ASHURST WELL FIELD NITRATE STUDY

CHORRO VALLEY, SAN LUIS OBISPO COUNTY

Prepared for the

City of Morro Bay

MAY 2009

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EXECUTIVE SUMMARY

Water supply wells have been operated at the City's Ashurst well field in the Chorro basin since the 1950's. Nitrate concentrations in excess of California drinking water standard of 45 milligrams per liter (as NO_3) began to occur at the well field on a seasonal basis in the late 1980's and continued until State Water Project water deliveries in 1997. Several years of low nitrate concentrations followed. In 2003, and seasonally since 2006, nitrate concentrations in groundwater at the well field again began exceeding the drinking water standard. In 2008, nitrate concentrations of up to 120 milligrams per liter were measured, the highest level reported at the well field to date.

The purpose of the study was to evaluate potential sources of dissolved nitrate contamination in groundwater at the Ashurst well field along Chorro Creek Road. Potential sources include agricultural and turf fertilizers, private septic system discharges, wastewater treatment plant discharges/overflows, animal operations, and miscellaneous sources. **Results of the study indicate that the primary source of nitrate contamination at the Ashurst well field is agricultural fertilizer.**

Nitrate concentrations in groundwater samples collected during this study are less than 15 mg/l NO_3 in the Canet Road area and points upstream. Based on the nitrate data and the regional hydraulic gradient (toward the estuary), the source of nitrate contamination appears to be somewhere between Canet Road and Chorro Creek Road. This is also where the greatest concentration of irrigated truck crops in the Chorro Valley are, and consequently where the most fertilizer is applied.

General mineral water quality at the Ashurst well field is predominantly magnesium-calcium bicarbonate, and mixing with sources of wastewater would increase the sodium chloride content. When nitrate concentrations are correlated with calcium and sodium concentrations, the samples with elevated nitrate concentrations do not show any increase in sodium compared to background levels, but do show an increase in calcium. Calcium is a common component of agricultural fertilizer used to improve the drainage capacity of clayey soils.

General mineral, nitrate isotope, water isotope, and organic wastewater constituents data do not collectively support a wastewater origin as the primary source of nitrate concentrations. Recharge dynamics indicate that Chorro Valley subsurface inflow to the Ashurst well field transports the elevated nitrate concentrations. Subsurface inflow comes from the east, where there is intensive agriculture with fertilizer use.

Options for mitigating the problem of elevated nitrate contamination in groundwater at the City's Ashurst well field include reducing the nitrogen load from agricultural fertilizer applications, and reducing nitrates in produced groundwater by treatment/blending. The latter option would not reduce the actual nitrate concentrations in groundwater at the well field, but could be used as an interim measure.

INTRODUCTION

Cleath-Harris Geologists was retained by the City of Morro Bay (City) to complete a nitrate source study in the Chorro Valley groundwater basin. The purpose of the study was to evaluate potential sources of dissolved nitrate contamination in groundwater at the City's Ashurst well field along Chorro Creek Road.

The City has operated water supply wells at the Ashurst well field in the Chorro basin since the 1950's. Dissolved nitrogen concentrations in groundwater at the well field were generally below 20 mg/l as nitrate (NO_3) through the late1960's, and below 30 mg/l NO_3 through the 1970's and early 1980's. During the late 1980's and early 1990's, nitrate concentrations began to exceed the State drinking water limit of 45 mg/l NO_3 annually in some of the Ashurst wells, and on occasion also exceeded the drinking water limit at the City's Romero well field, approximately 1.4 miles east (upstream) of Ashurst at the terminus of Canet Road. By the end of the 1990's nitrate concentrations in groundwater from the Ashurst and Romero well fields had declined to background levels of below 20 mg/l NO_3, and remained at generally low levels until 2006. Over the last three years (2006-2008) several Ashurst wells have exceeded the drinking water standard on an annual basis. The City's wells at Ashurst are shown in Figure 1.

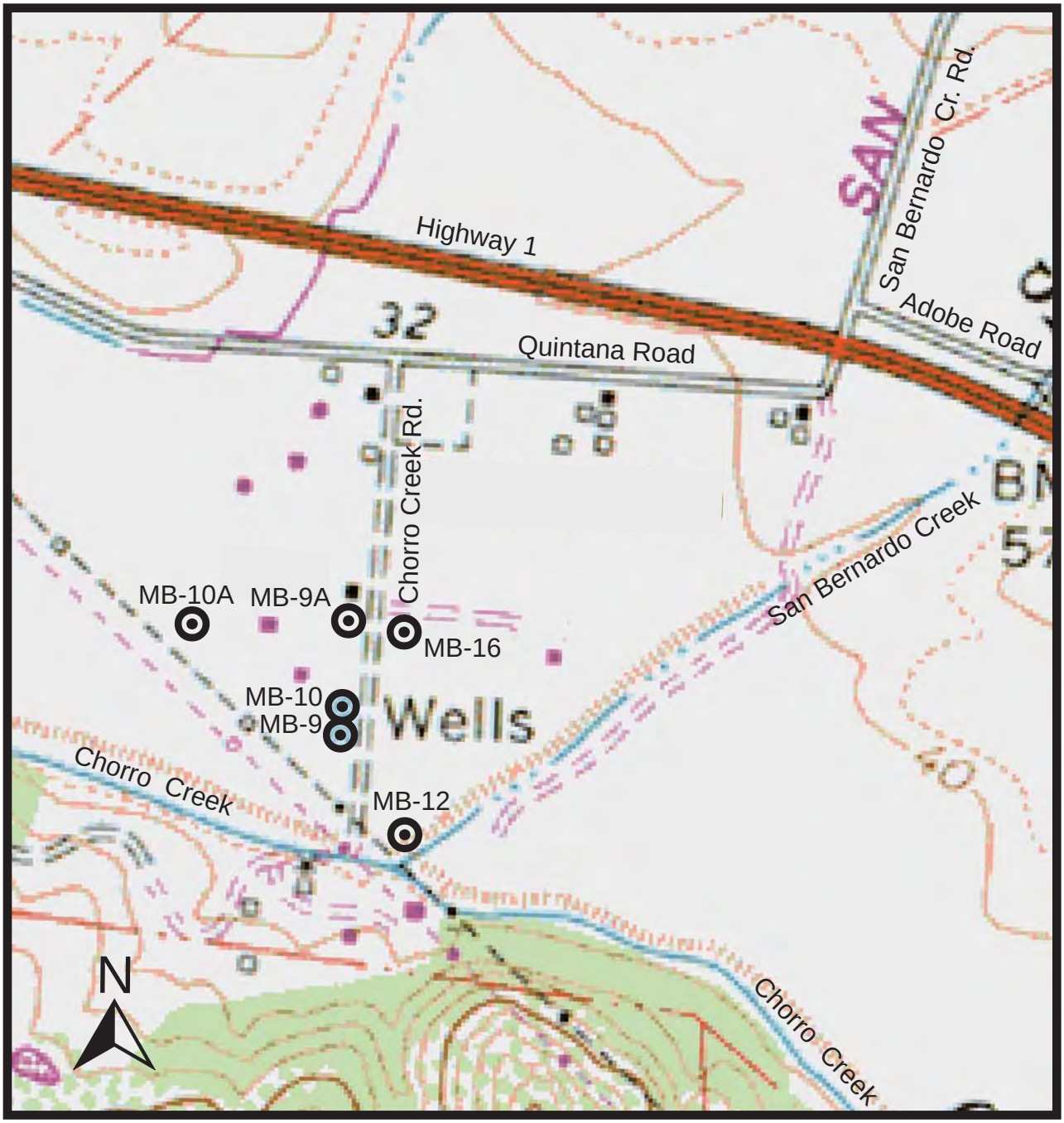
The potential sources for nitrate contamination include agricultural and turf fertilizers, private septic system discharges, wastewater treatment plant discharges/overflows, animal operations, and miscellaneous sources. Work completed for the study to investigate these sources included compilation of historical data sets on water quality, water levels, precipitation, and stream flow, a land use survey, collection and analysis of groundwater and surface water samples, and data analysis and interpretation.

This report presents information in four sections: Hydrogeology, Land Use, Nitrogen Loading, and Water Quality. The information developed in these four sections is then used in a fifth section, Source of Nitrate Contamination, to discuss and interpret the information. Conclusions are followed by a final section on Mitigation, where applicable management goals and practices are referenced.

HYDROGEOLOGY

The Department of Water Resources Bulleting 118 describes the Chorro basin as encompassing 3,200 acres (five square miles) of Holocene and late Pleistocene age alluvium up to 70 feet thick, consisting of sand, gravel, and clay. The basin underlies the alluvial valley drained by Chorro Creek and is bounded on the west by the Pacific Ocean and elsewhere by Cretaceous to Jurassic age Franciscan Formation rocks and Miocene age volcanic intrusive rocks (DWR, 2004).

Not all of the alluvial areas overlie significant saturated thickness of basin sediments. Based on prior work in the Chorro Valley, the estimated effective area of saturated sediments is approximately 1,900



Base Map: U.S.G.S. 7.5 Minute Series (Topographic)
Morro Bay South (1994) Quadrangle
San Luis Obispo County, California,

0 500

Scale: 1 inch = 500 feet

Explanation

MB-12 City of Morro Bay Well Location

Figure 1
Site Map
Ashurst Well Field Nitrate Study
City of Morro Bay

Cleath-Harris Geologists, Inc.

acres (3 square miles). Area geology, with the approximate extent of saturated alluvial deposits, is shown in Figure 2.

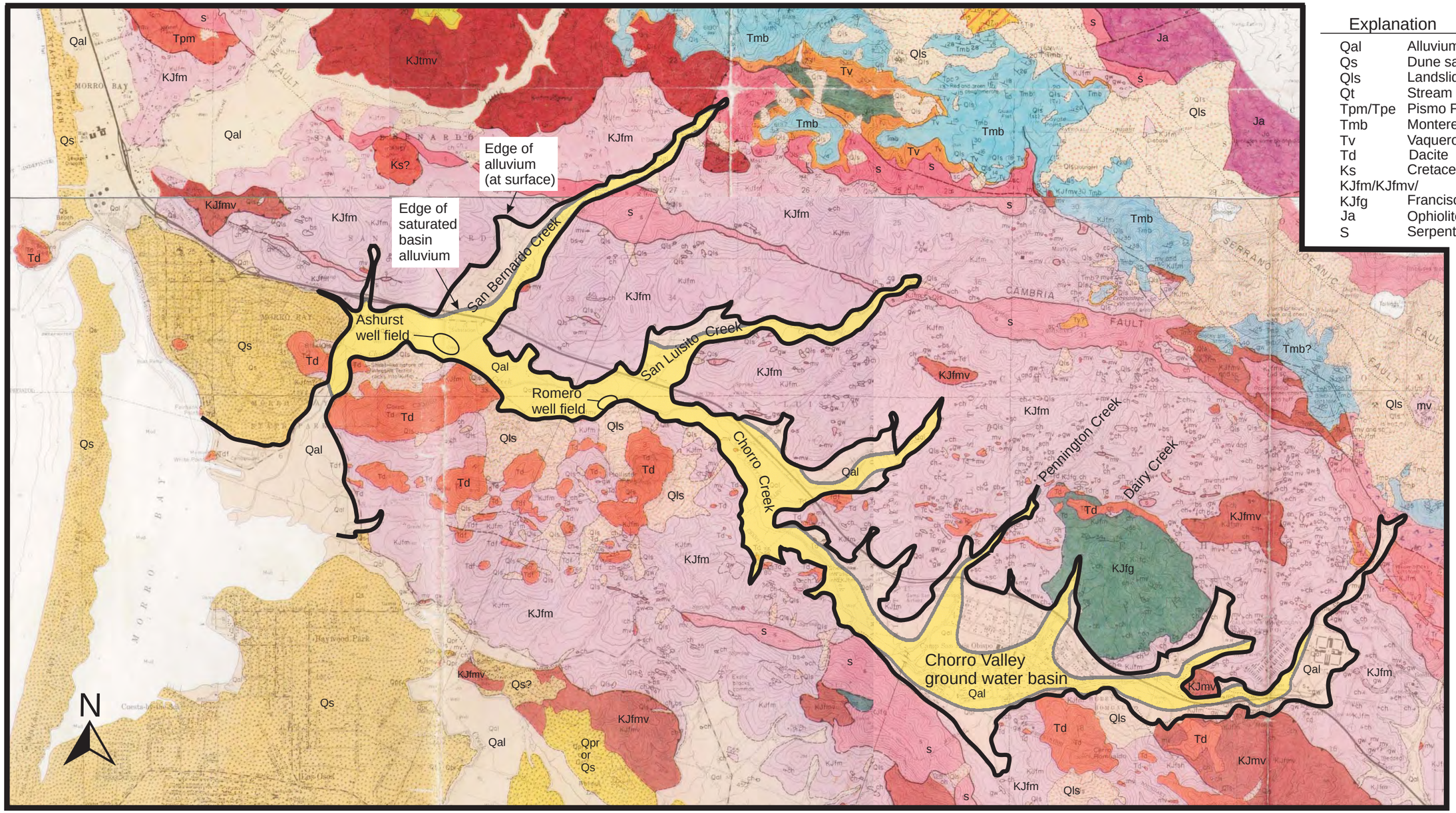
The Chorro Creek watershed drains approximately 45 square miles at it's confluence with Morro Bay estuary. Dairy, Pennington, San Luisito, and San Bernardo Creeks are the main tributaries to Chorro Creek. Chorro Creek and San Luisito Creek are gaged. At the Chorro Creek gage on Canet Road (22 square-mile watershed), annual flows range from approximately 400 acre-feet in critical drought to over 20,000 acre-feet in wet years. The average annual and median flow at the Canet Road gage between water years 1988 and 2000 was approximately 8,700 acre-feet and 7,500 acre-feet, respectively. Annual precipitation on the Chorro Valley floor ranges from 18 to 22 inches, increasing to 24 inches at higher elevations in the watershed.

Groundwater Occurrence and Movement

Basin sediments consist of alluvial deposits in the Chorro Valley, which extend approximately 50 to 70 feet beneath the valley floor in the area downstream of Canet Road. The alluvial sediments include a permeable basal sand and gravel bed up to 30 feet thick, overlain by finer-grained flood plain deposits of silt, clay and sand with some shallow gravel lenses. In the Ashurst well field area, sediments overlying the basal gravel are mostly clay, which acts as a semi-confining layer. During stream flow interference testing in 1998, reductions in Chorro Creek stream flow adjacent to the well field were measured up to approximately 20 percent of total well field production. The City wells were pumped at higher than average flow rates to maximize potential interference effects. Flow in adjacent San Bernardo Creek, however, was not impacted during the testing (Cleath & Associates, 1998).

Groundwater levels in the Chorro basin have been monitored over the past five decades. Hydrographs for the Ashurst and Romero wells are included in Appendix A. Water levels in the basin fluctuate seasonally, typically less than 10 feet, but up to 40 feet during drought at Ashurst and up to 20 feet at Romero. Water levels at Ashurst have generally been shallower over the last 10 years, which is attributable to less production at this well field and upstream groundwater wells since the onset of State Water Project water deliveries in 1997.

Groundwater in the Chorro basin alluvial deposits moves toward the coast. Equal-elevation groundwater contour lines for October 2007, and April 2008 (Figures 3 and 4) show westerly hydraulic gradients between the Romero and Ashurst well fields averaging between 0.003 and 0.004 feet of decline in head per horizontal foot of distance (ft/ft). A historical water level figure for October 1990 is included in Appendix B. During this period of low water levels when the well field was still in production, the hydraulic gradient toward the well field increased to 0.025 ft/ft (Cleath & Associates, 2001b).



Explanation

Qal	Alluvium
Qs	Dune sand
Qls	Landslide
Qt	Stream terrace
Tpm/Tpe	Pismo Formation
Tmb	Monterey Formation
Tv	Vaqueros sandstone
Td	Dacite
Ks	Cretaceous sandstone
KJfm/KJfmv/ KJfg	Franciscan Formation
Ja	Ophiolite
S	Serpentinite

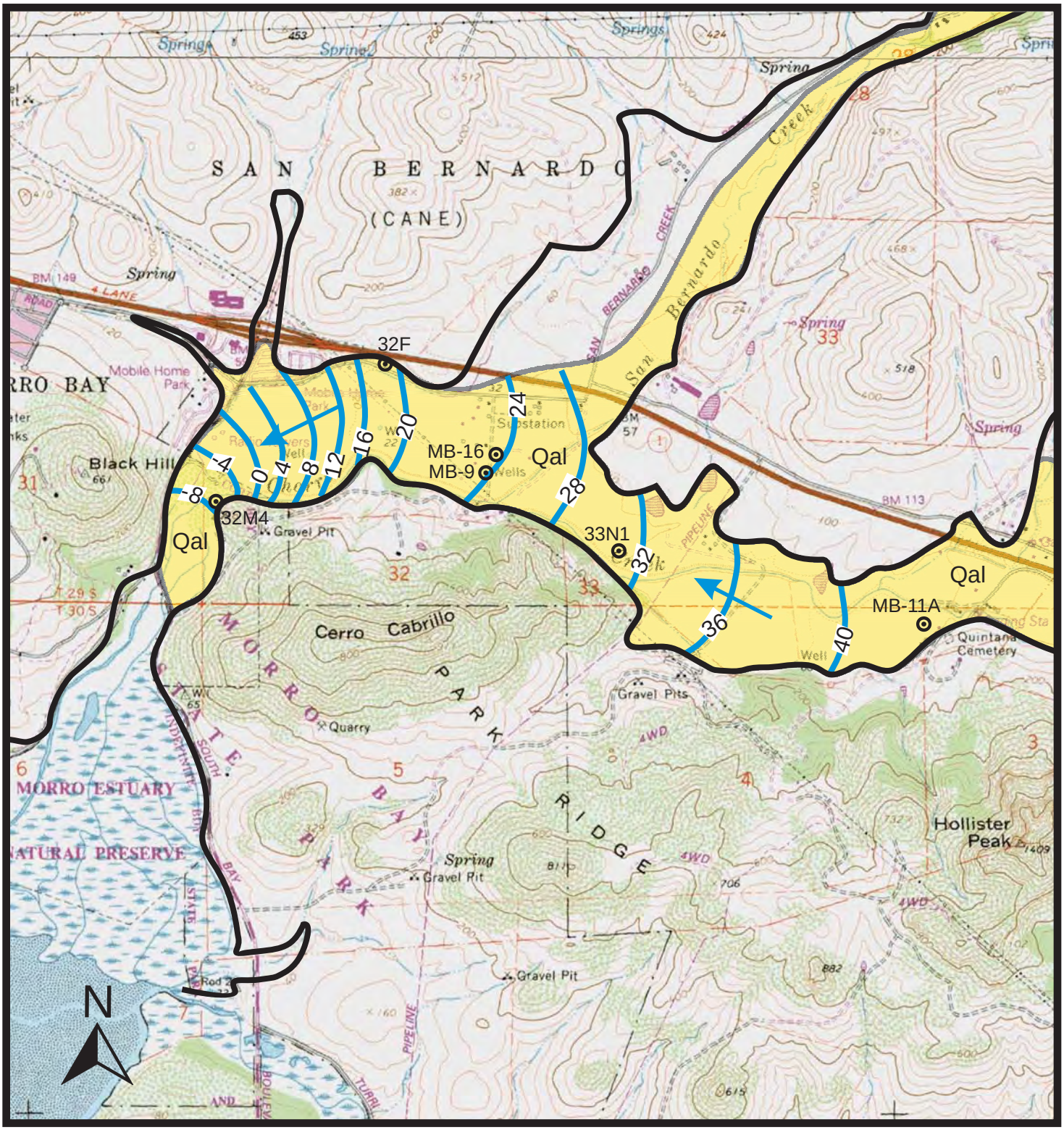
Base Map: C.A. Hall, Jr., W.G. Ernst, S.W. Prior, and J.W. Wiese - Geologic Map of the San Luis Obispo-San Simeon Region, U.S.G.S. Miscellaneous Investigations Series, Map I-1097, Published 1979

0 4,000

Scale: 1 inch = 4,000 feet

Figure 2
Area Geology
Ashurst Well Field Nitrate Study
City of Morro Bay

Cleath-Harris Geologists,Inc.



Base Maps: U.S.G.S. Morro Bay North (1995), Atascadero (1995), Morro Bay South (1994) Quadrangles, San Luis Obispo County, California, 7.5 Minute Series (Topographic)

0 2,000

Scale: 1 inch = 2,000 feet

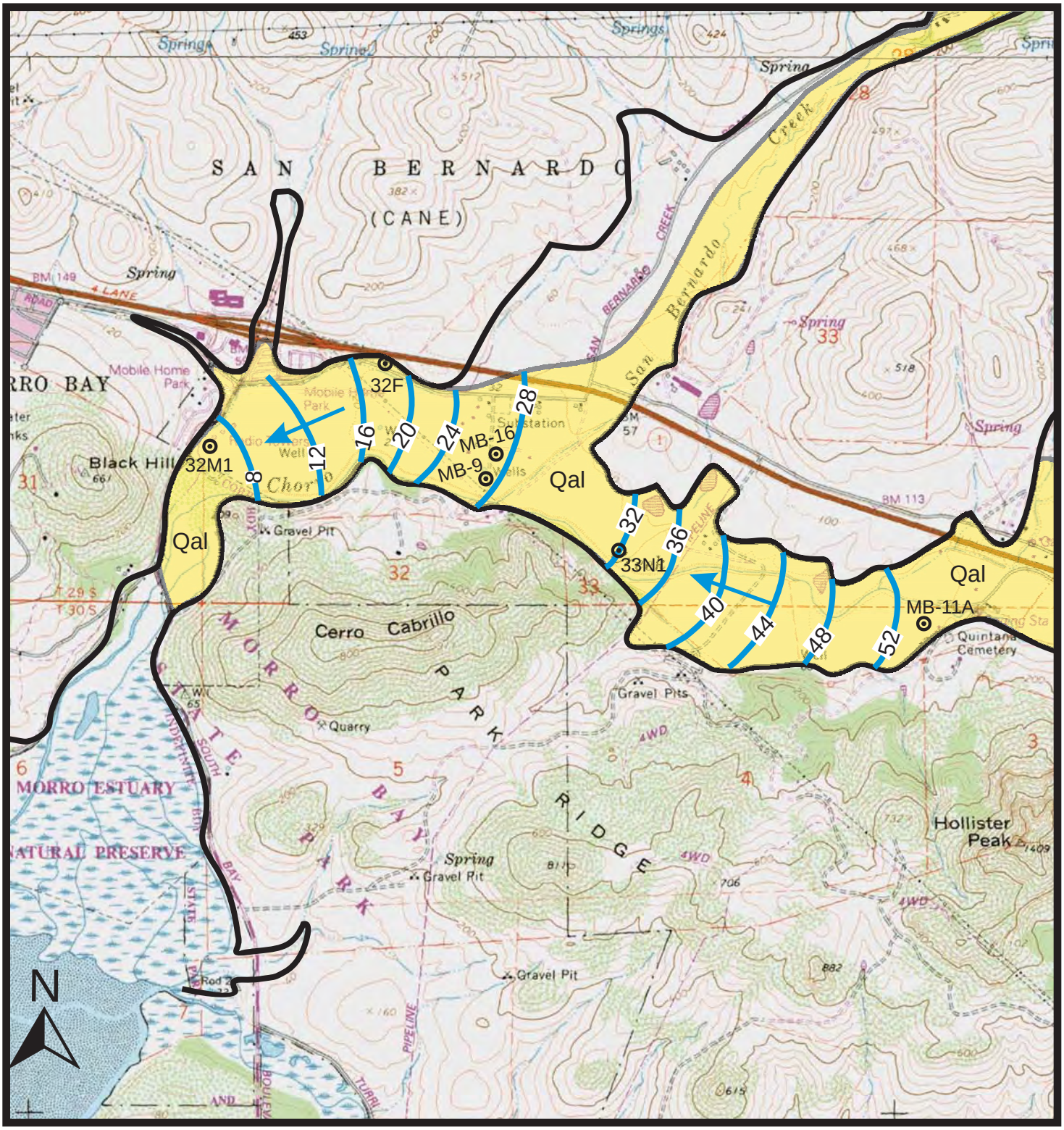
Explanation

Qal	Basin alluvial deposits
40	Groundwater elevation contour
	Groundwater flow direction
32M4	Well location and designation

Figure 3

Groundwater Elevation Contours
October 2007
Ashurst Well Field Nitrate Study
City of Morro Bay

Cleath-Harris Geologists, Inc.



Base Maps: U.S.G.S. Morro Bay North (1995), Atascadero (1995), Morro Bay South (1994) Quadrangles, San Luis Obispo County, California, 7.5 Minute Series (Topographic)

0 2,000

Scale: 1 inch = 2,000 feet

Explanation

Qal	Basin alluvial deposits
52	Groundwater elevation contour
	Groundwater flow direction
32M1	Well location and designation

Figure 4

Groundwater Elevation Contours
April 2008
Ashurst Well Field Nitrate Study
City of Morro Bay

Cleath-Harris Geologists, Inc.

City Groundwater Production

The City has operated nine wells in the Chorro Basin according to historical records, six at the Ashurst field (MB-9, MB-9A, MB-10, MB-10A, MB-12, and MB-16) and three at the Romero field (MB-8, MB-11, and MB-11A). Of these nine, four have been active in recent years at Ashurst (MB-9, MB-9A, MB-10, and MB-16) and one active well remains at Romero (MB-11A).

Figure 5 summarizes the City's Chorro Basin well field production since 1966. Production data is also included in Appendix C.

The Ashurst well field produced an average of 560 acre-feet per year and the Romero field produced an average of 470 acre-feet per year for the community supply during the 10 years prior to State Water Project deliveries in 1997. Production dropped to less that 50 acre-feet per year from 1998 to 2004. Beginning in 2005, Well 11A (Romero field) production has averaged 210 acre-feet per year, while Ashurst wells have been mostly idle.

Groundwater Recharge

Groundwater extracted by City wells at the Ashurst well field is replenished through Chorro Creek stream seepage, San Bernardo Creek stream seepage, percolation of precipitation, irrigation/septic system return flows, and subsurface inflow. During drought, sea water intrusion has been noted downstream of Ashurst at State park wells near the estuary.

Percolation of Precipitation

Direct percolation of precipitation into Chorro basin sediments at the Ashurst well field occurs seasonally. There are approximately 80 acres surrounding the well field bounded by Highway 1, San Bernardo Creek, and Chorro Creek. Rainfall at the fire station in Morro Bay has averaged 16.8 inches per year between 1958 and 2006 (SLO County Public Works records); the average annual rainfall over the Ashurst/Chorro Creek Road area is estimated to be 112 acre-feet.

The amount of deep percolation of precipitation can be highly variable, ranging from approximately 3 percent to over 20 percent. Given the flat topography, clayey soils, rural land use, and near proximity to the creeks, for the purposes of this study, a value of 8-10 percent percolation of precipitation is reasonable. That would result in a nominal 10 acre-feet per year of recharge to the basin from direct percolation of precipitation in the vicinity of the Ashurst well field.

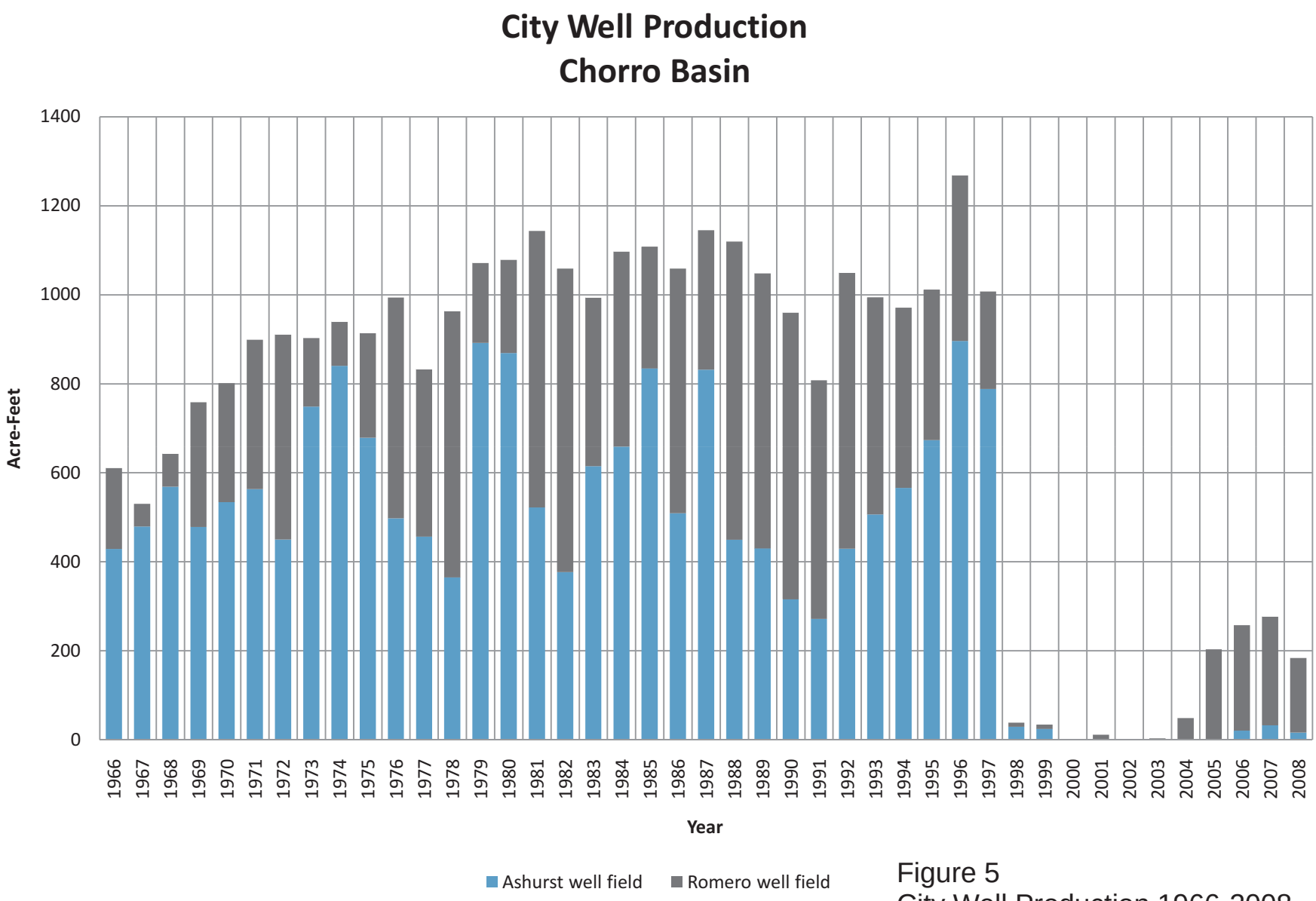


Figure 5
City Well Production 1966-2008
Ashurst Well Field Nitrate Study
City of Morro Bay

Cleath-Harris Geologists, Inc.

Irrigation/Septic Return Flows

Irrigation efficiencies vary between system (sprinkler, flood, or drip) and application rates. For discussion purposes, agricultural irrigation return flows are estimated at 20 percent, and home owner irrigation return flows at 10 percent. Septic systems return water indoor use, which can be estimated at 0.25 to 0.3 acre-feet per year for a typical single family home. Within the 80-acre Ashurst vicinity, there are approximately 10 acres in agriculture, and the equivalent of 18 homes (the homeless shelter is counted as eight homes). Using an agricultural irrigation water duty factor of 3 feet per year per acre, and a nominal 1 acre-foot of outdoor water use per home, the resulting recharge from local irrigation and septic return flows in the vicinity of the Ashurst well field is estimated at 13 acre-feet per year.

Subsurface inflow

Subsurface groundwater flow toward the Ashurst well field can be estimated using cross-sectional flow area, aquifer permeability, and hydraulic gradient. The alluvial valley upstream of the San Bernardo Creek - Chorro Creek confluence is approximately 900 feet wide. Permeable sediments extend to a depth of approximately 30 feet below sea level (60 feet below ground surface), with the permeable aquifer zones totaling an estimated 20 feet in thickness.

The hydraulic gradient upstream of the Ashurst well fields fluctuates between approximately 0.003 ft/ft when the well field is inactive, to 0.025 ft/ft when the well field is in production, based on a comparison between October 1990 and October 2007 water levels.

Groundwater basin flow modeling in the Chorro Valley for the City's Water Management Plan was calibrated using average hydraulic conductivities of 60 ft/day to 65 ft/day in the Ashurst area over the saturated basin thickness (Cleath & Associates, 1993). Using these values, under static, non-operating conditions, subsurface inflow toward the well field is estimated at 75 acre-feet per year. When the well field is in production, with lower water levels, subsurface inflows from the alluvial valley upstream of the San Bernardo Creek - Chorro Creek confluence can increase up to a few hundred acre-feet per year.

Stream Flow Seepage

It has been known for many years that stream flow seepage at the Ashurst well field is significantly restricted by shallow clays. In 1997, stream flow interference tests at the well field confirmed this, showing a reduction in local Chorro Creek stream flow corresponding to only 20 percent of the well field production rate (Cleath & Associates, 1998).

Prior investigators cited evidence for restricted stream flow seepage: the thickness of shallow clays; periods of several months when static water levels in the Ashurst wells were substantially below sea level without sea water intrusion; and water levels remaining below the Chorro Creek channel invert

when the creek was flowing (Converse, 1985) with all of the Ashurst wells pumping at higher than normal flow rates. The 1985 Converse report also noted that water level recovery at the onset of the wet season was rapid and complete (from a few weeks to two months), even in the limited wet season separating the summers of 1976 and 1977. This was subsequently interpreted to indicate that the source of recharge must be very close, and was assumed to be surface flow in Chorro Creek (Morro Group, 1990).

The Ashurst Wells are located along Chorro Creek below the confluences of San Luisito and San Bernardo Creeks while the Romero well field is located above those confluences. Recharge from stream seepage at Ashurst, however, includes San Bernardo Creek and San Luisito Creek, not just Chorro Creek. San Bernardo recharges the Chorro basin just downstream of Highway 1. Surface flows of up to 1.74 cubic feet per second at Adobe Road have been observed to percolate completely into the channel deposits before reaching Chorro Creek (Cleath & Associates, 2004). Once the alluvial deposits near the highway are filled, San Bernardo begins to flow across the shallow clays of the valley floor and into Chorro Creek.

No significant stream flow interference adjacent to the Ashurst well field was measured on San Bernardo Creek during the 1997 well field test. The high seepage capacity of the creek near the highway, but not adjacent to the Ashurst well field, indicates that there is a buried channel connecting San Bernardo Creek with the main basin that runs beneath the shallow clays. This buried channel does not necessarily coincide with the current channel alignment.

San Bernardo Creek has a watershed area of approximately 8.6 square miles, similar to San Luisito Creek (8.5 square miles). Flow in San Bernardo Creek has been estimated to average 1,163 acre-feet in a normal rainfall year, 275 acre-feet in a dry year, and 3,454 acre-feet in a wet year (Morro Group, 1990). With channel seepage capacity of at least 1.74 cubic feet per second at Highway 1, San Bernardo Creek appears to have a greater potential for recharge to the Ashurst well field during normal (or wet) years than either Chorro Creek, where the maximum observed interference was 0.55 cubic feet per second (at 1,150 gallons per minute total well field discharge) or subsurface inflow.

LAND USE

A land use survey was conducted in July 2008. The purpose of the survey was to identify current land uses as they relate to potential nitrate loading in the groundwater basin. Categories for the land use survey include irrigated crops, animal enclosures and grazing lands, the wastewater treatment plant, and septic systems.

Crop Survey

The results of the July 2008 crop survey are shown in Figure 6. A comparison of current irrigated agricultural acreage with prior crop surveys is shown in Table 1.

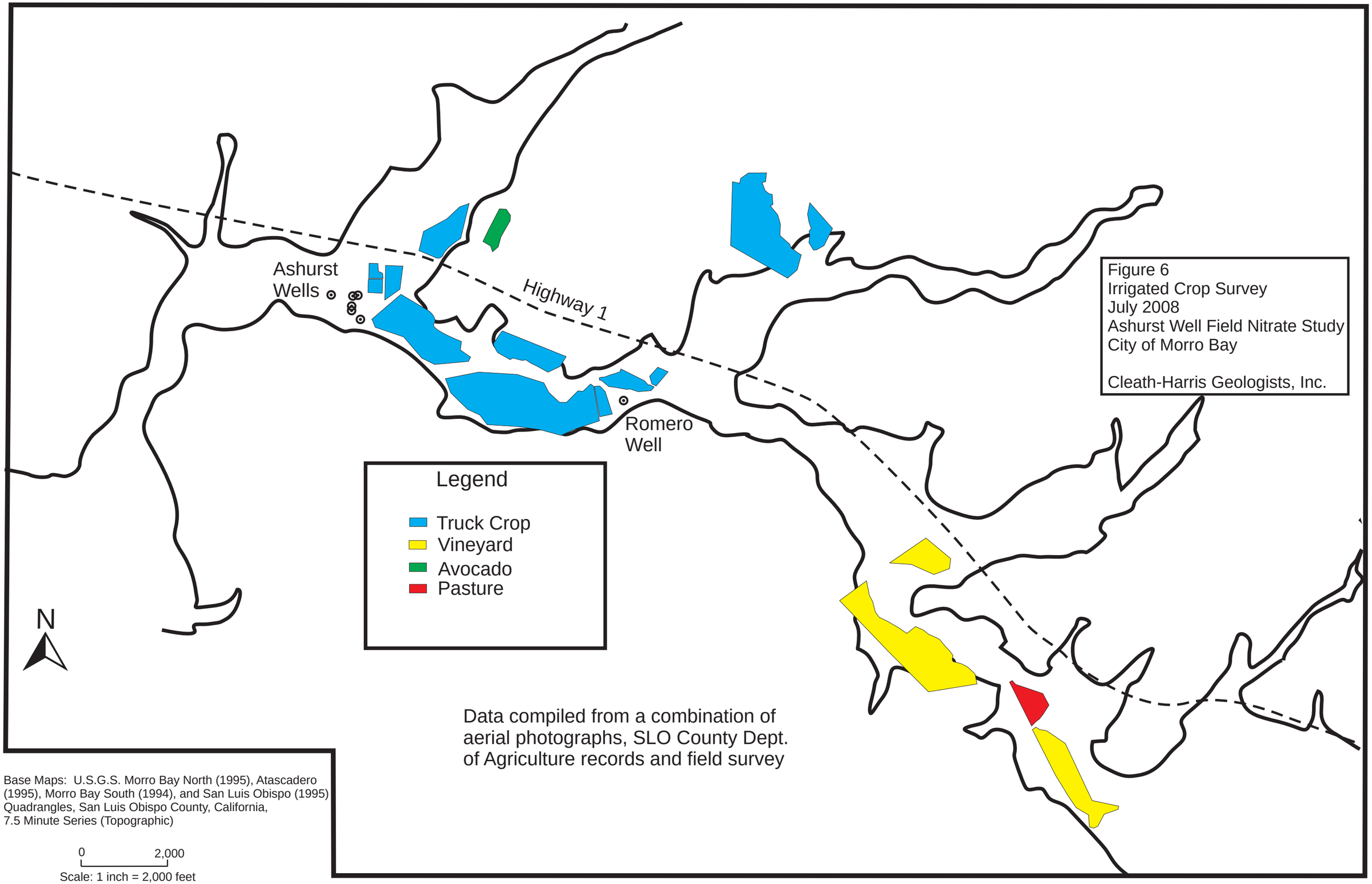
Table 1
Irrigated Acreage 1977-2008
Chorro Valley

Crop Type	Irrigated Acreage				
	1977	1985	1995	2001	2008
Truck (except peas)	32	41	231	153	235
Peas	0*	176	238	39	28
Field	235	335	0	0	0
Pasture	84	70	0	12	12
Orchard	0	0	0	50	10
Vineyard	0	0	0	55	110
Subtotal	351	622	469	309	395

Notes: *peas were non-irrigated in 1977
1995 survey data for summer growing season.
Survey by DWR in 1977, 1985 and 1995.
Survey by Cleath & Associates in 2001 (2001a), and 2008 w/assistance from County records.

