Chevron

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August 31, 1992

Mr. Rich Hiett
San Francisco Bay Regional Water Quality Control Board
2101 Webster Street, Suite 500
Oakland, CA 94612

Subject: Former Chevron Station # 9-5607, 5269 Crow Canyon Road, Castro Valley, CA
Enclosed Fate and Transport Model comparing extraction options (CRTC, 8/13/92)
Proposal for remediation system modifications

Dear Mr. Hiett:

This letter is written in response to the letter from the San Francisco Regional Water Quality Control Board (RWQCB) to Chevron dated June 4, 1992 regarding the subject site. The RWQCB letter stated that the Alameda County Health Department (ACHD) had referred oversight of the subject case to the RWQCB. The letter requested that data concerning the performance of the groundwater extraction system be submitted to the RWQCB by June 29, 1992. On June 26, 1992 the requested performance data including the extraction rates and the radius of influence of extraction wells RW and C-9 was submitted by Chevron. The June 26 submittal proposed the use of a groundwater fate and transport model to determine the projected future characteristics of the benzene plume under various extraction system scenarios. Chevron's proposal called for the use of the model results to help determine the appropriateness of any modifications to the current extraction system design.

The results of the fate and transport modeling are enclosed for your review. The modeling was performed by hydrogeologists at Chevron Research and Technology Company (CRTC) in Richmond, California. For accuracy, the model was calibrated to actual groundwater data collected over the course of the site investigation, remediation, and monitoring activities. The model was utilized to predict the future size and concentration of the dissolved benzene plume under various groundwater extraction well placement scenarios. These extraction system scenarios included:

- no groundwater extraction at the site (0 wells)
- groundwater extraction from wells RW and C-9 (2 wells, the current scenario)
- groundwater extraction from wells RW, C-9, and C-6 (3 wells)
- groundwater extraction from wells RW, C-9, C-6, and RW-2 (4 wells)

The model predicted the characteristics of the benzene plume in 1996 under each of the above groundwater extraction well options. In summary, the model showed:

- With no groundwater extraction at the site, the benzene plume in 1996 would remain virtually unchanged from its present size and concentration in 1992. This is because the rate of natural degradation of benzene along the boundary of the plume was shown to be equal to the rate of benzene migration toward the boundary.

- With the continued use of the current groundwater extraction system which consists of the two wells RW and C-9, the benzene plume in 1996 would only be slightly smaller than it's present 1992 size. This indicates that the current extraction system is capable of counteracting the threat of benzene migration to Crow Creek, but it is not capable of significantly decreasing the benzene plume over the next several years.

- With the addition of well C-6 to the current extraction system, and thus extracting from a total of three wells, the benzene plume would be greatly reduced in 1996 from its current size. The improved capture of the groundwater extraction system in conjunction with the degradation process would cause a shrinking of the dissolved benzene plume over a relatively short time frame.

- With the addition of well C-6 and a new well RW-2 to the current extraction system, thus bringing the total number of extraction wells to four, the benzene plume would be greatly reduced by 1996. However, the effect of four extraction wells does not appear to be significantly different from the effect of three wells.

I encourage your review of the model parameters and results. I requested CRTC to write the report in a "reader-friendly" manner to facilitate easy understanding by all readers without requiring previous groundwater modeling experience. If there are any questions regarding the use of the model or the interpretation of its results, please do not hesitate to call me to discuss.

The model was used to predict future characteristics of the benzene plume under a variety of viable groundwater extraction options. Other remedial approaches were considered, but each was discounted due to being unfeasible based upon the site conditions and property use. For instance, excavation of impacted soils was ruled out because Chevron no longer leases the property and legally has no permission to excavate, because the current business use of the property would be irreparably hampered by an excavation project, and because excavation of impacted soils would increase the risk of exposure for nearby residents. In addition, vapor extraction and air-sparging remedial techniques were determined to be unfeasible due to the fine grained clay stratigraphy of the subsurface. One remedial technique in addition to groundwater extraction which may prove beneficial is the use of a hydrocarbon skimmer in well C-3. The skimmer would effectively remove any separate phase product occurring in the well and thus help to remove the source of dissolved hydrocarbons.

Based upon my review of the model results and the associated costs of the various extraction system scenarios, I propose the addition of a third well, C-6, to the current groundwater extraction system. The marginal difference in performance between the four well and the three well extraction systems does not justify the additional expense of the four well system. The three well system would utilize an already existing well, while the four well system would require the drilling and installation of an additional extraction well. In addition to the use of well C-6 for groundwater extraction, I propose the installation of a hydrocarbon skimmer in well C-3 to remove periodically occurring separate phase hydrocarbons from the source area.

Upon receiving concurrence with this proposal from the RWQCB and/or the ACHD, Chevron will contract the proposed work and schedule it in a timely manner.

If you have any questions or comments, I can be reached at (510) 842-8658.

Sincerely,

Clint B. Rogers

Clint B. Rogers
Environmental Engineer
Site Assessment and Remediation

Enclosure

cc: Scott Seery, Alameda County Health Department, Oakland, CA
Kevin Hinckley, 5269 Crow Canyon Road, Castro Valley, CA 94546
Paul Hehn, Geraghty and Miller, Richmond, CA
Sheldon Nelson, CRTC, Richmond, CA (w/o enclosure)

MEMORANDUM

Richmond, California
August 13, 1992

Former Chevron Service
Station No. 9-5607
5269 Crow Canyon Rd.
<u>Castro Valley, CA.</u>

Mr. C.B. Rogers,

As you requested, I have evaluated the present groundwater remediation system at former Chevron Service Station No. 9-5607 and make the following predictions concerning the fate and transport of dissolved benzene (see Site Map - Figure 1).

Paul Hildebrandt (CRTC) has used a numerical model to predict concentrations of dissolved benzene at the site. Various well placement options were incorporated into the models, to determine the most effective strategy to remediate the dissolve phase BTEX which has migrated off-site.

Benzene was the component considered for the model due to the following characteristics of the compound:

(a) it is considered a carcinogen, and as such is a primary substance to consider for site assessment and remediation activity.

(b) dissolved benzene is the most mobile of the BTEX compounds. As a means of comparison, Table 1, provides a list of pure phase solubility values and the organic carbon partition coefficient (Koc) of the BTEX components. The water solubility is the amount of a chemical that can dissolve in pure water at a specific temperature and pressure. The Koc is a measure of dissolved phase mobility, as the coefficient reflects the affinity of the compound to adsorb onto organic carbon within the sediment matrix.

Therefore, because benzene more readily dissolves in water and adheres less to the soil, it is more mobile than the other BTEX compounds.

Table 1

	Water Solub. (mg/L)	Koc (ml/g)
Benzene	1791	97
Toluene	535	300
Ethylbenzene	152	1100
Xylenes	130	240

Groundwater flow and contaminant fate of dissolved benzene, in the vicinity of the former Chevron facility, was modeled using MODFLOW/MT3D. MODFLOW is a finite difference model, developed by the U.S. Geological Survey for the purpose of simulating groundwater flow. MT3D is a finite difference model, developed in part by Konikow and Bredehoft of the U.S. Geological Survey, which simulates the fate and transport of dissolved compounds. This method of simulating partical movement has survived legal scrutiny at such sites as Rocky Flats, Colorado, and has been readily accepted by various federal and state regulatory agencies.

A finite difference model involves the approximation of the partial derivatives, which describe site conditions, by a series of algebraic expressions. As a result of the approximation, the partial differential equation describing the problem is replaced by a finite number of easier to compute algebraic equations. The values at selected points, the nodes on the finite difference grid (see Section a, below), become the unknowns which are solved by the series of algebraic equations.

The groundwater flow and contaminant fate and transport model presented in this memo is a combined MODFLOW/MT3D simulation. The groundwater flow simulation, using MODFLOW, is constructed first. The MODFLOW results are then stored for access by MT3D, the contaminant fate and transport portion of the model. The contaminant fate and transport model then accesses the groundwater flow data to generate a combined simulation.

The basic parameters used to construct the groundwater flow and contaminant fate model are shown on Tables A and B.

(a) Finite difference grid - The grid spacing represents the nodes used for the algebraic calculations of the model. The grid is constructed of 28 columns and 30 rows, with the nodes separated by 15 foot uniform spacing in the x and y directions.

(b) Specified head boundaries - depth to groundwater at the site is defined as 288 feet above sea level along the bottom row of the grid (eastern portion of map), and 235 feet above sea level along Crow Creek, at the upper portion of the grid (western portion of the map).

The specified head boundaries define the groundwater gradient, which is based on groundwater elevations regularly measured at monitor wells C-1 to -3, -5 to -8, and -10 to -16. Groundwater elevation data has been unavailable from C-4 since September 24, 1990, as the well has not been located. Groundwater depth measurements are also not available for C-9 and RW-1 since June 18, 1991 and June 12, 1990, respectively, due to groundwater extraction at these wells.

(c) Aquifer thickness - the unconfined saturated thickness of the silts and clays are defined by information contained in the well installation logs. The installation logs are provided by Chevron consultants Groundwater Technology, Inc. (monitor wells C-1 to -9 and RW-1), and Pacific Environmental Group (monitor wells C-10 to -16).

Within the primary area of concern, between Crow Creek and the eastern boundary of the grid, the aquifer thickness is maintained at a constant 20 foot thickness.

(d) Bottom elevation - The bottom of the aquifer (sediment/bedrock interface), along with the measured groundwater elevation, defines the thickness of the aquifer. The depth to bedrock is available from the well installation logs.

(e) Hydraulic conductivity - the hydraulic conductivity is a measurement of the ability of a fluid to pass through a porous medium. The higher the hydraulic conductivity, the greater the ability of the liquid to pass through the medium. In this case, the value reflects the ability of water to flow through the silts and clays characterizing the saturated zone at the site.

The hydraulic conductivity values used in the model (clay - 0.0279 ft/day, = 1.0×10^{-5} cm/sec; silt - 0.2790 ft/day, =1.0×10^{-4} cm/sec) are based on published values for these specific soil types (Table 2.2, Groundwater, Freeze and Cherry, 1979, Prentice Hall).

