

---

**FINAL REMEDY  
REMEDIAL INVESTIGATION  
REPORT  
MOTOROLA 52ND ST.**

---

**VOLUME I OF IV  
REPORT**

*Prepared for*

***MOTOROLA INC.***



*by*

**Dames & Moore**



---

February 1992



**MOTOROLA INC.**

March 16, 1992

Mr. Edward Z. Fox, Director  
Ms. Jacqueline Maye, Project Coordinator  
Arizona Department of Environmental Quality  
2005 North Central Avenue  
Phoenix, Arizona 85004

Final Remedy Remedial Investigation Report  
Motorola 52nd St. Facility

Dear Mr. Fox and Ms. Maye:

Transmitted herewith is the Final Remedy Remedial Investigation Report, February 1992, prepared by Dames & Moore for the Motorola 52nd St. project. This document is submitted for your review pursuant to the general requirements of Article 27.0 of the Motorola 52nd St. Consent Order. This document supersedes the draft FR RI report transmitted under cover of our letter dated September 30, 1991, and responds to agency comments submitted under cover of the ADEQ letter dated February 18, 1992 (RPU92,072).

Motorola wishes to convey its intention to cooperate fully with the agencies to actively evaluate alternative remedial actions as required. In accordance with that, Motorola proposes to proceed with the development of the Final Remedy Feasibility Study and looks forward to meeting with agency representatives as soon as possible to discuss plans for proceeding.

In addition, Motorola is continuing to investigate and remediate the area of the Southwest Parking Lot to reduce concentrations of volatile organic compounds in the vadose zone and ground water. Attachment SW to the enclosed report presents the work completed through December 1991, and will be supplemented with additional information being obtained at this time. Motorola looks forward to meeting with agency representatives to review the work presently being performed and proposed in the Southwest Parking Lot.



**MOTOROLA INC.**

Mr. Edward Z. Fox, Director  
March 16, 1992  
Page 2

If you have any questions regarding this report, please call me or Mr. James R. Hussey with Dames & Moore.

Sincerely,

John Seeger  
Project Coordinator

JS/tc

Enclosure

Received by:

\_\_\_\_\_  
Mr. Edward Z. Fox, Director

\_\_\_\_\_  
Date

\_\_\_\_\_  
Ms. Jacqueline Maye, Project Coordinator

\_\_\_\_\_  
Date

cc: See attached list

**FINAL REMEDY REMEDIAL INVESTIGATION REPORT**  
**February 19, 1992**

**MOTOROLA INC.**

52nd Street and McDowell Road  
Phoenix, Arizona

**DISTRIBUTION CONTROL**

---

---

<u>Distribution</u>	<u>Number of Copies</u>
Arizona Department of Environmental Quality	6
E. Fox	
J. Maye (3)	
L. Carty	
S. Calloway	
Arizona Department of Water Resources	2
K. Berry (2)	
Environmental Protection Agency	2
M. Montgomery (2)	
Arizona Department of Health Services	1
W. Chromec	
Motorola Inc.	10
D. Johns	
G. Fisher (8)	
J. Seeger	
Dames & Moore	10
J. Hussey	
L. Bartlett	
D. Bartlett	
B. Loughlin	
Files (6)	

# DAMES & MOORE

POINTE CORPORATE CENTRE, 7500 NORTH DREAMY DRAW DRIVE, SUITE 145, PHOENIX, ARIZONA 85020  
(602) 371-1110 FAX: (602) 861-7431

March 16, 1992

09448-139-033

Mr. John Seeger  
Project Coordinator  
Motorola Inc.  
5005 East McDowell Road  
Phoenix, Arizona 85008

Dear John:

Please find enclosed the Final Remedy Remedial Investigation Report, February 1992, for the Motorola 52nd St. Superfund project. This document contains a comprehensive characterization of the extent of ground-water contamination for the Motorola 52nd St. facility. The report forms the basis for proceeding with a Final Remedy Feasibility Study.

This report supersedes the draft FR RI report transmitted to the Arizona Department of Environmental Quality under your cover letter dated September 30, 1991. This document reflects comments received from ADEQ under cover of letter dated February 18, 1992. The responses to general and specific comments on the draft report provided by ADEQ are included behind the main text of this report, and are reflected in changes to the text, tables and figures contained herein.

Please call if you have any questions.

Sincerely,

DAMES & MOORE



James R. Hussey, P.E.  
Principal



JRH/tc

Enclosure

cc: File 09448-140-033



**FINAL REMEDY RI REPORT**

**MOTOROLA 52ND ST.**

**SUMMARY OF TABLE OF CONTENTS**



**VOLUME I**

- 1.0 INTRODUCTION
- 2.0 GEOLOGIC SETTING
- 3.0 HYDROGEOLOGY
- 4.0 VOC CHARACTERIZATION
- 5.0 INORGANIC GROUND-WATER QUALITY
- 6.0 GROUND-WATER FLOW AND TRANSPORT MODELING
- 7.0 SUMMARY AND CONCLUSIONS
- 8.0 REFERENCES
- 9.0 DEFINITION OF TERMS

ATTACHMENT A - RESPONSES TO AGENCY COMMENTS

**VOLUME II**

- A WELL INSTALLATION
- B BEDROCK SUMMARY
- C1 WELL INVENTORY
- C2 OTHER POTENTIAL SOURCES
- D MODELING
- E0 PRELIMINARY DATA
- E1 RI ORGANICS
- E2 POST-RI ORGANICS

**VOLUME III**

- E3 RI INORGANICS
- E4 POST-RI INORGANICS
- E5 QA/QC
- E6 VOC WATER QUALITY
- E7 INORGANIC WATER QUALITY
- F AQUIFER TESTS
- G WATER ELEVATIONS

**VOLUME IV**

ATTACHMENT SW - SOUTHWEST PARKING LOT



**FINAL REMEDY RI REPORT**  
**MOTOROLA 52ND ST.**



**TABLE OF CONTENTS - VOLUME I**

	<u>Page</u>
<b>1.0 INTRODUCTION</b>	
1.1 BACKGROUND .....	1-1
1.2 OBJECTIVES AND SCOPE OF WORK .....	1-4
1.3 OVERVIEW OF THE FR RI INVESTIGATION .....	1-7
1.4 ORGANIZATION OF THE FR RI REPORT .....	1-10
<b>2.0 GEOLOGIC SETTING</b>	
2.1 BACKGROUND .....	2-1
2.1.1 Previous Geologic Investigations .....	2-1
2.1.2 Installation of New Monitor Wells .....	2-2
2.2 STRATIGRAPHY .....	2-3
2.2.1 Precambrian Metarhyolite .....	2-3
2.2.2 Precambrian Granite .....	2-4
2.2.3 Tertiary Camels Head Formation .....	2-5
2.2.4 Tertiary Tempe Beds .....	2-6
2.2.5 Tertiary Volcanics .....	2-7
2.2.6 Quarternary Alluvium .....	2-8
2.3 STRUCTURAL GEOLOGY .....	2-9
2.3.1 Tectonic History .....	2-9
2.3.2 Local Geologic Structure .....	2-12
2.3.3 Lineaments .....	2-13
2.4 SIGNIFICANCE OF GEOLOGIC SETTING .....	2-14

**TABLE OF CONTENTS (Continued)**

**3.0 HYDROGEOLOGY**

3.1	INTRODUCTION .....	3-1
3.2	AQUIFERS .....	3-1
3.2.1	Alluvium .....	3-2
3.2.2	Bedrock .....	3-3
3.3	FLOW PATTERNS .....	3-3
3.4	HYDRAULIC CHARACTERISTICS .....	3-5
3.4.1	Alluvium .....	3-6
3.4.2	Bedrock .....	3-7
3.4.3	Summary .....	3-8
3.5	RECHARGE .....	3-8
3.5.1	Canal Recharge .....	3-9
3.5.2	Flood Irrigation .....	3-10
3.6	SUMMARY .....	3-10

**4.0 VOC CHARACTERIZATION**

4.1	INTRODUCTION .....	4-1
4.2	PROCEDURES AND METHODS .....	4-4
4.3	WATER QUALITY CHARACTERISTICS: NEAR PLANT AREA ..	4-5
4.3.1	Introduction .....	4-5
4.3.2	Pilot Treatment Plant Operation .....	4-5
4.3.3	TCE and TCA Concentration Trends .....	4-6
4.3.4	Evaluation of Concentration Declines .....	4-7
4.3.5	Near-Plant Concentration Increases .....	4-11
4.3.6	The Distribution of Solvent Degradation .....	4-11
4.3.7	Summary of Near-Plant Observations .....	4-13

**TABLE OF CONTENTS (Continued)**

4.4	WATER QUALITY CHARACTERISTICS: FAR-FIELD AREA . . . . .	4-14
4.4.1	Introduction . . . . .	4-14
4.4.2	VOC Trends/Distributions . . . . .	4-15
4.4.3	Vertical Distribution of VOCs . . . . .	4-16
4.4.4	The Distribution of VOC Degradation Products . . . . .	4-17
4.5	SUMMARY AND CONCLUSIONS . . . . .	4-18
<b>5.0</b>	<b>INORGANIC GROUND-WATER QUALITY</b>	
5.1	INTRODUCTION . . . . .	5-1
5.1.1	Objective . . . . .	5-2
5.1.2	Collection of Data . . . . .	5-2
5.1.3	Presentation of Data . . . . .	5-3
5.2	CHARACTERIZATION OF INORGANIC GROUND-WATER QUALITY . . . . .	5-5
5.2.1	Characterization of Major Ions in Study Area . . . . .	5-6
5.2.2	Inorganic Water Quality Standards . . . . .	5-6
5.2.2.1	Inorganic Ground-Water Quality Exceedances . . . . .	5-8
5.2.3	Background Inorganic Ground-Water Quality . . . . .	5-9
5.2.3.1	Geologic Factors . . . . .	5-9
5.2.3.2	Cultural Factors . . . . .	5-10
5.2.3.3	Evaluation of Background Inorganic Water Quality . . . . .	5-11
5.3	AREAS OF INORGANIC CONTAMINATION . . . . .	5-12
5.3.1	Inorganic Contamination in the Courtyard Area . . . . .	5-13
5.3.2	Inorganic Contamination in the SWPL Area . . . . .	5-14
5.4	SUMMARY AND CONCLUSIONS . . . . .	5-15

**TABLE OF CONTENTS (Continued)**

**6.0 GROUND-WATER FLOW AND TRANSPORT MODELING**

6.1	INTRODUCTION .....	6-1
6.1.1	Purpose .....	6-1
6.1.2	Previous Modeling Work .....	6-2
6.2	APPROACH .....	6-3
6.2.1	Model Framework .....	6-4
6.2.2	Site-Specific Data .....	6-5
6.3	ASSUMPTIONS .....	6-10
6.3.1	Hydrodynamic Conditions .....	6-10
6.3.2	Transport Factors .....	6-11
6.4	SENSITIVITY ANALYSIS .....	6-14
6.5	MODEL CALIBRATION .....	6-16
6.5.1	Hydrodynamic Factors .....	6-17
6.5.2	Transport Factors .....	6-18
6.6	SUMMARY AND CONCLUSIONS .....	6-23

**7.0 SUMMARY AND CONCLUSIONS**

**8.0 REFERENCES**

8.1	REFERENCES BY CHAPTER .....	8-1
8.2	DAMES & MOORE SOURCE MATERIAL .....	8-7

**9.0 DEFINITION OF TERMS**

9.1	GLOSSARY .....	9-1
9.2	ACRONYMS .....	9-13
9.3	CHEMICAL ABBREVIATIONS .....	9-15

**ATTACHMENT A - FR RI RESPONSES TO AGENCY COMMENTS**

**TABLE OF CONTENTS (Continued)**

**LIST OF TABLES**

- 1.1 LOCATION AND TYPE OF POTENTIAL SOURCES
- 1.2 CHEMICAL ABBREVIATIONS
- 2.1 SUMMARY OF BEDROCK FRACTURE DATA
- 3.1 CALCULATION OF VERTICAL HYDRAULIC GRADIENTS FOR MULTI-PORT WELLS
- 3.2 AQUIFER TEST RESULTS
- 3.3 HYDRAULIC CONDUCTIVITY (k) IN ALLUVIUM BASED ON RISING HEAD TEST DATA
- 3.4 HYDRAULIC CONDUCTIVITY (k) IN BEDROCK BASED ON RISING HEAD TEST DATA
- 4.1 FEDERAL AND STATE VOC DRINKING WATER QUALITY STANDARDS
- 5.1 STATISTICAL EVALUATION OF ARSENIC OBSERVATIONS: 1985 - 1991
- 5.2 STATISTICAL EVALUATION OF FLUORIDE OBSERVATIONS: 1985 - 1991
- 5.3 STATISTICAL EVALUATION OF NITRATE OBSERVATIONS: 1985 - 1991
- 6.1 MODEL INPUT DATA
- 6.2 COMPARISON OF OBSERVED AND PREDICTED ETHYLENE (TCE + TDCE + DCE) CONCENTRATIONS

**LIST OF FIGURES**

- 1.1 VICINITY MAP
- 1.2 LOCATIONS OF POTENTIAL SOURCES AND PLANT BUILDINGS
- 1.3 MOTOROLA 52ND STREET WELL LOCATIONS
- 1.4A LOCATIONS OF OFFSITE OU EXTRACTION AND MONITOR WELLS
- 1.4B LOCATIONS OF ONSITE OU EXTRACTION WELLS
- 2.1 BEDROCK OUTCROP MAP

**TABLE OF CONTENTS (Continued)**

**LIST OF FIGURES (Continued)**

- 2.2A LOCATION OF WELLS INSTALLED DURING 1990 AND 1991
- 2.2B LOCATION OF OFFSITE MONITOR WELLS
- 2.C LOCATION OF ONSITE MONITOR WELLS
- 2.3 STRATIGRAPHIC COLUMN
- 2.4 GEOLOGIC BEDROCK MAP
- 2.5 GENERALIZED GEOLOGIC CROSS-SECTION (A-A')
- 2.6 GENERALIZED GEOLOGIC CROSS-SECTIONS (B-B' AND C-C')
- 2.7 ELEVATIONS OF THE TOP OF BEDROCK
- 3.1 LOCATIONS OF MONITOR WELLS
- 3.2 LOCATION OF ONSITE MONITOR WELLS
- 3.3 REGIONAL GROUND-WATER CONDITIONS
- 3.4A WATER TABLE ELEVATION CONTOUR MAP
- 3.4B APPROXIMATE DEPTH TO WATER TABLE
- 3.5 SATURATED THICKNESS OF THE ALLUVIUM
- 3.6A WATER ELEVATION HISTORIES FOR SELECTED WELLS (18E-5N AND 16.9E-6N)
- 3.6B WATER ELEVATION HISTORIES FOR SELECTED WELLS (MP 03A, MP 36A, DM 117, MP 49A AND MP 52B)
- 3.7 VERTICAL DISTRIBUTION OF PRESSURE HEADS, MULTIPOINT WELL INSTALLATIONS
- 3.8 VERTICAL HYDRAULIC GRADIENT DISTRIBUTION
- 3.9 GROUND-WATER RECHARGE AREAS
- 4.1 PILOT TREATMENT PLANT, INFLUENT VOC CONCENTRATIONS VS. TIME

TABLE OF CONTENTS (Continued)

LIST OF FIGURES (Continued)

- 4.2 TOTAL PUMPING RATE: ONSITE EXTRACTION WELLS
- 4.3 ETHYLENE CONCENTRATIONS VS. TIME (SELECTED ONSITE WELLS)
- 4.4 ETHYLENE CONCENTRATIONS VS. TIME (SELECTED NEAR-PLANT WELLS)
- 4.5 MP 36A: TCE CONCENTRATIONS VS. TIME
- 4.6 DM 102: TOTAL ETHYLENE CONCENTRATIONS VS. TIME
- 4.7 DM 120: TOTAL ETHYLENE CONCENTRATIONS VS. TIME
- 4.8 DM 504: TOTAL ETHYLENE CONCENTRATIONS VS. TIME
- 4.9 VINYL CHLORIDE VS. TIME (SELECTED NEAR-PLANT WELLS)
- 4.10 DISTRIBUTION OF DISSOLVED OXYGEN AND BIOLOGICAL OXYGEN DEMAND, JUNE 1991
- 4.11 1991 ETHYLENE CONCENTRATIONS IN ALLUVIUM (NEAR-PLANT WELLS)
- 4.12 1991 ETHYLENE CONCENTRATIONS IN BEDROCK (NEAR-PLANT WELLS)
- 4.13 1991 TCA + DCE CONCENTRATIONS IN ALLUVIUM (NEAR-PLANT WELLS)
- 4.14 1991 TCA + DCE CONCENTRATIONS IN BEDROCK (NEAR-PLANT WELLS)
- 4.15 1991 TCE/TDCE CONCENTRATIONS IN ALLUVIUM
- 4.16 1991 TCE/TDCE CONCENTRATIONS IN BEDROCK
- 4.17 1991 ETHYLENE CONCENTRATIONS IN ALLUVIUM
- 4.18 1991 ETHYLENES CONCENTRATIONS IN BEDROCK
- 4.19 ETHYLENE CONCENTRATIONS VS. TIME (SELECTED FAR-FIELD WELLS)
- 4.20 1991 TCA + DCE CONCENTRATIONS IN ALLUVIUM

**TABLE OF CONTENTS (Continued)**

**LIST OF FIGURES (Continued)**

- 4.21 1991 TCA + DCE CONCENTRATIONS IN BEDROCK
- 4.22 1991 TCE CONCENTRATIONS IN ALLUVIUM
- 4.23 1991 TCE CONCENTRATIONS IN BEDROCK
- 4.24 1991 TDCE CONCENTRATIONS IN ALLUVIUM
- 4.25 1991 TDCE CONCENTRATIONS IN BEDROCK
- 4.26 1991 DCE CONCENTRATIONS IN ALLUVIUM
- 4.27 1991 DCE CONCENTRATIONS IN BEDROCK
- 4.28 1991 TCA CONCENTRATIONS IN ALLUVIUM
- 4.29 1991 TCA CONCENTRATIONS IN BEDROCK
- 4.30 VERTICAL DISTRIBUTION OF ETHYLENES (TCE + TDCE + DCE)
- 4.31 1991 TCA/DCE CONCENTRATIONS IN ALLUVIUM
- 4.32 1991 TCA/DCE CONCENTRATIONS IN BEDROCK
- 5.1 STIFF DIAGRAMS FOR MEAN CONCENTRATIONS OF MAJOR IONS IN ALLUVIUM
- 5.2 TRILINEAR DIAGRAM OF MEAN CONCENTRATIONS OF MAJOR IONS IN THE ALLUVIUM
- 5.3 C1, SO<sub>4</sub>, AND TDS IN THE ALLUVIUM
- 5.4 C1, SO<sub>4</sub>, AND TDS IN THE COURTYARD ALLUVIUM
- 5.5 As, F, AND NO<sub>3</sub>, IN THE ALLUVIUM
- 5.6 As, F, AND NO<sub>3</sub>, IN THE COURTYARD ALLUVIUM
- 5.7 Cr, Pb, Se AND Ba IN THE ALLUVIUM
- 5.8 Cr, Pb, Se AND Ba IN THE COURTYARD ALLUVIUM
- 5.9 Fe, Mn, Ni, CN IN THE ALLUVIUM

**TABLE OF CONTENTS (Continued)**

**LIST OF FIGURES (Continued)**

- 5.10 Fe, Mn, Ni, CN IN THE COURTYARD ALLUVIUM
- 5.11 ARSENIC VS. GROUND-WATER FLOW DIRECTION
- 5.12 ARSENIC IN ONSITE ALLUVIUM
- 5.13 FLUORIDE VS. GROUND-WATER FLOW DIRECTION
- 5.14 FLUORIDE IN ONSITE ALLUVIUM
- 5.15 NITRATE VS. GROUND-WATER FLOW DIRECTION
- 5.16 NITRATE IN ONSITE ALLUVIUM
- 6.1 MODEL CALCULATION DOMAINS
- 6.2 FINAL REMEDY REMEDIAL INVESTIGATION MODEL APPROACH
- 6.3 SECTION THROUGH MODEL CALCULATION MESH
- 6.4 DISTRIBUTION OF SIMULATED ALLUVIAL MATERIAL PROPERTIES AT THE ALLUVIUM/BEDROCK INTERFACE
- 6.5 DISTRIBUTION OF HYDROGEOLOGIC UNITS IN CROSS SECTIONS
- 6.6 EXTRAPOLATED BEDROCK TOPOGRAPHY
- 6.7 PREDICTED AND OBSERVED VERTICAL HYDRAULIC GRADIENTS
- 6.8 VERTICAL CROSS-SECTION VELOCITY VECTORS
- 6.9 BOUNDARY CONDITIONS
- 6.10 GROUND-WATER RECHARGE AREAS
- 6.11 GRAND CANAL RECHARGE RATE SENSITIVITY TEST RESULTS; COMPARISON OF MODEL RUNS 24 AND 25 1991 - ALLUVIUM
- 6.12 GRAND CANAL RECHARGE RATE SENSITIVITY TEST RESULTS; COMPARISON OF MODEL RUNS 24 AND 25 1991 - BEDROCK
- 6.13 PREDICTED AND OBSERVED HYDRAULIC HEADS IN ALLUVIUM MODEL RUN 24-1991

**TABLE OF CONTENTS (Continued)**

**LIST OF FIGURES (Continued)**

- 6.14 PREDICTED VS. OBSERVED WATER LEVEL ELEVATIONS: TRANSPORT RUN 24
- 6.15 PREDICTED AND OBSERVED ALLUVIUM SATURATED THICKNESS
- 6.16 PREDICTED TCE AND RI MAXIMUM MEAN ETHYLENE CONCENTRATIONS IN ALLUVIUM, MODEL RUN 24-1986
- 6.17 PREDICTED TCE AND RI MAXIMUM MEAN ETHYLENE CONCENTRATIONS IN BEDROCK, MODEL RUN 24-1986
- 6.18 PREDICTED TCE AND POST-RI MAXIMUM MEAN ETHYLENE CONCENTRATIONS IN ALLUVIUM, MODEL RUN 24-1991
- 6.19 PREDICTED TCE AND POST-RI MAXIMUM MEAN ETHYLENE CONCENTRATIONS IN BEDROCK, MODEL RUN 24-1991
- 6.20 PREDICTED VS. OBSERVED ETHYLENE CONCENTRATIONS, TRANSPORT RUN 24
- 6.21 PREDICTED TCE AND POST-RI MEAN ETHYLENE CONCENTRATIONS IN ALLUVIUM, MODEL RUN 23-1991
- 6.22 PREDICTED TCE AND POST-RI MEAN ETHYLENE CONCENTRATIONS IN BEDROCK, MODEL RUN 23-1991
- 6.23 PREDICTED VS. OBSERVED ETHYLENE CONCENTRATIONS, TRANSPORT RUN 23
- 6.24 PREDICTED AND OBSERVED ETHYLENE CONCENTRATIONS VS. DISTANCE FROM SOURCE
- 6.25 PREDICTED AND OBSERVED VERTICAL DISTRIBUTION OF ETHYLENES
- 7.1 LOCATION OF FACILITIES THAT MAY BE OTHER POTENTIAL SOURCES
- 7.2 REPORTED LEAKING UNDERGROUND STORAGE TANKS

TABLE OF CONTENTS (Continued)

LIST OF APPENDICES

A	WELL INSTALLATION
B	BEDROCK SUMMARY
C1	WELL INVENTORY
C2	OTHER POTENTIAL SOURCES
D	MODELING
E	WATER QUALITY DATA
E0	PRELIMINARY DATA
E1	RI ORGANICS
E2	POST-RI ORGANICS
E3	RI INORGANICS
E4	POST-RI INORGANICS
E5	QA/QC
E6	VOC WATER QUALITY
E7	INORGANIC WATER QUALITY
F	AQUIFER TESTS
G	WATER ELEVATIONS

## 1.0 INTRODUCTION

The Motorola 52nd St. Facility is listed on the National Priorities List under the Federal Superfund Act. The results of the Final Remedy Remedial Investigation (FR RI) conducted since 1987 are presented in this report. This report supersedes the Draft FR RI Report, which was submitted to the reviewing government agencies on September 30, 1991 (Dames & Moore, 1991n). The Draft was reviewed by the Arizona Department of Environmental Quality (ADEQ), the Arizona Department of Water Resources (ADWR) and the United States Environmental Protection Agency (EPA). Their written comments were provided by letter dated February 18, 1992. This report reflects the results of discussions and written comments on the Draft by these agencies.

This report is intended to supplement the 1987 Draft RI Report (Dames & Moore, 1987b) and form the basis for proceeding with a Final Remedy Feasibility Study. This work is conducted under the guidelines of the Comprehensive Environmental Response Compensation and Liability Act of 1980 (CERCLA, or the Superfund Act, 42 U.S.C. 9601 et.seq.) and the State of Arizona's Water Quality Assurance Revolving Fund (WQARF), Arizona Revised Statute 49-282.

### 1.1 BACKGROUND

The location of the Motorola 52nd St. Facility is shown relative to the surrounding area on the Vicinity Map, Figure 1.1. The Motorola Facility is located in the eastern part of the City of Phoenix. Motorola Inc. commenced manufacturing operations in this facility in 1956. Numerous expansions have taken place since 1956. The present plant site includes more than 20 buildings on approximately 90 acres.

In November 1982, Motorola discovered a leaking underground TCA (1,1,1-trichloroethane) tank at the 52nd St. Facility in Phoenix, Arizona. The Arizona Department of

Health Services (ADHS) was notified and Motorola initiated a preliminary investigation of soil and ground-water contamination. As a result of the preliminary investigation, other volatile organic compounds (VOCs) were also discovered in the ground water.

A Remedial Investigation/Feasibility Study (RI/FS) was initiated by Motorola in 1983, and was conducted under regulatory oversight of ADHS (prior to October 1986), ADEQ (after October 1986), the Arizona Department of Water Resources and the U.S. Environmental Protection Agency.

While the RI/FS was being prepared, Motorola voluntarily designed and constructed an on-site ground-water treatment plant. This plant, referred to as the Pilot Treatment Plant (PTP), has been cleaning up contaminated ground water since 1986.

In June 1987, Draft RI and FS reports (Dames & Moore, 1987b) were prepared for regulatory review and public comment. These documents represent an extensive investigation of potential sources of contamination at the Motorola 52nd St. Facility, characterization of the hydrogeological environment, prediction of the extent of contaminant migration in ground water and a review of potential remedial action alternatives.

After review by the regulatory agencies, Motorola prepared a Draft Remedial Action Plan (RAP), dated June 24, 1988, (Dames & Moore, 1988a) and submitted the RAP to ADEQ and the EPA for review. A remedial action was proposed as a partial remedy in accordance with CERCLA criteria for an Operable Unit, and WQARF criteria for a remedial action.

Remedial action alternatives were reviewed in a public meeting in Phoenix on July 11, 1988. Public comments were addressed in a Responsiveness Summary that was reviewed by the agencies.

After review of the Draft Remedial Action Plan and public comments, ADEQ issued a "Letter of Determination" for Motorola 52nd St. Facility, Phoenix on September 27, 1988. The Letter of Determination provided official approval to implement the recommendations contained in the Draft Remedial Action Plan. In addition, the decision was noted as consistent with recommendations made in the Health Assessment conducted by the Agency for Toxic Substances and Disease Registry (ATSDR) of the U.S. Public Health Service (U.S. Public Health Service, 1988). A Responsiveness Summary was prepared to address comments on the RI/FS and the Draft RAP, and EPA issued a Record of Decision (ROD).

In 1989, the State of Arizona and Motorola drafted an agreement to implement the recommendations of the RAP. This agreement was executed on July 26, 1989 and is referred to as the Motorola 52nd St. Consent Order (AG, 1989). The Consent Order defines the scope of the Operable Unit (OU), the schedule for work and administrative provisions for conducting the work. In addition, Section 27 of the Consent Order contains provisions for Motorola to continue work on a revised RI/FS work plan to define work components leading to a final remedy that would take place concurrently with implementation of the RAP.

Since 1989, Motorola has conducted a Final Remedy Remedial Investigation (FR RI), the results of which are reflected in this report. The objectives of the remedial investigation and the guidelines for conducting the RI are summarized in Section 1.2, and were developed in accordance with provisions of the Consent Order with review by ADEQ, ADWR, and EPA.

The locations of potential sources identified as a part of the 1987 remedial investigation and plant buildings are shown on Figure 1.2 as they were identified in 1987. As noted in the 1987 Draft RI, and subsequently in the RAP and the 1989 Motorola 52nd St. Consent Order, three areas were targeted for further investigation and cleanup: the Courtyard, Acid Treatment Plant, and Southwest Parking Lot. The Courtyard area contains the locations of the former leaking underground TCA storage tank (Source 25) and the former dry well (Source 2), which were found to represent the major sources of volatile organic compound (VOC)

contamination. The other two areas requiring remediation in accordance with the Consent Order are the Acid Treatment Plant (ATP) and the Southwest Parking Lot (SWPL).

For reference, Table 1.1 identifies the location and type of potential sources identified in 1987 and reported in the 1987 Draft RI report. Further study as part of the FR RI has revealed an additional source of potential solvent discharge in the SWPL. This discharge is believed to have occurred in Building A-D, and is currently (February 1992) the subject of extensive investigation and initial remediation. The results of RI/FS work conducted through 1991 in the SWPL are described in a separate attachment (Attachment SW) to this report.

Table 1.2 lists chemical abbreviations that are referred to throughout this document. For convenience, laboratory results reported in micrograms per liter (ug/l) are referred to throughout this report in parts per billion (ppb) for VOC concentrations in ground water.

This report was prepared for Motorola Inc. by Dames & Moore in Phoenix, Arizona. The work was conducted under the direction of Mr. James R. Hussey, P.E. Key contributions to the report were made by Ms. Lori Bartlett, Assistant Project Manager, Mr. Doug Bartlett, P.G., Senior Hydrogeologist and ground-water modeler, Mr. Bill Loughlin, P.G., Senior Hydrogeologist, and Ms. Katherine Bush, Project Coordinator. Mr. Greg Fisher, Senior Environmental Manager, provided guidance and technical review for Motorola Inc. Overall direction was provided by Mr. John Seeger, designated as Motorola's Project Coordinator for work conducted under provisions of the Motorola 52nd St. Consent Order.

## **1.2 OBJECTIVES AND SCOPE OF WORK**

The Motorola 52nd St. Consent Order stipulates in Section 27.1 that Motorola develop a work plan that leads to a final remedy that will take place parallel/concurrently with RAP activities. In addition, Consent Order Section 27.2 indicates that "additional characterization

and definition of the nature and extent of contaminant migration" be conducted. Section 27 includes other requirements related to the completion of a final remedy.

Although it is understood that a final remedy would include any partial remedies, e.g. the Operable Unit, it is understood that the main purpose of Section 27 is to supplement the extensive remedial investigation reported in 1987. As a consequence, FR RI work is focused primarily on supplementing the 1987 Draft RI Report, particularly to define the nature and extent of contaminant migration. Data obtained since 1987 as part of this investigation were compared with the findings reported in the 1987 Draft RI and significant differences are noted.

To accomplish the overall objective of the FR RI, a "Draft Work Plan, Final Remedy RI/FS" was submitted for agency review on September 20, 1990 (Dames & Moore, 1990i). Comments from ADEQ, ADWR and EPA were submitted by ADEQ on November 6, 1990 (ADEQ, 1990). The Draft Work Plan together with supplementary sampling, health and safety and other plans, plus task specifications and agency comments, formulated the basis for conducting the FR RI scope of work.

In Section 1.3 of the Draft Work Plan, specific objectives were established as follows:

1. installation of monitor wells downgradient of the Operable Unit to define the extent of ground-water contaminant plume relative to contaminants associated with the Motorola facility,
2. evaluation of ground-water quality data to ascertain the significance of historical water quality trends,
3. evaluation of potential remedial action alternatives, including bioremediation, pump-and-treat scenarios, and other options for cleanup of the contaminated portion of the aquifer,
4. completion of a public health risk assessment, and

5. continuation of community relations activities as necessary to support these activities.

This FR RI Report includes the results of items Nos. 1 and 2. The feasibility study draft will include an evaluation of potential remedial action alternatives, No. 3. The public health risk assessment is being conducted by the Arizona Department of Health Services utilizing data provided by Motorola. Those results will be evaluated together with the FR RI/FS reports. Community relations activities have continued, although results are not reported herein. Community relations activities have been necessary at each monitor well drilling location to inform the public of drilling activities. A newsletter was prepared by ADEQ and EPA and submitted to the public in December of 1991.

To supplement these objectives, ADEQ requested: the description of the conceptual model of the site; a discussion of existing data gaps based on an evaluation of data collected to date; data quality objectives to fill in the data gaps; and a list of the Maximum Contaminant Levels (MCLs) for the contaminants of concern (ADEQ, November 1990). It was also requested that "in the absence of an MCL or proposed MCL for a contaminant, Motorola may be required to define the contaminant plume to contaminant concentrations corresponding to a Health Based Guidance Level (HBGL or AHBGL, Arizona Health Based Guidance Level)." These and other requests provided in the November 6, 1990 ADEQ review comments of the Draft Work Plan are addressed in this FR RI.

In response to agency requests, MCLs, proposed MCLs, and draft Arizona HBGLs have been identified for both volatile organic compounds and inorganic constituents "of concern". It should be noted, however, that these standards and proposed guidelines are for human consumption of drinking water. To the extent that information regarding ground-water use in the area has been developed since 1982, no known use of ground water for drinking has been identified with one known exception. As reported by Mr. Gerald Morgan in a letter to ADWR dated October 21, 1991 (Morgan, 1991), a private well exists on his property at 4626 East

Granada Rd., Phoenix, Arizona, and that well has been used for drinking water. According to Mr. Morgan "the well is pumped almost continually (emphasis is Mr. Morgan's) during the summer and regularly through the whole year, at a rate of up to 35 gpm for filling a swimming pool weekly during swimming season and for lawn sprinklers. It is sometimes used for drinking water and for washing." The Morgan well is referred to in this FR RI Report as the 4626G well.

As noted in the general comments transmitted under cover of the letter to Motorola from ADEQ, (ADEQ, February 1992), ground water in the study area is not controlled with regard to use. It has been reported by ADWR that no statute or regulation exists to provide either the State of Arizona or a private entity such as Motorola Inc. with the legal means to either prohibit the future use of ground water as drinking water, or to control the use of water from existing private wells. However, the Director of ADEQ has the authority under A.R.S. Section 49-224 to classify an aquifer for a protected use other than drinking water. Also, it is understood that the Director of ADWR could "redline" an area whereby those who apply to drill new wells would be notified of potential ground-water contamination.

Drinking water is supplied to the study area via pipe by the City of Phoenix from remote locations. "Standards" referred to in this report are used only for relative comparison to observed water quality, and are not intended to signify a prescribed level of cleanup. The appropriate level(s) of cleanup of ground water, if appropriate, will be addressed in the FR Feasibility Study.

### **1.3 OVERVIEW OF THE FR RI INVESTIGATION**

The principal objectives of the continuing remedial investigation have focused on defining contaminant migration and characterizing ground water offsite, with a couple of exceptions. The focus on offsite contamination is necessary to define the extent of contaminant migration, principally by volatile organic compounds; however other parallel activities are being conducted that provide information for the remedial investigation. These include the installation

of extraction wells and monitor wells for the implementation of the Operable Unit, and further investigations related to the detection of recent increases in VOC concentrations in ground water in the area of Southwest Parking Lot (see Attachment SW). Available data from these other two activities are included in this report.

The purpose of the Plume Definition Program, which comprised a major part of the remedial investigation, was to define the downgradient extent of ground-water contamination as required in Section 27.2 of the Motorola 52nd St. Consent Order. The program of plume definition was conducted in phases and included a total of nine (9) monitor wells located between 46th Street (or near the Old Crosscut Canal) to just west of 32nd Street. The Plume Definition wells (500 - series designation) that were installed to supplement the existing data base are illustrated on Figure 1.3. This figure also illustrates previous monitor wells that have now been abandoned due to construction of the Papago and Hohokam freeways.

The preliminary results of the plume definition program were presented to the agencies in the "Draft Well Installation, Plume Definition Report", dated June 17, 1991 (Dames & Moore, 1991). That report included the initial well construction diagrams for all 9 wells (DM 501 through DM 509) installed by May 1991 as part of the Plume Definition Program. The water quality data obtained from the entire monitoring network are presented in appendices and summarized in Chapters 4.0 and 5.0 of this report; model predictions are presented in Chapter 6.0.