Notable trends in Chorro Valley farming during the last 30 years include the elimination of irrigated field crops, which were dominant in 1977 (mostly corn) and 1985 (corn and sudan grass), and the emergence of vineyards, which are now second in total farmed acreage. Irrigated peas have been largely phased out from a high in 1995. Truck crop acreage, which was a minor component of the Chorro Valley through 1985, became the dominant crop type between 1985 and 1995.

The short, mild winters of the central coast allow farming on a year-round basis. The harvested acreage may be several times the farmed acreage, due to multiple cropping. Lands that are fallow during a crop survey may be planted the following month. Fertilizer applications are estimated on a per crop basis, therefore, adjustment of farmed acreage to account for multiple crops would be necessary for comparing fertilizer use from year to year.


Ashurst
Wells
Highway 1
Romero
Well
Legend
Truck Crop
Vineyard
Avocado
Pasture
N
Figure 6
Irrigated Crop Survey
July 2008
Ashurst Well Field Nitrate Study
City of Morro Bay
Cleath-Harris Geologists, Inc.
Data compiled from a combination of
aerial photographs, SLO County Dept.
of Agriculture records and field survey
Base Maps: U.S.G.S. Morro Bay North (1995), Atascadero
(1995), Morro Bay South (1994), and San Luis Obispo (1995)
Quadrangles, San Luis Obispo County, California,
7.5 Minute Series (Topographic)
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Scale: 1 inch = 2,000 feet

Information on multiple cropping for surveys prior to 1995 is not readily available. There were some adjustments to the irrigated land acreage made in prior surveys to account for the use of fallow land, but details of crop rotations were not available until 1994-95 when summer, winter, and spring surveys were reported.

The 1995 DWR survey shows an average of 2 crops per acre in the Chorro Valley, except for fields with peas only, which averaged 1.5 crops per year. Beginning in 2001, data provided by the County Department of Agriculture/Measurement Standards was used to estimate the ratio of truck crops per year per field. Where the data showed four or more crops in a field (up to eight are reported), it was assumed that two or more of the crops were being grown during the same season, such that no more than three crop rotations were allowed for any single field. Using this method, the data indicated 1.9 truck crops per year per field in 2001, increasing to between 2.3 and 2.9 per year between 2002 and 2007, and then declining to 1.8 in 2008. For harvested acreage calculations, a nominal value of two crops per acre for truck crops (except peas) has been applied. Peas are assigned a multiplier of 1.5 crops per acre. The harvested acreage adjustments are shown in Table 2.

Table 2
Harvested Acreage Adjustments 1977-2007
Chorro Valley

Crop Type	Harvested Acreage (adjusted for multiple crops)				
	1977	1985	1995	2001	2008
Truck (except peas)	64	82	462	306	470
Peas	0	264	357	59	42
Field	235	335	0	0	0
Pasture	84	70	0	12	12
Orchard	0	0	0	50	10
Vineyard	0	0	0	55	110
Total	383	751	819	482	644

Other Land Uses

Approximately 50 residential septic systems discharge to land overlying the groundwater basin. Most of the residences are along Adobe Road, Canet Road, and Chorro Creek Road.

The wastewater treatment plant (WWTP) serving the California Men's Colony, Cuesta College, California National Guard and various County facilities is located on Chorro Creek at the Pennington Creek confluence, a distance of approximately 3 miles above the Romero well field and 4.3 miles above the Ashurst well field. This facility discharges a minimum 0.75 cubic feet per second of tertiary treated wastewater into Chorro Creek. Treated wastewater is also used to irrigate Dairy Creek Golf Course.

There is one horse boarding facility along Adobe Road, and two horses being tended on vacant land along Chorro Creek Road. Less than a dozen llamas are being raised along San Bernardo Creek Road. Cattle were present on the valley floor west of Cuesta College and have been noted to be grazing in other portions of the watershed seasonally.

Large irrigated turf areas (Cuesta College and Dairy Creek Golf Course) are located on both sides of Highway 1 at Cuesta College. The golf course is north of the highway and does not overlie the groundwater basin. The community college irrigated turf area overlies shallow alluvial deposits which are mostly unsaturated.

NITROGEN LOADING

The potential sources for nitrate contamination to groundwater evaluated herein include agricultural and turf fertilizers, private septic system discharges, wastewater treatment plan discharges/overflows, animal operations, and miscellaneous sources. Nitrogen loading from each of these potential sources is discussed below.

Agricultural Fertilizers

The application of fertilizer with nitrogen is a common practice in commercial farming. Many factors affect the nitrogen (N) requirement of crops, and different growers may have different approaches to fertilizer use. The estimates discussed below are provided for general discussion purposes.

The 2008 crop survey categories in the study area included various truck crops (cabbage, celery, cauliflower, bok choy, lettuce, peppers, onions, tomatoes, leeks, squash,), alfalfa (pasture), avocados, and vineyard. Prior crop surveys also included significant acreage in forage pasture, corn, sudan grass, and peas. To compare the nitrogen (N) loading potential for the crop survey years, the applied nitrogen of various crop types published by the University of California were averaged and are presented in Table 3.

Table 3
Estimates for Applied Nitrogen per Crop
Chorro Valley

Crop Type	UC Source	Applied Nitrogen as pounds N per acre		
		Low	High	Average
Truck (lettuce)	Pub. 8098	120	200	160
Truck (hot peppers)	Pub. 7244	150	250	200
Truck (peas)	Pub. 7233	75	130	100
Truck (celery)	Pub. 7220	200	250	225
Truck (cabbage)	Pub. 7208	--		160
Truck (tomatoes)	Pub. 8017	125	350	240
Field (sudan)	Circ. 104-F	assume 3 cuttings		200
Pasture (alfalfa)	CAFA, 2004	none		0
Pasture (other forage)	assume none			0
Orchard (mature avocado)	UCCE 2002	--		100
Vineyard	UCCE 1998b, and B. McCarthy 2000	0	50	25

Using the above values as guidelines, estimates of the relative nitrogen applications for each crop survey year based on harvested acreage have been developed. Truck crops (except peas) average 200 pounds N per acre, peas average 100 pounds/acre, field crops average 200 pounds per acre, avocado averages 100 pounds N per acre for mature trees, and vineyards average 25 pounds per acre. The resulting nitrogen fertilizer applications are as follows:

1977: 60,000 pounds N
1985: 110,000 pounds N
1995: 128,000 pounds N
2001: 73,000 pounds N
2008: 102,000 pounds N

The above estimates for nitrogen applications do not account for any nitrogen removal from harvest, which is substantial, and therefore are not estimates of nitrate loading to groundwater. There are many variables, such as soil types, fertilizer type, crop rotations, weather patterns, irrigation practices and

other individual grower practices that affect the potential for the applied nitrogen to leach to groundwater. Crop residues recycled into the soils are also associated with the agricultural fertilizer source. Nitrate loading factors with spreadsheet calculations are included in Appendix D.

Nitrate fertilizer applications are estimated to have roughly doubled in the Chorro Valley from 1977 to 1985. The largest increases in irrigated agriculture were on two ranches between Canet Road and Chorro Creek Road. Between 1995 and 2001, intensive agriculture at the upstream ranch (Chorro Valley Ranch) was mostly phased out, and replaced with a 50-acre avocado orchard north of Highway 1. In 2002, the Chorro Valley Ranch (now the Chorro Ecological Reserve) was purchased by the State trust for public land and farming there was stopped.

Turf Fertilizers

The irrigated turf areas at the County golf course and Cuesta College are effectively outside of the groundwater basin but overlie areas that drain to tributary creeks. Excess fertilizer applications or applications immediately prior to storm events could impact basin water quality. There are approximately 80 acres of irrigated turf areas at the golf course, and 20 acres of play field areas at the college. Assuming an average nitrogen application of 2 to 3 pounds per 1,000 square-feet per year, applications for the turf areas would be less than 15,000 pounds N per year.

Private Septic System Discharges

Septic systems discharge nitrogen primarily as ammonia and ammonium. Total nitrogen in septic system discharges is typically in the 40-60 mg/l N range. Assuming a discharge of 200 gallons per day, a residential septic system would be releasing approximately 30 pounds N per year to the soils. For 50 systems overlying the basin, the potential nitrogen loading, with no reduction due to subsurface denitrification (maximum loading even for a failed system), would be approximately 1,500 pounds N per year.

One septic system for a community facility on Chorro Creek Road at the Ashurst well field has historically served close to two dozen residents. Septic flows for this facility are estimated to be equivalent to approximately eight single-family homes.

Wastewater Treatment Plant Discharges/Overflows

The nitrogen concentrations associated wastewater discharges from the California Mens Colony WWTP would not be expected to exceed (on average) the maximum allowable discharge limit, which is 10 mg/l nitrogen (45 mg/l NO_3). For a nominal discharge of 1,100 acre-feet per year (twice the required

minimum flow, and close to average annual flows), the resulting nitrogen loading to Chorro Creek would be up to 30,000 pounds N per year.

CMC has brought a new sewer plant online that produces a substantially lower nitrate effluent quantity than their previous treatment plant. Sewer overflows have ranged from 100 gallons up to 200,000 gallons. The reported annual overflow volume reaching Chorro Creek between 1998 and 2008 has ranged from no overflows in 1999 or 2002, to 132,000 gallons reaching the creek in 2004. The average total annual overflow reaching Chorro Creek between 1998 and 2008 was 38,000 gallons (less than 1 acre-foot). Using a nominal 50 mg/l nitrogen concentration for raw wastewater, sewer overflows into Chorro creek would amount to an average of 15 pounds N annually.

Animal Operations

For nitrate loading estimates, the nitrogen content of horse manure is assumed to be 13 pounds N per ton (UCCE, publ. # NG7-97). A 1,000-pound horse produces roughly 9 tons of manure per year, equivalent to 120 pounds of nitrogen. Only two horses were observed during the survey, but assuming the boarding facility accommodates a dozen more, the total nitrogen load from horses, before attenuation due to ammonia volatilization, soil/plant fixation, and denitrification, would be less than 2,000 pounds N per year.

Cattle grazing occurs on open lands in the watershed. One small herd was observed during the survey, but there are likely more in the surrounding hills. For the purposes of comparing nitrogen loading for different land uses, the order of magnitude for nitrogen loading from animal sources is estimated at up to 10,000 pounds N per year.

Miscellaneous Sources

Miscellaneous sources of nitrogen loading include native nitrogen-fixing plants, grading/erosion, and weed abatement, all of which involve the nitrification and leaching of organic nitrogen in soils, which can accumulate in the root zone from plant debris. Crop residue recycled into the soils is not considered part of the miscellaneous sources, but it is directly associated with the agricultural fertilizer source.

The nitrogen load from miscellaneous sources is likely not significant relative to the other sources discussed above. Plant debris or sediment that was not flushed out to the ocean during storm events would accumulate along the stream channels, where the available nitrogen could be used for plant growth along the riparian corridor.

Nitrogen Loading Summary

Agricultural fertilizers used in the Chorro Valley contain approximately twice the nitrogen mass of all the other nitrogen sources combined, based on the 2008 land use survey. Agricultural fertilizer is applied directly to the soils overlying the groundwater basin. Among the various nitrogen sources considered, agricultural fertilizer has the greatest potential for nitrate contamination to groundwater.

WATER QUALITY

The focus of this report is investigating nitrate contamination in groundwater produced by the City's Ashurst well field on Chorro Creek Road. Potential sources of nitrate loading to the basin were discussed in the previous section. This report section presents both historical and current water quality data for the Ashurst well field, and includes Romero well field data and the results of recent groundwater sampling in the Chorro Valley.

A total of 25 samples of stream flow and groundwater were collected between August and December 2008 from 18 locations in the groundwater basin (some locations were sampled twice). Samples were analyzed for the irrigation minerals suite at Creek Analytical Laboratories (San Luis Obispo), with selected samples tested for all forms of nitrogen. In addition, selected surface water and groundwater samples were analyzed by Zymax Forensics (San Luis Obispo) for stable isotopes of nitrate and water, and by the University of Iowa Hygienics Laboratory (Iowa City) for organic wastewater constituents. Water sampling results are discussed below. Laboratory reports are in Appendix E.

Historical Trends in Nitrate Concentrations

Historical water quality data was compiled from City records, the EPA Storet Legacy database, and available reports. Trends of dissolved nitrate concentrations in groundwater at the City's Ashurst and Romero Well fields are discussed below.

Ashurst Well Field

Nitrate concentrations in groundwater have been monitored at City wells in the Chorro basin for over 50 years (Appendix F). Dissolved nitrogen concentrations were generally below 20 mg/l NO_3 through the 1960's, and below 30 mg/l NO_3 through the 1970's and early 1980's. Chemographs showing nitrate concentrations over time at the Ashurst supply wells are shown in Figures 7, 8, and 9.

Nitrate concentration trends in wells MB-9 and MB-10 generally follow the same pattern. There was a notable increase in nitrate in the early 1990's to levels at or above the 45 mg/l NO_3 drinking water standard. Nitrate concentrations subsequently declined to below 20 mg/l in 1998 (well field production

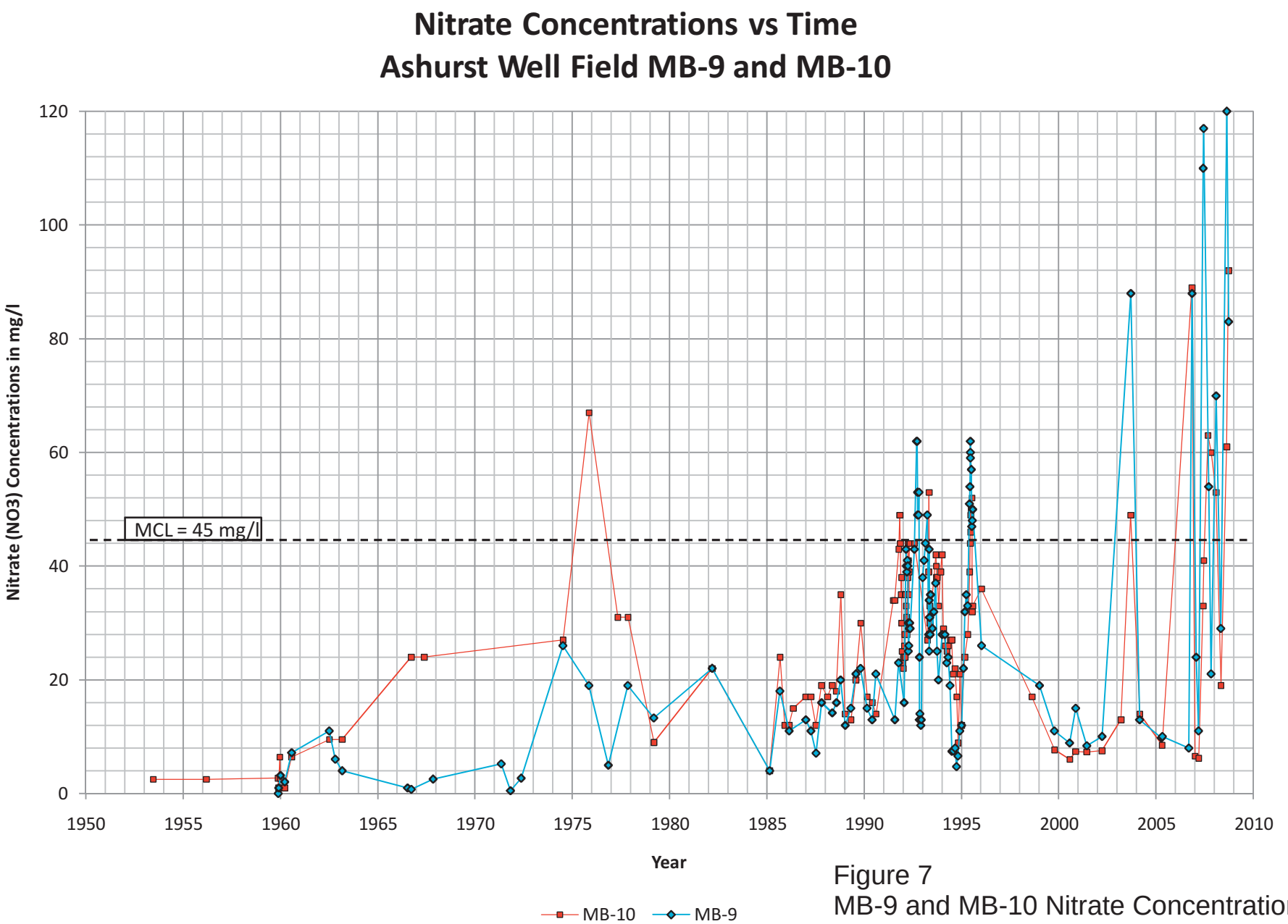


Figure 7
MB-9 and MB-10 Nitrate Concentrations
Ashurst Well Field Nitrate Study
City of Morro Bay

Cleath-Harris Geologists, Inc.

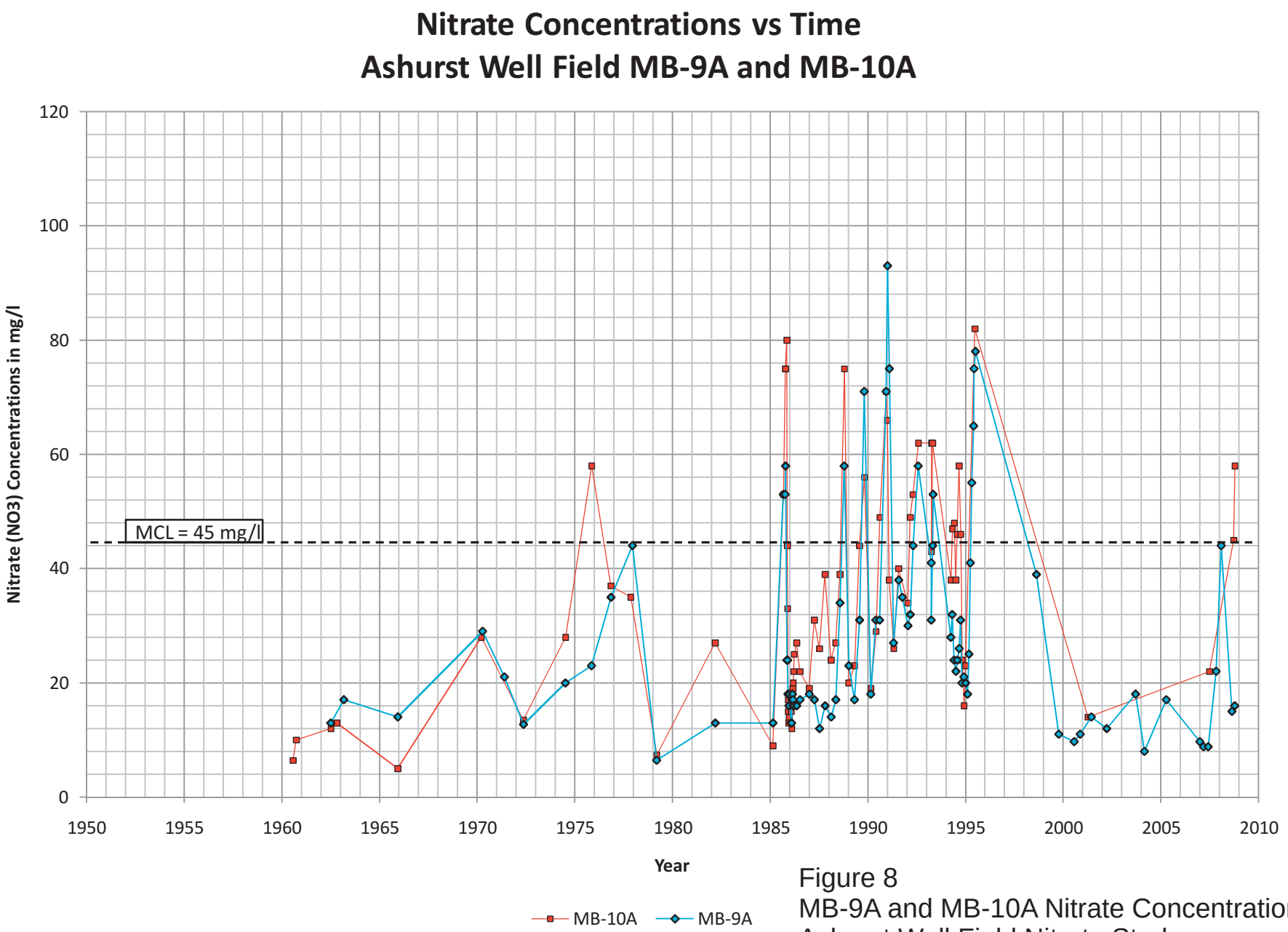


Figure 8
MB-9A and MB-10A Nitrate Concentrations
Ashurst Well Field Nitrate Study
City of Morro Bay

Cleath-Harris Geologists, Inc.

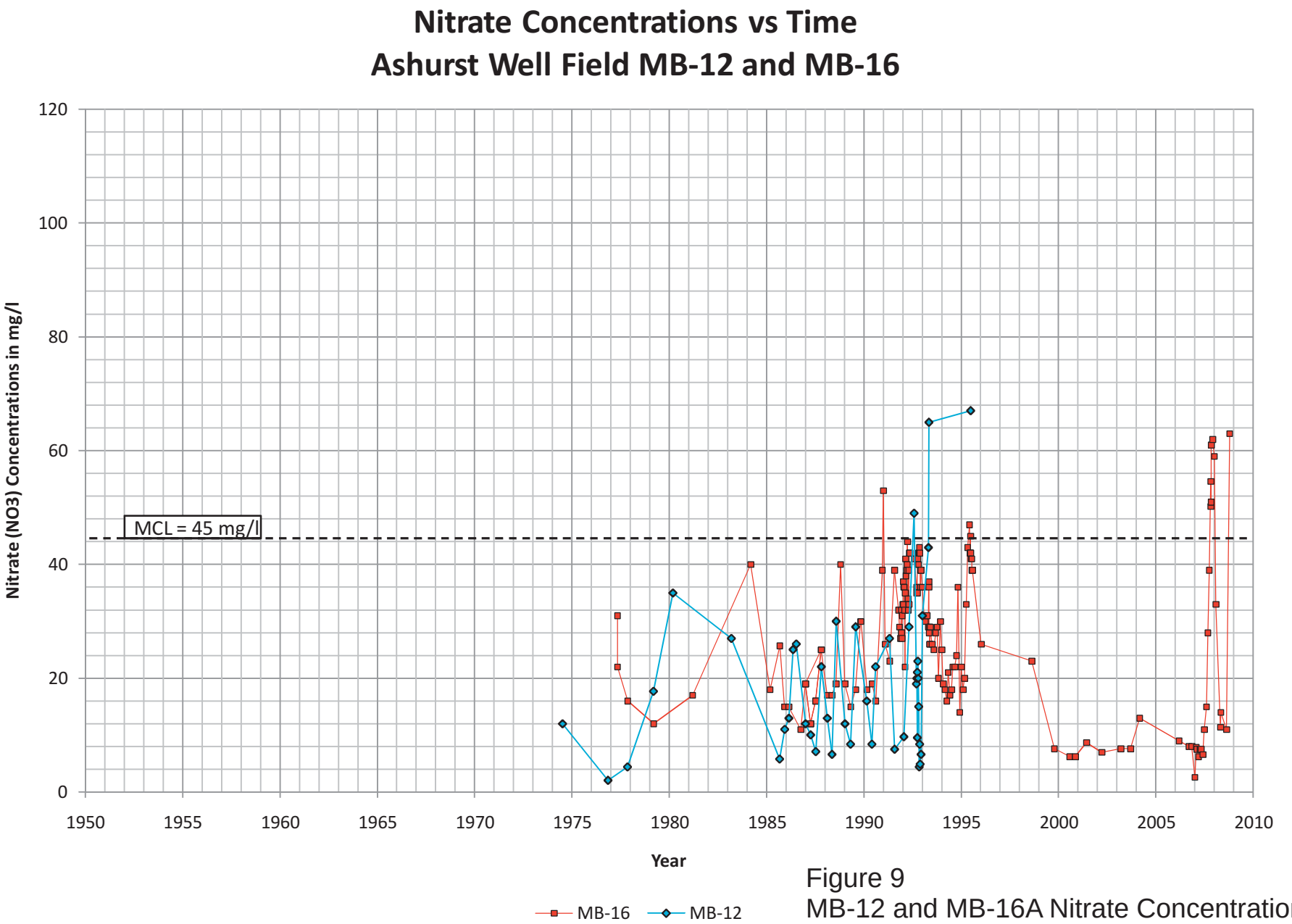


Figure 9
MB-12 and MB-16A Nitrate Concentrations
Ashurst Well Field Nitrate Study
City of Morro Bay

Cleath-Harris Geologists, Inc.

was significantly reduced when the State Water Project was put on-line in late 1997), and remained at low levels until 2003. Beginning in 2003, and annually since 2006, nitrate concentrations in MB-9 and MB-10 have spiked to levels exceeding the drinking water standard.

Trends at wells MB-9A and MB-10A are also similar to one another, but follow a different pattern from MB-9 and MB-10. At wells MB-9A and MB-10A, nitrate concentrations begin spiking to levels above the drinking water standard beginning in 1985, several years earlier than at MB-9 and MB-10. Concentrations declined to levels below 20 mg/l NO_3 around year 2000, and stayed at relatively low levels at MB-9A (MB-10A data is lacking) until last year, when nitrate concentrations in both wells were at or above drinking water standards.

The nitrate concentration trends at wells MB-12 and MB-16 appear to follow a pattern similar to MB-9 and MB-10, although the recent concentrations at MB-16 only reached 63 mg/l NO_3, as opposed to 90-120 mg/l NO_3 in MB-9 and MB-10. Well MB-12 was last sampled in 1995, when it was disconnected from the water system.

Apart from the long-term trends, there are also seasonal fluctuations in nitrate concentrations. A comparison of seasonal fluctuations in MB-9A nitrate concentrations with Chorro Creek stream flow, precipitation, water levels and Ashurst well field production during the 1980's and 1990's is shown in Figure 10. Similar graphs showing the full period of record for each well are included in Appendix G.

In general, nitrate concentrations at Ashurst wells have tended to increase during periods of lower water levels over the period of historical production prior to the State Water Project (through 1997). This type of correlation was also observed in the Morro Valley, where recharge from Morro Creek stream flow served to dilute nitrate concentrations during periods of high flow (Cleath & Associates, 2007).

Romero Well Field

Nitrate concentrations at the Romero wells follow historical trends similar to the Ashurst wells, with a rise in concentrations during the 1990's (Figure 11) . Unlike the Ashurst field, however, there have been no nitrate concentrations exceeding drinking water standards over the last several years.

Data for the Romero field consists of wells MB-8 and MB-11A. Water quality data for MB-8 is available from 1966 to 1995 when this well was abandoned, while MB-11A data is available from 1979 to present. In the 16 years of overlapping data, nitrate concentrations were very similar in both wells through at least 1991. There is insufficient data at MB-11A between 1991 and 1995 to correlate between the wells. In 1998, nitrate concentrations at MB-11A reached 68 mg/l NO3, which is similar to the maximum level recorded at MB-8 in 1995.

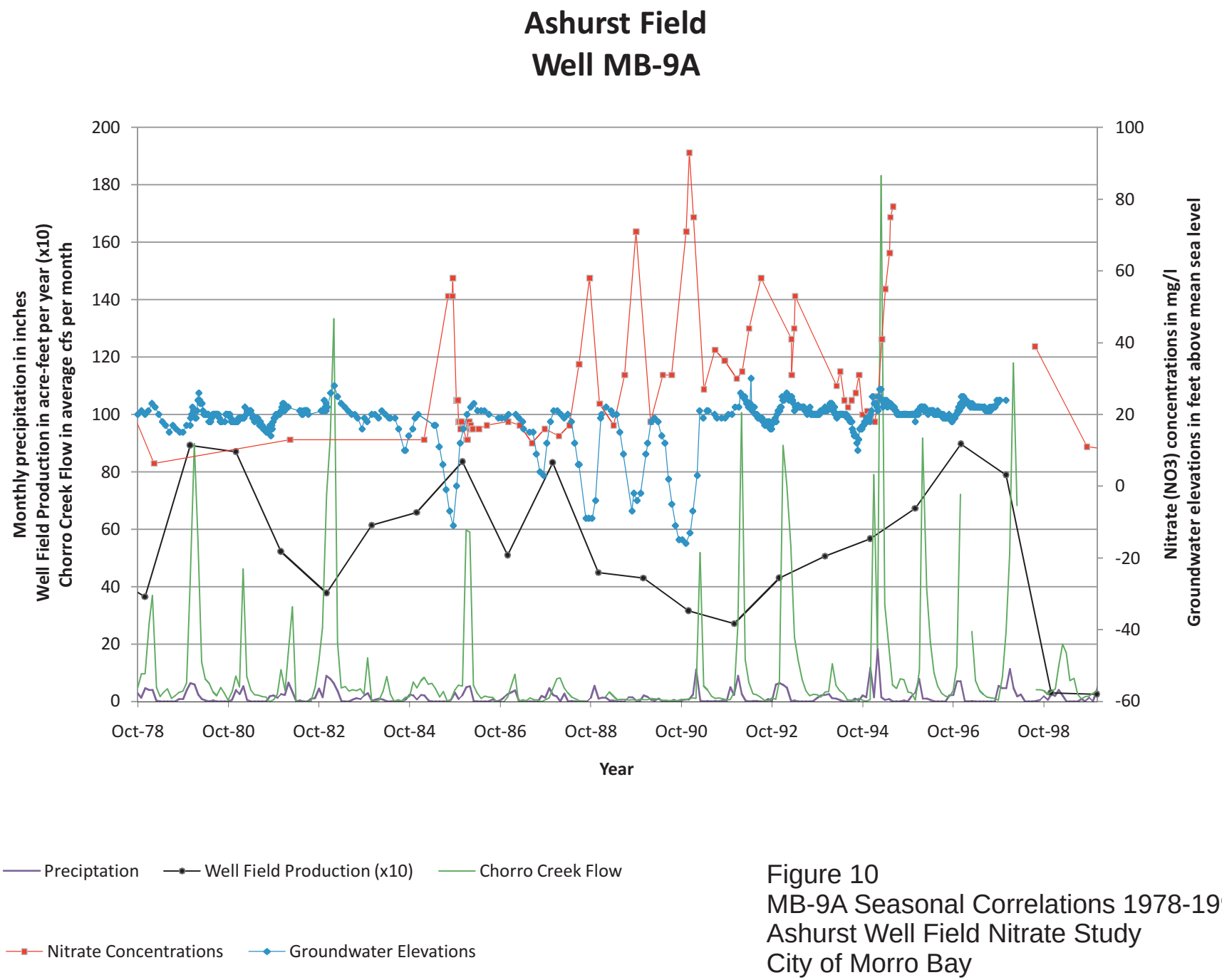


Figure 10
MB-9A Seasonal Correlations 1978-1999
Ashurst Well Field Nitrate Study
City of Morro Bay

Cleath-Harris Geologists, Inc.

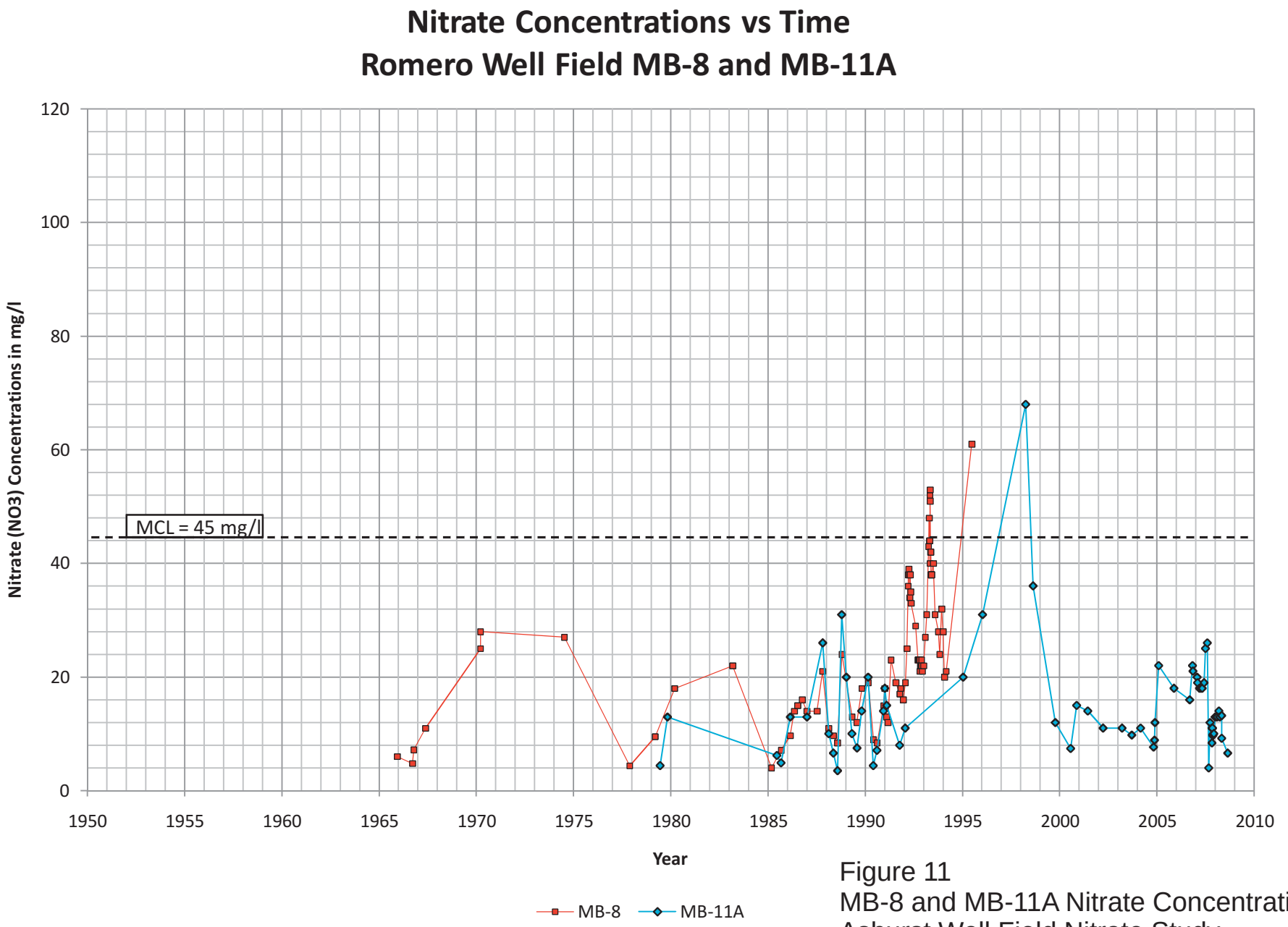


Figure 11
MB-8 and MB-11A Nitrate Concentrations
Ashurst Well Field Nitrate Study
City of Morro Bay

Cleath-Harris Geologists, Inc.

Recent Trends in Nitrate Concentrations

Following a period of relatively low nitrate concentrations between 1998 and 2002 (less than 20 mg/l NO_3), concentrations at the Ashurst well field began exceeding the drinking water standards in 2003. Concentration fluctuations (differences between maximum and minimum values) at individual wells have been close to 100 mg/l NO_3 within a three month period, and do not appear to correlate with any other monitored parameters.

Figures 12 and 13 plot nitrate concentrations at wells MB-9 and MB-9A from 1997 through present with precipitation, well production, and water levels (a current rating curve for Chorro Creek is not yet available to reduce the recent stream gage data). The pattern of extreme nitrate concentrations fluctuations over the last four years does not show a noticeable correlation with any of these parameters.

Recent nitrate concentrations in the basin are shown in Figure 14. Figure 15 compares nitrate concentrations in groundwater with distance from the California Mens Colony WWTP discharge point. A major increase in nitrate concentrations occurs approximately three miles downstream from the WWTP, immediately after the largest concentration of truck crops in the valley.

Other Forms of Nitrogen and Repeat Sampling

Dissolved nitrogen compounds other than nitrate may be present in water, including nitrite, ammonia, ammonium, and organic compounds such as urea. Most dissolved nitrogen reaching groundwater has been oxidized to form nitrate, which is regulated in drinking water.

Selected water samples collected during this study were analyzed for other forms of nitrogen. These additional tests were performed at wells MB-9, MB-10, MB-10A, and in surface water samples from Chorro and San Luisito Creek. The nitrogen reporting suite includes organic nitrogen, total ammonia (includes ammonium), nitrate, nitrite, total Kjeldahl nitrogen (sum of organic-N and ammonia-N) and total nitrogen (sum of Kjeldahl nitrogen, nitrate-N and nitrite-N).

Only one water sample, from well MB-10A, contained nitrogen compounds other than nitrate, with a reported 0.4 mg/l of ammonia. Ammonia is a component of fertilizers and also the primary form of nitrogen in raw wastewater.

Nitrate samples were collected more than once at several locations, for comparison purposes. Wells MB-9, MB-10, MB-9A, and MB-16 were sampled twice, and flows in Chorro Creek at Chorro Creek Road were sampled twice. The results of the repeat samples are included in Figure 14. Sample MB-16 showed the greatest fluctuation when re-sampled, with 11 mg/l NO_3 on August 20th and 63 mg/l NO_3 on October 15th, 2008.