(f) Specific porosity - the specific porosity reflects the percentage of the sediment composed of interconnected pore space, which will allow groundwater to flow. The value used in the model, 10%, is based on published numbers for silts and clays.

(g) Recharge - The Castro Valley area is characterized as a region of low annual rainfall, and little if any irrigation. Recharge, or net addition of surface water to the aquifer, is therefore neglected for the model.

(h) Evapotransportation - Depth to local groundwater is 20 feet below ground level. At this depth evaporation will be minimal and the factor was therefore not considered for the model.

(i) Source concentration - the presence of liquid phase hydrocarbon (LHC) in on-site groundwater indicates that a continual dissolved benzene source exists at the site.

The benzene source concentration is calculated as the product of the pure phase solubility (1791 mg/l) and the weight percent of benzene in gasoline. The pure phase solubility is a compound specific constant, at specific temperature and pressure conditions, and is readily available in published tables. The weight percent of benzene as a gasoline component has varied over time, and is assumed in this study to constitute 1.3% of the LHC present in on-site groundwater. A 1.3% benzene gasoline component is consistent with the 0.12-3.5% range stated in Appendix G of the California LUFT Manual as the weight percent of benzene in gasoline.

The source concentration is therefore calculated as 1791 mg/l x 0.013 = 24 mg/l (=24 ppm).

(j) Longitudinal dispersion - the dispersivity is an estimate of the degree of heterogeneity of the subsurface. The 15-30 foot values used in the model fall within the published range of clay/silt sediment, based on field studies.

(k) Transverse dispersion - published accounts of field studies suggest that the transverse dispersivity is commonly 0.1-0.2 of the longitudinal dispersion. The transverse dispersivity is a measurement of the subsurface heterogeneity, as it influences groundwater flow moving perpendicular to the gradient direction.

(l) Dry bulk density - a dry bulk density of 1.57 g/cm^3 was used in the calculations of contaminant fate. The 1.57 g/cm^3 is within the range of published values for a silt/clay sediment water bearing zone.

(m) Distribution coefficient - the distribution coefficient, K_d, is defined as the amount of compound (in mg) which will adsorb to 1 mg of soil. The distribution coefficient is calculated as the product of the adsorption coefficient (Koc), described above, and the total organic carbon content (TOC) of the soil.

The adsorption coefficient is a compound specific constant (Koc benzene = 97 ml/g), which is available in published texts. The TOC is estimated to be 0.05% (500 ppm) based on characteristic values for silt and clay sediment.

(n) Biodegradation half-life - the biodegradation half-life estimates the amount of time necessary to degrade 1/2 of the dissolved benzene in groundwater due to biologic activity. The biodegradation half-life is dependent primarily on the amount of available oxygen in the saturated zone and the nature of the aquifer. In general, the greater the amount of dissolved oxygen and the more permeable the aquifer, the greater the rate of biodegradation and the smaller the half-life value.

Published values of benzene biodegradation half-life vary from approximately 60 to 730 days. The 110 day half-life used in the model is based on calibration of the model to measured dissolved benzene concentrations, and is consistent with published values of benzene half-life in a silt/clay saturated zone.

Results of computer generated model

1) Figure 2 shows the areal grid used to generate the groundwater flow model. Each box within the grid has the dimensions of 15 x 15 feet.

2) Figure 3 is a site map exhibiting the areas characterized as having a hydraulic conductivity of 0.0279 ft/day (unshaded area on map). The hydraulic conductivity of 0.0279 ft/day is consistent with the clay sedimentary matrix observed at the level of the water table at on-site and off-site monitor wells.

The shaded area of the map is calculated as having a hydraulic conductivity of 0.279 ft/day, based on the presence of predominantly silts at the level of the water table, in monitor well C-12. Subsurface sediment data is available in the well installation logs of the site assessment reports prepared for Chevron.

The shape of the shaded (silt) area on the map was varied until simulated benzene concentrations in downgradient monitor wells C-12, -10A and -10B approximated the actual benzene concentration measured from these wells.

3) Figure 4 shows the groundwater flow as simulated by the MODFLOW flow model. The groundwater flow pattern in Figure 4 is based on groundwater elevations measured on-site April 13, 1992.

The anomalous flow pattern near monitor well C-12 is the result of the higher permeable sediment present in this portion of the site, thereby influencing the groundwater flow.

4) The shaded area of Figure 5 represents the initial (1986) area of the site containing liquid phase hydrocarbon (LHC). The areal extent of the LHC is the source area of the dissolved benzene. As stated above, the concentration of dissolved benzene within the source area is 24 ppm.

The extent of the shaded area is based on the measurable presence of LHC in MW-3 (GTI letter, March 7, 1985), recovery well RW-1 (GTI Update Report, July 31, 1986) and by calibration of the model to groundwater analytical data. The shape of the shaded area was varied slightly, until the simulated areal pattern of dissolved benzene approximated the observed dissolved benzene concentrations measured at the site.

5) Figure 6 represents 1992 dissolved benzene concentrations as predicted by the MODFLOW/MT3D computer generated groundwater flow and fate model. The initiation of the model simulation is 1986, with Figure 6 representing site conditions 6 years after initial site parameters were established (shown in Figure 5).

It should be noted that Figure 6 results assume no groundwater pumping at the site (see Table C for assumptions). A "no-pumping" situation represents a conservative set of parameters, which if anything, will tend to over-represent the downgradient extent of the dissolved benzene plume.

Comparison of the simulated results to actual dissolved benzene concentrations measured from groundwater samples (shown in bold type on Figure 6), provided the mechanism to calibrate the accuracy of the model. Figure 6 calibration was based on a comparison to April 13, 1992 groundwater analytical data.

The model predicts that the 1 ppb dissolved benzene contour does not presently reach Crow Creek. A biodegradation equilibrium front is present several feet downgradient of monitor wells MW-10A and -15. This equilibrium front is where biodegradation removes benzene at a rate which is equivalent to dissolution of benzene in the source area. Simply stated, benzene at the equilibrium front is degraded before it has a chance to migrate further.

6) Figure 7 shows predicted dissolved benzene concentrations 10 years after initial site conditions are established (corresponding to 1996 site conditions). As in Figure 6 results, this interpretation also assumes no groundwater extraction at the site.

The model predicts that under "steady state" conditions there is no net advance of dissolved benzene downgradient. Steady state conditions are defined as no fluctuations in the flow or water table elevations.

Dissolved benzene concentrations in downgradient monitor wells MW-10A, -10B and -15 have remained virtually unchanged since sampling began on these wells on March 7, 1990; further supporting these modeled results.

7) The data shown on Figure 8 represents the projected dissolved benzene concentrations in 1996, incorporating the effect of groundwater pumping from RW-1 and C-9 (see Table D). A pumping rate of 0.05-0.1 gpm is calculated into the model to simulate actual

site conditions. Groundwater extraction data are routinely supplied to Chevron by the consultant, Geraghty and Miller.

As stated on Table D, the model begins at Time = 0, corresponding to 1986. Extraction well RW-1 begins pumping 1490 days into the model (1990) at a rate of 0.1 gpm. At 1830 days (1991), the pumping rate of RW-1 is reduced to 0.05 gpm. Extraction well C-9 begins pumping at 1990 days (1991) at a rate of 0.1 gpm. At 2330 days (1992), the pumping rate is reduced to 0.05 gpm.

The variable pumping rates used in the model reflect the changing pumping rates observed on-site.

The total run time of the results displayed in Figure 8 corresponds to Time = 3650 days (1996).

The model suggests that the present groundwater extraction configuration, utilizing wells RW-1 and C-9, will have a minimal effect on reducing the downgradient benzene concentration over the next 4 years.

8) Figures 9 and 10 show model simulated groundwater elevation contour lines in response to pumping 1 and 2 wells, respectively (see Table D). Figure 9 contains only the groundwater extraction effect of pumping RW-1 at 0.1 gpm for 1 year. Figure 10 shows the effect of pumping RW-1 for 2 years (at 0.1 gpm - year 1, 0.05 gpm - year 2), and C-9 for 1 year at 0.1 gpm.

The estimated groundwater capture radius, based on model simulations, is 20-25 feet.

9) Figure 11 presents the groundwater elevation contour pattern in response to pumping RW-1, C-9 and C-6 (see Table E).

Figure 11 represents site conditions simulated for 1995, with RW-1, C-9 and C-6 pumping at 5, 4 and 3 years, respectively. The pumping rates of the 3 wells are listed on Table E. The pumping rates are shown to decrease with time due to the simulated dewatering effect that groundwater extraction has on the relatively low permeable aquifer.

10) Figure 12 shows model simulated groundwater elevation contour lines in response to pumping RW-1, C-9, RW-2 and C-6 (see Table F). RW-2 is located along the western property boundary, 40 feet from RW-1. Figure 12 represents site groundwater conditions in 1995, with RW-1, C-9, RW-2 and C-6 pumping 5, 4, 3 and 3 years, respectively. The pumping rates of the 4 wells are shown on Table F.

11) Figures 13 and 14 display the simulated dissolved benzene concentrations in response to pumping RW-1, C-9 and C-6. The pumping rates and other conditions concerning these figures are

presented on Table E. Figures 13 and 14 simulate conditions for 1994 and 1996, respectively.

It is apparent from the data presented in Figures 13 and 14 that the effect of pumping RW-1, C-9 and C-6, along with the biodegradation process, will reduce the concentration of downgradient hydrocarbons and "shrink" the dissolved hydrocarbon plume. The 3 pumping wells provide a partial barrier to off-site benzene migration as observed in the decreasing concentrations in the downgradient portion of the modeled area. The upgradient portion of the area, near the source, will still likely be characterized by elevated concentrations of dissolved benzene.

12) Figures 15 to 16 show simulated dissolved benzene concentrations in response to pumping RW-1, C-9, C-6 and RW-2. The pumping rates and other conditions concerning these wells are present in Table F. Figures 15 and 16 simulate site conditions for 1994 and 1996, respectively.

