Cleath-Harris Geologists, Inc.
11545 Los Osos Valley Road, Suite C-3
San Luis Obispo, California 93405
(805) 543-1413

Technical Memorandum

Date: July 29, 2009

From: Spencer Harris

To: ISJ Group

SUBJECT: **Flow Model Conversion and Urban Area Yield Update**

This memorandum documents revisions to the basin groundwater model and presents results of updating basin yield estimates using the revised model. The yield estimates include current conditions and two wastewater project scenarios (spray field only and VPA2b). The scope of work was performed in accordance with sub-tasks 3 and 4 of the ISJ consulting agreement dated December 17, 2008. Basin yield updates in this memorandum do not include potential development of surplus water in the Creek Valley, which is addressed separately.

Initial yield evaluations using the equivalent fresh water head (EFH) model confirmed that the analysis would be more rigorous and would provide more useful information to the ISJ group if the basin model was converted to full dual-density capability. An increased level of effort was given to sub-task 4 to successfully upgrade the basin model within the project schedule.

This memorandum includes several hypothetical examples of pumping patterns in the basin, including distribution of pumping between upper and lower aquifers and the three local water purveyors. These hypothetical examples were chosen by Cleath-Harris Geologists in order to test the basin yield under various potential future scenarios, and do not necessarily represent pumping patterns that are planned or agreed-upon by the water purveyors. There are a number of factors that must be taken into account by the water purveyors when determining any potential future basin water development, including but not limited to, ownership of land parcels, location of other water infrastructure, regulatory permitting requirements, allocation of water resources, and cost.

Prior Estimate

The basin yield was last estimated in the Draft LOCSD Water Management Plan (Cleath & Associates, 2005a). Under current conditions, basin yield was listed at 3,250 acre-feet per year (AFY), of which 800 AFY was for the creek valley, and 2,450 AFY was for the urban area.

Model Revisions

The original steady-state groundwater model was constructed in 2003 (Yates and Williams, 2003; Cleath & Associates, 2003) and updated in 2004 (Cleath & Associates, 2004). The model was subsequently converted to simulate sea water intrusion using Equivalent Freshwater Head (EFH) methodology in 2005 (Cleath & Associates, 2005b) and updated to current condition pumping in 2008 (Cleath & Associates, 2008).

In the Los Osos groundwater basin, the primary constraint on yield is sea water intrusion. The EFH model characterized sea water intrusion at the coast and has been useful for quantifying and comparing hydrologic budget items under various basin stresses. The EFH model, however, cannot simulate the movement of sea water inland of the coast.

For a basin yield analysis, understanding the transient, inland impacts on water quality from sea water intrusion is necessary for setting pumping thresholds and planning horizons that are appropriate for the existing water system infrastructure. This is only possible through conversion of the EFH model to a true dual-density model.

Density-dependent flow is now simulated in the basin model using the SEAWAT code, which was developed by the U.S. Geological Survey and combines MODFLOW and the solute transport package MT3DMS, while applying a density correction. Sea water intrusion is modeled over time as total dissolved solids (TDS), of which close to half of the mass is chloride.

Setting up the SEAWAT model involved the following changes to the EFH model:

1) Replace the general head boundaries at the ocean with constant head boundaries at mean sea level.

2) Install constant concentration boundaries at the ocean, with a TDS concentration of 2.185 pounds/cubic foot (35,000 mg/l) in Layer 1 (aquifer Zone C) and Layer 4 (Aquifer Zone E). The TDS concentration of Layer 3 (Zone D) was set at 1.093 pounds/cubic foot (17,500 mg/l) to reflect the existing maximum concentration in Zone D at the coast. Although the concentrations in Zone D at the coast could ultimately increase to sea water equivalent with continued intrusion, there has been little change on the sand spit in Zone D quality over the last 20 years, which is evidence of a significant brackish water reservoir offshore. Layer 2 (regional aquitard) is no-flow at the coast.

4) Convert from steady-state to transient modeling. The length of the simulations range from 50 years (calibration) to several thousand years (steady-state sustainability test).

Model Calibration

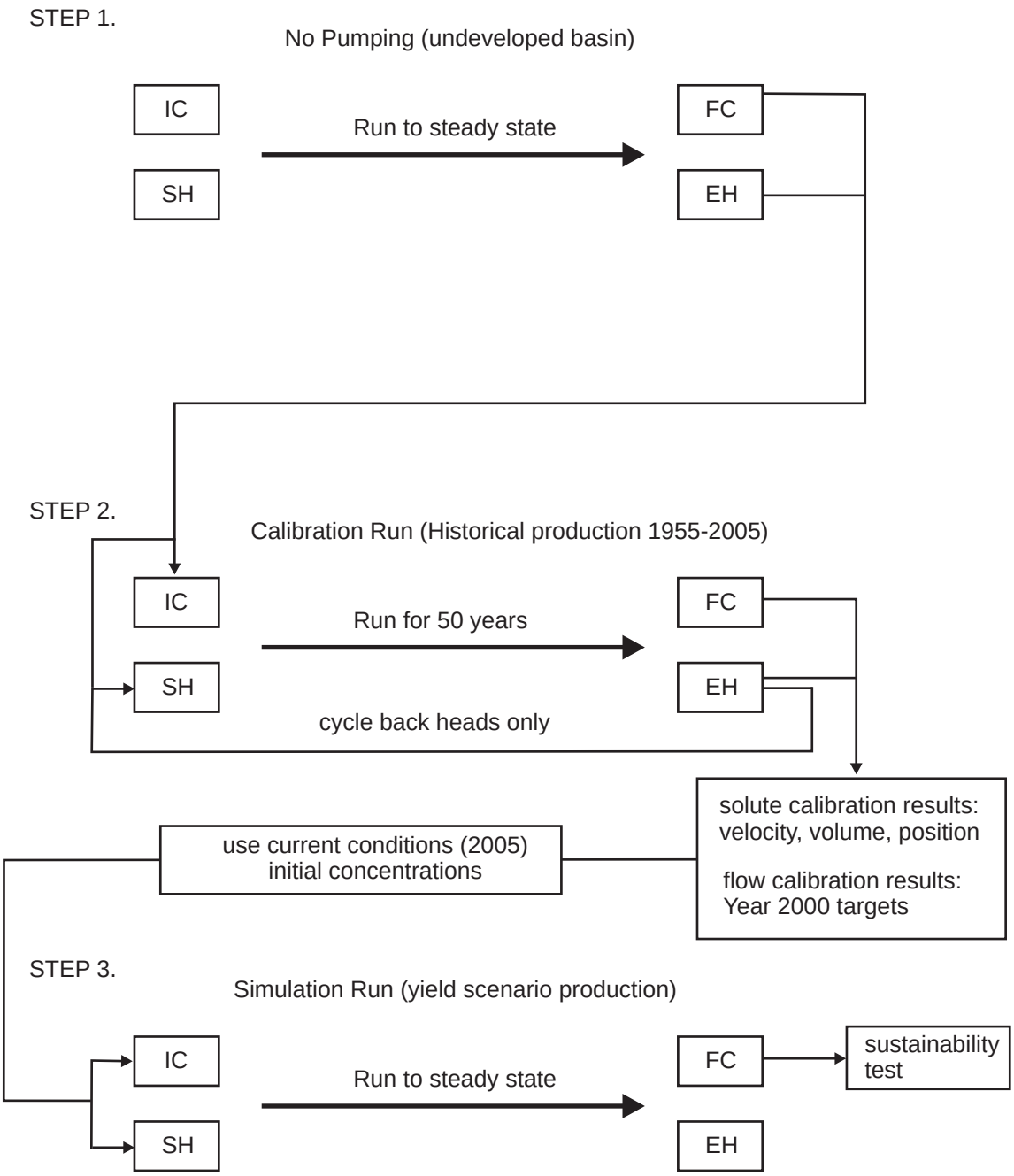
The SEAWAT model calibration consisted of two steps (Figure 1). The first step was to create initial concentrations and heads for the undeveloped basin, prior to pumping. The basin model was run with no pumping and natural recharge until there was no significant change in solute concentrations or heads (steady state).

The second step involved simulating 50 years of historical production from an undeveloped basin condition. Purveyor production was input to simulate three time periods: 25 years at early basin development (700 afy average), 20 years at year 2000 steady-state basin development (2,350 acre-feet per year average), and five years at current conditions (2,000 acre-feet per year).

The flow portion of the model remains calibrated to the steady-state head targets based on the equilibrium reached in 1999-2000. These targets were compared to the SEAWAT model heads after 45 years of pumping.

Due to the transient nature of the current model, aquifer storativity and porosity will affect the velocity of solute movement and the rate of change of head over time. A nominal storage coefficient of 0.0008 was assigned to the lower aquifer based on aquifer tests conducted by the U.S. Geological Survey in 1986, with a specific yield of 0.15 in unconfined areas of the basin. The porosity in the model ranges from 20-40 percent.

Solute transport in the basin is simulated by advection and dispersion. Diffusion is not a significant transport process in the sand and gravel aquifers. Advection was simulated using both finite-difference and total-variation diminishing (TVD) solutions, with comparable results. Flow and solute mass balance error was less than 1 percent at steady-state. Dispersion parameters were set at 100 feet longitudinal, 20 feet lateral, and 2 feet vertical. The flow calibration results, expressed in terms of the residual error statistics, are as follows:



LEGEND:

IC = Initial Concentrations
FC = Final Concentrations
SH = Starting Heads
EH = Ending Heads

Figure 1
Simulation Flow Chart
2009 SEAWAT Model

Cleath-Harris Geologists, Inc.

Table 1
Residual Error Statistics

Parameter	Original (2003)	Update (2004)	EFH (2005)	EFH (2008)	SEAWAT (2009)
Residual Mean	2.44 feet	0.03 feet	0.57 feet	0.93 feet	0.58 feet
Residual Standard Deviation	7.17 feet	5.61 feet	5.34 feet	4.66 feet	5.12 feet
Absolute Residual Mean	5.59 feet	4.42 feet	4.24 feet	3.73 feet	4.14 feet
Ratio of RSD to range	11.4%	8.9%	8.0%	7.0%	7.6%
Range in head	63 feet	63 feet	67 feet	67 feet	67 feet
Residual difference <10 feet	81%	92%	92%	95%	92%
Residual difference <20 feet	100%	100%	100%	100%	100%

Calibration of the dual-density (solute transport) portion of the model involved comparison of intrusion velocity and estimated volume of sea water intrusion at the coast with values estimated during the 2005 sea water intrusion study.

Prior work in 2005 estimated the velocity of sea water intrusion during the last 25-30 years in the lower aquifer at 50 to 60 feet per year. The SEAWAT model simulates an average velocity of 60 feet per year in the lower aquifer over the first 50 years of pumping, although the simulated velocity is higher in Zone D (80 feet/year) and lower in Zone E (40 feet per year).

After 50 years of simulated basin production, the inland position of the sea water transition zone in Zone D is relatively close to the current condition. The simulated position of Zone E is 1,000 to 2,000 feet closer to the coast than the current condition. This could be adjusted by adding more transient features to the model, such as refining historical production and recharge values. For a steady-state planning horizon, these differences do not affect long-term yield. Nevertheless, all simulations were started using initial concentrations that match 2005 conditions (Step 3; Figure 1). The volume of sea water intrusion estimated by the SEAWAT model for current conditions is 475 AFY, which is very close to the 469 AFY from the 2008 EFH model.

Urban Area Yield Update

Safe yield is historically defined as the maximum draft on a basin that will not produce undesirable impacts. In Los Osos, the primary undesirable impact is sea water intrusion. As sea water enters fresh water aquifers, chloride concentrations and associated TDS concentrations rise. The threshold

of undesirable impacts from chloride contamination is assumed to be 250 milligrams per liter (mg/l), which corresponds to the recommended maximum concentration for drinking water.

The Los Osos Valley groundwater basin has been divided, for discussion purposes, into the following areas:

West Side. The West side of the basin extends west of Palisades Avenue and includes Cuesta-by-the-Sea, Redfield Woods, the Martin Tract, Cabillo Estates, Sunset Terrace, and Monarch Grove. The division between the West side and the East side roughly corresponds to the edge of the perching clay.

East Side. The East side of the basin extends east of Palisades Avenue and includes Baywood, downtown Los Osos, Bayview Heights, Bayridge Estates, mobile home parks on Los Osos Valley Road, and all rural residential neighborhoods between South Bay Boulevard and Palomino Drive. The division between the East side and the creek valley area is defined by a change in the pattern and long-term trends of seasonal fluctuations in water levels (Cleath & Associates, 2002).

Creek Valley. The creek valley, also known as the Creek Compartment, extends from the East side, across the Los Osos Creek Valley to the east limits of the basin.

Urban Area. The urban area includes the West side and the East side.

The location and production capacity of existing or potential future purveyor wells in the Urban area provide a framework for developing the basin yield. The yield analysis consists of maximizing production while maintaining chloride concentrations at producing wells below 250 mg/l.

A steady-state planning horizon was selected. This corresponds to several thousand years of mass transport, given the large volumes of water stored in the basin aquifers. For perspective, 50-year and 500-year snapshots of simulated sea water intrusion are also presented for the current condition and VPA2b yield scenarios.

To configure the basin for yield scenarios, each existing well and potential future wells were assigned a maximum annual production cap, based on historical records, pumping tests, or anticipated yields. Production values were rounded to the closest 50-acre feet.

Current Condition Yield

The process of yield analysis begins with loading production values for a scenario into the model. Initial TDS concentrations and heads are calibrated to current conditions. Then the model is run to steady-state in 50-year stress periods over a 5000-year cycle. Model results after 50 and 500 years of simulated flow are extracted, along with the steady-state result.

A sustainability test is performed on the steady-state results. If the chlorides at a producing purveyor well exceeds 250 mg/l due to sea water intrusion, the yield is assumed to be unsustainable. Simulations are run until a sustainable yield is achieved. The optimum yield solution is reached when the difference between sustainable and unsustainable yield is reduced to approximately 50 acre-feet. Using this methodology, the updated yield for the basin under current conditions is shown below in Table 2.

Table 2
Basin Safe Yield Estimate - Current Conditions

Basin Area	Basin User	Yield (AFY)
Urban Area	Purveyor wells	2,100
	Sea Pines Golf Course	100
	Rural Residential (East side)	125
Creek Valley	Rural Residential (creek valley)	75
	Creek Valley (ag irrigation wells)	800
Basin Total		3,200

The overall basin yield estimate under current conditions (assuming no creek valley surplus water development) is 3,200 acre-feet per year. After subtracting 1,100 AFY in agricultural irrigation, private domestic use, and golf course irrigation, the purveyors have an estimated 2,100 AFY of sustainable yield. This is comparable to the current level of community demand, which has averaged approximately 2,040 AFY over the last five years (attached).

Balancing the basin, however, requires a significant redistribution of pumping between the upper and lower aquifers. These aquifers are not independent, and yield values should be interpreted accordingly. More lower aquifer yield can be obtained at the expense of upper aquifer yield, and vice-versa.

For the balanced basin simulation of current conditions listed in Table 2, the upper aquifer yield is 1,700 AFY and the lower aquifer yield is 1,500 AFY (basin-wide). The distribution of upper aquifer versus lower aquifer yield varies across the basin, however, with most of the lower aquifer yield in the East side and creek valley. For purveyor wells in the urban area, the yield distribution for a current conditions balanced basin is 1,490 AFY upper aquifer and 620 AFY lower aquifer.

One hypothetical optimum solution for urban area purveyor well production that mitigates sea water intrusion under current conditions is given below in Table 3. Figures showing seawater intrusion at 50 years, 500 years, and steady state, with chemographs for representative wells are attached. A hydrologic budget flow diagram is also attached. Note that 55 AFY of sea water intrusion continues to enter the basin, where it dilutes to below 250 mg/l chloride before reaching active production wells.

Table 3
Potential Purveyor Well Production under Current Septic Conditions

Purveyor	Well	Production (AFY)
GSWC	Upper Aquifer	740
	Lower Aquifer	310
	GSWC TOTAL	1,050
	Upper Aquifer	650
	Lower Aquifer	300
	LOCSD TOTAL	950
S&T	Upper Aquifer	100
PURVEYOR TOTAL		2,100

Note: Other optimum yield pumping distributions are possible. The actual distribution of well production would be subject to purveyor agreement.

Wastewater Project Conditions Yield

The same methodology was applied to the wastewater scenarios. Two wastewater scenarios have been simulated: Spray Field only and a VPA2b. Results of the wastewater project conditions yield simulations are shown below in Table 4.

Table 4
Basin Safe Yield Estimate - Wastewater Project Conditions

Basin Area	Basin User	Yield (AFY)	
		Spray Field Only	VPA 2b
Urban Area	Purveyor wells	1,600	2,050
	Sea Pines Golf Course	100	100
	Rural Residential (East side)	125	125
Creek Valley	Rural Residential (creek valley)	75	75
	Creek Valley (ag irrigation wells)	800	800
Basin Total		2,700	3,150

These basin yield estimates assume no creek valley surplus water development. The basin-wide upper aquifer yield is 1,320 AFY and the lower aquifer yield is 1,380 AFY for Spray Fields. For VPA2b, the basin-wide upper aquifer yield is 1,565 AFY and the lower aquifer yield is 1,585 AFY.

The purveyor well production distribution for a balanced basin, with all spray field disposal, is 1,070 AFY upper aquifer and 530 AFY lower aquifer. For VPA2b, the distribution is 1,325 upper aquifer and 725 lower aquifer.

Hypothetical optimum solutions for the urban area purveyor well production that mitigates sea water intrusion under these wastewater project scenarios is given below in Tables 5 and 6. Figures showing seawater intrusion at 50 years, 500 years (VPA2b only), and steady state, with chemographs for representative wells, are attached. A hydrologic budget flow diagram (VPA2b) is also attached. Note that 55 AFY of sea water intrusion continues to enter the basin, where it dilutes to below 250 mg/l chloride before reaching active production wells.

Table 5
Potential Purveyor Well Production under Wastewater Project Conditions with Spray Field Disposal Only

Purveyor	Well	Production (AFY)
GSWC	Upper Aquifer	485
	Lower Aquifer	265
	GSWC TOTAL	750
LOCSD	Upper Aquifer	485
	Lower Aquifer	265
	LOCSD TOTAL	750
S&T	Upper Aquifer	100
PURVEYOR TOTAL		1,600

Note: Other optimum yield pumping distributions are possible. The actual distribution of well production would be subject to purveyor agreement.

Table 6
Potential Purveyor Well Production under Wastewater Project Conditions with VPA2b Disposal

Purveyor	Well	Production (AFY)
GSWC	Upper Aquifer	740
	Lower Aquifer	310
	GSWC TOTAL	1,050
LOCSD	Upper Aquifer	485
	Lower Aquifer	415
	LOCSD TOTAL	900
S&T	Upper Aquifer	100
PURVEYOR TOTAL		2,050

Note: Other optimum yield pumping distributions are possible. The actual distribution of well production would be subject to purveyor agreement.

