to disrupt normal system operation. The control panels at the site provided readings of frequency (hertz), amps, voltage, pressure and flow rate (gpm).

From discussions with the water system operator at the site, information on pump run times and system operation was obtained. The operator indicated that the pump runs approximately 24 hours per day. Pump run hours for the 12 month period from August, 1996, to July, 1997, were collected. Additionally, the operator indicated that the quantity of water pumped by this booster was 11,994,040 gallons for the month of July, 1997. Information collected at the site is included in Appendix B.

Ex-Post Savings Methodology

Data collected at the site allowed us to calculate the kW demand at various speeds. Since the run time hours before and after the measure was installed are approximately the same, the hours run for both scenarios is assumed to be the same. The calculations in the attached table show the energy consumption for the pump operating at reduced speed and at full speed.

Assumptions for calculations with VSD

Assumptions of average motor demand were made for each month based on the total number of hours of operation for that month, which the Owner supplied. The combined hours are a sum of the hours for boosters 1 and 2. Booster 2 normally operates only to supplement booster 1 when necessary. Therefore, all hours totaling up to 24 hours per day are assumed to be booster 1 use. The following table shows the assumed average constant speed for each month based on the average number of hours per day the pump operated.

AVERAGE NUMBER OF HOURS PER DAY	ASSUMED PERCENT SPEED	ASSOCIATED SPEED (RPM)
23-24	95	1696
22	90	1606
21	85	1517
≤20	80	1428

The affinity laws for centrifugal pumps can be used to determine the kW demand based on the assumed speed. The following equation is used to calculate kW from percent speed:

$$kW_1/kW_2 = ((N_1/N_2)^3$$

The maximum kW measured during the site visit was 27.4 kW (kW_1) with the pump operating at 100% speed (1785 rpm, N_1). N_2 is the associated speed from the table above. The resulting kW for these speeds are shown in Table 5-1.

Assumptions for calculations with a constant speed pump

The calculations for comparison with a constant speed pump were made assuming the pump would operate at 100% of full speed. The pump that was replaced had a demand of 28.7 kW.

Using these assumptions, an approximation of actual energy used by booster 1 while on the VSD was calculated and is shown in Table 5-1. Also shown in this table is the calculated kW if the pump had not been replaced and was operating at full speed. The difference in these two figures is the estimated energy savings realized by the use of the VSD.

Since the hours run and the quantity of water pumped were available for July, 1997, a direct proportion was used to estimate the quantity of water pumped for the remaining months. This calculation does not take in to account the change in flow rate for the various speeds, however, it provides a reasonable estimate based on the estimated pump run hours for each month.

Summary of Calculated Savings

For the period from August 1996 to July 1997:

Estimated Energy Savings

CALCULATED CONSTANT SPEED		CALCULATED VSD		DIFFERENCE IN ENERGY USAGE	
kWh	kWh/ac-ft	kWh	kWh/ac-ft	kWh	kWh/ac-ft
238,841	561	190,933	468	47,908	113

Estimated Demand Savings

CONSTANT SPEED kW	VARIABLE SPEED kW	DIFFERENCE AVG kW
29	15-26	9

NOTE: The meter at the site records power use by lighting, control panels, and pumps that serve a different pressure zone, in addition to the new pump and motor. Estimated kWh and kW shown above are for the new pump and motor only.

From the attached calculations, the energy savings due to the VSD installation is estimated to be 47,908 kWh with a 113 kWh/ac-ft savings annually, and the average demand reduction is estimated to be 9 kW.

Description Of System Without Measure

Without the VSD, the pump would operate at a constant speed, regardless of the demand on the system. When pumps operate in this mode, they operate along a single pump curve. Typically, the design point of the pump is at a point on the curve where the pump is most efficient. When system demands fluctuate, the pump will move off the point of highest efficiency, decreasing the efficiency and thereby increasing energy demands. Since this pump serves to regulate pressure, it would likely be operating most of the time off its design point without the VSD.

Site No. 5

TABLE 5-1

	DATA FROM CUSTOMER				**CALCULATIONS**						
						W/ VSD		**W/O VSD**			
		RUN HOURS	EST. AC-FT/ MONTH	AVG. HOURS PER DAY	EST. PUMP SPEED					SAVINGS	SAVINGS
YEAR	MONTH					kW	kWh	kW	kWh	(kW)	(kWh)
1997	JULY	719	36.8	23.2	95	25.6	18395	28.7	20635	3	2240
	JUNE	544	27.8	18.1	80	15.3	8311	28.7	15613	13	7302
	MAY	743	38.0	24.0	95	25.6	19009	28.7	21324	3	2315
	APRIL	616	31.5	20.5	80	15.3	9411	28.7	17679	13	8268
	MAR	744	38.1	24.0	95	25.6	19035	28.7	21353	3	2318
	FEB	642	32.9	22.9	90	21.8	13966	28.7	18425	7	4460
	JAN	744	38.1	24.0	95	25.6	19035	28.7	21353	3	2318
1996	DEC	744	38.1	24.0	95	25.6	19035	28.7	21353	3	2318
	NOV*	682	34.9	22.7	90	21.8	14836	28.7	19573	7	4738
	OCT*	682	34.9	22.0	85	18.3	12498	28.7	19573	10	7075
	SEP	719	36.8	24.0	95	25.6	18395	28.7	20635	3	2240
	AUG	743	38.0	24.0	95	25.6	19009	28.7	21324	3	2315
ANNUAL TOTALS		8322	425.9	22.8			190933		238841		47908
kWh/ac-ft							448		561		

* Run hours data for these two months was averaged because installation of VSD caused booster 2 to operate more hours than would normally be expected.

Analysis for Site No. 6

Description Of Measure
Installation of new 150 hp pump and premium efficiency motor with a variable speed drive (VSD) and a new 75 hp pump and premium efficiency motor (without VSD) at a water booster station. Although this measure actually involves the installation of measures on 2 different pumps, the pumps operate at the same station and their operation is highly dependent on each other, therefore, these improvements are considered one measure.

System Description
The installation of the new pumps and motors and VSD was completed at this site in December, 1996. The new 150 hp pump and motor with VSD (pump 2) replaced an older constant speed 125 hp pump and motor. The new 75 hp pump and motor (pump 3) replaced an older 40 hp pump and motor. Additionally, there is a 200 hp constant speed pump and motor at this station (pump 1) that was not modified. The station control is set to maintain system pressure at 70 psi, and fill a storage reservoir. The number of pumps operating and the VSD speed varies as the system demand varies.

There is another booster station several miles away that also pumps water into this system, which affects the pumping operation of this booster station. When the other booster station is operating, the supply into the system increases, thereby reducing the pumping requirement of this station.

Pump 2, with the VSD, can operate efficiently through a range of flow rates, depending on the instantaneous demands. When the motor operates at a reduced speed, energy savings is achieved because of the reduced energy requirement to the motor. Additionally, the new motors have an efficiency of approximately 94%. Older motors typically have efficiencies ranging from 88-90%.