As mentioned previously, other ongoing activities contributed information to this FR RI investigation. In late 1990 and early 1991, the ongoing water quality monitoring program revealed anomalously greater concentrations of TCA and DCE in the area of the Southwest Parking Lot. After review with ADEQ, ADWR and EPA, Motorola began an investigation of potential sources in the SWPL, and the nature and extent of ground-water contamination. The location of the Southwest Parking Lot is shown on Figure 1.2. In addition, Motorola initiated interim remedial actions through pump-and-treat technology at existing wells in the SWPL; these

activities continue to date (February 1992). Motorola proposes to complete the investigation of potential sources and to define the extent of contamination in the SWPL area. See Attachment SW for a comprehensive discussion of the investigations conducted to date, and the remedial actions proposed. It is proposed to supplement the FR RI with a separate report focusing on the SWPL area.

Motorola initiated design and construction of the Operable Unit in 1989 after execution of the Motorola 52nd St. Consent Order. The OU consists of four major components: (1) the extraction of contaminated ground water at 13 wells; (2) the construction of a pipeline conveyance system to transport contaminated ground water to a central treatment plant; (3) the construction of a ground-water treatment plant to remove VOCs from the contaminated ground water; and, (4) the initiation and evaluation of soil-gas treatment in the Courtyard and other locations. The general configuration of the Operable Unit is illustrated on Figure 1.4A, which shows the locations of OU extraction and monitor wells offsite. A more detailed illustration of the location of onsite extraction wells and the Pilot Treatment Plant, which is still in operation, is shown on Figure 1.4B.

The legal authority to extract and treat contaminated ground water has been obtained from ADWR through a Poor Quality Groundwater Withdrawal Permit (PQGWWP), No. 59-530577, dated May 19, 1991 (ADWR, 1991). An application for the PQGWWP was submitted on January 7, 1991 and contained a "Hydrologic Report", dated January 4, 1991, (Dames & Moore, 1991a) which describes the impact of the ground-water withdrawal associated with implementation of the Operable Unit. The permit was issued pursuant to Arizona Revised Statute, Article 45-516.

As shown on Figure 1.4A, the OU offsite extraction system is located on the eastern bank of the relocated Old Crosscut Canal which aligns approximately with 46th Street. The extraction system, which was installed in 1991/1992, is located between McDowell Road on the north and Roosevelt Street on the south. Because the Arizona Department of Transportation

(ADOT) acquired an extensive amount of right-of-way for the construction of the Papago and Hohokam freeways, a number of existing monitor wells had to be abandoned. To monitor the effectiveness of the OU, additional monitor wells have been installed near the Old Crosscut Canal; information from these wells is available in this report. These additional wells include DM 601, which is located just downgradient of the Motorola 52nd St. Facility; DM 602 through DM 605, which are located downgradient of the proposed extraction system along the Old Crosscut Canal; and DM 606, which has been installed to replace the monitor well used previously, DM 103.

As noted, the offsite extraction system is located along the Old Crosscut Canal. Because freeway construction has yet to be finalized (February 1992), ADOT still holds control/title to this property. Therefore a permit was obtained from ADOT to construct, operate and maintain the offsite extraction well and piping system. This permit was applied for on May 14, 1991, and included proposed design drawings. ADOT Permit No. 55724 was issued on July 3, 1991, and extended on December 10, 1991.

#### **1.4 ORGANIZATION OF THE FR RI REPORT**

The general structure of the report includes a definition of the geologic setting (Chapter 2.0), regional hydrogeology (Chapter 3.0) and includes a detailed examination of VOCs detected in ground water (Chapter 4.0) and inorganic constituents detected in ground water (Chapter 5.0). The Target<sup>TM</sup> ground-water and transport model was expanded by Dames & Moore and compared to the results and predictions presented in the Draft 1987 RI Report. The model predictions are included in Chapter 6.0, and compared to observed water quality data. The conclusions reached during this remedial investigation are included in Chapter 7.0, and references in Chapter 8.0. The results of work conducted in the area of the Southwest Parking Lot are presented in Attachment SW, contained within Volume IV of this report.

Detailed data in support of this investigation are incorporated into appendices and contain information regarding: methods and procedures used for well installation, sampling and testing; an evaluation of bedrock information; well inventory; an examination of other potential sources in the area of investigation; aquifer test results; and water quality and water level data.

**Table 1.1**

**LOCATION AND TYPE OF  
POTENTIAL SOURCES<sup>(1)</sup>**

<b>I.D. Number</b>	<b>Facility</b>	<b>Chemicals</b>
1	Dry well east of "H" Building	Acid and area washdown
2	Dry well west of "F" Building	Virgin hydrocarbons and waste solvents
3	Dry well south of "L" Building	Blowdown from evap. coolers
4	Dry well in southeast corner of "K" Building	Small amounts of hydraulic fluids and area washdown
5	Dry well north of Mechanical Shop ("P" Building)	Area drain-small amounts of degreasers
6	Dry well in southwest corner of "M" Building	Solvents and paints
7	Dry well west of southwest corner of "M" Building	Solvents and paints
8	Sanitary leach field south of "D" Building	Sanitary sewage
9	Acid leach field along 50th Street	Treated acids
10	Trenches under "A" Building	Acids
11	Trenches and dry wells in "B" Building	Acids, small amounts of solvents
12	Acid mixing area by SRP Substation	Acids
13	Natural wash by "U" Building	Sanitary sewer - some degreasers*
14	Acid discharge "J"	Acids
15	Sewer break west of acid farm	Treated acids and sewage
16	Dry wash where "K" Building is now	Neutralized acids and treated chrome
17	Chemical salvage ("P" Building)	Spent solvents
18	Southwest Parking Lot	Spent solvents
19	Trench along 50th Street	Acids
20	Concrete treatment tank west of "B" Building	Treated acids and cyanides

(Source: 52ND ST. RI/FS, MOTOROLA INC.  
REMEDIAL INVESTIGATION, 1987)

**Table 1.1 (Continued)**

I.D. Number	Facility	Chemicals
21	Spent solvent line leading to waste solvent tanks by "F" Building	Spent solvents
22	Spent solvent line leading to waste solvent tank by acid farm	Spent solvents
23	Sump by "N" Building	Solvents
24	Cyanide line between "M" and "P" Buildings	Cyanide
25	Leaking virgin solvent tank by "F" Building	1,1,1-Trichloroethane

(1) Reference: GPI, 1983, Preliminary Report Chemical Leak Project, p. V-8.  
\* "U" Building used to be operated as a machine shop before Motorola purchased it. These discharges were prior to Motorola's purchase.

(Source: 52ND ST. RI/FS, MOTOROLA INC.  
REMEDIAL INVESTIGATION, 1987)

**Table 1.2**

**CHEMICAL ABBREVIATIONS**

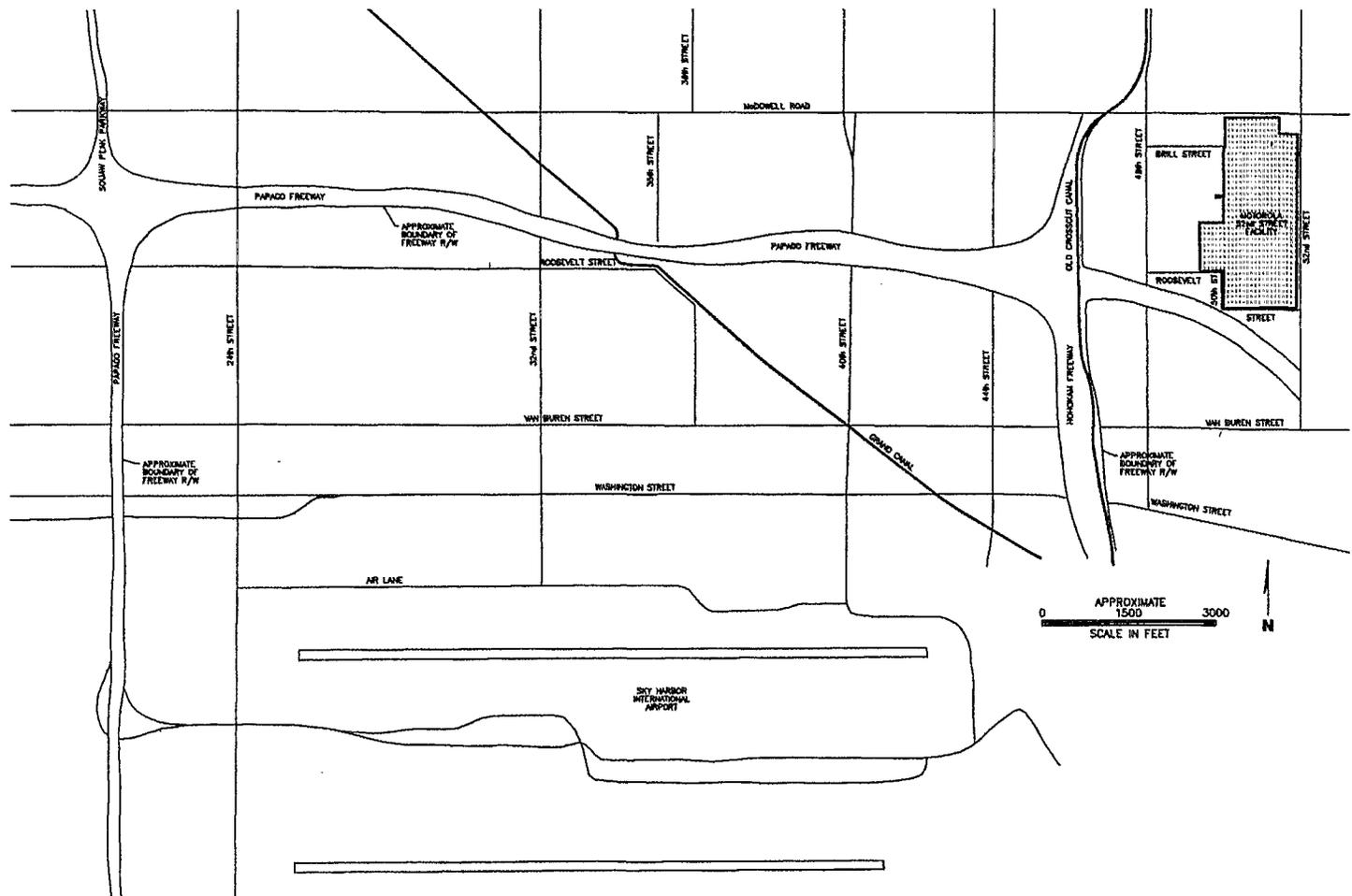
Proper Name	Abbreviation Used
<b>ORGANIC COMPOUNDS</b>	
Acetone	ACT
Benzene	BNZ
Carbon tetrachloride	CCL4
Chlorobenzene	CB
Chloroform	CLFM
1,2-Dichlorobenzene	DCB2
1,3-Dichlorobenzene	DCB3
1,4-Dichlorobenzene	DCB4
1,1-Dichloroethane	DCA
1,1-Dichloroethylene	DCE
Ethyl Benzene	ETB
Methylene Chloride	MEC
Solvent Naptha	VMP
1,1,2,2-Tetrachloroethane	TET
Tetrachloroethylene	PCE
Toluene	TOL
1,1,1-Trichloroethane	TCA
1,1,2-Trichloroethane	TCA2
Trichloroethylene	TCE
1,2-Dichloroethane	DCA2
Trans- and Cis-1,2-Dichlorethylene	TDCE
Trichlorofluoromethane	TCFM
Trichlorotrifluoroethane	F-113

(Source: 52ND ST. RI/FS, MOTOROLA INC.  
REMEDIAL INVESTIGATION, 1987)

**Table 1.2 (Continued)**

<b>Proper Name</b>	<b>Abbreviation Used</b>
Vinyl Chloride	VC
Xylenes	XYL
<b>INORGANIC CATIONS</b>	
Arsenic	As
Barium	Ba
Chromium	Cr
Copper	Cu
Lead	Pb
Nickel	Ni
Silver	Ag
Zinc	Zn
<b>INORGANIC ANIONS</b>	
Chloride	Cl
Cyanide	CN
Fluoride	F
Nitrate	NO <sub>3</sub>
Phosphorus	P
Phosphate	PO <sub>4</sub>
Sulfate	SO <sub>4</sub>
Total Dissolved Solids	TDS

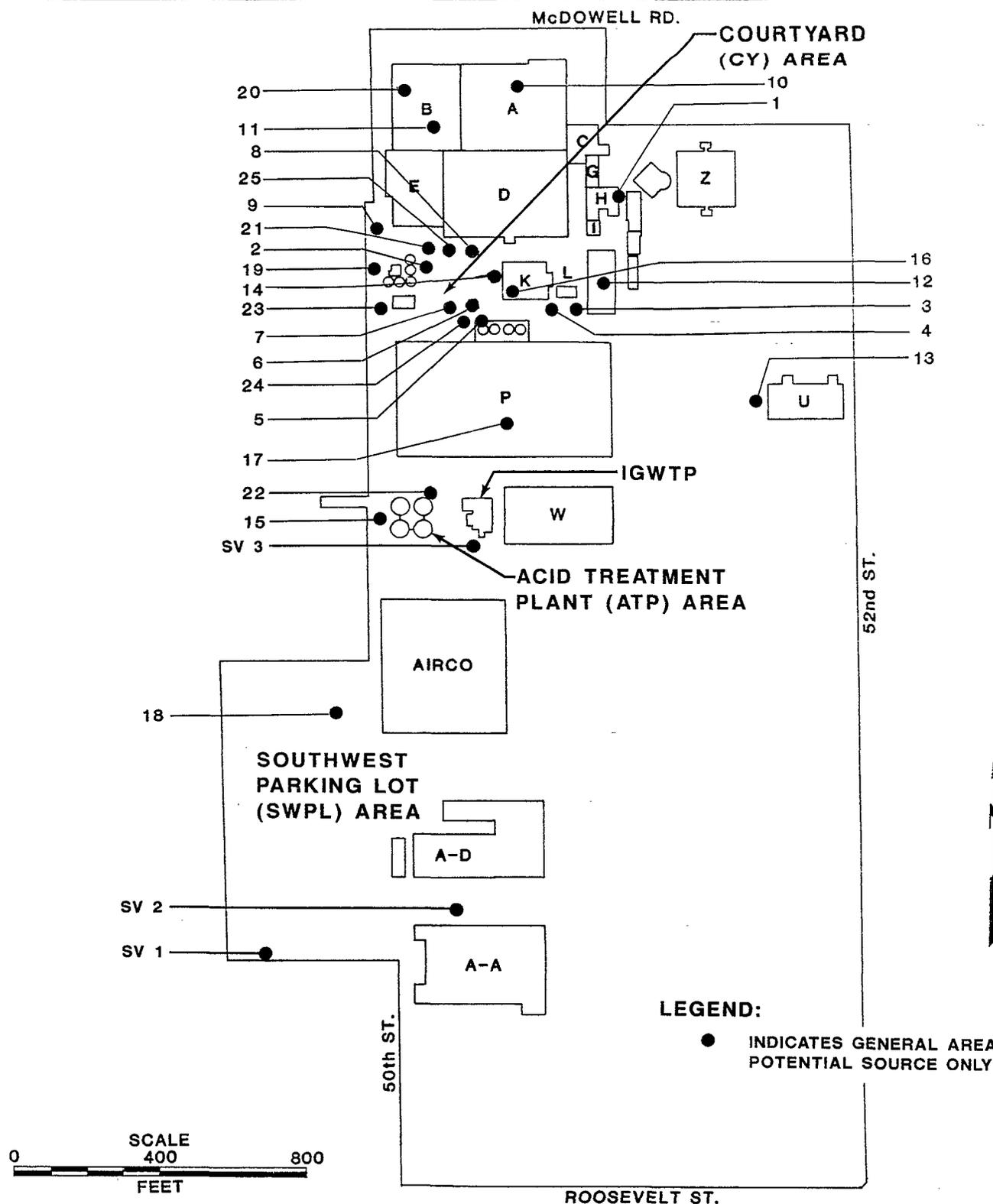
(Source: 52ND ST. RI/FS, MOTOROLA INC.  
REMEDIAL INVESTIGATION, 1987)



## VICINITY MAP

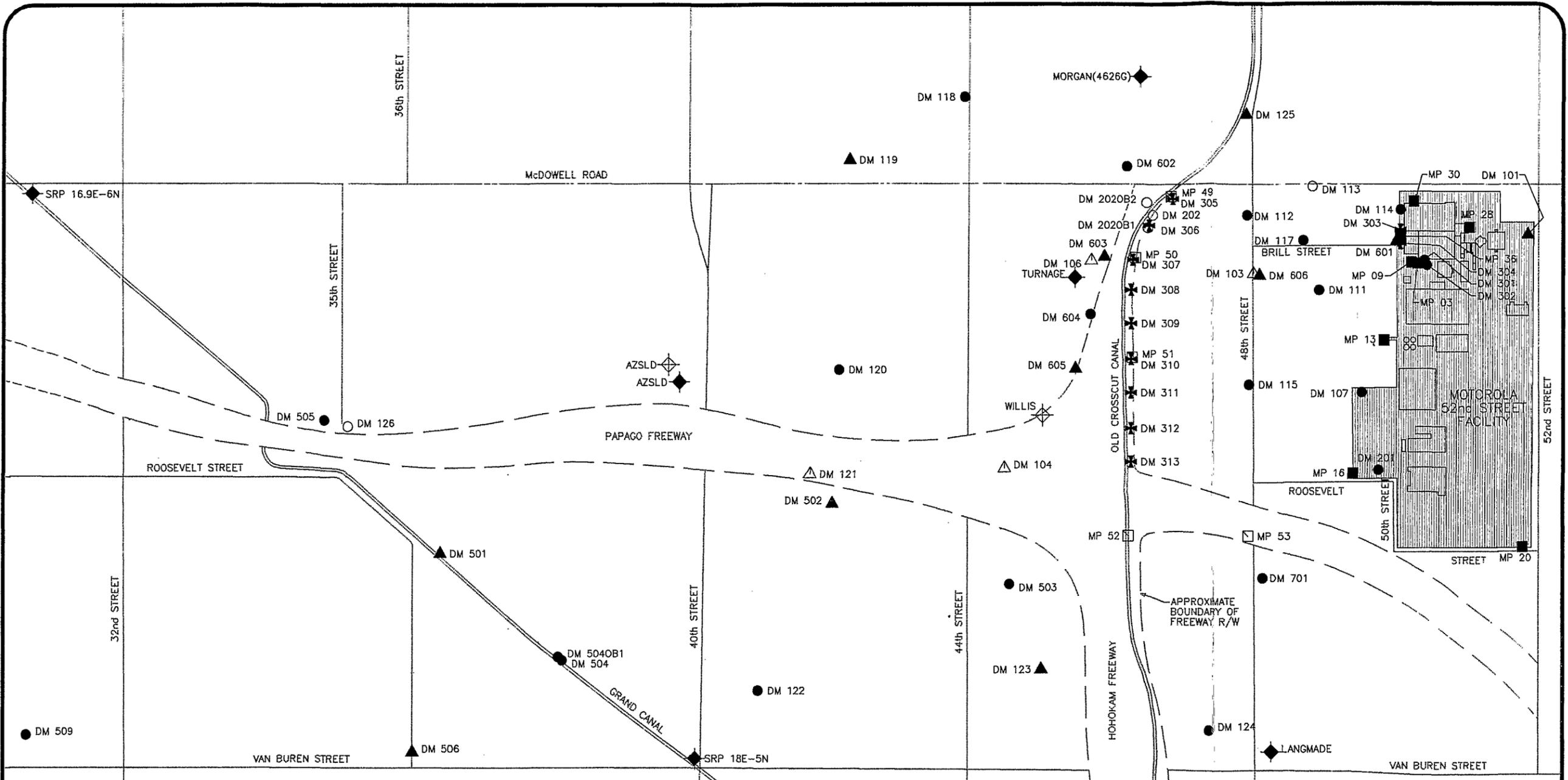
Figure 1.1

MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992



# LOCATIONS OF POTENTIAL SOURCES AND PLANT BUILDINGS

Figure 1.2  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992



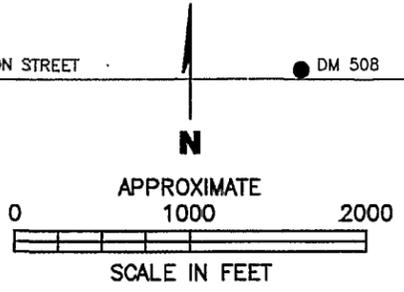
**LEGEND:**

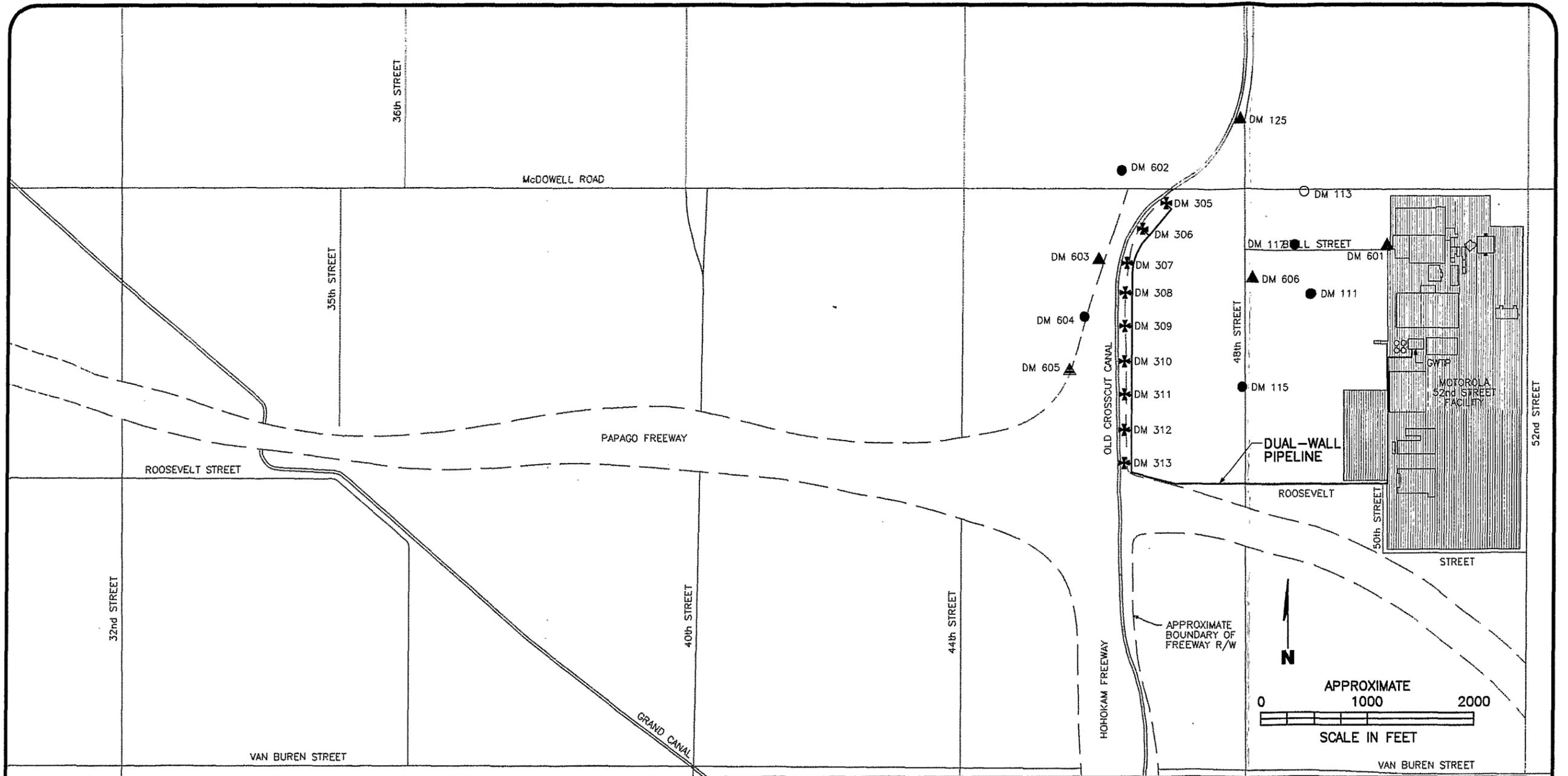
WELL TYPE	EXISTING	ABANDONED
WESTBAY	▲	△
CONVENTIONAL	●	○
MP	■	□
PRIVATE	◆	◇
EXTRACTION	✱	N/A
● DM 122	NAME OF WELL	

- NOTES:**
1. Please refer to the 1987 DRAFT RI and FR RI Figure 3.2 for the locations of onsite monitor wells.
  2. See Section 4.1 for complete definition of well types.
  3. See Appendix C, Tables C1.1 and C1.2 for well construction details.

# MOTOROLA 52nd STREET WELL LOCATIONS

**Figure 1.3**  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992





**LEGEND:**

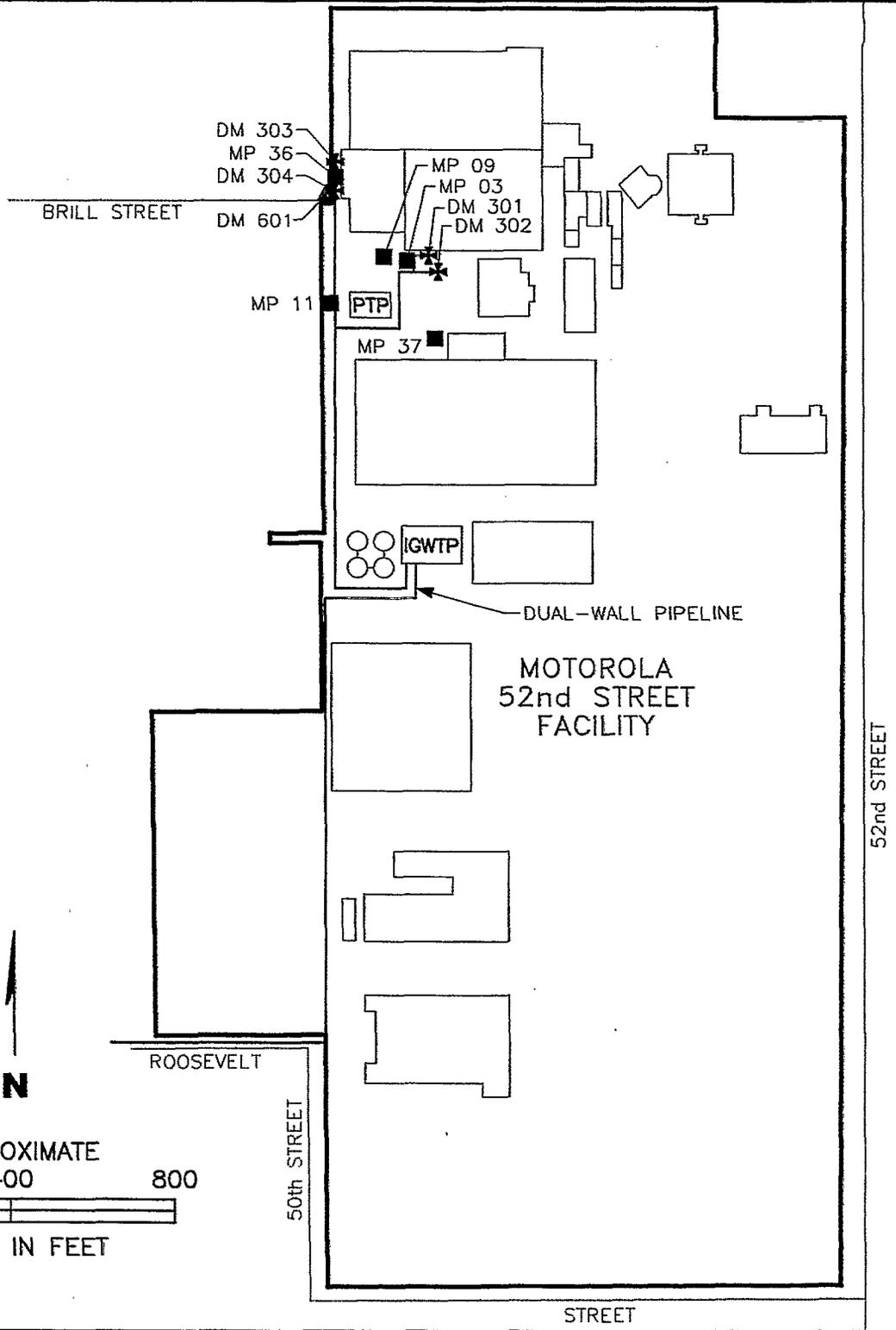
WELL TYPE	EXISTING
WESTBAY	▲
CONVENTIONAL	●
EXTRACTION	✱
✱ DM 305	NAME OF WELL

**NOTES:**

1. Wells (✱) designated DM 305 through DM 313 are the extraction wells for the OPERABLE UNIT.
2. IGWTP is the INTEGRATED GROUND WATER TREATMENT PLANT, constructed in 1991.
3. The locations of the onsite extraction wells are shown on Figure 1.4B.
4. See Appendix C, Table C1.2 for well construction details.

**LOCATION OF OFFSITE OU EXTRACTION AND MONITOR WELLS**

**Figure 1.4A**  
 MOTOROLA 52nd ST.  
 FR RI  
 FEBRUARY 1992



**LEGEND:**

WELL TYPE	EXISTING
WESTBAY	▲
CONVENTIONAL	●
MP	■
EXTRACTION	✱
✱ DM 301 NAME OF WELL	

- NOTES:**
1. IGWTP is the INTEGRATED GROUND WATER TREATMENT PLANT, constructed in 1991.
  2. PTP is the PILOT TREATMENT PLANT that began operation in 1986.
  3. The locations of offsite extraction wells are shown on Figure 1.4A.
  4. See Appendix C, Table C1.2 for well construction details.

## LOCATION OF ONSITE OU EXTRACTION WELLS

**Figure 1.4B**  
 MOTOROLA 52nd ST.  
 FR RI  
 FEBRUARY 1992

## **2.0 GEOLOGIC SETTING**

### **2.1 BACKGROUND**

The geology in the vicinity of the Motorola 52nd St. Facility is complex. A 1.8-billion-year history of faulting, folding, uplift, erosion and deposition is recorded in the rocks that crop out at the Papago Buttes, east of the facility. These same rock units are covered by alluvium near the facility. The location of the Motorola Facility relative to the Papago Buttes and other areas of bedrock outcrops is shown on Figure 2.1.

#### **2.1.1 Previous Geologic Investigations**

The geology of the area was first described by Lee (1905) in a hydrogeologic study of the lower Salt River Valley. Subsequent studies of the area were conducted by McDonald, Wolcott and Hem (1947), Wilson and others (1957), and Reynolds (1985). Schulten, Bales and Péwé of Arizona State University mapped the geology of the Tempe 7.5-Minute U.S. Geological Survey (USGS) Quadrangle for the cities of Tempe, Scottsdale and Phoenix. Their work focused on the surficial geology of the Papago Park and surrounding area, and is documented in unpublished masters theses by Schulten (1979) and Bales (1985), as well as a series of maps published by the Arizona Bureau of Geology and Mineral Technology (Péwé, Wellendorf, and Bales, 1986).

The geologic characteristics of the area near the facility were investigated extensively during the RI/FS study completed in 1987. As part of this earlier study, numerous monitor wells were installed and sampled, and many exploration borings were drilled. Boreholes and wells were visually and geophysically logged. From these data, plus the examination of outcrops in the nearby Papago Buttes, the geology at the facility was characterized in the following documents (see Chapter 8.0 for complete titles):

- Preliminary Report, Chemical Leak Project (Gutierrez-Palmenberg, Inc, 1983);
- the Strat-Boring Report (Dames & Moore, 1985h);
- the Draft RI Report (Dames & Moore, 1987b), and
- the Bedrock Data Report (Dames & Moore, 1991b).

### 2.1.2 Installation of New Monitor Wells

The interpretation of the geologic setting of the area of investigation, presented in the 1987 Draft RI Report and in the Bedrock Data Report, has been revised using geologic data obtained from 17 monitor wells that were recently installed at offsite and onsite locations. These new wells were installed from April 1990 through December 1991 and consist of ten wells downgradient from the Old Crosscut Canal, six wells to monitor the effectiveness of the Operable Unit (OU), one monitor well downgradient of the southern portion of the 52nd St. Facility on 48th Street, nine extraction wells installed along the eastern side of the Old Crosscut Canal, and two extraction wells along 50th Street near McDowell Road. The plume definition monitor wells are designated DM 501 through DM 509 (including DM 504OB1), the OU monitor wells are designated DM 601 through DM 606, the well on 48th Street is designated DM 701, and the extraction wells are designated DM 303 through DM 313. Locations of monitor wells installed during 1990 and 1991 are shown on Figure 2.2A. All wells included in the study are shown on Figure 2.2B and 2.2C. Well installation methods are described and geologic logs are presented in Appendix A. Bedrock information is summarized in Appendix B.

Geologic data include lithologic and geophysical logs. The geologic logs were constructed from observing drill cuttings and drive samples in the alluvium and continuous core in the bedrock. Copies of the geophysical logs are provided in Appendix A.

## 2.2 STRATIGRAPHY

Pertinent lithologic properties of the bedrock and alluvial units are described in this section. Ground water occurs in these units and is discussed in Chapter 3.0.

The geologic units exposed or penetrated by wells and borings in the project area have been divided into three groups based on age: Quaternary, Tertiary and Precambrian. A generalized stratigraphic column is shown on Figure 2.3. Bedrock is defined and identified as the lithified Tertiary and Precambrian units that underlie the unconsolidated sediments of the Quaternary alluvium. Bedrock geology of the area is mapped on Figure 2.4, geologic cross sections are shown on Figures 2.5 and 2.6, and the elevations of the top of bedrock (base of alluvium) are contoured on Figure 2.7.

The nomenclature used for Tertiary units in this investigation is from Péwé, Wellendorf, and Bales (1986) and include the Camels Head Formation, Tempe Beds, and Tertiary volcanics. The Camels Head and Tempe Beds are grouped together and identified as the Red Unit by Arteaga and others (1968), Laney and Hahn (1986), and Brown and Pool (1989). According to Pool (personal communication, 1990) the Red Unit correlates with the lower part of the Lower Conglomerate described by the U.S. Bureau of Reclamation (1976). Arteaga and others (1968) observed that the Tertiary volcanics are interbedded with the Red Unit. This observation is supported by data presented herein.

### 2.2.1 Precambrian Metarhyolite

The oldest known geologic unit in the area is the Precambrian metarhyolite which is exposed in a low hill on the north side of Van Buren Street, west of 52nd Street and south of Polk Street. The metarhyolite is fine grained, ranges in color from white to gray to pink, and weathers to a reddish orange. The texture varies from saccharoidal (sugar like) with a quartzite appearance to schistic, and even to gneissic in some areas depending upon the degree of

metamorphism. Locally, the metarhyolite is intensely fractured and brecciated. The continuity between clasts of breccia has been interpreted by Péwé, Wellendorf, and Bales (1986) to indicate that the brecciation was tectonic rather than sedimentary. The metarhyolite is apparently volcanic in origin but it has been metamorphosed and intruded by aplite and basalt dikes. The basalt dikes have been altered to greenstone. This formation correlates with other metarhyolites in the Phoenix and McDowell Mountains. The metarhyolite underlies the alluvium in the southern part of the facility where the metarhyolite thickness exceeds 200 feet.

### 2.2.2 Precambrian Granite

Schulten (1979) and Bales (1985) identified and mapped two granites in the Papago Buttes, naming them the Tovrea Granite and the Camelback Granite. The granites encountered in the numerous onsite and offsite borings may correlate with the Tovrea and Camelback granites but are not differentiated for this study. The granites have intruded and are younger than the metarhyolite. Xenoliths of metarhyolite are found in both granites.

The contact between the Tovrea Granite and Precambrian metarhyolite was exposed at the southern end of the Old Crosscut Canal, north of the Grand Canal. This exposure is no longer visible due to realignment and reconstruction of the Old Crosscut Canal during 1990 and 1991. The type section of the Tovrea Granite is exposed in the Tovrea Castle area, near 50th Street and Van Buren. The Tovrea Granite is a coarse grey granite with grey quartz, biotite and small white feldspars. Minor amounts of epidote and chlorite are also present. Basalt dikes intrude the Tovrea Granite and have been altered to greenstone. Aplite dikes and quartz veins are common according to Schulten (1979) and Bales (1985).