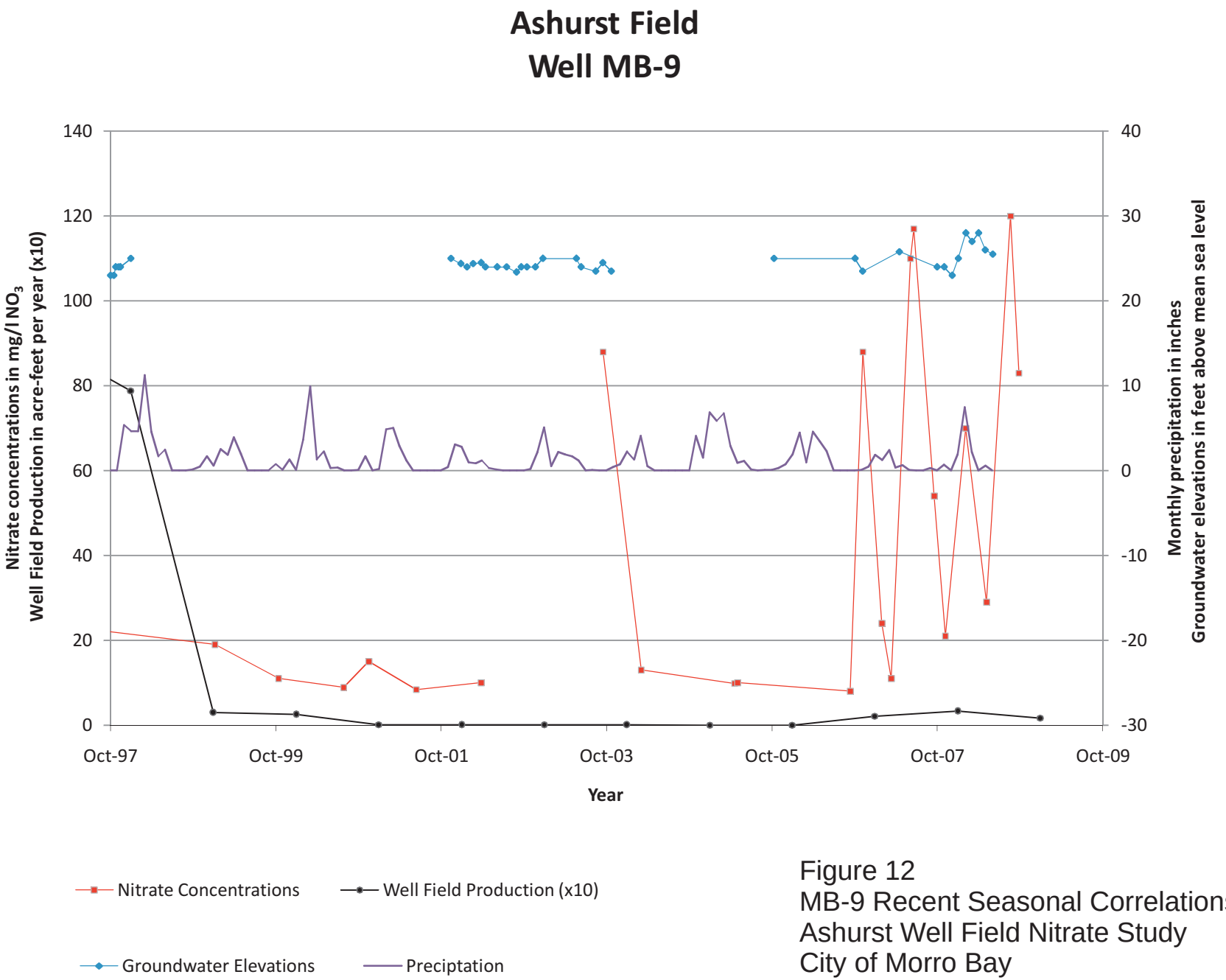


Figure 12
MB-9 Recent Seasonal Correlations
Ashurst Well Field Nitrate Study
City of Morro Bay

Cleath-Harris Geologists, Inc.

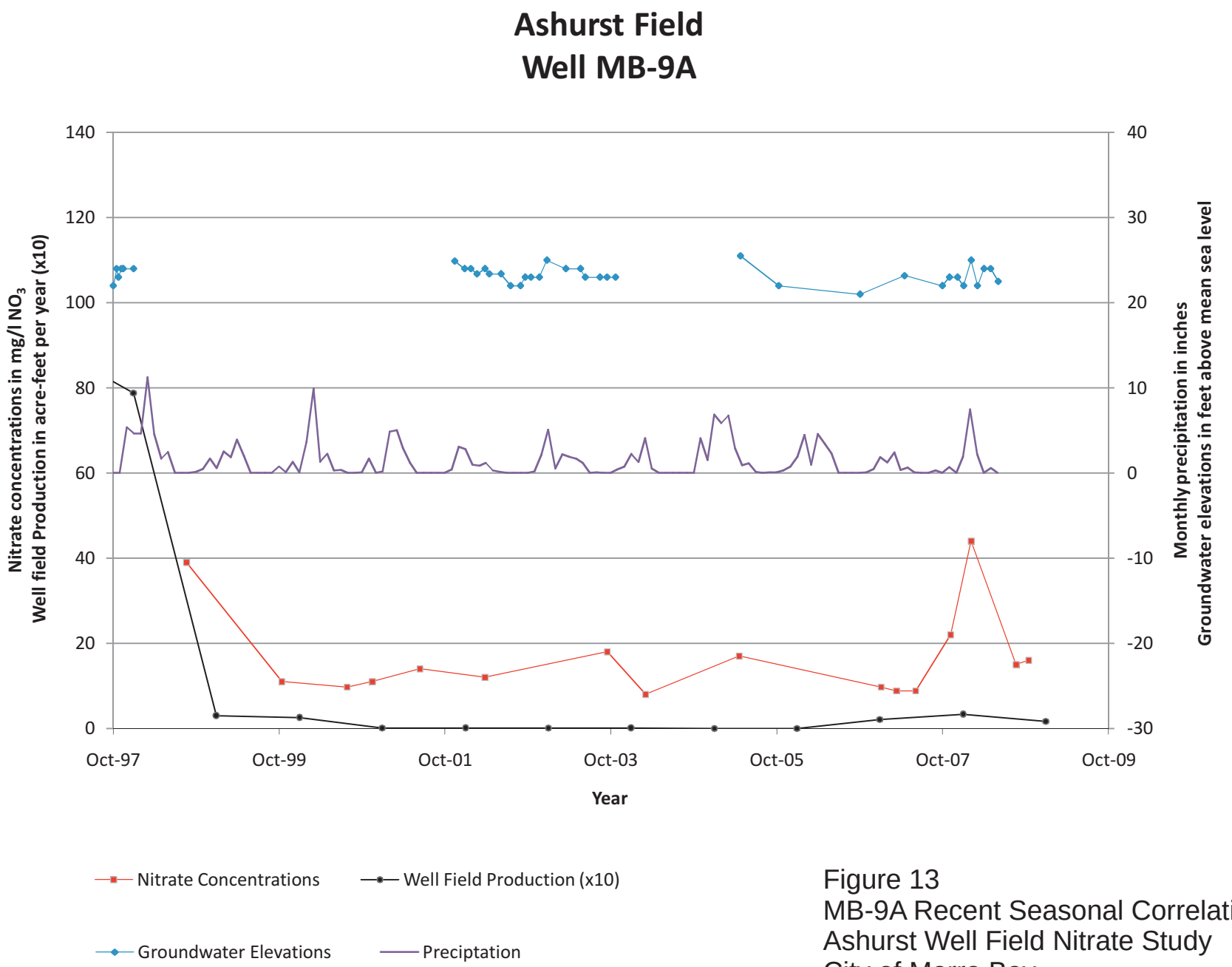
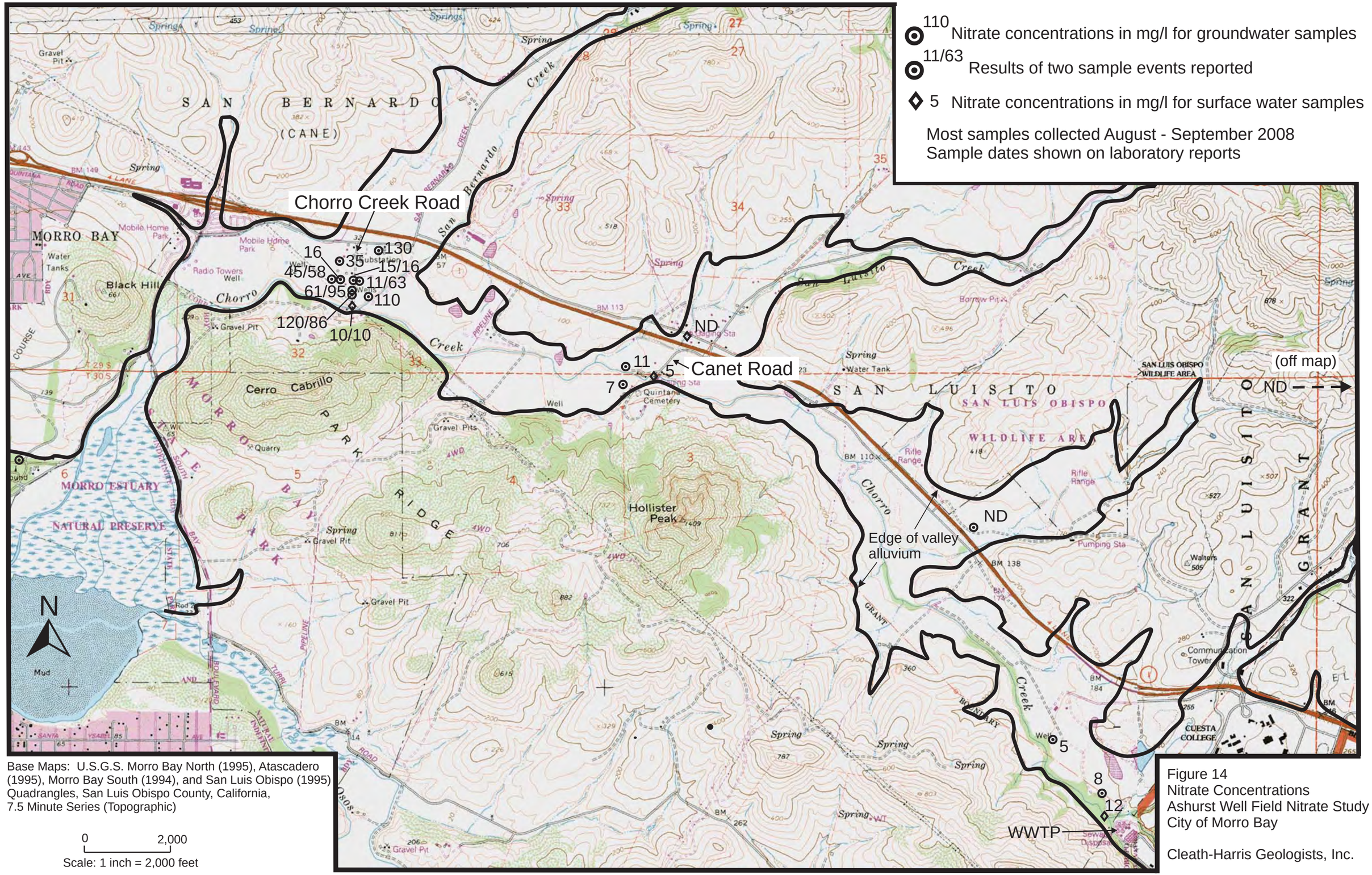


Figure 13
MB-9A Recent Seasonal Correlations
Ashurst Well Field Nitrate Study
City of Morro Bay

Cleath-Harris Geologists, Inc.



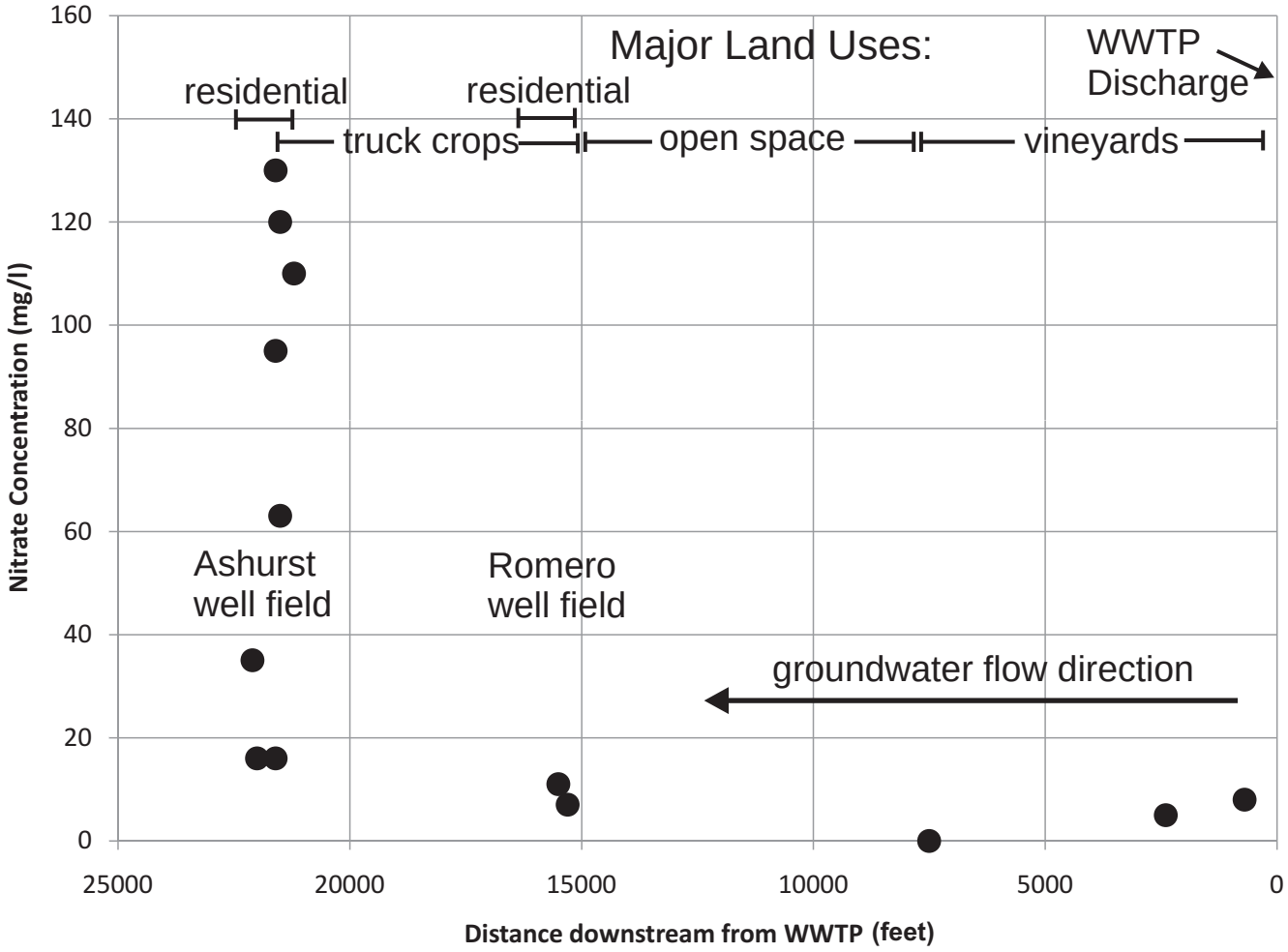
Base Maps: U.S.G.S. Morro Bay North (1995), Atascadero (1995), Morro Bay South (1994), and San Luis Obispo (1995) Quadrangles, San Luis Obispo County, California, 7.5 Minute Series (Topographic)

0 2,000

Scale: 1 inch = 2,000 feet

Figure 14
Nitrate Concentrations
Ashurst Well Field Nitrate Study
City of Morro Bay

Cleath-Harris Geologists, Inc.



Legend:

● Groundwater sample

Most samples collected August and September 2008

Figure 15
Nitrate vs Distance from WWTP
Ashurst Well Field Nitrate Study
City of Morro Bay

Cleath-Harris Geologists, Inc.

General Mineral Characterization

Groundwater in the Chorro basin is predominantly magnesium-calcium bicarbonate in character, which is consistent with the base flow sources from the surrounding watershed, such as San Luisito Creek. The other major source of inflow to the groundwater basin is the discharge from the CMC WWTP. The plant discharge water, when mixed with natural surface flows in Chorro Creek produces a magnesium-sodium bicarbonate-chloride water. There are several wells that exhibit this character, and most are adjacent to Chorro Creek below the WWTP site. Stiff diagrams with total dissolved solids concentrations for the sampled wells, along with sample locations, are shown in Figure 16.

A Piper diagram, showing the relative distribution of the major mineral ions, is included in Figure 17. There are linear trends in both the anion and cation distributions. These trends show an increase in chloride away from bicarbonate and an increase in sodium away from magnesium. Well D (upper Pennington Creek alluvial well) is at the magnesium bicarbonate end of the trends, and the Chorro Creek sample at Cal Poly (near the WWTP discharge) is at the sodium chloride end of the trends.

Figure 18 compares the relationship between calcium and sodium concentrations when plotted against nitrate concentrations. Background nitrate concentrations in the Chorro basin water samples are below 20 mg/l NO_3. When levels exceed this threshold, the calcium concentrations also rise above their respective background concentrations, while the sodium concentrations do not. In other words, there is a positive correlation between increased nitrate and increased calcium above the normal range of concentrations, but no similar correlation with sodium and nitrate concentrations.

Nitrate-Nitrogen and Nitrate-Oxygen Isotopes

The nitrate-nitrogen isotope ratio (nitrogen-14 to nitrogen-15) and nitrate-oxygen isotope ratio (oxygen-18 to oxygen-16) fall within specific ranges for various common nitrate sources. As a result, nitrate-nitrogen and nitrate-oxygen isotopes can be useful to groundwater investigations. Shifts in isotope ratios (fractionation) may occur for various reasons in the subsurface, however, and the results of isotope studies are subject to interpretation and reconciliation with other methods of investigation. A more detailed discussion of nitrate isotopes is included in Appendix H.

Groundwater samples from wells MB-9 and MB-10 at the Ashurst well field were collected on September 12, 2008 for isotope analyses. Analyses of the $\delta^{15}N$ and $\delta^{18}O$ isotope ratios of nitrate in groundwater were performed by Zymax Forensics. The results of the analyses are presented in Table 4. The laboratory analytical reports are included in Appendix E.

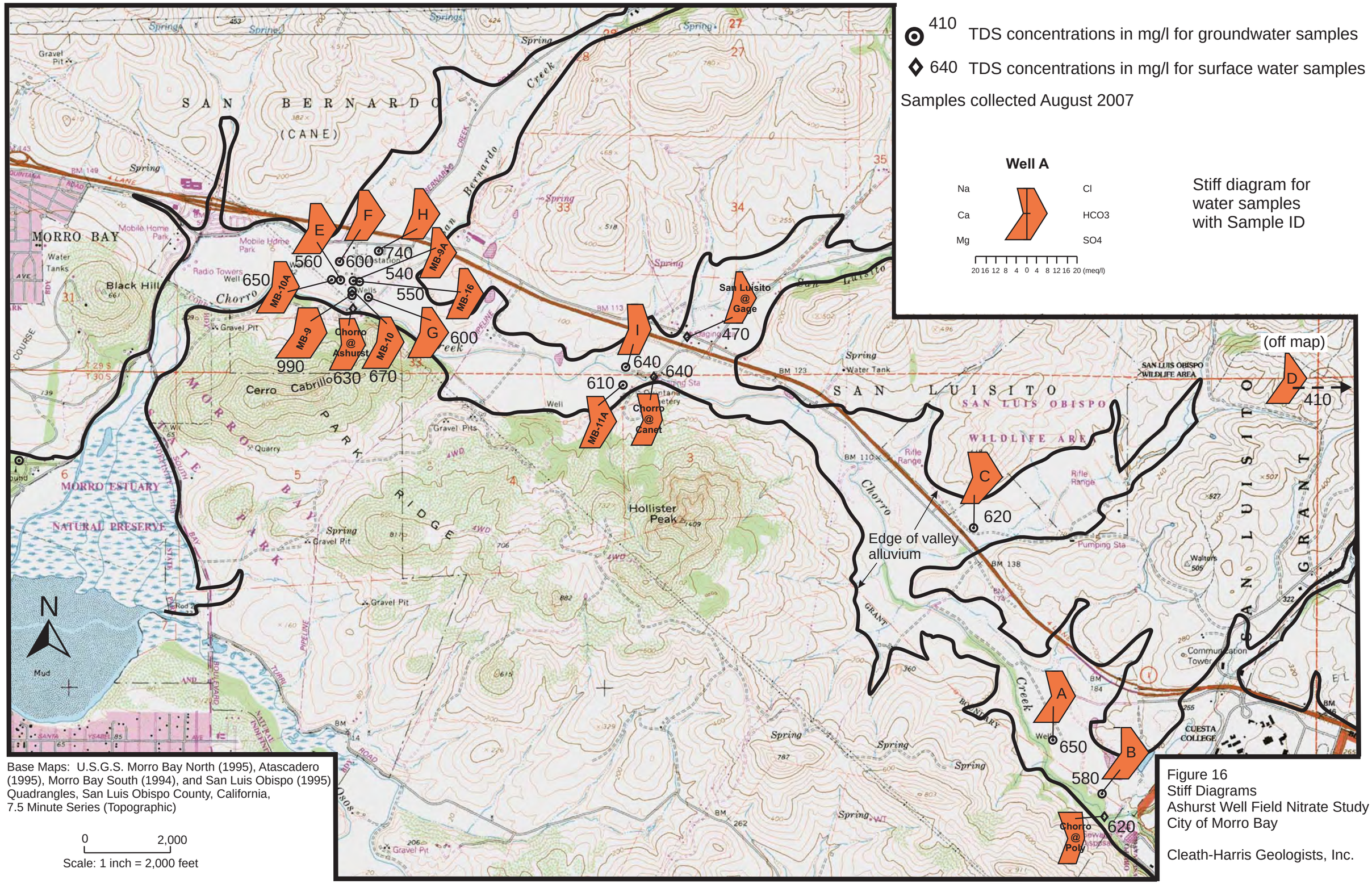


Figure 16
Stiff Diagrams
Ashurst Well Field Nitrate Study
City of Morro Bay

Cleath-Harris Geologists, Inc.

Legend

Surface water:

- Chorro @ Ashurst (8/20/08)
- Chorro @ Canet (8/20/08)
- Chorro @ Poly (8/20/08)
- San Luisito Creek (8/20/08)

City Wells:

- MB-10 (8/20/08)
- MB-10A (9/26/08)
- MB-11A (8/20/08)
- MB-16 (8/20/08)
- MB-9 (8/20/08)
- MB-9A (8/20/08)

Other participating wells:

- Well A (9/17/08)
- Well B (9/17/08)
- Well C (9/17/08)
- Well D (9/17/08)
- Well E (9/17/08)
- Well F (9/17/08)
- Well G (9/17/08)
- Well H (9/17/08)
- Well I (12/19/08)

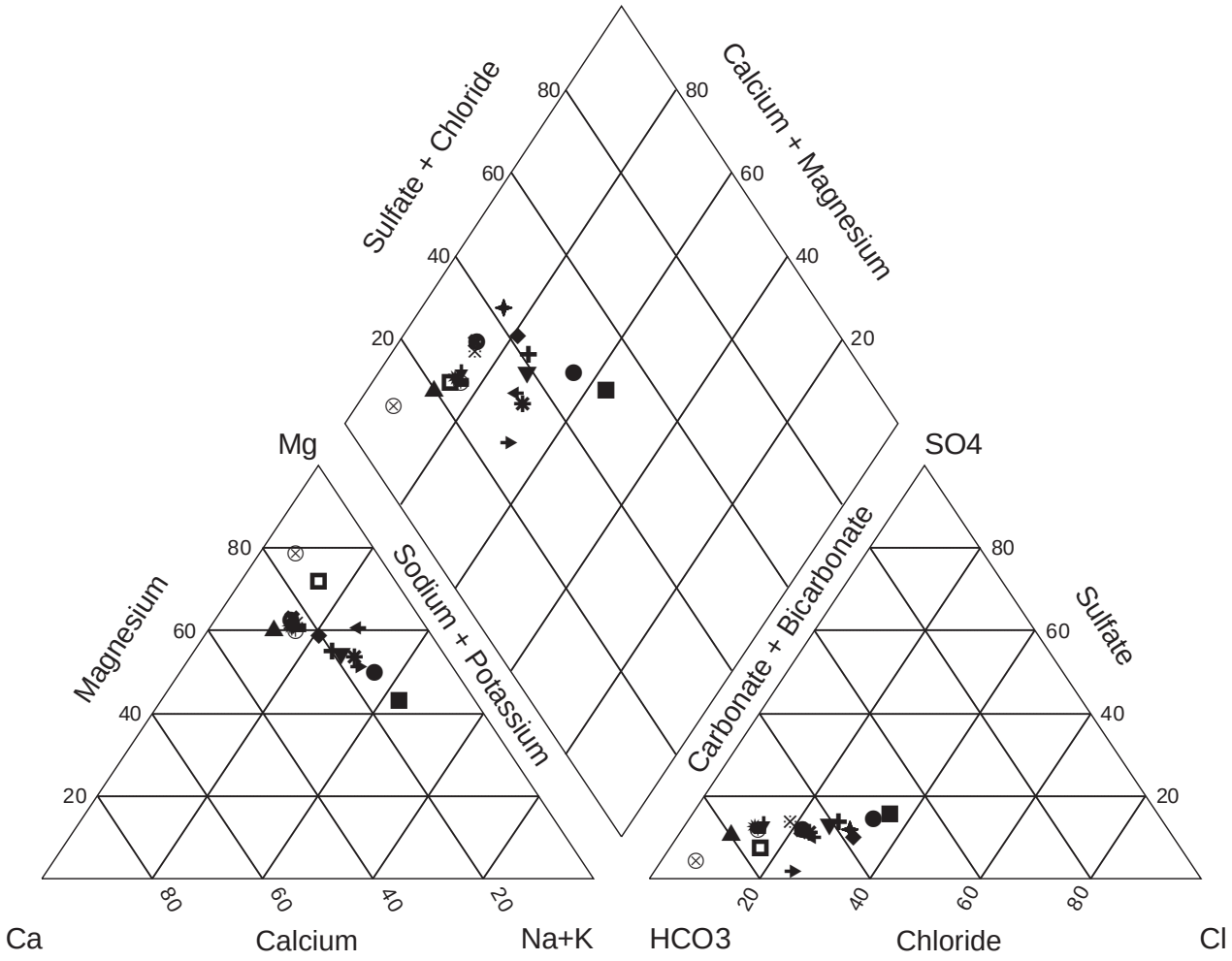


Figure 17
Piper Diagram
Ashurst Well Field Nitrate Study
City of Morro Bay

Cleath-Harris Geologists, Inc.

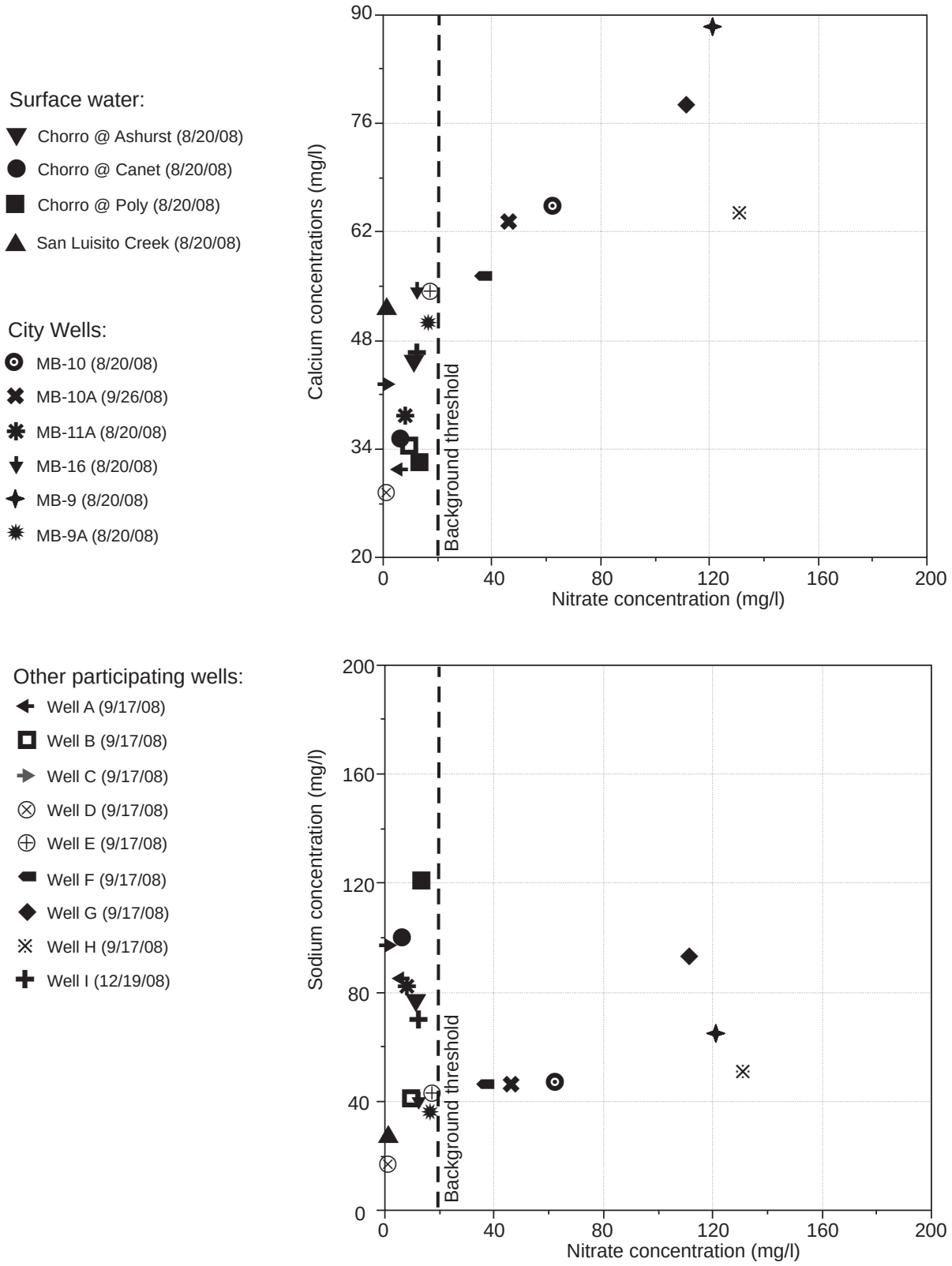


Figure 18
Cation Scatter Diagrams
Ashurst Well Field Nitrate Study
City of Morro Bay

Cleath-Harris Geologists, Inc.

Table 4
Nitrate Isotopes Results

Sample ID	$\delta^{15}N$ ($^0/_{00}$)	$\delta^{18}O$ ($^0/_{00}$)
MB-9	6.3	10.8
MB-10	6.5	12.2

$\delta^{15}N$($^0/_{00}$) : delta nitrogen-15 (per mil)
$\delta^{18}O$($^0/_{00}$) : delta oxygen-18 (per mil)

Stable Isotopes of Water

Oxygen and deuterium isotopes in water can also be useful to groundwater investigations. The importation of state water by the City and other users in the Chorro Valley presents an opportunity for distinguishing source waters based on their stable isotopes.

The ratios of oxygen-18 to oxygen-16 and deuterium to protium (the most common form of hydrogen) in precipitation are dependant on climatic factors, particularly the distance of precipitation events from the coast. These ratios are expressed in delta notation as units per mil. The per mil concentration of stable isotope ratios in sea water is the baseline, and is subtracted from other measured sample values to produce the reported delta value. Therefore, in delta notation, sea water is zero units per mil.

Evaporation off the ocean introduces stable isotopes into meteoric water. All other things being equal, the stable isotope ratios will be greater in earlier precipitation events than later precipitation events from the same storm system due to preferential evaporation of the heavier fractions (oxygen-18 and deuterium). As storm systems coming off the ocean travel inland, the ratio of oxygen-18 and deuterium isotopes in precipitation will lessen with increased distance traveled. Therefore, when the sea water baseline is subtracted, the resulting delta notation values for precipitation will become progressively more negative, or lighter. This variation in isotope concentration with distance from the coast results in differences between local waters on the central coast and state water, which originates in large part from precipitation and snow melt in the northern Sierra Nevada range.

Groundwater samples from wells MB-9 and MB-10 at the Ashurst well field were collected on August 20, 2008 for isotope analyses, and on October 15, 2008, water samples were also collected from MB-16 and MB-10A (Ashurst field), MB-11A (Romero field), the City's Kings Street storage tank, and from Chorro Creek at Cuesta College (upstream of the WWTP).

Analyses of the $\delta^{18}O$ and δD isotope ratios of nitrate in groundwater were performed by Zymax Forensics. The results of the analyses are presented in Table 5.

Table 5
Water Isotopes Results

Sample ID	$\delta^{18}O$ ($^0/_{00}$)	δD ($^0/_{00}$)
MB-9	-5.9	-33.5
MB-10	-6.6	-33.8
MB-10A	-5.2	-32.3
MB-11A	-6.0	-42
MB-16	-5.2	-30.9
Kings Street Tank	-8.6	-59
Chorro @ Cuesta	-5.1	-33

$\delta^{18}O$($^0/_{00}$) : delta oxygen-18 (per mil)
δD ($^0/_{00}$): delta deuterium (per mil)
Samples collected on August 20, 2008 (MB-9 and MB-10) and on October 15, 2008 (remaining samples).

Water in the Kings Street tank (mostly State Water) is the most isotopically light water tested, and is much different from local central coast water, which is represented by Chorro Creek at Cuesta College. The Romero field well, MB-11A, appears influenced by State Water, which would be through basin recharge from the CMC WWTP discharges. State Water is delivered to the California Mens Colony, County facilities, and Cuesta College, all of which use the treatment plant. Ashurst wells MB-10A and MB-16 do not appear to be influenced by State Water, while wells MB-9 and MB-10 have mixed results (lighter oxygen-18 than local water but a similar deuterium isotope ratio). The laboratory analytical reports are included in Appendix E.

Organic Wastewater Constituents

Organic wastewater constituents were tested as an indicator of wastewater influence. The organic wastewater constituents tested for this study include pharmaceuticals, antibiotics, and personal care products that do not have established California drinking water standards. The analytical testing was performed by the University Hygienics Laboratory (UHL) at the University of Iowa.

Groundwater samples from Ashurst field wells MB-9, MB-9A, MB-10, MB-10A and MB-16, and Romero field well MB-11A were collected on October 15, 2008 for organic wastewater constituents analyses. Surface water samples for analysis were also collected on October 15th from Chorro Creek at Ashurst, Chorro Creek at the WWTP (below the treatment plant discharge point), and Chorro Creek at Cuesta (upstream of the WWTP). The results of the analyses are presented below in Table 6.

Table 6
Organic Wastewater Constituents Results

Analyte	Unit	Morro Bay City Wells						Chorro Creek		
		9	9A	10	10A	11A	16	Ashurst	WWTP	Cuesta
Acetominophen	ng/l	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Carbamazepine	ng/l	<1.0	<1.0	<1.0	<1.0	**54**	<1.0	**60**	**110**	<1.0
Caffeine	ng/l	<25	<25	<25	<25	<25	<25	<25	<25	<25
Cotinine	ng/l	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	**1.1**	<1.0	<1.0
DEET	ng/l	<15	<15	<15	<15	<15	<15	<15	**48**	<15
Ibuprofen	ng/l	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Lincomycin	ng/l	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Sulfadimethoxine	ng/l	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Sulfamethazine	ng/l	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Sulfamethoxazole	ng/l	**15**	<1.0	**2.3**	**1.9**	**24**	<1.0	**44**	**8.6**	<1.0
Sulfathiazole	ng/l	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Triclosan	ng/l	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Trimetoprim	ng/l	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Tylosin	ng/l	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0

ng/l = nanograms per liter
all samples collected on October 15, 2008

Two constituents were identified in the groundwater samples, Carbamazepine (at MB-11A), and Sulfamethoxazole (at MB-9, MB-10, MB-10A, and MB-11A). Sulfamethoxazole is a human antibiotic that is commonly combined with another antibiotic, trimethoprim, and used to treat urinary infections. Carbamazepine is an anti-seizure drug use to treat a variety of physical and mental disorders. The concentrations detected are several orders of magnitude below prescription levels.

Carbamazepine and Sulfamethoxazole were also detected in two of the surface water samples (Chorro Creek at the WWTP and Ashurst), along with Cotinine (at Ashurst) and DEET (at the WWTP). Cotinine is a metabolite of nicotine, and DEET (N,N-Diethyl-meta-toluamide) is the active ingredient in insect repellent. Among the six wells tested, MB-11A has the greatest concentration of organic wastewater constituents, which is consistent with prior water isotope data showing an influence from State Water (via the WWTP discharges). Wells MB-9A and MB-16 did not have any detectable organic wastewater constituents, while Sulfamethoxazole only was detected in water from Wells MB-9, MB-10 and MB-10A. Concentrations of sulfamethoxazole in groundwater at Ashurst were greatest in the well closest to Chorro Creek (MB-9) and lowest in the wells farthest from the creek (MB-9A and MB-16), indicating that the creek was the local source for the constituent.

SOURCE OF NITRATE CONTAMINATION

The potential sources of nitrate contamination to groundwater at the City's Ashurst well field include agricultural and turf fertilizers, private septic system discharges, WTTP discharges/overflows, animal operations, and miscellaneous sources. Of these, turf fertilizers, animal operations, and miscellaneous sources are not considered capable of significant contributions to nitrate contamination at the well field. The rationale for eliminating these sources are:

- Turf fertilizers for Cuesta College and Dairy Creek golf course are applied to areas either at the edge of the groundwater basin or outside of the groundwater basin. Fertilizer applications immediately prior to storm events could move some of the nitrogen load into basin deposits through runoff, however, this scenario would be unlikely from a turf management perspective. The turf areas are also a few miles upstream of the City's wells, and there were no elevated nitrate concentrations detected in groundwater from wells between the City well fields and the turf areas.

- Animal operations are distributed at very low density. One or two horses have been in the vacant parcels between well MB-12 and other City wells at the Ashurst well field for several years. Two horses would generate an estimated 240 pounds of nitrogen per year. This is equivalent to the nitrogen fertilizer applied to one acre of truck crops, and is not considered sufficient to significantly affect groundwater nitrate concentrations across the well field. In addition, some of the highest nitrogen concentrations (Wells H and G) are hydraulically upgradient of the horses.

- Miscellaneous sources, including native nitrogen-fixing plants, grading/erosion, and weed abatement have a low nitrogen loading potential compared to other sources, and are not particularly concentrated in the vicinity of the Ashurst well field. Erosion and sedimentation can be significant during some years in Chorro flats, but this is hydraulically downgradient of the well field.

There are three remaining potential sources of nitrate contamination to groundwater, agricultural fertilizer applications, private septic system discharges, and WWTP discharges/overflows. Each of these are considered in greater detail below.