SCE Methodology and Findings

Review of 1996 ASD calculation:
- MARS version 2.2 run of December 12, 1996 used for original SCE ex ante calculations of ASD savings..

The MARS calculation did not adjust for the static water head pressure that the pump must overcome before water can start to flow.

Revised ASD calculation used these changes:
- Used pump curve data supplied by customer, dated October 12, 1995, for pump performance information.
- The base case was modified slightly by reallocation of low speed hours. All the MARS pumping hours for flows below 50% were added to the revised calculation 50% (50-59.9 % of full) category, based on the assumption that pump speeds and flows should not be below 50% of the pump design point.
- Used a water ASD calculation program that adjusts energy consumption to account for static water head pressure that the pump must overcome before water can start to flow. Static head was 102.3 feet.

Savings from 1996 Mars calculation = 290,653 kWh/year.
Savings from revised water ASD calculation = 117,651 kWh/year.
Reduction of 1996 Mars savings = 173,002 kWh/year.
Reduction of 1996 Mars savings, by percent = 60 %.

Annual average energy consumption per acre-foot of water used:
1996 base case = 172 kWh/AF
1996 ASD case = 70 kWh/AF

Revised base case = 191 kWh/AF
Revised ASD case = 150 kWh/AF

See Appendix F-6 for (1) October 1996 MARS run, (2) customer-supplied pump curve.

HDR Methodology and Findings

Data Collection and Sources

HDR staff visited the site on September 30, 1997. The purpose of the visit was to operate the pump with the VSD at various speeds and determine the kW loads at those speeds, and also check the kW demand and flows of the constant speed pumps. Additionally, information regarding the typical operation of the pumps was needed.

The VSD control was not set up so that the speed could be selectively changed in the field. Therefore, the speed of pump 2 was altered by manipulating the discharge pressure of the system. This was accomplished by turning on and off various combinations of pumps at this station and at the remote booster station, and by throttling, or partly closing, some of the discharge valves. These manipulations provided changes in system pressure which altered the pump speed from 100% to approximately 55% of full speed.

SCE pump test technicians were present and performed pump tests on pumps 2 and 3 during the site visit. Additional flow data for pump 1 was also collected at this time.

From discussions with the water system operator at the site, information on pumps run times and system operation was obtained. The operator indicated that the pumps sometimes run 24 hours per day (during agricultural growing season). Water pumping records for 1996 and 1997 (through September), and annual run hours for 1996, were obtained from the owner. Pump curves for all three pumps at this station were also obtained. Information collected at the site is in Appendix B.

Ex-Post Savings Methodology

The available data on water pumped before and after the measure were compared for differences in pumping demand. For the data collected in 1996 and 1997, the water demands before and after installation of the measure appear to be nearly equal, i.e., no significant change in water demands before and after installation of the measure.

The operator indicated that prior to the improvements, pump 1 and 2 operated approximately the same amount of the time. Run time hours for 1996 indicate the run time hours for pumps 1, 2, and 3 were 2563, 3082, and 1341, respectively. After installation of the measures, pump 2, with the VSD, became the lead pump. This is accounted for by the increase in hours for pump 2 in the calculations with the VSD shown in Table 6-1.

Assumptions for calculations with a constant speed pump

The attached Table 6-1 shows actual water pumped in terms of acre-feet. Based on the water pumped, pump capacities from previous pump tests, and the recorded annual run time hours, the monthly hours run for each pump were estimated. The difference in actual hours run and estimated hours run is due to variations in the field conditions over the pump test data. Using the estimated hours, and the kW demand from pump tests, kWh was calculated. Records of billing data were checked to verify that the calculated kWh was in the right magnitude. The calculated kWh was within 4% of the actual billed kWh. This is shown in Table 6-1 in the CONSTANT SPEED CALCULATIONS columns.

Assumptions for calculations with VSD

The calculations assume approximately the same water consumption before and after installation of the measures. Estimates of pump run times and speeds after the measure was installed are based on discussions with the operator. The kW demands for pump 2 are based on actual pump test values at various speeds and supplemented with calculated kW values from the following Affinity Law association.

$$(kW_1/kW_2) = ((N_1/N_2)^3)$$

Where:

kW_1/kW_2 = ratio of kiloWatt demand
N_1/N_2 = ratio of pump speed

The assumed values for the time the pump ran at a particular speed, and the calculated kW and gpm at that speed, are shown in Tables 6-2, 6-3 and 6-4, respectively.

Using these assumptions, and the above equation, approximations of energy usage before and after the measures were installed are shown in Table 6-1.

Summary of Calculated Savings

Because the horsepower of pumps 2 and 3 were increased when the measures were installed, an increase in energy demand occurred. The demand of pump 2 went from approximately 82 to a range between 61 and 122 kW. The demand of pump 3 went from approximately 29 to 54 kW. The demand of pump 1 stayed the same.

For the one year period through 1996 with a water requirement of 6798.5 acre-feet:

Estimated Energy Savings

CALCULATED CONSTANT SPEED		CALCULATED VSD		DIFFERENCE IN ENERGY USAGE	
kWh	kWh/ac-ft	kWh	kWh/ac-ft	kWh	kWh/ac-ft
761,274	112	652,249	96	109,025	16

Estimated Demand Savings

CONSTANT SPEED kW	VARIABLE SPEED kW	DIFFERENCE kW
288	236-332	0

From the attached calculations, the energy savings due to the VSD installation is estimated to be 109,025 kWh annually with a 16 kWh/ac-ft savings, and no demand reduction.

Description Of System Without Measure

Without the VSD, the 150 hp pump would operate at a constant speed, regardless of the demand on the system. When pumps operate in this mode, they operate along a single pump curve. Typically, the design point of the pump is at a point on the curve where the pump is most efficient. When system demands fluctuate, the pump will move off the point of highest efficiency, decreasing the efficiency and thereby increasing energy demands. Since this pump operates in conjunction with other pumping systems, it would likely be operating off its design point much of the time without the VSD. Additionally, the older motors that were in use prior to the measures would be burning additional energy due to their lower efficiencies.