Sea Level Rise

The Intergovernmental Panel on Climate Change estimates sea level will rise up to two feet within the next 100 years (IPCC, 2007), although more recent analysis by the U.S. Geological Survey indicate the rise may be significantly greater (USGS, 2008). Sea level rise is attributed to thermal expansion of the ocean water and melting of land-based ice. Both of these mechanisms would result in slightly lower average sea water density and salinity.

Sea water density is controlled by pressure, temperature, and salinity. Based on the equation of state, an increase density of one part per thousand (ppt) can be brought about by:

1) a decrease of about 5° Centigrade (from 17° to 12° C at 36 ppt salinity and atmospheric pressure).
2) an increase of about 1.2 ppt salinity; and
3) an increase of about 200 decibars pressure.
(Reid, 1954)

Using the above relationship, if global warming resulted in an approximate 5° Centigrade increase in mean ocean temperature (upper range of global warming predictions), sea water density could decrease approximately 1 part per thousand, from 64 pounds per cubic foot to 63.94 pounds per

cubic foot. The density of fresh water is 62.44 pounds per cubic foot. Using the SEAWAT model and this density correction, a 2-foot sea level rise appears to decrease yield under current conditions by 50 acre-feet.

Discussion

The SEAWAT model shows a balanced basin yield under current conditions (septic systems in place) of 3,200 AFY, similar to the July 2005 LOCSD Draft Water Management Plan estimate of 3,250 AFY. There is, however, significantly less yield from the lower aquifer (with a corresponding greater upper aquifer yield) in the urban area than previously estimated.

Wastewater simulations show that exporting all of the current septic flow from the prohibition zone (1,157 AFY before conservation) will decrease basin yield by approximately 500 AFY. The decline in yield is less than the exported water because most of current septic return flows cannot be effectively captured by purveyor wells before draining to local creeks or the bay. The VPA2b simulation shows that returning 448 AFY to Broderson increases basin yield by 450 AFY.

Under any balanced basin scenario, shutting down lower aquifer production wells may significantly affect system peaking capacity, since upper aquifer wells generally do not have as high an instantaneous discharge capacity as lower aquifer wells. Planning for nitrate removal or blending is also more challenging with less lower aquifer yield.

The SEAWAT model confirms that the strategy for sea water mitigation is to shift from lower to upper aquifer production in the urban area. An ISJ basin management plan can maximize system reliability by developing new upper aquifer wells, but allowing existing lower aquifer wells to continue operating for blending or peaking until specified water quality thresholds have been reached and sufficient replacement capacity has been developed.

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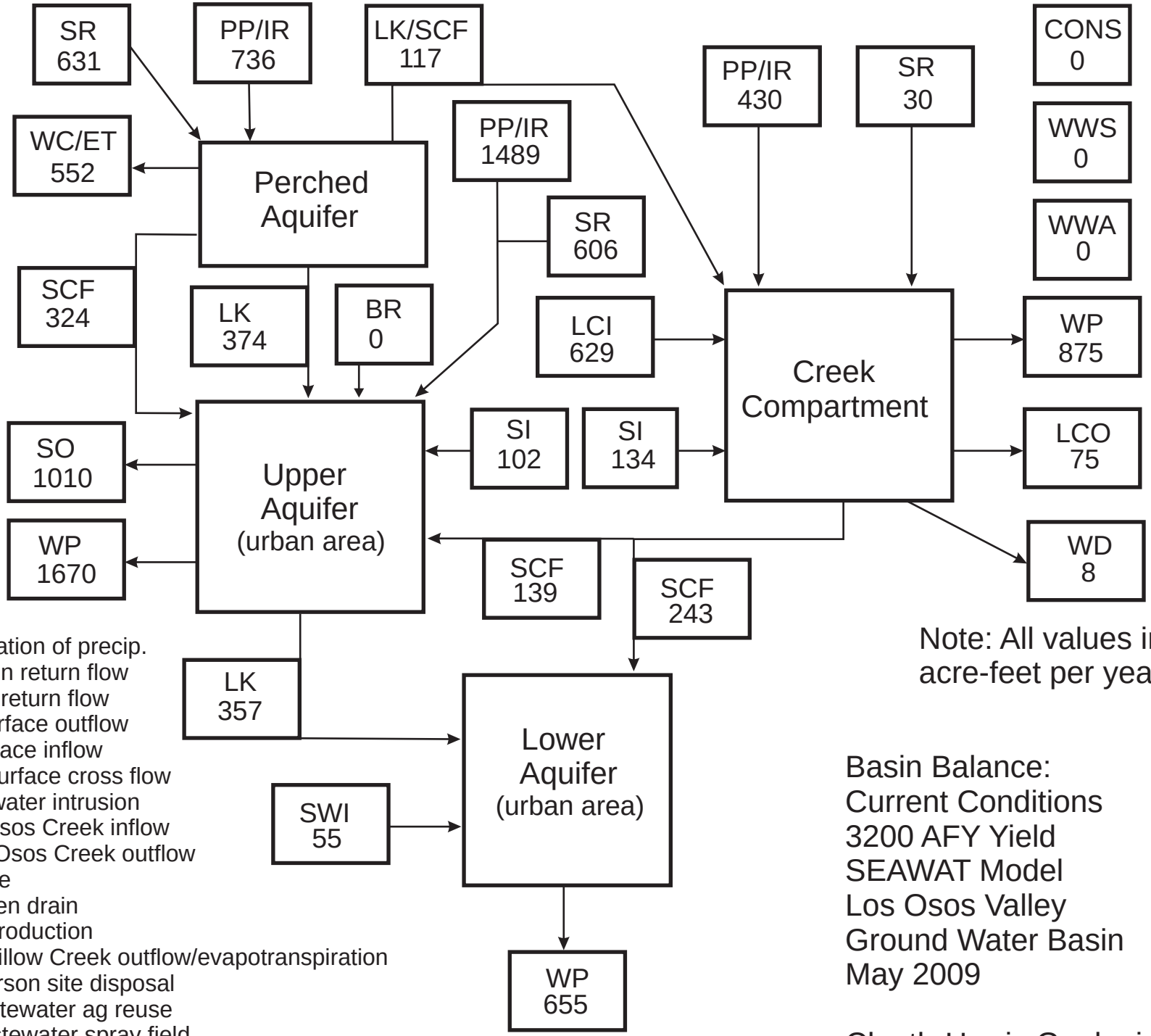
Yates & Williams, 2003. Simulated Effects of a Proposed Sewer Project on Nitrate Concentrations in the Los Osos Valley Groundwater Basin, June 2004.

ATTACHMENTS:

Purveyor Production Records
Purveyor Wells
Hydrologic Budget Flow Diagrams
TDS Isoconcentration Maps
TDS Chemographs

Los Osos Water Purveyor
Production in acre-feet

YEAR	LOCSD	GSWC	S&T	Purveyor total
1982	817	853	99.6	1769.6
1983	791	866	100.2	1757.2
1984	1004	984	117.9	2105.9
1985	1093	1049	109.9	2251.9
1986	1172	1067	112.5	2351.5
1987	1158	1095	112.4	2365.4
1988	1259	1181	123.4	2563.4
1989	1175	1154	107.4	2436.4
1990	1161	1120	108.7	2389.7
1991	1102	1045	102.5	2249.5
1992	1157	1038	108.2	2303.2
1993	1003	1018	101.4	2122.4
1994	1113	995	95.8	2203.8
1995	1364	989	95.8	2448.8
1996	1097	1033	98.9	2228.9
1997	1190	1107	111.2	2408.2
1998	1065	994	110.1	2169.1
1999	1069	1103	61.8	2233.8
2000	1149	1076	111.5	2336.5
2001	1099	1065	98.7	2262.7
2002	1158	1061	118.7	2337.7
2003	1131	1035	96.1	2262.1
2004	1045	1072	100.3	2217.3
2005	960	1018	93.3	2071.3
2006	939	966	88.2	1993.2
2007	943	990	95.6	2028.6
2008	870	945	91.4	1906.4
2004-2008 average	951.4	998.2	93.76	2043.36



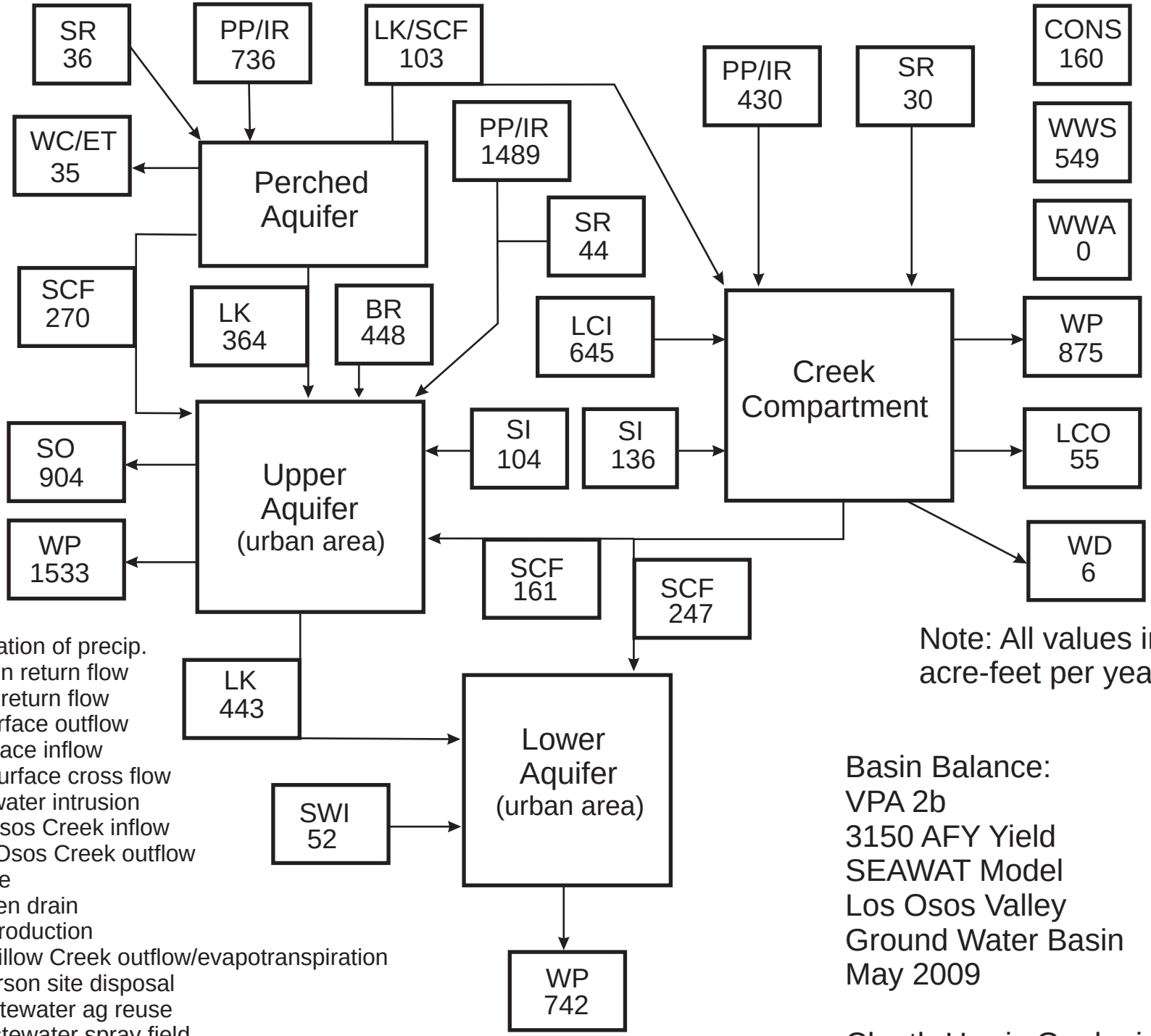
Legend

PP = percolation of precip.
IR = irrigation return flow
SR = septic return flow
SO = subsurface outflow
SI = subsurface inflow
SCF = subsurface cross flow
SWI = sea water intrusion
LCI = Los Osos Creek inflow
LCO = Los Osos Creek outflow
LK = leakage
WD = Warden drain
WP = well production
WC/ET = Willow Creek outflow/evapotranspiration
BR = Broderson site disposal
WWA = wastewater ag reuse
WWS = wastewater spray field
CONS = water conservation

Note: All values in acre-feet per year

Basin Balance:
Current Conditions
3200 AFY Yield
SEAWAT Model
Los Osos Valley
Ground Water Basin
May 2009

Cleath-Harris Geologists, Inc.



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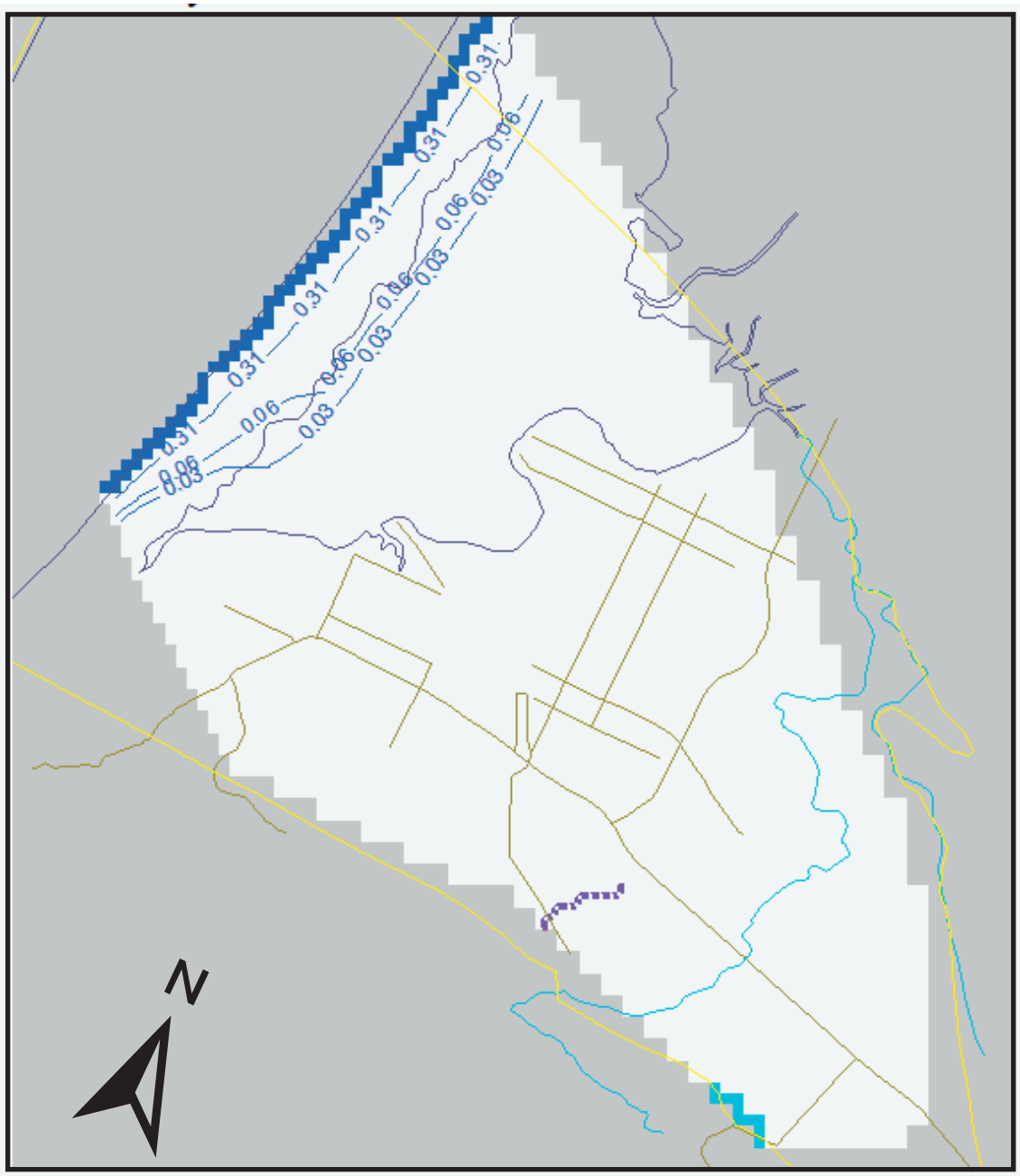
WP = well production
WC/ET = Willow Creek outflow/evapotranspiration
BR = Broderson site disposal
WWA = wastewater ag reuse
WWS = wastewater spray field
CONS = water conservation

Note: All values in acre-feet per year

Basin Balance:
VPA 2b
3150 AFY Yield
SEAWAT Model
Los Osos Valley
Ground Water Basin
May 2009

Cleath-Harris Geologists, Inc.



Scale 1" = 4000 feet

TDS isoconcentrations in lb/ft3

0.03 lb/ft3 = 500 mg/l TDS ≈ 250 mg/l Chloride
0.06 lb/ft3 = 1,000 mg/l TDS≈ 500 mg/l Chloride
0.31 lb/ft3 = 5,000 mg/l TDS≈ 2,500 mg/l Chloride

Figure A1

TDS Isoconcentrations
No Pumping Simulation - Zone D
May 2009 SEAWAT Model
Los Osos ISJ Group

Cleath-Harris Geologists, Inc.