Wastewater Treatment Plant Discharges

Discharges from the WWTP are treated to the standards currently prescribed in the Regional Water Quality Control Board (RWQCB) Order R3-2006-0032, which include maximum daily total nitrogen levels of 10 mg/l as N. The Morro Bay National Estuary Program (NEP) monitors various water quality parameters, including nitrate as nitrogen, in Chorro Creek on a monthly basis. A data summary report for the period from June 2002 through November 2007 shows monthly nitrate as nitrogen (NO_3-N)

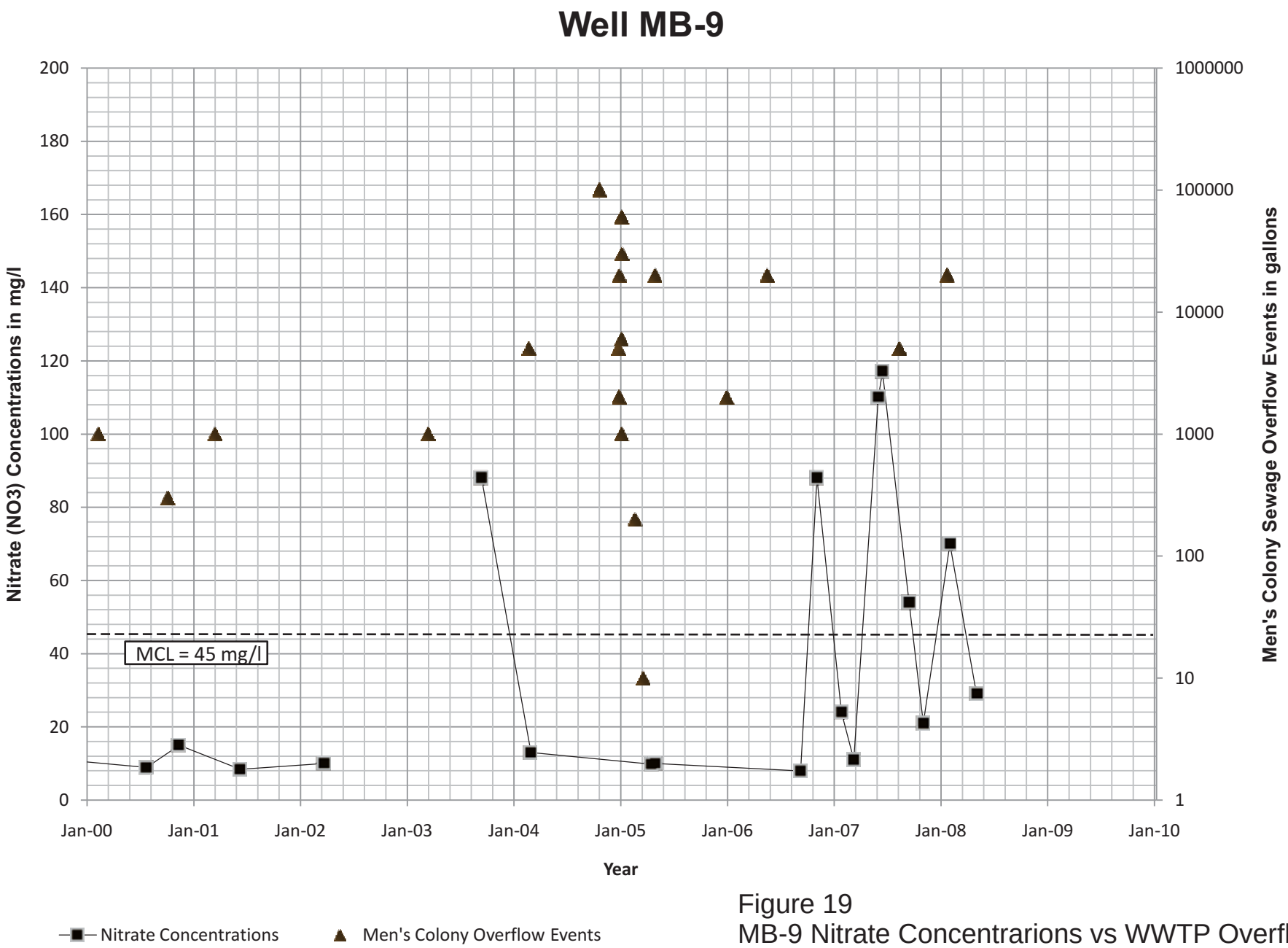
concentrations in Chorro Creek surface flow averaging 0.3 mg/l NO_3-N at the Highway 1 bridge (upstream of the WWTP) and 3.0 mg/l NO_3-N at the Chorro Ecological Reserve (downstream of the WWTP). The maximum monthly nitrate concentration reported by the NEP on Chorro Creek was 9 mg/l NO_3-N (41 mg/l NO_3) at the Chorro Ecological Reserve, which is within the permitted limits (Morro Bay NEP, 2008).

The peak nitrate levels in groundwater in the vicinity of Ashurst were recently measured at 130 mg/l NO_3 (Well H; equivalent to 29 mg/l NO_3-N), which is three times the discharge limit for treated wastewater at the WWTP. Therefore, if the WWTP discharges were the source of elevated nitrate concentrations in groundwater at Ashurst, it would be due to partially treated or untreated sewage spills, rather than the normal discharges. The treatment facility has had violations with respect to the discharge quality, including partially treated or untreated sewage overflows into Chorro Creek. Collection system improvements were completed in 2005, and new treatment facilities were completed in 2007, but most recently in 2008 a release of untreated effluent occurred due to equipment failure.

Despite these infrequent water quality violations at the WWTP, there are several lines of evidence that indicate sewage overflows or otherwise inadequately treated discharges from the facility are not the primary source of nitrate contamination in groundwater at the Ashurst well field. One indication is the lack of recent elevated nitrate concentrations at the Romero well field (MB-11A). Well MB-11A is subject to greater influence from WWTP discharges than wells at the Ashurst field, based on the water isotope and organic wastewater constituents testing. While nitrate concentrations have exceeded the State drinking water standard at Ashurst wells over the last few years, nitrate in groundwater from MB-11A has remained at background levels, despite being the City's most heavily used Chorro basin supply well.

A second indication that the WWTP is not the primary source of high nitrate concentrations at Ashurst is evident when considering the general mineral characteristics of the water samples. Figure 18 compared the relationship between calcium and sodium cations and nitrate concentrations in the samples collected for this study. When nitrate concentrations exceed background levels (20 mg/l NO_3) the calcium concentrations rise above their respective background concentrations, while the sodium concentrations do not. This water quality trend is the opposite of what would be expected from a wastewater source for nitrate. Mineral salt pickup in wastewater during the residential/institutional indoor use cycle is dominated by sodium (and chloride) ions. Calcium is a common soil amendment in agriculture used to improve the drainage capacity of clayey soils.

The timing and volume of spills have also been reviewed to check for correlations between reported sewer overflows and elevated nitrate concentrations at Ashurst well MB-9. Well MB-9 is the closest active Ashurst field well to Chorro Creek and has the highest concentration of organic wastewater constituents among the Ashurst wells. The record of nitrate concentrations at MB-9 and reported sewer overflow events at the WWTP is shown in Figure 19.



Overflow event durations not reported (gallons only)

Figure 19
MB-9 Nitrate Concentrarions vs WWTP Overflows
Ashurst Well Field Nitrate Study
City of Morro Bay

Cleath-Harris Geologists, Inc.

During overflows from the wastewater collection, treatment, and disposal facilities, raw or partially treated wastewater has been discharged into Chorro Creek. The RWQCB provides a database of these overflow events including dates of occurrence, volumes of overflow, and descriptions of the events (Integrated Water Quality System Project's Facility-at-a-Glance Report, Place ID 212681).

The period of record for the graph in Figure 19 includes nitrate concentration spikes at MB-9 from 2000 to May 2008. The elapsed time between an overflow event and a water sampling date ranges from one day to six months. The duration of overflow events are not reported, but are assumed to typically last less than one day. The graph shows no corresponding rise in nitrate concentrations following an overflow event. Following the high nitrate concentrations at MB-9 in November 2006, concentrations decreased during January and March 2007, then increased again to over 100 mg/l NO_3 in June 2007. There were no overflow events reported between November 2006 and June 2007, indicating the nitrate spikes are not related to wastewater overflows from the WWTP.

Additional points that indicate sewage spills are not the main source of nitrate contamination at Ashurst include:

- The lack of any evidence of wastewater influence, either from general mineral character, organic wastewater constituents testing or water isotopes results, at well MB-16, where nitrate levels of up to 63 mg/l NO_3 were recently measured.

- Wells sampled immediately downstream of the WWTP (Wells A and B) do not show any significant nitrate contamination - in fact none of the wells sampled upstream of the Ashurst/Chorro Creek Road area showed significant nitrate concentrations (Figure 15)

- The well with the greatest nitrate concentration measured, Well H (130 mg/l NO_3), has a magnesium-calcium bicarbonate character which precludes significant wastewater influence.

- The volume of sewer overflows are not significant with respect to nitrogen mass loading, as compared to other potential sources.

Private Septic System Discharges

Overall, the density of private residential septic systems in the Chorro Valley is low, and would not be perceived as a threat to basin water quality. Near the Ashurst well field, however, is a community septic system that serves a local homeless shelter. Concerns regarding the potential impacts on the well field from the shelter date back to the early 1970's, when San Luis Obispo County was issuing permits for the facility.

The septic system for the shelter, which currently serves a nominal two dozen residents, but has had a reported population of up to 100 in the past, is currently west of the main building, approximately 200

feet hydraulically upgradient of well MB-10A. If the facility has a significant impact on local water quality, well MB-10A would be the first place to look.

Nitrate concentrations at MB-10A are elevated, with recent measurements of 45 mg/l and 58 mg/l NO_3. Total ammonia was also detected at 0.4 mg/l, which is slightly above the laboratory reporting limit of 0.3 mg/l. Ammonia is not commonly reported in groundwater, as the compound typically oxidizes to nitrate, and its presence indicates a nearby source, such as a septic leach field.

The fact that total ammonia was detected at MB-10A, and no other City well at Ashurst, is evidence that this well is hydraulically downgradient of the shelter's leach field, which is presumably the source of the ammonia. The concentration of total ammonia detected is only a trace. Nevertheless, it presents the possibility that some of the nitrate at well MB-10A originated from local septic discharges.

Well MB-10A has only been used for sampling purposes (not water supply) since before state water deliveries, and was sampled for stable isotopes of water, organic wastewater constituents, and nitrate on October 15, 2008. The nitrate concentration was elevated at 58 mg/l NO_3. Organic wastewater constituents results show a trace of sulfamethoxazole in MB-10A, but that is probably related to Chorro Creek recharge, given the distribution at Ashurst as reported in Table 6 (greater concentrations closer to Chorro Creek). The stable isotopes of water show no significant association between water from well MB-10A and state water which was the predominant water source for the facility at the time of testing.

The shelter (and other local residences) receive water from the City of Morro Bay. During 2008, that water would have been from well MB-11A (Romero field), from state water, or a blend of the two, depending on the timing of MB-11A pumping and local water demand (production at the Ashurst well field in 2008 was not significant, at less than 10 percent of the Romero production). Therefore, the shelter would have been receiving water with a substantially different average isotope ratio from local waters, since both state water and MB-11A have been shown to have isotopically lighter water (Table 5).

Given a local background nitrate concentration of 20 mg/l NO_3, a significant percent of the water from MB-10A would need to originate from a septic source to produce water with a nitrate concentration of 58 mg/l NO_3. This is not supported by the water isotope data. Well MB-10A also has a magnesium-calcium bicarbonate character, which suggests limited septic/wastewater influence.

The only evidence for potential nitrate contamination at Ashurst wells by local septic systems is the trace of ammonia detected at MB-10A. Trace amounts of organic wastewater constituents at the well field are interpreted to be related to the influence of the WWTP discharges on Chorro Creek.

Outside of the homeless shelter, the local density of single-family septic systems is too low to impact nitrates across the well field, including private irrigation Wells G and H. These two wells are hydraulically upgradient of the shelter and most other residences, yet have the highest nitrate

concentration in the recent water quality survey. Private septic systems are not considered the primary source of nitrate contamination at the Ashurst well field, based on the available information.

Agricultural Fertilizer Applications

Annual fertilizer applications on crops in the Chorro Valley are estimated to contain approximately twice the nitrogen mass of all the other potential sources combined. Nitrate contamination in groundwater from agricultural fertilizers has been documented previously at the City's Highway 1 well field in the Morro Basin (Cleath & Associates, 2007). Both the Highway 1 well field and the Ashurst well field are hydraulically downgradient of large-acreage parcels of intensively farmed truck crops. It is not a coincidence that the data for this nitrate study also indicates the primary source of nitrate contamination is agricultural fertilizer applications.

Land Use

Nitrate concentrations in groundwater samples collected during this study are less than 15 mg/l NO_3 in the Canet Road area and points upstream (Figure 14). Based on the nitrate data, and the regional hydraulic gradient, which is toward the estuary, the source of nitrate contamination appears to be somewhere between Canet Road and Chorro Creek Road. This is also where there is the greatest concentration of irrigated agriculture in the Chorro Valley and, consequently, substantial fertilizer applications.

Nitrate concentrations in City wells at both the Ashurst and Romero fields began exceeding the State drinking water standard regularly on a seasonal basis in the late 1980's and early 1990's. More recently, however, only the Ashurst field wells have been impacted by nitrate contamination. The recent differences between nitrate concentration at Ashurst and Romero are interpreted to be due primarily to the change in land use immediately upstream of the Romero field, where farming was phased out at Chorro Valley Ranch (now the Chorro Ecological Reserve).

General Mineral Water Quality

As mentioned earlier, general mineral water quality at the Ashurst well field is predominantly magnesium-calcium bicarbonate, and mixing with sources of wastewater would increase the sodium chloride content. When nitrate concentrations are correlated with calcium and sodium concentrations, the samples with elevated nitrate concentrations do not show any increase in sodium, but do show an increase in calcium. Calcium is a common soil amendment in agriculture used to improve the drainage capacity of clayey soils.

Nitrate Isotope Results

Nitrate isotope results were presented in Table 4. The interpretation of the isotope data is presented in Figure 20, which shows the stable isotope results for the City's Ashurst wells MB-9 and MB-10 with respect to potential sources and their respective enrichment products.

The shaded areas represent stable isotope ratios that could be derived from 100 percent manure and septic system/sewer plant effluent (lower graph area) or 100 percent synthetic nitrate fertilizer applications (upper graph area). The City well field isotope values plot between these shaded areas.

A range of stable isotope values for soil organic matter nitrate is also included in Figure 20. Soil organic matter from decaying vegetation is a potentially significant source of nitrate in the Chorro Valley. Ultimately, this source of nitrate is directly linked with agricultural fertilizer, representing a secondary phase of the nitrogen cycle. As such, the potential nitrogen loading from agricultural fertilizer applications includes input from crop residue and soil organic matter.

The possible sources of nitrate contamination to groundwater at the City's Ashurst well field, based on the isotope data, are interpreted to be:

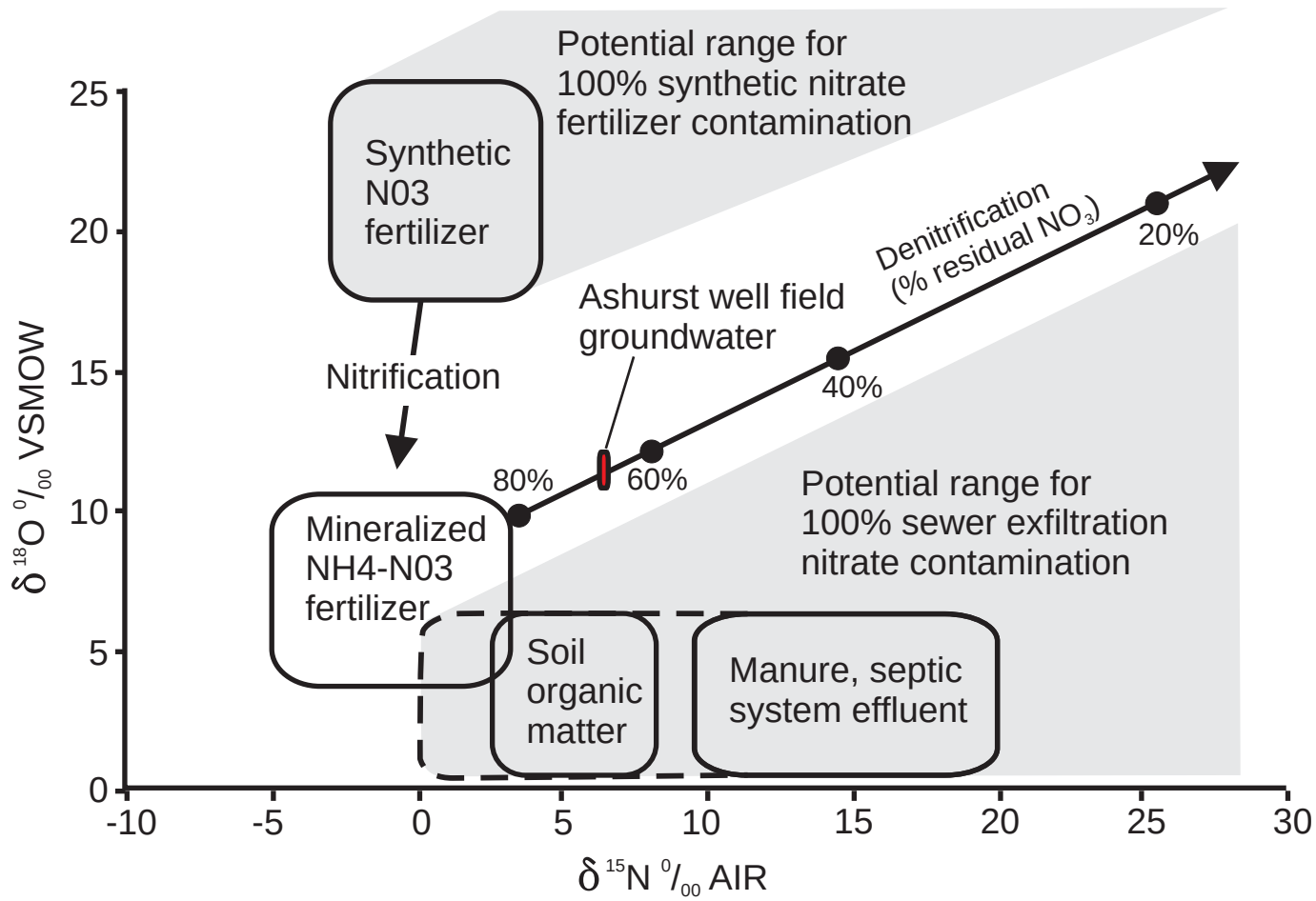
- Exclusively from ammonium fertilizer applications
- Mixtures of synthetic nitrate and ammonium fertilizer applications
- Mixtures of sewer overflow/septic returns and fertilizer applications

Figure 20 also includes a line showing the percent of residual NO_3 in groundwater following denitrification (with associated isotope fractionation) of nitrate loading from an ammonium nitrate fertilizer source. The City well field isotope values plot along this line at 35 percent denitrification (65 percent residual). For nitrate concentrations of up to 120 mg/l at the well field, the corresponding concentration of nitrate in groundwater beneath a hydraulically upgradient ammonium nitrate fertilizer source would be approximately 185 mg/l.

Recharge Dynamics

The dynamics of recharge at the Ashurst field involve four major sources, each of which have a unique hydraulic connection to the well field. These four sources of recharge are subsurface inflow, Chorro Creek stream seepage, San Bernardo Creek stream seepage, and San Luisito Creek stream seepage.

As previously discussed, Chorro Creek seepage is limited by shallow clays at Ashurst. Seepage from Chorro creek can be induced by well field production, but approaches a steady-state value which is only a fraction (close to 20 percent) of the total well field production, based on stream flow interference testing.



Modified from Clark and Fritz (1997) to extend range of septic system / sewer exfiltration based on Kendall (1998)

$\delta^{18}O$ values for nitrate vary according to the values of local groundwaters. Ranges shown are for groundwater with $\delta^{18}O$ (H_2O) values of -10°/₀₀ (Clark and Fritz, 1997).

Figure 20
Nitrate Isotope Data Interpretation
Ashurst Well Field Nitrate Study
City of Morro Bay

Cleath-Harris Geologists, Inc.

San Bernardo Creek seepage is negligible through the shallow clays, but there is a strong hydraulic connection through a buried channel which connects to the present-day channel near Highway 1, based on stream flow observations. During periods of seasonal runoff from the watersheds, the contribution of recharge from San Bernardo Creek to the Ashurst well field exceeds the steady-state potential of Chorro Creek. This would explain why seasonal water levels can recover rapidly at the well field, but historically are also below the invert of Chorro Creek for extended periods, despite significant flow in Chorro (from the WWTP).

Subsurface inflow from the east (down the valley) occurs year-round, but increases seasonally due to well field production, which increases the hydraulic gradient toward the well field. The amount of subsurface inflow can exceed the steady-state leakage capacity of Chorro during periods of well field production when San Bernardo Creek is not contributing recharge.

When the source of nitrate contamination as fertilizer is incorporated into the recharge dynamics model, the overall well field trends, and even some of the individual well trends, begin to make sense. The nitrate contamination is interpreted to be transported to the Ashurst well field by subsurface inflow from the east. Therefore, the periods when subsurface inflow contribution to recharge is greatest, which is historically when water levels are lowest, are when the nitrate contamination has spiked.

When state water arrived in Morro Bay in late 1997, production at the well field declined significantly, and seasonal water level fluctuations were muted. The hydraulic gradients were flatter, and subsurface inflow (and nitrate concentrations) declined to background levels. Fertilizer applications in the Chorro Valley also appeared to decline between 1995 and 2001, with much of this due to the phasing out of intensive agriculture at Chorro Valley Ranch.

Perplexing trends in nitrate concentrations have developed at the Ashurst well field in recent years, where levels have spiked higher than ever before, during a period of relatively high water levels. In addition, nitrate concentrations fluctuate differently at different wells, and have reversed some historical trends.

For example, at wells MB-9 and MB-10, nitrate concentrations began to moderately exceed State drinking water levels in the mid-1990's, declined to background levels after 1997, and now are spiking at levels two to three times the standard. In contrast, wells MB-9A and MB-10A began exceeding the State drinking water standard in 1985, several years before MB-9 and MB-10, reaching levels double the standard by the mid-1990's. Following the return to background nitrate concentrations after 1997, the recent spikes in nitrate concentrations have been significantly lower at MB-9A and MB-10A, a reverse of the historical record.

Recharge dynamics offers a potential explanation. Wells MB-9 and MB-10 are closer to Chorro Creek, and results of water quality testing indicate a greater hydraulic connection with Chorro than Wells MB-9A and MB-10A. During periods of lower water levels, while subsurface inflow dominates recharge to the well field as a whole, the distribution of recharge from Chorro Creek is skewed toward wells MB-

9 and MB-10, which historically has diluted nitrate concentrations at those wells, compared to wells MB-9A and MB-10A.

The trend has recently been reversed, however, with nitrates higher at MB-9 and MB-10, compared to MB-9A and MB-10A. This is interpreted to be due to the influence of San Bernardo Creek. The buried channel from San Bernardo Creek to the Ashurst well field area can transmit water at a higher pressure head than any other source (the elevation of the creek invert at Highway 1 is approximately 10-15 feet higher than ground surface at the Ashurst well field). Therefore, when the well field is not being pumped, recharge with low nitrate concentrations from San Bernardo Creek will tend to displace other sources of recharge.

Surface flows in San Bernardo Creek have nitrogen levels averaging 0.6 mg/l NO_3-N (Morro Bay NEP, 2008a) and conductivity averages 850 microsiemens (Morro Bay NEP, 2008b), which is equivalent to approximately 510 mg/l as total dissolved solids (TDS), based on local salinity correlations. The wells with the lowest salinity at Ashurst also had the lowest nitrate concentrations. Well E (560 mg/l TDS; 16 mg/l NO_3), MB-9A (540 mg/l TDS; 15 mg/l NO_3), and the first sample at MB-16 (550 mg/l TDS; 11 mg/l NO_3) are interpreted to have a greater influenced from San Bernard Creek recharge (through the buried channel) than the other wells, at least during periods of limited well field production. At well MB-9 and MB-10, where TDS concentrations were 990 mg/l and 670 mg/l, respectively, subsurface inflow is interpreted to be the dominant source of recharge during periods of well field inactivity, resulting in greater nitrate concentrations at these wells.

The effects of San Bernardo Creek recharge on nitrate concentrations at Ashurst under the post-State Water Project hydraulic regime are probably even more complex than described above. Not only are there lateral variations, but there are also likely vertical variations in both nitrate concentrations and pressure head. Overall, however, the general trends in nitrate concentrations can be explained by recharge dynamics if nitrate contamination at the well field is primarily from subsurface inflow, which would be the case for an agricultural fertilizer source.

CONCLUSIONS

The results of this study indicate that the main source of nitrate contamination in groundwater at the City's Ashurst well field is from nitrogen fertilizer applications associated with agricultural operations in the Chorro Valley between Canet Road and Chorro Creek Road. Historical land use trends, water quality trends (including general mineral and stable isotope analyses), and recharge dynamics in the basin all support this conclusion. The data also indicates that discharges/overflows from the California Mens Colony WWTP and local septic systems are not a major source of nitrate contamination in groundwater at the well field, although MB-10A may be subject to contamination from an adjacent private septic system.

MITIGATION

There are two basic options for mitigating the problem of elevated nitrate contamination in groundwater at the City's Ashurst well field. These options can be combined, and are:

- Reducing nitrogen loading from agricultural fertilizer applications; and
- Reducing nitrates in produced groundwater by treatment/blending.

The option for reducing nitrates by reducing agricultural nitrogen applications could take several years to effect appreciable decreases in groundwater nitrate concentrations at the Ashurst well field, or longer before these concentrations would consistently meet drinking water standards. Reducing nitrogen fertilizer use involves participation by Chorro Valley farmers.

A compilation of management goals and practices for cool-season vegetables, such as those grown in the Chorro Valley, is included in Appendix I (UC Publication 8097, 2003). This publication addresses nitrogen fertilizer applications and is designed to fit within the framework of the farm water quality management plan, which is required of local farm operators by the Central Coast Regional Water Quality Control Board under Order No. R3-2004-0117.

The option for reducing nitrates by treatment/blending at the wellhead would not reduce the actual nitrate concentrations in groundwater at the well field. Groundwater treatment during State Water Project shutdowns or other periods during which water production from the City's Ashurst well field is needed for community water demands could be used as an interim measure while the first option is implemented.

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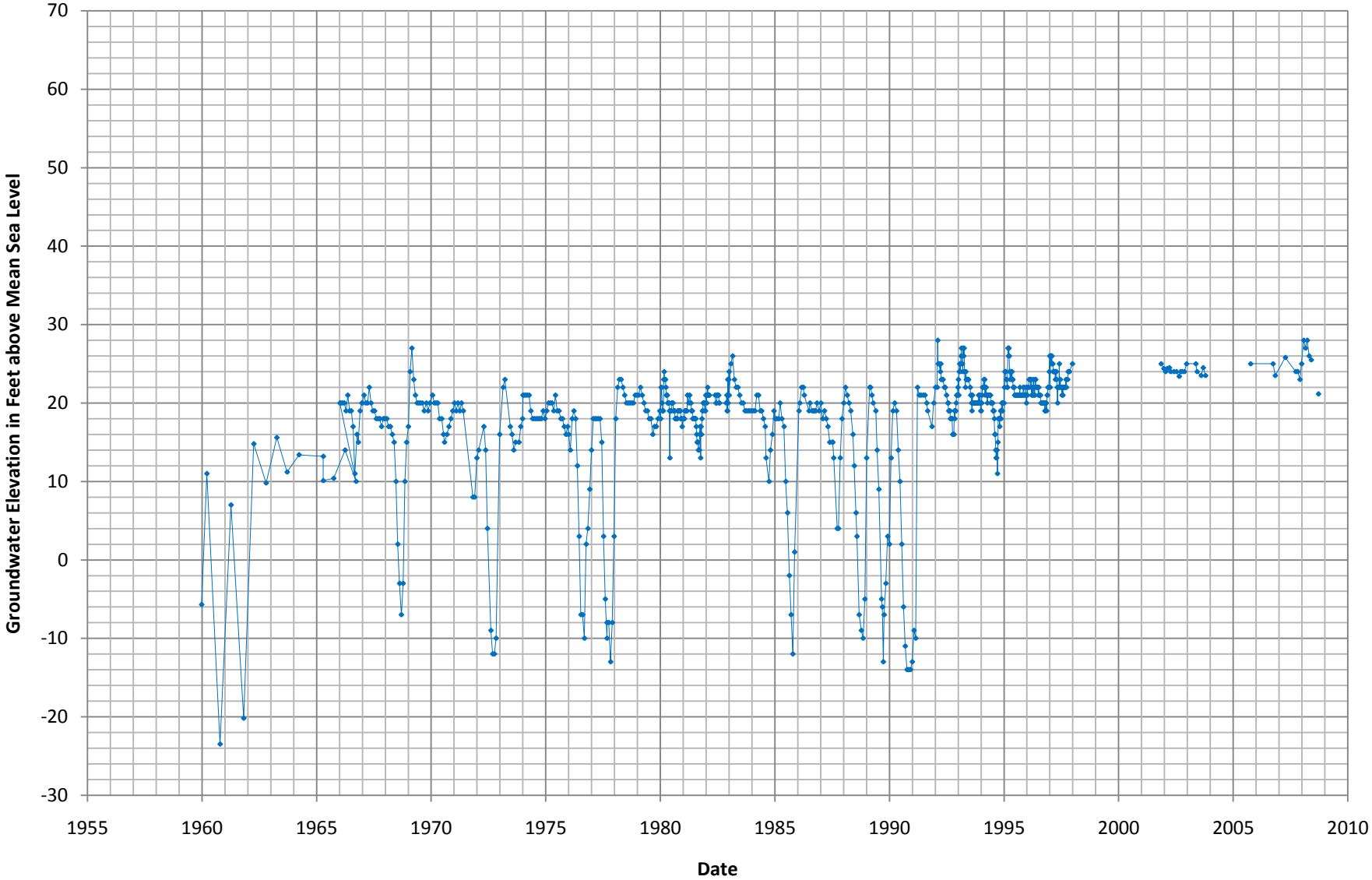
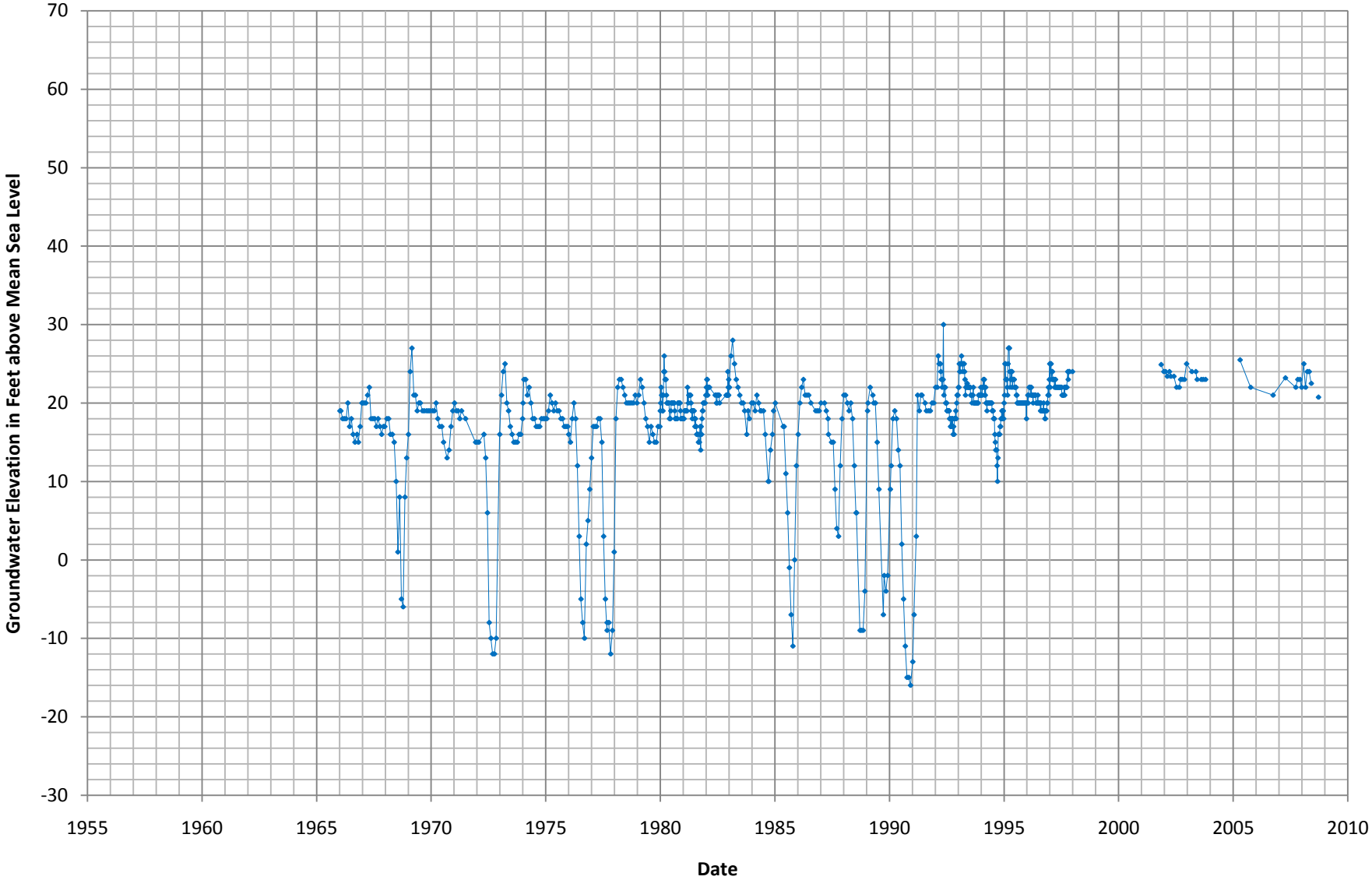
APPENDIX A