The simulations presented in Figures 15 and 16 indicate that the 4 pumping well model establishes a more effective benzene migration barrier than the previously discussed 3 pumping well model (compare Figures 14 and 15). Downgradient benzene concentrations are further reduced due to the more effective inhibition of off-site benzene migration.

It should be noted, however, that upgradient concentrations will still be elevated. The low attainable pumping rates, due to the relatively low permeability of the soil, make it difficult to establish a truly effective migration barrier.

In both the 3 and 4 pumping well cases, it is apparent that the potential impact of dissolved benzene on Crow Creek will be eliminated.

<u>Summary</u>

The MODFLOW/MT3D computer generated groundwater flow and contaminant fate model indicates the following:

(A) Dissolved benzene, originating from a source at the former Chevron facility, will not apparently impact Crow Creek. A no impact simulation is shown regardless of whether groundwater is pumped or not (Figures 6, 7 and 8).

(B) The present groundwater extraction system (RW-1 and C-9) does not provide sufficient capture to effectively limit the off-site migration of dissolved benzene (Figure 7 and 8).

(C) The 4 year simulation of a 3 pumping well situation indicates that the off-site migration of dissolved benzene is reduced, as observed in the decreased concentrations in the downgradient portion of the modeled area. Upgradient concentrations, near the source, are still elevated.

The effect of the additional pumping well (C-6) is observed by comparing the pair of 1996 simulations presented in Figure 8 (pumping wells RW-1 and C-9) and Figure 14 (pumping wells RW-1, C-9 and C-6).

(D) The 4 year simulation of a 4 pumping well situation indicates that the off-site dissolved benzene migration is further inhibited by the addition of a hypothetical pumping well (RW-2). The effect of the various pumping configurations may be observed by comparing the 1996 simulations in Figures 8 (pumping wells RW-1 and C-9), Figure 14 (pumping wells RW-1, C-9 and C-6), and Figure 16 (pumping wells RW-1, C-9, C-6 and RW-2).

If you wish to discuss this site further, please contact me at CTN 242-1383.

Sheldon N. Nelson

cc: T.E. Buscheck
P.L. Hildebrandt
J.L. Pease
J.W. Hartwig

Table A **Title: GROUNDWATER FLOW MODEL PARAMETERS**

Flow Model MODFLOW

Transport Model MT3D

Problem Statement (Flow Model)

Finite difference grid	28 columns by 30 rows
Grid spacing	15 foot uniform spacing in the x and y directions
Specified head boundaries	Constant head defined as 288 feet above sea level along the bottom row (east) and 235 feet above sea level along Crow Creek, at the top of the grid (west)
Layers	1 (unconfined aquifer)
Aquifer thickness	Set to 20 feet in transport model
Bottom elevation	Set at 268 feet along bottom row; thereafter, each successive row is set 2 feet less than the preceeding row
Hydraulic conductivity	Clay-0.0279 ft/d ($1x10^{-5}$ cm/sec) Silt-0.2790 ft/d ($1x10^{-4}$ cm/sec)
Porosity	10%
Recharge	Neglected
Evapotranspiration	Neglected

Table B Title: Benzene Fate Model Parameters

Problem Statement (Transport Model)

Source concentration	24 ppm benzene
Dispersion (longitudinal)	15 feet (30 feet for first run w/no source removal)
Dispersion (transverse)	1.5 feet
Dry bulk density of soil	1.57 g/cm^3
K_d (distribution coefficient)	0.0485
K_{oc} (benzene)	97 ml/g
TOC (total organic carbon)	0.05% (500 ppm)
Biodegradation half-life ($t_{1/2}$)	110 days

Table C Title: Benzene Concentrations With No Pumping Simulation #1

Simulation #1

<u>Assumptions</u>

No pumping wells

Total run time is 10 years (1986-1996)

Constant benzene source (no source removal)

Area of source constant from start to finish

No change in constant head elevations

Table D Title: Benzene Concentrations Including Effect of Pumping Simulation #2

Simulation #2

Assumptions

Two pumping wells

	RW-1	C-9
Begin	1490 days (1990) 0.1 gpm	1990 days (1991) 0.1 gpm
Change in pumping rate	1830 days (1991) 0.05 gpm	2330 days (1992) 0.05 gpm

Total run time is 10 years, time = 0-3650 days (1986-1996)

Constant benzene source (no source removal)

Area of source constant from start to finish

No change in constant head elevations

Table E Benzene Concentrations Including Effect of Pumping Simulation #3

Simulation #3

Assumptions

Three pumping wells

	RW-1	C-9	C-6
Begin	1990 0.1 gpm	1991 0.1 gpm	1992 0.04 gpm
Change in pumping rate	1991 0.05 gpm	1992 0.05 gpm	1995 0.03 gpm
	1992 0.04 gpm	1995 0.045 gpm	
	1995 0.035 gpm		

Total run time is 13 years (1986-1999)

Constant source (no source removal)

Area of source constant from start to finish

No change in constant head elevations

Table F Benzene Concentrations Including Effect of Pumping Simulation #6

Simulation #6

Assumptions

Four pumping wells (add RW-2 as pumping well at same time as C-6).

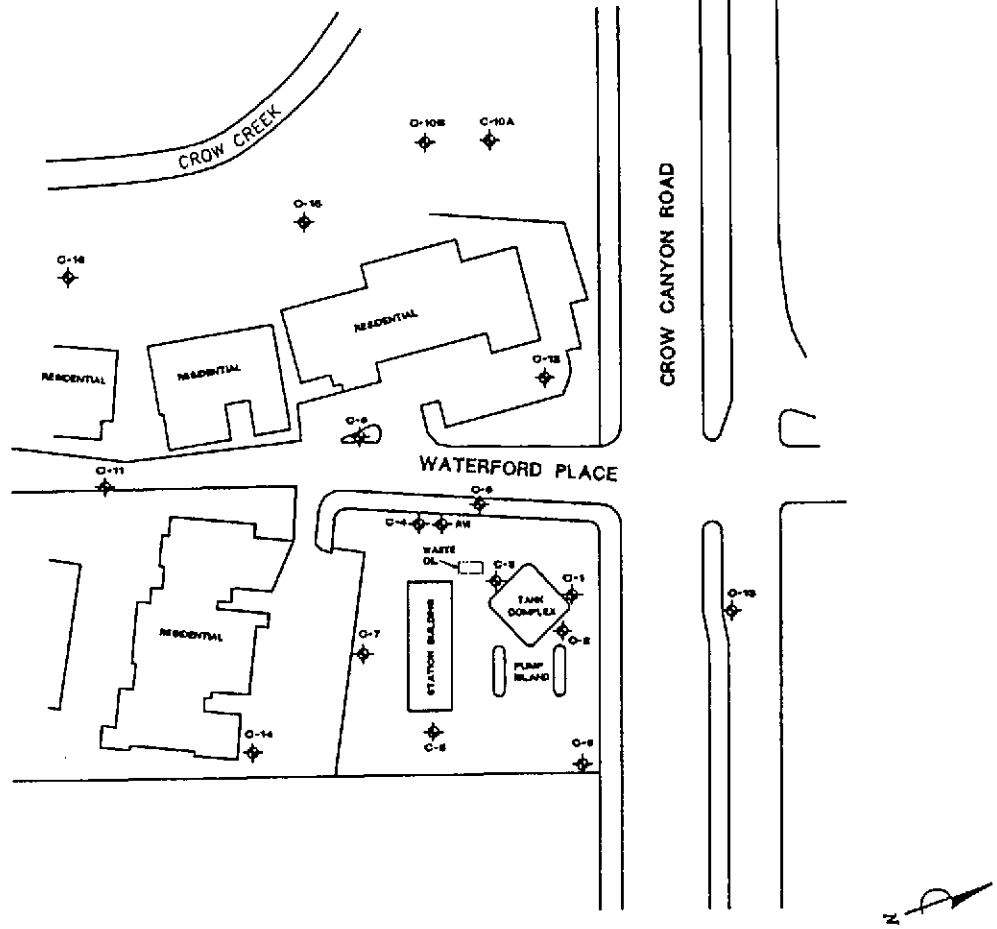
	RW-1	C-9	RW-2	C-6
Begin	1990 0.1 gpm	1991 0.1 gpm	1992 0.04 gpm	1992 0.03 gpm
Change in pumping rate	1991 0.05 gpm	1992 0.05 gpm	1995 0.02 gpm	1995 0.02 gpm
	1992 0.04 gpm	1995 0.045 gpm		
	1995 0.035 gpm			

Total run time is 13 years (1986-1999)

Constant source (no source removal)

Area of source constant from start to finish

No change in constant head elevations



C-1 = GROUND WATER MONITOR WELL

0 30 60
SCALE (ft)