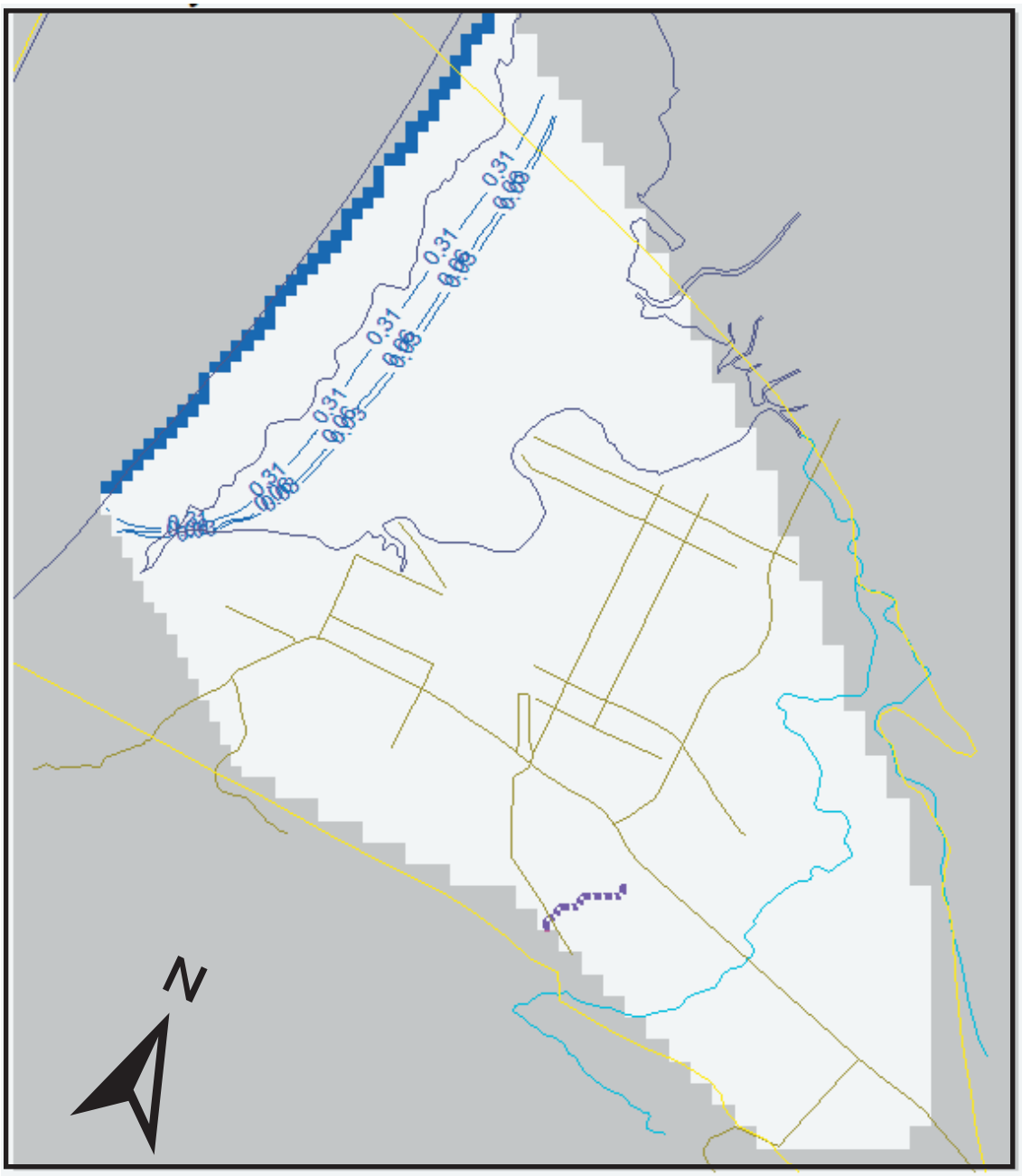


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Figure A2

TDS Isoconcentrations
No Pumping Simulation - Zone E
May 2009 SEAWAT Model
Los Osos ISJ Group

Cleath-Harris Geologists, Inc.

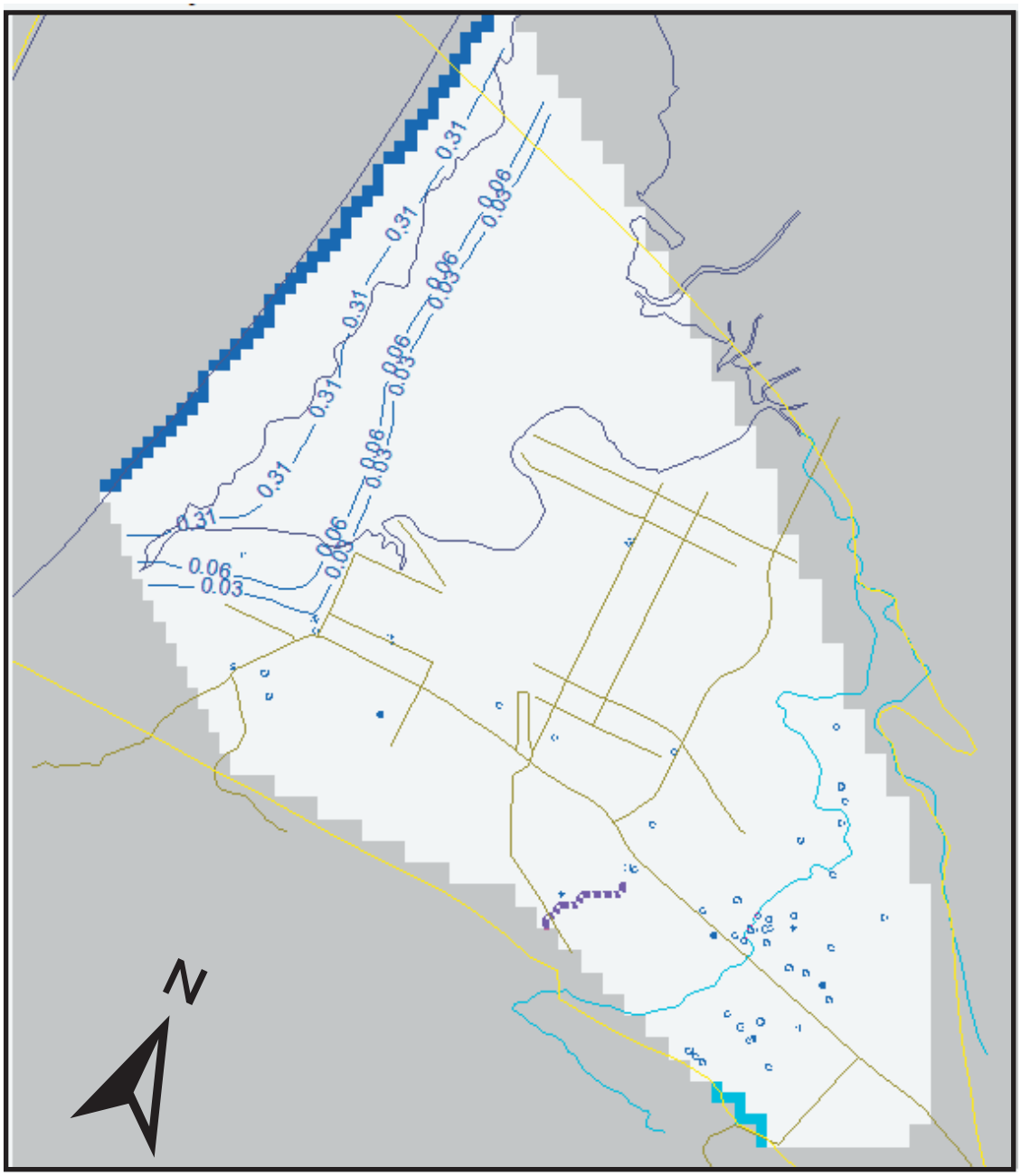

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Figure A3

TDS Isoconcentrations
Calibration Run-2005 Zone D
May 2009 SEAWAT Model
Los Osos ISJ Group

Cleath-Harris Geologists, Inc.

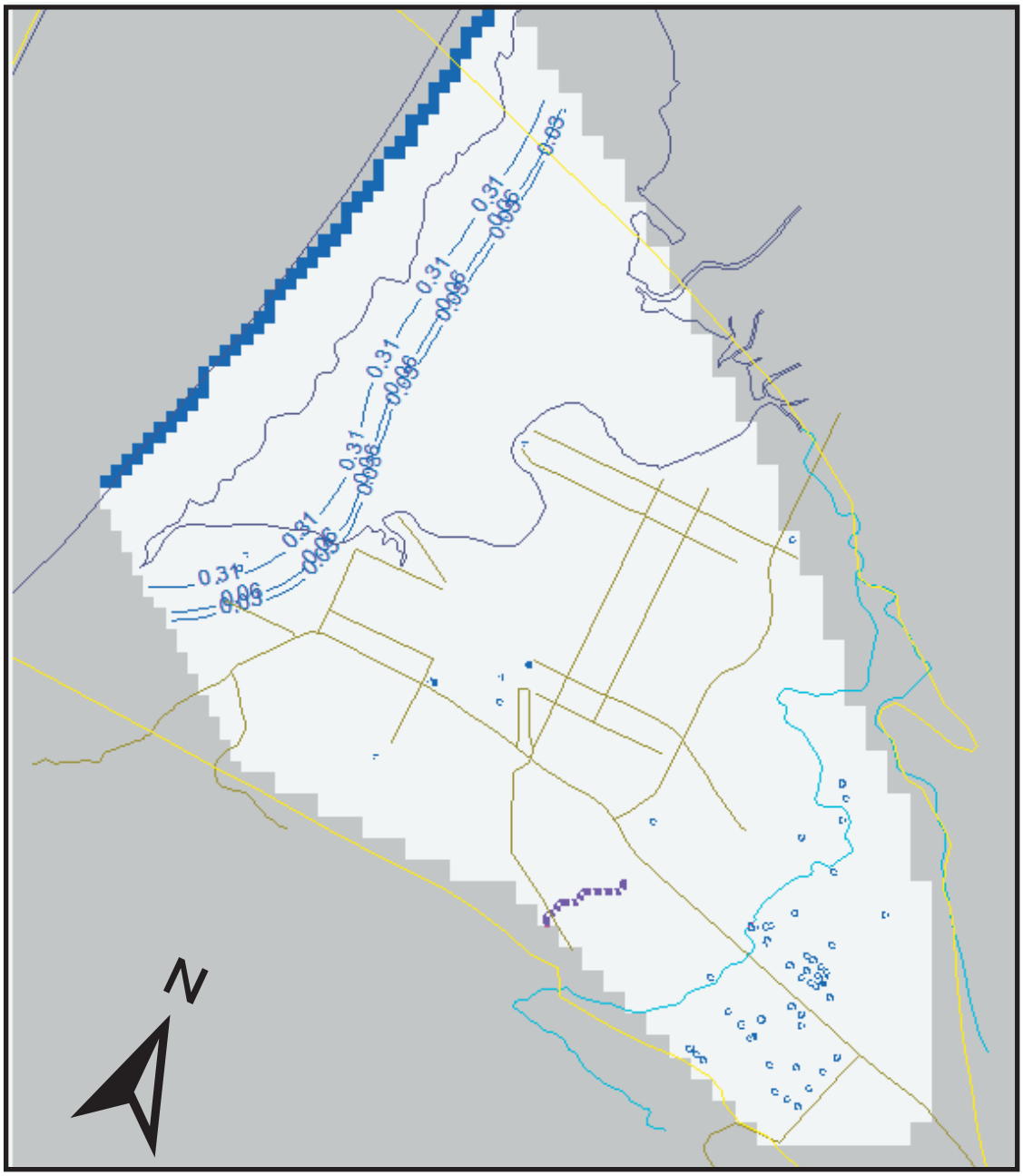

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Figure A4

TDS Isoconcentrations
Calibration Run - 2005 Zone E
May 2009 SEAWAT Model
Los Osos ISJ Group

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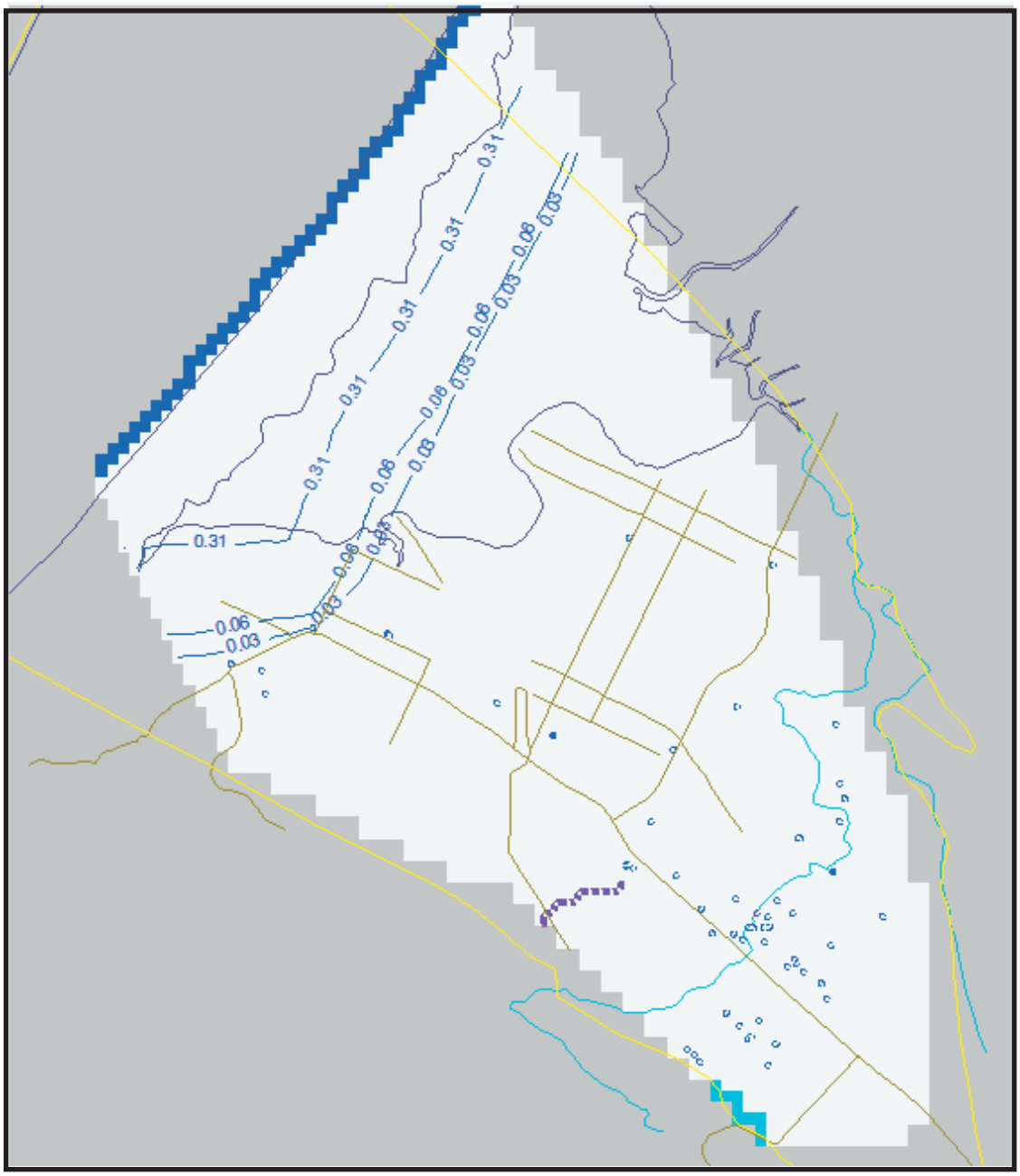

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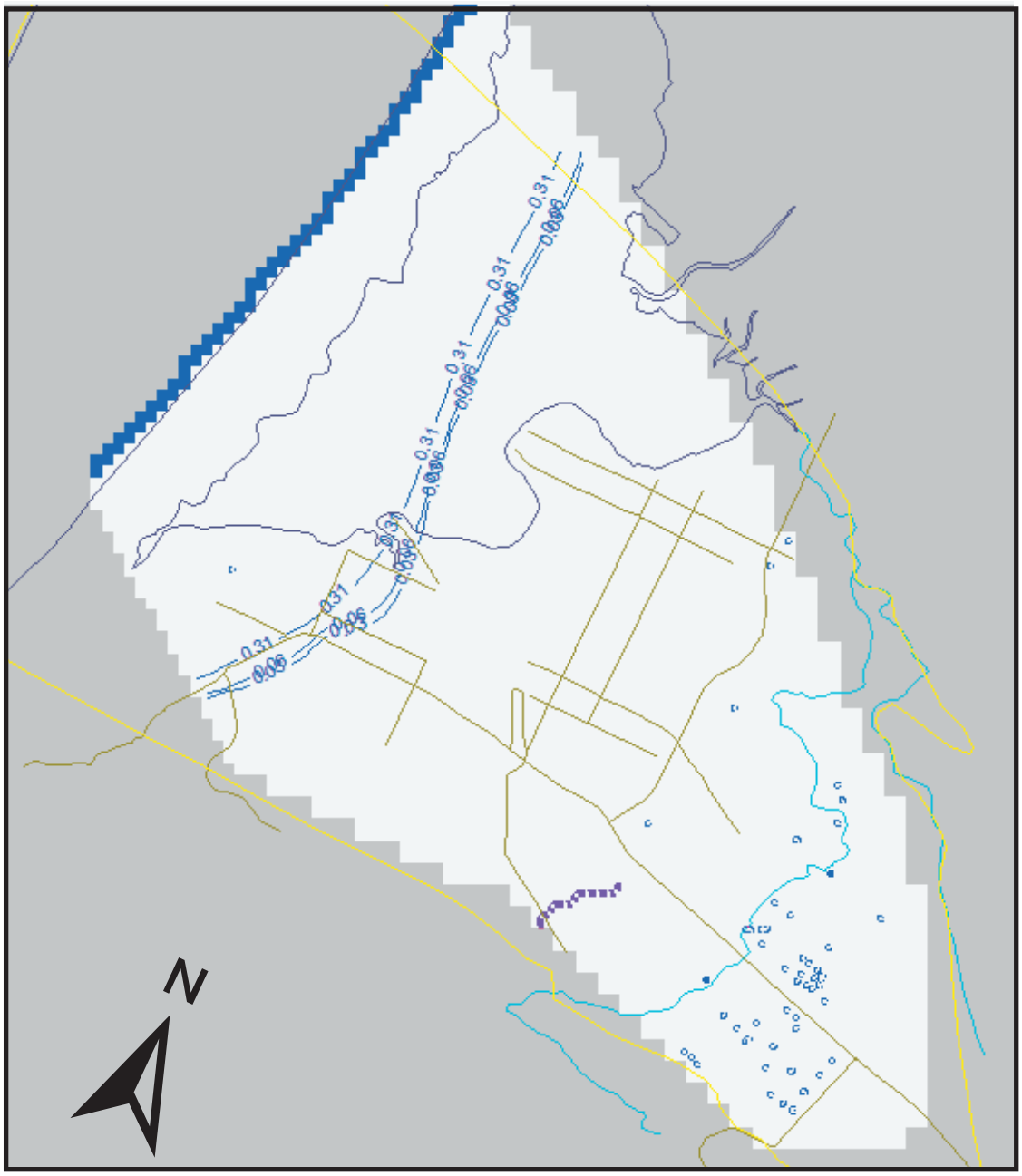
Figure A5

TDS Isoconcentrations
Current Conditions - Zone D
May 2009 SEAWAT Model
Los Osos ISJ Group

Cleath-Harris Geologists, Inc.