SITE 6

TABLE 6-1

	ACTUAL DATA		CONSTANT SPEED CALCULATIONS			ACTUAL DATA		WITH VSD CALCULATIONS		
	1996	PUMP #1	PUMP #2	PUMP #3		1996	PUMP #1	PUMP #2	PUMP #3	
	ACRE-	RUN	RUN	RUN		ACRE-	RUN	RUN	RUN	
MONTH	FEET	HOURS	HOURS	HOURS	kWh	FEET	HOURS	HOURS	HOURS	kWh
JAN	0.0	0	0	0	0	0.0	0	0	0	0
FEB	0.0	0	0	0	0	0.0	0	0	0	0
MAR	0.0	0	0	0	0	0.0	0	0	0	0
APR	133.2	51	61	29	14915	133.2	23	74	74	12779
MAY	997.6	384	456	216	111708	997.6	175	557	555	95710
JUN	1104.6	425	505	239	123690	1104.6	193	617	615	105976
JUL	1325.8	510	606	287	148459	1325.8	232	740	738	127197
AUG	1392.6	536	637	302	155939	1392.6	244	778	775	133606
SEP	1122.0	432	513	243	125638	1122.0	196	627	624	107645
OCT	722.7	278	331	157	80926	722.7	126	404	402	69336
NOV	0.0	0	0	0	0	0.0	0	0	0	0
DEC	0.0	0	0	0	0	0.0	0	0	0	0
ANNUAL	**6798.5**	**2616**	**3109**	**1472**	**761274**	**6798.5**	**1189**	**3797**	**3783**	**652249**
ACTUAL HOURS		2563	3082	1341						
CALC ACRE-FEET		3663	2695	310	6668		1700	3739	1360	6799
BILLED kWh					767840					

CALCULATIONS		
AVG. ANNUAL AC-FT	AVG. ANNUAL kWh/A-F	AVG. ANNUAL kWh
CONSTANT SPEED		
6798.5	112.0	761274
WITH VSD		
6798.5	95.9	652249
DIFFERENCE		
0.0	**16.0**	**109025**

CONSANT SPEED*			WITH VSD*		
PUMP	GPM	kW	PUMP	GPM	kW
1	7762	166	1	7762	159
2	4750	90	2**	6770	122
3	1254	32	3	1952	51

* Based on data from pump tests, modified as necessary to reflect actual operating conditions.

** Full speed gpm and kW pumping alone, see attached tables.

SITE 6

TABLE 6-2
PERCENT OF TIME AT PERCENT SPEED

PUMP	HP	PERCENT SPEED 60	70	80	90	100	SUM
1	200					100	100
2	150	10	15	25	25	20	95
3	75					100	100

TABLE 6-3
kW AT PERCENT SPEED

PUMP	HP	kW @ 100%	PERCENT SPEED 60	70	80	90	100
1	200	159.0					159.0
2	150	122.0	26.4	41.8	62.5	88.9	122.0
3	75	51.0					51.0

TABLE 6-4
GPM AT PERCENT SPEED

PUMP	(ALONE) GPM @ 100%	PERCENT SPEED 60	70	80	90	100	AVG
1	8170					7762	
2	6770	4062	4739	5416	6093	6770	5348
3	2055					1952	

Analysis for Site No. 7

Description Of Measure
Installation of variable speed drive (VSD) on a 150 HP well pump.

System Description
Construction of a VSD on this well was completed in June, 1996. The existing pump and motor were not changed. The pump control is set to maintain the system pressure at 77 psi. There is no elevated storage in this system. The pump flow rate varies as the motor speed varies to provide the quantity of water required for service to this zone. There are 6 wells that serve this system. Generally, 3-4 wells operate at any one time. When this well is off, the system pressure drops to approximately 65 psi.

Before the VSD was installed. the system was a remote on/off control based on an observed pressure in the system. The system pressure would fluctuate and the flow rate would vary, depending on the water use and supply from other operating wells. Based on the system pressure while the pump is off, it appears that the system pressure at that time was approximately 65 psi.

When the VSD was added, and the new control system installed, the pumping system operation was also changed. The new control is a local pressure sensor, which regulates the pump speed to maintain the system at 77 psi.

The flow rate observed while at the site was approximately 700 gpm at 77 psi. The original design point of this pump was 1500 gpm at 308 TDH (about 92 psi discharge pressure). The great difference in the design point, as compared to the actual field conditions observed, indicate that this pump has deteriorated dramatically.

SCE Methodology and Findings

Review of 1996 ASD calculation:
- MARS version 2.1 run of July 18, 1996 used for Edison's orginal ex ante ASD savings calculation.
- The MARS calculation did not adjust for the static water head pressure that the pump must overcome before water can start to flow.

Revised ASD calculation used these changes:
- Used Edison April 17, 1995 pump test data.
- Used pump curve data supplied by customer to find shut off head above normal operating point (158%) and that pump efficiency drops by 15% at 50% flow.
- The base case was modified slightly by reallocation of low speed hours. All the MARS pumping hours for flows below 50% were added to the revised calculation 50% (50-59% of full) category, based on the assumption that pump speeds and flows should not be below 50% of the pump design point.
- Used a water ASD calculation program that adjusts energy consumption to account for static water head pressure that the pump must overcome before water can start to flow. Static head was 287 feet.

Savings from 1996 Mars calculation = 278,070 kWh/year.
Savings from revised water ASD calculation = 50,175 kWh/year.
Reduction of 1996 Mars savings = 227,895 kWh/year.
Reduction of 1996 Mars savings, by percent = 82 %.

Annual average energy consumption per acre-foot of water used:
1996 base case = 603 kWh/AF
1996 ASD case = 191 kWh/AF

Revised base case = 576 kWh/AF
Revised ASD case = 541 kWh/AF

See Appendix F-7 for (1) July 1996 MARS output, (2) April 1995 pump test data, (3) customer-supplied pump curve.

HDR Methodology and Findings

Data Collection and Sources
HDR staff visited the well site on September 8, 1997. The purpose of the visit was to operate the well pump at various speeds and determine the kW loads at those speeds. Additional information regarding the typical operation of the pump was needed to estimate the amount of time the pump normally operates at reduced speeds.

During the site visit, the pump was operated at various speeds from 100% to 90% of full speed.

From discussions with the water system operator at the site, information on pump run times, seasonal water demand variations and water quantity pumped was obtained. The operator indicated that the pump runs approximately 24 hours per day. Information collected at the site is included in Appendix B.

Ex-Post Savings Methodology
With the VSD, the pump should operate efficiently through a range of flow rates, based on the instantaneous demands. When the motor operates at a reduced speed, energy savings is achieved because of the reduced energy requirement to the motor.

Because the pump is operating so far off of its design point, based on deterioration of the flow rate and the increased system pressure, the pump is operating very inefficiently. The SCE pump test technician calculated an efficiency at full speed of only 26%. Since the addition of the VSD was concurrent with the new pump control, which made the pump operate even farther off of is normal curve, the pump is actually using more energy than before the measure was implemented.

Pumping quantities were not available, so billing records were used to approximate water use. The number of hours the pump operated before the measure was installed to meet the water pumping requirements is estimated by the monthly full load hours (FLH), as provided on the billing worksheets. Based on the pump test data, the pump is normally operating at full load (actually it is operating higher than its full load of 112 kW). We have therefore assumed that it is operating constantly at full speed.

The water use calculations are as follows:

Full Load Hours (FLH) = kWh (from billing) / MAX kW (from billing)

Gallons pumped = flow (from pump test) X 60 (min/hour) X FLH

For example, the water use for May 1997 is:

FLH = 36880 kWh / 122 kW = 302 hours

Gallons pumped = 700 gpm X 60 X 302 = 12,696,393 gallons.

For the calculations shown in Table 7-1, the 700 gpm figure was used because this is actual data measured after the measure was installed. The kWh for before and after the measure was installed are then found using the appropriate gpm.

$$kWh = \frac{(kW)\ (gallons\ pumped)}{(gpm)\ (60\ min/hour)}$$

kW is taken from the respective pump test data. The difference between the kW and kWh with and without the VSD are the energy and demand savings.