The Camelback Granite is exposed in the northern and eastern parts of the Papago Buttes. The contact between Camelback Granite and Precambrian metarhyolite is exposed near the southern end of the Papago Buttes. The Camelback Granite is coarse to porphyritic with large pink potassium feldspar and blue quartz crystals. The granite has been intruded by veins

of quartz, and aplite and basalt dikes. At some locations the granite may be metamorphosed to a gneissic texture.

Undifferentiated granite underlies the alluvium in the area between the Courtyard and 48th Street and much of the study area southwest of a northwest-trending fault. As shown on Figure 2.4, this fault trends northwest, from an area south of the intersection of 50th Street and McDowell Road through an area north of the intersection of 48th Street and McDowell Road. In rock cores, the undifferentiated granite varies in appearance from massive and unjointed to intensely fractured and brecciated. In some intervals of core, the granite has been described as being deformed and folded and having a gneissic texture.

The granite is relatively resistant to erosion, and the bedrock surface is relatively shallow where granite is the uppermost unit. Elevations of the top of bedrock are contoured on Figure 2.7. The buried bedrock topographic high in the area between the Courtyard and 48th Street is comprised of granite.

### **2.2.3 Tertiary Camels Head Formation**

The Tertiary Camels Head Formation unconformably lies over the Precambrian granites. This unit is exposed in the Papago Park area and is comprised of thick alluvial fan deposits of coarse, angular rock debris. The Camels Head Formation accumulated at the base of mountains formed as a result of faulting during mid-Tertiary time.

At Barnes Butte in Papago Park, the basal section of the Camels Head Formation includes a pale green to gray tuffaceous sandstone and breccia. The coarse-grained breccia contains angular, boulder-sized fragments of granite and metarhyolite. Above the basal section, the Camels Head Formation consists of interbedded reddish-brown and arkosic breccias that contain large clasts of granite and metarhyolite. The upper units of the Camels Head Formation consist of a brownish-red arkosic fanglomerate that is finer grained than the lower breccia units.

Channel scours and cycles of graded bedding have been described at some locations by Schulten (1979) and Bales (1985).

A total thickness of about 750 feet of the Camels Head Formation has been mapped in Papago Park. The maximum thickness of Camels Head Formation encountered in borings is about 190 feet. Monitor well MP 25, which penetrated the greatest thickness of the Camels Head Formation, is located on the eastern boundary of the Motorola Facility. The formation has also been encountered in several borings west of the facility. Approximately 134 feet of Camels Head Formation was cored in monitor well DM 507, as indicated on the Cross-section A-A' on Figure 2.5.

The Camels Head Formation is relatively resistant to erosion. Where it is directly overlain by alluvium, the buried bedrock surface often has significant relief. The influence of the Camels Head Formation on the buried bedrock topography is evident in the area between 48th Street and the Old Crosscut Canal, as shown on Figure 2.4 and 2.7. The steep slope of the bedrock surface in this area may correspond to the underlying Camels Head Formation.

Criteria used to distinguish the upper part of the Camels Head Formation from the lower part of the Tempe Beds are discussed in Appendix B and summarized in Section 2.2.4.

#### **2.2.4 Tertiary Tempe Beds**

The Tempe Beds represent the distal facies of an alluvial fan sequence and directly overlie the Camels Head Formation. The type section of the Tempe Beds is at Bell Butte, where there are more than 300 feet of interbedded coarse and fine-grained pink to red arkose with some siltstone, volcanic arenite, and tuff. Bell Butte, as shown on Figure 2.1, is about 4 miles south of the Motorola 52nd St. Facility. The boundaries between individual beds are distinct in most cases, but can be gradational. Shale and siltstone are the dominant rock types in the upper part

of the Tempe Beds. The upper part of the Tempe Beds may be locally interbedded with tuffs and basalts indicating the beginning of active volcanism (Schulten, 1979; Bales, 1985).

The Tempe Beds have been encountered in onsite and offsite borings. The Tempe Beds directly underlie the alluvium in the extreme northern part of the facility, and they also directly underlie the alluvium northwest of the facility. Compared to other rock units, the Tempe Beds are softer and more easily eroded. Therefore, where the Tempe Beds directly underlie the alluvium, the bedrock surface is relatively flat and lower in elevation than in areas where the bedrock is more resistant. Bedrock topography is shown on Figure 2.7. In much of the area west of the facility, the Tempe Beds are interbedded with and/or overlain by the Tertiary volcanics. The maximum thickness of Tempe Beds encountered in borings was 205 feet in monitor well DM 506, as shown on Cross Section A-A' on Figure 2.5.

Characteristics of the upper part of the Camels Head Formation are similar to the lower part of the Tempe Beds. Criteria used to correlate rock core obtained during this investigation are described in Appendix B. Units characterized as clast supported with evidence of minimum weathering by transport processes, were assigned to the Camels Head Formation. Units characterized as matrix supported with evidence of greater weathering by transport processes, were assigned to the Tempe Beds. At many locations the Tempe Beds may be interbedded with the Camels Head Formation.

### **2.2.5 Tertiary Volcanics**

Four volcanic flows were recognized, but not differentiated, on the map by Péwé, Wellendorf, and Bales (1986). The flows range in composition from alkali-olivine basalt to rhyodacite. Three of the flows are exposed at Tempe Butte, which, as shown on Figure 2.1 is approximately 3 miles southeast of the facility. Elsewhere, the Tertiary volcanics are exposed in isolated knobs.

The Tertiary volcanics identified in this investigation consist of weathered volcanic tuff, andesite, and basalt. These rocks were encountered in drill holes north and west of the Motorola Facility. The thickness of the Tertiary volcanics ranges from 10 feet in boring DM 406 to 137 feet in monitor well DM 121. More than 100 feet of Tertiary volcanics were encountered in monitor well DM 502 as shown on Cross Sections A-A' and B-B' on Figure 2.5 and 2.6. The volcanic rocks logged in these wells and borings may correlate with the andesite flows which are exposed at Tempe Butte. According to Péwé, Wellendorf, and Bales (1986), radiometric dating by Dr. Paul Damon of the University of Arizona indicates that the flows at Tempe Butte are about 17 million years old.

Tertiary volcanic rocks in the Phoenix area were first identified by Wilson and others (1957). According to Arteaga and others (1968), the Tertiary volcanics are interbedded with the Red Unit (equivalent to the Camels Head Formation and Tempe Beds). Tertiary volcanics overlie Tempe Beds in monitor well DM 502, overlie Camels Head Formation in monitor well MP 51, and are overlain by Tempe Beds and underlain by Camels Head Formation in DM 605, as indicated on Cross Section A-A' shown on Figure 2.5. Tertiary volcanics were also encountered in monitor well DM 106, as shown on Cross Section C-C' on Figure 2.6.

#### **2.2.6 Quaternary Alluvium**

Unconsolidated alluvium of Quaternary age overlies bedrock at the Motorola Facility and throughout most of the area to the west. The alluvium ranges in thickness from less than 20 feet on the eastern boundary of the facility to more than 60 feet at some locations on the western boundary. The thickness of the alluvium varies, but, as indicated by Figure 2.5, generally increases to the west. At the Old Crosscut Canal, the alluvium is about 100 to 125 feet thick and approximately 215 feet thick at the Grand Canal. The maximum thickness of alluvium encountered during this investigation was 240 feet at monitor well DM 126. According to the U.S. Bureau of Reclamation (USBR, 1976) regional geophysical data indicate that the alluvium

may be several thousand feet thick near the center of the basin, about 20 miles northwest of the facility.

The alluvium was found to vary from silty sand to sandy gravel with varying amounts of clay. The median grain size increases in a fairly uniform manner with depth, and the alluvium closest to the bedrock surface usually contains the largest proportion of gravel. In places, the alluvium is strongly cemented by carbonates; however, the cementation is variable and does not appear to form continuous layers. Alluvium in the central part of the Salt River Valley is well stratified and has been subdivided into separate stratigraphic units by various investigators including the USBR (1976), Laney and Hahn (1986), and Brown and Pool (1989). Alluvium near the plant site is poorly stratified and has not been divided into subunits as part of this investigation.

## **2.3 STRUCTURAL GEOLOGY**

Geologic structures in the area include faults and fracture zones that have been observed in outcrop, inferred from subsurface data, or observed in core. The geologic structures in the vicinity of the Motorola 52nd Street Facility are described in this section. The hydraulic significance of the geologic structures is discussed in Chapter 3.0.

Geologic structure in the area is represented on the Geologic Map, Figure 2.4, the cross sections on Figures 2.5 and 2.6, and the contour map of bedrock on Figure 2.7.

### **2.3.1 Tectonic History**

Ten or more separate tectonic or deformational events ranging in age from Precambrian to Tertiary have affected the bedrock units. The two most recent events occurred during middle and late Tertiary time. As a result of these tectonic events, the bedrock has been faulted, rotated, and displaced vertically and horizontally.

## South Mountain Uplift and Listric Faulting

The oldest of the two most recent tectonic events is associated with the formation of the South Mountains. This resulted in two sets of faults: one set has a northwest trend; and a second, transverse set, has a northeast trend. The South Mountains is a metamorphic core complex which was created by heat from an igneous intrusion according to Reynolds (1985). As uplift occurred, the cooler, more rigid shallow rocks separated from the hotter, more ductile, deeper rocks along a detachment surface. Blocks of faulted rocks in this shallow upper plate, rotated and slid, on the detachment surface, away from the center of the uplift. The exposed Precambrian metarhyolite and granite rocks were eroded, and breccias and conglomerates of the Camels Head Formation were deposited in low areas between adjacent fault blocks. As erosion progressed and topographic relief was reduced, the finer grained sediments of the Tempe Beds were deposited over the Camels Head Formation. During and after the deposition of these sedimentary units, volcanic lava flows and ash beds were deposited in areas around local vents and fissures. The entire process is believed by Reynolds (1985) to have taken place during mid-Tertiary time.

The predominant mode of faulting that took place during uplift was listric. Listric faults are similar to slump block faults; the fault plane dips steeply near the surface but becomes nearly horizontal with depth. During faulting, rock units in the fault block rotate so that the direction of dip of originally horizontal bedding planes is opposite to the dip of the fault plane. In the vicinity of the facility, listric fault planes associated with the South Mountain uplift have predominately northwest strikes and northeast dips. The sedimentary strata in the fault blocks dip to the southwest, toward the center of the South Mountain's uplift.

Most of the faults shown on Figure 2.4 are believed to have resulted from this mid-Tertiary tectonic event. At least one of the northwest-trending faults mapped on Figure 2.4 is believed to be listric. This fault has a northwest strike, trends through the northwest corner of the plant site, and is located northeast of the Courtyard. Camels Head strata on the northeast side

of the fault dip steeply to the southwest, and have been downdropped relative to the Precambrian granite on the southwest side of the fault. If this fault is listric, then the dip of the fault plane must decrease with depth.

A second set of faults associated with the development of the South Mountain core complex has a northeast strike. These faults are believed to have formed in zones of transverse shear which developed as a result of differential displacement between adjacent listric fault blocks. In the study area, rocks on the northwest side of these transverse faults are downdropped. The fault which trends northeast across the study area, from a location near the intersection of 40th Street and Van Buren Street through the intersection of 52nd Street and McDowell Road, may be a mid-Tertiary transverse fault.

### **Basin and Range Extension and Normal Faulting**

The second major Tertiary-age tectonic event is Basin and Range extension, which began about 14 million years ago and continued until about 4 million years ago. Basin and Range extension reactivated preexisting zones of weakness in the bedrock resulting in faults that are predominantly steep to near vertical. The strike of Basin and Range extensional structures in Arizona is predominantly northwest. Some or all of the faults shown on Figure 2.4 may have been reactivated by Basin and Range extension.

In a typical Basin and Range setting, faults at the margin of the basin define the line along which the depth to bedrock and the thickness of the alluvium increases greatly. Rocks on the basin side of these faults are downdropped. None of the northwest-trending faults shown on Figure 2.4 appear to be of this type. If a major fault exists that could mark the eastern limit of the West Basin of the Salt River Valley, it has not been identified in this area. Logs of borings indicate that the bedrock surface slopes downward to the west in a relatively uniform fashion.

### 2.3.2 Local Geologic Structures

Bedrock in most of the area of investigation on Figure 2.4 is covered by alluvium; the map was developed from logs of wells and borings. The strikes of faults inferred from the subsurface data are similar to the strikes of faults exposed in the Papago Buttes. Faults with approximate strikes of N 60° W and N 60° E were inferred from the subsurface data.

Because the bedrock is covered by alluvium at and downgradient from the Motorola 52nd St. Facility, the bedrock can only be directly observed in rock core obtained from wells and borings. Geologic logs for the 16 monitor wells drilled from November 1990 through July 1991 are included in Appendix A. Bedrock was cored in all but one of these. Observation well DM 5040B1 was terminated just above the top of bedrock. These data were used to prepare the geologic map on Figure 2.4, the cross-sections on Figures 2.5 and 2.6, and topography of the top of bedrock on Figure 2.7.

Fractures and faults were the principal geologic structures observed in core from the bedrock. The occurrence, orientation, spacing, appearance, openness, degree of infilling or precipitation, degree of alteration, and type of fractures were properties described by direct observation of the core. The potential presence of fractures or faults could also be indicated by the percent recovery of core, the rock quality designation (RQD), the loss of drilling fluid (resulting from the loss of circulation during drilling), and significant increases in water production. Descriptions of fractures, their spacing, and orientation are compiled on the geologic logs in Appendix A along with percent recoveries, lost circulation zones, completion intervals, and hydraulic conductivity data. A discussion of the hydraulic significance of these features is provided in Appendix B.

The frequency and orientation of fractures in borings in the vicinity of the facility were evaluated in the Strat-Boring Report (Dames & Moore, 1985h). Minimum fracture frequencies in wells DM 101, DM 102, DM 103, DM 104, and DM 106 varied from less than

one to more than fifteen fractures per foot. According to the Strat-Boring Report (Dames & Moore, 1985h), the fewest fractures per foot were observed in the Camels Head Formation and the most fractures per foot were observed in the Tempe Beds. Many of the features described as fractures in the Tempe Beds may be partings along bedding planes. The granitic rocks averaged two to three fractures per foot; fracture frequency was observed to decrease with depth. An exception was DM 102, located in the Courtyard, where fractures appear more closely spaced below a depth of about 400 feet.

### 2.3.3 Lineaments

Results of a lineament analysis are presented in Appendix B. As part of this analysis, lineaments were mapped on aerial photographs taken in 1936 and 1954 to evaluate the correlation between lineaments and faults. Lineaments consist of straight or curvilinear, contiguous features or alignments of separate related features that can be identified on the earth's surface. These features can include linear variations in soil color, straight sections of valleys or ridges, breaks in slope, lines of or changes in vegetation, changes in drainage, and other anomalies. Results of the lineament analysis presented in Appendix B can be summarized as follows:

- lineaments mapped in offsite areas had predominantly northeast trends;
- lineaments mapped in onsite areas had predominantly northwest trends;
- field verification of lineaments in the area west of 52nd St. was found to be impractical because development in this area has obscured lineaments which can no longer be identified on recent photos or located in the field; and
- locations of mapped lineaments did not correlate with locations of bedrock faults.

Therefore, the locations of lineaments in the area do not correspond with and were not used to predict the locations of bedrock faults.

## 2.4 SIGNIFICANCE OF GEOLOGIC SETTING

The data presented in this chapter are used to identify and evaluate the geologic controls on:

- the occurrence and movement of ground water presented in Chapter 3.0 and Chapter 6.0;
- the correlation between hydraulic conductivity and geologic structures presented in Appendix B and Chapter 3.0;
- the occurrence of VOC contamination presented in Chapter 4.0;
- the sources, occurrence, and concentrations of inorganic constituents presented in Chapter 5.0.

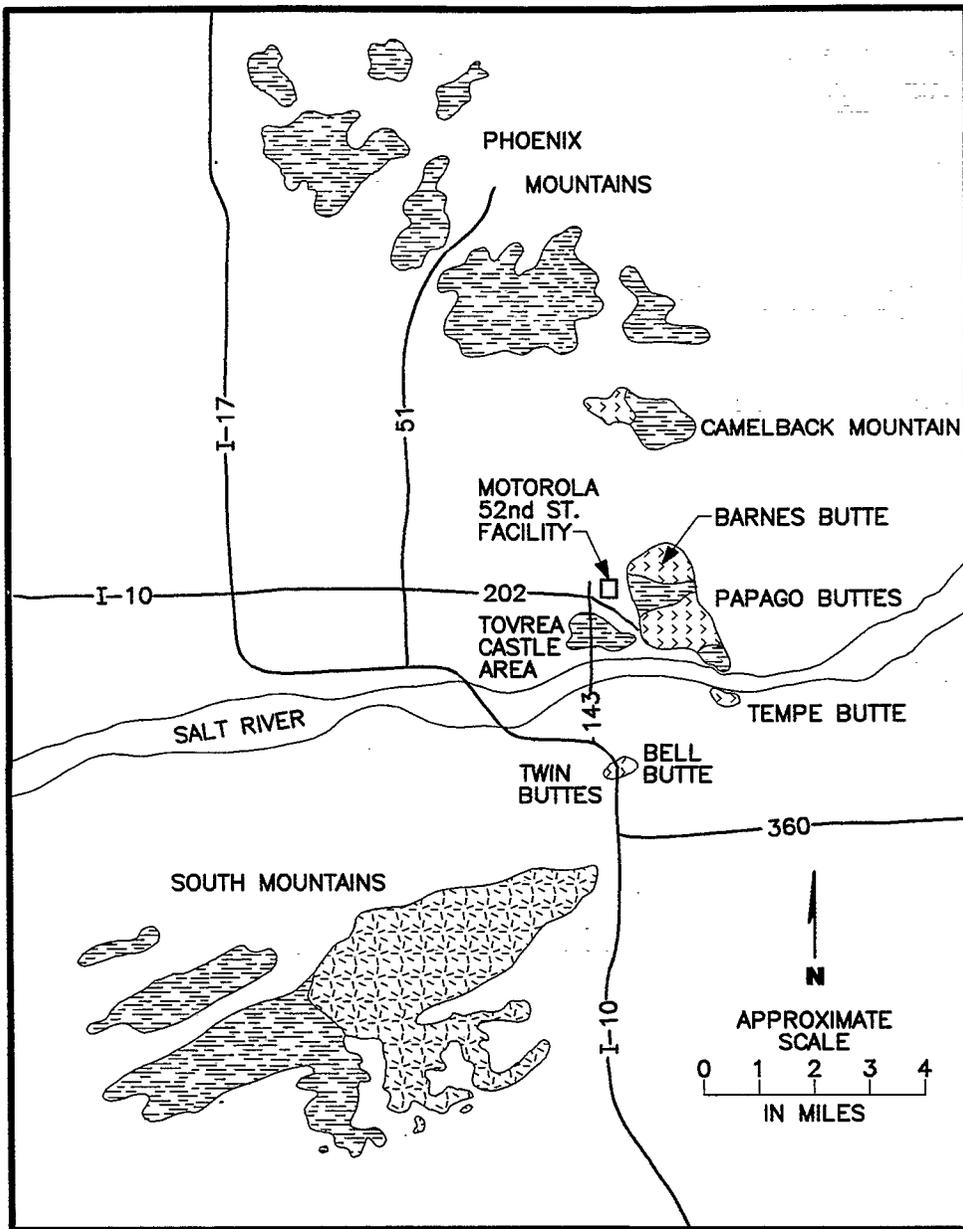
Geologic units were subdivided and discussed in this chapter on the basis of lithology and relative age. Subdivisions consisted of: 1) unconsolidated sediments of the Quaternary alluvium; 2) consolidated sediments and extrusive volcanic rocks of the Tertiary Camels Head Formation, Tempe Beds and Tertiary volcanics; and 3) crystalline rocks of the Precambrian granite and metarhyolite. In the chapters that follow, the geologic units are divided into two groups based on similar hydrogeologic properties: the alluvium and the bedrock. Bedrock includes all of the Tertiary and Precambrian units. Alluvium includes all of the unconsolidated sediments that overlie the bedrock.

**Table 2.1****SUMMARY OF BEDROCK FRACTURE DATA**

Well	Interval (ft)	Major Rock Type	Minimum Fractures per Foot	Percent of Fractures With Given Orientation		
				0°-30°	30°-60°	60°-90°
DM 101	36.5-84	Camels Head	8	48	28	24
	84-120	Camels Head	1	28	42	30
	120-150	Camels Head	6	29	38	33
DM 102	61.5-170	Granite	3	37	40	22
	170-285	Granite	1	12	49	39
	285-395	Granite	2	28	39	32
	395-498	Granite	2	40	45	*15
DM 103	54-101	Granite	*4	*12	*49	*38
	101-241	Granite	2	25	47	28
	241-321	Granite	1	26	56	18
	321-396	Granite	2	33	58	19
DM 104	105-181	Tempe Beds	*>15	*42	*21	*37
	181-306	Camels Head	1	17	33	50
DM 106	127-151	Tuff	4	32	49	19
	151-171	Basalt	2	38	50	12
	171-221	Camels Head	*1	*31	*58	*11
	221-286	Metarhyolite and Granite	11	21	35	44
	286-370	Granite	2	28	39	33

\* Numerous rubble zones not included.

Reference: Dames & Moore, 1985h. Draft Report, Stratigraphic Borings/Monitoring Wells, Remedial Investigation/Feasibility Study. July 24, 1985.



**LEGEND:**

- 
**TERTIARY SEDIMENTS AND VOLCANIC ROCKS (UNDIFFERENTIATED)**
- 
**TERTIARY GRANITE (UNDIFFERENTIATED)**
- 
**PRECAMBRIAN ROCKS (UNDIFFERENTIATED)**

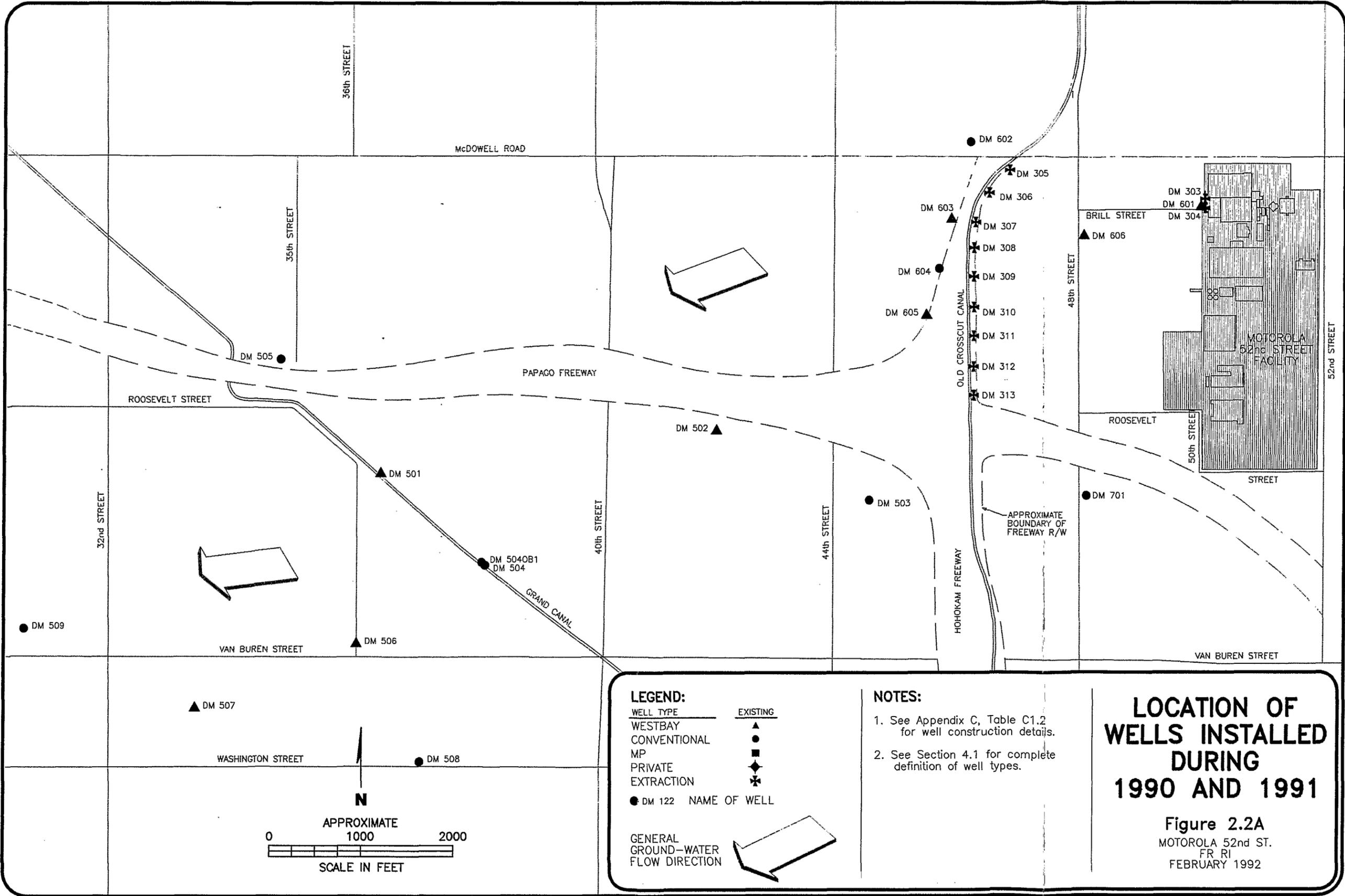
**NOTES:**

1. All locations and contacts are approximate.

Modified from: Schulten (1979), Scarborough (1979), and Reynolds (1985).

**BEDROCK OUTCROP MAP**

**Figure 2.1**  
 MOTOROLA 52nd ST.  
 FR RI  
 FEBRUARY 1992



**LEGEND:**

WELL TYPE	EXISTING
WESTBAY	▲
CONVENTIONAL	●
MP	■
PRIVATE EXTRACTION	◆
● DM 122	NAME OF WELL

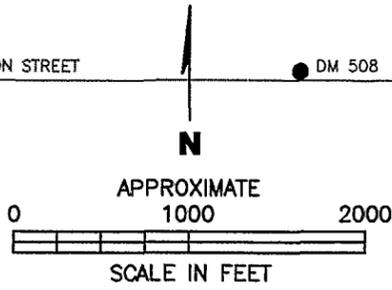
GENERAL GROUND-WATER FLOW DIRECTION

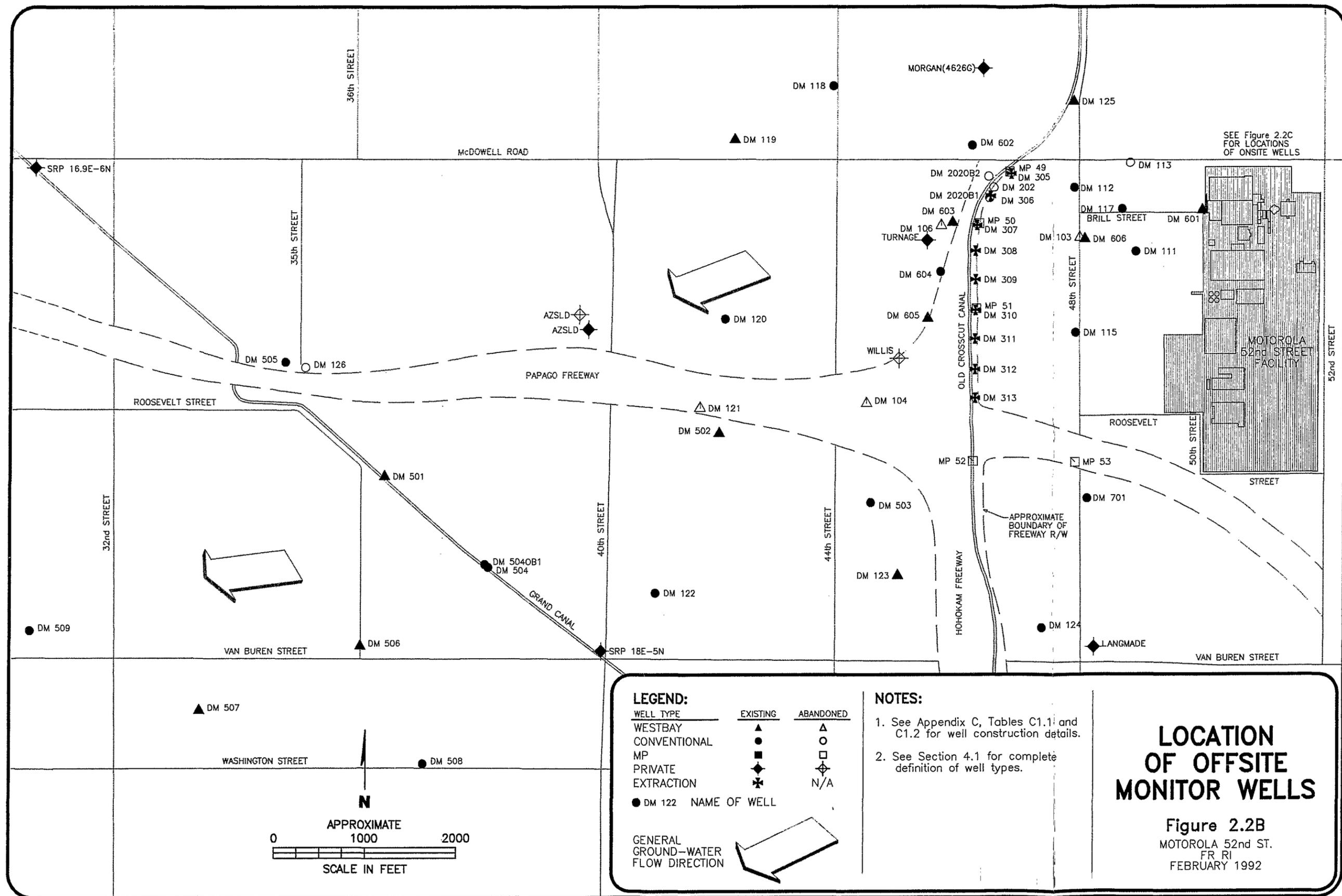
**NOTES:**

1. See Appendix C, Table C1.2 for well construction details.
2. See Section 4.1 for complete definition of well types.

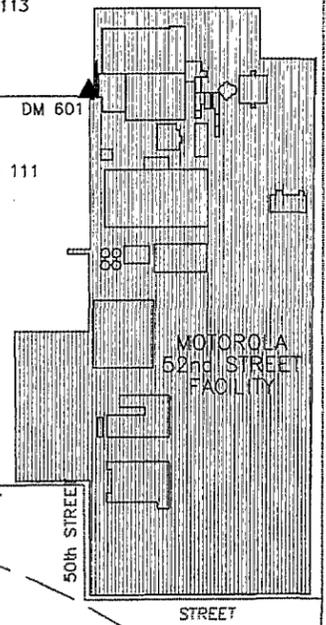
**LOCATION OF WELLS INSTALLED DURING 1990 AND 1991**

**Figure 2.2A**  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992





SEE Figure 2.2C  
FOR LOCATIONS  
OF ONSITE WELLS



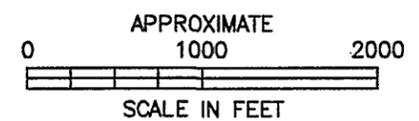
# LOCATION OF OFFSITE MONITOR WELLS

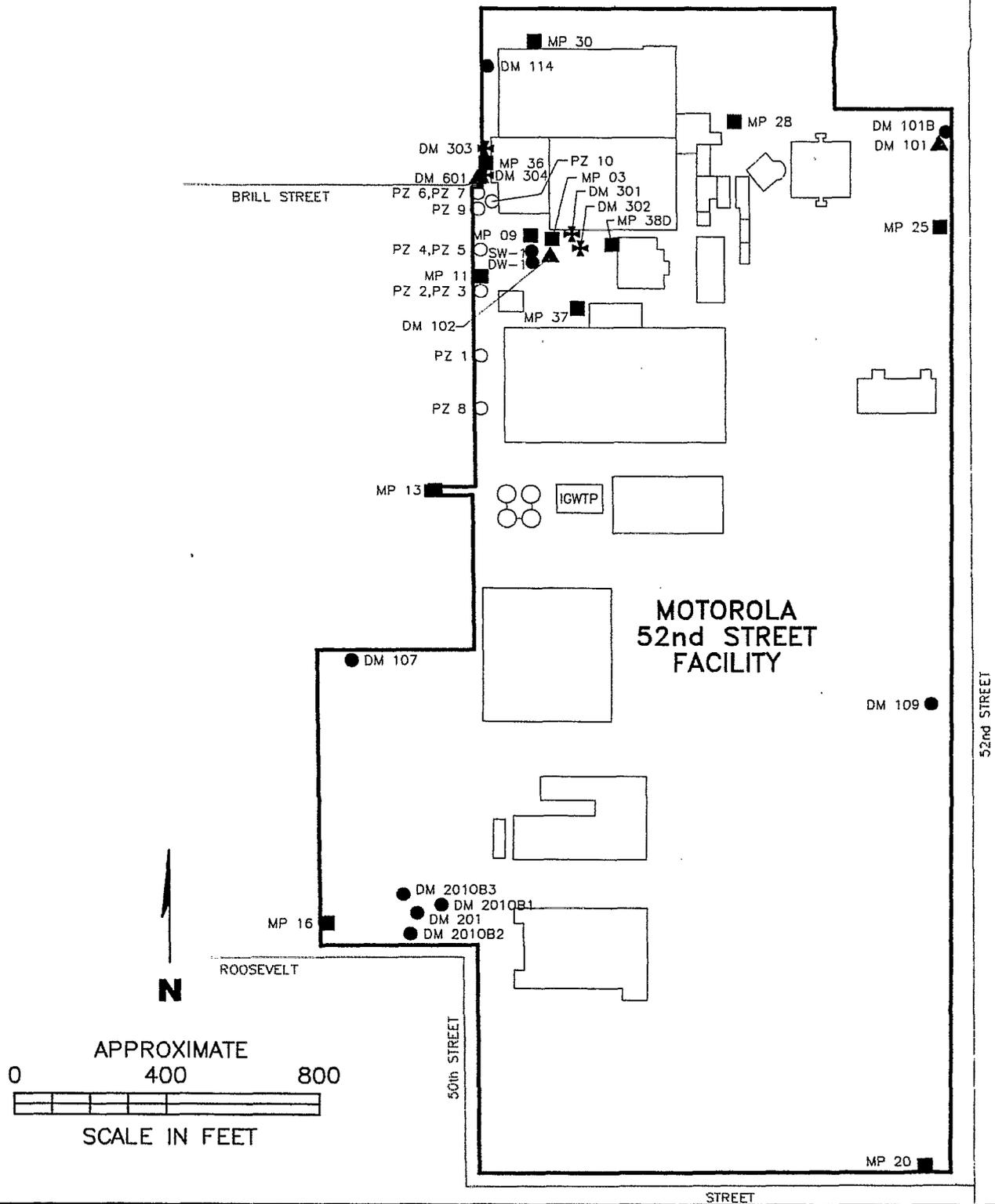
Figure 2.2B  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992

**LEGEND:**

WELL TYPE	EXISTING	ABANDONED
WESTBAY	▲	△
CONVENTIONAL	●	○
MP	■	□
PRIVATE EXTRACTION	◆	◇
	*	N/A
● DM 122	NAME OF WELL	

- NOTES:**
1. See Appendix C, Tables C1.1 and C1.2 for well construction details.
  2. See Section 4.1 for complete definition of well types.