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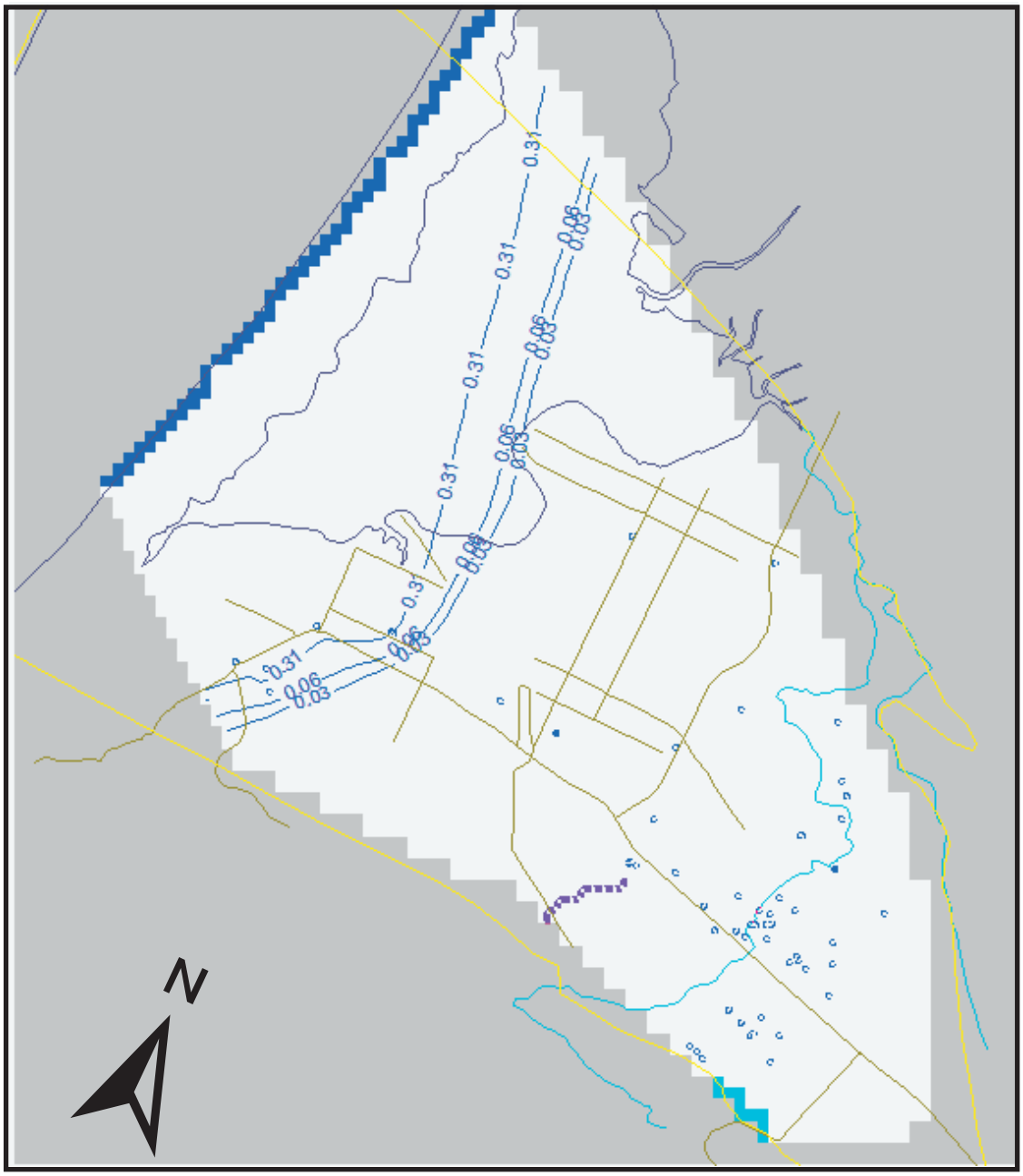
0.31 lb/ft3 = 5,000 mg/l TDS≈ 2,500 mg/l Chloride

Figure A6

TDS Isoconcentrations
Current Conditions - Zone E
May 2009 SEAWAT Model
Los Osos ISJ Group

Cleath-Harris Geologists, Inc.



Scale 1" = 4000 feet

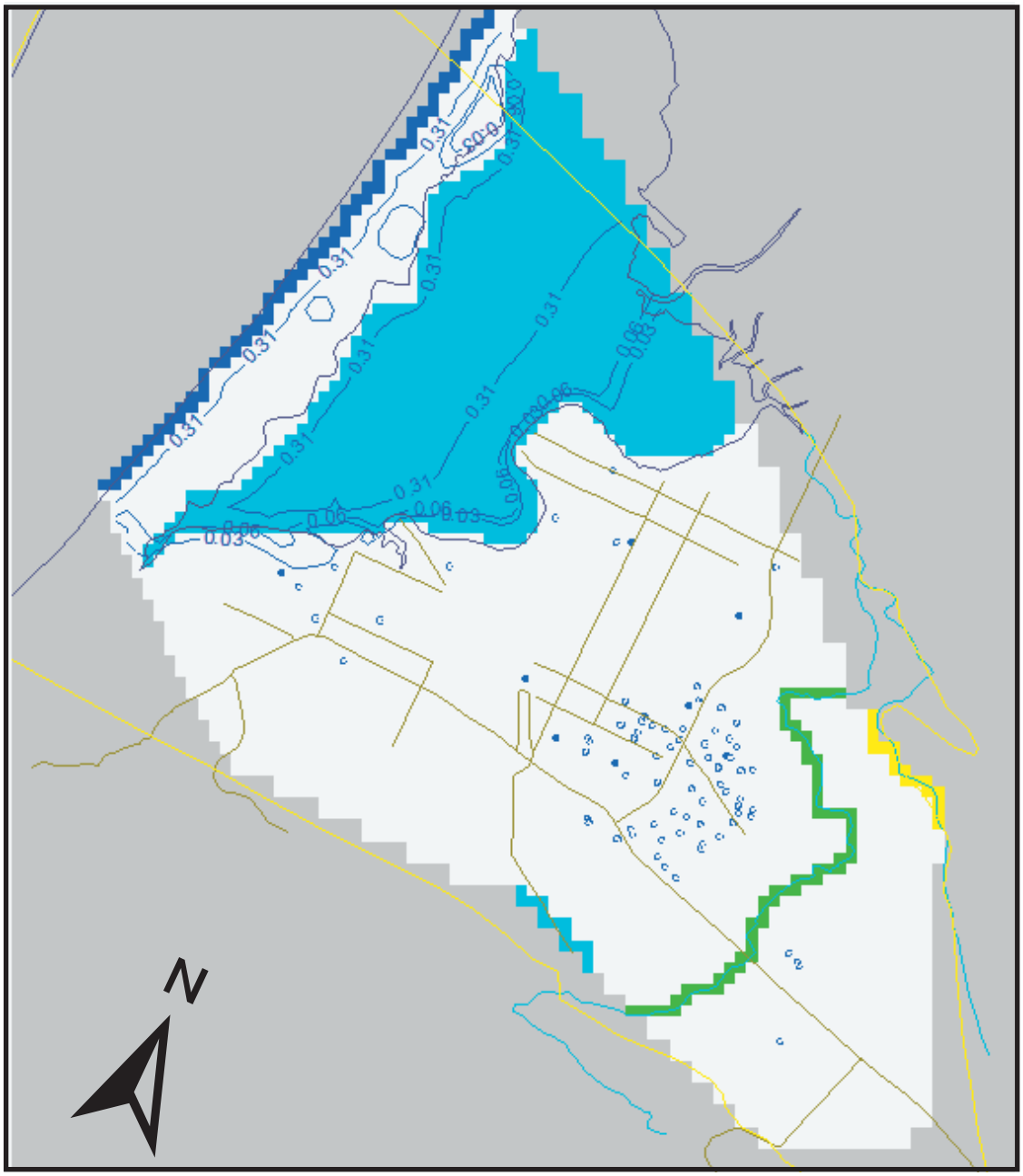
TDS isoconcentrations in lb/ft3

0.03 lb/ft3 = 500 mg/l TDS ≈ 250 mg/l Chloride
0.06 lb/ft3 = 1,000 mg/l TDS≈ 500 mg/l Chloride
0.31 lb/ft3 = 5,000 mg/l TDS≈ 2,500 mg/l Chloride

Figure A7

TDS Isoconcentrations
Current Conditions - Zone D
50-year planning horizon at 3066 AFY
(basin not in balance)
May 2009 SEAWAT Model
Los Osos ISJ Group

Cleath-Harris Geologists, Inc.



Scale 1" = 4000 feet

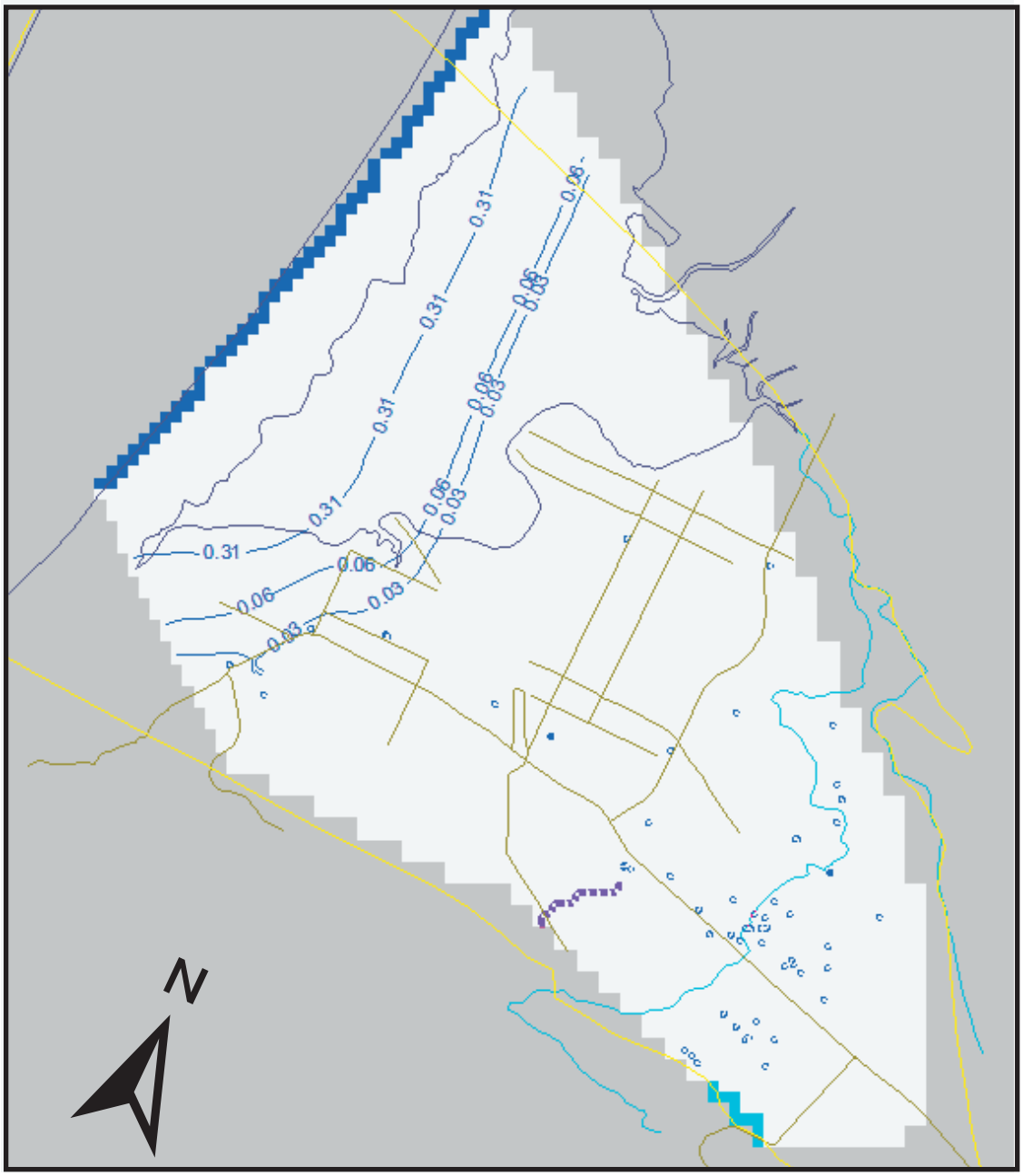
TDS isoconcentrations in lb/ft3

0.03 lb/ft3 = 500 mg/l TDS ≈ 250 mg/l Chloride
0.06 lb/ft3 = 1,000 mg/l TDS≈ 500 mg/l Chloride
0.31 lb/ft3 = 5,000 mg/l TDS≈ 2,500 mg/l Chloride

Figure A8

TDS Isoconcentrations
Current Conditions Yield - Zone C
Steady State at 3,200 AFY
May 2009 SEAWAT Model
Los Osos ISJ Group

Cleath-Harris Geologists, Inc.



Scale 1" = 4000 feet

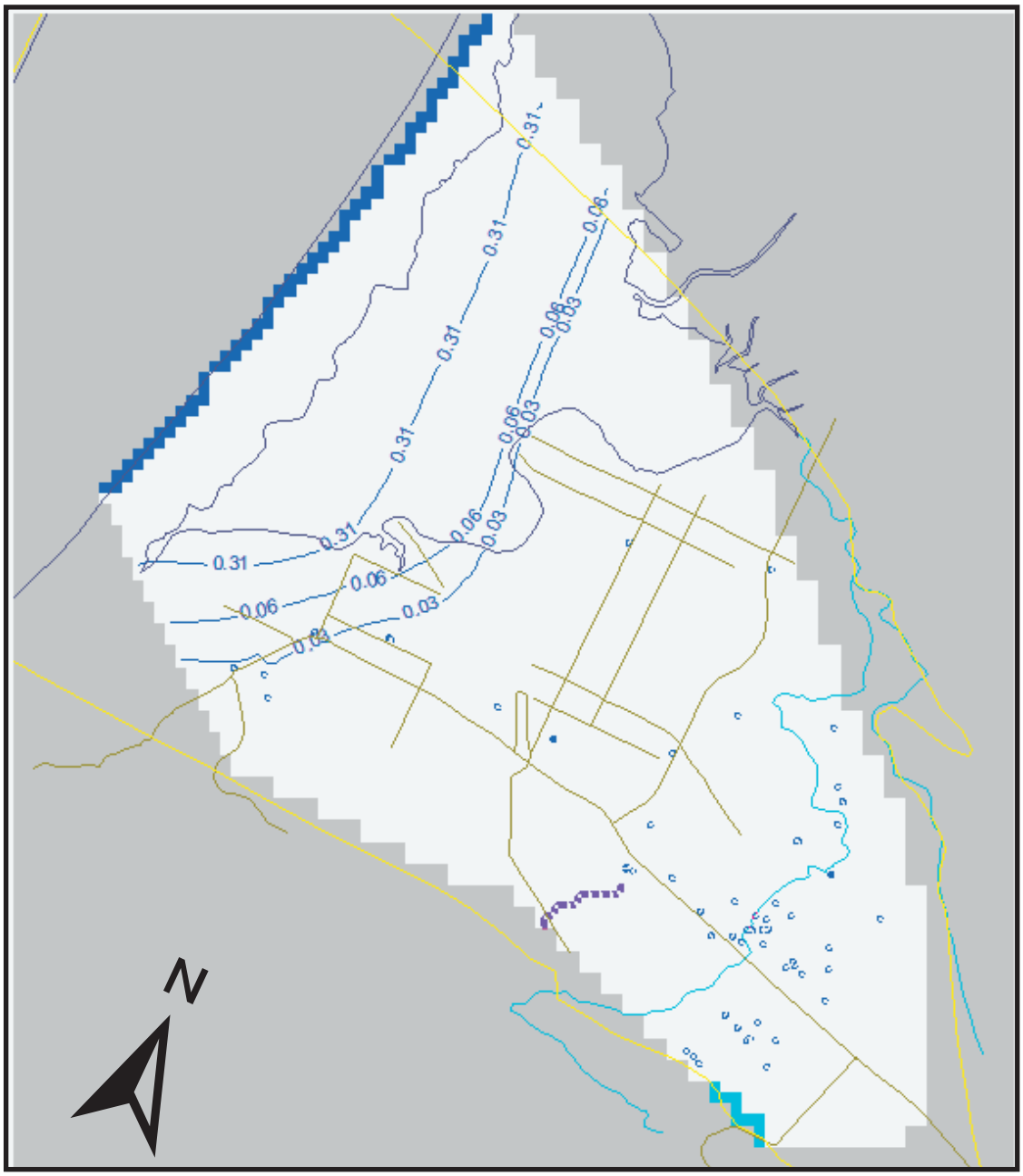
TDS isoconcentrations in lb/ft3

0.03 lb/ft3 = 500 mg/l TDS ≈ 250 mg/l Chloride
0.06 lb/ft3 = 1,000 mg/l TDS≈ 500 mg/l Chloride
0.31 lb/ft3 = 5,000 mg/l TDS≈ 2,500 mg/l Chloride

Figure A9

TDS Isoconcentrations
Current Conditions Yield - Zone D
50-year planning horizon at 3,200 AFY
May 2009 SEAWAT Model
Los Osos ISJ Group

Cleath-Harris Geologists, Inc.