Summary of Calculated Savings

For the period from June 1996 to May 1997:

Estimated Energy Savings

CALCULATED CONSTANT SPEED		CALCULATED VSD		DIFFERENCE IN ENERGY USAGE	
kWh	kWh/ac-ft	kWh	kWh/ac-ft	kWh	kWh/ac-ft
186,183	502	342,708	923	-156,525	-421

Estimated Demand Reduction

CALCULATED CONSTANT SPEED kW	CALCULATED WITH VSD kW	DIFFERENCE kW
117-125	119	-2 - 6

From the attached calculations, the ADDITIONAL energy spent due to the change in controls is estimated to be 156,525 kWh annually, with a 421 kWh/ac-ft increase, and a change in demand in the range of -2 to 6 kW.

Description Of System Without Measure

The addition of the VSD and the change in controls required that the pump also be modified to meet the new system requirements. The pump, and possibly the well, had already deteriorated dramatically, as indicated by the reduced capacity prior to the implementation of the measure. Therefore, the well and pump also required rehabilitation anyway. The system will continue to deteriorate and use an increasing amount of energy until the pump is repaired and modified to meet the new system design requirements.

NOTE: The installation of the VSD was not the direct cause of increase in energy usage. The change in the system operating pressure, the change in the system controls, and the deterioration of the pump (and well) are responsible for the increase energy use.

Site 7

TABLE 7-1														
DATA FROM BILLING WORKSHEETS					CALCULATIONS									
							CONSTANT SPEED			WITH VSD				
			kWh	FULL									SAVINGS	SAVINGS
		MAX	FROM	LOAD	GALLONS		FLOW	kW	CALC	FLOW	kW	CALC		
YEAR	MONTH	KW	BILLING	HOURS	PUMPED	AC-FT	gpm		kWh	gpm		kWh	(kW)	(kWh)
1997	MAY	122	36880	302	12,696,393	39	1304	117	18986	700	119	35973	-2.0	-16987
	APRIL	122	37000	303	12,737,705	39	1304	117	19048	700	119	36090	-2.0	-17042
	MAR	122	34600	284	11,911,475	37	1304	122	18574	700	119	33749	3.0	-15176
	FEB	123	17080	139	5,832,195	18	1304	123	9169	700	119	16525	4.0	-7356
	JAN	123	10800	88	3,687,805	11	1304	123	5798	700	119	10449	4.0	-4651
1996	DEC	123	28520	232	9,738,537	30	1304	123	15310	700	119	27593	4.0	-12283
	NOV	124	27390	221	9,277,258	28	1304	124	14703	700	119	26286	5.0	-11582
	OCT	119	28050	236	9,900,000	30	1304	119	15058	700	119	28050	0.0	-12992
	SEP	119	30900	260	10,905,882	33	1304	119	16587	700	119	30900	0.0	-14313
	AUG	120	31020	259	10,857,000	33	1304	120	16652	700	119	30762	1.0	-14110
	JULY	119	40800	343	14,400,000	44	1304	119	21902	700	119	40800	0.0	-18898
	JUNE	125	26820	215	9,011,520	28	1304	125	14397	700	119	25533	6.0	-11135
TOTALS (Annual Savings)			349860		120,955,771	371			186183			342708		-156525
kWh/ac-ft									502			923		

Analysis for Site No. 8-1

Description Of Measure
Installation of variable speed drive (VSD) on 350 HP well pump motor.

System Description
Construction of this well (a new water well) was completed in May 1996. The pump was installed with a 350 HP VSD and premium efficiency motor. The pump control is set up to maintain the water distribution system pressure at 70 psi. The pump flow rate varies as the motor speed varies, to provide a constant pressure discharge to the system. With the VSD, the pump can operate efficiently through a range of flow rates, based on the instantaneous demands. When the motor operates at a reduced speed, energy savings is achieved because of the reduced energy requirement to the motor.

SCE Methodology and Findings

Review of 1996 ASD calculation:

- MARS version 2.1 run of May 16, 1996 used for original SCE ex ante ASD savings calculations.
- The MARS calculation did not adjust for the static water head pressure that the pump must overcome before water can start to flow.

Revised ASD calculation used these changes:

- Used Edison August 13, 1996 pump test results for input for two test points.
- The base case was modified slightly by reallocation of low speed hours. All the MARS pumping hours for flows below 50% were added to the revised calculation 50% (50-59.9% of full) category, based on the assumption that pump speeds and flows should not be below 50% of the pump design point.
- Used a water ASD calculation program that adjusts energy consumption to account for static water head pressure that the pump must overcome before water can start to flow. Static head was 339.7 feet.

Savings from 1996 Mars calculation =	793,885 kWh/year.
Savings from revised water ASD calculation =	196,406 kWh/year.
Reduction of 1996 Mars savings =	597,479 kWh/year.
Reduction of 1996 Mars savings, by percent =	75 %.

Annual average energy consumption per acre-foot of water used:
1996 base case = 688 kWh/AF
1996 ASD case = 343 kWh/AF
Revised base case = 647 kWh/AF
Revised ASD case = 562 kWh/AF

See Appendix F-8 for (1) August 1996 pump test data, (2) May 1996 MARS run.

HDR Methodology and Findings

Data Collection and Sources
HDR staff visited the well site on July 17, 1997. The purpose of the visit was to operate the well pump at various speeds and determine the kW loads at those speeds. Additionally, information regarding the typical operation of the pump was needed. This information is used to estimate the amount of time the pump normally operates at reduced speeds, and what are the typical reduced speeds.

The pump was operated at various speeds from 100% of full speed to pump shutdown at approximately 77% of full speed. The control panels at the site provided readings of percent of motor speed, frequency (hertz), amps, and flow rate (cfs).

The operations staff at the site indicated that the pump was not fully operational until July/August of 1996. Information on pump run times, speeds, seasonal water demand variations and water quantity pumped was obtained from discussions with the water system operator at the site. Additional information regarding monthly run times, total quantity pumped and water levels was obtained from the water production supervisor on August 1, 1997. Information collected at the site is included in Appendix B.

Data supplied from Edison consisted of pump tests and billing worksheets.

Ex-Post Savings Methodology
Data collected at the site allowed us to calculate the kW demand at various speeds using the equation:

$$kW = \frac{A \times V \times (3)^{1/2} \times PF}{1000}$$

Where A = amperes
V = voltage
PF = power factor
kW = kilowatts

The power factor was calculated using previous Edison pump tests and has a value of 0.89. The voltage of the system is 480.

Historical billing data was used to assist in estimating the pump operation. Several assumptions were also made to estimate the actual energy savings. These assumptions are based on the information available, and typical water system operation.