Well Field Hydrographs

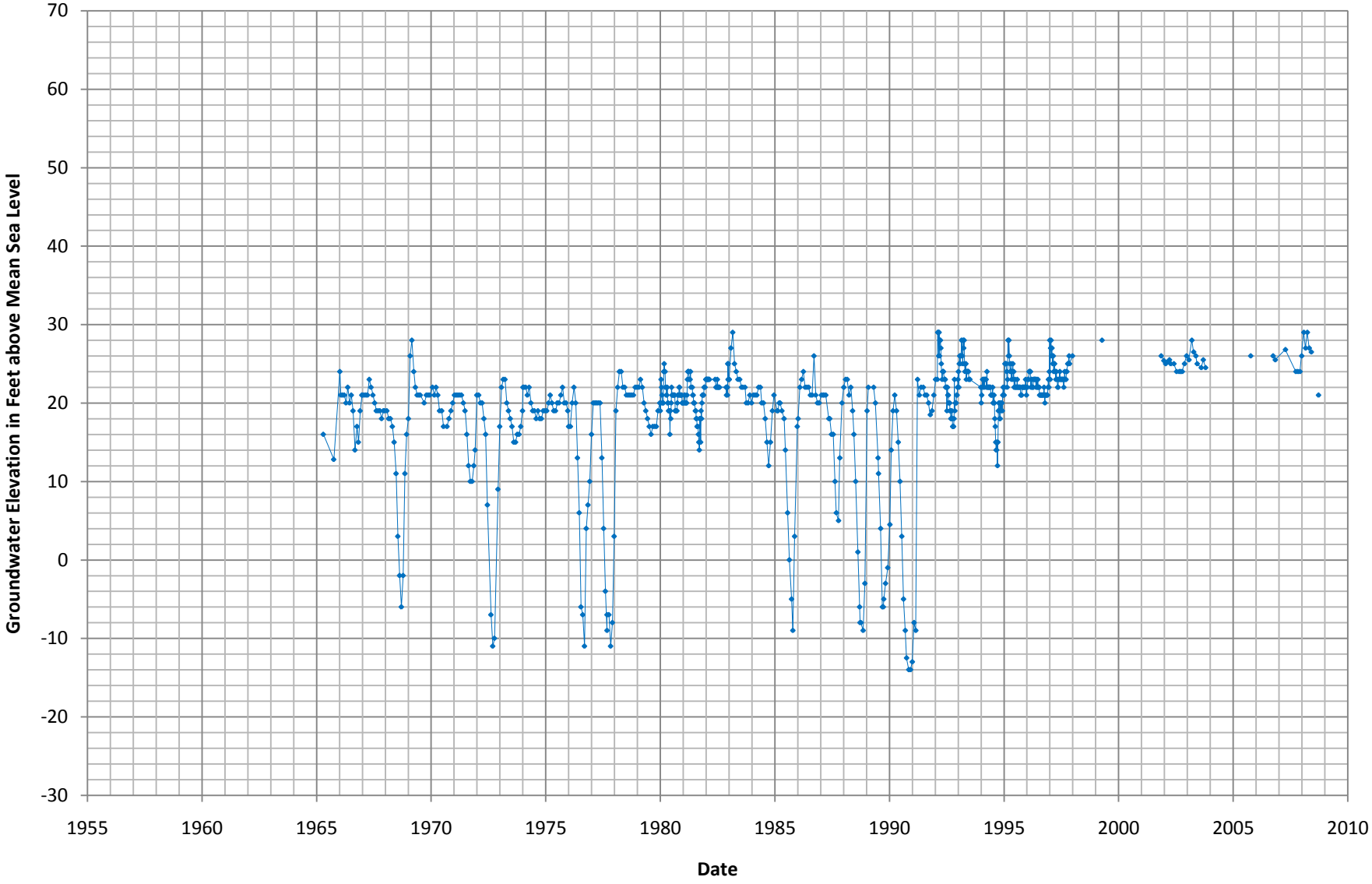
Water Level Hydrograph
Well MB - 9



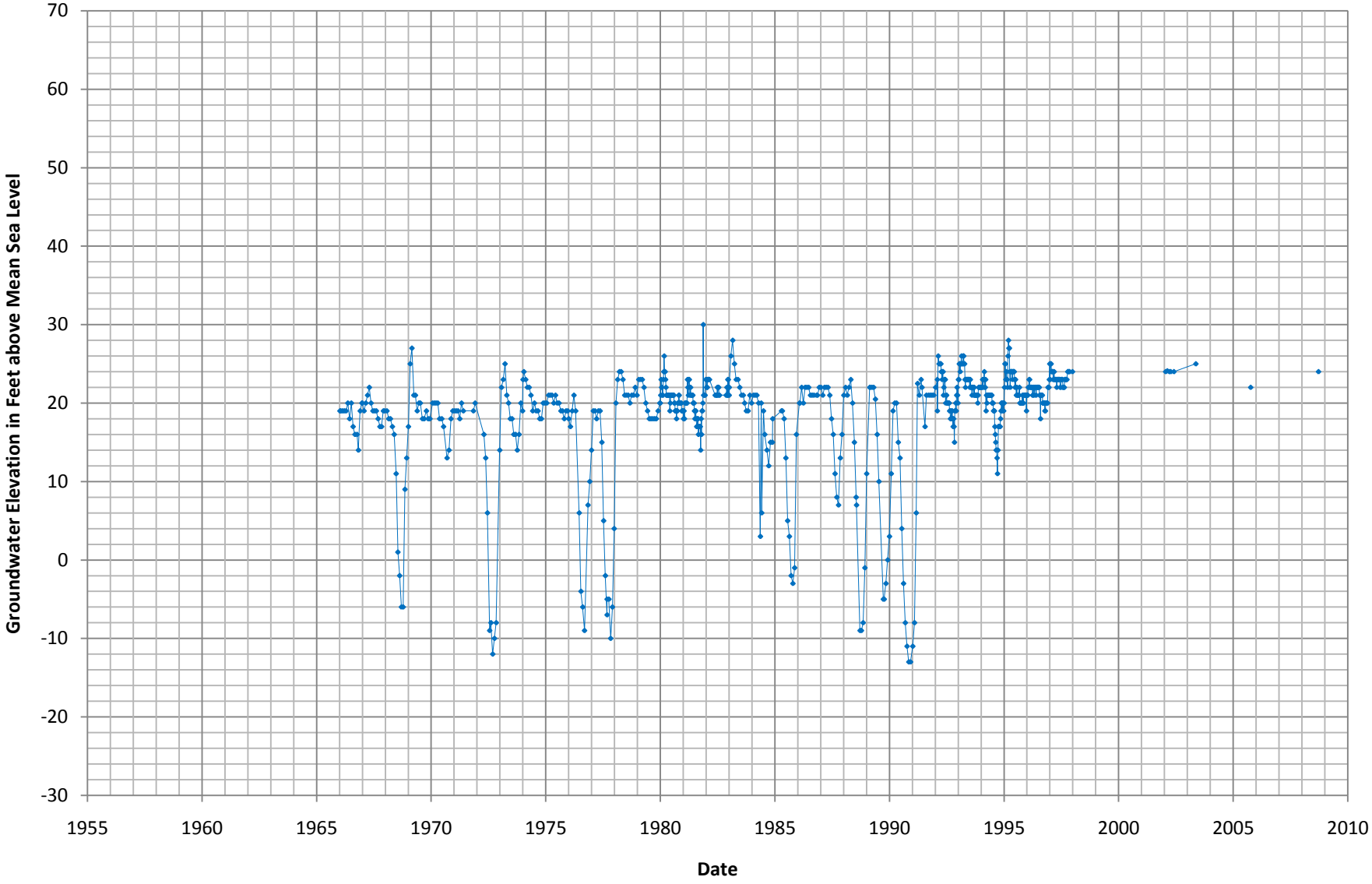
Water Level Hydrograph
Well MB - 9A



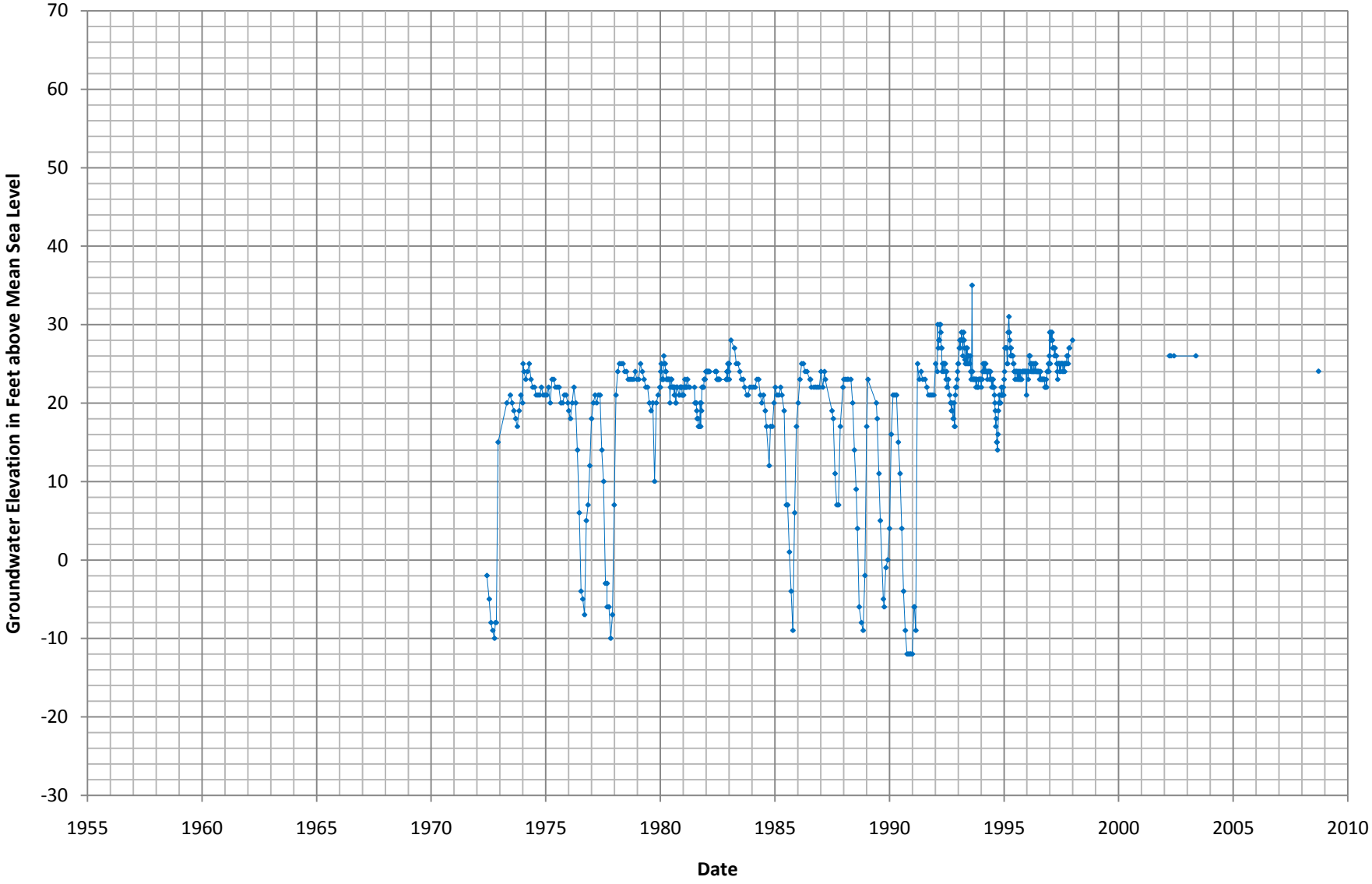
Water Level Hydrograph
Well MB - 10



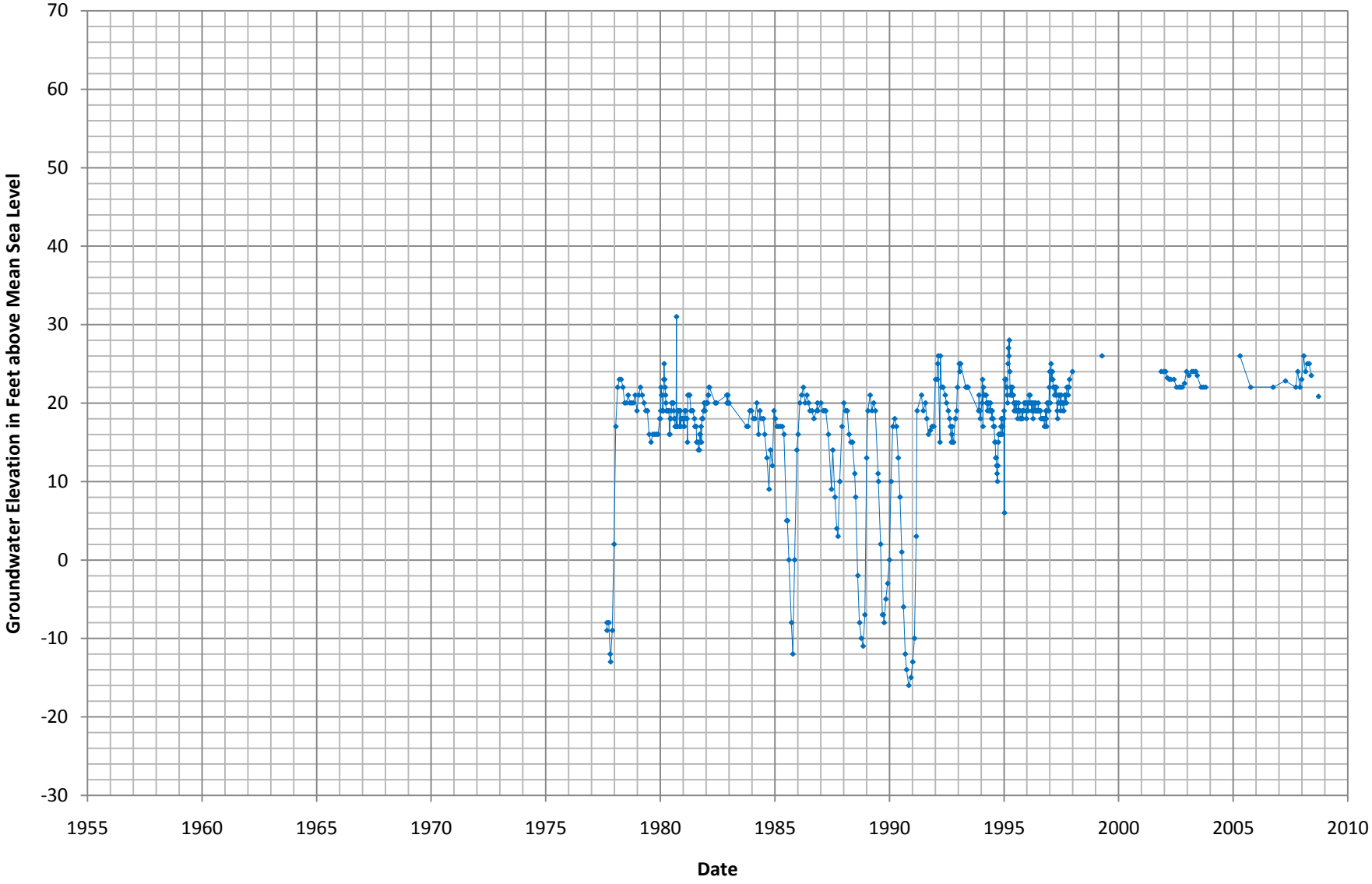
Water Level Hydrograph
Well MB - 10A



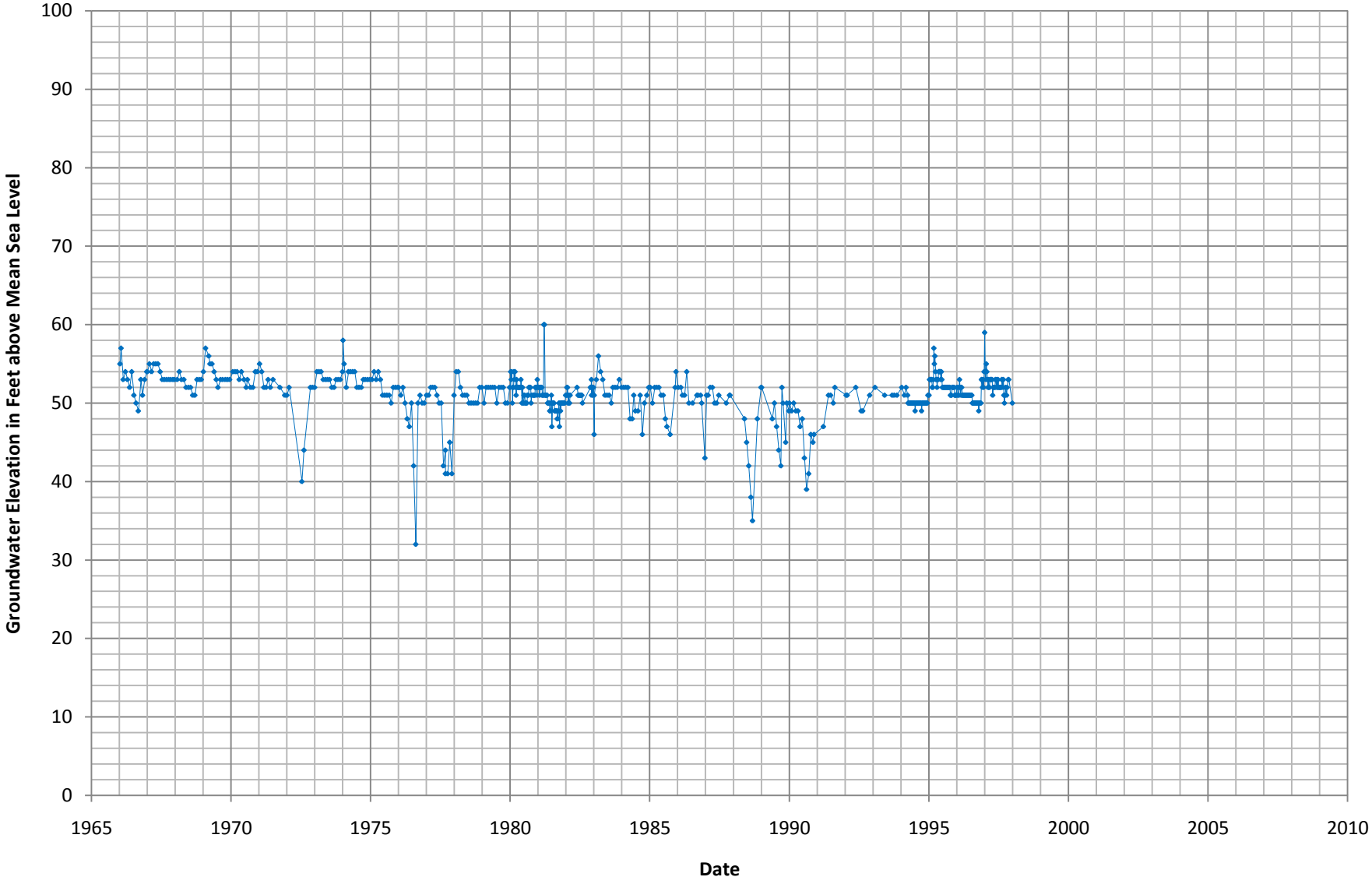
Water Level Hydrograph
Well MB - 12



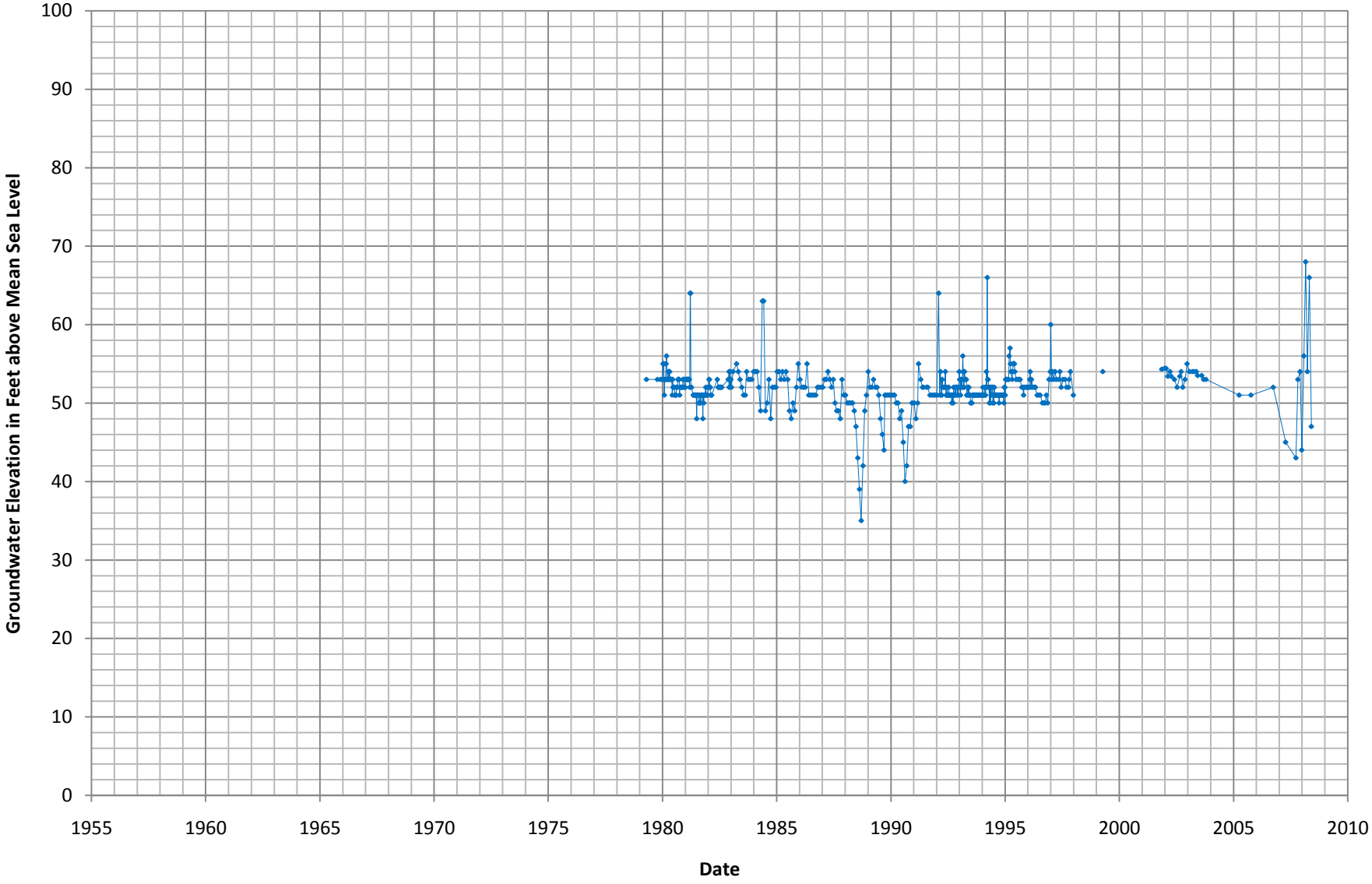
Water Level Hydrograph for Well MB - 16



Water Level Hydrograph
Well MB - 8

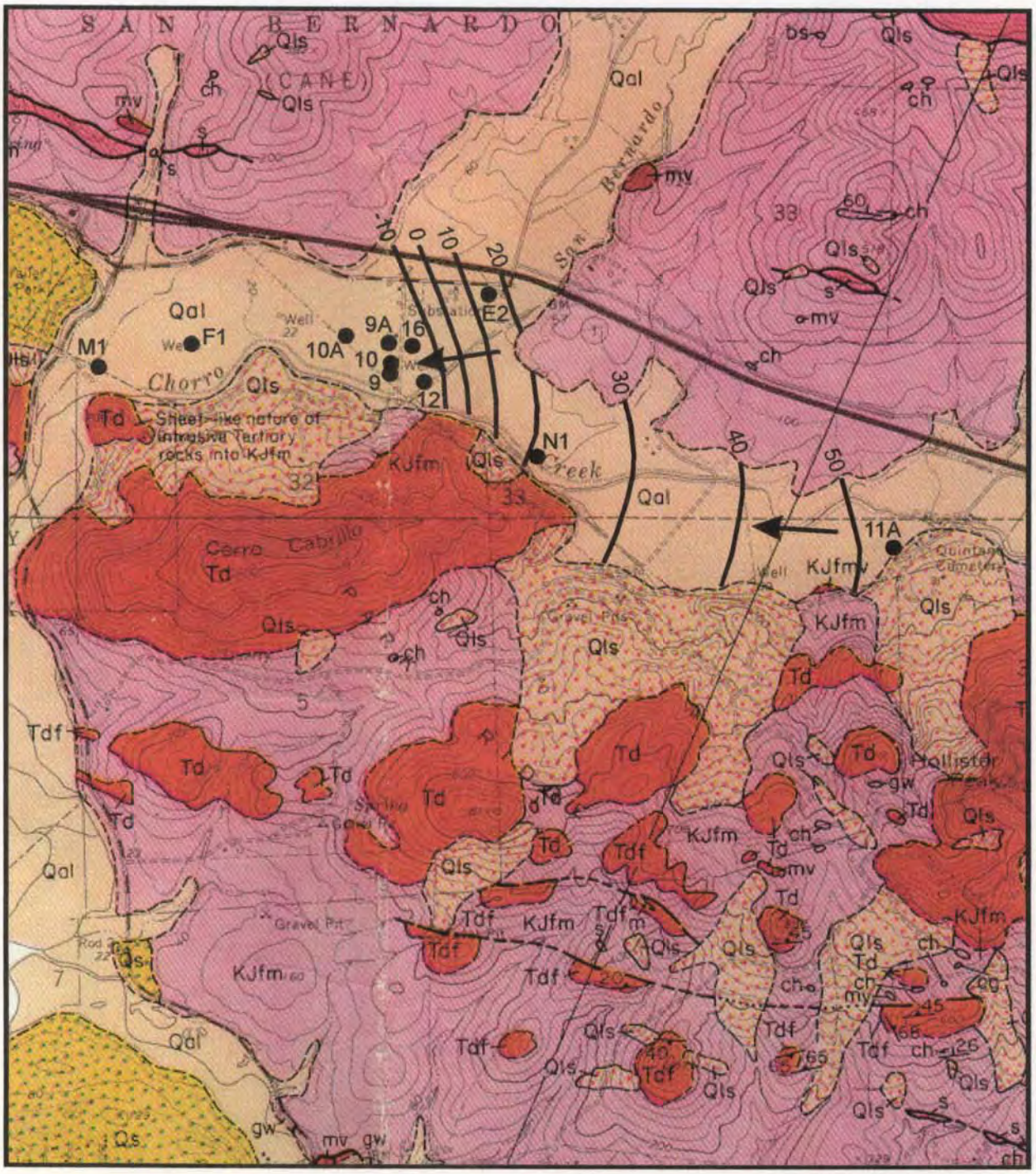


Water Level Hydrograph
Well MB - 11A



APPENDIX B

October 1990 Groundwater Elevation Contour Map



Base Map: Geologic Map of the San Luis Obispo-San Simeon Region, California, C.A. Hall, 1979, USGS Misc. Investigations Series, Map I-1097
Scale: 1 inch = 2,000 feet

Qal Alluvial deposits

30 Ground water elevation contour

Ground water flow direction

F1 Well location and designation

City of Morro Bay Drinking Water Source Assessment

Ground Water Contours In October 1990 Chorro Basin

Cleath & Associates
June, 2001

APPENDIX C

City Well Field Production in Chorro Basin

City Well Production in Chorro Basin
1966-2007

Year	Ashurst Field	Romero Field	Total
1966	429	181.6	611
1967	479.3	50.8	530
1968	568.8	73.5	642
1969	478.3	280	758
1970	534.3	267	801
1971	563.1	335.8	899
1972	450.2	460.4	911
1973	749	153.9	903
1974	840.4	98.5	939
1975	678.7	235.2	914
1976	497.8	496	994
1977	456.8	375.5	832
1978	365.1	597.9	963
1979	891.7	179.7	1071
1980	869.1	209.6	1079
1981	521.9	621.4	1143
1982	376.8	682.4	1059
1983	614.7	378.8	993
1984	658.7	438.2	1097
1985	834.7	273.6	1108
1986	508.9	549.8	1059
1987	831.6	313.7	1145
1988	449.5	670.1	1120
1989	430.2	617.7	1048
1990	315.4	644.5	960
1991	271.5	536.2	808
1992	429.3	619.7	1103
1993	506.4	488.1	995
1994	566	404.9	971
1995	673.5	338.5	1012
1996	896.5	371.7	1268
1997	788.3	218.9	1007
1998	29.3	9.2	39
1999	24.6	9.5	34
2000	0.8	0.2	1
2001	0.6	10.8	11
2002	0.7	0.2	1
2003	0.4	3.1	4
2004	0	48.6	49
2005	0	203.5	204
2006	20.7	236.6	257
2007	32.5	243.9	276
2008	16.3	167.3	184

APPENDIX D

Nitrogen Loading Factors

Nitrogen Loading Calculations
Chorro Valley

Farmed acreage

	1977	1985	1995	2001	2008
Truck (except peas)	32	41	231	153	235
Peas	0	176	238	39	28
Field	235	335	0	0	0
Pasture	84	70	0	12	12
Orchard	0	0	0	50	10
Vineyard	0	0	0	55	110
Total	351	622	469	309	395

Harvested acreage separated by N categories

multiplier (truck)	2	2	2	2	2
multiplier (peas)	1.5	1.5	1.5	1.5	1.5
Truck (except peas)	64	82	462	306	470
Peas	0	264	357	58.5	42
Field	235	335	0	0	0
Pasture	84	70	0	12	12
Orchard	0	0	0	50	10
Vineyard	0	0	0	55	110
Total	383	751	819	481.5	644

N loading unit rates (#N per acre)

Truck (except peas)	200	200	200	200	200
Peas	100	100	100	100	100
Field	200	200	200	200	200
Pasture	0	0	0	0	0
Orchard	100	100	100	100	100
Vineyard	25	25	25	25	25

Gross N loading (#/year)

	1977	1984	1995	2001	2008
Total	59800	109800	128100	73425	101950

APPENDIX E

Laboratory Reports for Groundwater and Surface Water Samples

CREEK ENVIRONMENTAL LABORATORIES, INC.
A Minority-owned Business Enterprise
141 SUBURBAN ROAD, SUITE C-5 • SAN LUIS OBISPO, CA 93401 • (805) 545-9838 • FAX (805) 545-0107

Spencer Harris
Cleath & Associates
1390 Oceanaire Drive
San Luis Obispo, CA 93405

Log Number: 08-C11517
Order: P4299
Project: Chorro Nitrate Study
Received: 08/20/08
Printed: 08/29/08

REPORT OF ANALYTICAL RESULTS

Sample Description	Sampled By	Sampled Date @ Time	Matrix
Well 9	Spencer Harris	08/20/08@13:20	Drinking Water

Analyte	Result	DLR	Dilution Factor	Units	Method	Date Analyzed	Date Prepared	Batch
Total Alkalinity as CaCO3	440	2	1	mg/L	SM 2320B	08/27/08		560
Chloride	170	10	10	mg/L	EPA 300.0	08/22/08		477
Electrical Conductance	1,600	1	1	umhos/cm	SM 2510B	08/25/08		495
Nitrate as N	27	0.1	1	mg/L	EPA 300.0	08/21/08		421
Nitrate as NO3	120	0.4	1	mg/L	EPA 300.0			
pH	7.2	0.1	1	pH units	SM 4500-H B	08/20/08		409
Sulfate	84	0.5	1	mg/L	EPA 300.0	08/21/08		421
Total Dissolved Solids	990	10	1	mg/L	SM 2540C	08/26/08		561
Boron	0.09	0.05	1	mg/L	EPA 200.7	08/28/08		610
Calcium	88	0.03	1	mg/L	EPA 200.7	08/28/08		610
Hardness as CaCO3	780	1	NA	mg/L	EPA 200.7			
Sodium Adsorption Ratio (SAR)	1.0	0.1	1		EPA 200.7	08/29/08		618
Copper	Not Detected	0.05	1	mg/L	EPA 200.7	08/28/08		610
Iron	0.15	0.02	1	mg/L	EPA 200.7	08/28/08		610
Potassium	1.2	0.1	1	mg/L	EPA 200.7	08/28/08		610
Magnesium	140	0.03	1	mg/L	EPA 200.7	08/28/08		610
Manganese	Not Detected	0.02	1	mg/L	EPA 200.7	08/28/08		610
Sodium	64	0.05	1	mg/L	EPA 200.7	08/28/08		610
Zinc	Not Detected	0.05	1	mg/L	EPA 200.7	08/28/08		610

DLR = Detection Limit for Reporting. Results of "Not Detected" are below DLR.

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Lab Director, Michael Ng

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Spencer Harris
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1390 Oceanaire Drive
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Log Number: 08-C13337
Order: P4970
Project: Chorro Nitrate Study
Received: 09/26/08
Printed: 10/07/08

REPORT OF ANALYTICAL RESULTS

Sample Description	Sampled By	Sampled Date @ Time	Matrix
Well 9	Spencer Harris	09/26/08@12:15	Drinking Water

Analyte	Result	DLR	Dilution Factor	Units	Method	Date Analyzed	Date Prepared	Batch
Organic Nitrogen Value	Not Detected	0.5	NA	mg/L	Calculated			
Total Nitrogen Value	19	0.5	NA	mg/L	Calculated			
Ammonia, Total, as N	Not Detected	0.3	1	mg/L	SM 4500-NH3 D	10/06/08		1750
Nitrate as N	19	0.1	1	mg/L	EPA 300.0	09/26/08		1480
Nitrite as N	Not Detected	0.1	1	mg/L	EPA 300.0	09/26/08		1480
Total Kjeldahl Nitrogen	Not Detected	0.5	1	mg/L	SM 4500-NH3 D	10/01/08	09/26/08	1589

DLR = Detection Limit for Reporting. Results of "Not Detected" are below DLR.

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Spencer Harris
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Log Number: 08-C11514
Order: P4299
Project: Chorro Nitrate Study
Received: 08/20/08
Printed: 08/29/08

REPORT OF ANALYTICAL RESULTS

Sample Description	Sampled By	Sampled Date @ Time	Matrix
Well 9A	Spencer Harris	08/20/08@13:00	Drinking Water

Analyte	Result	DLR	Dilution Factor	Units	Method	Date Analyzed	Date Prepared	Batch
Total Alkalinity as CaCO3	390	2	1	mg/L	SM 2320B	08/21/08		462
Chloride	49	1	1	mg/L	EPA 300.0	08/21/08		421
Electrical Conductance	960	1	1	umhos/cm	SM 2510B	08/25/08		495
Nitrate as N	3.4	0.1	1	mg/L	EPA 300.0	08/21/08		421
Nitrate as NO3	15	0.4	1	mg/L	EPA 300.0			
pH	7.3	0.1	1	pH units	SM 4500-H B	08/20/08		409
Sulfate	67	0.5	1	mg/L	EPA 300.0	08/21/08		421
Total Dissolved Solids	540	10	1	mg/L	SM 2540C	08/22/08		535
Boron	0.17	0.05	1	mg/L	EPA 200.7	08/28/08		610
Calcium	50	0.03	1	mg/L	EPA 200.7	08/28/08		610
Hardness as CaCO3	460	1	NA	mg/L	EPA 200.7			
Sodium Adsorption Ratio (SAR)	0.7	0.1	1		EPA 200.7	08/29/08		618
Copper	Not Detected	0.05	1	mg/L	EPA 200.7	08/28/08		610
Iron	1.1	0.02	1	mg/L	EPA 200.7	08/28/08		610
Potassium	0.9	0.1	1	mg/L	EPA 200.7	08/28/08		610
Magnesium	80	0.03	1	mg/L	EPA 200.7	08/28/08		610
Manganese	Not Detected	0.02	1	mg/L	EPA 200.7	08/28/08		610
Sodium	35	0.05	1	mg/L	EPA 200.7	08/28/08		610
Zinc	Not Detected	0.05	1	mg/L	EPA 200.7	08/28/08		610

DLR = Detection Limit for Reporting. Results of "Not Detected" are below DLR.

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Log Number: 08-C14338
Order: P5371
Project: Chorro Nitrate Study
Received: 10/15/08
Printed: 10/17/08

REPORT OF ANALYTICAL RESULTS

Sample Description	Sampled By	Sampled Date @ Time	Matrix
Well 9A	Spencer Harris	10/15/08@10:10	Drinking Water

Analyte	Result	DLR	Dilution Factor	Units	Method	Date Analyzed	Date Prepared	Batch
Nitrate as N	3.7	0.1	1	mg/L	EPA 300.0	10/16/08		2171
Nitrate as NO3	16	0.4	1	mg/L	EPA 300.0			

DLR = Detection Limit for Reporting. Results of "Not Detected" are below DLR.

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Spencer Harris
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Log Number: 08-C11516
Order: P4299
Project: Chorro Nitrate Study
Received: 08/20/08
Printed: 08/29/08

REPORT OF ANALYTICAL RESULTS

Sample Description	Sampled By	Sampled Date @ Time	Matrix
Well 10	Spencer Harris	08/20/08@13:12	Drinking Water

Analyte	Result	DLR	Dilution Factor	Units	Method	Date Analyzed	Date Prepared	Batch
Total Alkalinity as CaCO3	380	2	1	mg/L	SM 2320B	08/27/08		560
Chloride	90	1	1	mg/L	EPA 300.0	08/21/08		421
Electrical Conductance	1,200	1	1	umhos/cm	SM 2510B	08/25/08		495
Nitrate as N	14	0.1	1	mg/L	EPA 300.0	08/21/08		421
Nitrate as NO3	61	0.4	1	mg/L	EPA 300.0			
pH	7.3	0.1	1	pH units	SM 4500-H B	08/20/08		409
Sulfate	71	0.5	1	mg/L	EPA 300.0	08/21/08		421
Total Dissolved Solids	670	10	1	mg/L	SM 2540C	08/22/08		535
Boron	0.08	0.05	1	mg/L	EPA 200.7	08/28/08		610
Calcium	65	0.03	1	mg/L	EPA 200.7	08/28/08		610
Hardness as CaCO3	600	1	NA	mg/L	EPA 200.7			
Sodium Adsorption Ratio (SAR)	0.8	0.1	1		EPA 200.7	08/29/08		618
Copper	Not Detected	0.05	1	mg/L	EPA 200.7	08/28/08		610
Iron	0.11	0.02	1	mg/L	EPA 200.7	08/28/08		610
Potassium	0.7	0.1	1	mg/L	EPA 200.7	08/28/08		610
Magnesium	110	0.03	1	mg/L	EPA 200.7	08/28/08		610
Manganese	Not Detected	0.02	1	mg/L	EPA 200.7	08/28/08		610
Sodium	46	0.05	1	mg/L	EPA 200.7	08/28/08		610
Zinc	Not Detected	0.05	1	mg/L	EPA 200.7	08/28/08		610

DLR = Detection Limit for Reporting. Results of "Not Detected" are below DLR.

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Log Number: 08-C13336
Order: P4970
Project: Chorro Nitrate Study
Received: 09/26/08
Printed: 10/07/08

REPORT OF ANALYTICAL RESULTS

Sample Description	Sampled By	Sampled Date @ Time	Matrix
Well 10	Spencer Harris	09/26/08@12:05	Drinking Water

Analyte	Result	DLR	Dilution Factor	Units	Method	Date Analyzed	Date Prepared	Batch
Organic Nitrogen Value	Not Detected	0.5	NA	mg/L	Calculated			
Total Nitrogen Value	21	0.5	NA	mg/L	Calculated			
Ammonia, Total, as N	Not Detected	0.3	1	mg/L	SM 4500-NH3 D	10/06/08		1750
Nitrate as N	21	0.1	1	mg/L	EPA 300.0	09/26/08		1480
Nitrite as N	Not Detected	0.1	1	mg/L	EPA 300.0	09/26/08		1480
Total Kjeldahl Nitrogen	Not Detected	0.5	1	mg/L	SM 4500-NH3 D	10/01/08	09/26/08	1589

DLR = Detection Limit for Reporting. Results of "Not Detected" are below DLR.

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Log Number: 08-C13335
Order: P4970
Project: Chorro Nitrate Study
Received: 09/26/08
Printed: 10/07/08

REPORT OF ANALYTICAL RESULTS

Sample Description	Sampled By	Sampled Date @ Time	Matrix
Well 10A	Spencer Harris	09/26/08@11:58	Drinking Water

Analyte	Result	DLR	Dilution Factor	Units	Method	Date Analyzed	Date Prepared	Batch
Total Alkalinity as CaCO3	380	2	1	mg/L	SM 2320B	10/06/08		1740
Chloride	90	1	1	mg/L	EPA 300.0	09/26/08		1480
Electrical Conductance	1,200	1	1	umhos/cm	SM 2510B	09/26/08		1505
Organic Nitrogen Value	Not Detected	0.5	NA	mg/L	Calculated			
Total Nitrogen Value	10	0.5	NA	mg/L	Calculated			
Ammonia, Total, as N	0.4	0.3	1	mg/L	SM 4500-NH3 D	09/26/08		1503
Nitrate as N	10	0.1	1	mg/L	EPA 300.0	09/26/08		1480
Nitrate as NO3	45	0.4	1	mg/L	EPA 300.0			
Nitrite as N	Not Detected	0.1	1	mg/L	EPA 300.0	09/26/08		1480
pH	7.4	0.1	1	pH units	SM 4500-H B	09/26/08		1505
Sulfate	69	0.5	1	mg/L	EPA 300.0	09/26/08		1480
Total Dissolved Solids	650	10	1	mg/L	SM 2540C	09/30/08		1652
Total Kjeldahl Nitrogen	Not Detected	0.5	1	mg/L	SM 4500-NH3 D	10/01/08	09/26/08	1589
Boron	0.10	0.05	1	mg/L	EPA 200.7	10/02/08		1656
Calcium	63	0.03	1	mg/L	EPA 200.7	10/02/08		1656
Hardness as CaCO3	600	1	NA	mg/L	EPA 200.7			
Sodium Adsorption Ratio (SAR)	0.8	0.1	1		EPA 200.7	10/02/08		1659
Copper	0.05	0.05	1	mg/L	EPA 200.7	10/02/08		1656
Iron	0.22	0.02	1	mg/L	EPA 200.7	10/02/08		1656
Potassium	0.8	0.1	1	mg/L	EPA 200.7	10/02/08		1656
Magnesium	110	0.03	1	mg/L	EPA 200.7	10/02/08		1656
Manganese	0.07	0.02	1	mg/L	EPA 200.7	10/02/08		1656
Sodium	45	0.05	1	mg/L	EPA 200.7	10/02/08		1656
Zinc	Not Detected	0.05	1	mg/L	EPA 200.7	10/02/08		1656

DLR = Detection Limit for Reporting. Results of "Not Detected" are below DLR.

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1390 Oceanaire Drive
San Luis Obispo, CA 93405

Log Number: 08-C14339
Order: P5371
Project: Chorro Nitrate Study
Received: 10/15/08
Printed: 10/17/08

REPORT OF ANALYTICAL RESULTS

Sample Description	Sampled By	Sampled Date @ Time	Matrix
Well 10A	Spencer Harris	10/15/08@10:20	Drinking Water

Analyte	Result	DLR	Dilution Factor	Units	Method	Date Analyzed	Date Prepared	Batch
Nitrate as N	13	0.1	1	mg/L	EPA 300.0	10/16/08		2171
Nitrate as NO3	58	0.4	1	mg/L	EPA 300.0			

DLR = Detection Limit for Reporting. Results of "Not Detected" are below DLR.