Scale 1" = 4000 feet

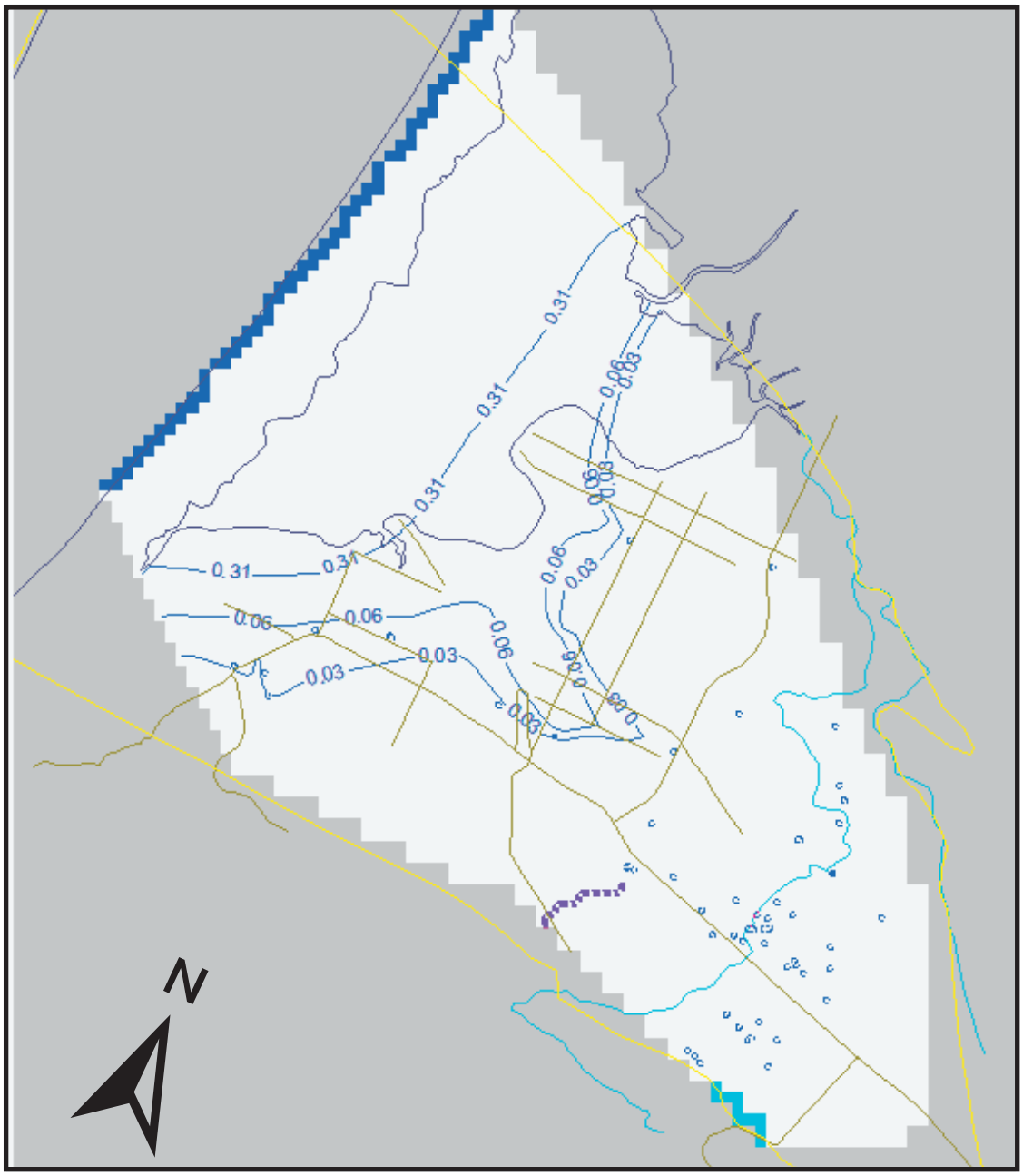
TDS isoconcentrations in lb/ft3

0.03 lb/ft3 = 500 mg/l TDS ≈ 250 mg/l Chloride
0.06 lb/ft3 = 1,000 mg/l TDS≈ 500 mg/l Chloride
0.31 lb/ft3 = 5,000 mg/l TDS≈ 2,500 mg/l Chloride

Figure A10

TDS Isoconcentrations
Current Conditions Yield - Zone D
500-year planning horizon at 3,200 AFY
May 2009 SEAWAT Model
Los Osos ISJ Group

Cleath-Harris Geologists, Inc.



Scale 1" = 4000 feet

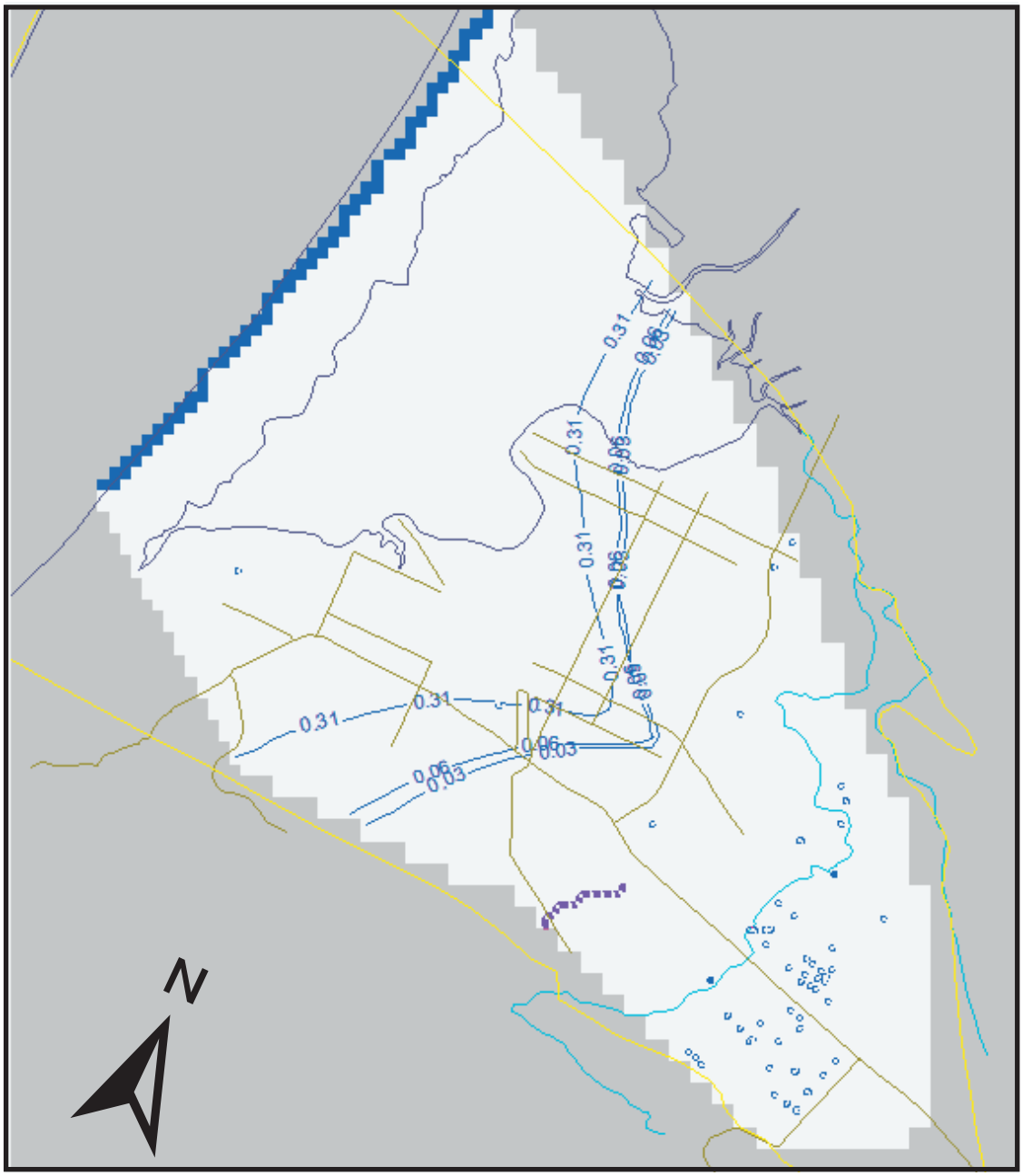
TDS isoconcentrations in lb/ft3

0.03 lb/ft3 = 500 mg/l TDS ≈ 250 mg/l Chloride
0.06 lb/ft3 = 1,000 mg/l TDS≈ 500 mg/l Chloride
0.31 lb/ft3 = 5,000 mg/l TDS≈ 2,500 mg/l Chloride

Figure A11

TDS Isoconcentrations
Current Conditions Yield - Zone D
Steady State at 3,200 AFY
May 2009 SEAWAT Model
Los Osos ISJ Group

Cleath-Harris Geologists, Inc.



Scale 1" = 4000 feet

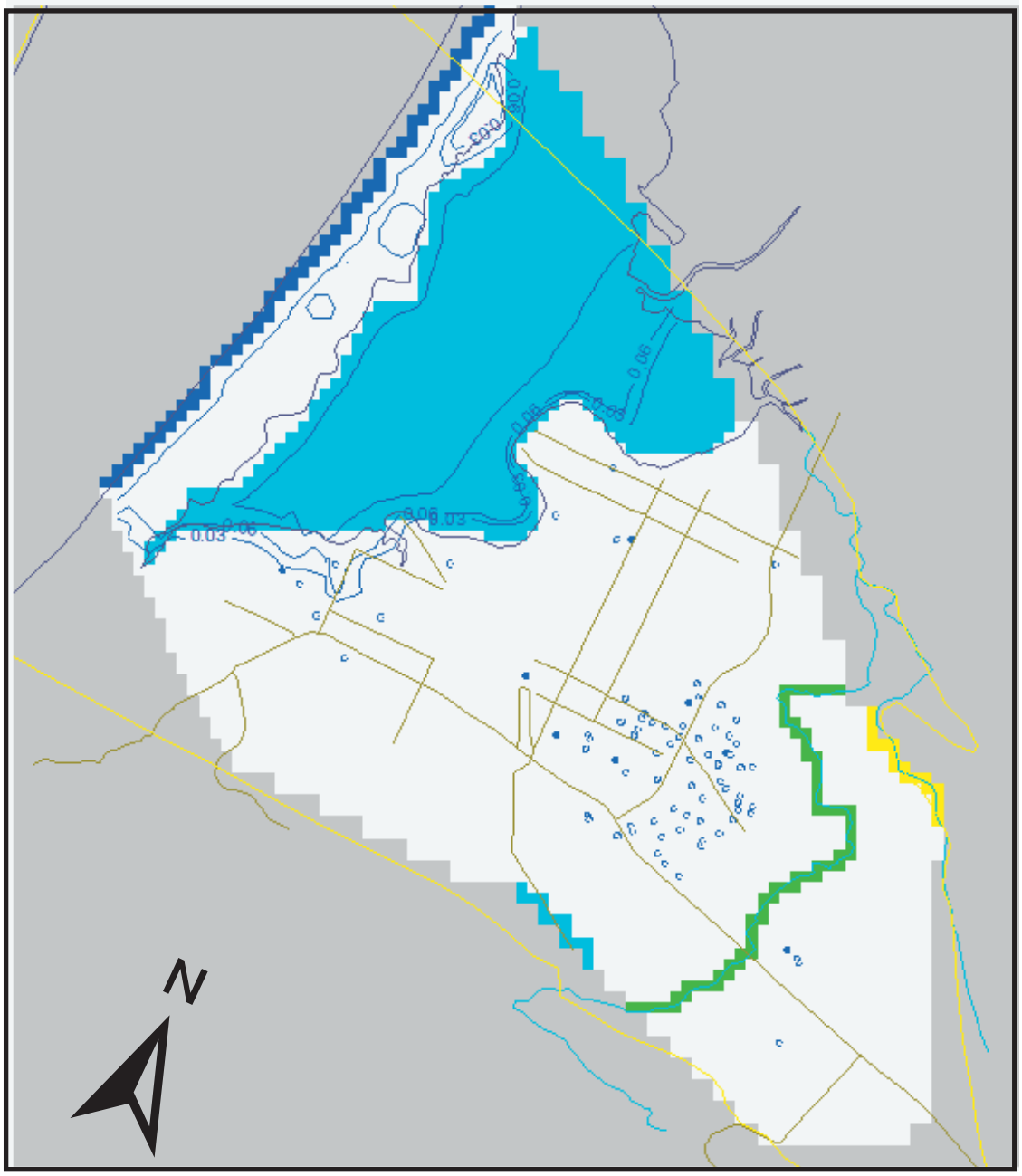
TDS isoconcentrations in lb/ft3

0.03 lb/ft3 = 500 mg/l TDS ≈ 250 mg/l Chloride
0.06 lb/ft3 = 1,000 mg/l TDS≈ 500 mg/l Chloride
0.31 lb/ft3 = 5,000 mg/l TDS≈ 2,500 mg/l Chloride

Figure A12

TDS Isoconcentrations
Current ConditionsYield - Zone E
Steady State at 3,200 AFY
May 2009 SEAWAT Model
Los Osos ISJ Group

Cleath-Harris Geologists, Inc.



Scale 1" = 4000 feet

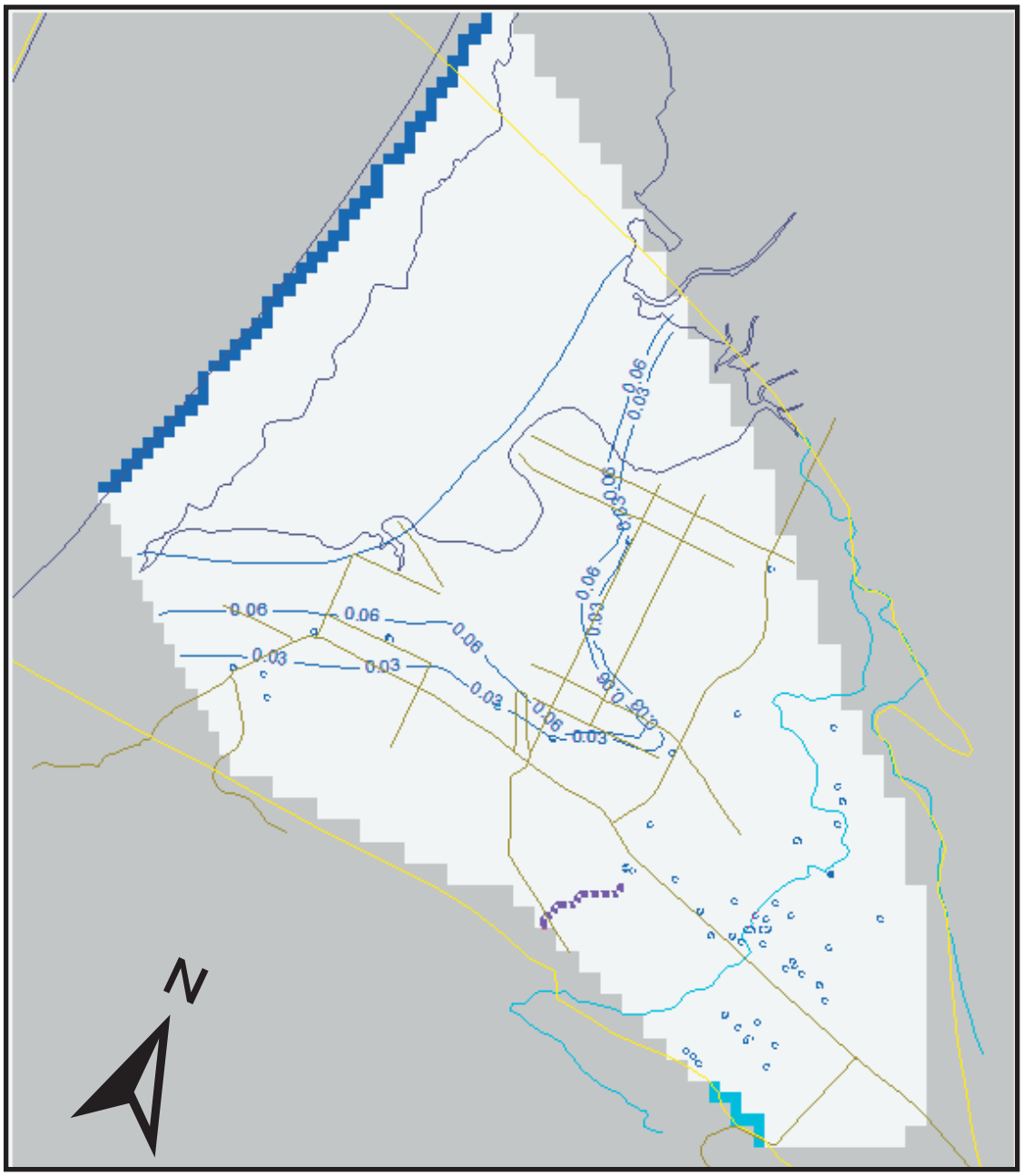
TDS isoconcentrations in lb/ft3

0.03 lb/ft3 = 500 mg/l TDS ≈ 250 mg/l Chloride
0.06 lb/ft3 = 1,000 mg/l TDS≈ 500 mg/l Chloride
0.31 lb/ft3 = 5,000 mg/l TDS≈ 2,500 mg/l Chloride

Figure A13

TDS Isoconcentrations
Spray Fields Yield - Zone C
Steady State at 2,700 AFY
May 2009 SEAWAT Model
Los Osos ISJ Group

Cleath-Harris Geologists, Inc.



Scale 1" = 4000 feet

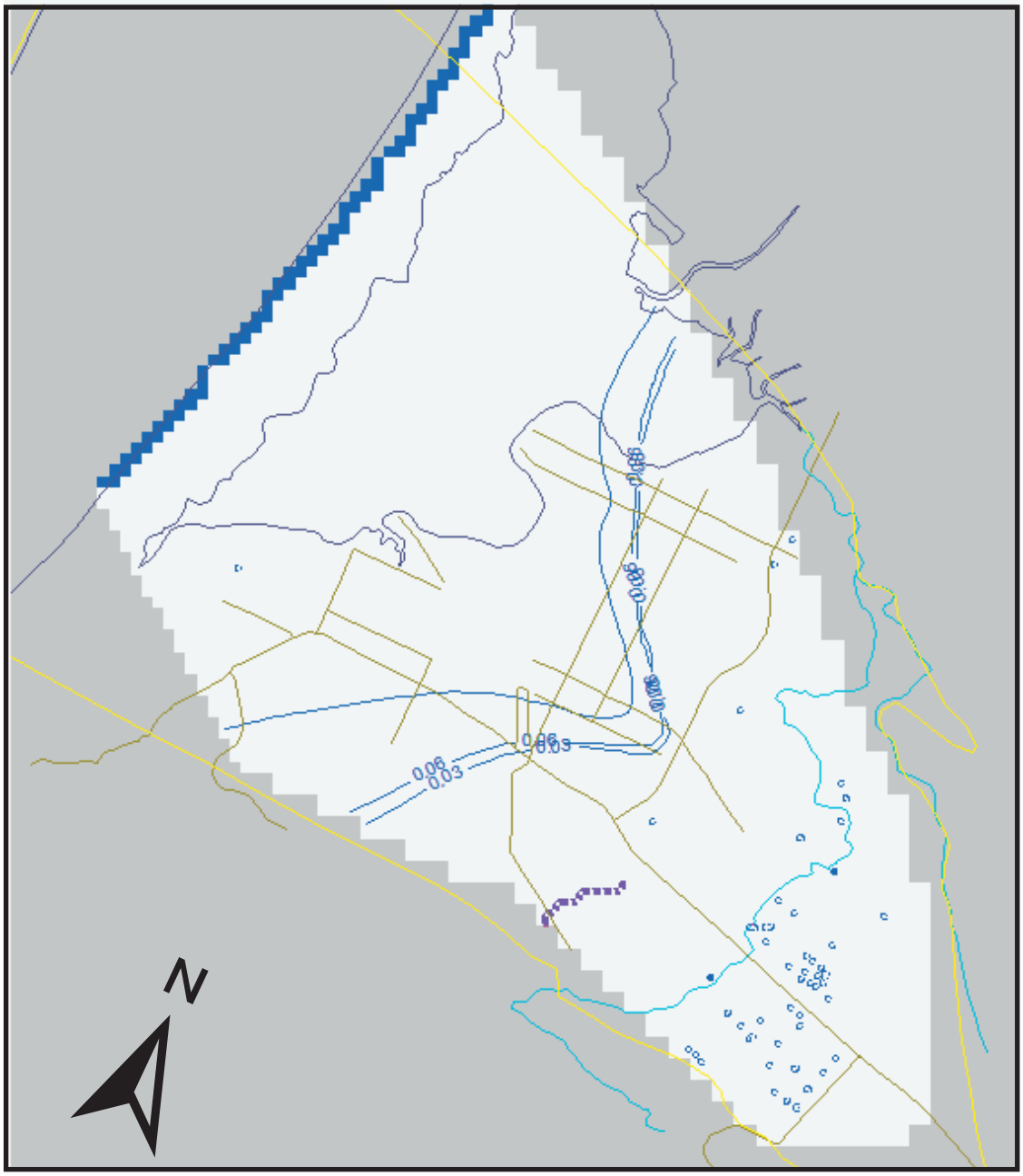
TDS isoconcentrations in lb/ft3

0.03 lb/ft3 = 500 mg/l TDS ≈ 250 mg/l Chloride
0.06 lb/ft3 = 1,000 mg/l TDS≈ 500 mg/l Chloride
0.31 lb/ft3 = 5,000 mg/l TDS≈ 2,500 mg/l Chloride

Figure A14

TDS Isoconcentrations
Spray Fields Yield - Zone D
Steady State at 2,700 AFY
May 2009 SEAWAT Model
Los Osos ISJ Group

Cleath-Harris Geologists, Inc.