Assumptions for calculations with VSD
Assumptions of average pump speed (APS) were made over one billing period based on the full load hours (FLH) for that period. The FLH is actually the total kWh metered through a billing period divided by the maximum kW metered for that same period. The FLH is a good estimate of the number of hours the pump would have run at *full speed* during that billing period, and is given on the Edison billing worksheets. For example, a FLH of 24 hours means that the pump ran at 100% speed 24 hours per day during that billing period. With a VSD, actual pump run hours are normally higher than the FLH because the pump periodically operates at less than the maximum kW.

The following are the assumed hours run and APS based on FLH:

FLH PER DAY	HOURS AT APS	APS
>22	24	100%
22-21	24	95%
20-18	23	90%
17-15	22	85%
14-12	20	85%
11-6	16	80%
<6	8	80%

Note: This pump's shut off point for zero flow is at 77% of full speed.

Assumptions for calculations with a constant speed pump.
The estimates for the number of hours the pump would have operated at constant speed (without a VSD) to meet the water pumping requirements are based on the FLH. The number of hours the pump needs to run at full speed is less than the number of hours it would need to run at reduced speeds (higher speed equals more water pumped). However, some of the operation of the pump is for pressure maintenance in the water system. We assumed an increase of pump run time of 10% for pressure maintenance. The following is an estimate of hours per day a constant speed pump would have operated for this system.

BILLING PERIOD	FLH PER DAY	CONSTANT SPEED HOURS
Jan '97	16.9	18.6
Feb	5.3	5.9
Mar	11.8	13.0
Apr	21.0	23.1
May	21.4	23.5
Jun '96	N/A	22.0
Jul	N/A	23.0
Aug	N/A	23.0
Sep	27.2	29.9
Oct	21.7	23.8
Nov	21.0	23.1
Dec	19.1	21.0

June, July, and August hours were assumed to be 22, 23, and 23 hours, respectively, based on typical mid-summer demands. This was done because the actual pump hours were low since the pump was new and not yet in full operation.

It should be noted that the City supplements its well water supply with treated water from Metropolitan Water District (MWD), who offers reduced water rates during wet weather and low use periods. Reviewing the billing worksheet, it appears that February and March were very low flow periods. This is reflected in the reduced number of run time hours and speeds for those periods.

Using these assumptions, and the equation above, an approximation of actual energy used was calculated and is shown in Table 9-1. Also shown in this table is the calculated kW if the pump had operated at full speed to meet the water demands and to maintain system pressure. The difference in these two figures is the estimated energy savings realized by the use of the VSD.

Summary of Calculated Savings
For the period from June 1996 to May 1997:

Estimated Energy Savings

CALCULATED CONSTANT SPEED		CALCULATED VSD		DIFFERENCE IN ENERGY USAGE	
kWh	kWh/ac-ft	kWh	kWh/ac-ft	kWh	kWh/ac-ft
1,747,308	446	1,615,491	412	131,817	34

Estimated Demand Reduction

ESTIMATED CONSTANT SPEED kW	ESTIMATED VSD kW	ESTIMATED AVERAGE SAVINGS kW
225	141 - 229	29

From the attached calculations, the energy savings due to the VSD installation is estimated to be 131,817 kWh, annually, with a 34 kWh/ac-ft savings and an average of 29 kW,.

Description Of System Without Measure

Without the VSD, the pump would operate at a constant speed, regardless of the demand on the system. When pumps operate in this mode, they operate along a single pump curve. Typically, the design point of the pump is at a point on the curve where the pump is most efficient. When system demands fluctuate, the pump will move off the point of highest efficiency, decreasing the efficiency and thereby increasing energy demands.

SITE 8-1

TABLE 8-1															
DATA FROM BILLING WORKSHEETS							CALCULATIONS			CALCULATIONS					
			FULL		kWh		CONSTANT SPEED			VSD				SAVINGS	SAVINGS
			LOAD	MAX	FROM	FLH/		HRS/		HRS/	AVG %				
YEAR	MONTH	DAYS	HOURS	kW	BILLING	DAY	AC-FT	DAY	kWh	DAY	SPEED	kW	kWh	(kW)	(kWh)
1997	MAY	28	598	226	135180	21.4	332.5	23.5	148663	24.0	95	207	139222	19	9441
	APRIL	28	588	224	131880	21.0	326.9	23.1	144883	24.0	95	207	139222	17	5662
	MAR*	33	389	214	83400	11.8	216.3	13.0	91571	16.0	80	141	74228	73	17343
	FEB*	27	144	223	31980	5.3	80.1	5.9	35323	8.0	80	141	30366	82	4957
	JAN	31	523	223	116520	16.9	290.8	18.6	128292	22.0	85	163	111016	60	17276
1996	DEC	32	612	225	137700	19.1	340.2	21.0	151470	23.0	90	185	136144	40	15326
	NOV	30	617	226	139620	21.0	350.3	23.1	156618	24.0	95	207	149166	19	7452
	OCT	30	650	227	147900	21.7	361.4	23.8	162305	24.0	95	207	149166	20	13139
	SEP**	33	896	228	204300	27.2	498.1	29.9	224717	28.0	100	229	211940	-1	12777
	AUG***	28	428	227	135180	23.0	358.0	25.3	160807	24.0	100	229	154138	-2	6669
	JULY***	33	504	227	159319	23.0	422.0	25.3	189522	24.0	100	229	181663	-2	7859
	JUNE***	28	35	226	144836	22.0	342.5	24.2	153138	24.0	95	207	139222	19	13916
ANNUAL TOTALS				225	1567815		3919		1747308				1615491	29	131817
									446	kwh/ac-ft			412	kwh/ac-ft	
* MWD supplements wells.															
** FLH hours are over 24 hrs per day, it is assumed that an									Numbers used for calculations:						
error in the meter reading was made.									AVG % SPEED		100	95	90	85	80
*** Pump was not in full operation; FLH assumed.									AMPS		310	280	250	220	190

Analysis for Site No. 8-2

Description Of Measure
Installation of variable speed drive (VSD) on 350 HP well pump motor.

System Description
Construction of this well (a new water well) was completed in May 1996. The pump was installed with a 350 HP VSD and premium efficiency motor. The pump control is set up to maintain the water distribution system pressure at 70 psi. The pump flow rate varies as the motor speed varies, to provide a constant pressure discharge to the system. With the VSD, the pump can operate efficiently through a range of flow rates, based on the instantaneous demands. When the motor operates at a reduced speed, energy savings is achieved because of the reduced energy requirement to the motor.

SCE Methodology and Findings

Review of 1996 ASD calculation:

- MARS version 2.1 run of May 16, 1996 used for original SCE ex ante ASD savings calculations.
- The MARS calculation did not adjust for the static water head pressure that the pump must overcome before water can start to flow.

Revised ASD calculation used these changes:
- Used the August 13, 1996 pump test results for input for two test points.
- The base case was modified slightly by reallocation of low speed hours. All the MARS pumping hours for flows below 50% were added to the revised calculation 50% (50-59.9% of full) category, based on the assumption that pump speeds and flows should not be below 50% of the pump design point.
- Used water ASD calculation program that adjust energy consumption to account for static water head pressure that the pump must overcome before water can start to flow. Static head was 344.0 feet.