**LEGEND:**

WELL TYPE	EXISTING
WESTBAY	▲
CONVENTIONAL	●
MP	■
EXTRACTION	✕
PIEZOMETER	○
✕ DM 301	NAME OF WELL

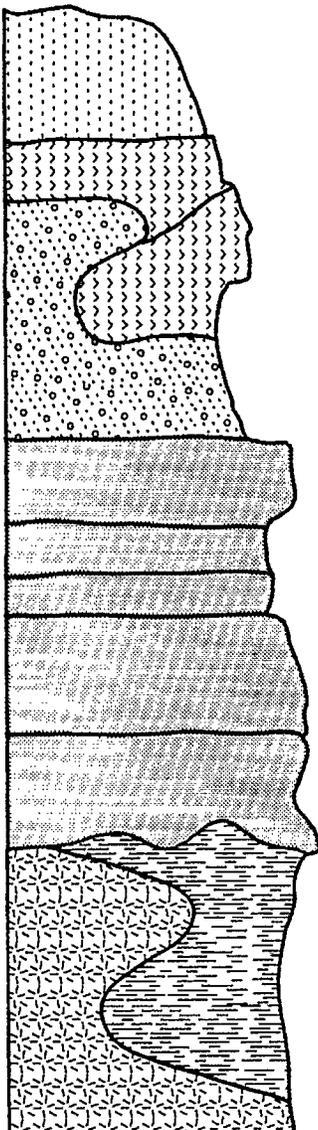
**NOTES:**

1. See Appendix C, Table C1.2 for well construction details.
2. See Section 4.1 for complete definition of well types.

**LOCATION OF ONSITE MONITOR WELLS**

**Figure 2.2C**  
 MOTOROLA 52nd ST.  
 FR RI  
 FEBRUARY 1992

**OUTCROP SCHEMATIC**



**FORMATION OR UNIT**

**GEOLOGIC PERIOD**

**APPROXIMATE AGE (10<sup>6</sup> YR)**

**APPROXIMATE THICKNESS (FT)**

ALLUVIUM (Qal)	QUATERNARY	0 TO 3	20 TO 240
VOLCANICS (Tv)	TERTIARY	17 TO 20	0 TO 137
TEMPE BEDS (Ttb)			0 TO 205
CAMELS HEAD FORMATION (Tcf)			0 TO 190
META-RHYOLITE (Pcmr)	PRECAMBRIAN	1,600 TO 1,800	0 TO 437
GRANITE (Pcg)			0 TO 341

REFERENCE: Figure 3.5,  
DRAFT RI REPORT, 1987  
M1 52nd STREET

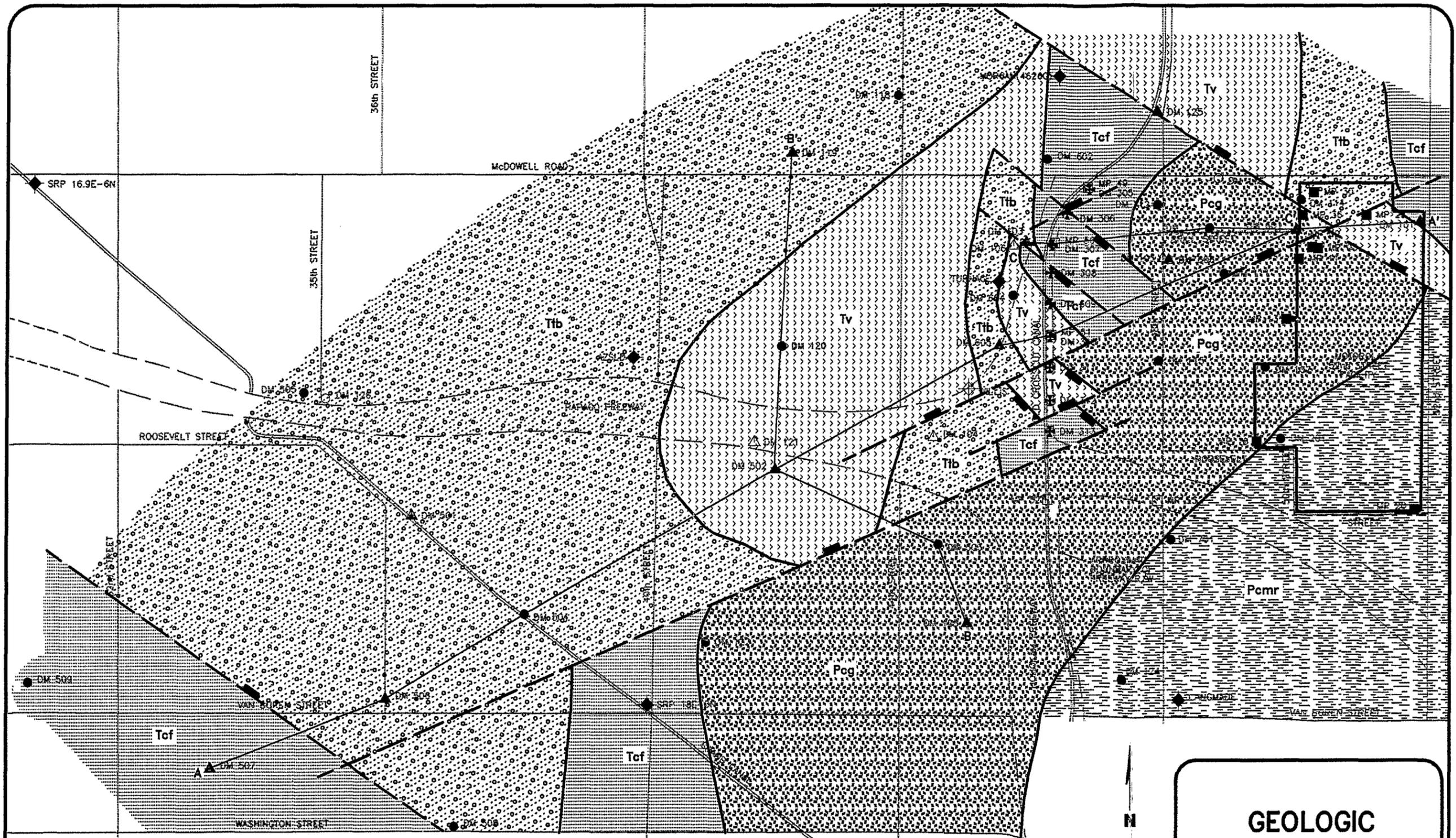
**NOTE:**

1. THICKNESSES BASED ON THICKNESSES IN BORINGS IN THE STUDY AREA. GREATER THICKNESSES OF ALL BEDROCK UNITS OCCUR IN OUTCROP.
2. OUTCROP SCHEMATIC IS A COMPOSITE FROM PAPAGO BUTTES, TEMPE BUTTE, TWIN BUTTE AND CAMELBACK MOUNTAIN.
3. NOT TO SCALE

**STRATIGRAPHIC COLUMN**

**Figure 2.3**

MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992

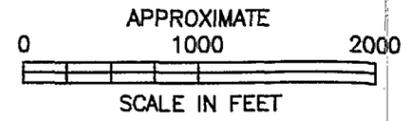


**LEGEND:**

- |  |  |  |  |
|--|--|--|--|
|  | TERTIARY VOLCANICS<br>PREDOMINANTLY ANDESITE FLOWS AND DIKES, MINOR RHYOLITE |  | PRECAMBRIAN GRANITE<br>TOVREA GRANITE AND CAMELBACK GRANITE<br>(UNDIFFERENTIATED)                  |
|  | TEMPE BEDS<br>SANDSTONE, SILTSTONE AND SHALEY SILTSTONE                      |  | PRECAMBRIAN METARHYOLITE<br>MASSIVE TO BRECCIATED, WITH OCCASIONAL<br>BANDING OF SPECULAR HEMATITE |
|  | CAMELSHEAD FORMATION<br>ARKOSIC SANDSTONE, FANGLOMERATE, AND BRECCIA         |  | INFERRED FAULT, BAR ON DOWNTHROWN SIDE   |
|  |  |  | INFERRED FORMATION CONTACT   |

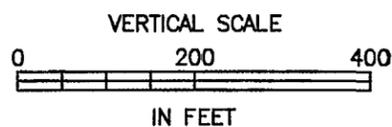
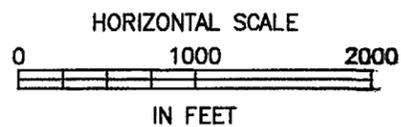
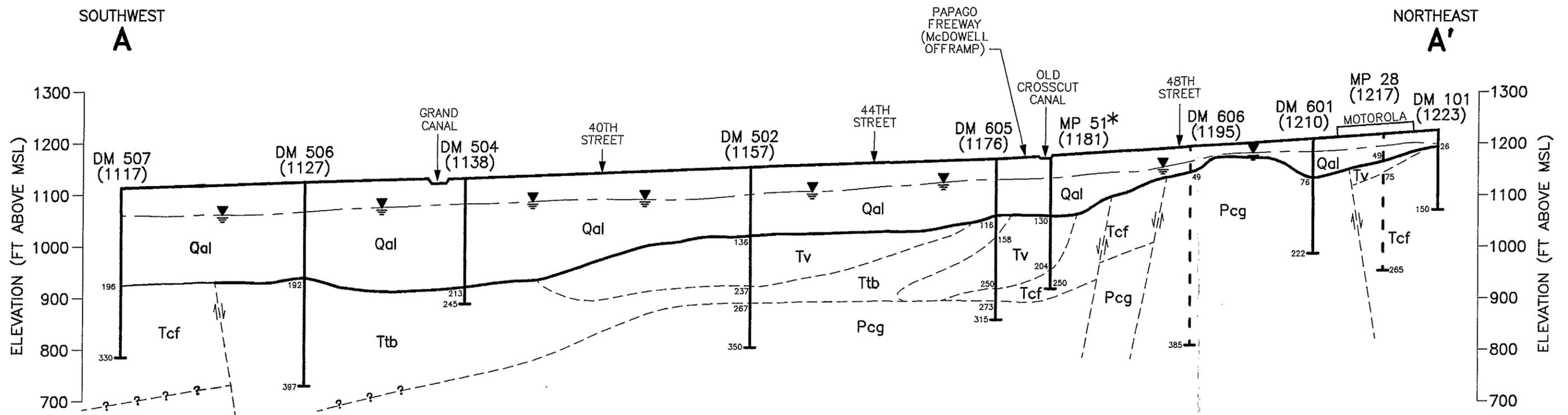
**NOTES:**

See Figure 2.2 for explanation of monitor well symbols.



**GEOLOGIC  
BEDROCK MAP**  
Figure 2.4

MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992



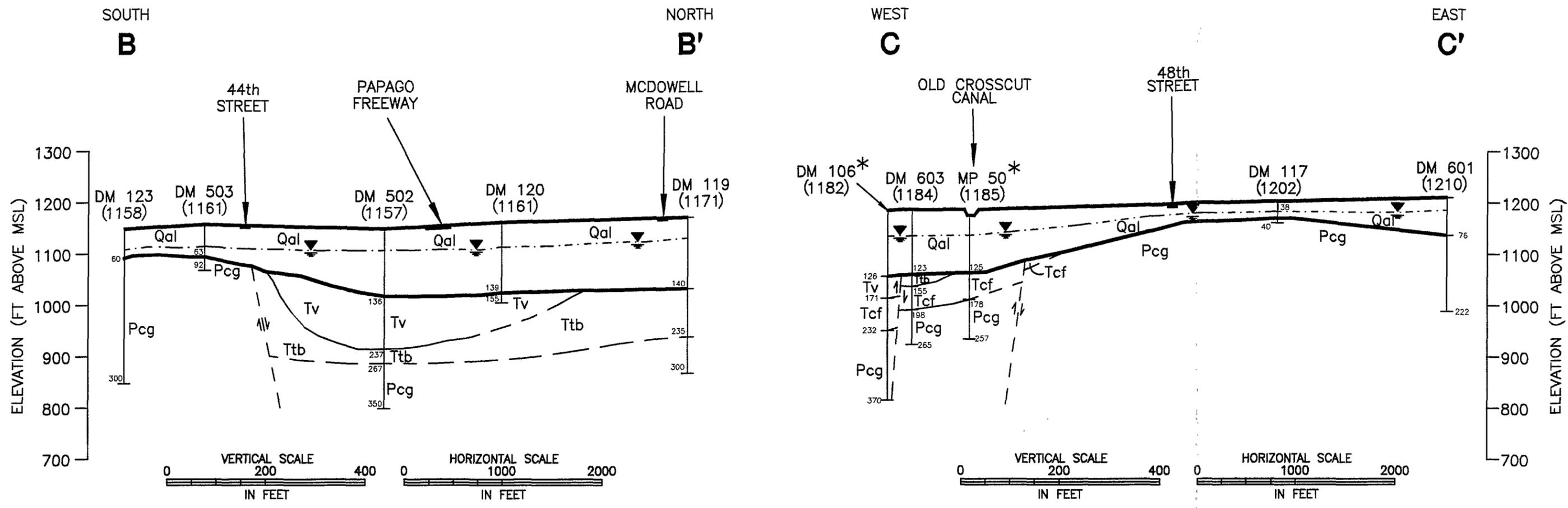
**LEGEND:**

- GROUND WATER TABLE  
JUNE 1991
- INFERRED FAULT WITH ARROWS  
INDICATING MOVEMENT
- DM 605  
(1176) WELL LOCATIONS (DASHED WHERE  
PROJECTED ONTO CROSS-SECTION)  
(GROUND SURFACE ELEVATION IN  
FEET, AMSL)
- 385 DEPTH IN FEET
- \* WELL HAS BEEN ABANDONED

- Qal** QUATERNARY ALLUVIUM/COLLUVIUM  
Silt, sand, gravel and cobbles
- Tv** TERTIARY VOLCANICS  
Predominantly andesite flows and dikes,  
minor Rhyolites
- Ttb** TERTIARY TEMPE BEDS  
Sandstone, siltstone and shaley siltstone
- Tcf** TERTIARY CAMELS HEAD FORMATION  
Arkosic sandstone, fanglomerate and breccia
- Pcg** PRECAMBRIAN GRANITE  
Tovrea granite and camelback granite  
(Undifferentiated)

**GENERALIZED  
GEOLOGIC  
CROSS-SECTION A-A'**

Figure 2.5  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992



**LEGEND:**

- GROUND WATER TABLE  
JUNE 1991
- INFERRED FAULT WITH ARROWS  
INDICATING MOVEMENT
- DM 606 (1195) WELL LOCATIONS  
PROJECTED ONTO CROSS-SECTION  
(GROUND SURFACE ELEVATION  
IN FEET, AMSL)
- 385 DEPTH IN FEET
- \* NOTE: Wells have been abandoned.

- Qal QUATERNARY ALLUVIUM/COLLUVIUM  
SILT, SAND, GRAVEL AND COBBLES
- Tv TERTIARY VOLCANICS  
PREDOMINANTLY ANDESITE FLOWS AND DIKES, MINOR RHYOLITES
- Ttb TERTIARY TEMPE BEDS  
SANDSTONE, SILTSTONE AND SHALEY SILTSTONE
- Tcf TERTIARY CAMELS HEAD FORMATION  
ARKOSIC SANDSTONE, FANGLOMERATE AND BRECCIA
- Pcg PRECAMBRIAN GRANITE  
TOVREA GRANITE AND CAMELBACK GRANITE  
(UNDIFFERENTIATED)

**GENERALIZED  
GEOLOGIC  
CROSS-SECTIONS  
(B-B' AND C-C')**

Figure 2.6  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992



## **3.0 HYDROGEOLOGY**

### **3.1 INTRODUCTION**

A summary of the hydrogeology of the Final Remedy (FR) RI study area is presented in this chapter. The information presented is intended to supplement and update the description of hydrogeology presented in the 1987 Draft RI Report (Dames & Moore, 1987b). Since the 1987 Draft RI Report, 17 additional monitor and 11 extraction wells have been installed and 15 wells have been abandoned. The purpose of the FR RI is to update and expand the 1987 Draft RI, and evaluate the downgradient extent of contamination. The hydrogeologic investigation presented below addresses the flow and contaminant transport properties of subsurface strata within the study area.

The locations of monitor wells utilized in the hydrogeologic investigation are presented in Figure 3.1. Figure 3.2 illustrates the locations of onsite monitor wells. Appendix A lists well construction specifications. The nine DM 500-series wells were installed between November 1990 and June 1991 in the downgradient portion of the plume, and were designed to augment the hydrogeologic database in the vicinity of the Grand Canal. In the following discussions, the general hydrogeologic setting is reviewed. Section 3.2 describes the alluvium and bedrock aquifers. Section 3.3 presents a review of ground-water flow and hydraulic gradients. The hydraulic characteristics are described in Section 3.4. Recharge to the aquifer is described in Section 3.5.

### **3.2 AQUIFERS**

Within the study area, water-bearing formations include two distinct hydrogeologic units: alluvium and bedrock. A general description of each unit is presented in the following sections of this report. Figure 3.3 presents ground-water conditions for the region; the location of the Motorola Facility is on the eastern boundary of the area.

### 3.2.1 Alluvium

The alluvial aquifer within the study area consists of saturated unconsolidated sands and gravels with varying amounts of silt and clay. Two distinct alluvial lithologic units were noted during installation of monitor wells near the Grand Canal. A coarse, sandy gravel was encountered from the surface to a depth of 80 to 100 feet, and included large cobbles and boulders of rounded igneous, sedimentary, and metamorphic rock of diverse origin. This gravel unit is interpreted to have been derived by a fluvial process. The fluvial gravel contains little silt or clay. In contrast, the underlying unconsolidated sediments, which are more typical of the study area, consist of clayey, sandy, gravels with angular to subrounded clasts of granite, basalt, and metarhyolite. These are similar in appearance to local bedrock formations. The lower unconsolidated unit of alluvial valley fill material was probably derived from erosion during local Tertiary Basin and Range development.

The shallow fluvial gravel was not noted in wells installed along the Old Crosscut Canal. The eastern limit of this unit is believed to be between monitor well DM 502 and the Old Crosscut Canal. The unit has been encountered in all monitor wells installed to-date west of and including DM 502. During installation of monitor wells, the zone usually required cementation to allow continuation of drilling by the mud rotary method. For this reason, monitoring zones were not installed in the fluvial gravel.

The lower alluvial unit is present throughout the study area, but varies considerably in thickness depending on the depth to the bedrock. Cross sections of the area are presented on Figures 2.4 and 2.5, and illustrate the vertical extent of the alluvial aquifer. Near the Motorola Facility, the alluvial unit extends to the surface and varies in thickness from 10 to 50 feet. Near the Grand Canal, the aquifer extends from a depth of 80 to 100 feet below the surface to a depth of as much as 230 feet. West of the Grand Canal, the alluvial aquifer is difficult to distinguish from the underlying Tertiary Camels Head Formation and Tempe Beds. A more detailed description of the alluvial aquifer east of the Grand Canal is included in the 1987 Draft RI Report

(Section 3.3). Chapter 2.0 and Appendix A of this report include more detailed descriptions of the alluvial aquifer west of the Old Crosscut Canal.

### 3.2.2 Bedrock

The bedrock geology is described in Chapter 2.0. The bedrock underlying the area west of well DM 502 is dominated by the sedimentary Tertiary Camels Head Formation and Tempe Beds. Igneous and metamorphic bedrock formations, which are commonly encountered east of the Grand Canal, were absent from wells drilled to depths in excess of 300 feet west of the Grand Canal.

## 3.3 FLOW PATTERNS

Figure 3.3 illustrates the regional ground-water flow pattern as it existed prior to development of the Salt River Valley and in 1986. Figure 3.4A presents a contour map of water table elevations as measured in June 1991. Depth to water as measured in July 1991 is shown in Figure 3.4B. The saturated thickness of the alluvium is shown in Figure 3.5, and was calculated by superimposing the water table map over the bedrock topography.

In general, ground water flows toward the southwest in the vicinity of the Motorola 52nd St. Facility. West of the Grand Canal, the flow direction changes toward the west-southwest. This change is consistent with the known regional pattern of ground-water flow presented on Figure 3.3. Figure 3.3 includes arrows depicting the regional ground-water flow directions based on measured water levels in 1986. Ground water at the Motorola 52nd St. Facility flows toward the southwest. Prior to extensive ground-water development in the Salt River Valley in the early 1900s, the Salt River was hydraulically connected to the ground-water system and is considered to have been a gaining stream. Ground water in the area of this investigation flowed toward the Salt River, as indicated by the dashed lines on Figure 3.3. After decades of ground-water pumping during development of the area, the regional ground-water flow

direction in the Salt River Valley changed significantly. West of the Grand Canal, ground water now flows to the west instead of flowing toward the Salt River. Farther to the west, ground-water flow is to the northwest. This change was caused by ground-water pumping in the vicinity of the Luke Air Force Base which created areas of depression in the ground-water table. Ground water which used to flow to the Salt River now flows toward the pumping centers. The Luke pumping center is approximately 25 miles northwest of the Motorola 52nd St. Facility.

The ground-water hydraulic gradient averaged approximately 0.011 ft/ft east of the Grand Canal during June 1991. The gradient gradually decreases to approximately 0.005 ft/ft west of the Grand Canal (Figure 3.4A).

The saturated thickness of the alluvium (Figure 3.5) varies from less than 10 feet in several areas east of 48th Street, near the 52nd St. Facility, to greater than 150 feet west of the Grand Canal, with one exception. Based on interpretation of drill cuttings and geophysical logs, it appears that the saturated thickness of the alluvium is less than 100 feet in the vicinity of well DM 509, west of the Grand Canal.

Long term water level trends are represented by time histories for two Salt River Project (SRP) wells, 18E-5N and 16.9E-6N (Figure 3.6A). SRP well 18E-5N is located on the Grand Canal at approximately 40th Street. The water level in the well has declined by approximately 8 feet between 1935 and 1991. SRP well 16.9E-6N, located on the Grand Canal at approximately 32nd Street, has declined by approximately 10 feet between the early 1950s and the late 1980s.

The saturated thickness of the alluvium has not significantly changed since completion of the 1987 Draft RI as evidenced by ground-water elevation time histories for key wells (Figure 3.6B). The water table plotted in Figure 3.6B has declined approximately 2 to 8 feet since 1985. In the vicinity of the Old Crosscut Canal, ground-water levels have declined by an average of approximately 7 feet since 1986. The average rate of decline in recent years has

increased from the historical average of 0.4 feet/year to greater than 1 foot per year. This increased rate of ground-water decline is attributed to the relatively dry conditions which have persisted since about 1987. Appendix G presents a table showing all water level measurements collected since 1985, and includes additional discussion of recent water level trends in the area of investigation.

Vertical ground-water flow is evaluated using vertical head distribution profiles as measured in multi-port wells. The results of vertical head distribution measurements are depicted in Figure 3.7 for wells DM 501, DM 502, DM 506, DM 507, DM 601, DM 603, DM 605, and DM 606. Upward vertical flow is indicated when the measured pressure head increases with depth. The bedrock portions of wells DM 501, DM 506, and DM 605 exhibit upward vertical flow. Downward vertical flow is indicated when the measured pressure head decreases with depth (DM 601 and DM 606). The upper two ports of well DM 501 exhibit downward ground-water flow. No vertical flow is indicated in wells DM 507 and DM 603 with the exception of the DM 507 port at the bedrock/alluvium interface which has a higher pressure head than the ports located either above or below it. Appendix G provides a complete listing of measured water levels in multi-port wells.

The distribution of upward versus downward vertical flow is depicted on Figure 3.8. On the figure, positive numbers indicate upward flow and negative numbers indicate downward flow. The vertical gradient measurements presented on the figure were derived from the most recent available data from each well. Table 3.1 shows the calculation of vertical hydraulic gradients for multi-port wells shown on Figure 3.8, including dates of measurements.

### 3.4 HYDRAULIC CHARACTERISTICS

The hydraulic characteristics of a saturated aquifer are described by the flow parameters, hydraulic conductivity and storage coefficient. These parameters are important for understanding flow in saturated aquifers, for predicting movement of contaminants, and for

evaluating the future response of the aquifer to remedial actions. Hydraulic conductivity and storage coefficient may vary with each stratigraphic unit and may change horizontally within one aquifer. The greatest contrast occurs between bedrock and alluvium, usually by several orders of magnitude.

Hydraulic conductivity and storage coefficient are best measured by long-term pumping and observation of water levels in several nearby wells. Other methods include single well pumping tests, slug tests, and rising head tests. A summary of alluvium and bedrock hydraulic characteristics is provided in the following sections and Appendix F.

### **3.4.1 Alluvium**

The hydraulic characteristics of alluvium were measured extensively and the results were reported in Section 3.3.2.1 and Appendix E of the 1987 Draft RI. The results of a pump test conducted in well DM 202 at the Old Crosscut Canal as reported in the 1987 Draft RI indicated that the measured hydraulic conductivity in alluvium ranged between 50 and 60 feet per day. The storage coefficient measured in well DM 202 ranged from 0.013 to 0.03 indicating semi-confined aquifer conditions.

One pumping test at well DM 504 and several rising head tests in multi-port wells were conducted in June 1991 to define the hydraulic characteristics of the alluvium in the vicinity of the Grand Canal. Well DM 504 is located along the Grand Canal in what has been estimated to be the approximate center of the contaminant plume. DM 504 is screened across the bedrock/alluvium interface. An observation well (DM 5040B1) was installed approximately 45 feet from DM 504. The observation well was screened across the lower 30 feet of alluvium. The pump test was conducted for 72 hours, after which water levels were monitored for an additional 2 days to obtain recovery data.

Interpretation of the pump test suggests that a combination of delayed yield, leakage from the upper fluvial aquifer, and perhaps recharge from the Grand Canal affected the response of the aquifer to pumping. Therefore, the hydraulic conductivity was developed principally by analysis of the early portion of the drawdown data.

The pump test results are included in Table 3.2, and the results of rising head tests in alluvium are summarized in Table 3.3. The rising head and pumping tests are described in detail in Appendix F. The results of the aquifer test in well DM 504 agree well with results of testing reported in the 1987 Draft RI. The value of hydraulic conductivity ranged from 34 to 57 feet per day using the Theis and Jacob methods of test evaluation; the storage coefficient ranged from 0.001 to 0.021. The average hydraulic conductivity value is approximately 45 ft/day in alluvium depending on the assumptions and analytical methods used to evaluate the test results.

Rising head tests were performed in seven alluvial monitoring ports west of the Old Crosscut Canal. Rising head tests tend to underestimate the value of hydraulic conductivity because this type of test does not stress the aquifer to the same degree as pumping. Rising head tests evaluate a much smaller area of an aquifer than a pumping test.

The results of rising head tests in alluvium yielded values of hydraulic conductivity ranging from 1.5 to 9.8 feet per day, approximately 10 times less than the results of the pump test. The value of storage coefficient cannot be measured by the rising head method.

#### **3.4.2 Bedrock**

The hydraulic characteristics of bedrock were measured using the rising-head method at multi-port well locations DM 501, DM 502, DM 506, DM 507 in the vicinity of the Grand Canal. A total of 13 monitoring ports in bedrock were tested. The results of the tests are presented in Table 3.4.

The results of the rising head tests in bedrock show that the average hydraulic conductivity of the Tertiary sedimentary units ranges from  $1.4 \times 10^{-3}$  ft/day ( $4.9 \times 10^{-7}$  cm/sec) in well DM 506 to 0.28 ft/day ( $9.9 \times 10^{-5}$  cm/sec) in well DM 501. The results of tests conducted for the 1987 Draft RI (Section 3.3.2.2) yielded hydraulic conductivity values ranging from  $1.6 \times 10^{-3}$  ft/day ( $5.8 \times 10^{-7}$  cm/sec) to 2.1 ft/day ( $7.5 \times 10^{-4}$  cm/sec) for Tertiary bedrock formations. The similarity in the range of hydraulic conductivity values indicates that the Tertiary bedrock units encountered in wells near the Grand Canal are not hydrogeologically different than Tertiary units encountered in wells at the Old Crosscut Canal.

### 3.4.3 Summary

In summary, results of the aquifer tests conducted near the Grand Canal are about the same as the results of aquifer tests conducted near the Old Crosscut Canal. The hydraulic conductivity obtained for the alluvium at well DM 504 ranged from 34 to 57 feet per day using the Theis and Jacob methods. The value of the storage coefficient ranged from 0.0017 to 0.021. The hydraulic conductivity derived from rising head test data obtained from monitor zones in bedrock were similar to values previously reported in the 1987 Draft RI. Bedrock hydraulic conductivity values are therefore assumed to average approximately 0.005 ft/day for Tertiary bedrock and 0.05 ft/day for Precambrian bedrock.

## 3.5 RECHARGE

The pattern of recharge to the ground water is presented in Figure 3.9. Recharge occurs principally in areas that receive flood irrigation and by seepage from irrigation canals. Natural recharge from precipitation and runoff was estimated in the 1987 Draft RI (p. 3-32) and is considerably less than irrigation and canal seepage.

Recharge was evaluated by the Arizona Department of Water Resources as part of the development of the Salt River Valley ground-water numerical model (ADWR, in

preparation). A compilation of recharge for the area in the vicinity of the Grand Canal was provided to Dames & Moore by the ADWR in June 1991 (S. Correl, personal communication). ADWR compiled the recharge data from several sources including SRP, the U.S. Bureau of Reclamation (USBR), and the USGS. The recharge data provided by ADWR did not include specific documentation to allow independent calculation of recharge values. However, the ADWR database is the most current source of available information for recharge in the study area.

The following discussion is based on the ADWR recharge database. Only canal recharge and flood irrigation are reviewed because both required modification from the 1987 Draft RI. Other recharge sources such as seepage from laterals and recharge from the plant are described in the 1987 Draft RI (Section 3.3.3.3) and have not been changed for the present investigation.

### **3.5.1 Canal Recharge**

Seepage from canals was estimated in the 1987 Draft RI by assuming that water moves through the sediment in the bottom of the canals under a vertical hydraulic gradient of 1.0 ft/ft. It was assumed that the hydraulic conductivity of the sediments lining the bottoms of canals averaged  $10^{-5}$  to  $10^{-6}$  cm/sec. Therefore, the average seepage rate estimated for irrigation canals was assumed to be 0.028 ft/day ( $1 \times 10^{-5}$  cm/sec) for the 1987 Draft RI. This rate differs from the rate estimated by the ADWR.

Canal seepage rates included in the ADWR database are reported in units of cubic feet of water infiltration per square foot of canal bottom per day ( $\text{ft}^3/\text{ft}^2/\text{day}$  or ft/day). Unlined canal seepage estimates were obtained by ADWR from SRP; lined current seepage estimates were obtained from the USBR and the USGS. SRP estimated that the system-wide average infiltration rate for unlined canals was 0.52 ft/day in 1977 and had decreased to 0.25 ft/day by 1988. This

decrease in the system-wide average was attributed to selectively lining sections of the canals with higher reported seepage losses over the 12-year period.

For a lined canal, the USBR (1989) estimated an infiltration rate of 0.05 ft/day. The USGS (1980) estimated the infiltration rate from lined canals was 0.0118 ft/day.

Records from SRP indicate that the Grand Canal was lined in the vicinity of the study area in 1987. Therefore, prior to 1987, the rate of infiltration from the Grand Canal would be approximated by the SRP estimates for unlined canals. These rates are more than 15 times larger than the rates estimated in the 1987 Draft RI. The rate of canal seepage and its impact on local flow patterns was investigated using the ground-water flow and transport model discussed in Chapter 6.0. It was concluded from the model analysis that the rate for a lined canal (0.028 ft/day) matches field measurements of water elevations near the canal better than the higher unlined canal seepage rates estimated by SRP.

### **3.5.2 Flood Irrigation**

Flood irrigation of lawns was estimated to cause seepage at an average rate of 1.15 feet per year (0.003 ft/day). This value was originally obtained from the result of a ground-water modeling study conducted by the ADWR (Long et. al., 1982) and was reported in the 1987 Draft RI. Areas of flood irrigation were identified by analysis of aerial photographs.

### **3.6 SUMMARY**

A hydrogeologic investigation has been conducted to evaluate the hydraulic properties of alluvium and bedrock in an area extending from the Old Crosscut Canal to approximately 32nd Street between Washington Street and McDowell Road. Four multi-port Westbay wells, five single-completion conventional monitor wells, and one observation well were

installed to provide field measurements of water levels and hydraulic pressure distributions. The field data provided the basis for evaluation of the ground-water flow gradient and flow direction.

The principal ground-water aquifer underlying the study area is comprised of unconsolidated alluvial sediments which were encountered at depths ranging from 100 to 220 feet in areas west of the Grand Canal. A coarse, fluvial gravel was encountered to a maximum depth of approximately 100 feet in wells west of 44th Street; this unit exhibited different hydraulic characteristics in comparison to the alluvial sediments.

Bedrock underlying the alluvial sediments is comprised predominantly of Tertiary Tempe Beds and Camels Head Formations. These formations are similar in appearance to the overlying alluvium but have greatly lower hydraulic conductivity. The maximum depth investigated was approximately 350 feet below ground surface. East of the Grand Canal, ground water flows toward the southwest. West of the Grand Canal, the flow direction gradually changes to west-southwest. The hydraulic gradient averages 0.011 ft/ft east of the Grand Canal and flattens to 0.005 ft/ft west of the Grand Canal.

A long-term aquifer test was conducted at well DM 504. Water level measurements obtained from an adjacent observation well (DM 504OB1) indicated that the hydraulic conductivity of the alluvial aquifer overlying the bedrock ranges from approximately 34 to 57 ft/day and averages approximately 45 ft/day. This value is similar to the results obtained from a pumping test conducted in well DM 202 at the OCC, and indicates that the aquifer hydraulic characteristics do not significantly change downgradient of the OCC.

Rising head tests were conducted in 20 monitoring ports of four multi-port Westbay wells. The results of the tests in bedrock ports indicated the hydraulic conductivity of Tertiary sedimentary formations varies from 0.0014 ft/day to 0.28 ft/day, in close agreement with similar tests conducted in wells to the east of DM 502 for the 1987 Draft RI.

Recharge to the ground water occurs primarily from flood irrigation, seepage from irrigation canals, and precipitation. Flood irrigation of lawns was estimated to cause seepage at an average rate of 1.15 feet per year (0.003 ft/day), as originally determined by the ADWR (Long et al., 1982).

Infiltration due to precipitation is difficult to estimate. In general, infiltration is greater along washes and other natural drainages. From evaluation of onsite water level measurements and their response to storm events, it was estimated that approximately 25 percent of precipitation infiltrates to ground water. The average annual precipitation in this area is approximately 7 inches per year; therefore, approximately 0.15 feet per year of precipitation infiltrates to ground water.

Canal seepage has been evaluated by SRP and ADWR. In general, lined canals infiltrate at a rate of between 4 and 18 feet per year. Canals which have not been lined have an infiltration rate of between 90 and 190 feet per year. An evaluation of the canal seepage rates was performed during calibration of the ground-water flow and contaminant transport model and is described in Section 6.4, Sensitivity Analyses.

**Table 3.1**

**CALCULATION OF VERTICAL HYDRAULIC GRADIENTS  
FOR MULTI-PORT WELLS**

Well	Date	Lower Port	Upper Port	Difference	Depth of Lower Port	Depth of Upper Port	Difference	Gradient
DM 101	06/24/91	1193.71	1194.08	-0.37	140	45	95	-0.004
DM 102	11/23/87	1184.83	1186.52	-1.69	489	48	441	-0.004
DM 103	11/13/90	1165.10	1163.89	1.21	389	32	357	0.003
DM 104	09/20/88	1132.14	1125.97	6.17	293	40	253	0.024
DM 106	06/04/86	1147.35	1147.05	0.3	332	40	292	0.001
DM 119	11/02/90	1137.15	1128.23	8.92	284	72	212	0.042
DM 121	01/20/89	1112.10	1112.51	-0.41	284	84	200	-0.002
DM 123	11/19/87	1120.00	1123.28	-3.28	285	85	200	-0.016
DM 125	11/08/90	1176.75	1173.89	2.86	270	76	194	0.015
DM 501	07/22/91	1082.57	1080.50	2.07	387	147	240	0.009
DM 502	06/28/91	1107.12	1105.66	1.46	335	79	256	0.006
DM 506	06/27/91	1072.23	1069.33	2.90	375	100	275	0.011
DM 507	06/25/91	1060.49	1060.66	-0.17	315	84	231	0.000
DM 601	10/28/91	1182.04	1182.85	-0.81	200	40	160	-0.005
DM 603	12/16/91	1139.10	1139.17	-0.07	245	68	177	0.000
DM 605	09/19/91	1134.24	1130.97	3.27	290	66	224	0.015
DM 606	12/17/91	1156.22	1161.05	-4.83	370	45	325	-0.015
MP 03	10/24/90	1187.77	1187.77	0	158	36.5	121.5	0.000
MP 09	07/03/91	1183.88	1184.00	-0.12	161	36	125	-0.001
MP 11	07/03/91	1183.50	1183.44	0.06	158	28.25	129.75	0.000
MP 13	02/06/91	1182.85	1181.11	1.74	163.5	24.5	139	0.013
MP 16	07/03/91	1164.21	1162.35	1.86	162.5	33	129.5	0.014
MP 20	10/24/90	1189.27	1188.62	0.65	250	34	216	0.003
MP 25	07/03/91	1188.88	1187.27	1.61	246	34	212	0.008
MP 28	07/01/91	1187.66	1188.34	-0.68	136	38	98	-0.007
MP 30	01/08/91	1187.58	1186.64	0.94	166	42	124	0.008
MP 36	07/03/91	1187.56	1183.76	3.8	162.5	35.5	127	0.030
MP 49	07/12/90	1152.92	1156.10	-3.18	249	41	208	-0.015

**Table 3.1 (Continued)**

Well	Date	Lower Port	Upper Port	Difference	Depth of Lower Port	Depth of Upper Port	Difference	Gradient
MP 50	11/13/89	1147.13	1147.80	-0.67	249.5	44.5	205	-0.003
MP 51	11/13/89	1143.02	1142.01	1.01	241	41	200	0.005
MP 52	09/09/86	1138.92	1144.46	-5.54	342.5	53	289.5	-0.019
MP 53	11/13/89	1149.60	1152.01	-2.41	249	45	204	-0.012

**Table 3.2**

**AQUIFER TEST RESULTS\***

Well	Method	Q gpm	b ft	T gpd/ft	T ft <sup>2</sup> /d	K ft/d	S
DM 504OB1	Theis Rec.	60	45	11,445	1,530	34	0.021
DM 504OB1	Jacob	60	155	65,888	8,808	57	0.0017

\* A discussion of the Aquifer Test results is included in Appendix F.