Scale 1" = 4000 feet

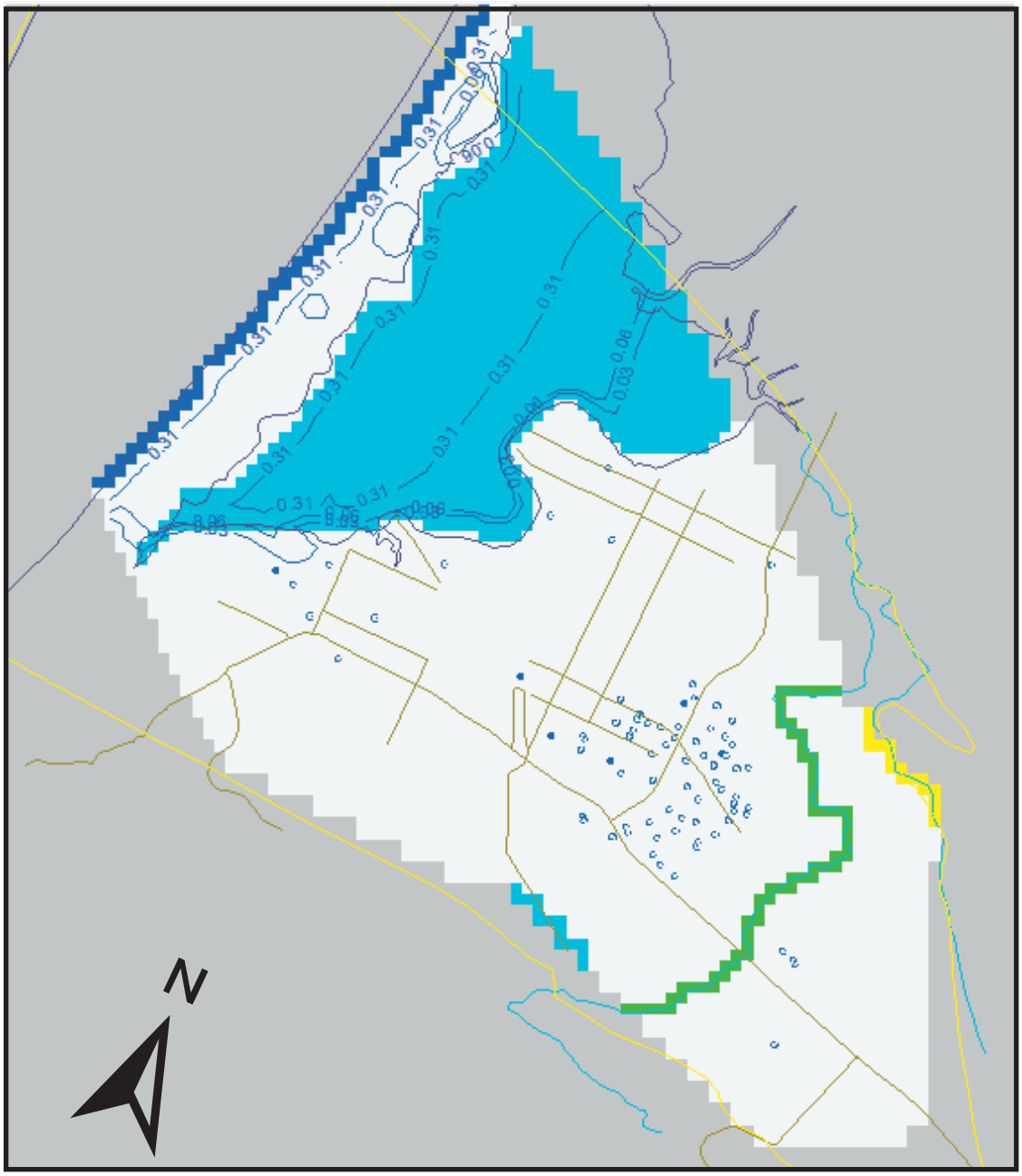
TDS isoconcentrations in lb/ft3

0.03 lb/ft3 = 500 mg/l TDS ≈ 250 mg/l Chloride
0.06 lb/ft3 = 1,000 mg/l TDS≈ 500 mg/l Chloride
0.31 lb/ft3 = 5,000 mg/l TDS≈ 2,500 mg/l Chloride

Figure A15

TDS Isoconcentrations
Spray Fields Yield - Zone E
Steady State at 2,700 AFY
May 2009 SEAWAT Model
Los Osos ISJ Group

Cleath-Harris Geologists, Inc.



Scale 1" = 4000 feet

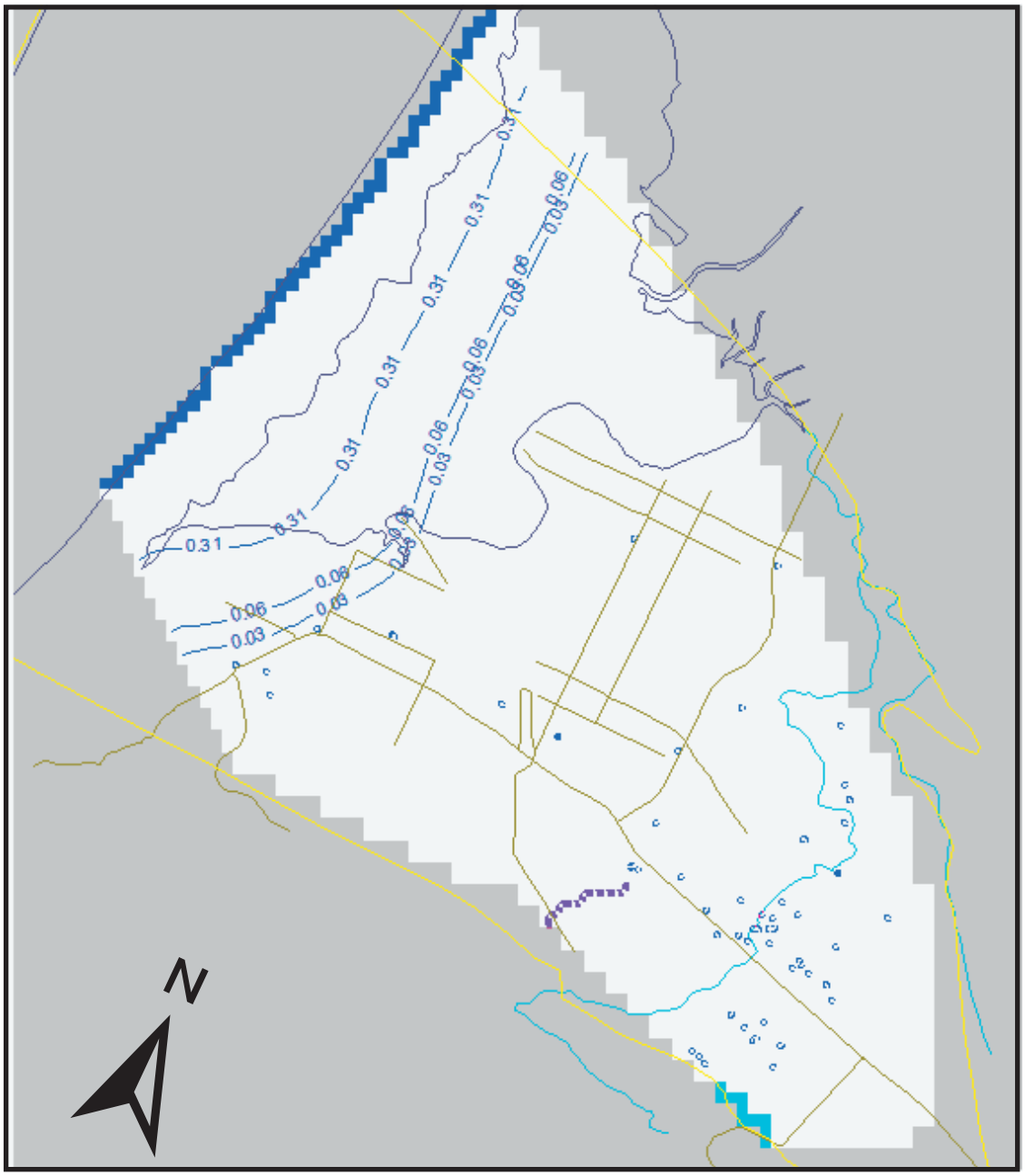
TDS isoconcentrations in lb/ft3

0.03 lb/ft3 = 500 mg/l TDS ≈ 250 mg/l Chloride
0.06 lb/ft3 = 1,000 mg/l TDS≈ 500 mg/l Chloride
0.31 lb/ft3 = 5,000 mg/l TDS≈ 2,500 mg/l Chloride

Figure A16

TDS Isoconcentrations
VPA2b Yield Simulation - Zone C
Steady State at 3,150 AFY
May 2009 SEAWAT Model
Los Osos ISJ Group

Cleath-Harris Geologists, Inc.



Scale 1" = 4000 feet

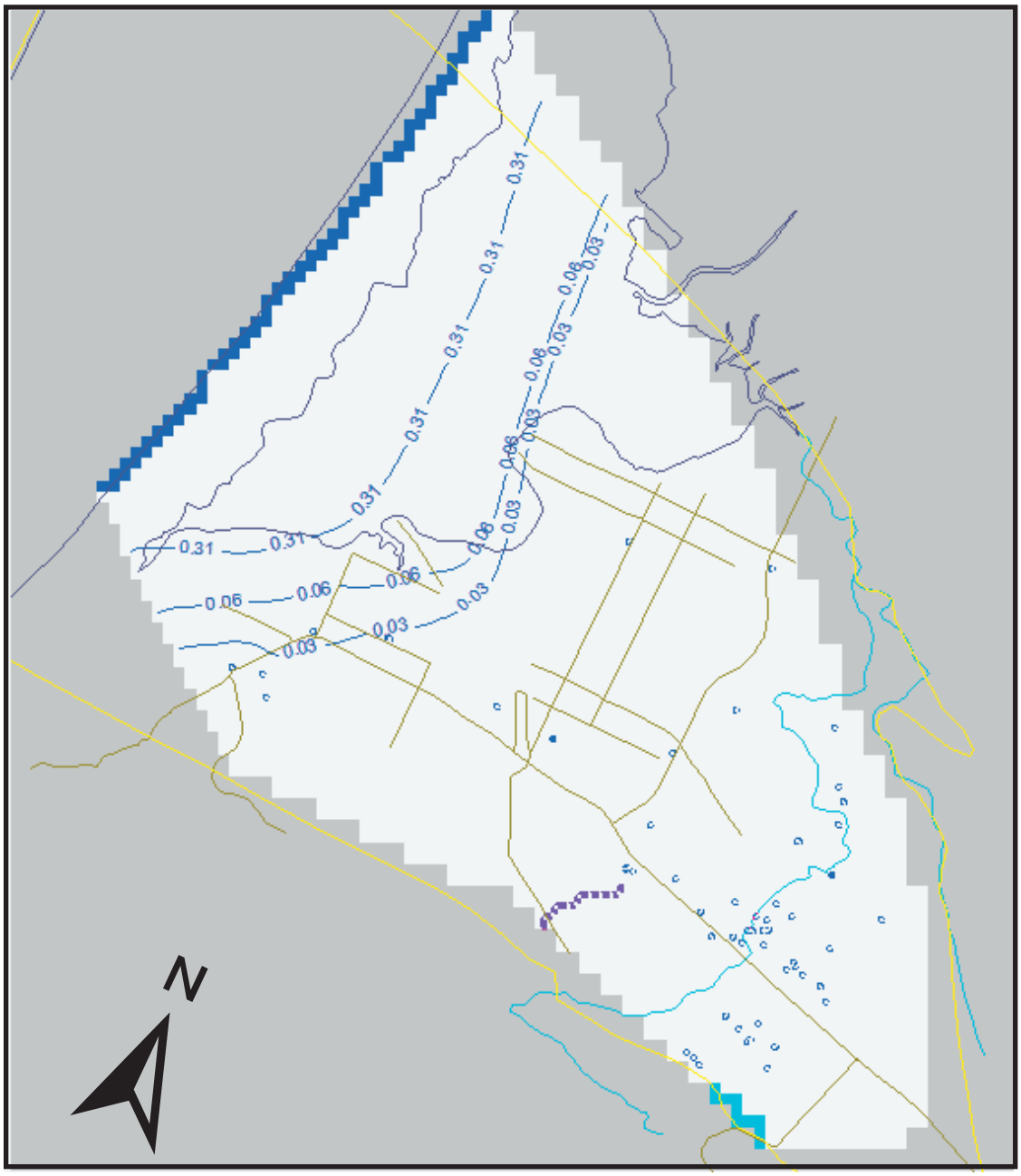
TDS isoconcentrations in lb/ft3

0.03 lb/ft3 = 500 mg/l TDS ≈ 250 mg/l Chloride
0.06 lb/ft3 = 1,000 mg/l TDS≈ 500 mg/l Chloride
0.31 lb/ft3 = 5,000 mg/l TDS≈ 2,500 mg/l Chloride

Figure A17

TDS Isoconcentrations
VPA2b Yield Simulation - Zone D
50-year planning horizon at 3,150 AFY
May 2009 SEAWAT Model
Los Osos ISJ Group

Cleath-Harris Geologists, Inc.



Scale 1" = 4000 feet

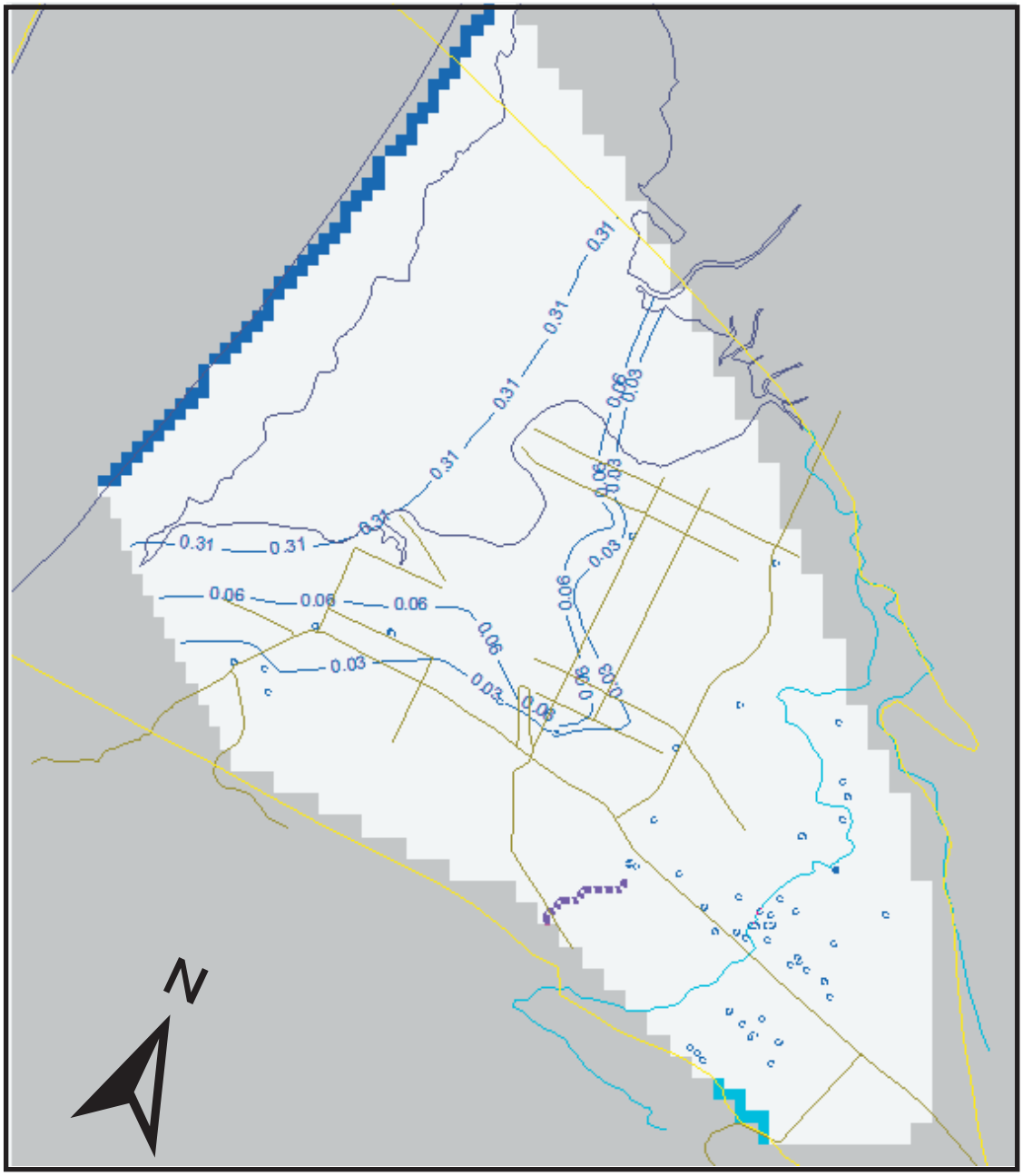
TDS isoconcentrations in lb/ft3

0.03 lb/ft3 = 500 mg/l TDS ≈ 250 mg/l Chloride
0.06 lb/ft3 = 1,000 mg/l TDS≈ 500 mg/l Chloride
0.31 lb/ft3 = 5,000 mg/l TDS≈ 2,500 mg/l Chloride

Figure A18

TDS Isoconcentrations
VPA2b Yield Simulation - Zone D
500-year planning horizon at 3,150 AFY
May 2009 SEAWAT Model
Los Osos ISJ Group

Cleath-Harris Geologists, Inc.