Savings from 1996 Mars calculation = 793,885 kWh/year.
Savings from revised water ASD calculation = 278,272 kWh/year.
Reduction of 1996 Mars savings = 515,613 kWh/year.
Reduction of 1996 Mars savings, by percent = 65 %.

Annual average energy consumption per acre-foot of water used:
1996 base case = 655 kWh/AF
1996 ASD case = 327 kWh/AF
Revised base case = 662 kWh/AF
Revised ASD case = 547 kWh/AF

See Appendix F-8 for (1) August 1996 pump test data, (2) May 1996 MARS run.

HDR Methodology and Findings

Data Collection and Sources
HDR staff visited the well site on July 17, 1997. The purpose of the visit was to operate the well pump at various speeds and determine the kW loads at those speeds. Additionally, information regarding the typical operation of the pump was needed. This information is used to estimate the amount of time the pump normally operates at reduced speeds, and what are the typical reduced speeds.

The pump was operated at various speeds from 100% of full speed to pump shutdown at approximately 77% of full speed. The control panels at the site provided readings of percent of motor speed, frequency (hertz), amps, and flow rate (cfs).

The operations staff at the site indicated that the pump was not fully operational until July/August of 1996. Information on pump run times, speeds, seasonal water demand variations and water quantity pumped was obtained from discussions with the water system operator at the site. Additional information regarding monthly run times, total quantity pumped and water levels was obtained from the water production supervisor on August 1, 1997. Information collected at the site in included in Appendix B.

Data supplied from Edison consisted of pump tests and billing worksheets.

Ex-Post Savings Methodology
Data collected at the site allowed us to calculate the kW demand at various speeds. The equation used was:

$$kW = \frac{A \times V \times (3)^{1/2} \times PF}{1000}$$

Where A = amperes
V = voltage
PF = power factor
kW = kilowatts

The power factor was calculated using previous Edison pump tests and has a value of 0.93. The voltage of the system is 480.

Historical billing data was used to assist in estimating the pump operation. Several assumptions were also made to estimate the actual energy savings. These assumptions are based on the information available, and typical water system operation.

Assumptions for calculations with VSD
Assumptions of average pump speed (APS) were made over one billing period based on the full load hours (FLH) for that period. The FLH is actually the total kWh metered through a billing period divided by the maximum kW metered for that same period. The FLH is a good estimate of the number of hours the pump would have run at *full speed* during that billing period, and is given on the Edison billing worksheets. For example, a FLH of 24 hours means that the pump ran at 100% speed 24 hours per day during that billing period. With a VSD, actual pump run hours are normally higher than the FLH because the pump periodically operates at less than the maximum kW.

The following are the assumed hours run and APS based on FLH:

FLH PER DAY	HOURS AT APS	APS
>=23	24	100%
22-21	24	95%
20-19	23	90%
18-17	22	90%
16-15	20	85%
14-11	17	85%
10-6	12	80%
<=5	FLH x 1.5	80%

Note: This pump shut off for zero flow is 77% of full speed.

Assumptions for calculations with a constant speed pump.
The estimates for the number of hours the pump would have operated at constant speed (without a VSD) to meet the water pumping requirements are based on the FLH. The number of hours the pump needs to run at full speed is less than the number of hours it would need to run at reduced speeds (higher speed equals more water pumped). However, some of the operation of the pump is for pressure maintenance in the water system. We assumed an increase of pump run time of 10% for pressure maintenance. The following is an estimate of hours per day a constant speed pump would have operated for this system.

BILLING MONTH	FLH PER DAY	CONSTANT SPEED HOURS
Jan '97	12.0	13.2
Feb	15.4	17.0
Mar	4.5	5.0
Apr	0.2	0.2
May	2.2	2.4
Jun '96	N/A	19.7
Jul	17.9	19.7
Aug	22.5	24.8
Sep	22.6	24.8
Oct	19.1	21.1
Nov	21.0	23.1
Dec	15.2	16.8

June hours were assumed to be 19.7 hours based on July hours. This was done because the actual pump hours were low since the pump was new and not yet in full operation.

It should be noted that the City supplements its well water supply with treated water from Metropolitan Water District (MWD), who offer reduced water rates during wet weather and low use periods. Reviewing the billing worksheet, it appears that March, April and May were very low flow periods. This is reflected in the reduced number of run time hours and speeds for those periods.

Using these assumptions, and the equation above, an approximation of actual energy used was calculated and is shown in Table 1. Also shown in this table is the calculated kW if the pump had operated at full speed to meet the water demands and to maintain system pressure. The difference in these two figures is the estimated energy savings realized by the use of the VSD.

Summary of Calculated Savings
For the period from June 1996 to May 1997:

Estimated Energy Savings

CALCULATED CONSTANT SPEED		CALCULATED VSD		DIFFERENCE IN ENERGY USAGE	
kWh	kWh/ac-ft	kWh	kWh/ac-ft	kWh	kWh/ac-ft
1,393,556	482	1,254,089	434	139,467	48

Estimated Demand Reduction

ESTIMATED CONSTANT SPEED kW	ESTIMATED VSD kW	ESTIMATED AVERAGE SAVINGS kW
238	155 - 224	48

From the attached calculations, the energy savings due to the VSD installation is estimated to be 139,467 kWh annually, with 48 kWh/ac-ft savings and an average of 48 kW,

Description Of System Without Measure

Without the VSD, the pump would operate at a constant speed, regardless of the demand on the system. When pumps operate in this mode, they operate along a single pump curve. Typically, the design point of the pump is at a point on the curve where the pump is most efficient. When system demands fluctuate, the pump will move off the point of highest efficiency, decreasing the efficiency and thereby increasing energy demands.

SITE 8-2

TABLE 9-2															
DATA FROM BILLING WORKSHEETS							CALCULATIONS			CALCULATIONS					
			FULL		kWh		CONSTANT SPEED			VSD				SAVINGS	SAVINGS
			LOAD	MAX	FROM	FLH/		HRS/		HRS/	AVG				
YEAR	MONTH	DAYS	HOURS	kW	BILLING	DAY	AC-FT	DAY	kWh	DAY	SPEED	kW	kWh	(kW)	(kWh)
1997	MAY*	28	61	245	14880	2.2	33.9	2.4	16440	3.3	80	155	14288	90	2151
	APRIL*	30	5	173	840	0.2	2.8	0.2	952	0.3	80	155	1392	18	-440
	MAR*	28	126	241	30480	4.5	70.1	5.0	33403	7.0	80	155	30308	86	3095
	FEB	30	463	241	111720	15.4	257.4	17.0	122741	20.0	85	178	106697	63	16045
	JAN	32	383	241	92400	12.0	212.9	13.2	101533	17.0	85	178	96738	63	4795
1996	DEC	30	457	241	110160	15.2	254.1	16.8	121151	20.0	85	178	106697	63	14454
	NOV	32	595	242	144120	21.0	373.6	23.1	178886	24.0	95	224	172199	18	6687
	OCT	29	555	246	136440	19.1	308.6	21.1	150183	23.0	90	201	134082	45	16101
	SEP	31	700	246	172320	22.6	389.2	24.8	189420	24.0	95	224	166818	22	22602
	AUG	28	631	245	154440	22.5	350.8	24.8	170055	24.0	95	224	150674	21	19380
	JULY	32	573	245	140280	17.9	318.6	19.7	154424	22.0	90	201	141520	44	12903
	JUNE**	32	47	245	142080	17.9	318.5	19.7	154370	22.0	90	201	132675	44	21695
				238	1250160		2890		1393556				1254089	48	139467
									482	kwh/ac-ft			434	kwh/ac-ft	
* MWD supplements wells.									Numbers used for calculations:						
** Pump was not in full operation.									AVG % SPEED		100	95	90	85	80
									AMPS		320	290	260	230	200

SECTION 5 - HVAC MEASURES

5.1 INTRODUCTION

Edison retained an independent engineering firm (ASW Engineers) to conduct measure installation verification and evaluation of gross ex-post load impacts of three HVAC measures installed at a customer facility. Table A summarizes the measures described in detail in this section.