CHEVRON CORPORATION

FORMER CHEVRON SERVICE STATION #9-5607
5269 CROW CANYON RD
CASTRO VALLEY, CALIFORNIA

FATE & TRANSPORT MODELING

SCALE	DATE		
SEE BAR	7/6/92	DRN	CAZ

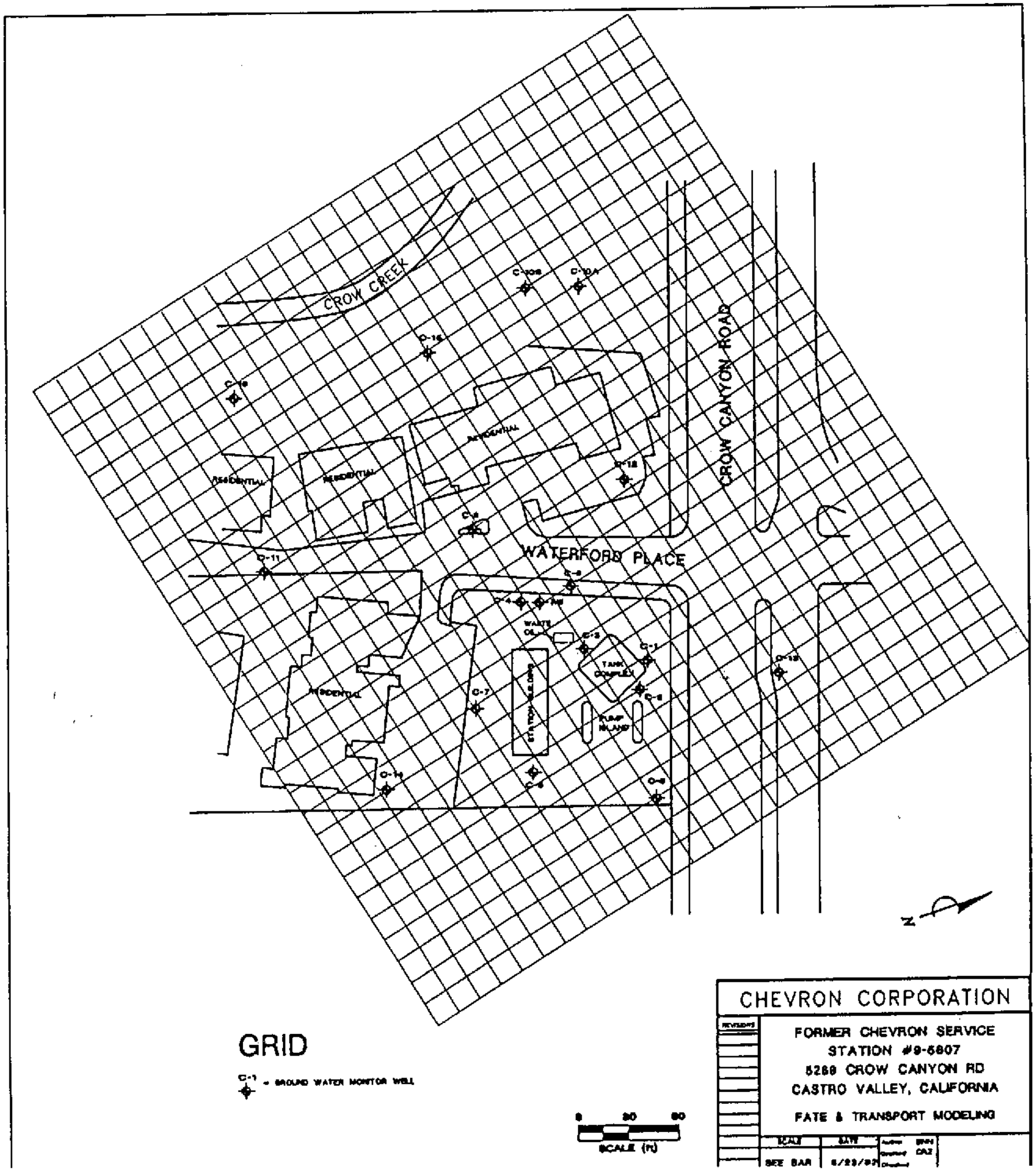
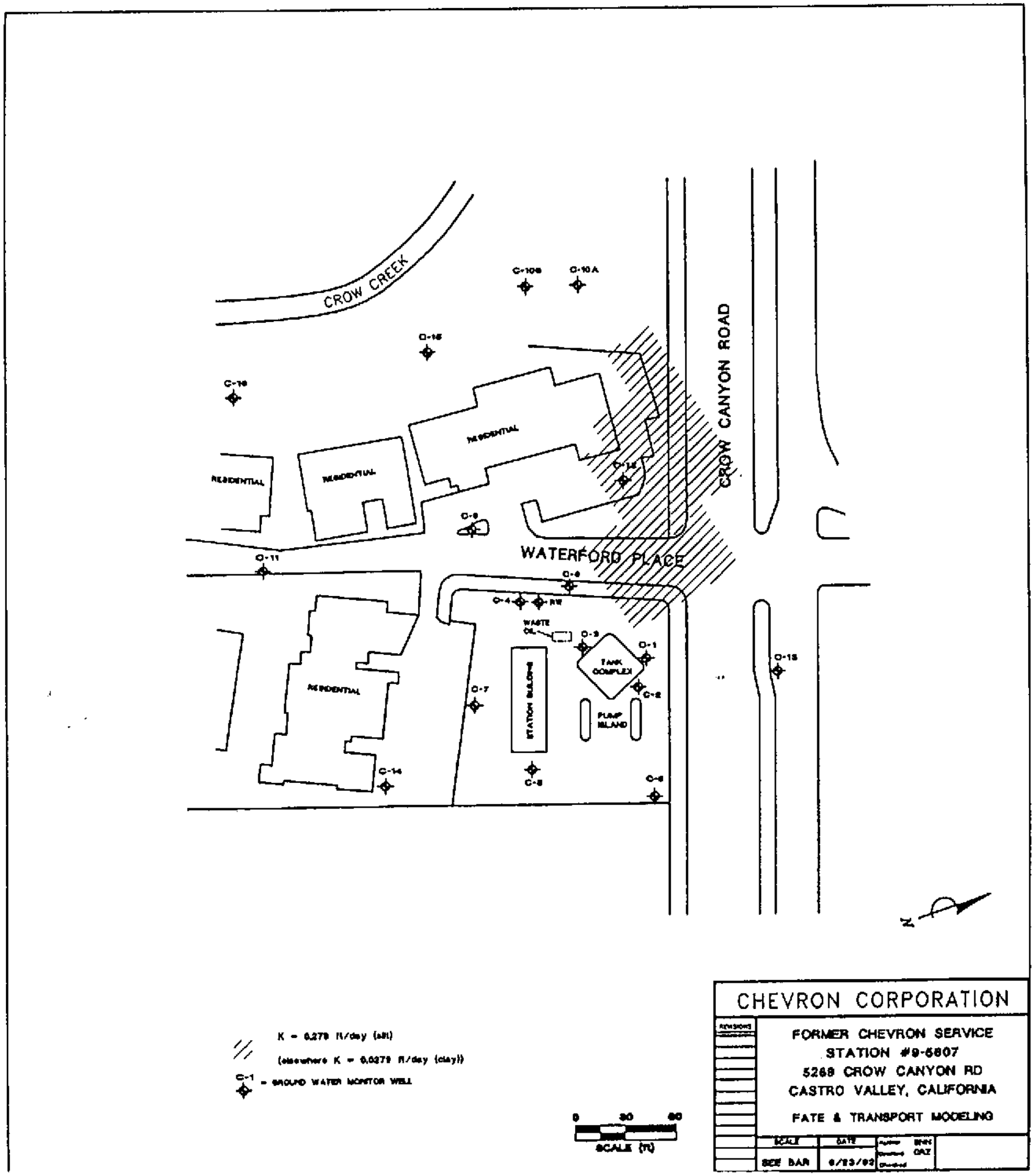