Scale 1" = 4000 feet

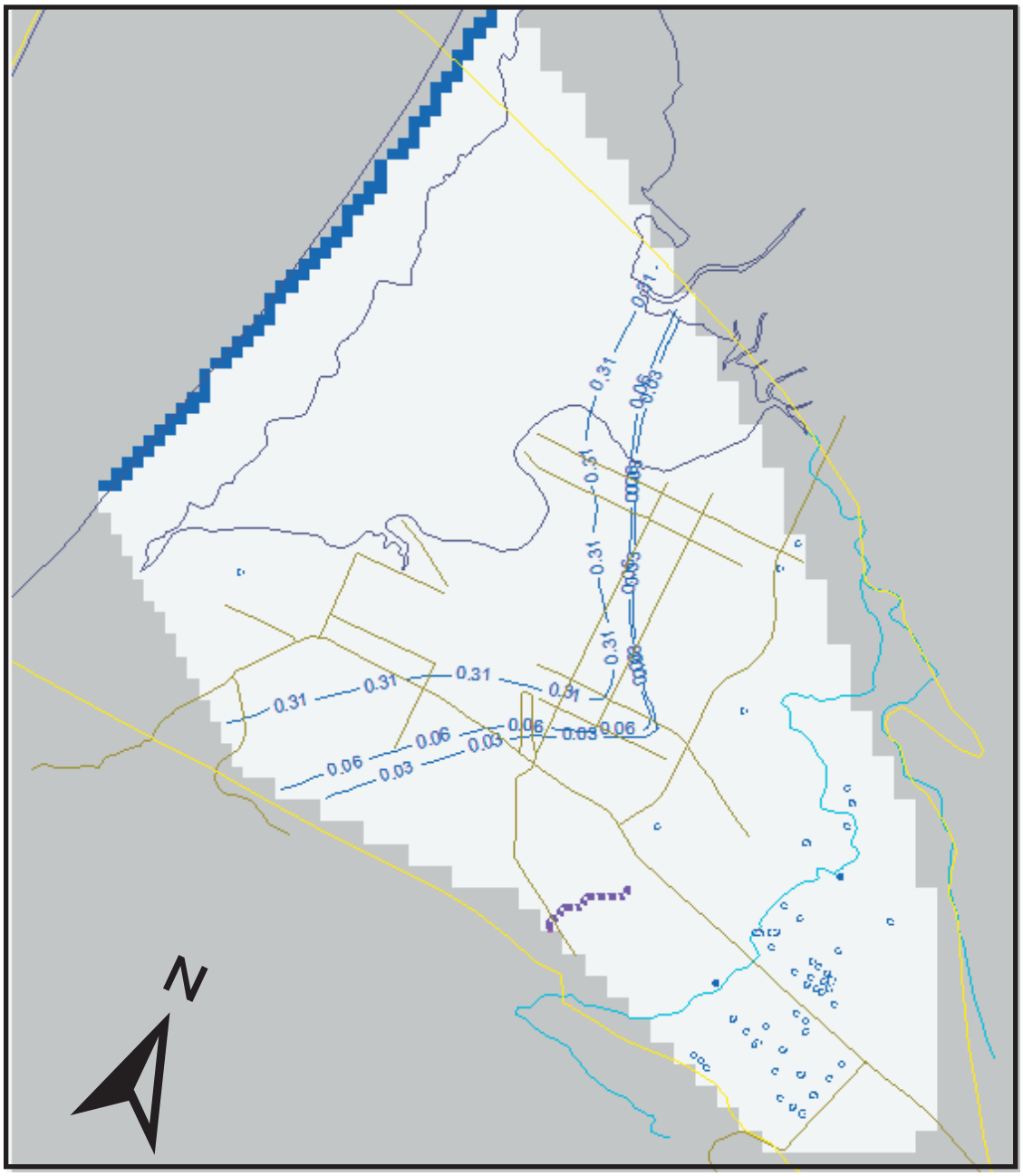
TDS isoconcentrations in lb/ft3

0.03 lb/ft3 = 500 mg/l TDS ≈ 250 mg/l Chloride
0.06 lb/ft3 = 1,000 mg/l TDS≈ 500 mg/l Chloride
0.31 lb/ft3 = 5,000 mg/l TDS≈ 2,500 mg/l Chloride

Figure A19

TDS Isoconcentrations
VPA2b Yield Simulation - Zone D
Steady State at 3,150 AFY
May 2009 SEAWAT Model
Los Osos ISJ Group

Cleath-Harris Geologists, Inc.



Scale 1" = 4000 feet

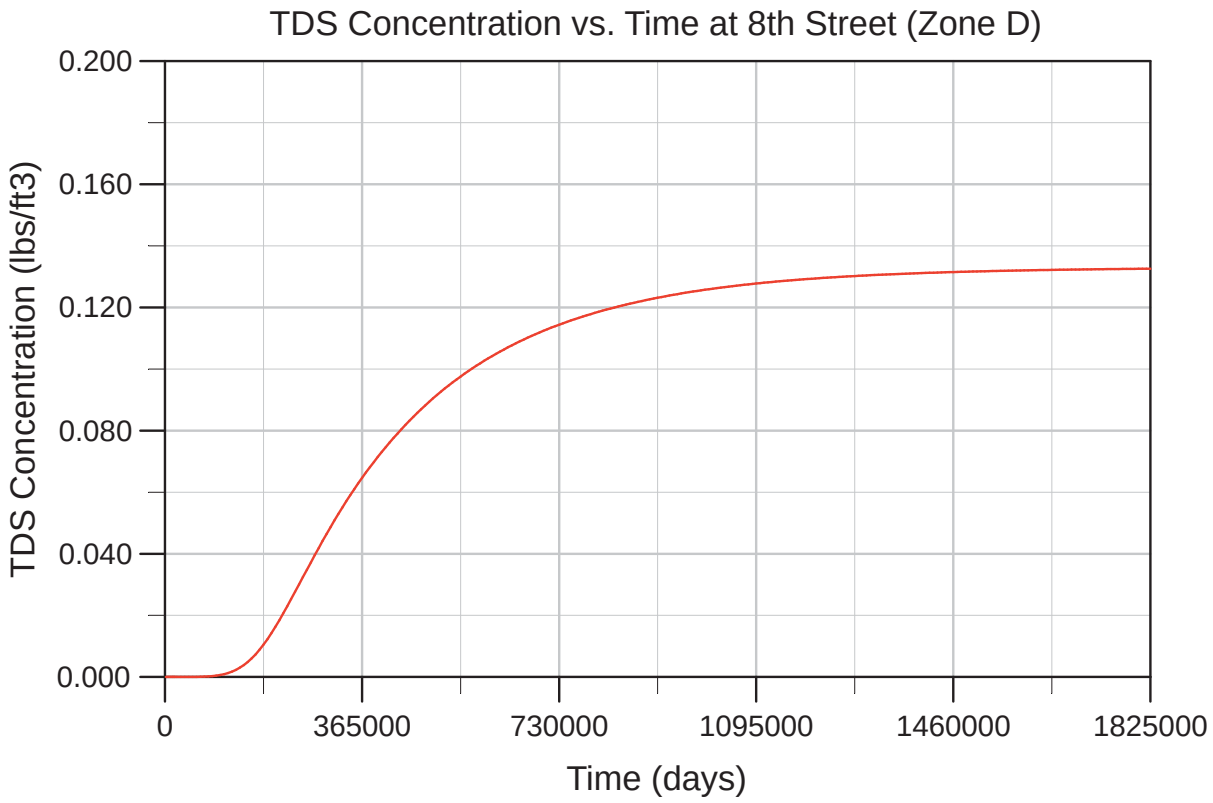
TDS isoconcentrations in lb/ft3

0.03 lb/ft3 = 500 mg/l TDS ≈ 250 mg/l Chloride
0.06 lb/ft3 = 1,000 mg/l TDS≈ 500 mg/l Chloride
0.31 lb/ft3 = 5,000 mg/l TDS≈ 2,500 mg/l Chloride

Figure A20

TDS Isoconcentrations
VPA2b Yield Simulation - Zone E
Steady State at 3,150 AFY
May 2009 SEAWAT Model
Los Osos ISJ Group

Cleath-Harris Geologists, Inc.



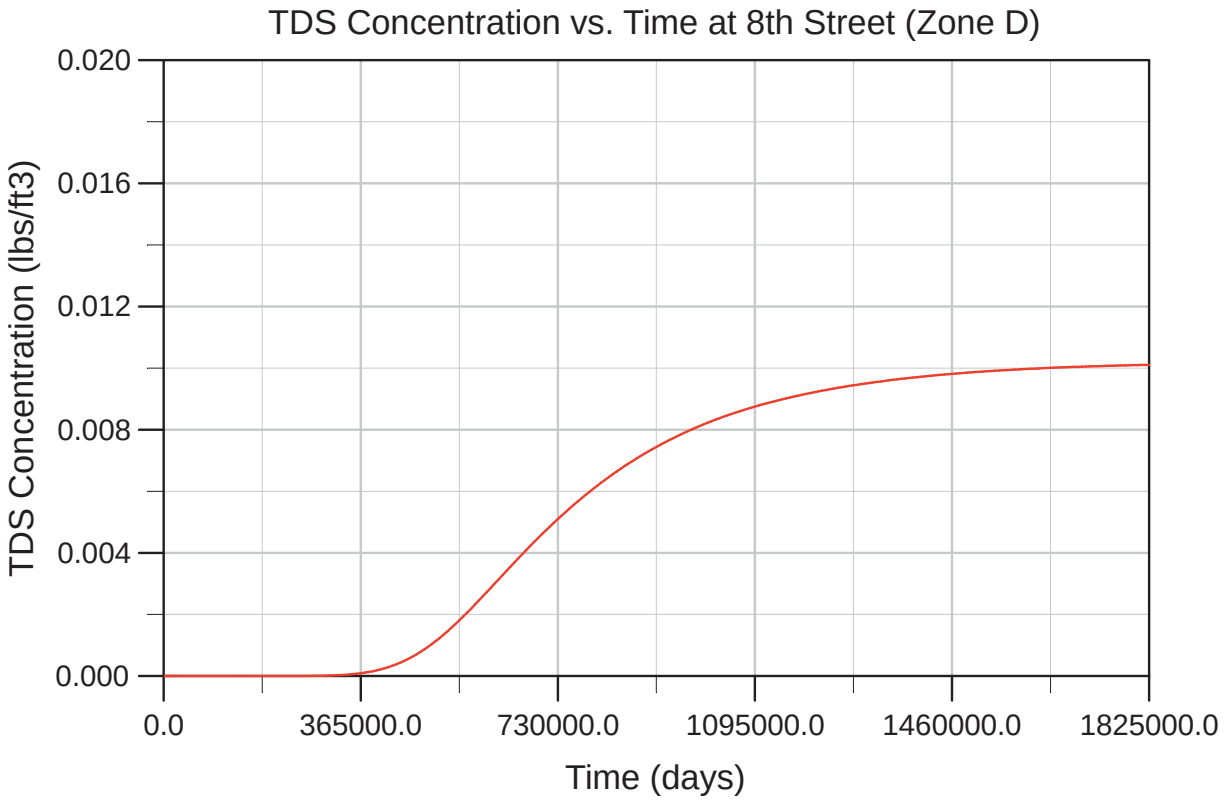
TDS concentrations in lb/ft3

0.03 lb/ft3 = 500 mg/l TDS ≈ 250 mg/l Chloride
0.06 lb/ft3 = 1,000 mg/l TDS≈ 500 mg/l Chloride
0.31 lb/ft3 = 5,000 mg/l TDS≈ 2,500 mg/l Chloride

Figure A21

TDS Chemograph
Current Condition No Shift Simulation
8th Street Zone D
May 2009 SEAWAT Model
Los Osos ISJ Group

Cleath-Harris Geologists, Inc.



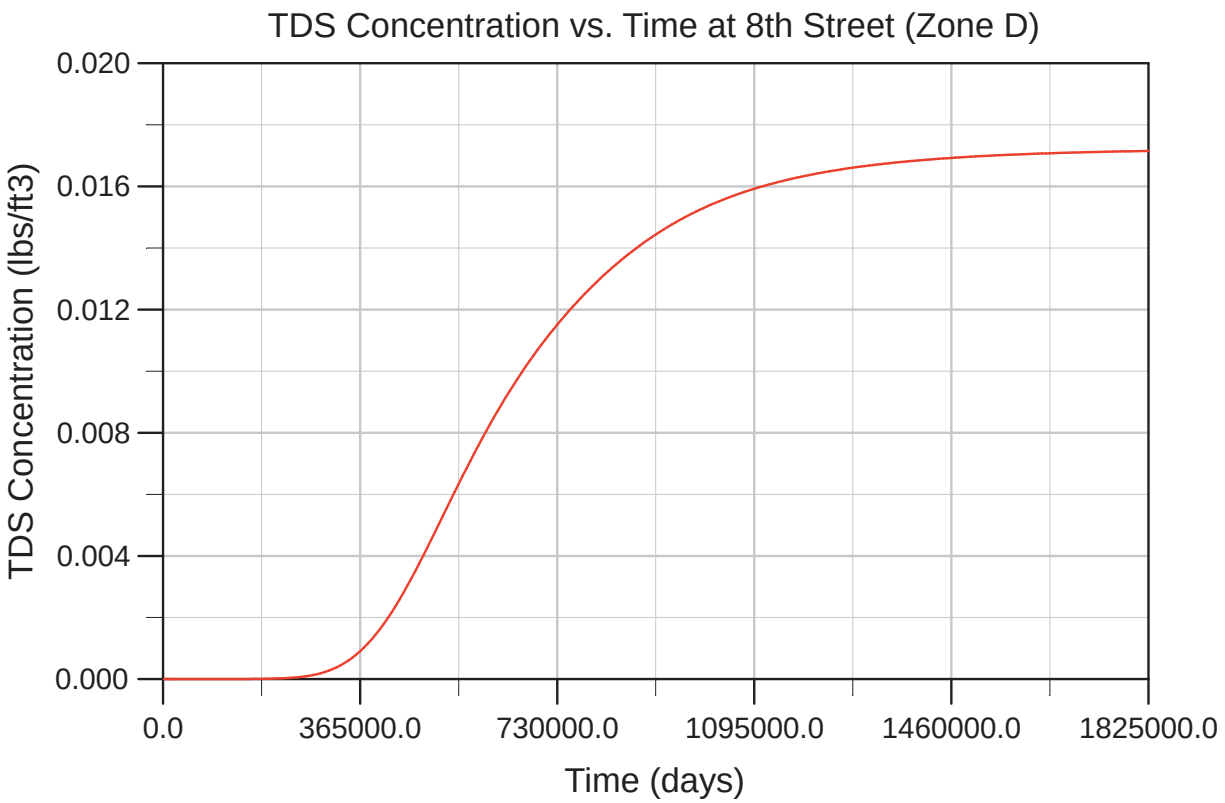
TDS concentrations in lb/ft3

0.03 lb/ft3 = 500 mg/l TDS ≈ 250 mg/l Chloride
0.06 lb/ft3 = 1,000 mg/l TDS≈ 500 mg/l Chloride
0.31 lb/ft3 = 5,000 mg/l TDS≈ 2,500 mg/l Chloride

Figure A22

TDS Chemograph
Current Condition Yield Simulation
8th Street Zone D
May 2009 SEAWAT Model
Los Osos ISJ Group

Cleath-Harris Geologists, Inc.



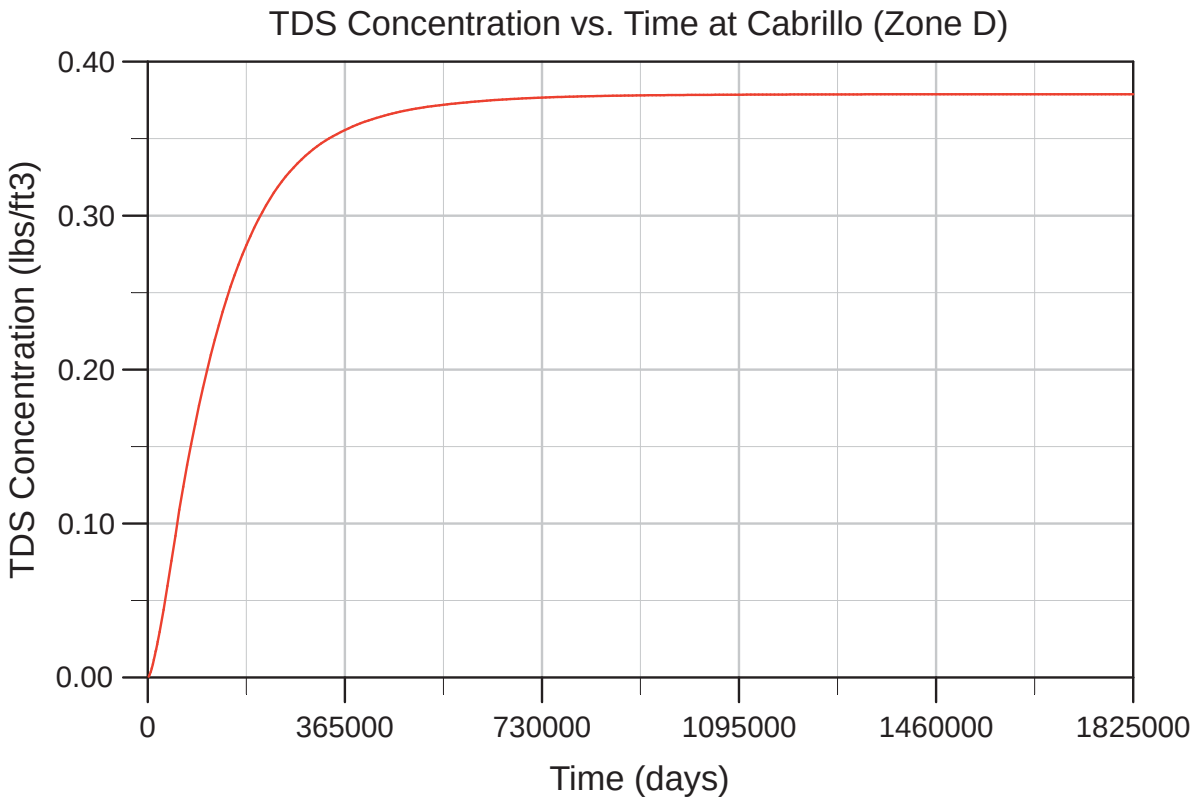
TDS concentrations in lb/ft3

0.03 lb/ft3 = 500 mg/l TDS ≈ 250 mg/l Chloride
0.06 lb/ft3 = 1,000 mg/l TDS≈ 500 mg/l Chloride
0.31 lb/ft3 = 5,000 mg/l TDS≈ 2,500 mg/l Chloride

Figure A23

TDS Chemograph
VPA2b Yield Simulation
8th Street Zone D
May 2009 SEAWAT Model
Los Osos ISJ Group

Cleath-Harris Geologists, Inc.