TABLE A

HVAC MEASURE DESCRIPTIONS

MEASURE NO.	MEASURE DESCRIPTION
1	Install VSDs on 2- 50 Hp chilled water pumps, change operating hours
2	Install VSDs on 2-25 Hp cooling tower fans, change operating hours
3	Reduction in operating hours of 4- 100 Hp supply air fans

5.2 ANALYSIS FOR HVAC MEASURE 1

Description of Measure and System

In 1996, the chilled water system was modified by adding VSDs to 2-50 hp pumps. After installation of the VSDs, the system was further modified from a primary loop with 3-way valves to a primary/secondary system with 2-way valves. Now only one 50 hp pump operates, the other pump is a standby. Two 15 hp pumps have been added for the primary loop.

Estimated Energy Savings

ESTIMATED CONSTANT SPEED kWh	ESTIMATED VSD kWh	ESTIMATED SAVINGS kWh
210,681	80,920	129,761

Estimated Demand Reduction

ESTIMATED CONSTANT SPEED kW	ESTIMATED VSD kW	ESTIMATED SAVINGS kWh
73	53	20

5.3 ANALYSIS FOR HVAC MEASURE 2

Description of Measure and System

In 1996, the cooling tower fans were modified by adding VSDs to 2-25 hp fans. Additionally, operating hours were changed. No demand savings were realized.

Estimated Energy Savings

ESTIMATED CONSTANT SPEED kWh	ESTIMATED VSD kWh	ESTIMATED SAVINGS kWh
95,700	28,764	66,936

5.4 ANALYSIS FOR HVAC MEASURE 3

Description of Measure and System

In 1996, the hours of operation were reduced from 416.6 hours per month to 240 hours per month. No demand savings were realized.

ESTIMATED CONSTANT SPEED kWh	ESTIMATED VSD kWh	ESTIMATED SAVINGS kWh
742,435	223,140	519,295

APPENDIX E

Tables 6 and 7 of Protocols

Table 6 A: 1996 AEEI Program Energy Impacts

	Point Estimate	Item 5[1] 90% confid interval	80% confid interval	Reference
Item 1: Average Participant Group and Average Comparison Group[2] Usage				
Participant Group Pumping[3] End Use				
A1. Pre-installation UEC	940,047	N/A	N/A	Load Impact Study
A2. Base UEC	940,047	N/A	N/A	Load Impact Study
A3. Base UEC/DUOM(acre-ft)	370	N/A	N/A	Load Impact Study
Participant Group Pumping[3]				
B1. Impact Year UEC	766,697	N/A	N/A	Load Impact Study
B2. Impact Year UEC/DUOM(acre-ft)	297	N/A	N/A	Load Impact Study
Item 2: Average Net and Gross End Use Load Impacts for the Impact Year				
A. Load Impacts				
SCE Total Program Gross Impact (MWh)[5]	4,737	N/A	N/A	SCE Table C filing
a. Pumping	3,678			
b. HVAC	1,026			
SCE Total Program Net Impact (MWh)[3]	4,216	N/A	N/A	SCE Table C filing
a. Pumping	3,274			
b. HVAC	913			
Ex post Total Program Gross Impacts (MWh)	2,136	N/A	N/A	Load Impact Study
a. Pumping	1,387			
b. HVAC	716			
Ex post Total Program Net Load Impacts (MWh)	1,599	N/A	N/A	Load Impact Study
a. Pumping	1,040			
b. HVAC	537			

[1] Not applicable because this study was based on attempted census.

[2] No Comparison Group was used in this study.

[3] UEC for HVAC end use was not estimated in the study.

[4] SCE load impact estimates are taken from SCE's earnings claim.

Table 6 A: 1996 AEEI Program Energy Impacts (continued)

[illegible]	Point Estimate	Item 5: 90% confid interval	Item 5: 80% confid interval	Reference
B. Load Impacts Per Designated Unit of Measurement (DUOM) [6]				
SCE Gross Load Impact		N/A	N/A	SCE Table C filing
a. Pumping (kWh/acre-foot)	500			
b. HVAC (kWh/sq.ft)	0.444			
SCE Net Load Impact		N/A	N/A	SCE Table C filing
a. Pumping (kWh/acre-foot)	445			
b. HVAC (kWh/sq.ft)	0.395			
Ex post Gross Load Impacts		N/A	N/A	Load Impact Study
a. Pumping (kWh/acre-foot)	67			
b. HVAC (kWh/sq.ft)	3.1			
Ex post Net Load Impacts		N/A	N/A	Load Impact Study
a. Pumping (kWh/acre-foot)	50.25			
b. HVAC (kWh/sq.ft)	2.32			
C. Percent Change in Usage of the Participant Group and Comparison Group[2]				
% change in UEC relative to base UEC for Participants[2] 18.4%				
D. Net and Gross Impact Realization Rates				
Gross Impact Realization Rate, Total Program Savings	0.45	N/A	N/A	Study Gross Impact / Claimed Gross Savings
Gross Impact Realization Rate, Savings per DUOM		N/A	N/A	Study Gross Impact / Claimed Gross Savings
a. Pumping (acre-ft.)	0.14			
b. HVAC (sq.ft.)	6.9			
Net Impact Realization Rate, Total Program Savings	0.38	N/A	N/A	Study Net Impact / Claimed Net Savings
Net Impact Realization Rate, Savings per DUOM		N/A	N/A	Study Net / Claimed Net Savings
a. Pumping (acre-ft)	0.11			
b. HVAC (sq.ft.)	5.8			

[6] DUOM for pumping is load impact per acre-foot of water pumped. DUOM for HVAC is load impact per square-foot of conditioned space.