Figure 2

Title: AREAL GRID USED FOR MODEL

Figure 2



Title: ILLUSTRATION OF HETEROGENEOUS HYDRAULIC CONDUCTIVITY IN SUBSURFACE

Figure 4

Title: GROUNDWATER ELEVATION CONTOURS - MODELED FROM 1992 FIELD

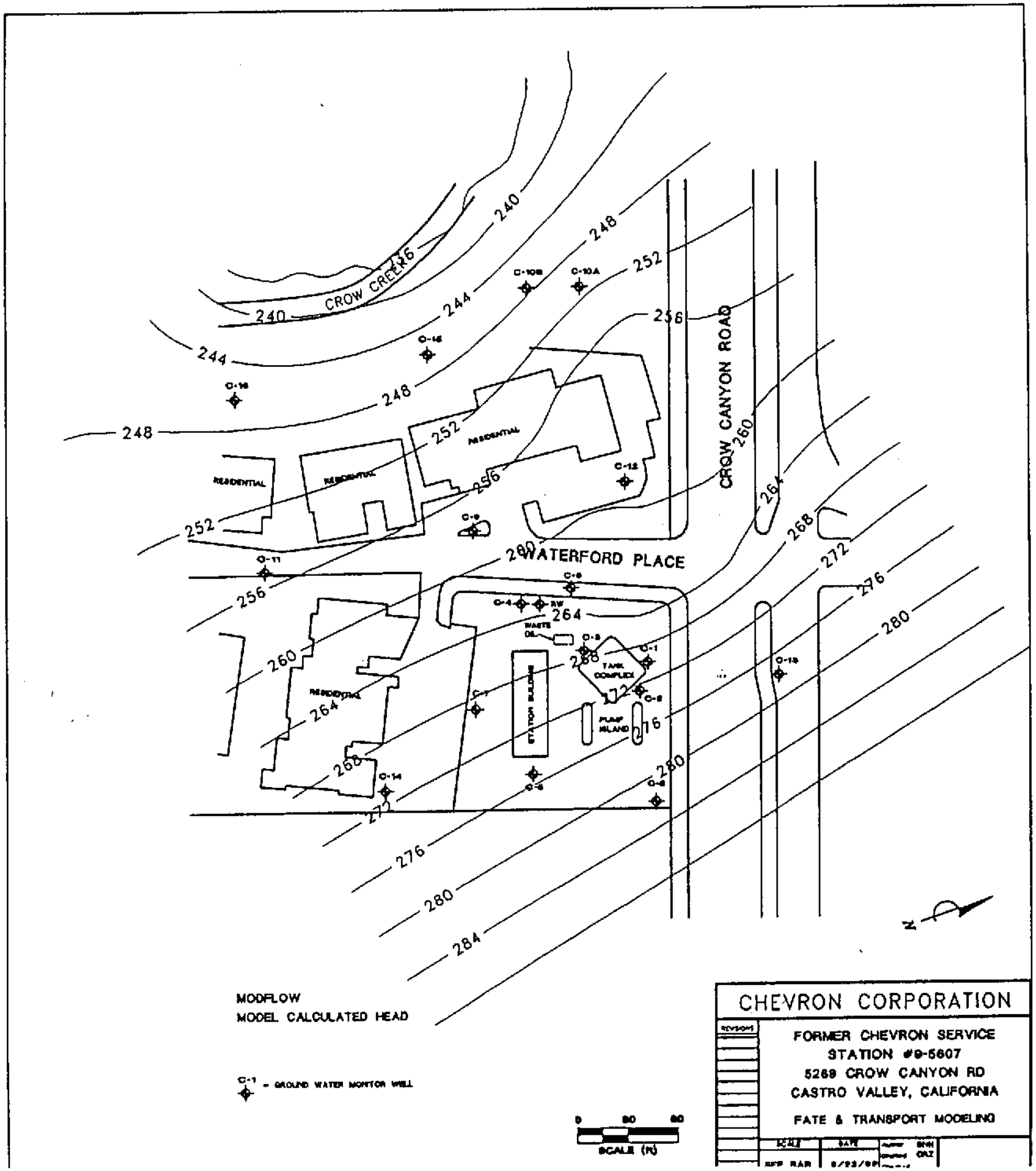


Figure 5

Title: INITIAL LIQUID PHASE HYDROCARBON SOURCE AREA - 1986

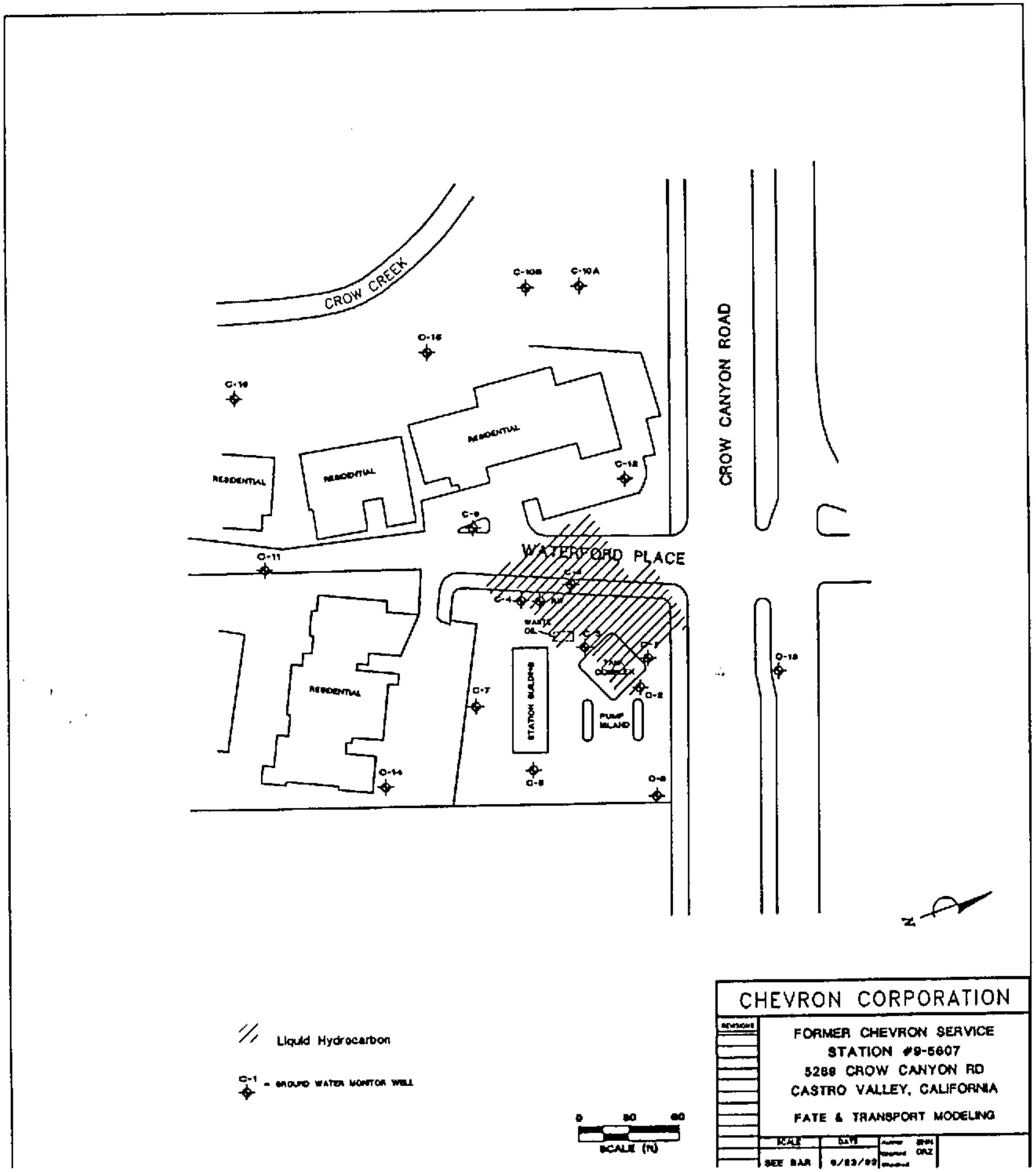
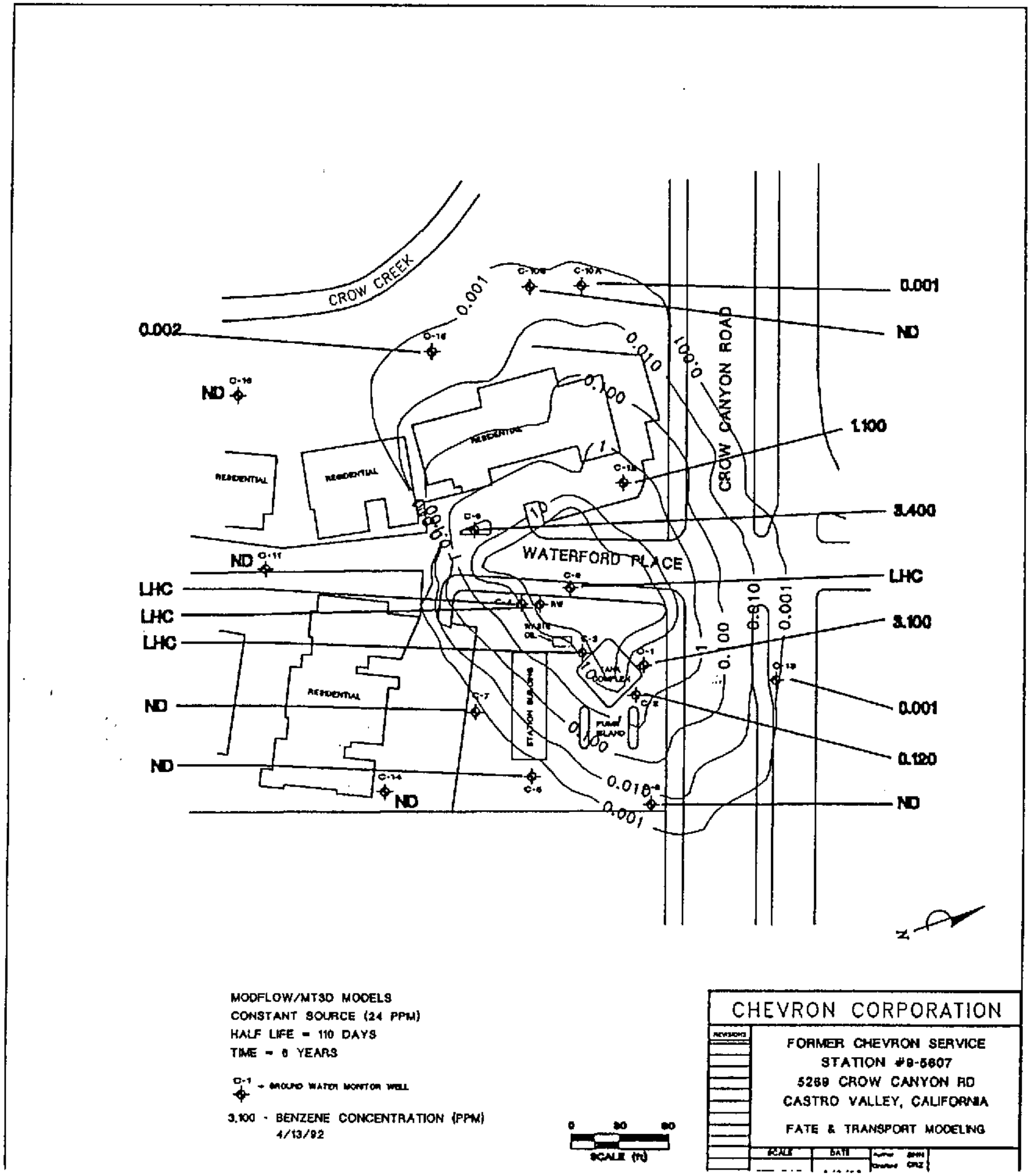


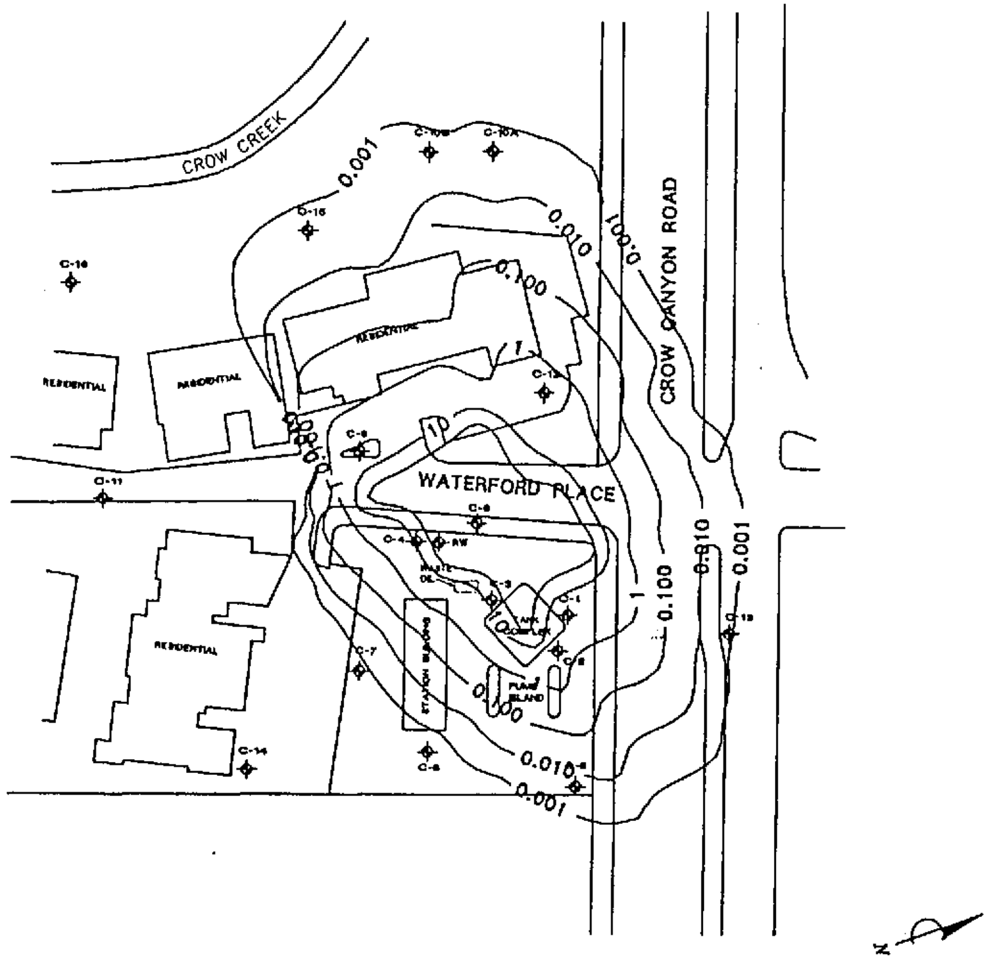
Figure 6.