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Spencer Harris
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1390 Oceanaire Drive
San Luis Obispo, CA 93405

Log Number: 08-C11518
Order: P4299
Project: Chorro Nitrate Study
Received: 08/20/08
Printed: 08/29/08

REPORT OF ANALYTICAL RESULTS

Sample Description	Sampled By	Sampled Date @ Time	Matrix
Well 11A	Spencer Harris	08/20/08@13:35	Drinking Water

Analyte	Result	DLR	Dilution Factor	Units	Method	Date Analyzed	Date Prepared	Batch
Total Alkalinity as CaCO3	310	2	1	mg/L	SM 2320B	08/27/08		560
Chloride	110	10	10	mg/L	EPA 300.0	08/22/08		477
Electrical Conductance	1,000	1	1	umhos/cm	SM 2510B	08/25/08		495
Nitrate as N	1.5	0.1	1	mg/L	EPA 300.0	08/21/08		421
Nitrate as NO3	6.6	0.4	1	mg/L	EPA 300.0			
pH	7.4	0.1	1	pH units	SM 4500-H B	08/20/08		409
Sulfate	73	0.5	1	mg/L	EPA 300.0	08/21/08		421
Total Dissolved Solids	610	10	1	mg/L	SM 2540C	08/26/08		561
Boron	0.16	0.05	1	mg/L	EPA 200.7	08/28/08		610
Calcium	38	0.03	1	mg/L	EPA 200.7	08/28/08		610
Hardness as CaCO3	420	1	NA	mg/L	EPA 200.7			
Sodium Adsorption Ratio (SAR)	1.8	0.1	1		EPA 200.7	08/29/08		618
Copper	Not Detected	0.05	1	mg/L	EPA 200.7	08/28/08		610
Iron	Not Detected	0.02	1	mg/L	EPA 200.7	08/28/08		610
Potassium	2.9	0.1	1	mg/L	EPA 200.7	08/28/08		610
Magnesium	79	0.03	1	mg/L	EPA 200.7	08/28/08		610
Manganese	Not Detected	0.02	1	mg/L	EPA 200.7	08/28/08		610
Sodium	81	0.05	1	mg/L	EPA 200.7	08/28/08		610
Zinc	Not Detected	0.05	1	mg/L	EPA 200.7	08/28/08		610

DLR = Detection Limit for Reporting. Results of "Not Detected" are below DLR.

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Log Number: 08-C11515
Order: P4299
Project: Chorro Nitrate Study
Received: 08/20/08
Printed: 08/29/08

REPORT OF ANALYTICAL RESULTS

Sample Description	Sampled By	Sampled Date @ Time	Matrix
Well 16	Spencer Harris	08/20/08@13:05	Drinking Water

Analyte	Result	DLR	Dilution Factor	Units	Method	Date Analyzed	Date Prepared	Batch
Total Alkalinity as CaCO3	380	2	1	mg/L	SM 2320B	08/21/08		422
Chloride	54	1	1	mg/L	EPA 300.0	08/21/08		421
Electrical Conductance	990	1	1	umhos/cm	SM 2510B	08/25/08		495
Nitrate as N	2.6	0.1	1	mg/L	EPA 300.0	08/21/08		421
Nitrate as NO3	11	0.4	1	mg/L	EPA 300.0			
pH	7.5	0.1	1	pH units	SM 4500-H B	08/20/08		409
Sulfate	69	0.5	1	mg/L	EPA 300.0	08/21/08		421
Total Dissolved Solids	550	10	1	mg/L	SM 2540C	08/22/08		535
Boron	0.08	0.05	1	mg/L	EPA 200.7	08/28/08		610
Calcium	54	0.03	1	mg/L	EPA 200.7	08/28/08		610
Hardness as CaCO3	500	1	NA	mg/L	EPA 200.7			
Sodium Adsorption Ratio (SAR)	0.8	0.1	1		EPA 200.7	08/29/08		618
Copper	Not Detected	0.05	1	mg/L	EPA 200.7	08/28/08		610
Iron	0.06	0.02	1	mg/L	EPA 200.7	08/28/08		610
Potassium	1.2	0.1	1	mg/L	EPA 200.7	08/28/08		610
Magnesium	88	0.03	1	mg/L	EPA 200.7	08/28/08		610
Manganese	Not Detected	0.02	1	mg/L	EPA 200.7	08/28/08		610
Sodium	39	0.05	1	mg/L	EPA 200.7	08/28/08		610
Zinc	Not Detected	0.05	1	mg/L	EPA 200.7	08/28/08		610

DLR = Detection Limit for Reporting. Results of "Not Detected" are below DLR.

CREEK ENVIRONMENTAL LABORATORIES

Lab Director, Michael Ng

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CREEK ENVIRONMENTAL LABORATORIES, INC.
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141 SUBURBAN ROAD, SUITE C • SAN LUIS OBISPO, CA 93401 • (805) 545-9838 • FAX (805) 545-0107

Spencer Harris
Cleath & Associates
1390 Oceanaire Drive
San Luis Obispo, CA 93405

Log Number: 08-C14337
Order: P5371
Project: Chorro Nitrate Study
Received: 10/15/08
Printed: 10/17/08

REPORT OF ANALYTICAL RESULTS

Sample Description	Sampled By	Sampled Date @ Time	Matrix
Well 16	Spencer Harris	10/15/08@10:08	Drinking Water

Analyte	Result	DLR	Dilution Factor	Units	Method	Date Analyzed	Date Prepared	Batch
Nitrate as N	14	0.1	1	mg/L	EPA 300.0	10/16/08		2171
Nitrate as NO3	63	0.4	1	mg/L	EPA 300.0			

DLR = Detection Limit for Reporting. Results of "Not Detected" are below DLR.

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Log Number: 08-C11520
Order: P4299
Project: Chorro Nitrate Study
Received: 08/20/08
Printed: 08/29/08

REPORT OF ANALYTICAL RESULTS

Sample Description	Sampled By	Sampled Date @ Time	Matrix
Chorro @ Ashurst	Spencer Harris	08/20/08@14:50	Aqueous

Analyte	Result	DLR	Dilution Factor	Units	Method	Date Analyzed	Date Prepared	Batch
Total Alkalinity as CaCO3	350	2	1	mg/L	SM 2320B	08/21/08		422
Chloride	110	10	10	mg/L	EPA 300.0	08/22/08		477
Electrical Conductance	1,100	1	1	umhos/cm	SM 2510B	08/25/08		495
Organic Nitrogen Value	Not Detected	0.5	NA	mg/L	Calculated			
Total Nitrogen Value	2.3	0.5	NA	mg/L	Calculated			
Ammonia, Total, as N	Not Detected	0.3	1	mg/L	SM 4500-NH3 D	08/29/08	08/29/08	641
Nitrate as N	2.3	0.1	1	mg/L	EPA 300.0	08/21/08		421
Nitrate as NO3	10	0.4	1	mg/L	EPA 300.0			
Nitrite as N	Not Detected	0.1	1	mg/L	EPA 300.0	08/21/08		421
pH	8.1	0.1	1	pH units	SM 4500-H B	08/20/08		409
Sulfate	77	0.5	1	mg/L	EPA 300.0	08/21/08		421
Total Dissolved Solids	630	10	1	mg/L	SM 2540C	08/26/08		561
Total Kjeldahl Nitrogen	Not Detected	0.5	1	mg/L	SM 4500-NH3 D	08/25/08	08/25/08	479
Boron	0.20	0.05	1	mg/L	EPA 200.7	08/28/08		610
Calcium	45	0.03	1	mg/L	EPA 200.7	08/28/08		610
Hardness as CaCO3	460	1	NA	mg/L	EPA 200.7			
Sodium Adsorption Ratio (SAR)	1.6	0.1	1		EPA 200.7	08/29/08		618
Copper	Not Detected	0.05	1	mg/L	EPA 200.7	08/28/08		610
Iron	Not Detected	0.02	1	mg/L	EPA 200.7	08/28/08		610
Potassium	3.5	0.1	1	mg/L	EPA 200.7	08/28/08		610
Magnesium	84	0.03	1	mg/L	EPA 200.7	08/28/08		610
Manganese	Not Detected	0.02	1	mg/L	EPA 200.7	08/28/08		610
Sodium	76	0.05	1	mg/L	EPA 200.7	08/28/08		610
Zinc	Not Detected	0.05	1	mg/L	EPA 200.7	08/28/08		610

DLR = Detection Limit for Reporting. Results of "Not Detected" are below DLR.

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Log Number: 08-C13338
Order: P4970
Project: Chorro Nitrate Study
Received: 09/26/08
Printed: 10/07/08

REPORT OF ANALYTICAL RESULTS

Sample Description	Sampled By	Sampled Date @ Time	Matrix
Chorro @ Ashurst	Spencer Harris	09/26/08@14:00	Aqueous

Analyte	Result	DLR	Dilution Factor	Units	Method	Date Analyzed	Date Prepared	Batch
Organic Nitrogen Value	Not Detected	0.5	NA	mg/L	Calculated			
Total Nitrogen Value	2.4	0.5	NA	mg/L	Calculated			
Ammonia, Total, as N	Not Detected	0.3	1	mg/L	SM 4500-NH3 D	10/06/08		1750
Nitrate as N	2.4	0.1	1	mg/L	EPA 300.0	09/26/08		1480
Nitrite as N	Not Detected	0.1	1	mg/L	EPA 300.0	09/26/08		1480
Total Kjeldahl Nitrogen	Not Detected	0.5	1	mg/L	SM 4500-NH3 D	10/01/08	09/26/08	1589

DLR = Detection Limit for Reporting. Results of "Not Detected" are below DLR.

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Log Number: 08-C11519
Order: P4299
Project: Chorro Nitrate Study
Received: 08/20/08
Printed: 08/29/08

REPORT OF ANALYTICAL RESULTS

Sample Description	Sampled By	Sampled Date @ Time	Matrix
Chorro @ Canet	Spencer Harris	08/20/08@14:30	Aqueous

Analyte	Result	DLR	Dilution Factor	Units	Method	Date Analyzed	Date Prepared	Batch
Total Alkalinity as CaCO3	300	2	1	mg/L	SM 2320B	08/27/08		560
Chloride	140	10	10	mg/L	EPA 300.0	08/22/08		477
Electrical Conductance	1,100	1	1	umhos/cm	SM 2510B	08/25/08		495
Organic Nitrogen Value	Not Detected	0.5	NA	mg/L	Calculated			
Total Nitrogen Value	1.1	0.5	NA	mg/L	Calculated			
Ammonia, Total, as N	Not Detected	0.3	1	mg/L	SM 4500-NH3 D	08/29/08	08/29/08	641
Nitrate as N	1.1	0.1	1	mg/L	EPA 300.0	08/21/08		421
Nitrate as NO3	4.8	0.4	1	mg/L	EPA 300.0			
Nitrite as N	Not Detected	0.1	1	mg/L	EPA 300.0	08/21/08		421
pH	8.2	0.1	1	pH units	SM 4500-H B	08/20/08		409
Sulfate	83	0.5	1	mg/L	EPA 300.0	08/21/08		421
Total Dissolved Solids	640	10	1	mg/L	SM 2540C	08/26/08		561
Total Kjeldahl Nitrogen	Not Detected	0.5	1	mg/L	SM 4500-NH3 D	08/25/08	08/25/08	479
Boron	0.28	0.05	1	mg/L	EPA 200.7	08/28/08		610
Calcium	35	0.03	1	mg/L	EPA 200.7	08/28/08		610
Hardness as CaCO3	410	1	NA	mg/L	EPA 200.7			
Sodium Adsorption Ratio (SAR)	2.2	0.1	1		EPA 200.7	08/29/08		618
Copper	Not Detected	0.05	1	mg/L	EPA 200.7	08/28/08		610
Iron	Not Detected	0.02	1	mg/L	EPA 200.7	08/28/08		610
Potassium	5.7	0.1	1	mg/L	EPA 200.7	08/28/08		610
Magnesium	77	0.03	1	mg/L	EPA 200.7	08/28/08		610
Manganese	Not Detected	0.02	1	mg/L	EPA 200.7	08/28/08		610
Sodium	99	0.05	1	mg/L	EPA 200.7	08/28/08		610
Zinc	Not Detected	0.05	1	mg/L	EPA 200.7	08/28/08		610

DLR = Detection Limit for Reporting. Results of "Not Detected" are below DLR.

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Log Number: 08-C11522
Order: P4299
Project: Chorro Nitrate Study
Received: 08/20/08
Printed: 08/29/08

REPORT OF ANALYTICAL RESULTS

Sample Description	Sampled By	Sampled Date @ Time	Matrix
Chorro @ Poly	Spencer Harris	08/20/08@16:05	Aqueous

Analyte	Result	DLR	Dilution Factor	Units	Method	Date Analyzed	Date Prepared	Batch
Total Alkalinity as CaCO3	260	2	1	mg/L	SM 2320B	08/27/08		560
Chloride	140	10	10	mg/L	EPA 300.0	08/22/08		477
Electrical Conductance	1,100	1	1	umhos/cm	SM 2510B	08/25/08		495
Organic Nitrogen Value	Not Detected	0.5	NA	mg/L	Calculated			
Total Nitrogen Value	2.8	0.5	NA	mg/L	Calculated			
Ammonia, Total, as N	Not Detected	0.3	1	mg/L	SM 4500-NH3 D	08/29/08	08/29/08	641
Nitrate as N	2.8	0.1	1	mg/L	EPA 300.0	08/21/08		421
Nitrate as NO3	12	0.4	1	mg/L	EPA 300.0			
Nitrite as N	Not Detected	0.1	1	mg/L	EPA 300.0	08/21/08		421
pH	8.1	0.1	1	pH units	SM 4500-H B	08/20/08		409
Sulfate	86	0.5	1	mg/L	EPA 300.0	08/21/08		421
Total Dissolved Solids	620	10	1	mg/L	SM 2540C	08/26/08		561
Total Kjeldahl Nitrogen	Not Detected	0.5	1	mg/L	SM 4500-NH3 D	08/25/08	08/25/08	479
Boron	0.30	0.05	1	mg/L	EPA 200.7	08/28/08		610
Calcium	32	0.03	1	mg/L	EPA 200.7	08/28/08		610
Hardness as CaCO3	350	1	NA	mg/L	EPA 200.7			
Sodium Adsorption Ratio (SAR)	2.8	0.1	1		EPA 200.7	08/29/08		618
Copper	Not Detected	0.05	1	mg/L	EPA 200.7	08/28/08		610
Iron	0.05	0.02	1	mg/L	EPA 200.7	08/28/08		610
Potassium	9.4	0.1	1	mg/L	EPA 200.7	08/28/08		610
Magnesium	67	0.03	1	mg/L	EPA 200.7	08/28/08		610
Manganese	Not Detected	0.02	1	mg/L	EPA 200.7	08/28/08		610
Sodium	120	0.05	1	mg/L	EPA 200.7	08/28/08		610
Zinc	Not Detected	0.05	1	mg/L	EPA 200.7	08/28/08		610

DLR = Detection Limit for Reporting. Results of "Not Detected" are below DLR.

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Log Number: 08-C11521
Order: P4299
Project: Chorro Nitrate Study
Received: 08/20/08
Printed: 08/29/08

REPORT OF ANALYTICAL RESULTS

Sample Description	Sampled By	Sampled Date @ Time	Matrix
San Luisito @ Gage	Spencer Harris	08/20/08@15:20	Aqueous

Analyte	Result	DLR	Dilution Factor	Units	Method	Date Analyzed	Date Prepared	Batch
Total Alkalinity as CaCO3	340	2	1	mg/L	SM 2320B	08/27/08		560
Chloride	29	1	1	mg/L	EPA 300.0	08/21/08		421
Electrical Conductance	790	1	1	umhos/cm	SM 2510B	08/25/08		495
Organic Nitrogen Value	Not Detected	0.5	NA	mg/L	Calculated			
Total Nitrogen Value	Not Detected	0.5	NA	mg/L	Calculated			
Ammonia, Total, as N	Not Detected	0.3	1	mg/L	SM 4500-NH3 D	08/29/08	08/29/08	641
Nitrate as N	Not Detected	0.1	1	mg/L	EPA 300.0	08/21/08		421
Nitrate as NO3	Not Detected	0.4	1	mg/L	EPA 300.0			
Nitrite as N	Not Detected	0.1	1	mg/L	EPA 300.0	08/21/08		421
pH	8.3	0.1	1	pH units	SM 4500-H B	08/20/08		409
Sulfate	50	0.5	1	mg/L	EPA 300.0	08/21/08		421
Total Dissolved Solids	470	10	1	mg/L	SM 2540C	08/26/08		561
Total Kjeldahl Nitrogen	Not Detected	0.5	1	mg/L	SM 4500-NH3 D	08/25/08	08/25/08	479
Boron	0.07	0.05	1	mg/L	EPA 200.7	08/28/08		610
Calcium	52	0.03	1	mg/L	EPA 200.7	08/28/08		610
Hardness as CaCO3	430	1	NA	mg/L	EPA 200.7			
Sodium Adsorption Ratio (SAR)	0.6	0.1	1		EPA 200.7	08/29/08		618
Copper	Not Detected	0.05	1	mg/L	EPA 200.7	08/28/08		610
Iron	Not Detected	0.02	1	mg/L	EPA 200.7	08/28/08		610
Potassium	0.8	0.1	1	mg/L	EPA 200.7	08/28/08		610
Magnesium	72	0.03	1	mg/L	EPA 200.7	08/28/08		610
Manganese	Not Detected	0.02	1	mg/L	EPA 200.7	08/28/08		610
Sodium	27	0.05	1	mg/L	EPA 200.7	08/28/08		610
Zinc	Not Detected	0.05	1	mg/L	EPA 200.7	08/28/08		610

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Log Number: 08-C12897
Order: P4796
Project: Chorro Nitrate Study
Received: 09/17/08
Printed: 10/01/08

REPORT OF ANALYTICAL RESULTS

Sample Description	Sampled By	Sampled Date @ Time	Matrix
Well A	S. Harris	09/17/08@08:45	Aqueous

Analyte	Result	DLR	Dilution Factor	Units	Method	Date Analyzed	Date Prepared	Batch
Total Alkalinity as CaCO3	400	2	1	mg/L	SM 2320B	09/23/08		1349
Chloride	110	10	10	mg/L	EPA 300.0	09/18/08		1256
Electrical Conductance	1,200	1	1	umhos/cm	SM 2510B	09/17/08		1306
Nitrate as N	1.1	0.1	1	mg/L	EPA 300.0	09/17/08		1206
Nitrate as NO3	4.8	0.4	1	mg/L	EPA 300.0			
pH	7.5	0.1	1	pH units	SM 4500-H B	09/17/08		1306
Sulfate	63	0.5	1	mg/L	EPA 300.0	09/17/08		1206
Total Dissolved Solids	650	10	1	mg/L	SM 2540C	09/23/08		1426
Boron	0.12	0.05	1	mg/L	EPA 200.7	09/26/08		1531
Calcium	31	0.03	1	mg/L	EPA 200.7	09/26/08		1531
Hardness as CaCO3	500	1	NA	mg/L	EPA 200.7			
Sodium Adsorption Ratio (SAR)	1.7	0.1	1		EPA 200.7	09/30/08		1555
Copper	Not Detected	0.05	1	mg/L	EPA 200.7	09/26/08		1531
Iron	Not Detected	0.02	1	mg/L	EPA 200.7	09/26/08		1531
Potassium	1.0	0.1	1	mg/L	EPA 200.7	09/26/08		1531
Magnesium	100	0.03	1	mg/L	EPA 200.7	09/26/08		1531
Manganese	Not Detected	0.02	1	mg/L	EPA 200.7	09/26/08		1531
Sodium	84	0.05	1	mg/L	EPA 200.7	09/26/08		1531
Zinc	0.10	0.05	1	mg/L	EPA 200.7	09/26/08		1531

DLR = Detection Limit for Reporting. Results of "Not Detected" are below DLR.

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Log Number: 08-C12898
Order: P4796
Project: Chorro Nitrate Study
Received: 09/17/08
Printed: 10/01/08

REPORT OF ANALYTICAL RESULTS

Sample Description	Sampled By	Sampled Date @ Time	Matrix
Well B	S. Harris	09/17/08@08:55	Aqueous

Analyte	Result	DLR	Dilution Factor	Units	Method	Date Analyzed	Date Prepared	Batch
Total Alkalinity as CaCO3	460	2	1	mg/L	SM 2320B	09/24/08		1424
Chloride	72	1	1	mg/L	EPA 300.0	09/17/08		1206
Electrical Conductance	1,100	1	1	umhos/cm	SM 2510B	09/17/08		1306
Nitrate as N	1.8	0.1	1	mg/L	EPA 300.0	09/17/08		1206
Nitrate as NO3	7.9	0.4	1	mg/L	EPA 300.0			
pH	7.6	0.1	1	pH units	SM 4500-H B	09/17/08		1306
Sulfate	48	0.5	1	mg/L	EPA 300.0	09/17/08		1206
Total Dissolved Solids	580	10	1	mg/L	SM 2540C	09/23/08		1426
Boron	0.10	0.05	1	mg/L	EPA 200.7	09/26/08		1531
Calcium	34	0.03	1	mg/L	EPA 200.7	09/26/08		1531
Hardness as CaCO3	520	1	NA	mg/L	EPA 200.7			
Sodium Adsorption Ratio (SAR)	0.8	0.1	1		EPA 200.7	09/30/08		1555
Copper	Not Detected	0.05	1	mg/L	EPA 200.7	09/26/08		1531
Iron	0.05	0.02	1	mg/L	EPA 200.7	09/26/08		1531
Potassium	1.5	0.1	1	mg/L	EPA 200.7	09/26/08		1531
Magnesium	110	0.03	1	mg/L	EPA 200.7	09/26/08		1531
Manganese	0.10	0.02	1	mg/L	EPA 200.7	09/26/08		1531
Sodium	40	0.05	1	mg/L	EPA 200.7	09/26/08		1531
Zinc	Not Detected	0.05	1	mg/L	EPA 200.7	09/26/08		1531

DLR = Detection Limit for Reporting. Results of "Not Detected" are below DLR.

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Log Number: 08-C12899
Order: P4796
Project: Chorro Nitrate Study
Received: 09/17/08
Printed: 10/01/08

REPORT OF ANALYTICAL RESULTS

Sample Description	Sampled By	Sampled Date @ Time	Matrix
Well C	S. Harris	09/17/08@09:15	Aqueous

Analyte	Result	DLR	Dilution Factor	Units	Method	Date Analyzed	Date Prepared	Batch
Total Alkalinity as CaCO3	480	2	1	mg/L	SM 2320B	09/24/08		1424
Chloride	120	10	10	mg/L	EPA 300.0	09/18/08		1256
Electrical Conductance	1,200	1	1	umhos/cm	SM 2510B	09/17/08		1306
Nitrate as N	Not Detected	0.1	1	mg/L	EPA 300.0	09/17/08		1206
Nitrate as NO3	Not Detected	0.4	1	mg/L	EPA 300.0			
pH	7.6	0.1	1	pH units	SM 4500-H B	09/17/08		1306
Sulfate	18	0.5	1	mg/L	EPA 300.0	09/17/08		1206
Total Dissolved Solids	620	10	1	mg/L	SM 2540C	09/23/08		1404
Boron	0.15	0.05	1	mg/L	EPA 200.7	09/26/08		1531
Calcium	42	0.03	1	mg/L	EPA 200.7	09/26/08		1531
Hardness as CaCO3	450	1	NA	mg/L	EPA 200.7			
Sodium Adsorption Ratio (SAR)	2.0	0.1	1		EPA 200.7	09/30/08		1555
Copper	Not Detected	0.05	1	mg/L	EPA 200.7	09/26/08		1531
Iron	Not Detected	0.02	1	mg/L	EPA 200.7	09/26/08		1531
Potassium	0.2	0.1	1	mg/L	EPA 200.7	09/26/08		1531
Magnesium	83	0.03	1	mg/L	EPA 200.7	09/26/08		1531
Manganese	0.04	0.02	1	mg/L	EPA 200.7	09/26/08		1531
Sodium	96	0.05	1	mg/L	EPA 200.7	09/26/08		1531
Zinc	Not Detected	0.05	1	mg/L	EPA 200.7	09/26/08		1531

DLR = Detection Limit for Reporting. Results of "Not Detected" are below DLR.

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Log Number: 08-C12900
Order: P4796
Project: Chorro Nitrate Study
Received: 09/17/08
Printed: 10/01/08

REPORT OF ANALYTICAL RESULTS

Sample Description	Sampled By	Sampled Date @ Time	Matrix
Well D	S. Harris	09/17/08@09:40	Aqueous

Analyte	Result	DLR	Dilution Factor	Units	Method	Date Analyzed	Date Prepared	Batch
Total Alkalinity as CaCO3	380	2	1	mg/L	SM 2320B	09/24/08		1424
Chloride	20	1	1	mg/L	EPA 300.0	09/17/08		1206
Electrical Conductance	740	1	1	umhos/cm	SM 2510B	09/17/08		1306
Nitrate as N	Not Detected	0.1	1	mg/L	EPA 300.0	09/17/08		1206
Nitrate as NO3	Not Detected	0.4	1	mg/L	EPA 300.0			
pH	7.5	0.1	1	pH units	SM 4500-H B	09/17/08		1306
Sulfate	22	0.5	1	mg/L	EPA 300.0	09/17/08		1206
Total Dissolved Solids	410	10	1	mg/L	SM 2540C	09/23/08		1404
Boron	Not Detected	0.05	1	mg/L	EPA 200.7	09/26/08		1531
Calcium	28	0.03	1	mg/L	EPA 200.7	09/26/08		1531
Hardness as CaCO3	500	1	NA	mg/L	EPA 200.7			
Sodium Adsorption Ratio (SAR)	0.3	0.1	1		EPA 200.7	09/30/08		1555
Copper	Not Detected	0.05	1	mg/L	EPA 200.7	09/26/08		1531
Iron	Not Detected	0.02	1	mg/L	EPA 200.7	09/26/08		1531
Potassium	0.3	0.1	1	mg/L	EPA 200.7	09/26/08		1531
Magnesium	100	0.03	1	mg/L	EPA 200.7	09/26/08		1531
Manganese	Not Detected	0.02	1	mg/L	EPA 200.7	09/26/08		1531
Sodium	16	0.05	1	mg/L	EPA 200.7	09/26/08		1531
Zinc	Not Detected	0.05	1	mg/L	EPA 200.7	09/26/08		1531

DLR = Detection Limit for Reporting. Results of "Not Detected" are below DLR.

CREEK ENVIRONMENTAL LABORATORIES

Lab Director, Michael Ng

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Spencer Harris
Cleath & Associates
1390 Oceanaire Drive
San Luis Obispo, CA 93405

Log Number: 08-C12901
Order: P4796
Project: Chorro Nitrate Study
Received: 09/17/08
Printed: 10/01/08

REPORT OF ANALYTICAL RESULTS

Sample Description	Sampled By	Sampled Date @ Time	Matrix
Well E	S. Harris	09/17/08@10:45	Aqueous

Analyte	Result	DLR	Dilution Factor	Units	Method	Date Analyzed	Date Prepared	Batch
Total Alkalinity as CaCO3	400	2	1	mg/L	SM 2320B	09/24/08		1424
Chloride	53	1	1	mg/L	EPA 300.0	09/17/08		1206
Electrical Conductance	970	1	1	umhos/cm	SM 2510B	09/17/08		1306
Organic Nitrogen Value	Not Detected	0.5	NA	mg/L	Calculated			
Total Nitrogen Value	3.6	0.5	NA	mg/L	Calculated			
Ammonia, Total, as N	Not Detected	0.3	1	mg/L	SM 4500-NH3 D	09/18/08		1248
Nitrate as N	3.6	0.1	1	mg/L	EPA 300.0	09/17/08		1206
Nitrate as NO3	16	0.4	1	mg/L	EPA 300.0			
Nitrite as N	Not Detected	0.1	1	mg/L	EPA 300.0	09/17/08		1206
pH	7.5	0.1	1	pH units	SM 4500-H B	09/17/08		1306
Sulfate	66	0.5	1	mg/L	EPA 300.0	09/17/08		1206
Total Dissolved Solids	560	10	1	mg/L	SM 2540C	09/23/08		1404
Total Kjeldahl Nitrogen	Not Detected	0.5	1	mg/L	SM 4500-NH3 D	09/25/08	09/22/08	1414
Boron	0.19	0.05	1	mg/L	EPA 200.7	09/29/08		1539
Calcium	54	0.03	1	mg/L	EPA 200.7	09/29/08		1539
Hardness as CaCO3	480	1	NA	mg/L	EPA 200.7			
Sodium Adsorption Ratio (SAR)	0.9	0.1	1		EPA 200.7	09/30/08		1555
Copper	Not Detected	0.05	1	mg/L	EPA 200.7	09/29/08		1539
Iron	Not Detected	0.02	1	mg/L	EPA 200.7	09/29/08		1539
Potassium	0.8	0.1	1	mg/L	EPA 200.7	09/29/08		1539
Magnesium	84	0.03	1	mg/L	EPA 200.7	09/29/08		1539
Manganese	Not Detected	0.02	1	mg/L	EPA 200.7	09/29/08		1539
Sodium	42	0.05	1	mg/L	EPA 200.7	09/29/08		1539
Zinc	Not Detected	0.1	2	mg/L	EPA 200.7	09/29/08		1539

DLR = Detection Limit for Reporting. Results of "Not Detected" are below DLR.

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Log Number: 08-C12902
Order: P4796
Project: Chorro Nitrate Study
Received: 09/17/08
Printed: 10/01/08

REPORT OF ANALYTICAL RESULTS

Sample Description	Sampled By	Sampled Date @ Time	Matrix
Well F	S. Harris	09/17/08@11:20	Aqueous

Analyte	Result	DLR	Dilution Factor	Units	Method	Date Analyzed	Date Prepared	Batch
Total Alkalinity as CaCO3	410	2	1	mg/L	SM 2320B	09/26/08		1455
Chloride	56	1	1	mg/L	EPA 300.0	09/17/08		1206
Electrical Conductance	1,000	1	1	umhos/cm	SM 2510B	09/17/08		1306
Organic Nitrogen Value	Not Detected	0.5	NA	mg/L	Calculated			
Total Nitrogen Value	8.0	0.5	NA	mg/L	Calculated			
Ammonia, Total, as N	Not Detected	0.3	1	mg/L	SM 4500-NH3 D	09/18/08		1248
Nitrate as N	8.0	0.1	1	mg/L	EPA 300.0	09/17/08		1206
Nitrate as NO3	35	0.4	1	mg/L	EPA 300.0			
Nitrite as N	Not Detected	0.1	1	mg/L	EPA 300.0	09/17/08		1206
pH	7.5	0.1	1	pH units	SM 4500-H B	09/17/08		1306
Sulfate	66	0.5	1	mg/L	EPA 300.0	09/17/08		1206
Total Dissolved Solids	600	10	1	mg/L	SM 2540C	09/23/08		1404
Total Kjeldahl Nitrogen	Not Detected	0.5	1	mg/L	SM 4500-NH3 D	09/25/08	09/22/08	1414
Boron	0.14	0.05	1	mg/L	EPA 200.7	09/29/08		1539
Calcium	56	0.03	1	mg/L	EPA 200.7	09/29/08		1539
Hardness as CaCO3	510	1	NA	mg/L	EPA 200.7			
Sodium Adsorption Ratio (SAR)	0.9	0.1	1		EPA 200.7	09/30/08		1555
Copper	Not Detected	0.05	1	mg/L	EPA 200.7	09/29/08		1539
Iron	Not Detected	0.02	1	mg/L	EPA 200.7	09/29/08		1539
Potassium	0.5	0.1	1	mg/L	EPA 200.7	09/29/08		1539
Magnesium	91	0.03	1	mg/L	EPA 200.7	09/29/08		1539
Manganese	Not Detected	0.02	1	mg/L	EPA 200.7	09/29/08		1539
Sodium	45	0.05	1	mg/L	EPA 200.7	09/29/08		1539
Zinc	Not Detected	0.1	2	mg/L	EPA 200.7	09/29/08		1539

DLR = Detection Limit for Reporting. Results of "Not Detected" are below DLR.

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Log Number: 08-C12903
Order: P4796
Project: Chorro Nitrate Study
Received: 09/17/08
Printed: 10/01/08

REPORT OF ANALYTICAL RESULTS

Sample Description	Sampled By	Sampled Date @ Time	Matrix
Well G	S. Harris	09/17/08@11:50	Aqueous

Analyte	Result	DLR	Dilution Factor	Units	Method	Date Analyzed	Date Prepared	Batch
Total Alkalinity as CaCO3	480	2	1	mg/L	SM 2320B	09/26/08		1455
Chloride	190	10	10	mg/L	EPA 300.0	09/18/08		1256
Electrical Conductance	1,700	1	1	umhos/cm	SM 2510B	09/17/08		1306
Organic Nitrogen Value	Not Detected	0.5	NA	mg/L	Calculated			
Total Nitrogen Value	25	0.5	NA	mg/L	Calculated			
Ammonia, Total, as N	Not Detected	0.3	1	mg/L	SM 4500-NH3 D	09/18/08		1248
Nitrate as N	25	0.1	1	mg/L	EPA 300.0	09/17/08		1206
Nitrate as NO3	110	0.4	1	mg/L	EPA 300.0			
Nitrite as N	Not Detected	0.1	1	mg/L	EPA 300.0	09/17/08		1206
pH	7.8	0.1	1	pH units	SM 4500-H B	09/17/08		1306
Sulfate	84	0.5	1	mg/L	EPA 300.0	09/17/08		1206
Total Dissolved Solids	1,000	10	1	mg/L	SM 2540C	09/23/08		1404
Total Kjeldahl Nitrogen	Not Detected	0.5	1	mg/L	SM 4500-NH3 D	09/25/08	09/22/08	1414
Boron	0.13	0.05	1	mg/L	EPA 200.7	09/29/08		1539
Calcium	78	0.03	1	mg/L	EPA 200.7	09/29/08		1539
Hardness as CaCO3	770	1	NA	mg/L	EPA 200.7			
Sodium Adsorption Ratio (SAR)	1.5	0.1	1		EPA 200.7	09/30/08		1555
Copper	Not Detected	0.05	1	mg/L	EPA 200.7	09/29/08		1539
Iron	Not Detected	0.02	1	mg/L	EPA 200.7	09/29/08		1539
Potassium	1.0	0.1	1	mg/L	EPA 200.7	09/29/08		1539
Magnesium	140	0.03	1	mg/L	EPA 200.7	09/29/08		1539
Manganese	Not Detected	0.02	1	mg/L	EPA 200.7	09/29/08		1539
Sodium	92	0.05	1	mg/L	EPA 200.7	09/29/08		1539
Zinc	Not Detected	0.05	1	mg/L	EPA 200.7	09/29/08		1539

DLR = Detection Limit for Reporting. Results of "Not Detected" are below DLR.

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Spencer Harris
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San Luis Obispo, CA 93405

Log Number: 08-C12904
Order: P4796
Project: Chorro Nitrate Study
Received: 09/17/08
Printed: 10/01/08

REPORT OF ANALYTICAL RESULTS

Sample Description	Sampled By	Sampled Date @ Time	Matrix
Well H	S. Harris	09/17/08@12:10	Aqueous

Analyte	Result	DLR	Dilution Factor	Units	Method	Date Analyzed	Date Prepared	Batch
Total Alkalinity as CaCO3	400	2	1	mg/L	SM 2320B	09/26/08		1455
Chloride	80	1	1	mg/L	EPA 300.0	09/17/08		1206
Electrical Conductance	1,300	1	1	umhos/cm	SM 2510B	09/17/08		1306
Organic Nitrogen Value	Not Detected	0.5	NA	mg/L	Calculated			
Total Nitrogen Value	29	0.5	NA	mg/L	Calculated			
Ammonia, Total, as N	Not Detected	0.3	1	mg/L	SM 4500-NH3 D	09/18/08		1248
Nitrate as N	29	0.1	1	mg/L	EPA 300.0	09/17/08		1206
Nitrate as NO3	130	0.4	1	mg/L	EPA 300.0			
Nitrite as N	Not Detected	0.1	1	mg/L	EPA 300.0	09/17/08		1206
pH	7.8	0.1	1	pH units	SM 4500-H B	09/17/08		1306
Sulfate	81	0.5	1	mg/L	EPA 300.0	09/17/08		1206
Total Dissolved Solids	740	10	1	mg/L	SM 2540C	09/23/08		1404
Total Kjeldahl Nitrogen	Not Detected	0.5	1	mg/L	SM 4500-NH3 D	09/25/08	09/22/08	1414
Boron	0.10	0.05	1	mg/L	EPA 200.7	09/29/08		1539
Calcium	64	0.03	1	mg/L	EPA 200.7	09/29/08		1539
Hardness as CaCO3	610	1	NA	mg/L	EPA 200.7			
Sodium Adsorption Ratio (SAR)	0.9	0.1	1		EPA 200.7	09/30/08		1555
Copper	Not Detected	0.05	1	mg/L	EPA 200.7	09/29/08		1539
Iron	0.14	0.02	1	mg/L	EPA 200.7	09/29/08		1539
Potassium	0.6	0.1	1	mg/L	EPA 200.7	09/29/08		1539
Magnesium	110	0.03	1	mg/L	EPA 200.7	09/29/08		1539
Manganese	Not Detected	0.02	1	mg/L	EPA 200.7	09/29/08		1539
Sodium	50	0.05	1	mg/L	EPA 200.7	09/29/08		1539
Zinc	0.28	0.05	1	mg/L	EPA 200.7	09/29/08		1539

DLR = Detection Limit for Reporting. Results of "Not Detected" are below DLR.

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Spencer Harris
Cleath & Associates
1390 Oceanaire Drive
San Luis Obispo, CA 93405

Log Number: 08-C17632
Order: P6712
Project: Chorro Nitrate Study
Received: 12/19/08
Printed: 12/24/08

REPORT OF ANALYTICAL RESULTS

Sample Description	Sampled By	Sampled Date @ Time	Matrix
Well I	Spencer Harris	12/19/08@11:35	Aqueous

Analyte	Result	DLR	Dilution Factor	Units	Method	Date Analyzed	Date Prepared	Batch
Total Alkalinity as CaCO3	320	2	1	mg/L	SM 2320B	12/23/08		4452
Chloride	110	10	10	mg/L	EPA 300.0	12/23/08		4462
Electrical Conductance	1,080	1	1	umhos/cm	SM 2510B	12/19/08		4424
Nitrate as N	2.4	0.1	1	mg/L	EPA 300.0	12/19/08		4381
Nitrate as NO3	11	0.4	1	mg/L	EPA 300.0			
pH	7.4	0.1	1	pH units	SM 4500-H B	12/19/08		4424
Sulfate	77	0.5	1	mg/L	EPA 300.0	12/19/08		4381
Total Dissolved Solids	642	10	1	mg/L	SM 2540C	12/22/08		4451
Boron	0.12	0.05	1	mg/L	EPA 200.7	12/22/08		4423
Calcium	46	0.03	1	mg/L	EPA 200.7	12/22/08		4423
Hardness as CaCO3	450	1	NA	mg/L	EPA 200.7			
Sodium Adsorption Ratio (SAR)	1.5	0.1	1		EPA 200.7	12/24/08		9999
Copper	Not Detected	0.05	1	mg/L	EPA 200.7	12/22/08		4423
Iron	Not Detected	0.02	1	mg/L	EPA 200.7	12/22/08		4423
Potassium	1.4	0.1	1	mg/L	EPA 200.7	12/22/08		4423
Magnesium	82	0.03	1	mg/L	EPA 200.7	12/22/08		4423
Manganese	Not Detected	0.02	1	mg/L	EPA 200.7	12/22/08		4423
Sodium	69	1	1	mg/L	EPA 200.7	12/22/08		4423
Zinc	Not Detected	0.05	1	mg/L	EPA 200.7	12/22/08		4423

DLR = Detection Limit for Reporting. Results of "Not Detected" are below DLR.