**Table 3.3**

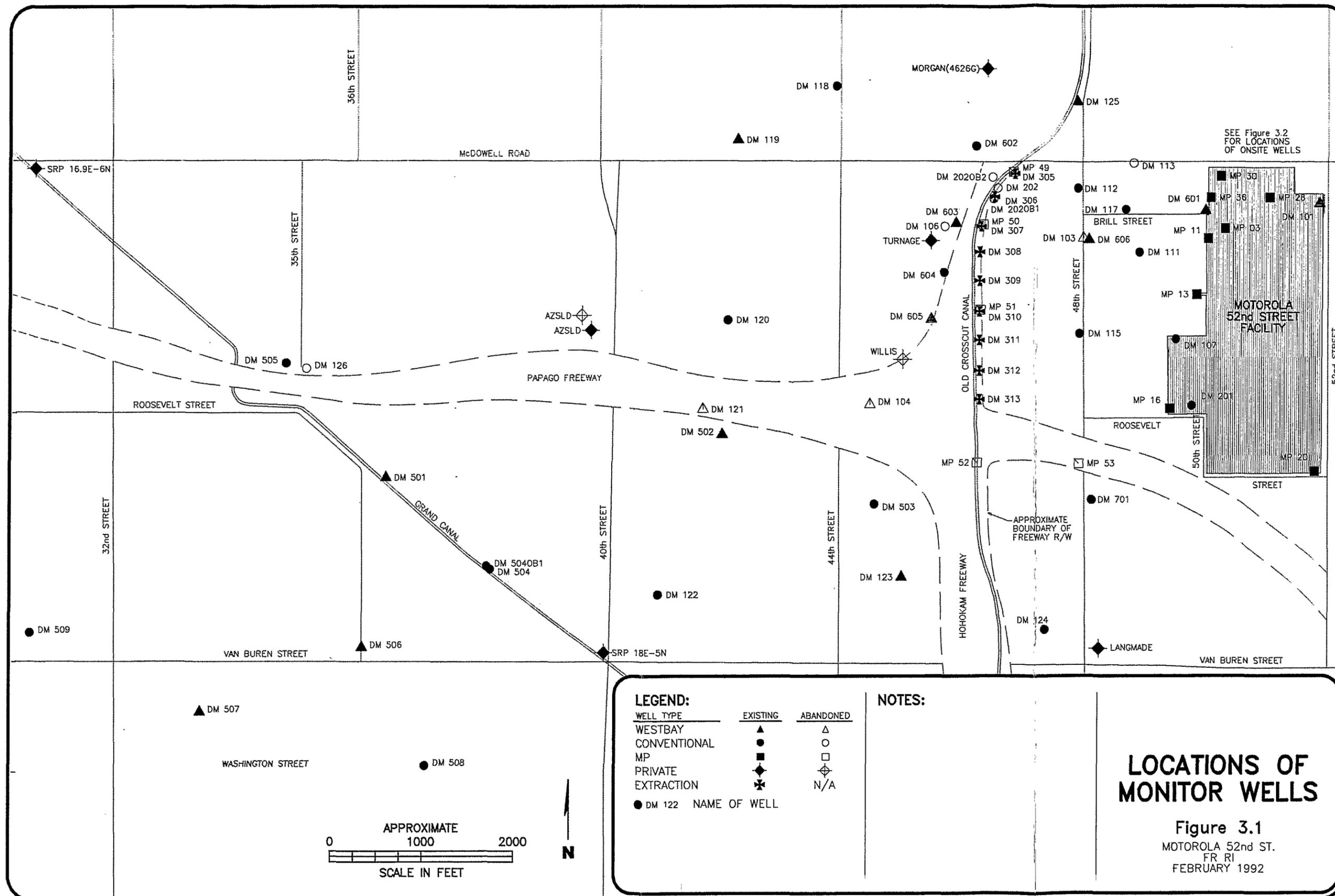
**HYDRAULIC CONDUCTIVITY (K) IN ALLUVIUM  
BASED ON RISING HEAD TEST DATA**

Well	Mean k (ft/day)	Range of k (ft/day)
DM 501	2.95	1.5 to 4.4
DM 502	7.0	4.2 to 9.8
DM 506	3.25	3.0 to 3.5
DM 507	7.3	7.3

**Table 3.4**

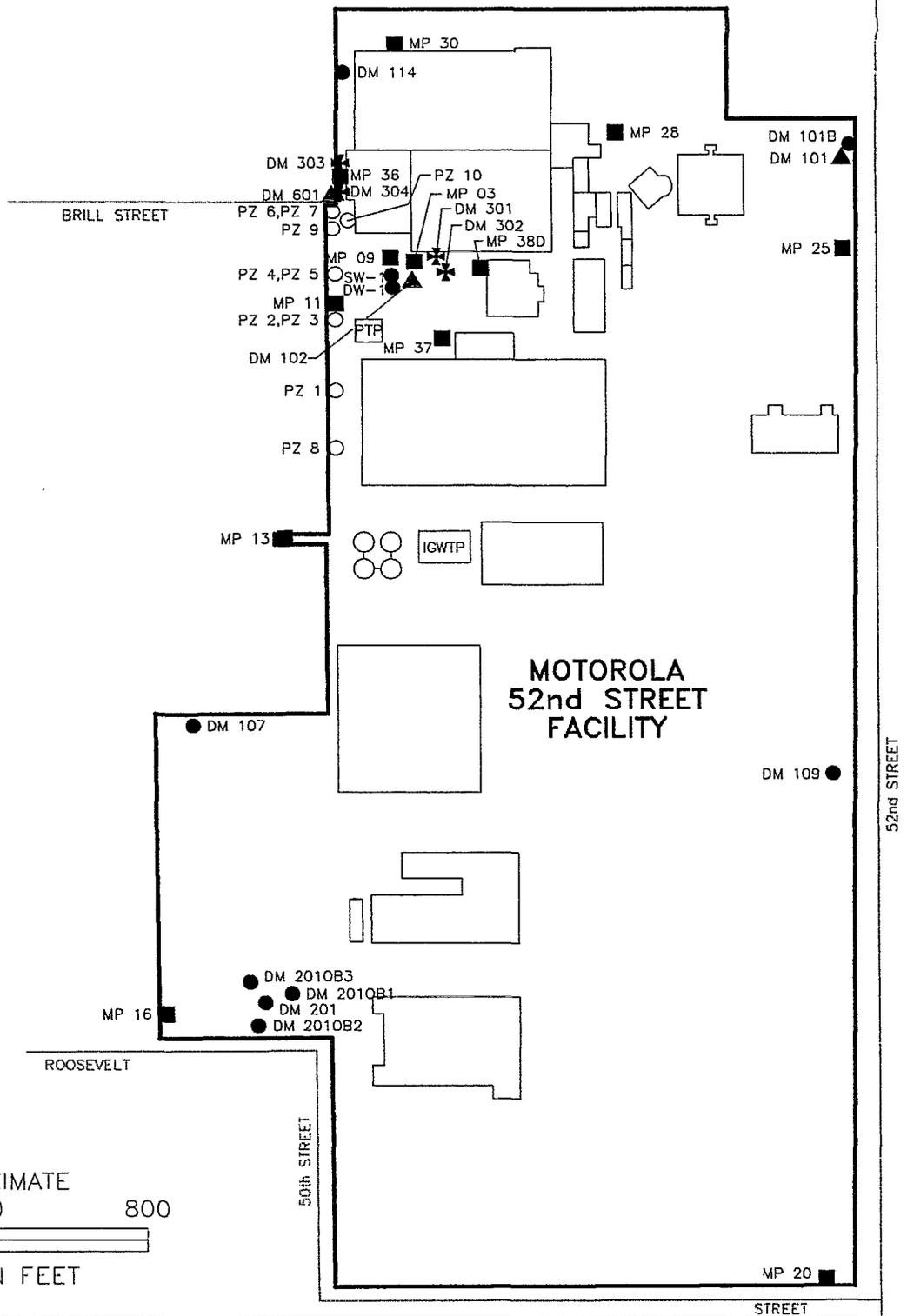
**HYDRAULIC CONDUCTIVITY (K) IN BEDROCK  
BASED ON RISING HEAD TEST DATA**

Well	Mean k (ft/day)	Range of k (ft/day)
DM 501	0.28	0.063 to 0.39
DM 502	0.02	0.0037 to 0.045
DM 506	0.0014	0.00087 to 0.0014
DM 507	0.01	0.0029 to 0.014



# LOCATIONS OF MONITOR WELLS

Figure 3.1  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992



**LEGEND:**

WELL TYPE	
WESTBAY	▲
CONVENTIONAL	●
MP	■
EXTRACTION	✱
PIEZOMETER	○
✱ DM 301	NAME OF WELL

**NOTES:**

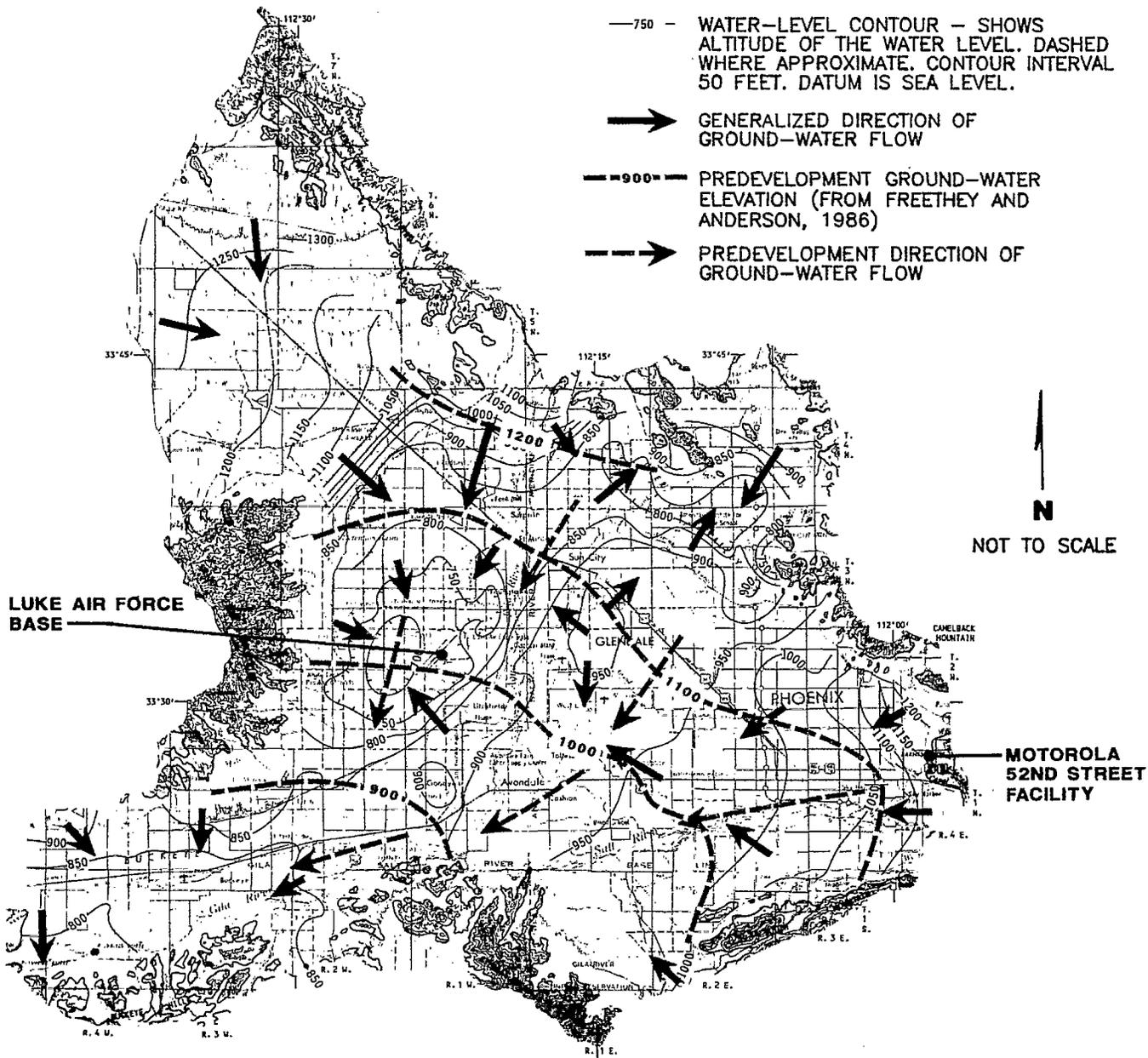
1. See Appendix C, Table C1.2 for well construction details.
2. See Section 4.1 for complete definition of well types.

**LOCATION OF ONSITE MONITOR WELLS**

**Figure 3.2**  
 MOTOROLA 52nd ST.  
 FR RI  
 FEBRUARY 1992

**LEGEND:**

-  UNCONSOLIDATED SEDIMENTARY DEPOSITS INCLUDES UPPER, MIDDLE, AND LOWER UNITS
-  RED UNIT, EXTRUSIVE ROCKS, AND CRYSTALLINE ROCKS
-  -750 - WATER-LEVEL CONTOUR - SHOWS ALTITUDE OF THE WATER LEVEL. DASHED WHERE APPROXIMATE. CONTOUR INTERVAL 50 FEET. DATUM IS SEA LEVEL.
-  GENERALIZED DIRECTION OF GROUND-WATER FLOW
-  -900- PREDEVELOPMENT GROUND-WATER ELEVATION (FROM FREETHEY AND ANDERSON, 1986)
-  PREDEVELOPMENT DIRECTION OF GROUND-WATER FLOW



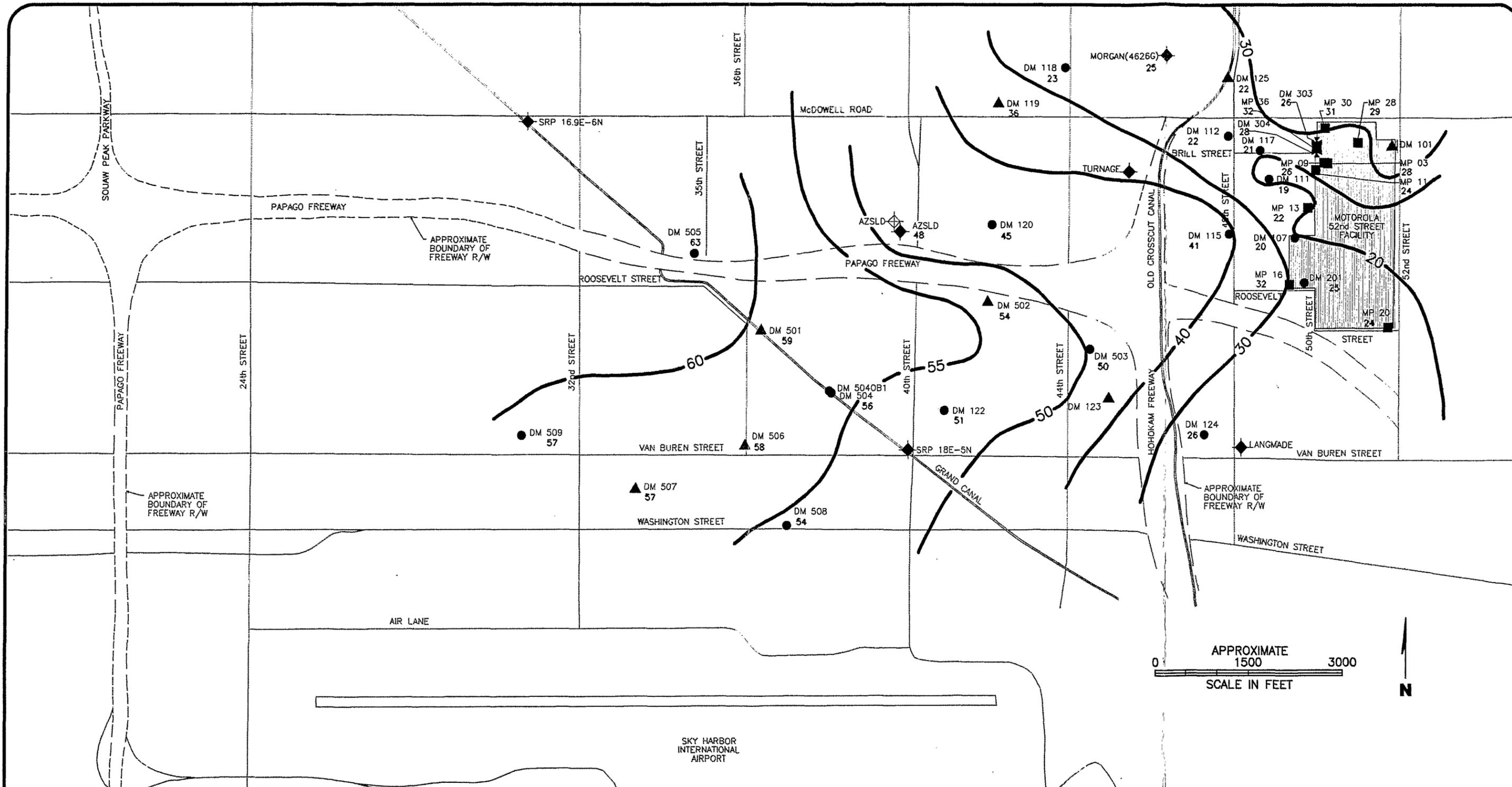
**REFERENCE:**

Brown, J.G., and Pool, D.R., 1989, Hydrogeology of the Western Part of the Salt River Valley Area, Maricopa County, Arizona; Water Resources Investigations Report 88-4202, sheet 1.  
 Freethey, G.W., and Anderson, T.W., 1986, Predevelopment Hydrologic Conditions in the Alluvial Basins of Arizona and Adjacent Parts of California and New Mexico; U.S. Geologic Survey, Hydrologic Investigations Atlas HA-664.

**REGIONAL GROUND-WATER  
CONDITIONS**

Figure 3.3  
 MOTOROLA 52nd ST.  
 FR RI  
 FEBRUARY 1992

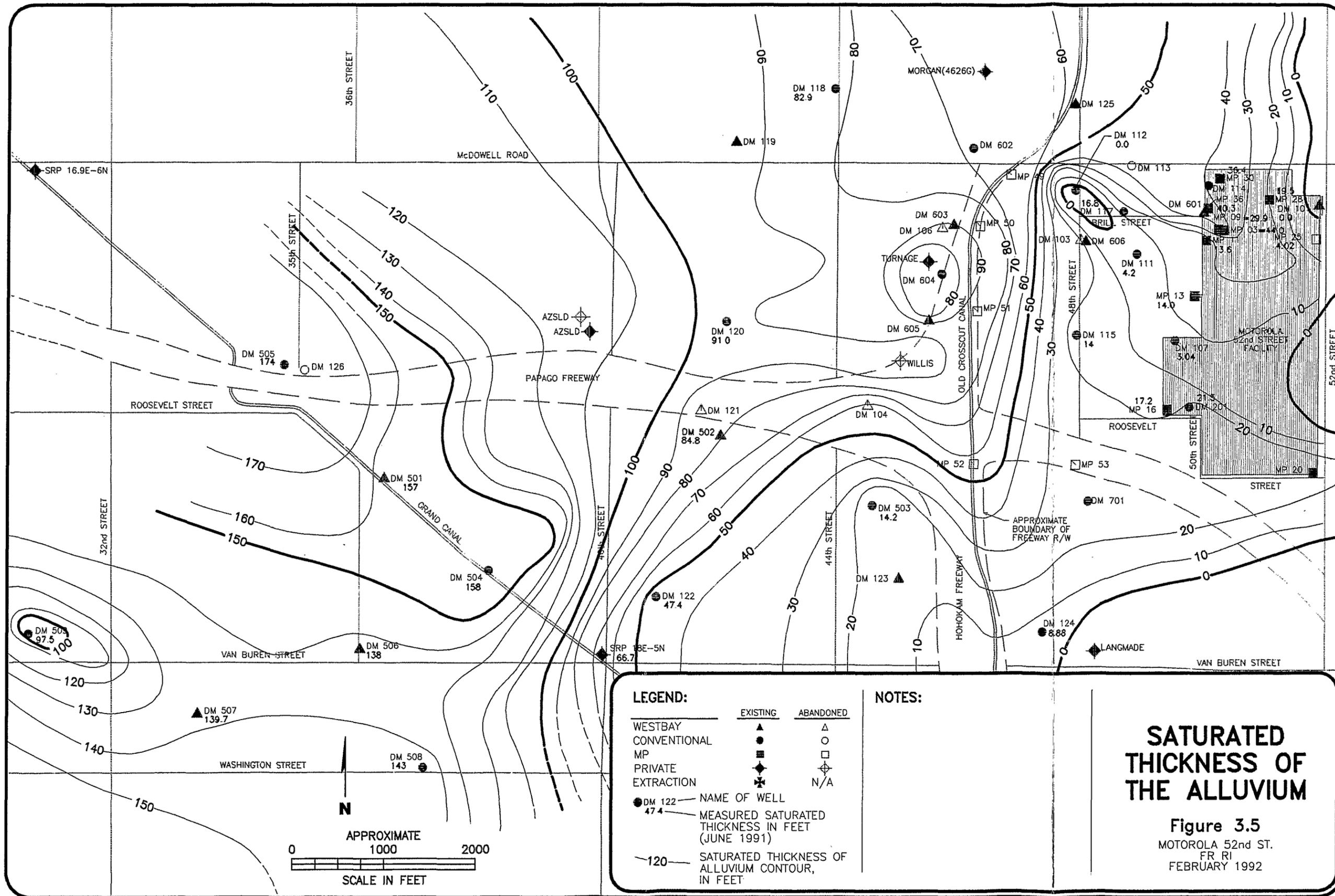




LEGEND:		NOTES:	
WELL TYPE	EXISTING		
WESTBAY	▲		
CONVENTIONAL	●		
MP	■		
PRIVATE	◆		
EXTRACTION	✱		
● DM 120	— NAME OF WELL		
45	— DEPTH TO WATER (FEET)		
	— JUNE 1991		
—50—	— DEPTH TO WATER CONTOUR (FEET)		

**APPROXIMATE DEPTH TO WATER TABLE**

Figure 3.4B  
 MOTOROLA 52nd ST.  
 FR RI  
 FEBRUARY 1992



**LEGEND:**

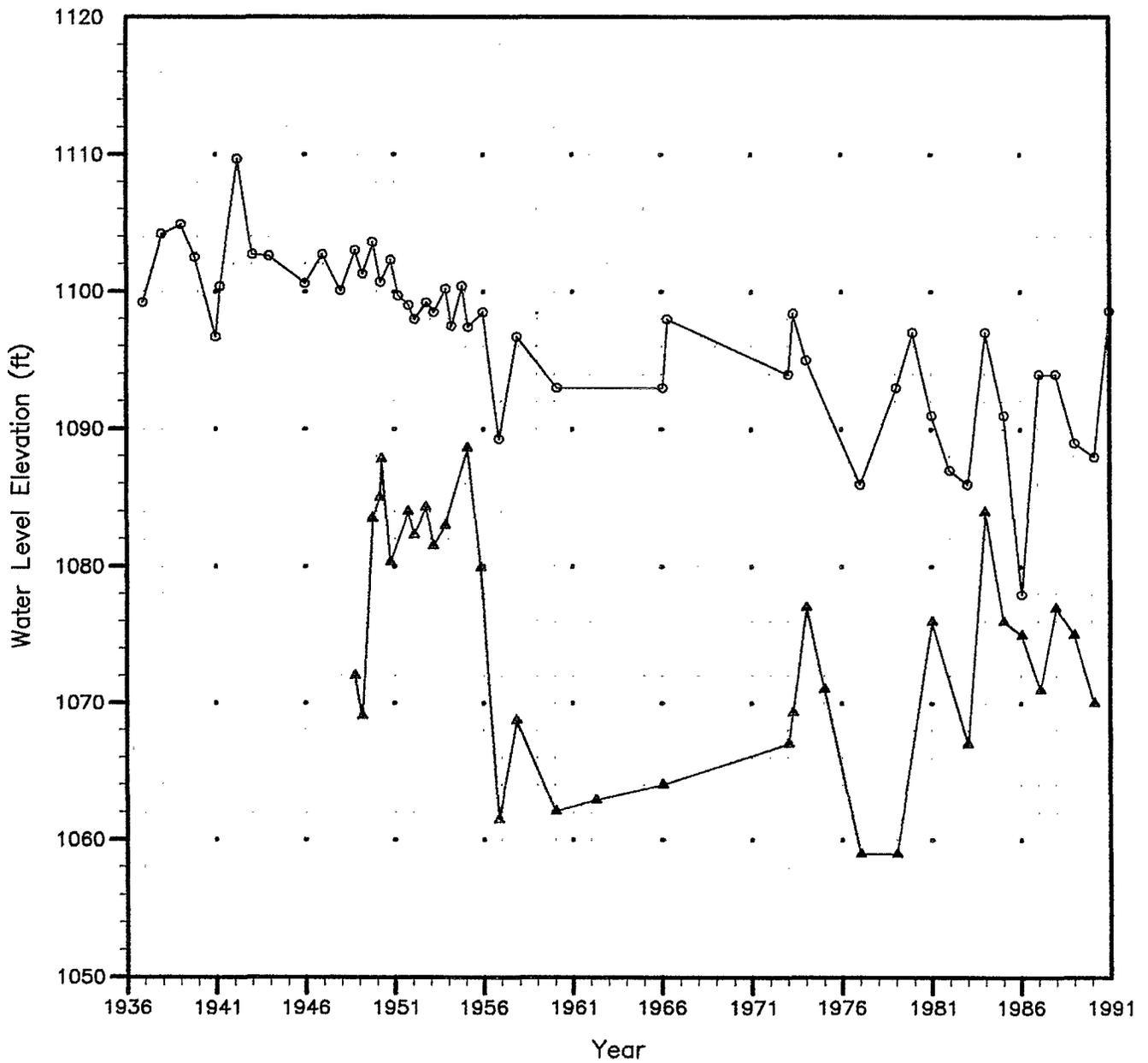
	EXISTING	ABANDONED
WESTBAY	▲	△
CONVENTIONAL	●	○
MP	■	□
PRIVATE	◆	◇
EXTRACTION	✱	N/A
● DM 122 47.4	NAME OF WELL	
— 120 —	MEASURED SATURATED THICKNESS IN FEET (JUNE 1991)	
— 120 —	SATURATED THICKNESS OF ALLUVIUM CONTOUR, IN FEET	

**NOTES:**

APPROXIMATE BOUNDARY OF FREEWAY R/W

**SATURATED THICKNESS OF THE ALLUVIUM**

**Figure 3.5**  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992



**LEGEND:**

- 18E-5N
- ▲—▲—▲ 16.9E-6N

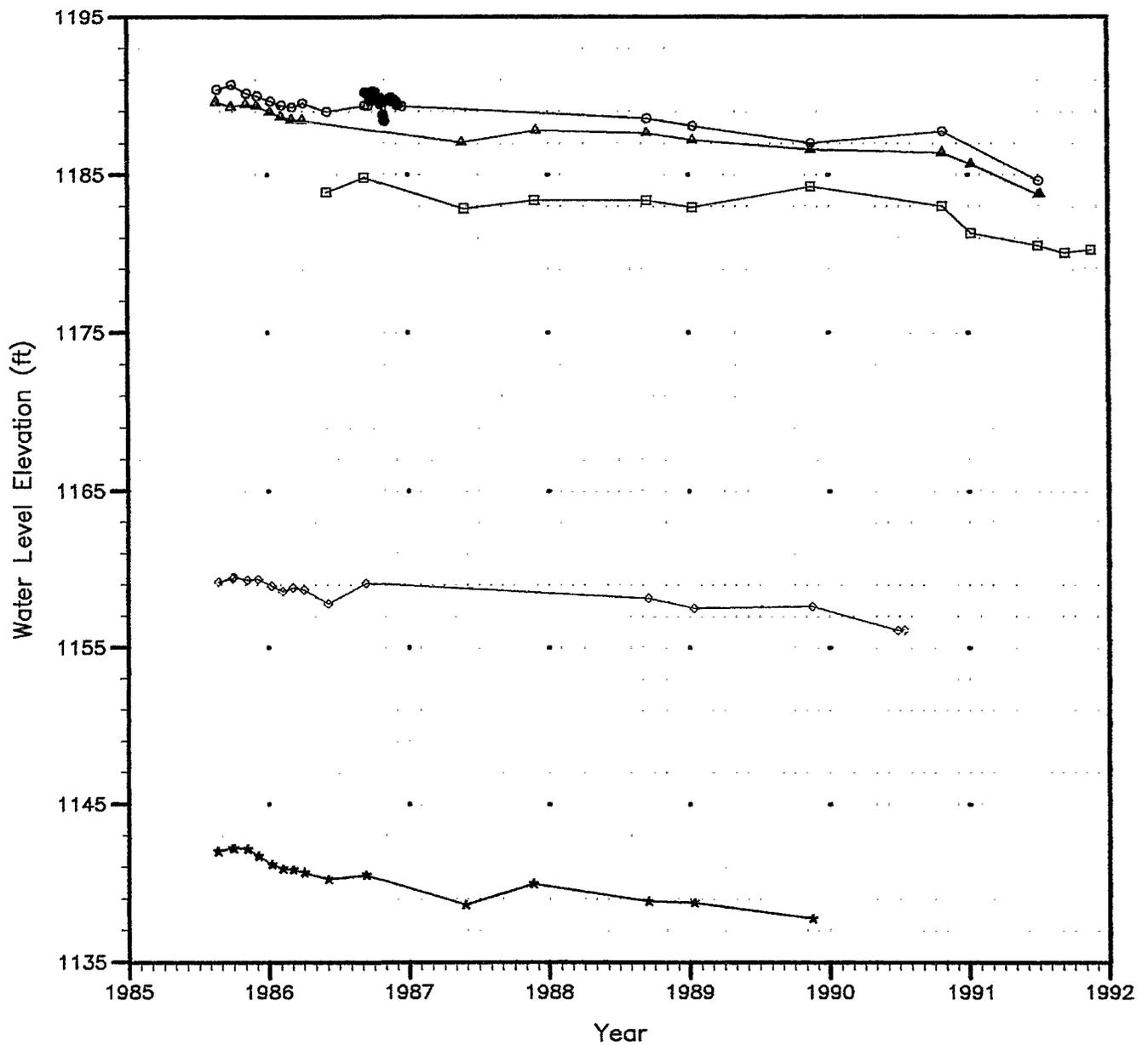
**WATER ELEVATION HISTORIES  
FOR SELECTED WELLS  
(18E-5N AND 16.9E-6N)**