Title: DISSOLVED BENZENE CONCENTRATIONS - 1992
NO PUMPING WELLS - SIMULATION #1

Figure 7.

Title: DISSOLVED BENZENE CONCENTRATIONS - 1996 NO PUMPING WELLS - SIMULATION #1



MODFLOW/MT3D MODELS
CONSTANT SOURCE (24 PPM)
HALF LIFE = 110 DAYS
TIME = 10 YEARS

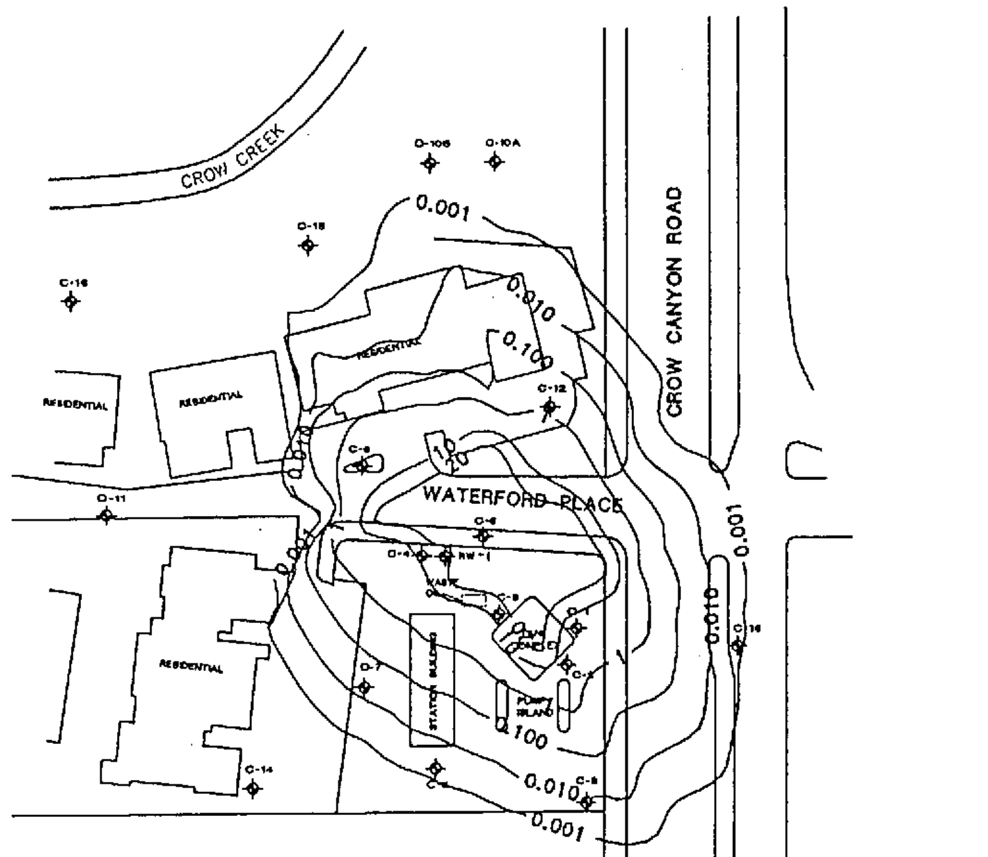
C-1 = GROUND WATER MONITOR WELL

0 30 60
SCALE (ft)

CHEVRON CORPORATION
FORMER CHEVRON SERVICE STATION #9-5607 5289 CROW CANYON RD CASTRO VALLEY, CALIFORNIA
FATE & TRANSPORT MODELING
SCALE: SEE BAR · DATE: 6/23/92

Figure 8.

Title: DISSOLVED BENZENE CONCENTRATIONS - 1996
2 PUMPING WELLS (RW-1 AND C-9) - SIMULATION #2



MODFLOW/MT3D MODELS
CONSTANT SOURCE (24 PPM BENZENE)
HALF LIFE = 110 DAYS
TIME 10 YEARS TOTAL
FIRST WELL BEGINS PUMPING AT 1490 DAYS
SECOND WELL BEGINS PUMPING AT 1890 DAYS

FOUR YEARS FROM PRESENT

C-1 = GROUND WATER MONITOR WELL

0 30 60
SCALE (ft)

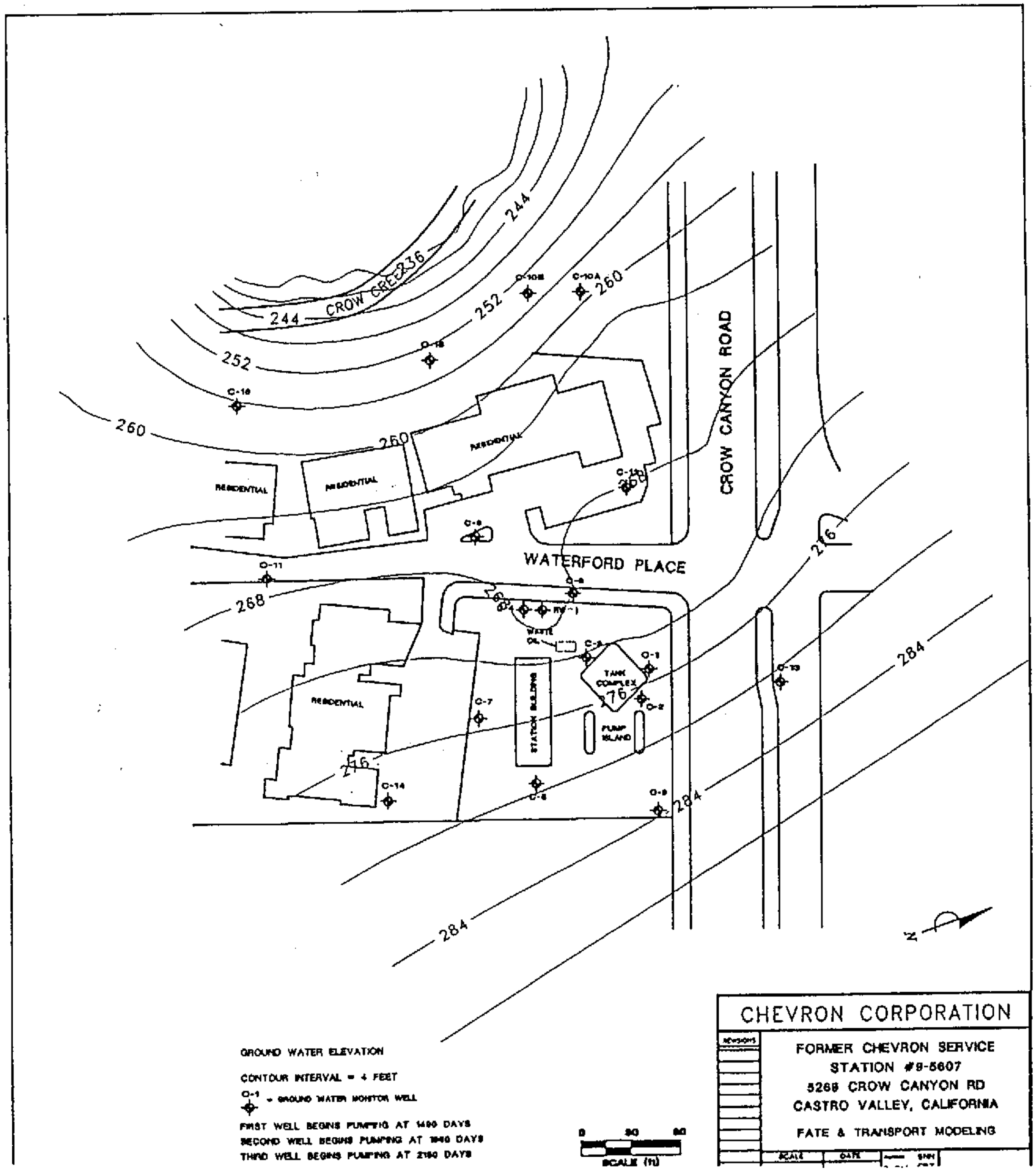
CHEVRON CORPORATION

FORMER CHEVRON SERVICE
STATION #9-5607
5269 CROW CANYON RD
CASTRO VALLEY, CALIFORNIA

FATE & TRANSPORT MODELING

REVISIONS | SCALE | DATE | Author | DWN

Figure 9.