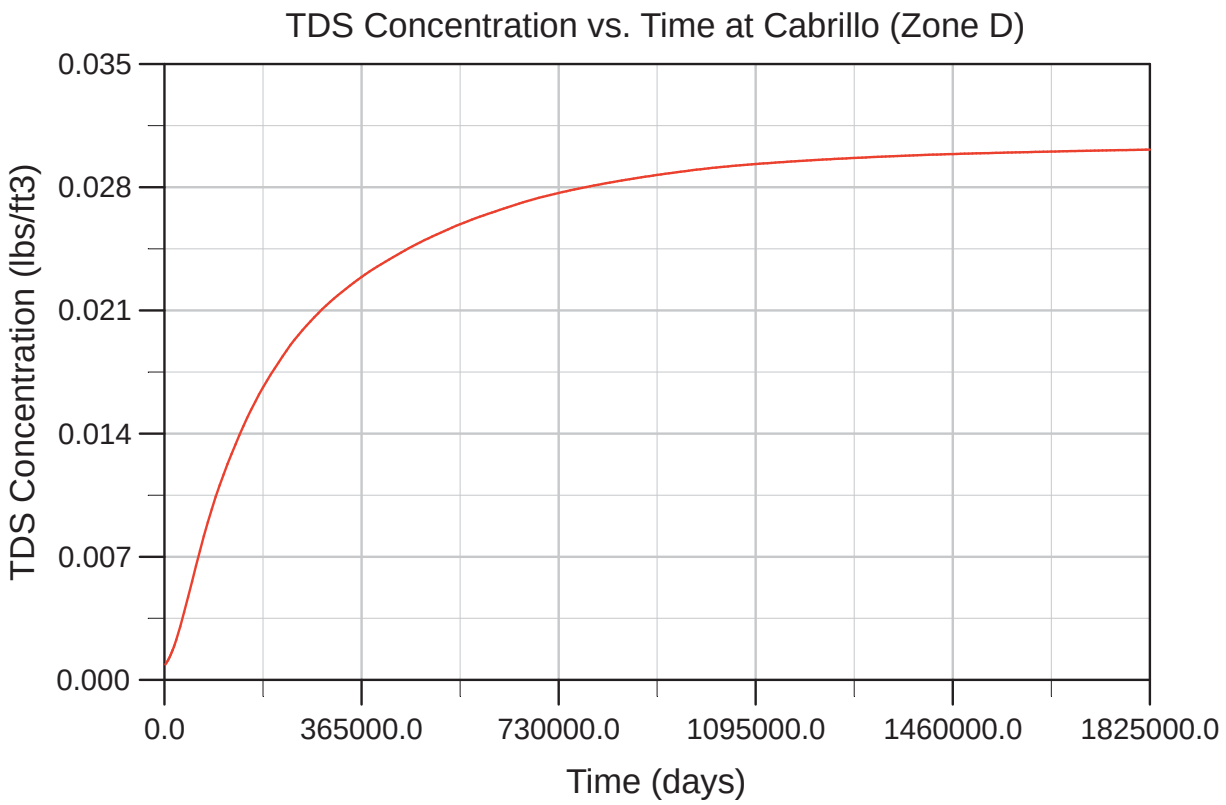
TDS concentrations in lb/ft3

0.03 lb/ft3 = 500 mg/l TDS ≈ 250 mg/l Chloride
0.06 lb/ft3 = 1,000 mg/l TDS≈ 500 mg/l Chloride
0.31 lb/ft3 = 5,000 mg/l TDS≈ 2,500 mg/l Chloride

Figure A24

TDS Chemograph
Current Condition No Shift Simulation
Cabrillo Zone D
May 2009 SEAWAT Model
Los Osos ISJ Group

Cleath-Harris Geologists, Inc.



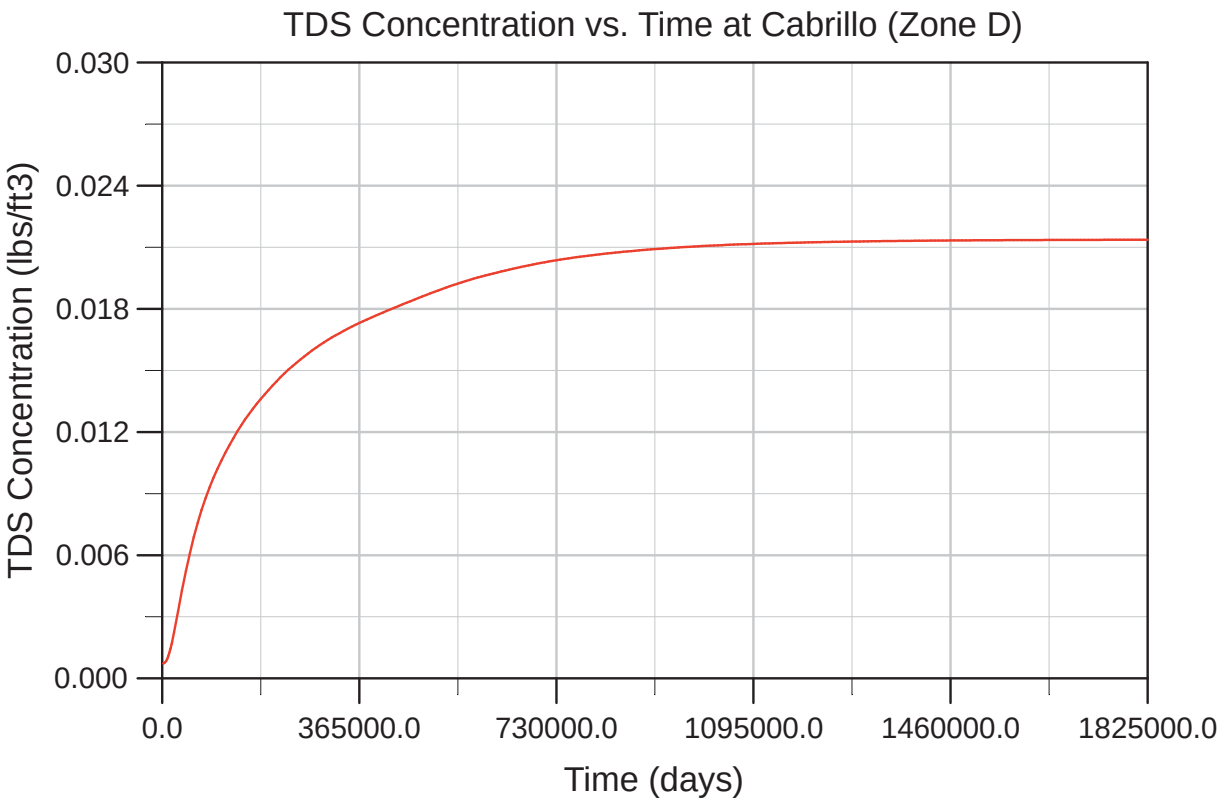
TDS concentrations in lb/ft3

0.03 lb/ft3 = 500 mg/l TDS ≈ 250 mg/l Chloride
0.06 lb/ft3 = 1,000 mg/l TDS≈ 500 mg/l Chloride
0.31 lb/ft3 = 5,000 mg/l TDS≈ 2,500 mg/l Chloride

Figure A25

TDS Chemograph
Current Condition Yield Simulation
Cabrillo Zone D
May 2009 SEAWAT Model
Los Osos ISJ Group

Cleath-Harris Geologists, Inc.



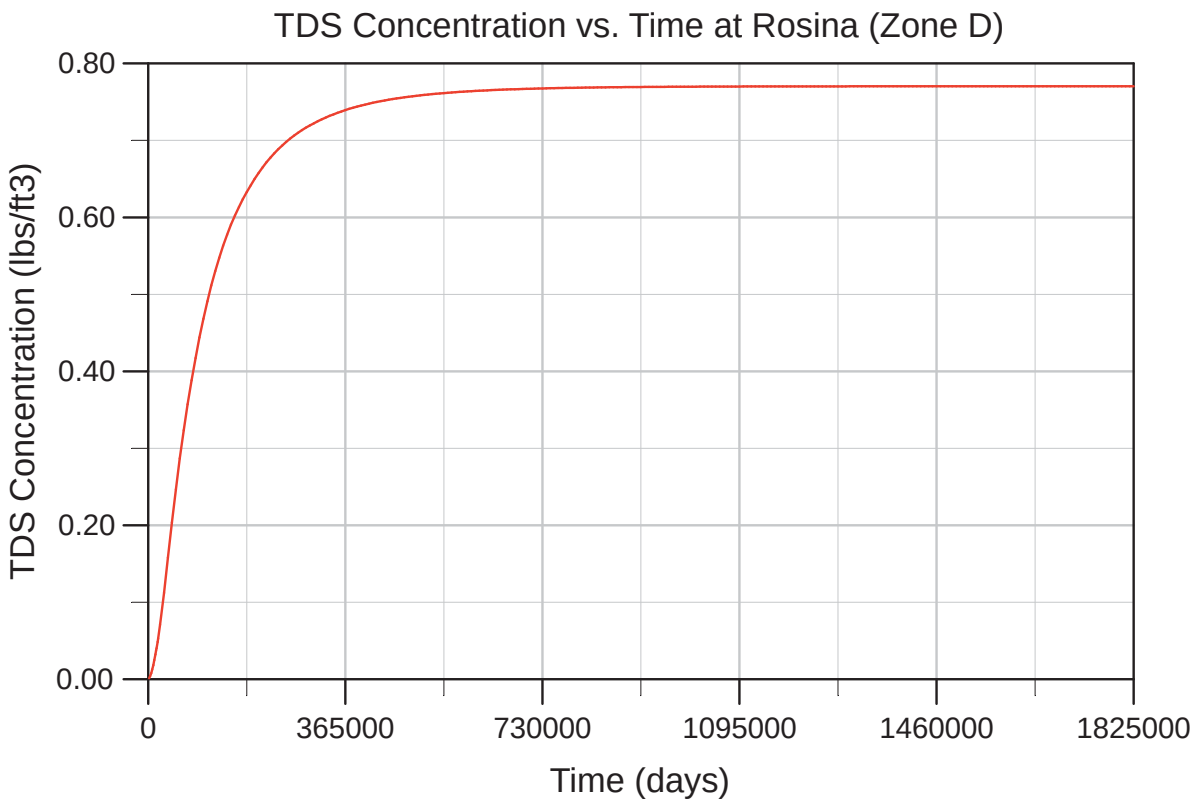
TDS concentrations in lb/ft3

0.03 lb/ft3 = 500 mg/l TDS ≈ 250 mg/l Chloride
0.06 lb/ft3 = 1,000 mg/l TDS≈ 500 mg/l Chloride
0.31 lb/ft3 = 5,000 mg/l TDS≈ 2,500 mg/l Chloride

Figure A26

TDS Chemograph
VPA2b Yield Simulation
Cabrillo Zone D
May 2009 SEAWAT Model
Los Osos ISJ Group

Cleath-Harris Geologists, Inc.



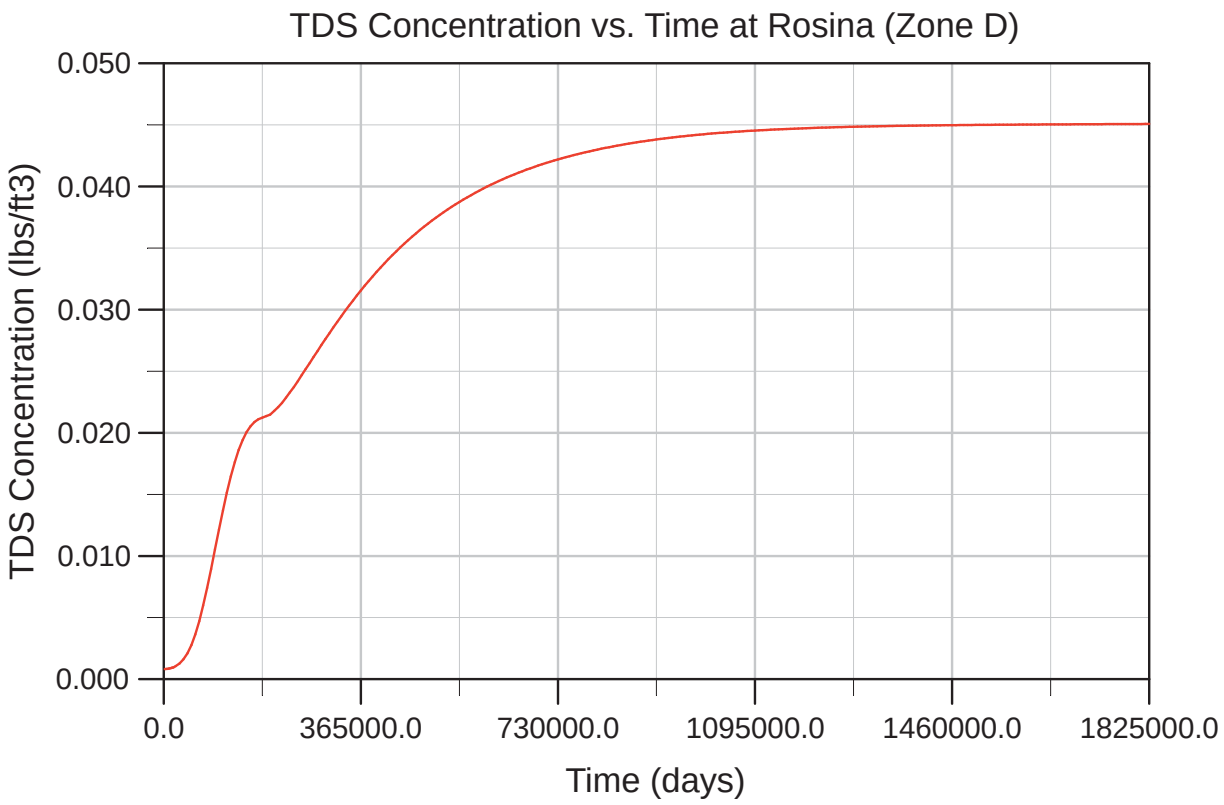
TDS concentrations in lb/ft3

0.03 lb/ft3 = 500 mg/l TDS ≈ 250 mg/l Chloride
0.06 lb/ft3 = 1,000 mg/l TDS≈ 500 mg/l Chloride
0.31 lb/ft3 = 5,000 mg/l TDS≈ 2,500 mg/l Chloride

Figure A27

TDS Chemograph
Current Condition No Shift Simulation
Rosina Zone D
May 2009 SEAWAT Model
Los Osos ISJ Group

Cleath-Harris Geologists, Inc.



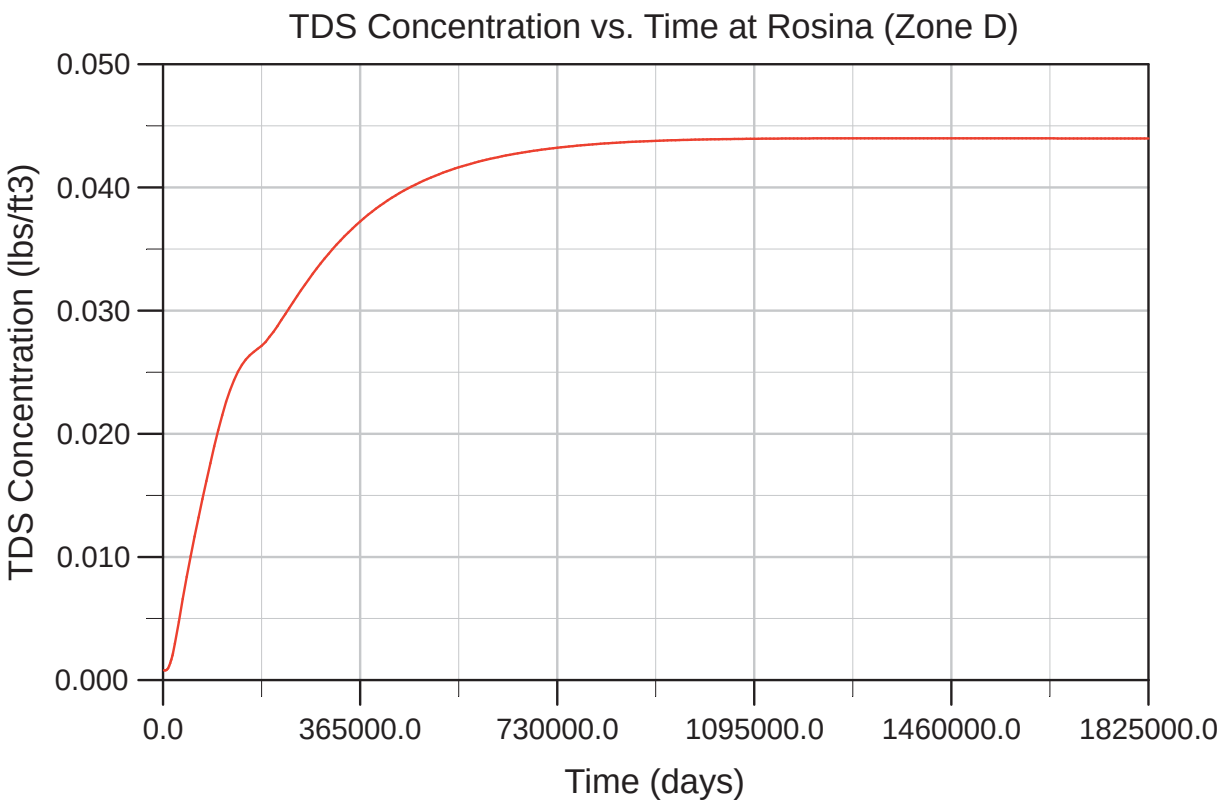
TDS concentrations in lb/ft3

0.03 lb/ft3 = 500 mg/l TDS ≈ 250 mg/l Chloride
0.06 lb/ft3 = 1,000 mg/l TDS≈ 500 mg/l Chloride
0.31 lb/ft3 = 5,000 mg/l TDS≈ 2,500 mg/l Chloride

Figure A28

TDS Chemograph
Current Condition Yield Simulation
Rosina Zone D
May 2009 SEAWAT Model
Los Osos ISJ Group

Cleath-Harris Geologists, Inc.



TDS concentrations in lb/ft3

0.03 lb/ft3 = 500 mg/l TDS ≈ 250 mg/l Chloride
0.06 lb/ft3 = 1,000 mg/l TDS≈ 500 mg/l Chloride
0.31 lb/ft3 = 5,000 mg/l TDS≈ 2,500 mg/l Chloride

Figure A29

TDS Chemograph
VPA2b Yield Simulation
Rosina Zone D
May 2009 SEAWAT Model
Los Osos ISJ Group

Cleath-Harris Geologists, Inc.