**NOTE:**

Data presented in Appendix G

**Figure 3.6A**

MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992



**LEGEND:**

- MP 03A
- ▲—▲—▲ MP 36A
- DM 117
- ◇—◇—◇ MP 49A
- \*—\*—\* MP 52B

**NOTE:**

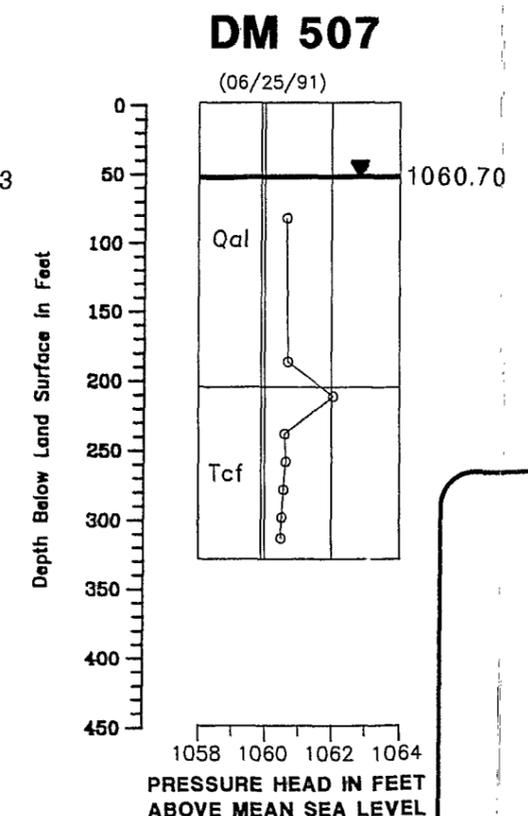
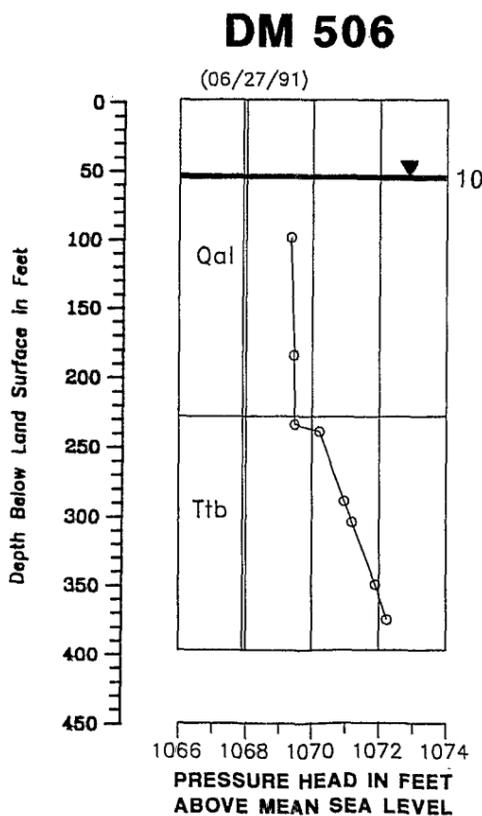
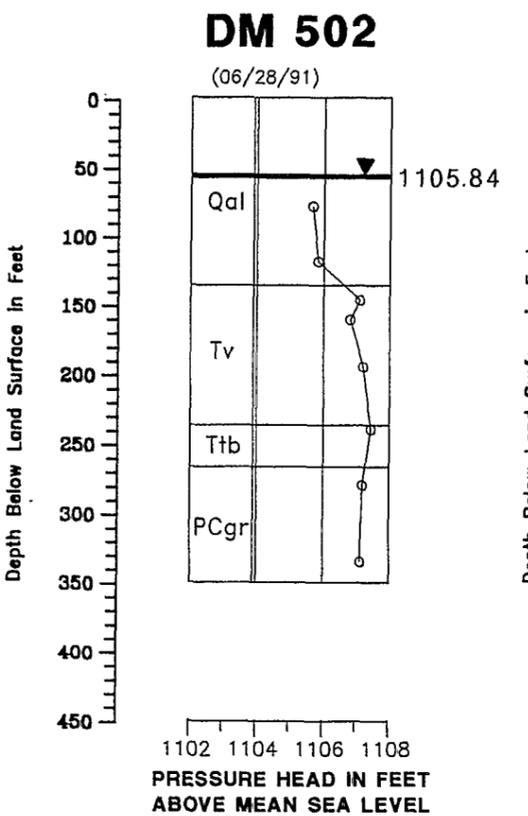
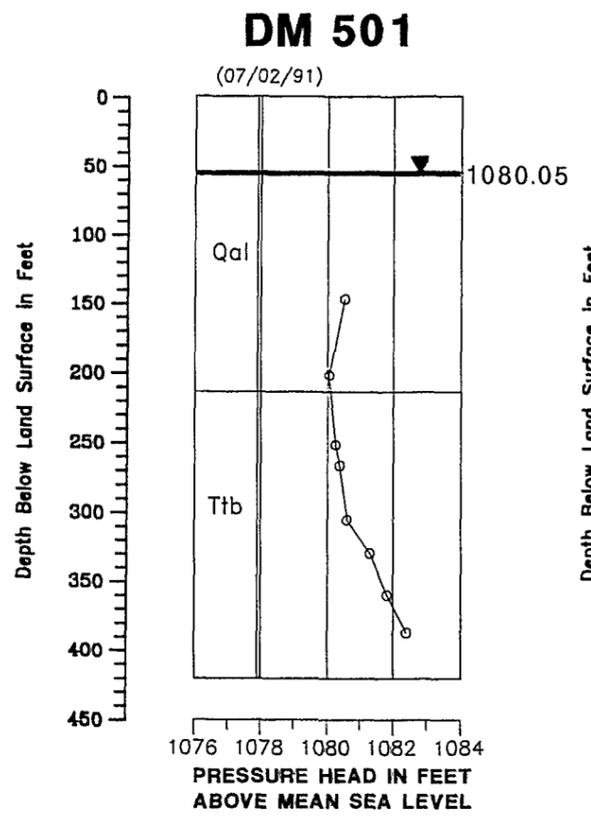
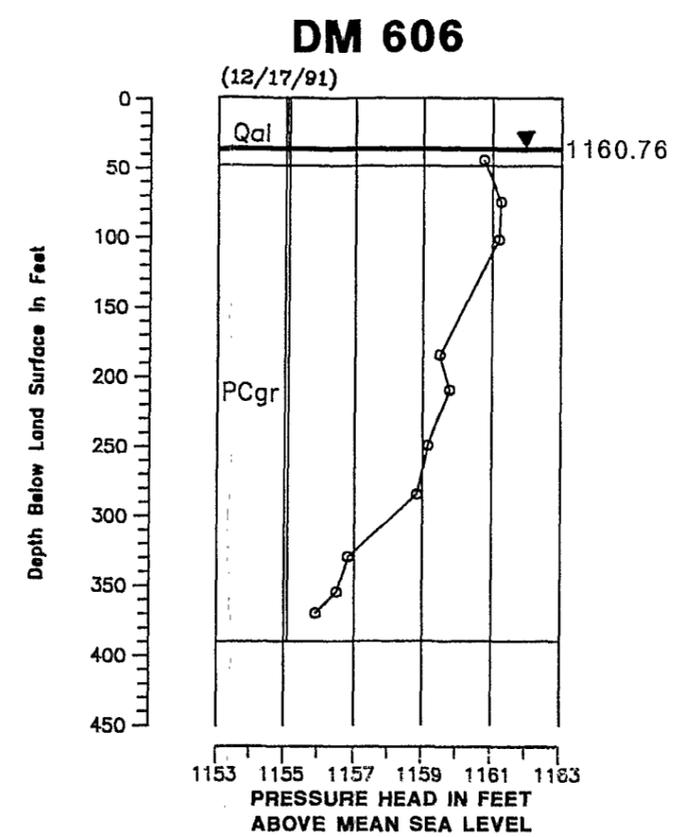
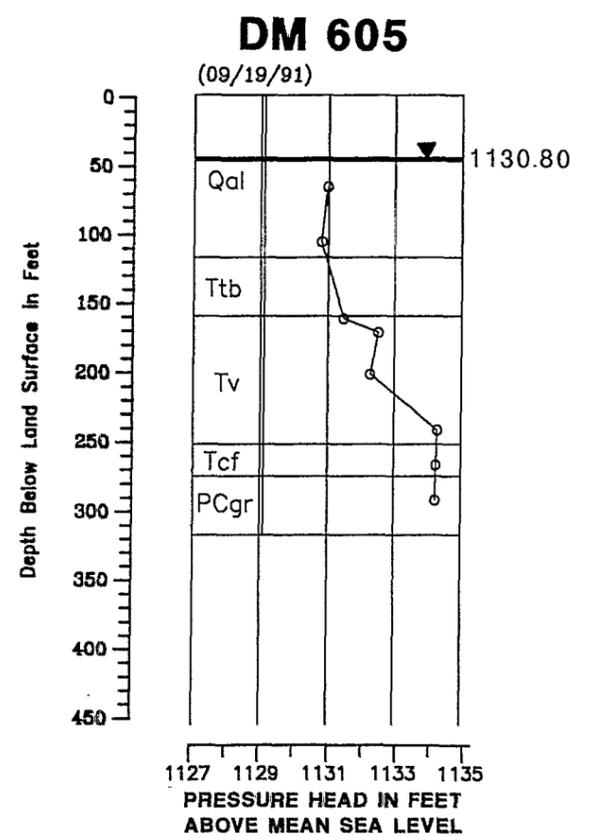
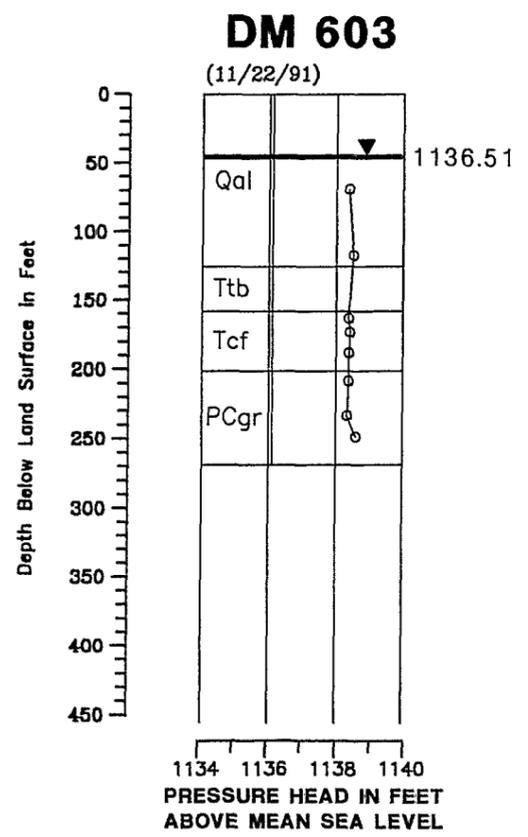
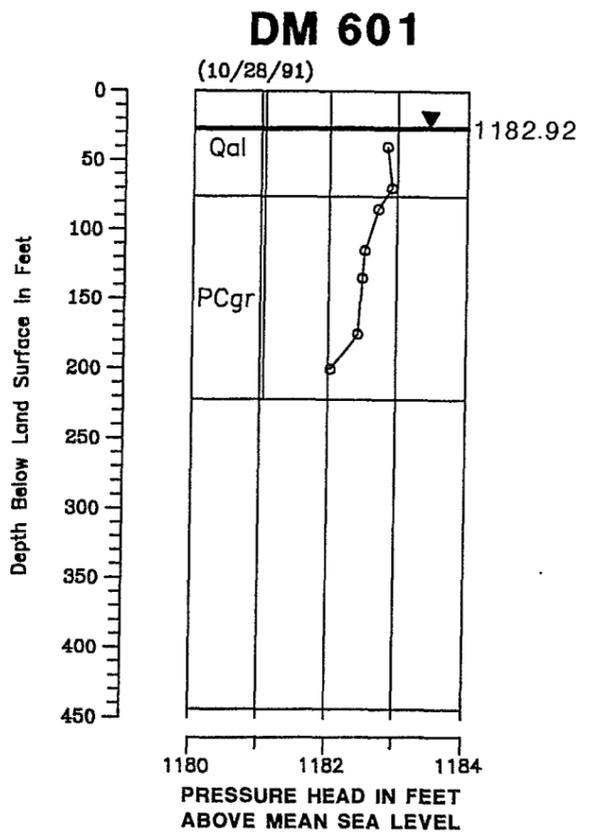
Data presented in Appendix G

## WATER ELEVATION HISTORIES FOR SELECTED WELLS

(MP 03A, MP 36A, DM 117,  
MP 49A, AND MP 52B)

**Figure 3.6B**

MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992



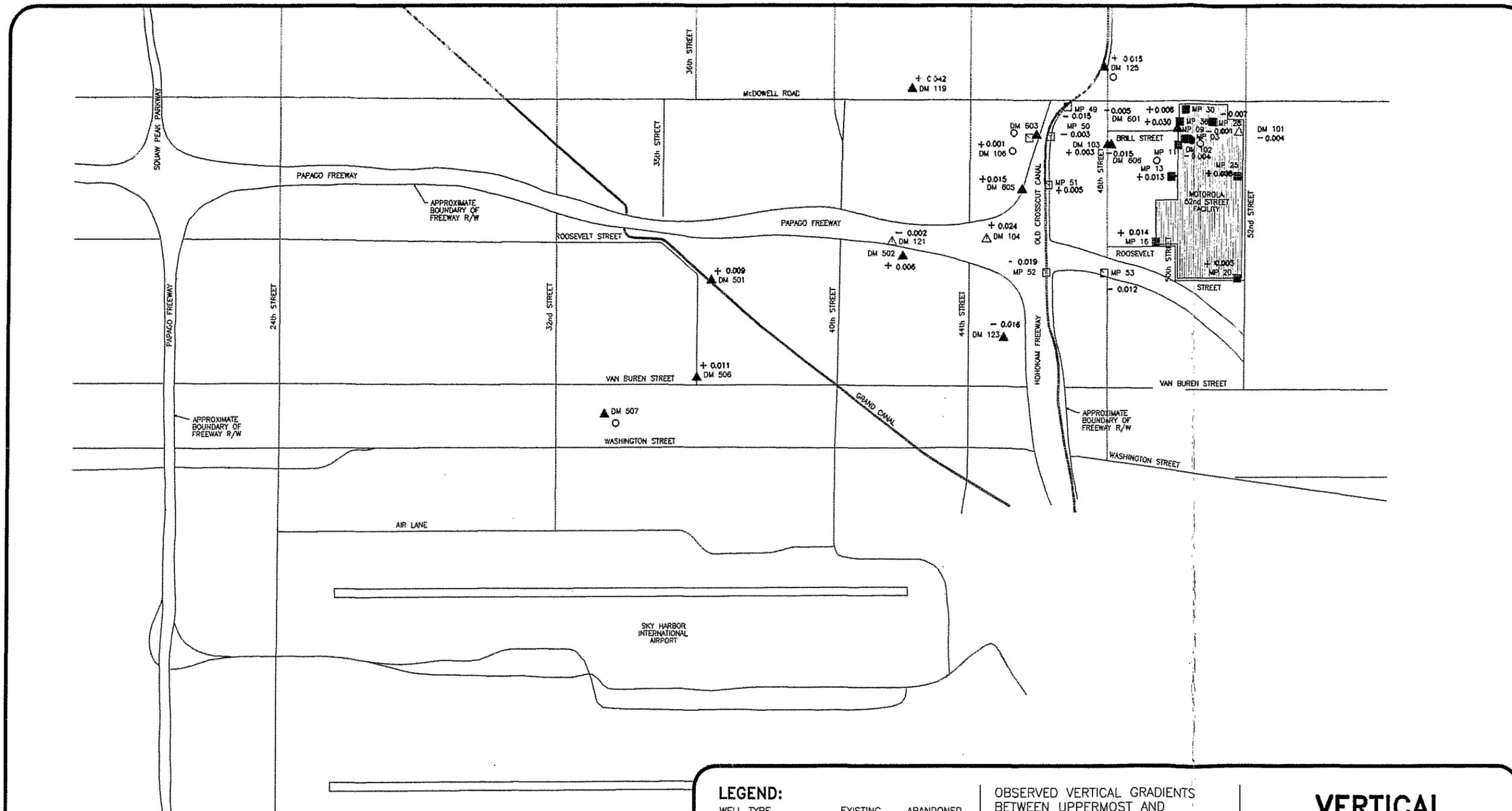
**LEGEND:**

- WELL PORT MEASUREMENT
- (07/02/91) DATE MEASURED
- Qal ALLUVIUM
- Tv VOLCANICS
- Ttb TEMPE BEDS
- Tcf CAMELS HEAD FORMATION
- Pcg GRANITE

**NOTE:** See Figure 3.1 for well locations.

**VERTICAL DISTRIBUTION OF PRESSURE HEADS MULTI-PORT WELL INSTALLATIONS**

Figure 3.7  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992



**LEGEND:**

WELL TYPE	EXISTING	ABANDONED
WESTBAY	▲	△
CONVENTIONAL	●	○
MP	■	□
PRIVATE EXTRACTION	◆	◇
	✦	N/A
DM 122	NAME OF WELL	

OBSERVED VERTICAL GRADIENTS BETWEEN UPPERMOST AND LOWERMOST COMPLETION INTERVALS

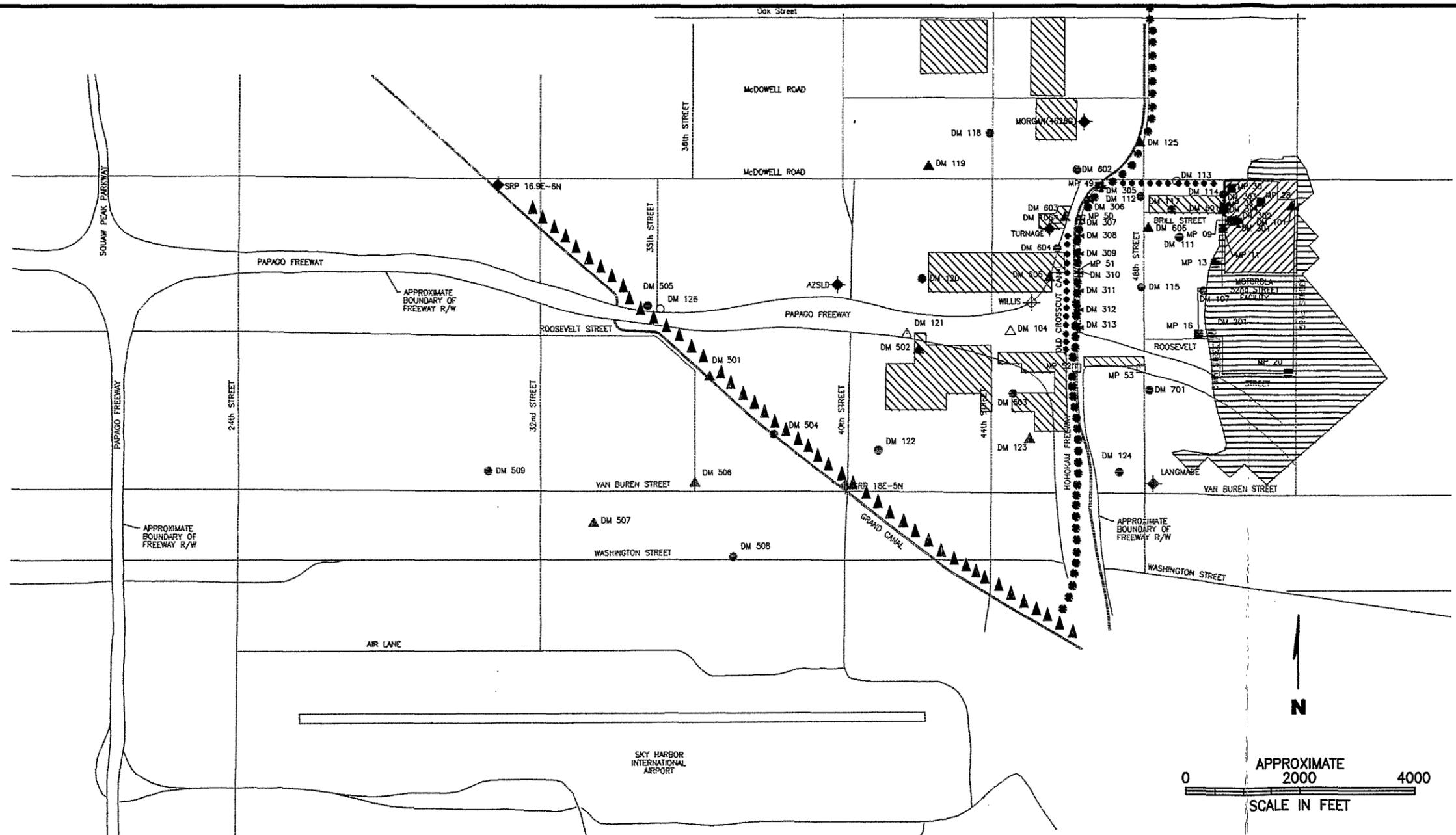
- + 0.005 UPWARD
- 0.011 DOWNWARD
- NO SIGNIFICANT VERTICAL GRADIENT

**NOTES:**

1. See Table 3.1 for data.

**VERTICAL HYDRAULIC GRADIENT DISTRIBUTION**

**Figure 3.8**  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992



**LEGEND:**

-  RECHARGE FROM FLOOD IRRIGATION OF LAWNS (80 ACRE-FEET/YEAR)
-  RECHARGE FROM THE CROSSCUT CANAL (39 ACRE-FEET/YEAR)
-  RECHARGE FROM LATERALS (4 ACRE-FEET/YEAR)
-  RECHARGE FROM MOTOROLA FACILITY SOURCES (41 ACRE-FEET/YEAR)
-  RECHARGE FROM NATURAL PRECIPITATION AND RUNOFF (99 ACRE-FEET/YEAR)
-  RECHARGE FROM THE GRAND CANAL (91 ACRE-FEET/YEAR)

**NOTES:**

1. Recharge amounts are estimates for calculation domain of ground-water model for 1991.
2. For purpose of ground-water modeling, recharge is assumed to take place uniformly over indicated areas.

**GROUND-WATER RECHARGE AREAS**

**Figure 3.9**  
 MOTOROLA 52nd ST.  
 FR RI  
 FEBRUARY 1992

## 4.0 VOC CHARACTERIZATION

### 4.1 INTRODUCTION

Volatile organic compounds (VOCs) in ground water have been the primary focus of previous investigations in the vicinity of the Motorola 52nd St. Facility. This chapter provides an overview of VOC characterization studies conducted since completion of the 1987 Draft Remedial Investigation (RI) with an emphasis on the downgradient portion of the VOC plume. The primary purpose of the FR RI is to define the downgradient extent and geometry of VOC contamination in ground water.

The ground-water monitor well network is depicted on Figures 3.1 and 3.2 and has included a total of about 80 monitor wells and 13 extraction wells. Of these wells, many are constructed to allow sampling of more than one monitoring zone. With the multi-port completions, a total of about 270 monitoring ports have comprised the historical monitor well network. Since completion of the 1987 Draft RI Report, a total of 15 monitor wells have been abandoned due to highway construction activities. Seventeen new monitor wells have been installed since November 1990.

Nine of the new monitor wells were installed to evaluate downgradient areas of the plume and were designated DM 501 through DM 509; one observation well, DM 5040B1, was also installed for an aquifer pump test. Six new monitor wells, given DM 600-series designations, were installed as part of the Operable Unit (OU) monitoring system. The DM 600-series wells were sampled in the fall of 1991 to provide a baseline for the OU operation. Well DM 701 was installed along 48th Street southwest of the 52nd St. Facility, and is used to monitor water quality downgradient of the facility.

In addition, 13 extraction wells have been installed as part of the Operable Unit extraction system and are used for evaluation of water quality. Including all extraction wells and

monitor zones in multi-port wells, there are about 190 available sampling locations in the Motorola 52nd St. monitor well network.

A summary of all wells plus a description of the construction details for the recently installed monitor and extraction wells is included in Appendix A. In general, there are three types of monitor wells: 1) single-completion wells with one sampling interval; 2) multiple-completion wells (MP wells) with several casing strings nested in the same borehole; and 3) multiple-completion wells with a single casing string containing multiple sampling ports. The first two types of wells have a screened section within a gravel-packed zone that is usually about 20 to 80 feet long. The third type of well is constructed using Westbay™ casing, with numerous sampling ports that are about 20 to 60 feet apart.

The wells that are used to monitor both alluvium and bedrock are the MP and Westbay™ wells. Sampling levels in the MP wells are identified by the well number and a letter code; levels A and B are usually in the alluvium, and levels C, D, and E are usually in the bedrock. Sampling levels in the Westbay™ wells are identified by the well number with the port depth below ground surface indicated in feet. All single-completion wells are denoted by a well number without a depth or letter designation.

Eight sampling rounds have been conducted from plume definition monitor wells since completion of the 1987 Draft RI Report. Data analyzed in the 1987 Draft RI Report were obtained through 1986 and are referred to in this report as the "RI" data. "Post-RI" data refer to measurements made after 1986 which were not included in the 1987 Draft RI. These distinctions have been made to facilitate comparison of older and more recent data and do not imply any difference in data accuracy or collection and analytical procedures. Sampling included monitor wells specified in the monitoring plan described in "Task Specification, Long-Term Ground Water Sampling Program for the Motorola Inc. 52nd St. RI/FS" dated May 12, 1987 (Dames & Moore, 1987a). The monitor wells included in each round have changed as wells were abandoned and new wells installed. During the sampling round conducted in June 1991,

a total of 16 wells and 72 monitoring zones were sampled. The data generated from this investigation were used in conjunction with ground-water modeling to evaluate the contaminant plume geometry. The results of the modeling analyses are described in Chapter 6.0.

Operable Unit monitor wells and OU extraction wells were sampled between October and December 1991 to establish a baseline of water level and water quality data. The results will be used for comparison with sample analytical results and water level measurements collected after startup of the OU extraction system.

Three rounds of samples have been collected for the OU program; one each in the months of October, November, and December 1991. The analytical results from the first two rounds are included with this report (see Appendix E). Analytical results from the third round were not received in time to include here, but will be submitted when available.

The following discussions and graphical presentations include results of the OU baseline sampling. Section 4.2 provides a brief review of the procedures and methods used during the water quality investigation. Sections 4.3 and 4.4 summarize the ground-water quality VOC characteristics for the near-plant and far-field areas, respectively. The **near-plant area** is defined, for the purposes of this discussion, as extending from the 52nd St. Facility west to the Old Crosscut Canal (OCC). This area has been singled out from the far-field area for several reasons: (1) a more extensive, and lengthy investigation of water quality has occurred east of the OCC; (2) the Operable Unit is being implemented east of the OCC; and (3) the more recent, new data base used to define downgradient contamination has been obtained west of the OCC. The area west of the OCC extending southwest of the Grand Canal is defined as the **far-field area**.

The water quality data described in the following paragraphs are presented in tabular and graphical form in Appendices E1, E2, and E6. Appendix E5 presents the results of quality assurance/quality control (QA/QC) data.

Ground-water sampling results which have been conducted in the vicinity of the Southwest Parking Lot (SWPL) of the 52nd St. Facility are discussed in Attachment SW. As stated in the Introduction, Chapter 1.0, greater concentrations of VOCs were recently noted in the SWPL area, prompting additional investigations. Because the investigation of the SWPL area is ongoing at the time of this report (February 1992), the results are to be considered preliminary, and have been presented separately in the Attachment. It is planned to expand the discussion of the SWPL when the investigation is near completion, and to update Attachment SW.

#### 4.2 PROCEDURES AND METHODS

The procedures used for collection of ground-water samples are described in the "Draft Sample Collection and Analysis Plan, Final Remedy RI/FS, Motorola 52nd St. (Dames & Moore, 1990j). The procedures used to conduct the ground-water sampling prior to October 1990 were described in "Task Specification for Water Sampling and Analysis" (Dames & Moore, 1985m) and in "Task Specification; Long-Term Ground-Water Sampling Program, 52nd Street RI/FS" (Dames & Moore, 1987a).

The objectives of the Sampling and Analysis Program, as defined in the Task Specifications, are to:

- Routinely sample ground-water monitor wells and measure the concentrations of organic contaminants that occurred above detection limits during the RI/FS.
- Measure concentrations of inorganic cations, anions, and metals in onsite and offsite ground-water monitor wells.

For this discussion, "onsite" refers to the Motorola Inc. property at the 52nd St. Facility.

EPA Method 601 was used to analyze ground-water samples for 36 volatile organic compounds. Both laboratory and field quality control procedures were followed during

the Final Remedy RI. The quality assurance/quality control procedures are described in the "Draft Sample Collection and Analysis Plan, Final Remedy RI/FS" (Dames & Moore, 1990j), and the QA/QC data are presented in Appendix E5. Qualifications have been made to the data presented in Appendix E that describe when a sample result does not meet EPA specified criteria.

Federal and State drinking water quality standards have been established or proposed for a number of the VOCs analyzed using EPA Method 601. Table 4.1 presents a list of the VOC compounds analyzed and their respective Federal Maximum Contaminant Levels (MCL), proposed Federal MCL, and/or ADEQ (State of Arizona) MCL concentrations. As shown in Table 4.1, the ADEQ MCL concentrations are the same as the Federal MCLs for the compounds listed.

### **4.3 WATER QUALITY CHARACTERISTICS: NEAR-PLANT AREA**

#### **4.3.1 Introduction**

The near-plant area includes the area defined as the OU which encompasses the Facility and the area east of the OCC. The source for VOC migration to the ground water has been assumed to occur primarily in the Courtyard area of the Motorola 52nd St. Facility. In May 1986, extraction wells DM 301 and DM 302 were installed in the Courtyard in conjunction with construction of the Pilot Treatment Plant (PTP). In September 1986, pumping and treatment of contaminated ground water from the extraction wells began, and continues into 1992.

#### **4.3.2 Pilot Treatment Plant Operation**

The PTP has been in operation since 1986, treating water from wells DM 301 and DM 302, the well located immediately downgradient of the former leaking underground TCA storage tank. Pumping rates have varied over the years. Initially, the instantaneous pumping rate ranged between 15 and 25 gpm, but was not maintained continuously. Usually, pumping varied

from 24 to 8 hours per day, and from 7 to less than 5 days per week. By mid-1988, the nominal pumping rate was approximately 10 gpm, mainly from well DM 302. The impact of pumping on ground-water VOC concentrations is depicted in Figure 4.1, which is a graphical plot of selected VOC influent concentrations to the PTP versus time. The change in the active pumping rate with time is depicted in Figure 4.2 and was developed by evaluation of totalizing flow meter readings at the PTP.

The concentrations of TCA and other VOCs entering the PTP vary with time (see Table E6.14). Average TCA concentrations varied from as low as approximately 8,000 ppb to greater than 50,000 ppb, the greatest concentrations occurring initially. TCE and other VOCs varied from a low of about 2,400 ppb to a high of about 6,000 ppb.

In general, the concentration of TCA influent to the PTP decreased from greater than 50,000 ppb in 1987 to approximately 16,000 ppb in early 1988. Since 1988, and coincident with a decrease in both the duration and rate of pumping, TCA influent concentrations appear to have stabilized. The larger changes in TCA concentrations are attributed to the proximity of well DM 302 to the former leaking TCA tank.

#### 4.3.3 TCE and TCA Concentration Trends

The ethylene concentrations versus time for select onsite wells in the alluvium are depicted in Figure 4.3. These wells are located in the vicinity (MP 11A), or directly downgradient of the principal TCA source (No. 25) or TCE source (No. 2) (see source designations on Table 1.1 and 1.2, and on Figure 1.2). To reiterate, ethylenes are considered to be the sum of TCE, TDCE and DCE. The summation of ethylenes is used to account for the effects of chemical and biological degradation of TCE. Similarly, DCE concentrations, a degradation product of TCA, are added to TCA concentrations to examine TCA migration. Note that in the following discussion there is no attempt to distinguish TCE-derived DCE from TCA-derived DCE. Thus, in the near-plant area where the relatively recent release of TCA from

Source 25 has impacted ground water, the ethylene summation could include a component of TCA-derived DCE. In the far-field area, the component of TCA-derived DCE is less because the effect of the Source 25 release does not extend as far downgradient. Degradation and its effects on VOC concentrations observed in ground water are discussed more fully in subsequent paragraphs.

In general, ethylene concentrations have declined since water quality data were first obtained at monitor wells installed between 1983 and 1985. The decline in concentrations may be due to onsite pumping activities or to other (geochemical) mechanisms. The decline in VOC concentrations shown in Figure 4.3 is similar to the ethylene concentrations observed in offsite wells. This phenomenon is discussed in more detail in the following paragraphs.

Figure 4.4 depicts the change in ethylene concentrations for select wells in both the alluvium and bedrock located in the near-plant area, immediately downgradient of the 52nd St. Facility but upgradient of the Old Crosscut Canal (OCC). Concentrations of ethylenes have declined in these wells since water quality measurements began in 1986. A comparison of mean ethylene concentrations reported in the 1987 Draft RI (Dames & Moore, 1987b) and mean ethylene concentrations measured in post-RI sampling rounds (see Table 4.2) indicate that ethylene concentrations have declined by a factor of about 4 in alluvium and about 10 in bedrock.

#### **4.3.4 Evaluation of Concentration Declines**

Pumping from onsite extraction wells may explain declines in VOC concentrations (ethylenes and/or TCA) in wells located in or near the Courtyard. Declines observed in wells farther downgradient from the Courtyard are less easily explained.

Observations made during this investigation indicate that, for some wells, rehabilitation of the well or installation of a nearby well results in a sudden (hours to days) increase in ethylene concentrations. Wells which have exhibited this response include MP 36,

DM 102, DM 120, and, most recently, DM 504. Figures 4.5, 4.6, 4.7, and 4.8 illustrate changes in ethylene concentrations with time for wells MP 36A, DM 102, DM 120, and DM 504, respectively. In each figure, significant development or testing events are indicated in relation to the observed concentration of ethylenes (or TCE in the case of MP 36A).

On Figure 4.5, TCE concentrations in well MP 36A are plotted versus time. TCE concentrations in MP 36A were observed to increase from less than 5,000 ppb to more than 20,000 ppb in late 1985; this change was coincident with renovation and development of the well.

In April 1990, extraction well DM 303 was installed approximately 10 feet north of MP 36. As depicted on Figure 4.5, concentrations of TCE in well MP 36A increased from less than 200 ppb (in December 1989) to more than 5,000 ppb (in June 1990).

Multiport Westbay well DM 102 was installed in January 1985. Figure 4.6 illustrates total ethylene concentrations versus time for several sampling ports in both alluvium and bedrock. In September 1986, ground-water extraction began from onsite wells DM 301 and DM 302. Well DM 102 was sampled frequently during the initial phases of PTP operation to evaluate the affect of pumping on ground-water levels and water quality. Total ethylene concentrations in the 199-foot-deep port in DM 102 increased from approximately 400 to 4,000 ppb between June and December 1986. This change and water quality changes observed at other ports in DM 102 are illustrated on Figure 4.6. Extraction wells DM 301 and DM 302 are located 85 and 40 feet, respectively, from well DM 102. Sampling at DM 102 was discontinued after December 1986 because packers in the well were found to have lost their integrity.

On November 20, 1990, monitor well DM 120 was pumped for 3 hours at a rate of 100 gpm specifically to evaluate the relationship between pumping and water quality changes. During the test, more than 17,000 gallons of water were withdrawn from the well. Figure 4.7 illustrates the changes in total ethylene concentrations versus time for well DM 120. On

November 1, 1990, the measured total ethylene concentration was approximately 90 ppb. After pumping the well on November 20, the total ethylene concentration increased to 172 ppb.

Figure 4.8 illustrates the variations of ethylene concentrations versus time since development of well DM 504 on December 28, 1990. Initial concentrations of ethylenes exceeded 2,000 ppb shortly after development of the well. By May 1991, the average concentration of ethylenes had declined to approximately 800 ppb. An observation well (DM 5040B1) was installed on July 9, 1991. Shortly thereafter, a pumping test was conducted in DM 504. The well (DM 504) was pumped continuously for three days at a rate of approximately 60 gpm as described in Appendix F. Several water quality samples were collected from well DM 504 during the pumping test. The measurements of ethylene concentrations in DM 504 increased to approximately 2,300 ppb after 48 hours of pumping.

The affect of contact between atmosphere in the well and ground water has been evaluated through field studies of VOC concentration changes with increasing purge water volumes. Well purging is conducted prior to sampling to remove stagnant well water and draw undisturbed ground water into the well. The results of initial tests were presented in the Well Evaluation Report (Dames & Moore, 1985a). Since 1985, additional field work has corroborated the 1985 evaluation (see data collected from DM 103-047, DM 103-178, DM 117, DM 120, and MP 16C in December 1989 (Appendix E2). The results of both the 1985 and 1989 field investigations indicate that increasing the volume of purged water to greater than two well volumes prior to sampling does not result in a significant change in VOC concentrations. As a result of this testing, the increased VOC concentrations observed in DM 504 during the June 1991 pumping test are not believed to be related to chemical changes caused by atmospheric oxygen in the well bore prior to the test.

The response of ethylene concentrations in monitor wells after well development or rehabilitation can be compared to the change in concentrations of inorganic constituents over the same interval of time. Appendix E7 (Figures E7.1A through E7.6C) includes graphs of

various inorganic concentrations versus time for selected wells. These figures indicate that in most monitor wells, concentrations of dissolved inorganic constituents do not change with time even in wells where solvent concentrations have declined sharply (e.g. DM 117, MP 36, and DM 120). The inorganic constituents can be influenced by chemical changes around a monitor well caused by contact of ground water with atmospheric oxygen in the well bore. Inorganic concentrations do not vary after emplacement of a monitor well, supporting the assertion that ground water collected for analysis is not chemically altered or disturbed by the atmosphere in the well, and is therefore representative of undisturbed ground water.

Observations obtained from wells MP 36, DM 102, DM 120, and DM 504 illustrate an association between vigorous pumping and VOC concentration changes within the aquifer - a marked decrease in concentrations after pumping. The rapid decrease in VOC concentrations observed in sampling rounds subsequent to installation of many Motorola 52nd St. monitor wells indicate a similar pattern. The installation of a monitor well includes vigorous pumping as part of the installation process. Immediately after a well is installed, the concentration of VOCs in the aquifer surrounding the well may be elevated due to the development pumping. The following decline in VOC concentrations occurs as the aquifer returns to its equilibrium concentration level. Similarly, the initial VOC concentrations measured in a newly installed monitor well may represent non-equilibrium conditions. The non-equilibrium VOC concentrations appear to persist for a period of days to several months.

To summarize, observations which support the association of vigorous pumping and elevated VOC concentrations include the following:

1. VOC concentrations have been observed to increase in monitor wells located near wells which have been pumped due to installation or other activities (see discussion regarding wells MP 36 and DM 102).
2. Vigorous pumping has been associated with VOC concentration increases in wells DM 120 and DM 504.

3. An examination of inorganic water quality associated with wells which have exhibited an increase in VOC concentrations after pumping show no significant changes as a result of pumping. Therefore, exposure of ground water to the atmosphere in the well bore does not significantly affect VOC concentrations.

#### **4.3.5 Near-Plant Concentration Increases**

The measured concentrations of ethylenes increased in one well in the near-plant area, MP 36D, which is located in the bedrock immediately downgradient of the Courtyard area. The concentrations of TCE in MP 36D increased from 178,000 ppb in 1987 to 690,000 ppb in December 1989 (refer to Figure E6.94). The concentration of TCE in MP 36D subsequently declined to 144,000 ppb in June 1991. With this one exception, increases in VOC concentrations have not been observed in the near-plant area.

#### **4.3.6 The Distribution of Solvent Degradation**

Degradation products of TCE and TCA occur at elevated concentrations in several near-plant wells. The degradation of TCE and TCA is discussed in the 1987 Draft RI (Section 4.2.1.4, p. 4-14). Figure 4.2 of the 1987 Draft RI illustrates the various potential degradative pathways for VOCs. Generally, TCE degrades to cis- and trans-1,2-dichloroethylene (TDCE) and 1,1-dichloroethylene (DCE). TCA degrades to 1,1-dichloroethane (DCA). Since completion of the 1987 RI, research has indicated that TCA also degrades to DCE (Cline and Delfino, 1989). Both TDCE and DCE degrade to vinyl chloride (VC), another ethylene isomer.