Title: GROUNDWATER ELEVATION CONTOURS EFFECT OF ONE PUMPING WELL (RW-1)

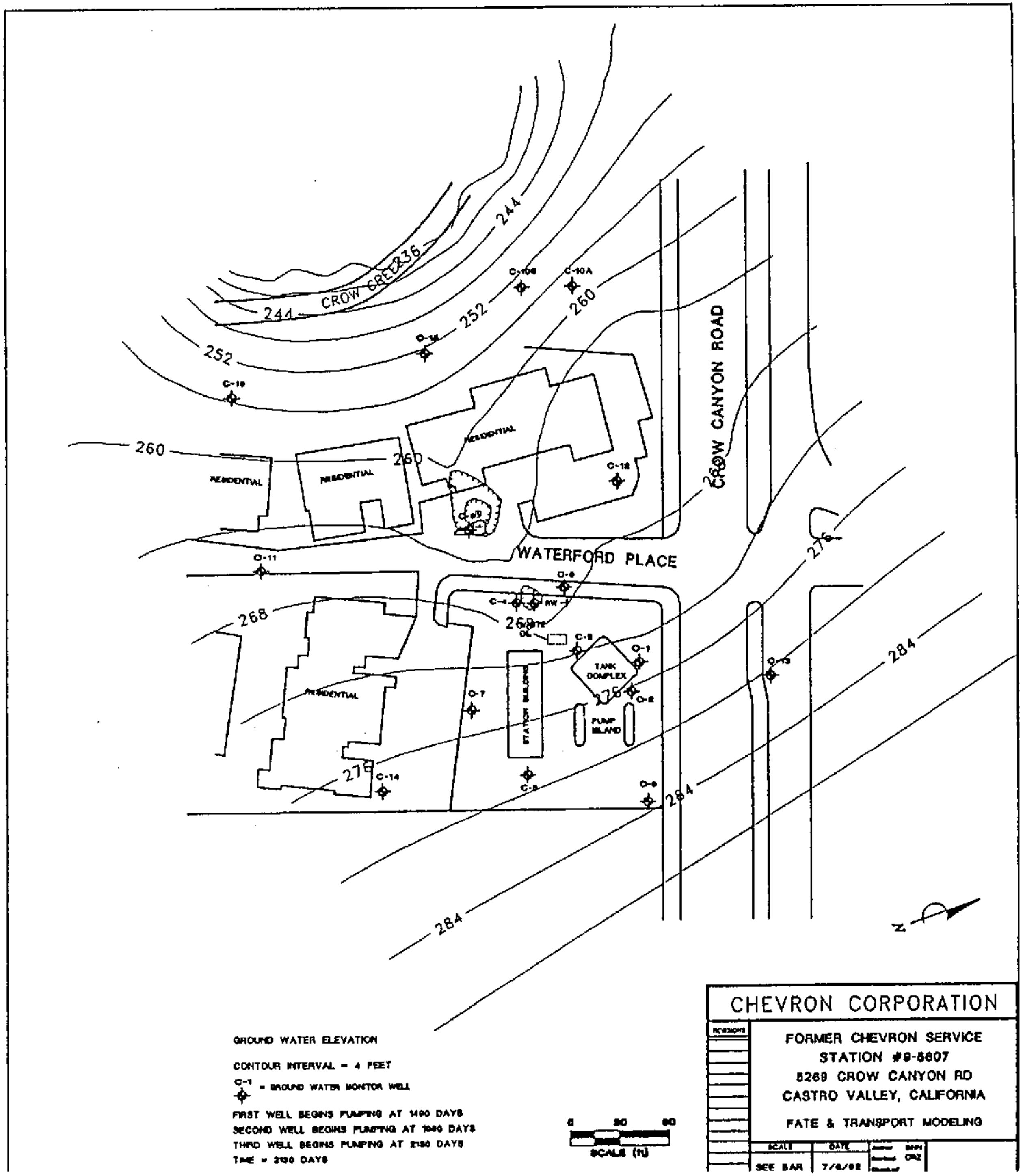


Figure 10.

Title: GROUNDWATER ELEVATION CONTOURS
EFFECT OF TWO PUMPING WELLS (RW-1 AND C-9)

Figure 11.

Title: GROUNDWATER ELEVATION CONTOURS
EFFECT OF THREE PUMPING WELLS (RW-1, C-9 AND C-6)
1995

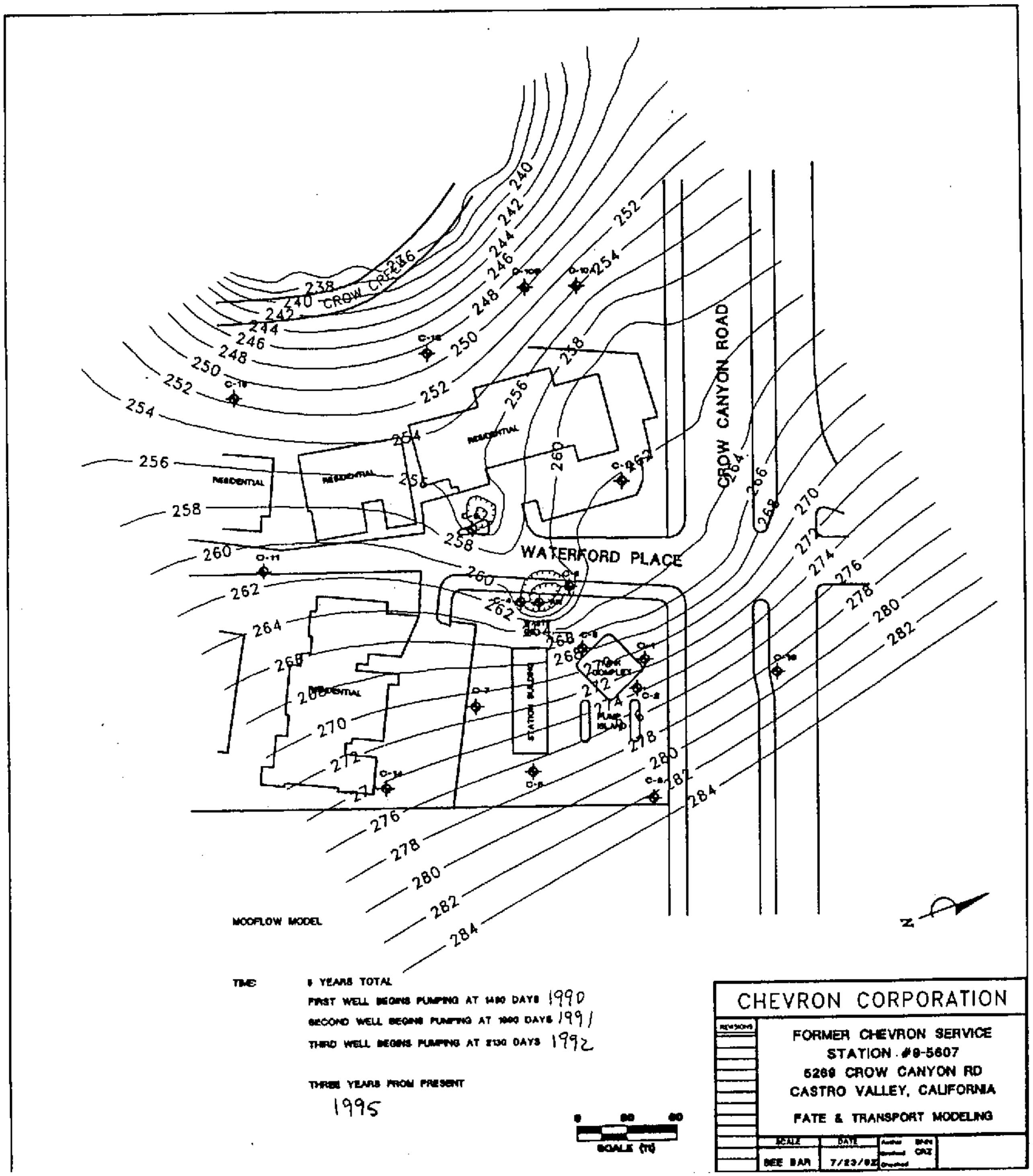
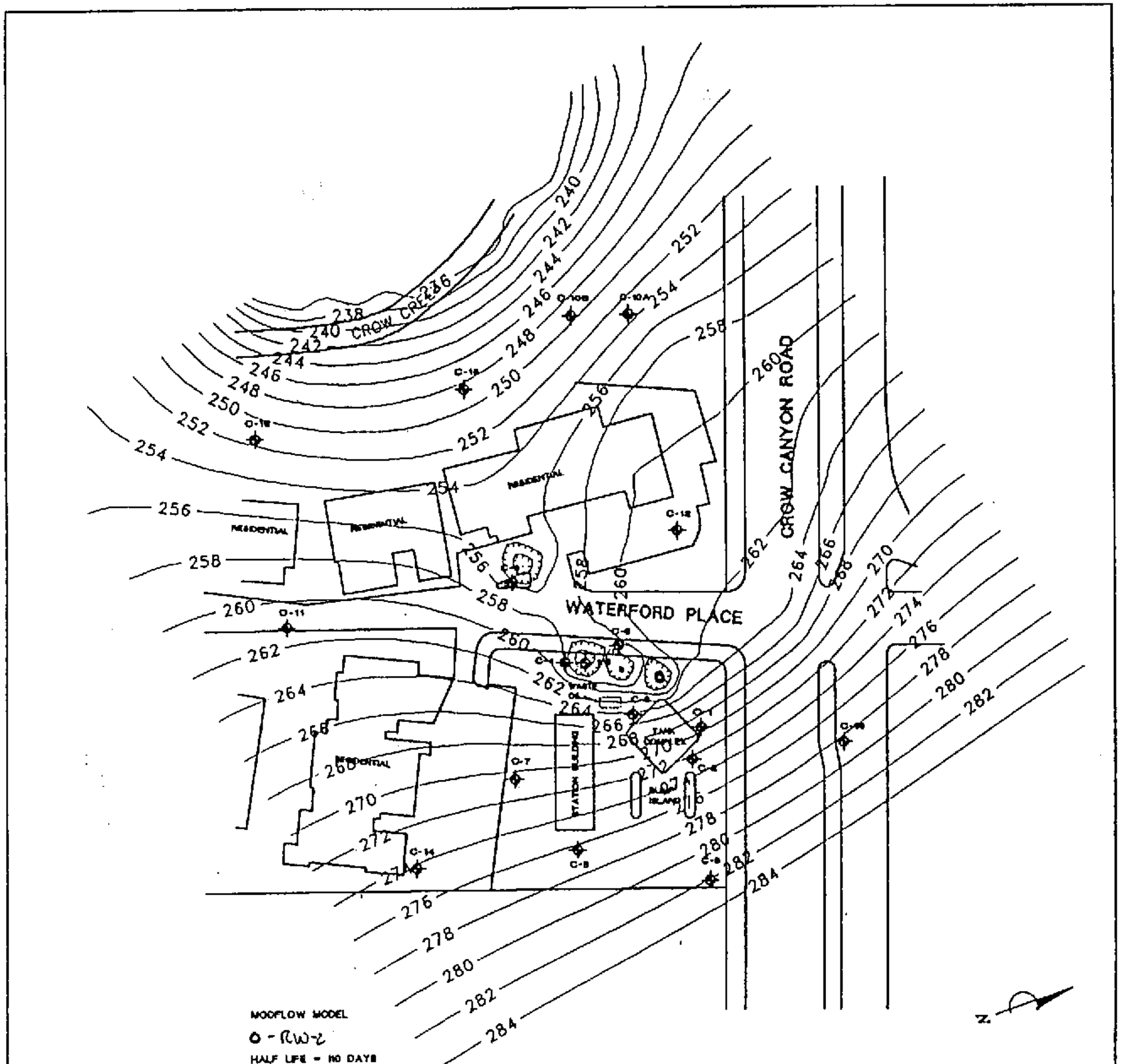