CREEK ENVIRONMENTAL LABORATORIES

Lab Director, Michael Ng

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REPORT OF ANALYTICAL RESULTS

ZymaX FORENSICS

Client: Spencer Harris Cleath & Associates 1390 Oceanaire Dr. San Luis Obispo, CA 93405	**Lab Number:** 41235 **Received:** 8/26/2008 **Matrix:** Water
Project: CHORRONITRATE STUDY **Project Number:** **Collected by:** S. Harris	**Sample Description:** See Below **Analyzed:** 9/12/2008 **Method:** CF-IRMS

$\delta^{15}N$ $\delta^{18}O$ (nitrate)

LAB NUMBER	SAMPLE DESCRIPTION	$\delta^{15}N$ ‰	$\delta^{18}O$ ‰
41235-1	WELL 10	6.3	10.8
41235-2	WELL 9	6.5	12.2
Analytical Precision (1-sigma)		0.3	0.3

Submitted by,
Zymax Forensics, a DPRA company

River He, PhD
Isotope Lab Manager

41235-1d15n.xls
RH

REPORT OF ANALYTICAL RESULTS

ZymaX FORENSICS

Client:	Spencer Harris Cleath & Associates 1390 Oceanaire Dr. San Luis Obispo, CA 93405	Lab Number:	41235
		Received:	8/26/2008
		Matrix:	Water

Project:	CHORRONITRATE STUDY	Sample Description:	See Below
Project Number:		Analyzed:	10/4/2008
Collected by:	S. Harris	Method:	CF-IRMS

$\delta^{18}O$ δD (water)

LAB NUMBER	SAMPLE DESCRIPTION	$\delta^{18}O$ ‰	δD ‰
41235-1	WELL 10	-6.6	-33.8
41235-2	WELL 9	-5.9	-33.5
Analytical Precision (1-sigma)		0.2	0.8

Submitted by,
Zymax Forensics, a DPRA company

River He, PhD
Isotope Lab Manager

41235-1h2o.xls
RH D12.03 04

REPORT OF ANALYTICAL RESULTS

Client:	Spencer Harris Cleath & Associates 1390 Oceanaire DR. San Luis Obispo, CA 934o5	Lab Number:	41341
		Received:	10/23/2008
		Matrix:	Water

Project:	CHORRO NITRATE STUDY	Sample Description:	See Below
Project Number:	41341	Analyzed:	11/30/2008
Collected by:	S. HARRIS	Method:	CF-IRMS

$\delta^{18}O$ δD

LAB NUMBER	SAMPLE DESCRIPTION	$\delta^{18}O$ ‰	δD ‰
41341-1	WELL 16	-5.2	-30.9
41341-2	WELL 10A	-5.2	-32.3
41341-3	WELL 11A	-6.0	-42
41341-4	KINGS TANK	-8.6	-59
41341-5	CHORRO @ CUESTA	-5.1	-33

Submitted by,
Zymax Forensics, a DPRA company

41341-1h2o.xls
STL/TH D12.03 04

River He, PhD
Isotope Lab Manager

Hygienic Laboratory

The University of Iowa

Date of report: 11-04-2008

SPENCER HARRIS
CLEATH & ASSOCIATES
1390 OCEANAIRE DR

SAN LUIS OBISPO CA 93405

Sample Number	**2008040059**
Date Received	10-16-2008
Project	
Date Collected	10-15-2008 10:05
Collection Site	well 9
Collection Town	Morro Bay Ca
Description	water
Reference	
Collector	HARRIS SPENCER
Phone	(805) 543-1413
Purchase Order	

Comments: *Upon arrival, sample met container and preservation requirements for the analysis requested. Please review carefully your sample results for additional analyte comments or method exceptions.*

Results of Analyses

misc pharma/antibiotic/pcp by LC/MS/MS

Analyte	Concentration ng/L	Quantitation Limit ng/L
Acetominophen	<5.0	5.0
Carbamazepine	<1.0	1.0
Caffeine	<25	25
Cotinine	<1.0	1.0
DEET	<15	15
Ibuprofen	<2.0	2.0
Lincomycin	<5.0	5.0
Sulfadimethoxine	<1.0	1.0
Sulfamethazine	<1.0	1.0
Sulfamethoxazole	15	1.0
Sulfathiazole	<2.0	2.0
Triclosan	<5.0	5.0
Trimethoprim	<1.0	1.0
Tylosin	<2.0	2.0

Comments: *This data was generated using an UHL developed procedure. Data should not be used for compliance purposes.*

Date Analyzed: 10-23-2008
Method: PHARMA LC MISC
Date Prepared: 10-21-2008

Analyst: DLZ
Verified: LS
Analyst: KB
Verified: GJ

Description of units used within this report

ng/L - Nanograms per Liter

Quant Limit - Lowest concentration reliably measured

The results of this report relate only to the items analyzed. This report shall not be reproduced except in full without the written approval of the laboratory.

Page 1 - Continued on next page

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Hygienic Laboratory

The University of Iowa

Date of report: 11-04-2008

SPENCER HARRIS
CLEATH & ASSOCIATES
1390 OCEANAIRE DR

SAN LUIS OBISPO CA 93405

Sample Number	**2008040061**
Date Received	10-16-2008
Project	
Date Collected	10-15-2008 10:10
Collection Site	well 9a
Collection Town	Morro Bay Ca
Description	water
Reference	
Collector	HARRIS SPENCER
Phone	(805) 543-1413
Purchase Order	

Comments: *Upon arrival, sample met container and preservation requirements for the analysis requested. Please review carefully your sample results for additional analyte comments or method exceptions.*

Results of Analyses

misc pharma/antibiotic/pcp by LC/MS/MS

Analyte	Concentration ng/L	Quantitation Limit ng/L
Acetominophen	<5.0	5.0
Carbamazepine	<1.0	1.0
Caffeine	<25	25
Cotinine	<1.0	1.0
DEET	<15	15
Ibuprofen	<2.0	2.0
Lincomycin	<5.0	5.0
Sulfadimethoxine	<1.0	1.0
Sulfamethazine	<1.0	1.0
Sulfamethoxazole	<1.0	1.0
Sulfathiazole	<2.0	2.0
Triclosan	<5.0	5.0
Trimethoprim	<1.0	1.0
Tylosin	<2.0	2.0

Comments: *This data was generated using an UHL developed procedure. Data should not be used for compliance purposes.*

Date Analyzed: 10-23-2008
Method: PHARMA LC MISC
Date Prepared: 10-21-2008

Analyst: DLZ
Verified: LS
Analyst: KB
Verified: GJ

Description of units used within this report

ng/L - Nanograms per Liter

Quant Limit - Lowest concentration reliably measured

The results of this report relate only to the items analyzed. This report shall not be reproduced except in full without the written approval of the laboratory.

Page 1 - Continued on next page

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Hygienic Laboratory

The University of Iowa

Date of report: 11-04-2008

SPENCER HARRIS
CLEATH & ASSOCIATES
1390 OCEANAIRE DR

SAN LUIS OBISPO CA 93405

Sample Number	**2008040058**
Date Received	10-16-2008
Project	
Date Collected	10-15-2008 10:03
Collection Site	well 10
Collection Town	Morro Bay Ca
Description	water
Reference	
Collector	HARRIS SPENCER
Phone	(805) 543-1413
Purchase Order	

Comments: *Upon arrival, sample met container and preservation requirements for the analysis requested. Please review carefully your sample results for additional analyte comments or method exceptions.*

Results of Analyses

misc pharma/antibiotic/pcp by LC/MS/MS

Analyte	Concentration ng/L	Quantitation Limit ng/L
Acetominophen	<5.0	5.0
Carbamazepine	<1.0	1.0
Caffeine	<25	25
Cotinine	<1.0	1.0
DEET	<15	15
Ibuprofen	<2.0	2.0
Lincomycin	<5.0	5.0
Sulfadimethoxine	<1.0	1.0
Sulfamethazine	<1.0	1.0
Sulfamethoxazole	2.3	1.0
Sulfathiazole	<2.0	2.0
Triclosan	<5.0	5.0
Trimethoprim	<1.0	1.0
Tylosin	<2.0	2.0

Comments: *This data was generated using an UHL developed procedure. Data should not be used for compliance purposes.*

Date Analyzed: 10-23-2008
Method: PHARMA LC MISC
Date Prepared: 10-21-2008

Analyst: DLZ
Verified: LS
Analyst: KB
Verified: GJ

Description of units used within this report

ng/L - Nanograms per Liter

Quant Limit - Lowest concentration reliably measured

The results of this report relate only to the items analyzed. This report shall not be reproduced except in full without the written approval of the laboratory.

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Hygienic Laboratory

The University of Iowa

Date of report: 11-04-2008

SPENCER HARRIS
CLEATH & ASSOCIATES
1390 OCEANAIRE DR

SAN LUIS OBISPO CA 93405

Sample Number	**2008040062**
Date Received	10-16-2008
Project	
Date Collected	10-15-2008 10:20
Collection Site	well 10a
Collection Town	Morro Bay Ca
Description	water
Reference	
Collector	HARRIS SPENCER
Phone	(805) 543-1413
Purchase Order	

Comments: *Upon arrival, sample met container and preservation requirements for the analysis requested. Please review carefully your sample results for additional analyte comments or method exceptions.*

Results of Analyses

misc pharma/antibiotic/pcp by LC/MS/MS

Analyte	Concentration ng/L	Quantitation Limit ng/L
Acetominophen	<5.0	5.0
Carbamazepine	<1.0	1.0
Caffeine	<25	25
Cotinine	<1.0	1.0
DEET	<15	15
Ibuprofen	<2.0	2.0
Lincomycin	<5.0	5.0
Sulfadimethoxine	<1.0	1.0
Sulfamethazine	<1.0	1.0
Sulfamethoxazole	1.9	1.0
Sulfathiazole	<2.0	2.0
Triclosan	<5.0	5.0
Trimethoprim	<1.0	1.0
Tylosin	<2.0	2.0

Comments: *This data was generated using an UHL developed procedure. Data should not be used for compliance purposes.*

Date Analyzed: 10-23-2008
Method: PHARMA LC MISC
Date Prepared: 10-21-2008

Analyst: DLZ
Verified: LS
Analyst: KB
Verified: GJ

Description of units used within this report

ng/L - Nanograms per Liter

Quant Limit - Lowest concentration reliably measured

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Hygienic Laboratory

The University of Iowa

Date of report: 11-04-2008

SPENCER HARRIS
CLEATH & ASSOCIATES
1390 OCEANAIRE DR

SAN LUIS OBISPO CA 93405

Sample Number	**2008040063**
Date Received	10-16-2008
Project	
Date Collected	10-15-2008 10:30
Collection Site	well 11a
Collection Town	Morro Bay Ca
Description	water
Reference	
Collector	HARRIS SPENCER
Phone	(805) 543-1413
Purchase Order	

Comments: *Upon arrival, sample met container and preservation requirements for the analysis requested. Please review carefully your sample results for additional analyte comments or method exceptions.*

Results of Analyses

misc pharma/antibiotic/pcp by LC/MS/MS

Analyte	Concentration ng/L	Quantitation Limit ng/L
Acetominophen	<5.0	5.0
Carbamazepine	54	1.0
Caffeine	<25	25
Cotinine	<1.0	1.0
DEET	<150	15
Ibuprofen	<2.0	2.0
Lincomycin	<5.0	5.0
Sulfadimethoxine	<1.0	1.0
Sulfamethazine	<1.0	1.0
Sulfamethoxazole	24	1.0
Sulfathiazole	<2.0	2.0
Triclosan	<5.0	5.0
Trimethoprim	<1.0	1.0
Tylosin	<2.0	2.0

Comments: *This data was generated using an UHL developed procedure. Data should not be used for compliance purposes.*

Date Analyzed: 10-23-2008
Method: PHARMA LC MISC
Date Prepared: 10-21-2008

Analyst: DLZ
Verified: LS
Analyst: KB
Verified: GJ

Description of units used within this report

ng/L - Nanograms per Liter

Quant Limit - Lowest concentration reliably measured

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Hygienic Laboratory

The University of Iowa

Date of report: 11-04-2008

SPENCER HARRIS
CLEATH & ASSOCIATES
1390 OCEANAIRE DR

SAN LUIS OBISPO CA 93405

Sample Number	**2008040060**
Date Received	10-16-2008
Project	
Date Collected	10-15-2008 10:08
Collection Site	well 16
Collection Town	Morro Bay Ca
Description	water
Reference	
Collector	HARRIS SPENCER
Phone	(805) 543-1413
Purchase Order	

Comments: *Upon arrival, sample met container and preservation requirements for the analysis requested. Please review carefully your sample results for additional analyte comments or method exceptions.*

Results of Analyses

misc pharma/antibiotic/pcp by LC/MS/MS

Analyte	Concentration ng/L	Quantitation Limit ng/L
Acetominophen	<5.0	5.0
Carbamazepine	<1.0	1.0
Caffeine	<25	25
Cotinine	<1.0	1.0
DEET	<15	15
Ibuprofen	<2.0	2.0
Lincomycin	<5.0	5.0
Sulfadimethoxine	<1.0	1.0
Sulfamethazine	<1.0	1.0
Sulfamethoxazole	<1.0	1.0
Sulfathiazole	<2.0	2.0
Triclosan	<5.0	5.0
Trimethoprim	<1.0	1.0
Tylosin	<2.0	2.0

Comments: *This data was generated using an UHL developed procedure. Data should not be used for compliance purposes.*

Date Analyzed: 10-23-2008
Method: PHARMA LC MISC
Date Prepared: 10-21-2008

Analyst: DLZ
Verified: LS
Analyst: KB
Verified: GJ

Description of units used within this report

ng/L - Nanograms per Liter

Quant Limit - Lowest concentration reliably measured

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Hygienic Laboratory

The University of Iowa

Date of report: 11-04-2008

SPENCER HARRIS
CLEATH & ASSOCIATES
1390 OCEANAIRE DR

SAN LUIS OBISPO CA 93405

Sample Number	**2008040057**
Date Received	10-16-2008
Project	
Date Collected	10-15-2008 09:40
Collection Site	chorro creek @ ashurst
Collection Town	Morro Bay Ca
Description	water
Reference	
Collector	HARRIS SPENCER
Phone	(805) 543-1413
Purchase Order	

Comments: *Upon arrival, sample met container and preservation requirements for the analysis requested. Please review carefully your sample results for additional analyte comments or method exceptions.*

Results of Analyses

misc pharma/antibiotic/pcp by LC/MS/MS

Analyte	Concentration ng/L	Quantitation Limit ng/L
Acetominophen	<5.0	5.0
Carbamazepine	60	1.0
Caffeine	<25	25
Cotinine	1.1	1.0
DEET	<15	15
Ibuprofen	<2.0	2.0
Lincomycin	<5.0	5.0
Sulfadimethoxine	<1.0	1.0
Sulfamethazine	<1.0	1.0
Sulfamethoxazole	44	1.0
Sulfathiazole	<2.0	2.0
Triclosan	<5.0	5.0
Trimethoprim	<1.0	1.0
Tylosin	<2.0	2.0

Comments: *This data was generated using an UHL developed procedure. Data should not be used for compliance purposes.*

Date Analyzed: 10-23-2008
Method: PHARMA LC MISC
Date Prepared: 10-21-2008

Analyst: DLZ
Verified: LS
Analyst: KB
Verified: GJ

Description of units used within this report

ng/L - Nanograms per Liter

Quant Limit - Lowest concentration reliably measured

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The University of Iowa

Date of report: 11-04-2008

SPENCER HARRIS
CLEATH & ASSOCIATES
1390 OCEANAIRE DR

SAN LUIS OBISPO CA 93405

Sample Number	**2008040065**
Date Received	10-16-2008
Project	
Date Collected	10-15-2008 12:30
Collection Site	chorro creek @ wwtp
Collection Town	Morro Bay Ca
Description	water
Reference	
Collector	HARRIS SPENCER
Phone	(805) 543-1413
Purchase Order	

Comments: *Upon arrival, sample met container and preservation requirements for the analysis requested. Please review carefully your sample results for additional analyte comments or method exceptions.*

Results of Analyses

misc pharma/antibiotic/pcp by LC/MS/MS

Analyte	Concentration ng/L	Quantitation Limit ng/L
Acetominophen	<5.0	5.0
Carbamazepine	83	1.0
Caffeine	<25	25
Cotinine	<1.0	1.0
DEET	20	15
Ibuprofen	<2.0	2.0
Lincomycin	<5.0	5.0
Sulfadimethoxine	<1.0	1.0
Sulfamethazine	<1.0	1.0
Sulfamethoxazole	<1.0	1.0
Sulfathiazole	<2.0	2.0
Triclosan	<5.0	5.0
Trimethoprim	<1.0	1.0
Tylosin	<2.0	2.0

Comments: *This data was generated using an UHL developed procedure. Data should not be used for compliance purposes.*

Date Analyzed: 10-23-2008
Method: PHARMA LC MISC
Date Prepared: 10-21-2008

Analyst: DLZ
Verified: LS
Analyst: KB
Verified: GJ

Description of units used within this report

ng/L - Nanograms per Liter

Quant Limit - Lowest concentration reliably measured

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Hygienic Laboratory ADDITIONAL RESULTS

The University of Iowa

pharmas, antibiots, pcps by LCMSMS

Analyte	Concentration ng/L	Quantitation Limit ng/L
Carbamazepine	110	2.0
Caffeine	<28	28
DEET	48	23
Sulfamethoxazole	8.6	2.0

Comments: *This data was generated using an UHL developed procedure. Data should not be used for compliance purposes.*
Re-extraction of original sample on 1/8/09, analysis on 1/9/09, shows similar results to originally reported results. Supports conclusion that 2008040057 and 2008040065 were not switched in processing. DLZ 1/12/2009

Date Analyzed: 01-09-2009
Method: UHL-H-020
Date Prepared: 01-08-2009

Analyst: DLZ
Verified: JV
Analyst: KB
Verified: GJ

Description of units used within this report

ng/L - Nanograms per Liter

Quant Limit - Lowest concentration reliably measured

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Iowa Environmental Laboratory ID #027.

If you have any questions please call Client Services at 800/421-IOWA (4692) or 319/335-4500. Thank you.

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Hygienic Laboratory

The University of Iowa

Date of report: 11-04-2008

SPENCER HARRIS
CLEATH & ASSOCIATES
1390 OCEANAIRE DR

SAN LUIS OBISPO CA 93405

Sample Number	**2008040064**
Date Received	10-16-2008
Project	
Date Collected	10-15-2008 11:45
Collection Site	chorro creek @ cuesta
Collection Town	Morro Bay Ca
Description	water
Reference	
Collector	HARRIS SPENCER
Phone	(805) 543-1413
Purchase Order	

Comments: *Upon arrival, sample met container and preservation requirements for the analysis requested. Please review carefully your sample results for additional analyte comments or method exceptions.*

Results of Analyses

misc pharma/antibiotic/pcp by LC/MS/MS

Analyte	Concentration ng/L	Quantitation Limit ng/L
Acetominophen	<5.0	5.0
Carbamazepine	<1.0	1.0
Caffeine	<25	25
Cotinine	<1.0	1.0
DEET	<15	15
Ibuprofen	<2.0	2.0
Lincomycin	<5.0	5.0
Sulfadimethoxine	<1.0	1.0
Sulfamethazine	<1.0	1.0
Sulfamethoxazole	<1.0	1.0
Sulfathiazole	<2.0	2.0
Triclosan	<5.0	5.0
Trimethoprim	<1.0	1.0
Tylosin	<2.0	2.0

Comments: *This data was generated using an UHL developed procedure. Data should not be used for compliance purposes.*

Date Analyzed: 10-23-2008
Method: PHARMA LC MISC
Date Prepared: 10-21-2008

Analyst: DLZ
Verified: LS
Analyst: KB
Verified: GJ

Description of units used within this report

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Quant Limit - Lowest concentration reliably measured

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Hygienic Laboratory

The University of Iowa

Date of report: 11-04-2008

SPENCER HARRIS
CLEATH & ASSOCIATES
1390 OCEANAIRE DR

SAN LUIS OBISPO CA 93405

Sample Number	**2008040066**
Date Received	10-16-2008
Project	
Date Collected	
Collection Site	trip blank/blank
Collection Town	
Description	water
Reference	
Collector	HARRIS SPENCER
Phone	(805) 543-1413
Purchase Order	

Comments: *Upon arrival, sample met container and preservation requirements for the analysis requested. Please review carefully your sample results for additional analyte comments or method exceptions.*

Results of Analyses

misc pharma/antibiotic/pcp by LC/MS/MS

Analyte	Concentration ng/L	Quantitation Limit ng/L
Acetominophen	<5.0	5.0
Carbamazepine	<1.0	1.0
Caffeine	<25	25
Cotinine	<1.0	1.0
DEET	<15	15
Ibuprofen	<2.0	2.0
Lincomycin	<5.0	5.0
Sulfadimethoxine	<1.0	1.0
Sulfamethazine	<1.0	1.0
Sulfamethoxazole	<1.0	1.0
Sulfathiazole	<2.0	2.0
Triclosan	<5.0	5.0
Trimethoprim	<1.0	1.0
Tylosin	<2.0	2.0

Comments: *This data was generated using an UHL developed procedure. Data should not be used for compliance purposes.*

Date Analyzed: 10-23-2008
Method: PHARMA LC MISC
Date Prepared: 10-21-2008

Analyst: DLZ
Verified: LS
Analyst: KB
Verified: GJ

Description of units used within this report

ng/L - Nanograms per Liter

Quant Limit - Lowest concentration reliably measured

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APPENDIX F

Well Field Nitrate Concentrations

Nitrate Concentrations MB-9 Ashurst Well Field

DATE	NO3 (mg/l)
11/24/59	0
12/2/59	1
1/4/60	3.2
3/22/60	2
8/2/60	7.2
7/11/62	11
10/30/62	6
3/7/63	4
7/20/66	1
9/26/66	0.7
11/6/67	2.5
5/14/71	5.2
11/4/71	0.5
5/16/72	2.7
7/16/74	26
11/13/75	19
11/9/76	5
11/15/77	19
3/14/79	13.3
3/12/82	22
2/25/85	4
9/6/85	18
2/24/86	11
1/5/87	13
4/9/87	11
7/15/87	7.1
10/26/87	16
5/13/88	14.2
7/29/88	16
10/21/88	20
1/11/89	12
5/2/89	15
7/31/89	21
10/31/89	22
2/27/90	15
6/4/90	13
8/15/90	21
7/30/91	13
10/15/91	23
1/21/92	16
3/3/92	43
3/10/92	40
3/17/92	39
3/24/92	41
3/31/92	40
4/7/92	30
4/14/92	25
4/21/92	26
4/28/92	29
5/5/92	30

DATE	NO3 (mg/l)
5/12/92	29
8/4/92	43
9/15/92	62
9/22/92	62
9/29/92	53
10/6/92	49
10/13/92	49
10/20/92	49
10/27/92	53
11/3/92	24
11/10/92	13
11/17/92	14
11/24/92	13
12/1/92	12
12/8/92	13
1/5/93	38
2/2/93	41
3/2/93	44
4/6/93	49
4/27/93	28
5/4/93	34
5/7/93	43
5/11/93	25
5/18/93	31
5/18/93	31
5/21/93	28
5/25/93	28
6/1/93	35
6/1/93	35
7/6/93	29
8/3/93	32
9/7/93	37
10/5/93	25
11/2/93	20
1/4/94	28
3/1/94	28
4/5/94	23
5/3/94	24
6/6/94	19
7/5/94	7.4
8/3/94	7.5
9/6/94	8
10/4/94	4.7
11/1/94	6.6
12/6/94	11
1/3/95	12
2/7/95	22
3/7/95	32
4/5/95	35
5/2/95	33

DATE	NO3 (mg/l)
6/6/95	51
6/13/95	54
6/20/95	62
6/23/95	60
6/23/95	59
7/5/95	57
7/18/95	47
7/25/95	48
8/1/95	50
1/16/96	26
1/6/99	19
10/14/99	11
7/27/00	8.9
11/16/00	15
6/13/01	8.4
3/26/02	10
9/16/03	88
3/3/04	13
4/19/05	9.8
5/3/05	10
9/12/06	8
11/7/06	88
1/30/07	24
3/13/07	11
6/5/07	110
6/19/07	117
9/18/07	54
11/6/07	21
2/5/08	70
5/6/08	29
8/20/08	120
9/26/08	83

Nitrate Concentrations MB-9A

DATE	NO3 (mg/l)
7/12/62	13
3/7/63	17
12/9/65	14
4/16/70	29
6/2/71	21
5/16/72	13
7/16/74	20
11/13/75	23
11/9/76	35
12/14/77	44
3/14/79	6
3/12/82	13
2/25/85	13
9/6/85	53
10/11/85	53
10/15/85	58
11/13/85	24
11/18/85	24
11/25/85	24
12/2/85	18
12/9/85	18
12/16/85	16
12/23/85	18
2/3/86	13
2/10/86	13
2/18/86	17
2/24/86	18
3/3/86	16
3/10/86	17
3/17/86	16
3/24/86	16
5/13/86	16
7/15/86	17
1/5/87	18
4/9/87	17
7/15/87	12
10/26/87	16
2/17/88	14
5/13/88	17
7/29/88	34
10/21/88	58
1/11/89	23
5/2/89	17
7/31/89	31
10/31/89	71
2/27/90	18
6/4/90	31
8/15/90	31
12/11/90	71
1/3/91	93
2/7/91	75
4/30/91	27

Ashurst Well Field

DATE	NO3 (mg/l)
7/30/91	38
10/15/91	35
1/21/92	30
3/5/92	32
4/28/92	44
8/4/92	58
4/6/93	41
4/7/93	31
4/27/93	44
5/4/93	53
4/5/94	28
5/3/94	32
6/6/94	24
7/5/94	22
8/3/94	24
9/6/94	26
10/4/94	31
11/1/94	20
12/6/94	21
1/3/95	20
2/7/95	18
3/7/95	25
4/5/95	41
5/2/95	55
6/6/95	65
6/13/95	75
7/5/95	78
8/20/98	39
10/14/99	11
7/27/00	10
11/16/00	11
6/13/01	14
3/26/02	12
9/16/03	18
3/3/04	8
4/19/05	17
1/4/07	10
3/13/07	9
6/5/07	9
11/6/07	22
2/5/08	44
8/20/08	15
10/15/08	16

Nitrate Concentrations MB-10 Ashurst Well Field

DATE	NO3 (mg/l)
6/23/53	2.5
3/15/56	2.5
11/24/59	2.7
12/2/59	1
12/22/59	6.4
1/4/60	2.7
3/22/60	1
8/2/60	6.4
7/12/62	10
3/7/63	9.5
9/26/66	24
5/24/67	24
7/16/74	27
11/13/75	67
5/4/77	31
11/15/77	31
3/14/79	9
3/14/79	9
3/12/82	22
3/12/82	22
2/25/85	4
9/6/85	24
12/9/85	12
2/24/86	12
5/13/86	15
1/5/87	17
4/9/87	17
7/15/87	12
10/26/87	19
2/17/88	17
5/13/88	19
7/29/88	18
10/21/88	35
1/11/89	14
5/2/89	13
7/31/89	20
10/31/89	30
2/27/90	17
6/4/90	16
8/15/90	14
6/30/91	34
7/30/91	34
10/15/91	43
10/29/91	49
11/5/91	49
11/12/91	44
11/26/91	35
12/3/91	38
12/10/91	30
12/10/91	30
12/17/91	25
12/24/91	23

DATE	NO3 (mg/l)
12/31/91	23
1/7/92	22
1/14/92	24
1/21/92	24
1/28/92	26
2/4/92	28
2/11/92	24
2/18/92	35
2/25/92	35
3/3/92	33
3/10/92	31
3/17/92	28
3/24/92	30
3/31/92	38
4/7/92	44
4/14/92	41
4/21/92	35
4/28/92	39
5/5/92	44
5/12/92	44
8/4/92	44
4/6/93	27
4/27/93	39
5/4/93	53
5/11/93	28
5/18/93	33
5/18/93	33
5/21/93	30
5/25/93	30
9/7/93	42
9/16/93	40
9/21/93	38
10/5/93	38
11/2/93	33
12/8/93	39
1/4/94	42
2/1/94	29
3/1/94	26
4/5/94	25
5/3/94	26
6/6/94	27
7/5/94	27
8/3/94	21
9/6/94	22
10/4/94	17
11/1/94	8.9
12/6/94	21
1/3/95	12
3/7/95	24
5/2/95	28
6/6/95	39
6/19/95	44

DATE	NO3 (mg/l)
6/27/95	49
6/29/95	46
7/5/95	50
7/18/95	52
7/25/95	32
8/1/95	33
1/16/96	36
8/20/98	17
10/14/99	7.7
7/27/00	6
11/16/00	7.4
6/13/01	7.3
3/26/02	7.5
3/18/03	13
9/16/03	49
3/3/04	14
4/26/05	8.5
1/4/07	6.6
3/13/07	6.2
6/5/07	33
6/19/07	41
9/4/07	63
11/6/07	60
2/5/08	53
5/6/08	19
8/20/08	61
9/26/08	92

Nitrate Concentrations MB-10A Ashurst Well Field

DATE	NO3 (mg/l)
8/2/60	6.4
10/1/60	10
7/11/62	12
10/30/62	13
12/9/65	5
3/23/70	28
5/16/72	13.5
7/16/74	28
11/13/75	58
11/9/76	37
11/15/77	35
3/14/79	7.4
3/12/82	27
2/25/85	9
9/6/85	53
10/11/85	75
10/15/85	75
11/13/85	80
11/18/85	44
11/25/85	33
12/2/85	17
12/9/85	15
12/16/85	13
12/23/85	14
2/3/86	15
2/10/86	12
2/18/86	18
2/24/86	16
3/3/86	19
3/10/86	20
3/17/86	22
3/24/86	25
5/13/86	27
7/15/86	22
1/5/87	19
4/9/87	31
7/15/87	26
10/26/87	39
2/17/88	24
5/13/88	27
7/29/88	39
10/21/88	75
1/11/89	20
5/2/89	23
7/31/89	44
10/31/89	56
2/27/90	19
6/4/90	29
8/15/90	49
12/11/90	71
1/3/91	66
2/7/91	38

DATE	NO3 (mg/l)
4/30/91	26
7/30/91	40
1/21/92	34
3/5/92	49
4/28/92	53
8/4/92	62
4/6/93	62
4/7/93	43
4/27/93	62
4/5/94	38
5/3/94	47
6/6/94	48
7/5/94	38
8/3/94	46
9/6/94	58
10/4/94	46
11/1/94	24
12/6/94	16
1/3/95	23
6/26/95	82
4/12/01	14
7/3/07	22
9/26/2008	45
10/15/2008	58

Nitrate Concentrations MB-12 Ashurst Well Field

DATE	NO3 (mg/l)
7/16/74	12
11/9/76	2
11/15/77	4.4
3/14/79	17.7
3/14/80	35
3/14/83	27
9/6/85	5.8
12/9/85	11
2/24/86	13
5/13/86	25
7/15/86	26
1/5/87	12
4/9/87	10
7/15/87	7.1
10/26/87	22
2/17/88	13
5/13/88	6.6
7/29/88	30
1/11/89	12
5/2/89	8.4
7/31/89	29
2/27/90	16
6/4/90	8.4
8/15/90	22
4/30/91	27
7/30/91	7.5
1/21/92	9.7
4/28/92	29
8/4/92	49
9/15/92	19
9/22/92	20
9/29/92	9.5
10/6/92	21
10/13/92	23
10/20/92	20
10/27/92	15
11/3/92	4.4
11/10/92	5.8
11/17/92	8.4
11/24/92	4.9
12/1/92	6.6
12/8/92	6.6
1/5/93	31
4/27/93	43
5/4/93	65
5/11/93	53
5/18/93	50
5/18/93	50
6/26/95	67

Nitrate Concentrations MB-16 Ashurst Well Field

DATE	NO3 (mg/l)
5/4/77	31
5/5/77	22
11/15/77	16
3/14/79	12
3/16/81	17
3/13/84	40
3/7/85	18
9/6/85	25.7
12/9/85	15
2/24/86	15
10/6/86	11
1/5/87	19
4/9/87	12
7/15/87	16
10/26/87	25
1/5/87	19
4/9/87	12
7/15/87	16
10/26/87	25
2/17/88	17
5/13/88	17
7/29/88	19
10/21/88	40
1/11/89	19
5/2/89	15
7/31/89	18
10/31/89	30
11/9/89	30
2/27/90	18
6/4/90	19
8/15/90	16
12/11/90	39
1/3/91	53
2/7/91	26
4/30/91	23
7/30/91	39
10/15/91	32
10/29/91	29
11/19/91	27
12/3/91	32
12/10/91	28
12/10/91	28
12/17/91	27
12/24/91	31
12/31/91	33
1/7/92	33
1/14/92	37
1/21/92	36
1/28/92	36
2/4/92	32
2/11/92	22

DATE	NO3 (mg/l)
2/18/92	35
2/25/92	41
3/3/92	38
3/10/92	39
3/17/92	39
3/24/92	40
3/31/92	44
4/7/92	34
4/14/92	32
4/21/92	39
4/28/92	33
5/5/92	42
5/12/92	42
8/4/92	41
8/4/92	41
9/15/92	36
9/22/92	35
9/29/92	35
10/6/92	40
10/13/92	41
10/20/92	40
10/27/92	42
11/3/92	42
11/10/92	43
11/17/92	42
11/24/92	36
12/1/92	39
12/8/92	39
1/5/93	36
2/2/93	31
3/2/93	30
4/6/93	31
4/27/93	29
5/4/93	36
5/7/93	37
5/11/93	28
5/18/93	29
5/18/93	29
5/21/93	26
5/25/93	26
6/1/93	29
6/1/93	29
7/6/93	26
8/3/93	25
9/7/93	28
10/5/93	29
11/2/93	20
12/8/93	30
1/4/94	25
2/1/94	19
3/1/94	18

DATE	NO3 (mg/l)
4/5/94	16
5/3/94	21
6/6/94	17
7/5/94	18
8/3/94	22
9/6/94	22
10/4/94	24
11/1/94	36
12/6/94	14
1/3/95	22
2/7/95	18
3/7/95	20
4/5/95	33
5/2/95	43
6/6/95	47
6/13/95	42
6/19/95	42
6/27/95	45
6/29/95	42
7/5/95	41
7/18/95	41
7/25/95	39
8/1/95	39
1/16/96	26
8/20/98	23
10/14/99	7.6
7/27/00	6.2
11/16/00	6.2
6/13/01	8.7
3/26/02	7
3/18/03	7.6
9/16/03	7.6
3/3/04	13
3/14/06	9
9/12/06	8
11/16/06	8
1/4/07	2.6
1/30/07	7.9
2/6/07	7.5
3/13/07	6.2
4/10/07	7.5
5/1/07	7.5
6/5/07	6.6
7/3/07	11
8/7/07	15
9/4/07	28
10/2/07	39
10/30/07	54.6
11/1/07	50.2
11/5/07	51
11/6/07	51

DATE	NO3 (mg/l)
11/8/07	61
12/5/07	62
1/2/08	59
2/5/08	33
4/29/08	11.4
5/6/08	14
8/20/08	11
10/15/08	63

Nitrate Concentrations MB-8

DATE	NO3 (mg/l)
12/9/65	6
9/25/66	4.8
10/14/66	7.2
5/25/67	11
3/23/70	25
3/24/70	28
7/16/74	27
11/22/77	4.4
3/14/79	9.5
3/14/79	9.5
3/14/80	18
3/14/80	18
3/14/83	22
3/14/83	22
3/7/85	4
9/6/85	7.1
2/24/86	9.7
5/13/86	14
7/15/86	15
7/15/86	15
10/6/86	16
1/5/87	14
7/15/87	14
10/26/87	21
2/17/88	11
5/13/88	9.7
7/29/88	8.4
10/21/88	24
5/2/89	13
7/31/89	12
10/31/89	18
2/27/90	19
6/4/90	9
8/15/90	8.4
12/11/90	15
1/3/91	18
2/7/91	13
3/6/91	12
4/30/91	23
7/30/91	19
10/15/91	17
10/15/91	17
10/29/91	18
10/29/91	18
12/17/91	16
1/24/92	19
2/25/92	25
3/17/92	36
3/24/92	38
3/31/92	39
4/7/92	38
4/14/92	34

Romero Well Field

DATE	NO3 (mg/l)
4/21/92	34
4/28/92	38
5/5/92	35
5/12/92	33
8/4/92	29
9/15/92	23
9/22/92	23
9/29/92	23
10/6/92	23
10/13/92	23
10/20/92	21
10/27/92	23
11/3/92	22
11/10/92	22
11/17/92	22
11/24/92	23
12/1/92	22
12/8/92	21
1/5/93	22
2/2/93	27
3/2/93	31
4/6/93	43
4/20/93	48
4/27/93	44
4/28/93	44
4/29/93	44
4/30/93	40
5/3/93	52
5/4/93	53
5/7/93	51
5/11/93	42
5/18/93	42
5/18/93	42
5/21/93	38
5/25/93	38
6/1/93	38
6/1/93	38
7/6/93	40
8/3/93	31
10/5/93	28
11/2/93	24
12/8/93	32
1/4/94	28
2/1/94	20
3/1/94	21
6/26/95	61

Nitrate Concentrations MB-11A

DATE	NO3 (mg/l)
6/18/79	4.4
10/31/79	13
6/20/85	6.2
9/6/85	4.9
2/24/86	13
1/5/87	13
10/26/87	26
2/17/88	10
5/13/88	6.6
7/29/88	3.5
10/21/88	31
1/11/89	20
5/2/89	10
7/31/89	7.5
10/31/89	14
2/27/90	20
6/4/90	4.4
8/15/90	7.1
12/11/90	14
1/3/91	18
2/7/91	15
10/15/91	8
1/21/92	11
1/17/95	20
1/16/96	31
4/8/98	68
8/20/98	36
10/14/99	12
7/27/00	7.4
11/16/00	15
6/13/01	14
3/26/02	11
3/18/03	11
9/16/03	9.8
3/3/04	11
11/2/04	7.7
11/16/04	8.9
11/23/04	12
2/8/05	22
11/15/05	18
9/12/06	16
11/1/06	22
11/20/06	21
1/30/07	20
2/6/07	19
3/13/07	18
4/10/07	18
5/1/07	18
6/5/07	19
7/3/07	25
8/7/07	26
9/4/07	4