Degradation of TCE was reported in the 1987 Draft RI as the most likely explanation for the presence of several volatile organic compounds such as TDCE, DCE, and VC that were not known to be used as solvents at the Motorola 52nd St. Facility. Data collected since the 1987 RI from wells in the near-plant area indicate that the degradation process is continuing as shown by data in the Courtyard at well MP 09, and in the vicinity of wells DM

117 and DM 103 in the near-plant area. (For purposes of discussion, the apparent change from one isomer to a related isomer is assumed to be due to biodegradation. Whether this is the correct mechanism is immaterial for this discussion because the transformation of ethylene or ethane isomers occurs in a relatively predictable pattern).

Concentrations of vinyl chloride began to appear in well DM 117 (1,500 ppb) and MP 09 (20,000 ppb) in December 1989 and in well DM 103 (1,000 ppb) in about December 1990 (Figure 4.9). The concentrations of vinyl chloride have remained high in each of the three wells in every sampling round since December 1990. The degradation of "ethylenes" to the isomer vinyl chloride is believed to occur in areas of the aquifer where the ground-water chemistry is advantageous for the development of fermentative anaerobes. Specifically, ground water must be reduced (i.e., have a low oxidation potential), and contain a substrate nutrient to allow the microbes to grow and flourish. These conditions may be induced by the presence of natural sources of reduced water in the bedrock (i.e., local springs and upwellings of deep reduced water along bedrock structures). To test for reducing conditions in ground water, dissolved oxygen and biological oxygen demand (BOD) were measured at selected wells during the June 1991 sampling round. The results are depicted on Figure 4.10. Duplicate measurements were collected and are also depicted on the figure.

Dissolved oxygen measurements ranged from less than 2 mg/l (ppm) to 7.4 ppm (DM 122A). The solubility limit of dissolved oxygen in ground water is approximately 10 ppm. The results indicate ground water in the area ranges widely in dissolved oxygen content but is generally less than about 5 ppm (refer to Figure 4.10).

BOD is used to identify the presence of sewage contamination, but can also be used to indicate the presence of aerobic biological activity. Large concentrations indicate significant aerobic biological activity. Measurements of BOD in June 1991 were below the detection limit of 2 ppm with the exception of one measurement of 6 ppm at well DM 509. A

second sample collected at DM 509 had less than 2 ppm. It is concluded that aerobic biological activity is not prevalent in the area.

The results of DO and BOD measurements, although not direct measurements of the oxidation potential, indicate that reducing conditions necessary for biodegradation of dissolved VOCs exist within the alluvium.

#### **4.3.7 Summary of Near-Plant Observations**

To illustrate the distribution of TCE and TCA, the suspected degradation concentrations of each have been added to the measured TCE and TCA concentration. Figures 4.11 and 4.12 depict the distribution of ethylenes (TCE plus TDCE plus DCE) in the near-plant area in alluvium and bedrock, respectively. Similarly, the distribution of TCA plus DCE, are presented in Figure 4.13 and 4.14 for alluvium and bedrock, respectively. As noted previously, TCE-derived DCE is not distinguished from TCA-derived DCE. Each figure presents the maximum, mean, and the minimum observed concentrations in 1991. At each multi-port monitor well locations, data from the zone exhibiting the highest ethylene concentrations are presented.

A discussion addressing the historical water quality trends is provided in Section 4.4. The results indicate that the areal distribution of ethylenes and TCA plus DCE in the near-plant area is similar to the areal distribution defined in the 1987 Draft RI Report; however, the magnitude of observed concentrations has declined. A more complete discussion of this decline is provided in Section 4.4.

Areas of VOC degradation may be indicated by analysis of the ratio of solvents to their degradation products. For instance, TCE degrades to TDCE, and TCA degrades to DCE. Therefore, the ratio of TCE to TDCE and the ratio of TCA to DCE may be used to suggest areas where degradation is most prevalent. A lower ratio would tend to indicate greater degradation

to the next isomer. The ratio of TCE to TDCE has been plotted for alluvium and bedrock wells on Figures 4.15 and 4.16, respectively. TCE to TDCE ratios illustrated on Figure 4.15 for alluvium reveal that the lowest ratios occur in the area centered around wells DM 117, DM 103, and DM 606 (ratios of 0.14, 0.09, and 0.17 respectively). These indicate that TCE is about 10 percent of TDCE in that area. Other areas with low ratios exist west of the OCC and are discussed in Section 4.4.

In summary, the onsite and near-plant areas have exhibited declines in ethylene concentrations. This decline has been observed in most wells within the VOC plume with sufficient historical ground-water quality data. Increases in ethylene concentrations were observed in one bedrock monitor well (MP 36D). Biodegradation appears to be continuing in local areas of the aquifer, particularly near wells DM 117 and DM 103.

#### **4.4 WATER QUALITY CHARACTERISTICS: FAR-FIELD AREA**

##### **4.4.1 Introduction**

The far-field area extends to the west of the OCC. Nine additional monitor wells and one observation well were installed since November 1990 to better define the downgradient extent of ground-water contamination. A total of 19 wells have been installed in the far-field area; 9 of the wells were installed as Westbay multi-port wells; and 10 as conventional, single-completion wells. Since completion of the 1987 Draft RI Report, four of the far-field wells have been abandoned due to highway construction activities. Therefore, a total of 15 wells can be monitored in the far-field study area.

The most recently installed wells, designated the DM 500-series, were located to evaluate the downgradient extent of VOC contamination and to provide field measurements of aquifer hydraulic characteristics. These wells are widely separated and provide a general

overview of the downgradient area. The following discussion summarizes the results of the VOC characterization in the far-field area.

#### 4.4.2 VOC Trends/Distributions

The maximum, mean, and minimum concentrations of ethylenes observed in 1991 in the alluvium and bedrock of the offsite area are depicted in Figures 4.17 and 4.18, respectively. Figure 4.19 shows changes in ethylene concentrations over time for selected wells in the far-field area. Ethylene concentration trends for all monitor wells have been plotted graphically and are presented in Appendix E6 (Figure E6.17 through E6.115). As in other areas previously discussed, ethylene concentrations have declined with time. Concentrations of ethylenes in excess of 1,000 ppb were encountered in monitor well DM 504 along the Grand Canal (Figure 4.17). DM 504 is interpreted to be near the center of the plume (see Chapter 6, Figure 6.18). The lateral extent of the plume in the vicinity of the Grand Canal is delimited by wells DM 126 and DM 505 (northwest), and DM 508 (southeast) where ethylene concentrations do not exceed 2 ppb (Figure 4.17).

Figures 4.20 and 4.21 present the distribution of 1991 TCA plus DCE concentrations for alluvium and bedrock, respectively. DCE is a degradation product of TCA (see discussion in Section 4.3.6); therefore, to represent the distribution of TCA, DCE has been added to the TCA concentrations. Maximum, mean, and minimum concentrations are presented for 1991 observations. At each multi-port monitor well location, data from the zone exhibiting the highest ethylene concentration is presented.

The downgradient wells DM 507 and DM 509 both contain concentrations of VOCs in excess of several hundred ppb (refer to Figure 4.17). Monitor well DM 506, which is located between DM 504 and DM 507, has a mean concentration of ethylenes of 161 ppb. DM 507 has mean ethylene concentrations of 751 ppb. Well DM 509, the farthest downgradient, has

a mean ethylene concentration of 351 ppb. All of the DM 500-series wells were sampled at least three times to confirm the observed concentrations.

The distribution of the principal VOC compounds (TCE, TDCE, DCE, and TCA) are presented for alluvium and bedrock in Figures 4.22 through 4.29. Each figure presents the maximum, mean, and minimum concentrations of each compound observed in samples collected in 1991. For multi-port wells, data from the zone exhibiting the highest ethylene concentrations are presented. Appendix E6 includes Figures E6.1 through E6.16 which compare mean concentrations of total VOCs, ethylenes (TCE + TDCE + DCE), TCA + DCE, TCE, TCA, DCE, TCE/TDCE, and TCA/DCE for the Draft RI (1984 to 1986), the Post-RI (1987 to 1991), and the total period of investigation, 1984 to 1991.

In general, the distribution of VOC compounds is similar to the distribution presented in the 1987 Draft RI except that the concentrations have declined in many wells since 1987. The installation of additional wells DM 501 through DM 509 in 1990-1991 has provided water quality data for an area extending approximately 3,500 feet west of the Grand Canal. VOC concentrations were observed in all of the additional monitor wells. Monitor wells DM 505 and DM 508 exhibit low concentrations of VOCs and therefore define the lateral edge of the plume.

#### 4.4.3 Vertical Distribution of VOCs

In the vertical dimension, the distribution of VOCs in the area east of the Grand Canal is consistent with the historical observation (1987 Draft RI) that concentrations of VOCs tend to be highest at the bedrock/alluvium interface. The vertical distribution of total ethylenes is shown on Figure 4.30 for several selected multi-port wells. At well DM 501, the highest mean ethylene concentration (70 ppb) occurs at the 202-foot-deep port which is screened across the bedrock/alluvium interface. The highest mean concentration of ethylenes in well DM 502 occurs at the bedrock/alluvium interface at a depth of 119 feet (714 ppb). Similarly, at well DM 506,

the highest mean ethylene concentration of 161 ppb was recorded at a depth of 185 feet, also in the zone that is screened across the bedrock/alluvium interface.

At DM 507, the distribution of total ethylenes is anomalous with respect to vertical distribution. The uppermost port at a depth of 84 feet has a mean ethylene concentration of 751 ppb for 3 observations (see Figure 4.30). The mean ethylene concentration in lower ports does not exceed 413 ppb. The bedrock/alluvium interface is interpreted to occur at a depth of 188 feet. The upper port at 84 feet is screened approximately 15 feet below the water table within alluvial material not far below the fluvial gravel aquifer described in Section 3.0. In addition, TCA concentrations on the order of 5 to 10 ppb were measured throughout alluvium and bedrock. The VOC plume emanating from the Motorola 52nd St. Facility would not be expected to contain TCA this far downgradient; TCA releases are reported to be more recent (1982) than TCE releases (before 1970). These observations indicate that the concentrations of VOCs observed in well DM 507 are anomalous with respect to other monitor wells sampled during this investigation in the far-field area. This may indicate that another, perhaps recent source of VOC contamination has been detected at DM 507.

#### **4.4.4 The Distribution of VOC Degradation Products**

As discussed in Section 4.3, degradation is suspected to occur in localized areas of the plume. The ratio of a VOC to its degradation product is one method of evaluating the biodegradation activity in the aquifer. The degradation of various VOCs is discussed in Section 4.3.6. The principal degradation pathways of interest to this investigation are: (1) TCE degrades to TDCE (and/or DCE) then VC; and (2) TCA degrades to DCE and VC. The ratios of TCE to TDCE and TCA to DCE are useful in defining whether and where degradation is occurring. Figures 4.15 and 4.16, plus 4.31 and 4.32, present the ratios of TCE to TDCE and TCA to DCE for alluvial and bedrock monitoring locations, respectively.

Well DM 509 is anomalous with respect to observed areas of degradation because DM 509 exhibits a high ratio of TCE to TDCE (about 35). As noted previously, high ratios of TCE to TDCE indicate no significant degradation. Figures 4.15, 4.16, 4.31, and 4.32 indicate that in the downgradient area of the plume, TCE degradation is most active in the vicinity of DM 502 and DM 504 (upgradient of DM 509) where the ratio of TCE to TDCE in alluvium is relatively low, averaging .33 and 1.2 respectively (Figure 4.15). At wells DM 506 and DM 507, however, the TCE to TDCE ratios in alluvium are higher, 5.0 and 3.5, respectively, which are generally typical of areas with less degradation. The anomalously high ratio of TCE to TDCE in well DM 509 suggest that an alternate, recent source of TCE may exist in the vicinity of DM 509.

#### 4.5 SUMMARY AND CONCLUSIONS

Ground-water quality has been evaluated by monitoring more than 32 wells located at and downgradient from the Motorola 52nd St. Facility as part of the Final Remedy Remedial Investigation. All well locations were reviewed and approved by the ADEQ, ADWR, and EPA. Eight sampling rounds have been conducted from the monitor well network since completion of the 1987 Draft RI (Dames & Moore, 1987b). Three sampling rounds were completed between October and December 1991 at 6 new monitor wells and 9 new extraction wells as part of the Operable Unit extraction system. The data developed during this program are discussed in this Chapter and are presented in Appendix E. The conclusions reached from analysis of the data are as follows:

1. The concentrations of VOCs in ground-water monitor wells have declined throughout the plume since 1986. Near the Courtyard area of the 52nd St. Facility, onsite pumping of extraction wells may explain the reduced concentrations. Farther downgradient from the Courtyard, the cause of the decline in VOC concentrations is uncertain. Installation of monitor wells is thought to have a temporary influence on the observed concentrations of VOCs because of disturbance of the aquifer immediately surrounding the wells. This disturbance could cause an artificial increase in the concentrations of VOCs initially observed in recently installed or renovated

monitor wells. Regardless of the cause, concentrations of VOCs in the aquifer are believed to be better represented by data collected since completion of the 1987 Draft RI, or more recently-1991.

2. Degradation, perhaps related to biological factors, continues to occur in localized areas of the aquifer. The areas of degradation are local and may be related to local upwellings of reduced ground water along geologic structures. Centers of degradation are located in the vicinity of wells DM 117 and DM 103 in the near-plant area, and near well DM 502 in the far-field area. Vinyl chloride, an isomer which is an end-product of ethylene degradation, has been observed in monitor wells DM 117, DM 103, and MP 09 coincident with low ratios of TCE to TDCE. (TDCE is a degradation product of TCE.)
3. The highest observed concentrations ground-water contamination occur in multiport wells at the bedrock/alluvium interface.
4. VOC contamination has been observed west of the Grand Canal. Observations at wells downgradient of the Grand Canal suggest that an alternate source(s) of VOC contamination may occur in the vicinity of wells DM 507 and DM 509. VOC concentrations at well DM 507 are highest in the upper part of the well, 15 feet below the water table. In contrast, well DM 506 exhibits the highest VOC concentrations at the bedrock/alluvium interface. The pattern at DM 506 is typical of the vertical distribution of VOC concentrations throughout the alluvial portion of the plume. Well DM 509 has a ratio of TCE to TDCE that is significantly higher than upgradient wells, indicating only minor degradation.
5. TCA and DCE concentrations exceeding historical measurements have been observed in the Southwest Parking Lot (SWPL) area at greater levels since approximately October 1990. Investigation of the area is continuing. The preliminary results are presented in Attachment SW to this report.

In summary, the FR RI investigation indicates that VOC concentrations in ground water have declined since data were first obtained between 1982 and 1987. The decline in observed concentrations is widespread and well documented. Therefore, these trends have been taken into account for predicting the extent of ground-water contamination. Although water quality observations confirm VOC contamination downgradient of the Grand Canal, other sources besides the Motorola 52nd St. Facility may have contributed to the observed VOC contamination of ground water west of the Grand Canal.

**Table 4.1**

**FEDERAL AND STATE VOC DRINKING WATER QUALITY STANDARDS**

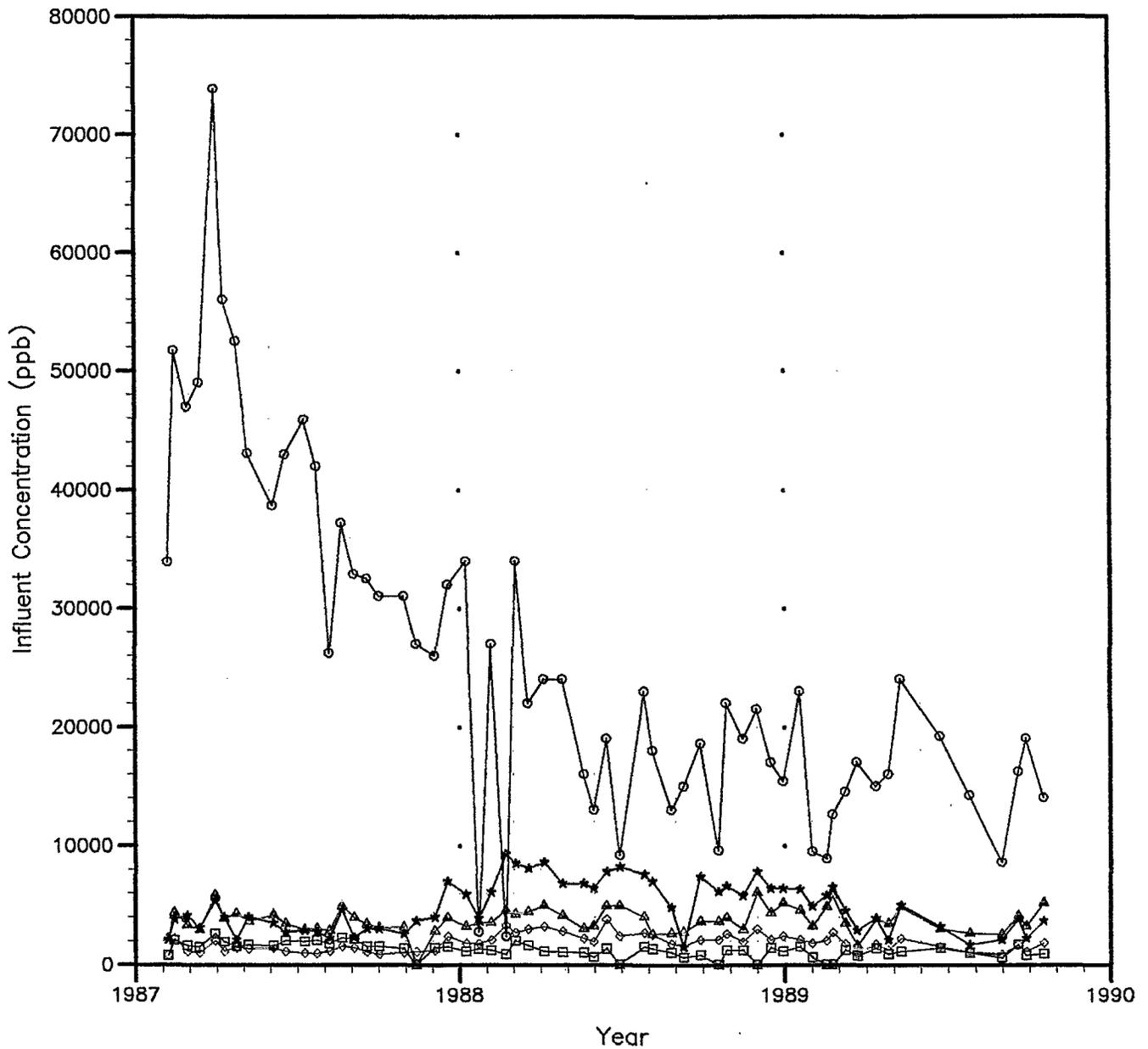
Volatile Organic Compound	Federal MCL (ppb) <sup>(b)</sup>	Proposed Federal MCL (ppb) <sup>(c)</sup>	ADEQ MCL (ppb) <sup>(d)</sup>
Bromodichloromethane	100(a)	-	100(a)
Bromoform	100(a)	-	100(a)
Bromomethane	-	-	-
Carbon Tetrachloride	5	-	5
Chlorobenzene		100	
Chloroethane	-	-	-
Chloroform	100(a)	-	100(a)
Chloromethane	-	-	-
Dibromochloromethane	100(a)	-	100(a)
1,3-dichlorobenzene	-	-	-
1,2-dichlorobenzene	-	600	-
1,4-dichlorobenzene	75	-	75
Dichlorodifluoromethane	-	-	-
1,1-dichloroethane	-	-	-
1,2-dichloroethane	5	-	5
1,1-dichloroethylene	7	-	7
cis-1,2-dichloroethylene		70	-
trans-1,2-dichloroethylene		100	-
1,2-dichloropropane	-	5	-
cis-1,3-dichloropropene	-	-	-
trans-1,3-dichloropropene	-	-	-
Methylene chloride	-	5	-
1,1,2,2-tetrachloroethane	-	-	-

**Table 4.1 (Continued)**

Volatile Organic Compound	Federal MCL (ppb) <sup>(b)</sup>	Proposed Federal MCL (ppb) <sup>(c)</sup>	ADEQ MCL (ppb) <sup>(d)</sup>
Tetrachloroethylene (PCE)	-	5	-
1,1,1-trichloroethane	200	-	200
1,1,2-trichloroethane	-	5	-
Trichloroethylene	5	-	5
Trichlorofluoromethane	-	-	-
Vinyl chloride	2	-	2
Trichlorotrifluoroethane	-	-	-
2-chloroethyl vinyl ether	-	-	-
Benzene	5	-	5
Toluene	-	2,000	-
Ethylbenzene	-	700	-
Acetone	-	-	-
O,P-xylene	-	-	-
M-xylene	-	-	-
1,2-dibromoethane	-	-	-
Total xylenes	-	10,000	-

Notes:

(a) Based on the standard for total trihalomethanes of 100 ug/l.  
 (b) Maximum Contaminant Level, 40 CFR 141 and 143.  
 (c) Published in Federal Register: v. 54, no. 97, 5/22/89; v. 55, no. 143, 7/25/90.  
 (d) ADEQ, Draft Human Health-Based Guidance Levels for Contaminants in Drinking Water and Soil; Sept. 1990. Note: the State MCLs listed here are the same as, and derived from Federal MCLs.



**LEGEND:**

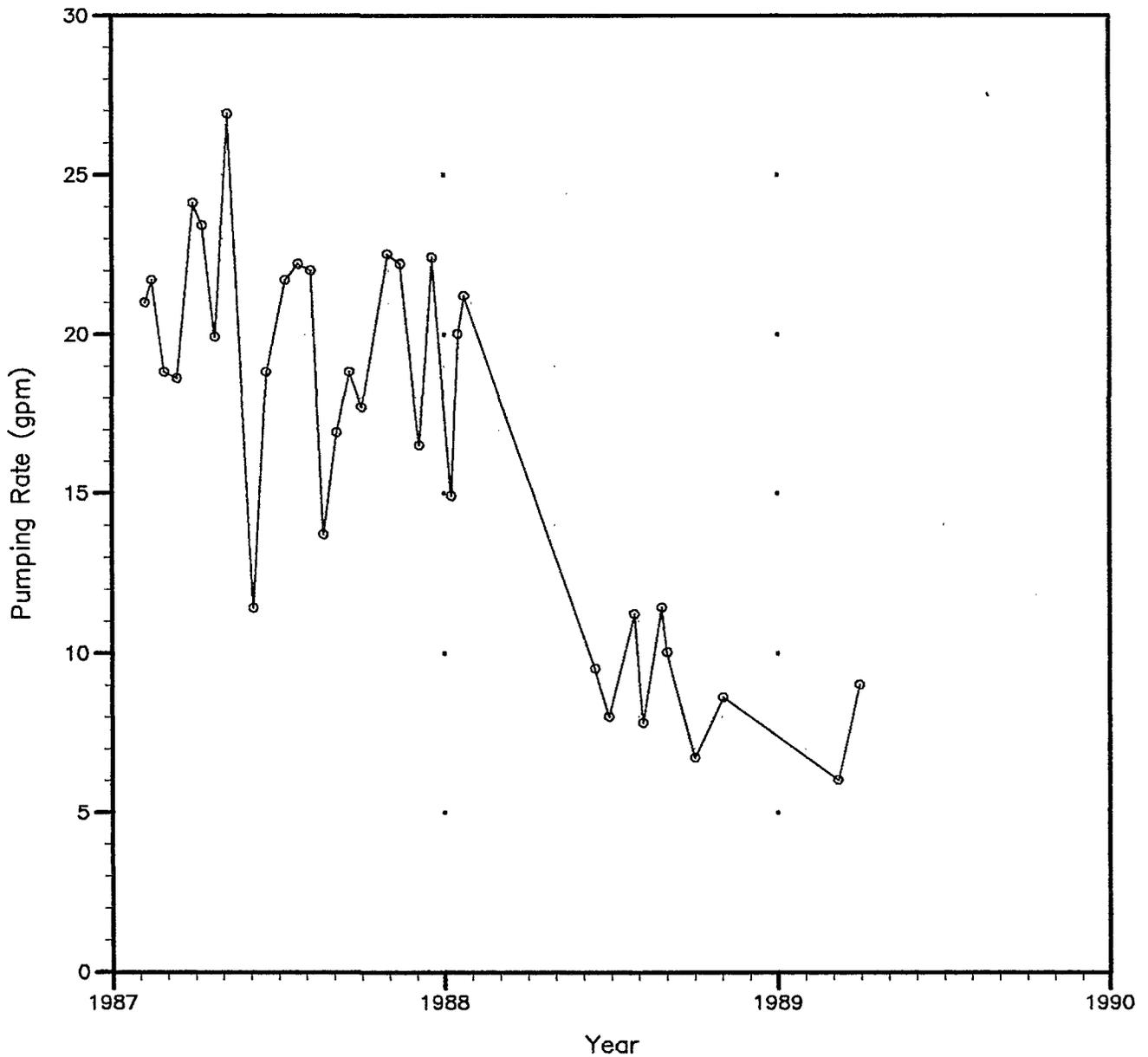
- TCA
- ▲—▲—▲ TCE
- DCE
- ◇—◇—◇ PCE
- ★—★—★ DCB2

**NOTE:**

Data presented in Appendix E6,  
table E6.14

**PILOT TREATMENT PLANT  
INFLUENT VOC  
CONCENTRATIONS VS. TIME**

**Figure 4.1**  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992



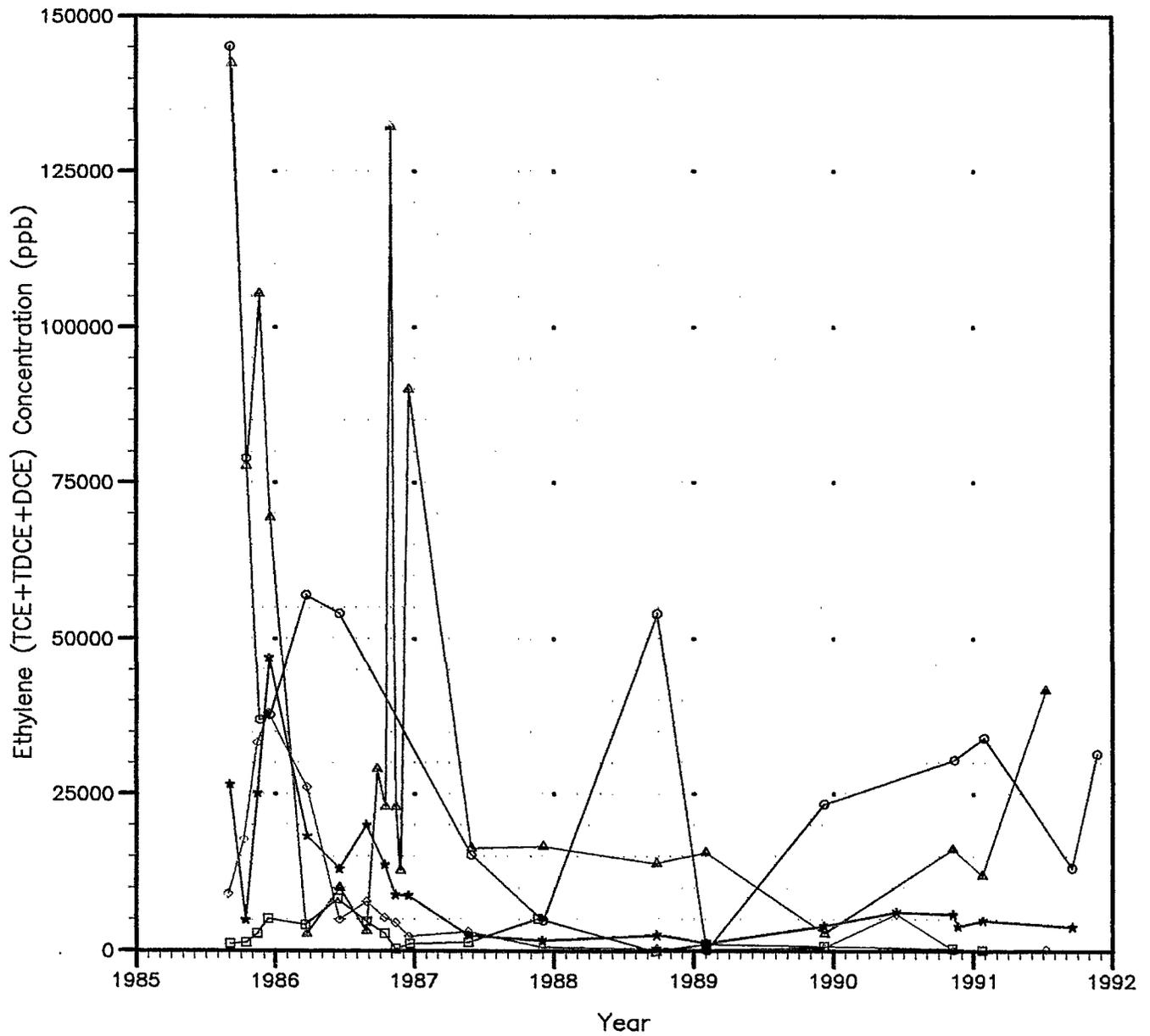
**NOTE:**

Pumping rate was calculated using totalizing flow meter readings and the assumption that pumping occurred for a period of 8 hours a day, 5 days a week. All extraction occurs from either well DM 301 or DM 302.