Table 6 A: 1996 AEEI Program Energy Impacts (continued)

		Item 5:		
	Point Estimate	90% confid interval	80% confid interval	Reference
Item 3: Net-to-Gross Ratios[7]				
A. Net-to-Gross Ratios based on Program Load Impacts	0.75	N/A	N/A	Appendix A
B. Net-to-Gross Ratios based on Average Load Impacts per DUOM	0.75	N/A	N/A	Appendix A
Item 4: Designated Unit Intermediate Data (DUI)				
a. Pumping Pre-installation average participant acre-feet = 2,541 Post-installation average participant acre-feet = 2,578 **b. HVAC [8]** Pre-installation average participant operating hours (5,000 hrs/yr) Post-installation average participant operating hours (2,890 hrs/yr)				
Item 6: Measure Count Data				
A. No. of measures installed by Participants in the Participant Group[9] = 16 **B.** No. of measures installed by all program participants in the 12 months of the program year=18[8] **C.** No. of measures installed by comparison group N/A				

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[7] Net-to-Gross ratio presented here is agreed on ratio per approved Retroactive Waiver Request in Appendix A.
[8] Only one participant for HVAC end uses.
[9] This Participant Group excludes one customer (2 process measures) from the total number of program participants per Approved Waiver Request in Appendix A.
[8] Includes two process measures not studied in the study per approved Retroactive Waiver Request in Appendix A

Table 6 B: 1996 AEEI Program Demand Impacts

		Item 5:		
	Point Estimate	90% confid interval	80% confid interval	Reference
Item 2: Average Net and Gross End Use Load Impacts for the Impact Year				
A. Load Impacts				
SCE Total Program Gross Impact (MW)	.01	N/A	N/A	SCE Table C filing
a. Pumping	.00			
b. HVAC	.00			
SCE Total Program Net Impact (MW)	.01	N/A	N/A	SCE Table C filing
a. Pumping	.00			
b. HVAC	.00			
Ex post Total Program Gross Impacts (MW)	0.426	N/A	N/A	Load Impact Study
a. Pumping	.37			
b. HVAC	.053			
Ex post Total Program Net Load Impacts (MW)	0.32	N/A	N/A	Load Impact Study
a. Pumping	0.28			
b. HVAC	0.04			
B. Load Impacts Per Designated Unit				
SCE Gross Impact per DUOM		N/A	N/A	SCE Table C filing
a. Pumping (kW/acre-ft.)	.00			
b. HVAC (kW/sq.ft.)	.00			
SCE Net Impact per DUOM		N/A	N/A	SCE Table C filing
a. Pumping (kW/acre-ft.)	.00			
b. HVAC (kW/sq.ft.)	.00			
Ex post Gross Load Impacts per DUOM[9]		N/A	N/A	
a. Pumping (kW/acre-ft.)	.00			
b. HVAC (kW/sq.ft.)	.00			
Estimated Net Load Impacts per DUOM		N/A	N/A	
a. Pumping (kW/acre-ft.)	.00			
b. HVAC (kW/sq.ft.)	.00			
C. Percent Change in Usage of the Participant Group and Comparison Group				
Not applicable.				
D. Net and Gross Impact Realization Rates				

[9] The study did not produce kW/DUOM load impacts

Table 6 B: 1995 AEEI Program Demand Impacts (continued)

	Point Estimate	Item 5: 90% confid interval	80% confid interval	Reference
Gross Impact Realization Rates				
Study Gross Impact Realization Rate, Total Program Savings	42.3	N/A	N/A	Gross Impact/ Filed Gross Savings
Study Gross Impact Realization Rate, Savings per DUOM	N/A	N/A	N/A	
a. Pumping (acre-ft.)				
b. HVAC (sq.ft.)				
Net Impact Realization Rates				
Net Impact Realization Rate, Total Program Savings	32	N/A	N/A	Net Impact / Filed Net Savings
Net Impact Realization Rate, Savings per DUOM	N/A	N/A	N/A	
a. Pumping (kWh/acre-ft.)				
b. HVAC (kWh/sq.ft.)				
Item 3: Net-to-Gross Ratios				
A. Net-to-Gross Ratios based on Program Load Impacts	0.75	N/A	N/A	Appendix A
B. Net-to-Gross Ratios based on Average Load Impacts DUOM	0.75	N/A	N/A	Appendix A
Item 4: Designated Unit Intermediate Data				
See Item 4 Table 6 A.				
Item 6: Measure Count Data				
See Item 6 Table 6 A.				
Item 7: 1996 AEEI Program Market Segmentation Data				

CEC Climate Zone	Participant Group	Comparison Group
06 Coastal/08 LA Basin	30%	N/A
09 Valley/10 Inland Empire	40%	N/A
13 Joaquin/14 High Desert	30%	N/A
15 Low Desert	0%	N/A
16 Mountain	0%	N/A
All Zones	100.0%	N/A

Table 7: 1996 AEEI Program Data Quality and Processing

7.A Overview Information
1. 1996 Agricultural/Water Supply Energy Efficiency Incentive (AEEI) Program First Year Load Impact Evaluation: Study ID number 542
2. The program year is 1996. This is an incentive program See Section 1 for more detailed description.
3. The end uses covered in the study include pumping/water services and HVAC. The measures covered are VSD applications in pumping/water services and HVAC end uses.
4. This study uses engineering algorithms utilizing on-site measurement data collection to estimates ex post load impacts of the program
5. Program participants are defined as all agricultural/water supply customers who participated in the AEEI Program during 1996; there were approximately 10 participants in the Program. No nonparticipant group was used in this evaluation study.
6. The analysis utilized attempted census.
7.B Database Management
1. The key components include participant on-site measurement data, 1996 AEEI Program tracking data, and consumption data. See Section 4 for a description of these elements.
2. SCE provided all Program data, and on-site measurement data was collected as part of this analysis. Sources for each data element are identified in Section 4.
3. The program database consisted of 10 participants; 1 Process end-use customer was dropped from the study frame per approved waiver request (see appendix A).
4. On-site measurement data and customer program participation data were matched by unique identification numbers.
5. 5. All data collected for analysis figured in analysis through inclusion in the engineering calculations.
7.C Sampling
1. The study relied on attempted census
2. Survey instruments are provided in Appendix C.
The response rate was 100%
3. Appendix B includes complete documentation on data collection on each participant site.

Table 7: 1996 AEEI Program Data Quality and Processing

7.D Data Screening and Analysis
1. Not applicable 2. Not applicable. 3. Not applicable 4. Not applicable 5. Section 4 lays out the engineering algorithms used in each site analysis to determine the load impact. 6. Not applicable 7. Not applicable 8. Not applicable 9. Not applicable. 10. Not applicable 11. Missing field data values were filled using the following supplemental data. Typically, monthly missing data such as water pumped, run hours, kWh, etc., were filled with, in preferred order, 1. an average of preceding month and following month data, 2. data for the same month(s) of the preceding year, if annual values were similar, or 3. annual quantity divided by 12. Annual data was filled with values from the appropriate (either before or after installation of measure) pump efficiency test reports. Where calculations were required, they are presented in each individual site summary. Where assumptions were used, they are stated in each individual site summary 12. Not applicable
7.E Data Interpretation and Application
1. Net Program impacts are calculated to be 1,599 MWh. 2. Refer to Section 4. for a discussion of the process and rationale for the engineering algorithms used in each site analysis.