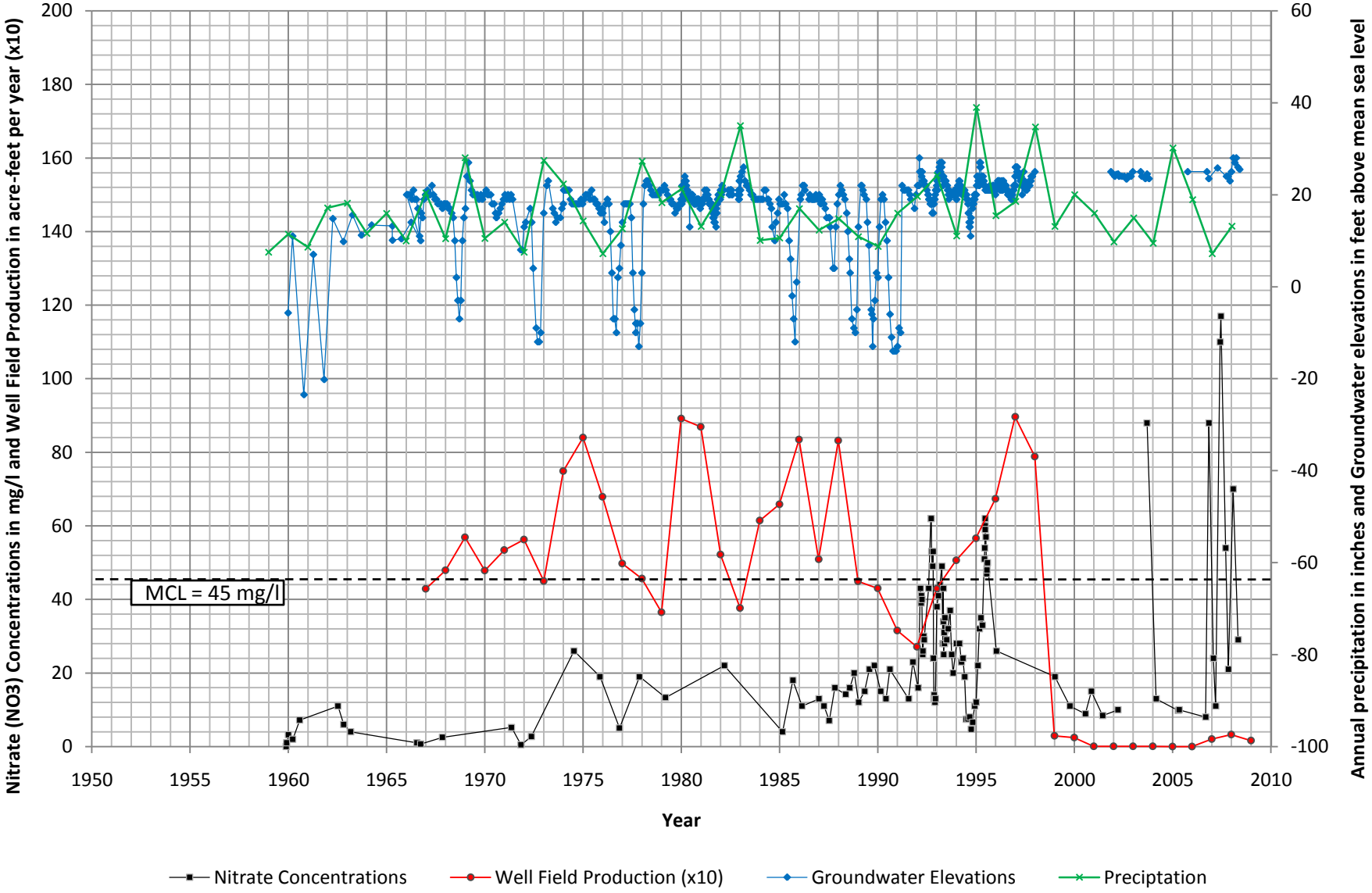
Romero Well Field

DATE	NO3 (mg/l)
10/2/07	12
10/30/07	8.4
11/6/07	11
11/8/07	11
11/13/07	11
11/15/07	9.7
11/16/07	9.9
12/5/07	10
1/2/08	13
2/5/08	13
3/11/08	14
4/1/08	13
4/29/08	13.2
5/6/08	9.2
8/20/08	6.6

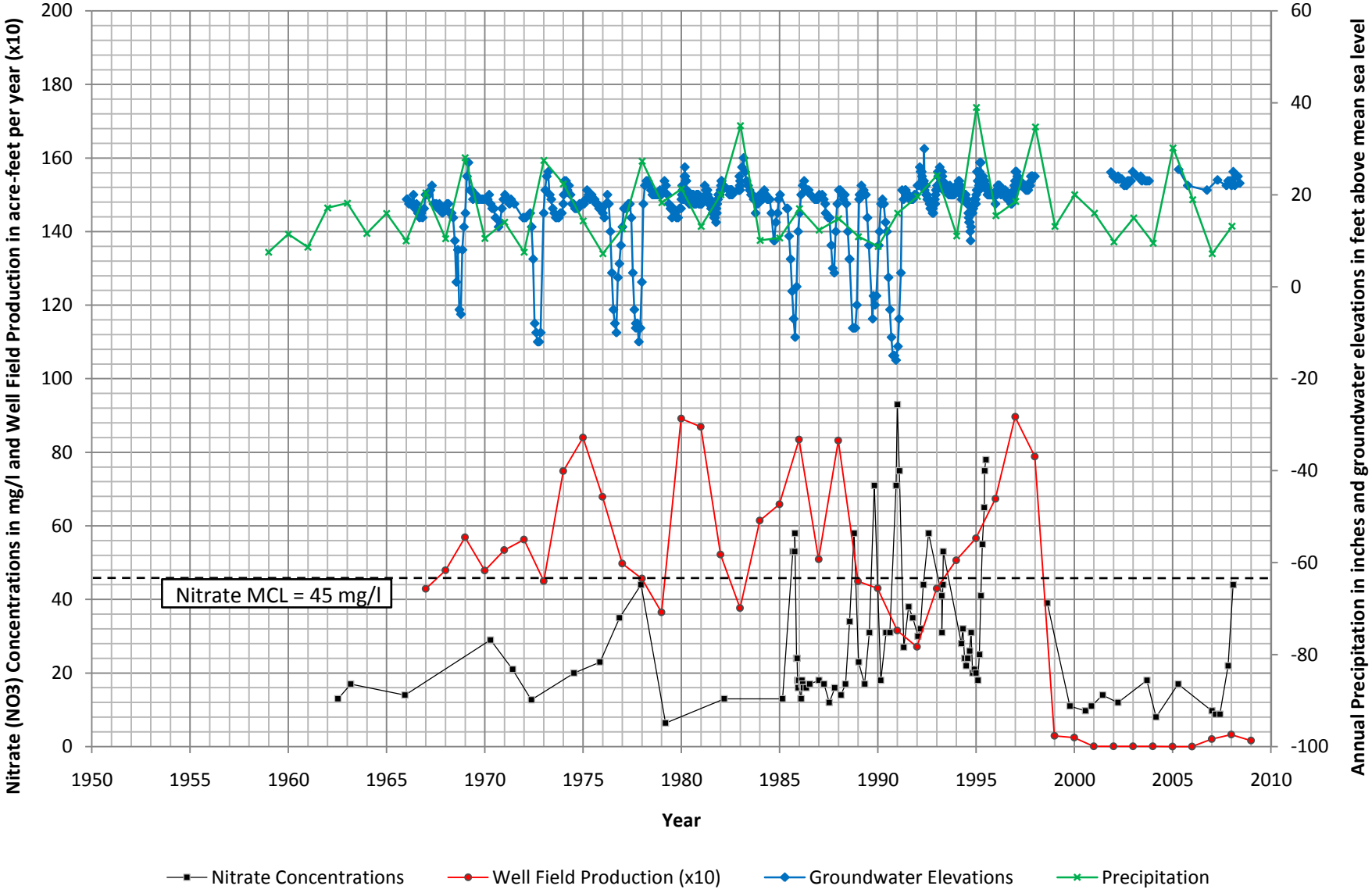
APPENDIX G

Data Correlation Graphs

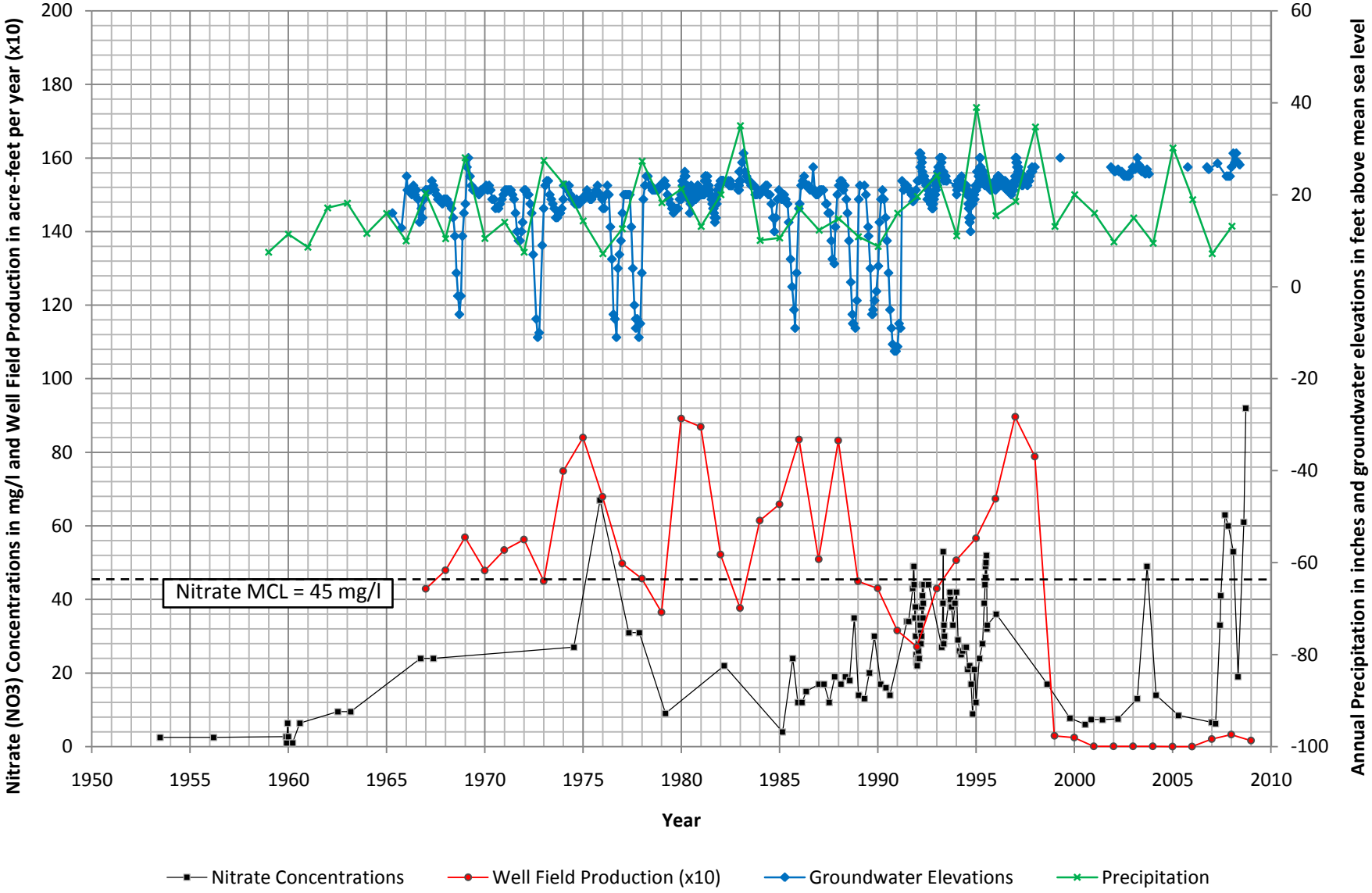
Ashurst Field
Well MB-9



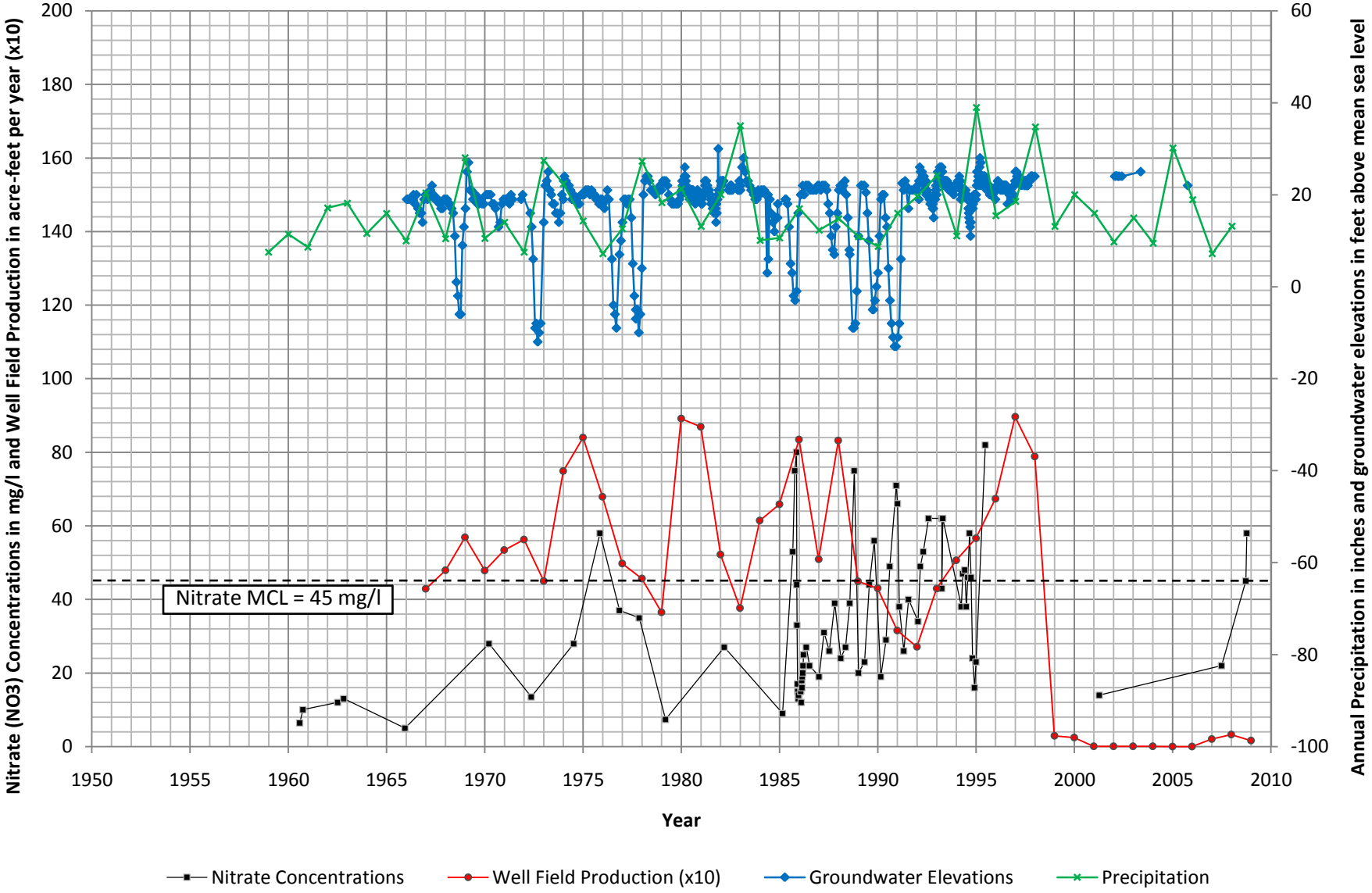
Ashurst Field
Well MB-9A



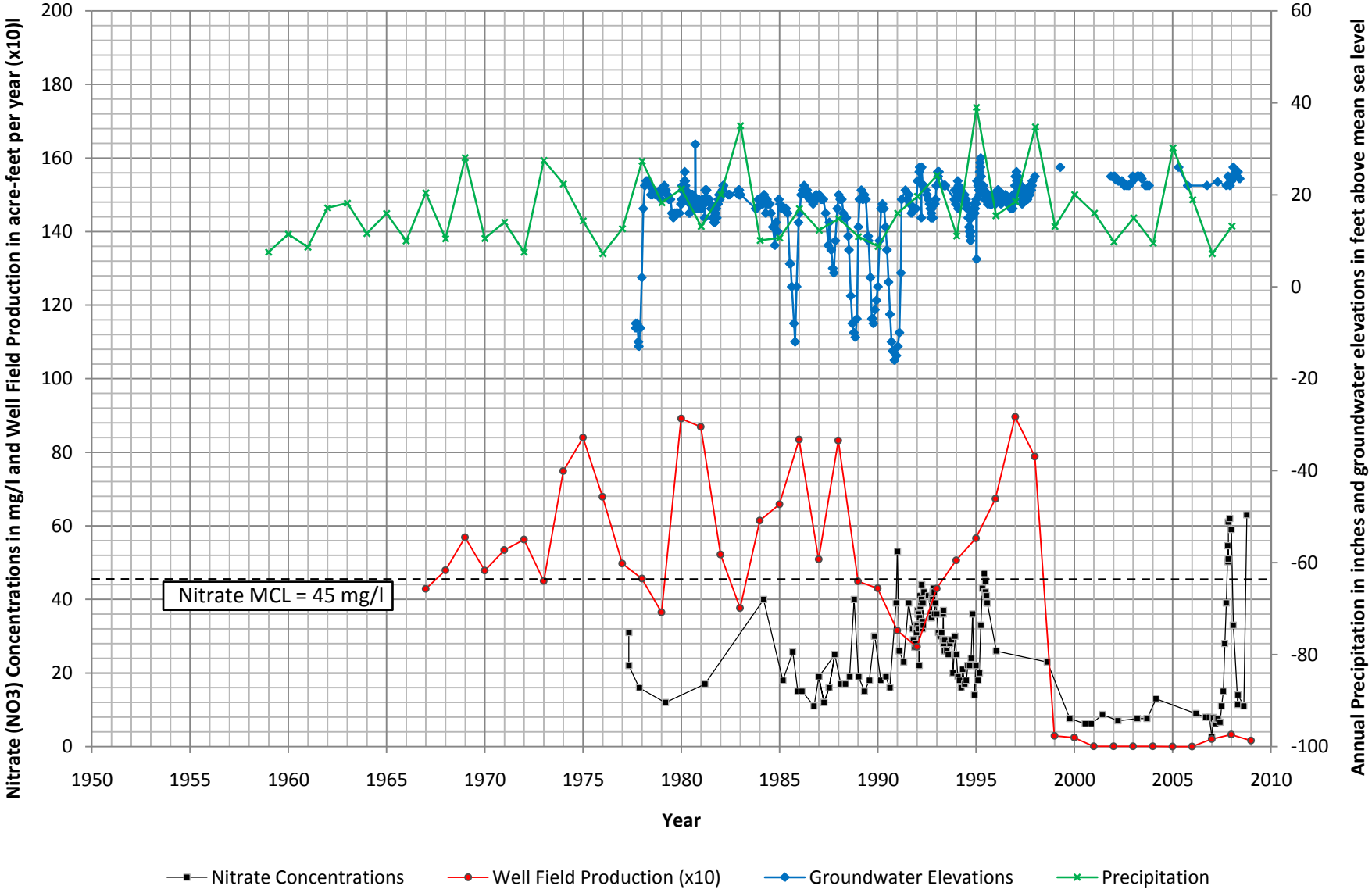
Ashurst Field
Well MB-10

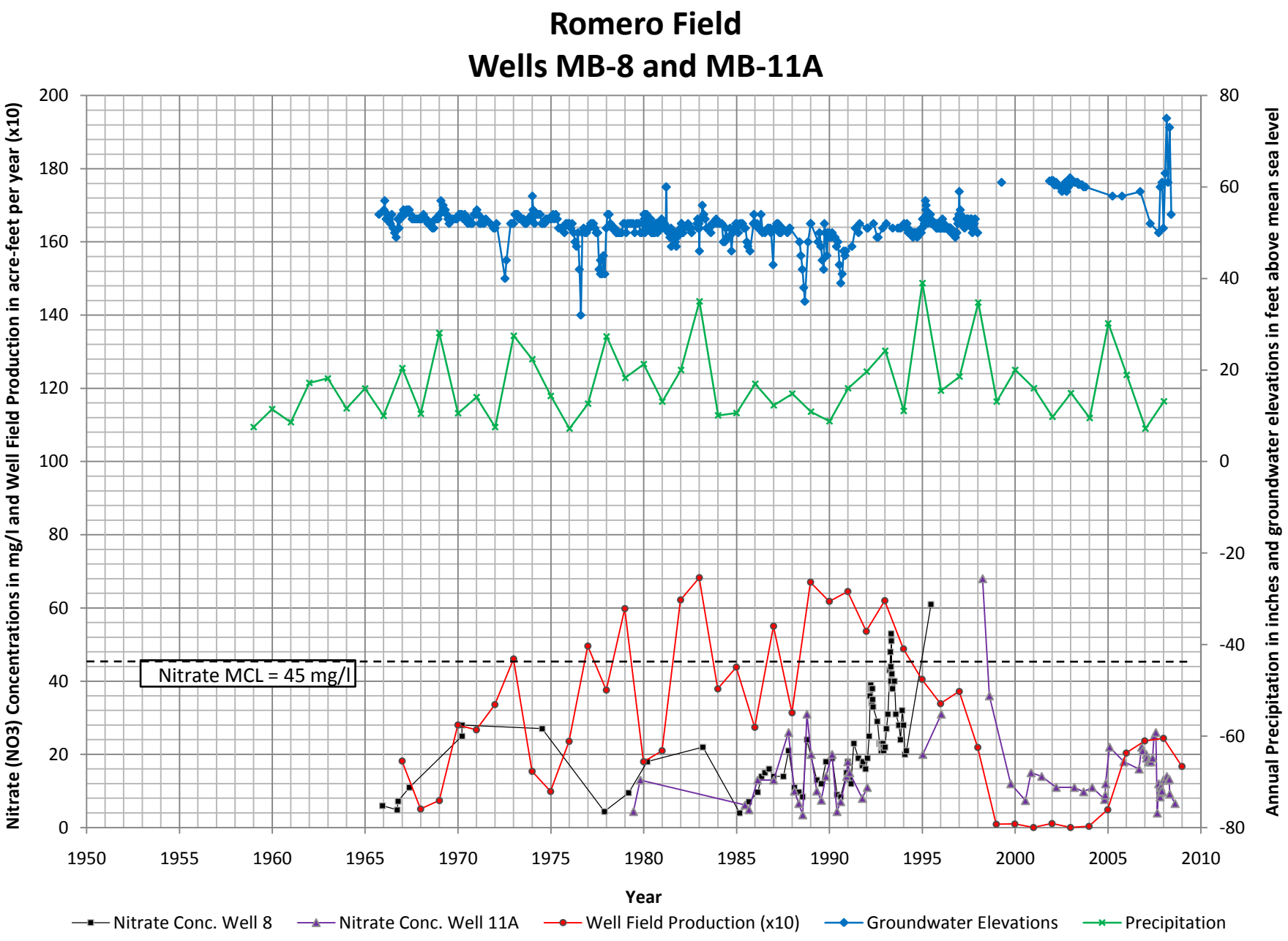


Ashurst Field
Well MB-10A



Ashurst Field
Well MB-16




Romero Field
Wells MB-8 and MB-11A
Nitrate (NO3) Concentrations in mg/l and Well Field Production in acre-feet per year (x10)
Annual Precipitation in inches and groundwater elevations in feet above mean sea level
Nitrate MCL = 45 mg/l
Year
Nitrate Conc. Well 8
Nitrate Conc. Well 11A
Well Field Production (x10)
Groundwater Elevations
Precipitation

APPENDIX H

Nitrate Isotopes Discussion

Nitrate Isotopes Discussion

Manure and septic system effluent is typically represented in isotope literature as having $\delta^{15}N$ of nitrate values greater than +10 $^{0}/_{00}$, which distinguishes it from synthetic fertilizers, which have $\delta^{15}N$ values closer to 0 $^{0}/_{00}$ (e.g. Clark and Fritz, 1997). It is interesting, however, that range of measured values for animal waste is quite broad, and that only the solid waste is ^{15}N enriched, while urine is $\delta^{15}N$ depleted. As reported by Kendall (1998):

> *The increases in $\delta^{15}N$ in animal tissue and solid waste relative to diet are due mainly to the excretion of isotopically light N in urine or its equivalent (Wolterink et al., 1979). Animal waste products may be further enriched in ^{15}N because of volatilization of ^{15}N-depleted ammonia, and subsequent oxidation of much of the residual waste material may result in nitrate with a high $\delta^{15}N$. By this process, animal waste with a typical $\delta^{15}N$ value of about +5‰ is converted to nitrate with $\delta^{15}N$ values generally in the range of +10 to +20‰ (Kreitler, 1975; 1979), and human and other animal waste become isotopically indistinguishable under most circumstances (an exception is Fogg et al., 1998).*

Another aspect of isotope analysis that results in overlapping ranges of $\delta^{15}N$ for various sources is isotope fractionation. For example, microbial denitrification can enrich the ^{15}N composition of residual dissolved nitrate and lead to nitrate derived from fertilizer having $\delta^{15}N$ values close to sewage nitrogen (Jeffrey et al, 2002).

The other stable isotope analyzed in groundwater from the City well field was the oxygen-nitrate isotope ^{18}O. The $\delta^{18}O$ of nitrate in septic effluent and animal waste is typically below +5 ‰, while synthetic nitrate fertilizer has $\delta^{18}O$ of nitrate values greater than +20 ‰ (Clark and Fritz, 1997). Nitrate derived from the biological nitrification of synthetic ammonium fertilizers should have much lower $\delta^{18}O$ of nitrate values (Aravena at al, 1993). This is because the oxygen used for synthetic nitrate fertilizer production is derived from the atmosphere, where $\delta^{18}O$ (of air) values are +23 ‰, while the oxygen used during the biological nitrification of ammonia is partially derived from local waters, which have depleted $\delta^{18}O$ (of H_2O) values, compared to the international standard (various authors after Hollocher, 1984). The $\delta^{18}O$ (of H_2O) in local groundwater is typically -5 to -6 ‰.

Using values of +23 ‰ $\delta^{18}O$ (air) and -6 ‰ $\delta^{18}O$ (irrigation water), the resulting $\delta^{18}O$ for nitrate originating from nitrification of ammonium, anhydrous ammonia, or urea-based fertilizer applications would be approximately +4 ‰. Commercial fertilizer mixtures often include ammonium nitrate (NH_4NO_3), which provides a portion of the nitrogen for immediate plant uptake (as nitrate) and a portion for slower-release uptake (as ammonium). $\delta^{18}O$ values for nitrate derived from ammonium nitrate fertilizer would be close to +13 ‰ (+23 ‰ from the nitrate portion and +4 ‰ from the ammonium portion). Ammonium nitrate fertilizer may also be amended with calcium nitrate and potassium nitrate to provide the grower with a choice of proportions of immediate versus delayed nitrogen availability. The $\delta^{18}O$ for nitrate from these fertilizer would vary accordingly.

Isotope fractionation during denitrification also enriches $\delta^{18}O$ of nitrate values. The proportion of $\delta^{15}N$ enrichment to $\delta^{18}O$ enrichment in nitrate residual during denitrification has been found on many occasions to be 2:1 (e.g. Kendall, 1998).

References (for Appendix H)

Aravena, R., Evans, M.L., and Cherry, J.A., 1993, Stable isotopes of oxygen and nitrogen in source identification of nitrate from septic systems, Groundwater, 31: 180-186.

Clark, I., and Fritz, P., 1997, Environmental Isotopes in Hydrogeology, Lewis Publishers.

Cleath & Associates, 2007, Morro Basin Nitrate Study, December 2007

Hollocher, T.C., 1984, Source of the oxygen atoms of nitrate in the oxidation of nitrite by Nitrocacter agilis and evidence against a P-O-N anhydride mechanism in oxidative phosphorylation, Archives of Biochemistry and Biophysics, 233: 721-727

Jeffrey, A., Kaplan, I. Zhang, D., Lu, S., and Nielsen, J., 2002, Environmental Tracers: Identifying the Sources of Nitrate Contamination in Groundwater, Contaminated Soil, Sediment & Water, June 2002, 34-35.

Kendall, C. and McDonnell, J.J., 1998, Isotope Tracers in Catchment Hydrology, Elsevier Science BV, Amsterdam.

APPENDIX I

Management Goals and Practices
(UC Publication 8097)

PUBLICATION 8097 FWQP FACT SHEET 3.4

Management Goals and Management Practices:

Nutrient Management Goals and Management Practices for Cool-Season Vegetables

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This Fact Sheet includes Management Goals and Management Practices for reduction of nutrient pollution in cool-season vegetables. For our purposes, we are defining a *Management Goal* (MG) as the best economically achievable technology or process for limiting the movement of nutrients, particularly nitrogen (N) and phosphorus (P), into ground or surface waters. Management Goals are general (for example, "Base the amount and timing of N fertilizer applied on crop needs").

As used here, a *Management Practice* (MP) is a specific practice to be used in accomplishing a Management Goal (for example, "Use plant tissue analysis to aid in fertilization decisions"). Growers and crop advisors have found these practices suitable for vegetable production in California's coastal region. Management Practices are not requirements and will not necessarily be feasible or necessary for pollution control in every situation. Rather, they are options for managing N and P fertilizers and water efficiently.

The development of a comprehensive farm plan for nutrient management on cool-season vegetable crops involves a series of ten Management Goals:

MG 1. Evaluate current irrigation and fertilization practices and plan improvements in management.

MG 2. Avoid fertilizer material spills during all phases of transport, storage, and application.

MG 3. Base the amount and timing of N fertilizer applications on crop needs and production goals.

MG 4. Place N fertilizer materials where maximum plant uptake will occur.

MG 5. Minimize leaching losses of nitrate during non-crop periods.

MG 6. Operate irrigation systems to minimize deep percolation and N losses.

MG 7. Improve the uniformity of existing furrow irrigation.

MG 8. Improve the uniformity of existing sprinkler irrigation.

MG 9. Improve the uniformity of existing drip irrigation.

MG 10. Evaluate and maintain nutrient management goals and recommended practices.

To implement the Management Practices, you may require specific technical information. Consult your local UCCE Farm Advisor or visit the UC Davis Vegetable Research and Information Center Web site for help with developing these practices.

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Farm Water Quality Planning
A Water Quality and Technical Assistance Program for California Agriculture
http://waterquality.ucanr.org

This Fact Sheet is part of the **Farm Water Quality Planning (FWQP)** series, developed for a short course that provides training for growers of irrigated crops who are interested in implementing water quality protection practices. The short course teaches the basic concepts of watersheds, nonpoint source pollution (NPS), self-assessment techniques, and evaluation techniques. Management goals and practices are presented for a variety of cropping systems.

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MG 1. Evaluate current irrigation and fertilization practices and plan improvements in management

MP 1.1. Determine nitrate and salt contamination of ground water in existing wells; and assess the potential for transport of soluble contaminants such as nitrates and salts downward to the ground water and laterally to surface

MP 1.2. Develop and implement a system for keeping long-term records on each field for water and nutrient/soil amendment inputs, cultural operations, pest problems, land leveling or other improvements, and crop yield and quality. The Farm Water Quality Plan (ANR Pub 9002) gives one method for developing a long-term system.

MP 1.3. Review current cultural practices to develop improved nutrient and water management plans.

MG 2. Avoid fertilizer material spills during all phases of transport, storage, and application

MP 2.1. Have organized training sessions for field personnel.

MP 2.2. When transporting fertilizer, do not overfill trailers or tanks. Cover or cap loads properly and display appropriate placards on vehicles.

MP 2.3. When transferring fertilizer into on-farm storage or into a fertilizer applicator, take care not to allow materials to accumulate on the soil.

MP 2.4. Maintain all fertilizer storage facilities to meet government and industry standards and protect them from the weather.

MP 2.5. Clean up fertilizer spills promptly.

MP 2.6. Shut off fertilizer applicators during turns and use check valves on application equipment.

MP 2.7. Maintain proper calibration of fertilizer application equipment.

MP 2.8. Whenever injecting fertilizer into irrigation water, ensure that there is no backflow into wells or other water sources.

MP 2.9. Distribute rinse water from fertilizer application equipment evenly throughout the field.

MG 3. Base the amount and timing of N and P fertilizer applications on crop needs

MP. 3.1. Determine crop nutrient requirements and establish a crop nutrient budget.

MP 3.2. Measure nitrate levels in the irrigation water and adjust N fertilizer rate accordingly.

MP 3.3. Before applying N and P early in the growth cycle, assess the amount of nitrate and phosphorous already present through the use of soil sampling and analysis. For soils with pH > 6.2, the most appropriate soil test is the Olsen (or *bicarbonate*) procedure. The Olsen procedure is acceptable for soils with a lower pH, but some laboratories may recommend a different method.

MP 3.4. Use soil nitrate quick tests or plant tissue sampling to guide your decisions on N fertilization in the middle and late periods of the crop growth cycle.

MP 3.5. Make multiple small applications of N fertilizer.\

MP 3.6. Make efficient P fertilizer applications.

MP 3.6.1. When appropriate, apply injected bands of P fertilizer into the soil. P fertilizer is generally more available to the plants if it is injected in bands than if it is applied as a broadcast application.

MP 3.6.2. Apply P fertilizer as close to the time of planting as possible. The longer P fertilizer is in contact with the soil, the less accessible it is to plants.

MP 3.6. When applying manure before you plant a crop, determine the nutrient content and release rate of the manure and the amount of nitrate already present in the soil. Apply manure at a rate consistent with the crop nutrient requirements.

MP 3.7. When possible, avoid water-running N fertilizer in the furrows. If fertilizer N must be water-run, make sure to maximize the uniformity of the irrigation, inject the fertilizer during the last half of the irrigation set, and manage the tailwater.

MP 3.8. Do not apply fertilizer N or surface broadcast P less than 24 hours in advance of a predicted large storm event.

MG 4. Place N fertilizer materials where maximum plant uptake will occur

MP 4.1. Incorporate N fertilizer into the crop bed by placing fertilizer on the seed row and watering it in, by knifing fertilizer into the bed, or by broadcasting fertilizer and then listing it up into the bed.

MG 5. Minimize leaching losses of nitrate during non-crop periods

MP 5.1. If conditions permit, grow a cover crop rather than leave fields fallow during the rainy season.

MP 5.2. Use only low-N fertilizers (such as $N:P_2O_5:K_2O$ equal to 1:3:3) during bed preparation in the fall. Higher N materials may be appropriate if a crop is to be planted soon.

MG 6. Operate irrigation systems to minimize deep percolation and N and P losses (These practices apply to all system types.)

MP 6.1. Monitor soil moisture between irrigations and use that information to guide your irrigation timing decisions.

MP 6.2. Crop need should determine irrigation amount.

MP 6.3. Know the irrigation system flow rates and the time required to apply the desired inches of water.

MP 6.4. Use the minimum leaching fraction that will prevent stand establishment problems or yield reductions from salinity.

MP 6.5. When fertigating with a drip or sprinkler system, run the fertilizer in the later part of the set so as not to leach nutrients beyond the root zone. Avoid fertigating with furrow systems.

MP 6.6. Follow state regulatory requirements and industry guidelines for backflow prevention when injecting fertilizer into irrigation water (CCR Title 3). Schedule regular maintenance of backflow prevention devices.

MP 6.7. If irrigation uniformity remains low after all practical improvements have been made, consider converting to an irrigation system with a greater potential to improve uniformity in a way that minimizes deep percolation.

MP 6.8. Minimize the amount of tailwater leaving the farm during the irrigation season. Even tailwater from fields with only moderate soil nutrient levels can contain significant quantities of N and P that can lead to algal blooms and associated problems.

MG 7. Improve existing furrow irrigation uniformity

MP 7.1. Convert to surge irrigation.

MP 7.2. Where furrow runs are more than 1000 feet long, consider cutting the furrow run length in half with a corresponding decrease in set time.

MP 7.3. Use high irrigation flow rates initially to get water down the furrow and then cut the flow rates back to finish the irrigation.

MP 7.4. Reduce variations in slope when preparing irrigation furrows.

MP 7.5. Use practices that increase irrigation uniformity between furrows (e.g., by using torpedoes in furrows that don't get wheel traffic or by alternating wheel rows with each tractor pass, you can ensure greater uniformity in water advance time in all furrows).

MP 7.6. Recirculate, rechannel, or reuse surface water runoff.

MP 7.7. Keep records on a field-by-field basis of advance and recession times.

MP 7.8. Utilize the services of a mobile irrigation lab.

MG 8. Improve existing sprinkler irrigation uniformity

MP 8.1. Monitor flows and pressure variations throughout the system to detect non-uniform application.

MP 8.2. Maintain the irrigation system by repairing leaks, replacing malfunctioning sprinklers, monitoring nozzle performance for wear, and maintaining adequate water pressure through the entire set.

MP 8.3. Operate sprinklers during the least windy periods, whenever possible. When sprinkler irrigating under windy conditions, reduce the spacing between laterals when possible to optimize application uniformity.

MP 8.4. Use offset lateral moves on successive irrigations to improve distribution uniformity.

MP 8.5. Use flow-control nozzles when the pressure variation throughout the system is excessive.

MP 8.6. Make set times as short as possible during stand establishment.

MP 8.7. For very large blocks, consider converting to linear-move sprinkler systems.

MP 8.8. Utilize the services of a mobile irrigation lab.

MG 9. Improve existing drip irrigation uniformity

MP 9.1. Monitor flows and pressure variations throughout the system to detect non-uniform application.

MP 9.2. Use lateral hose lengths that ensure uniformity.

MP 9.3. Use drip tape that has a small emitter discharge exponent to reduce flow variations that result from pressure differences.

MP 9.4. Check for the potential for emitter clogging by conducting water analysis and fertilizer/water compatibility tests.

MP 9.5. Use filtration, chemical treatments, and flushing as needed to prevent or correct clogging problems.

MP 9.6. Maintain appropriate water pressure throughout the system.

MP 9.7. Utilize the services of a mobile irrigation lab.

MG 10. Evaluate and maintain nutrient management goals and recommended practices

MP 10.1. Periodically evaluate management goals and recommended practices implemented for nutrient management. Correct deficiencies as needed.

REFERENCE

Pettygrove, G. S., S. R. Grattan, B. R. Hanson, T. K. Hartz, L. E. Jackson, T. R. Lockhart, K. F. Schulbach, and R. Smith. 1998. Production guide: Nitrogen and water management for coastal cool-season vegetables. Oakland: University of California Division of Agriculture and Natural Resources, Publication 21581.

FOR MORE INFORMATION

You'll find detailed information on many aspects of field crop production and resource conservation in these titles and in other publications, slide sets, CD-ROMs, and videos from UC ANR:

Nutrients and Water Quality, slide set 90/104

Protecting Groundwater Quality in Citrus Production, publication 21521

Sediments and Water Quality, slide set 91/102

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