Figure 12



MODFLOW MODEL

O - RW-2

HALF LIFE = 110 DAYS

TIME: 9 YEARS TOTAL

FIRST WELL BEGINS PUMPING AT 1490 DAYS 1990

SECOND WELL BEGINS PUMPING AT 1900 DAYS 1991

THIRD WELL BEGINS PUMPING AT 2130 DAYS 1992

FOURTH WELL BEGINS PUMPING AT 2130 DAYS 1992

THREE YEARS FROM PRESENT

1995

0 30 60

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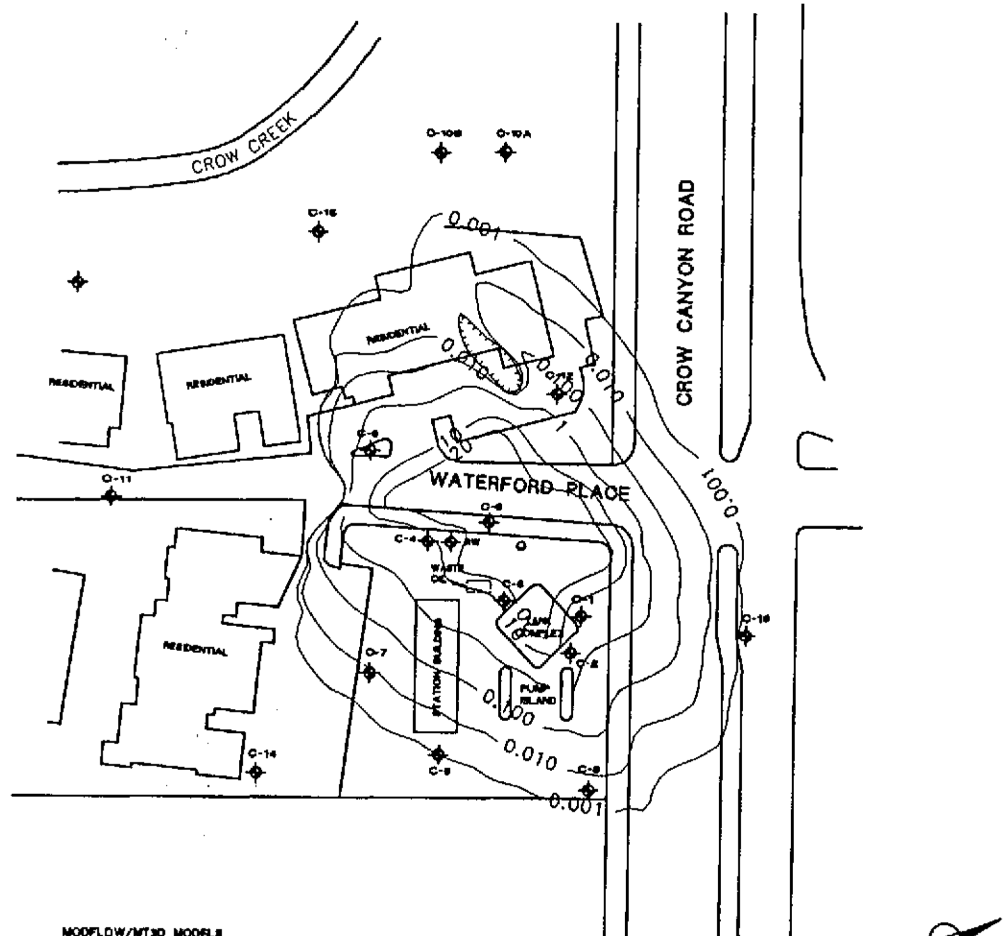
Title: GROUNDWATER ELEVATION CONTOURS
EFFECT OF FOUR PUMPING WELLS (RW-1, C-9, RW-2 AND C-6)

Figure 13

Title: DISSOLVED BENZENE CONCENTRATIONS THREE PUMPING WELLS (RW-1, C-9 AND C-6) 1994



MODFLOW/MT3D MODELS

CONSTANT SOURCE (24 PPM BENZENE)

HALF LIFE = 70 DAYS

TIME: 8 YEARS TOTAL

FIRST WELL BEGINS PUMPING AT 1460 DAYS 1990

SECOND WELL BEGINS PUMPING AT [illegible] DAYS 1991

THIRD WELL BEGINS PUMPING AT 2190 DAYS 1992

TWO YEARS FROM PRESENT

1994

0 50 60

SCALE (ft)

CHEVRON CORPORATION
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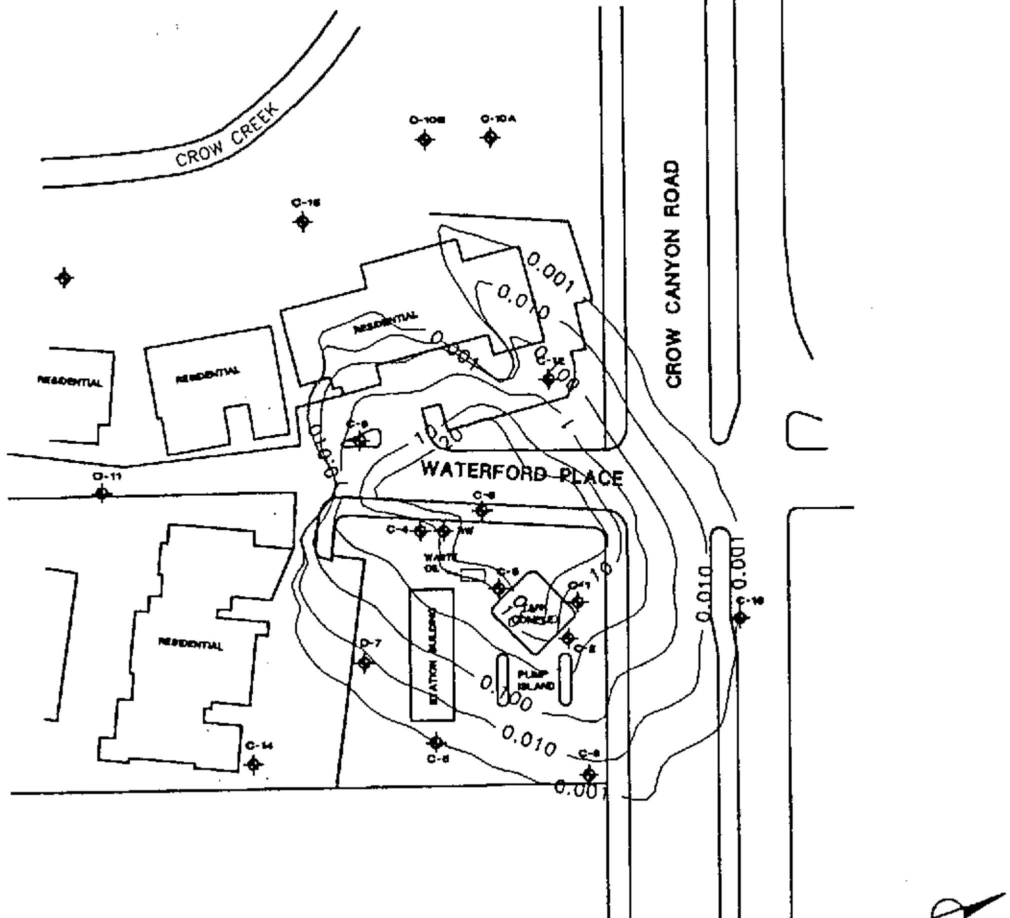
FATE & TRANSPORT MODELING

SCALE	DATE	Author / Revised / Checked
SEE BAR	7/23/92	SNY CRZ

Figure 14.

Title: DISSOLVED BENZENE CONCENTRATIONS
THREE PUMPING WELLS (RW-1, C-9 AND C-6)
1996



MODFLOW/MT3D MODELS
CONSTANT SOURCE (24 PPM BENZENE)
HALF LIFE = 110 DAYS
TIME 10 YEARS TOTAL
FIRST WELL BEGINS PUMPING AT 1460 DAYS 1990
SECOND WELL BEGINS PUMPING AT 1800 DAYS 1991
THIRD WELL BEGINS PUMPING AT 2190 DAYS 1992

FOUR YEARS FROM PRESENT
1996

0 30 60
SCALE (ft)

CHEVRON CORPORATION

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CASTRO VALLEY, CALIFORNIA

FATE & TRANSPORT MODELING

SCALE	DATE
SEE BAR	7/23/92

Figure 16.

Title: DISSOLVED BENZENE CONCENTRATIONS
FOUR PUMPING WELLS (RW-1, C-9, RW-2 AND C-6)
1996