**TOTAL PUMPING RATE:  
ONSITE  
EXTRACTION WELLS**

**Figure 4.2**

MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992



**LEGEND:**

- MP 03B
- ▲—▲—▲ MP 09A
- MP 11A
- ◇—◇—◇ MP 36A
- ★—★—★ MP 36B

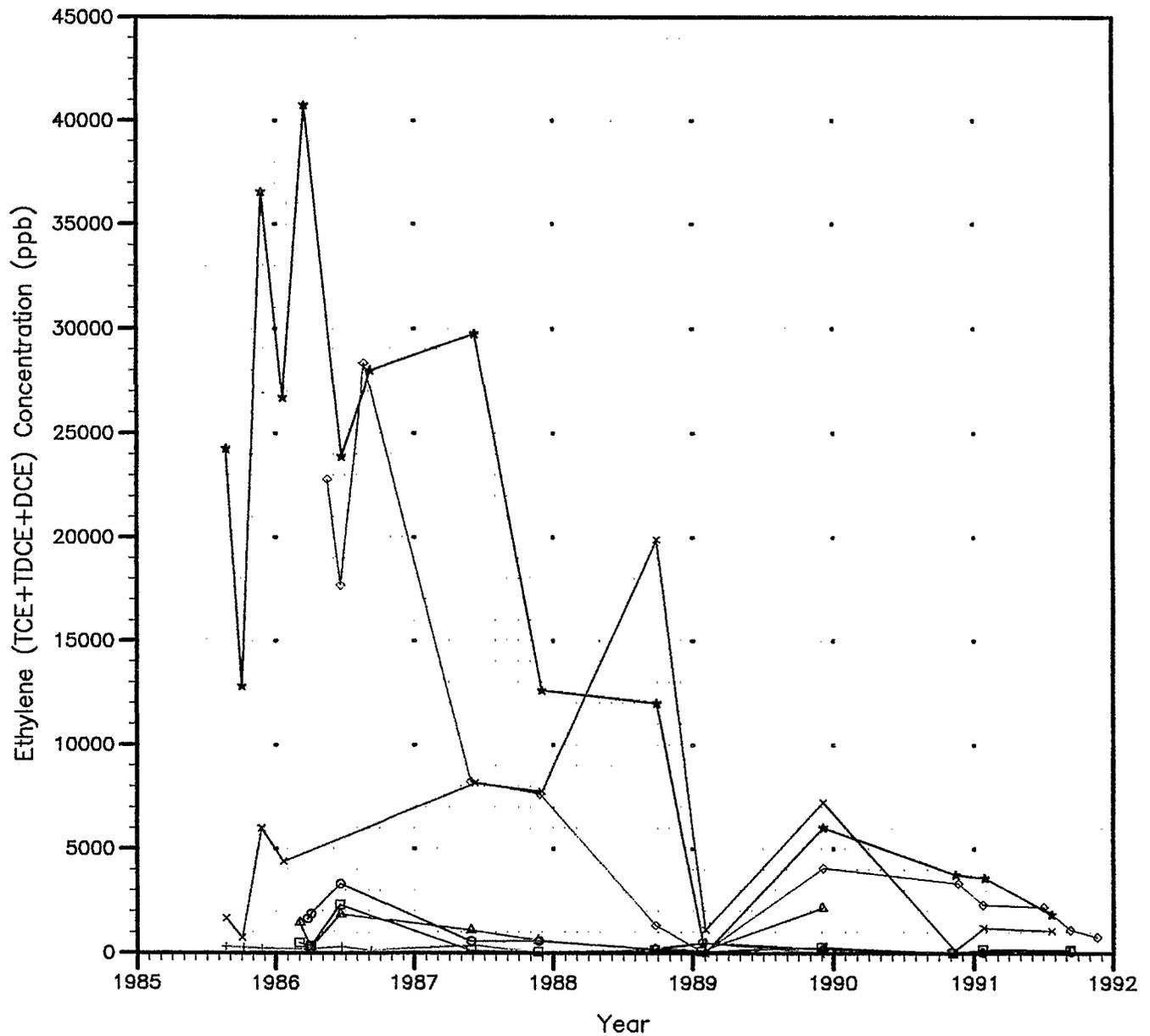
**NOTE:**

Data presented in Appendix E

**ETHYLENE  
CONCENTRATIONS VS. TIME  
(SELECTED ONSITE WELLS)**

**Figure 4.3**

MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992



**LEGEND:**

- DM 111
- ▲—▲—▲ DM 113
- ◻—◻—◻ DM 115
- ◇—◇—◇ DM 117
- ★—★—★ DM 103-178
- ×—×—× DM 103-223
- +—+—+ DM 103-389

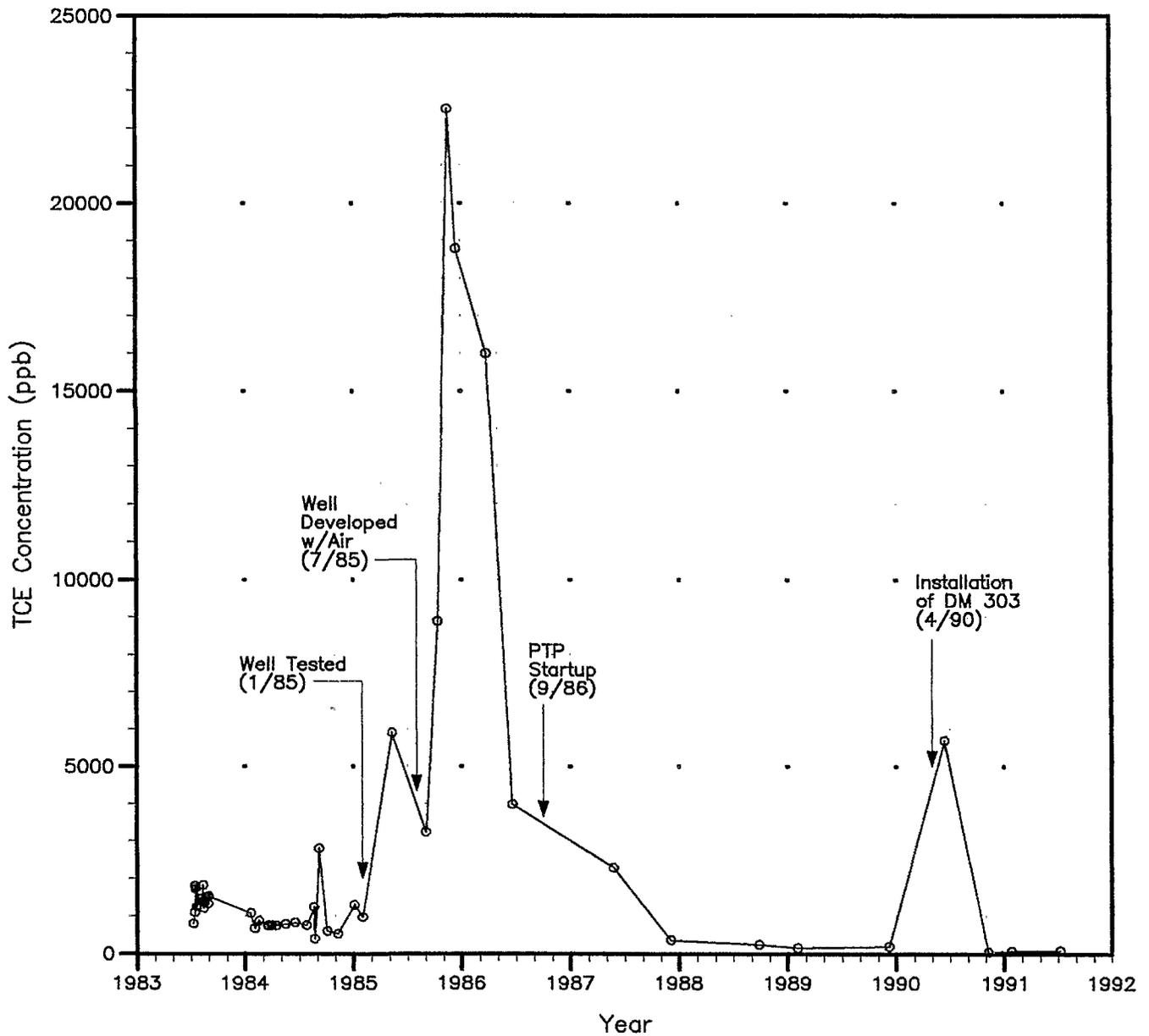
**NOTE:**

Data presented in Appendix E

## ETHYLENE CONCENTRATIONS VS. TIME (SELECTED NEAR-PLANT WELLS)

**Figure 4.4**

MOTOROLA 52nd ST.  
FR R1  
FEBRUARY 1992



**LEGEND:**

○—○—○ MP 36A

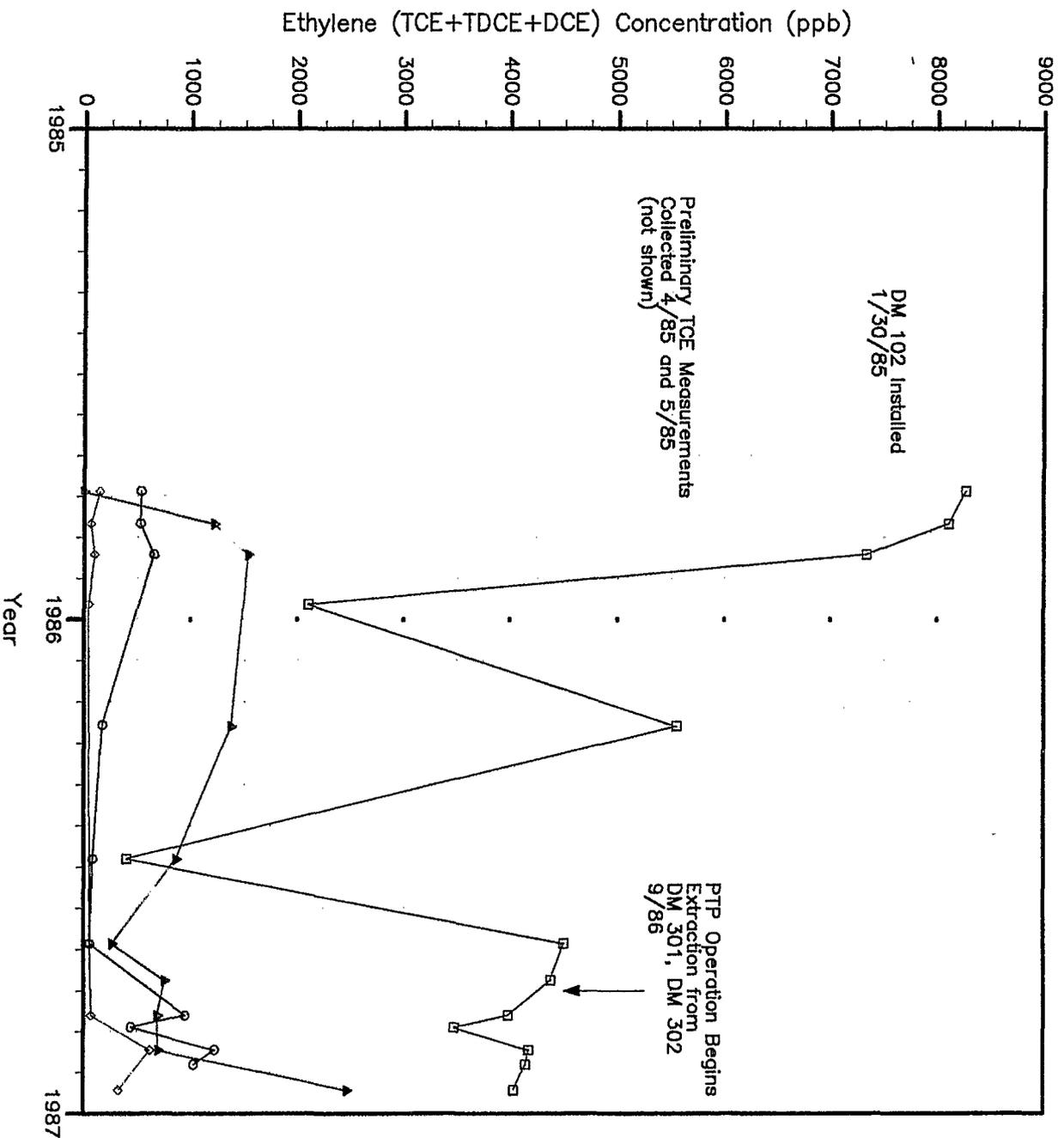
**NOTE:**

Total ethylene concentrations have not been plotted for MP 36A because only TCE data are available between 1983 and 1985.

**MP 36A:  
TCE CONCENTRATIONS  
VS. TIME**

**Figure 4.5**

MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992



**LEGEND:**

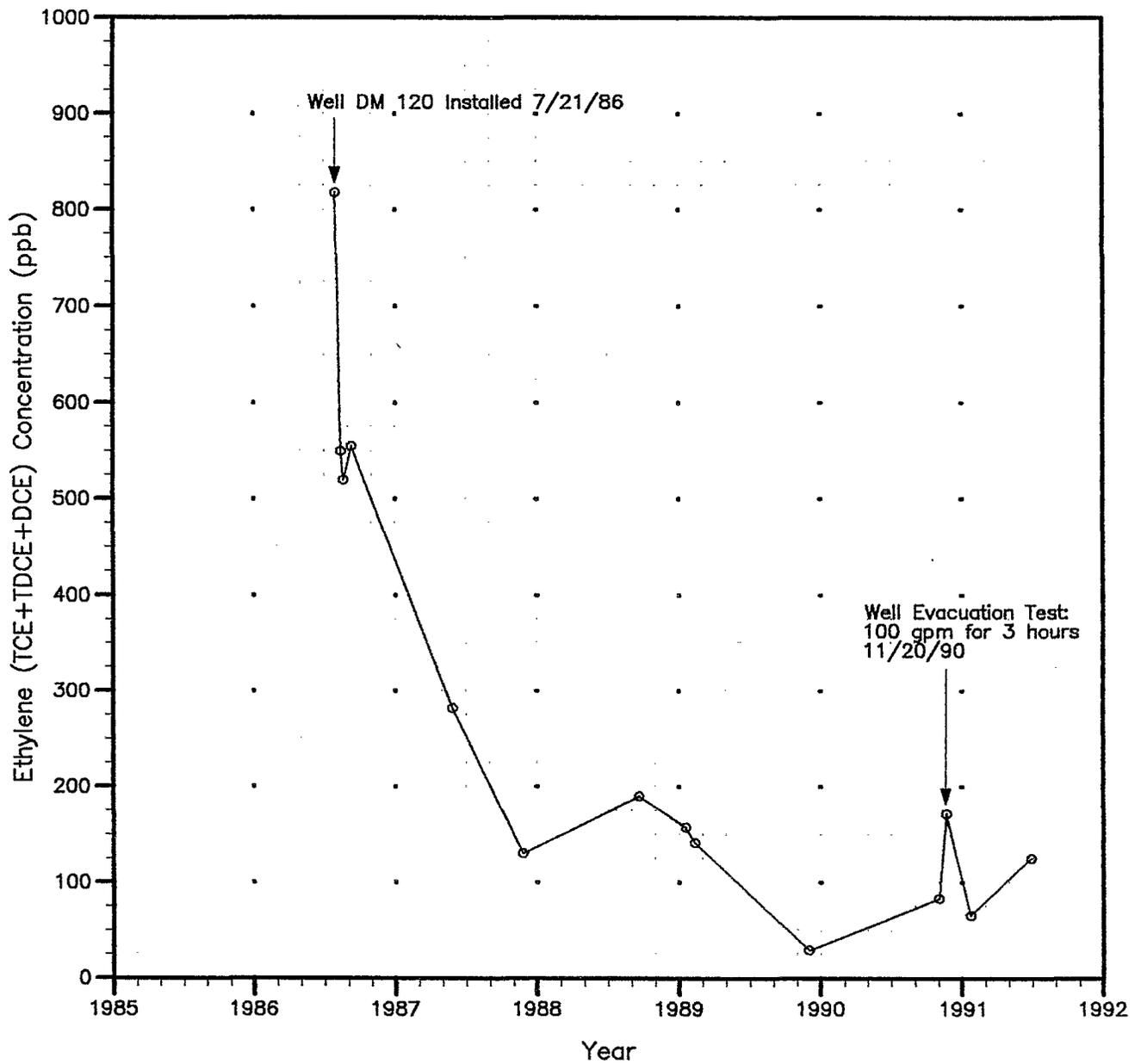
- DM 102-048
- ▲—▲ DM 102-082
- DM 102-119
- ◇—◇ DM 102-299

**NOTE:**  
Data presented in Appendix E

**DM 102:  
TOTAL ETHYLENE  
CONCENTRATIONS VS. TIME**

**Figure 4.6**

MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992



LEGEND:

○—○—○ DM 120

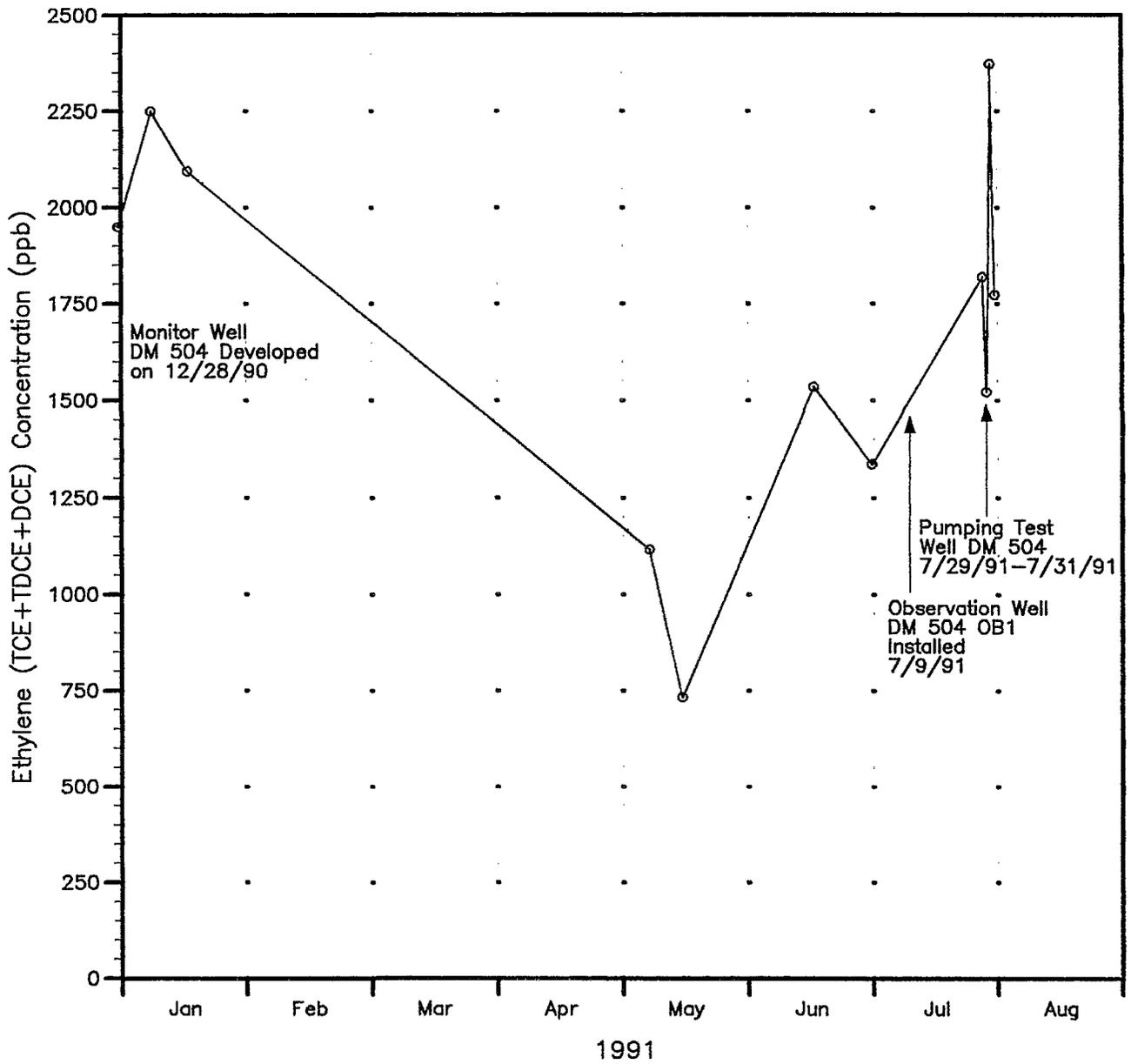
**DM 120:  
TOTAL ETHYLENE  
CONCENTRATIONS VS. TIME**

NOTE:

Data presented in Appendix E6,  
Table E6.14

Figure 4.7

MOTOROLA 52nd ST.  
FR R1  
FEBRUARY 1992



**LEGEND:**

○—○—○ DM 504

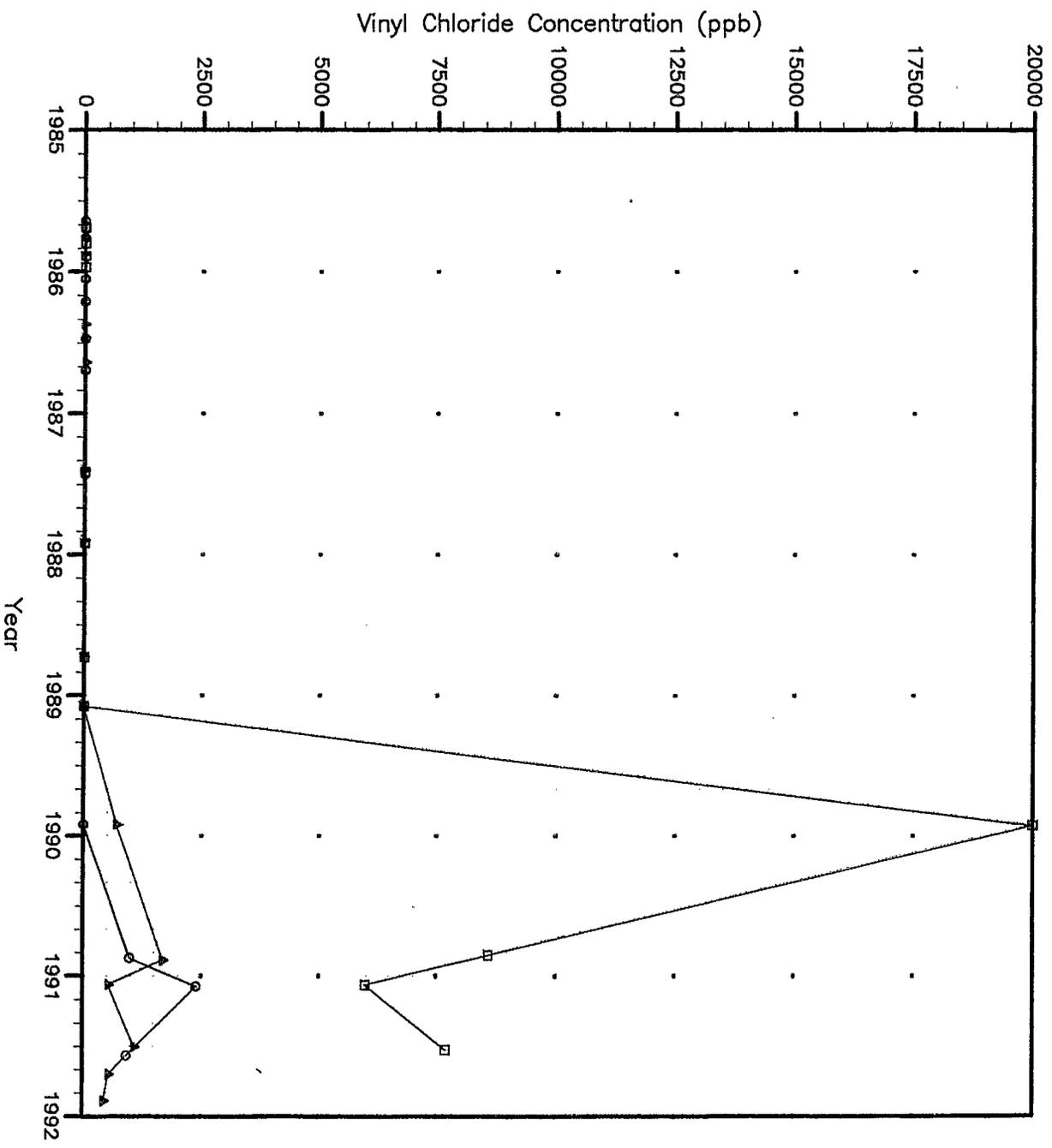
**DM 504:  
TOTAL ETHYLENE  
CONCENTRATIONS VS. TIME**

**NOTE:**

Data presented in Appendix E

**Figure 4.8**

MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992

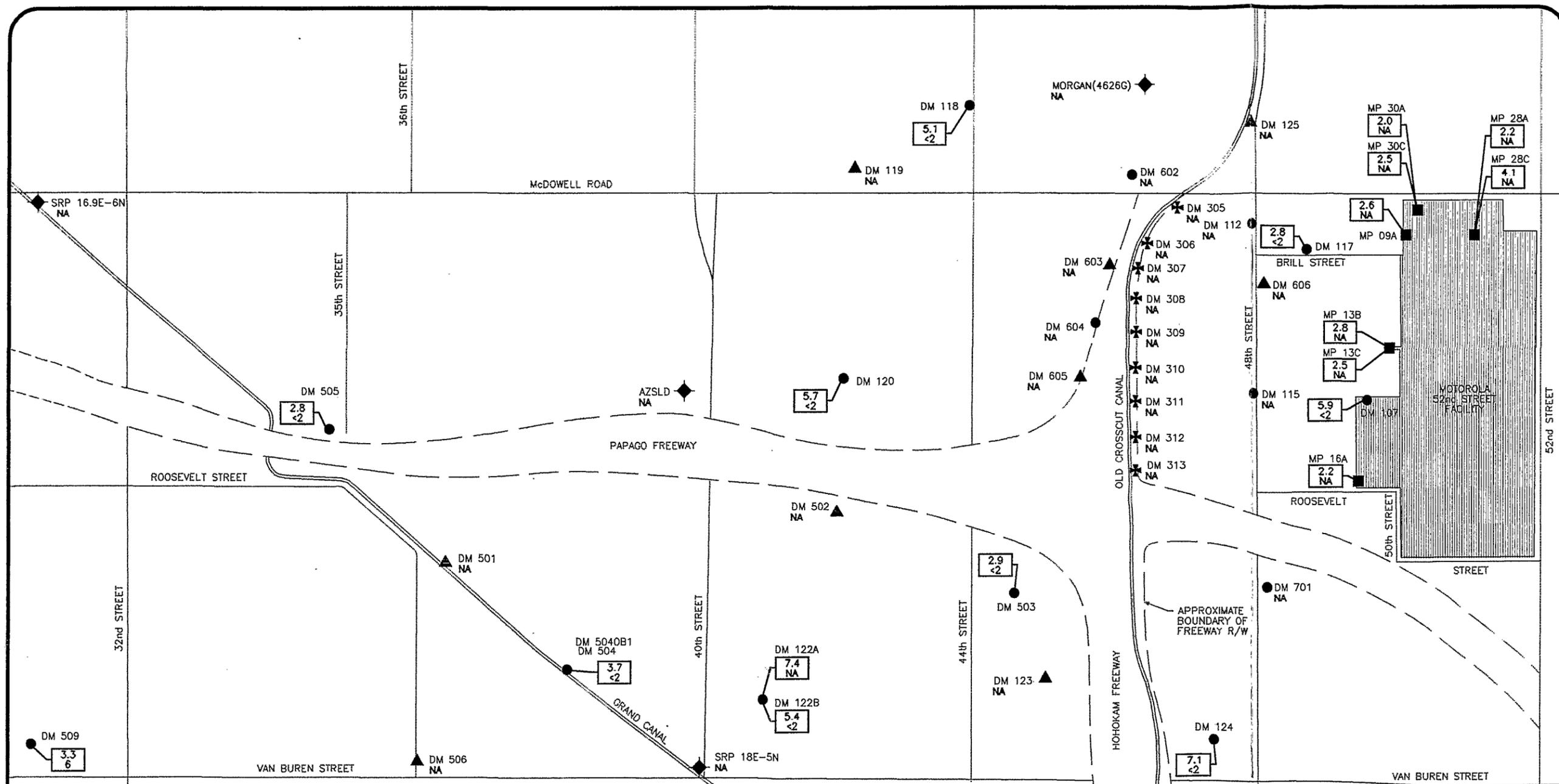


**LEGEND:**  
 ○—○—○ DM 103-178  
 ▲—▲—▲ DM 117  
 □—□—□ MP 09C

**VINYL CHLORIDE  
 CONCENTRATIONS VS. TIME  
 (SELECTED NEAR-PLANT WELLS)**

**NOTE:**  
 Data presented in Appendix E

**Figure 4.9**  
 MOTOROLA 52nd ST.  
 FR, RI  
 FEBRUARY 1992



**LEGEND:**

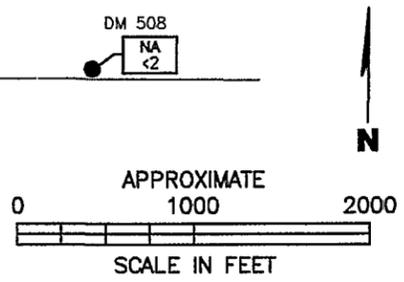
WESTBAY	▲	EXISTING
CONVENTIONAL	●	
MP	■	
PRIVATE	◆	
EXTRACTION	✱	
● DM 122		NAME OF WELL
2.8		DISSOLVED OXYGEN (mg/l)
<2		MEASUREMENTS (7/91)
		BOD (mg/l) (6/91)
NA		NOT ANALYZED

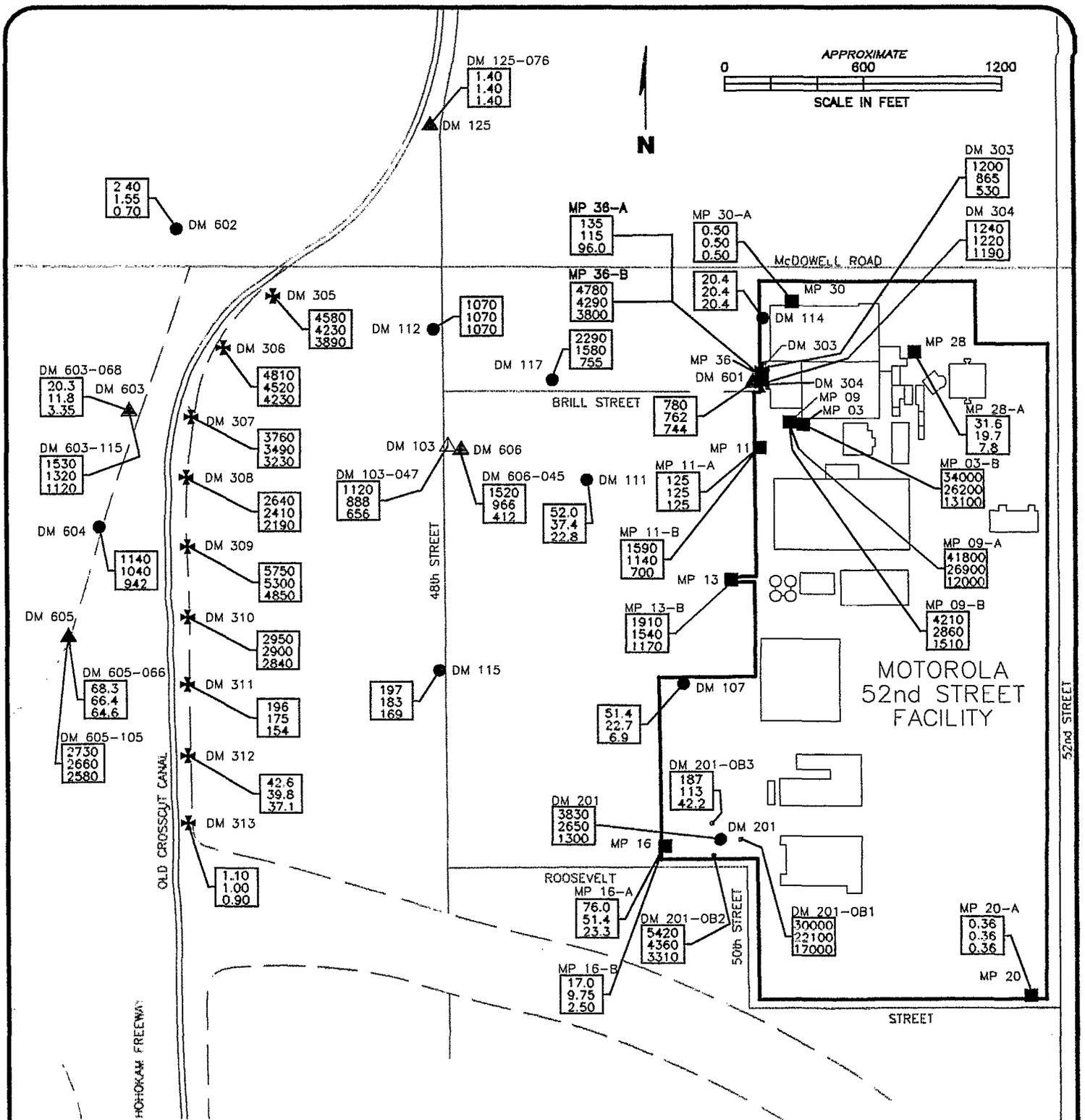
**NOTES:**

- O<sub>2</sub> solubility in water = ≈10 mg/l.
- Dissolved Oxygen data presented in Appendix E4.2, and BOD data presented in Appendix E4.1

## DISTRIBUTION OF DISSOLVED OXYGEN AND BIOLOGICAL OXYGEN DEMAND JUNE 1991

Figure 4.10  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992





**LEGEND:**

WELL TYPE	EXISTING	ABANDONED
WESTBAY	▲	△
CONVENTIONAL	●	○
MP	◆	◻
PRIVATE	◆	◻
EXTRACTION	✱	N/A

● DM 201 NAME OF WELL

1170	MAXIMUM
944	MEAN
710	MINIMUM

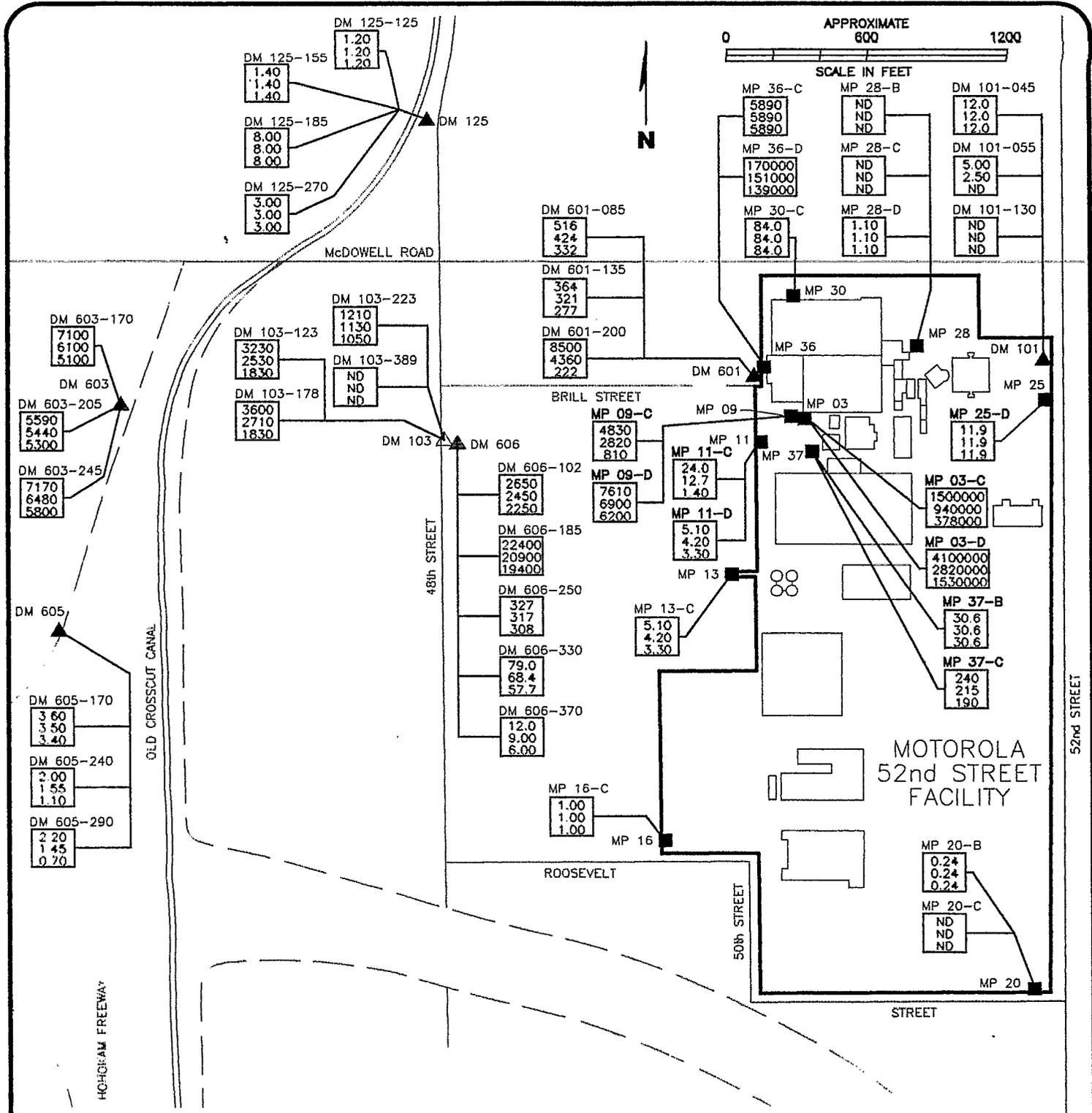
NS NOT SAMPLED  
ND NOT DETECTED

**NOTES:**

1. All units are ppb.
2. Data presented in Appendix E6.
3. See Attachment SW for discussion of solvent concentrations observed in DM 201.

**1991 ETHYLENE CONCENTRATIONS IN ALLUVIUM (NEAR-PLANT WELLS)**

Figure 4.11  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992



**LEGEND:**

WELL TYPE	EXISTING	ABANDONED
WESTBAY	▲	△
CONVENTIONAL	●	○
MP	■	□
PRIVATE	◆	⊕
EXTRACTION	✱	N/A

● DM 201 NAME OF WELL

1170	MAXIMUM
944	MEAN
710	MINIMUM

NS NOT SAMPLED  
 ND NOT DETECTED

**NOTES:**

1. All units are ppb.
2. Data presented in Appendix E6.

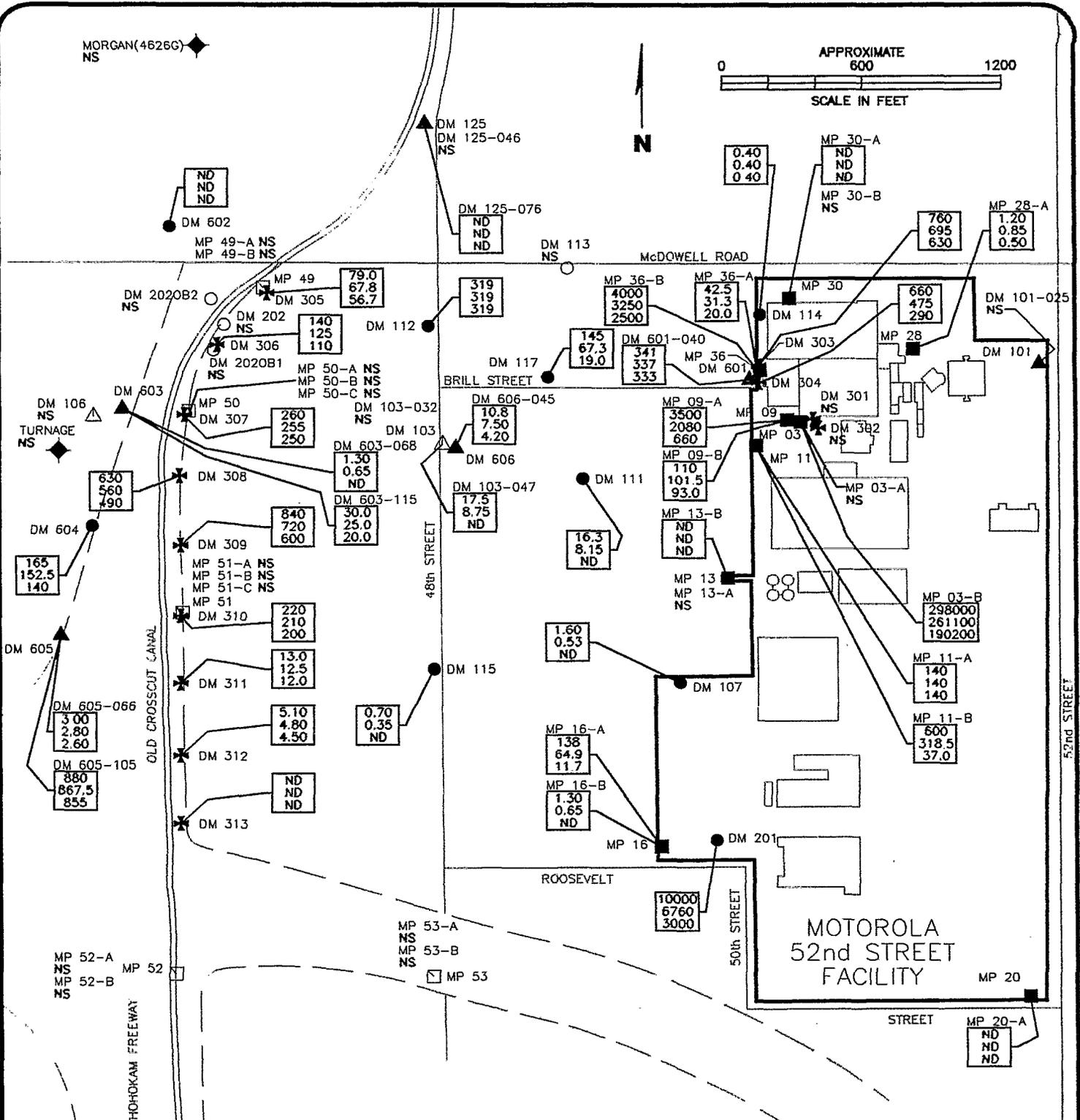
**1991 ETHYLENE CONCENTRATIONS IN BEDROCK (NEAR-PLANT WELLS)**

**Figure 4.12**  
 MOTOROLA 52nd ST.  
 FR, RI  
 FEBRUARY 1992

MORGAN(4626G)  
NS



N



**LEGEND:**

WELL TYPE	EXISTING	ABANDONED
WESTBAY	▲	△
CONVENTIONAL	●	○
MP	■	□
PRIVATE	◆	◇
EXTRACTION	✱	N/A

● DM 201 NAME OF WELL

1170	MAXIMUM
944	MEAN
710	MINIMUM

NS NOT SAMPLED  
ND NOT DETECTED

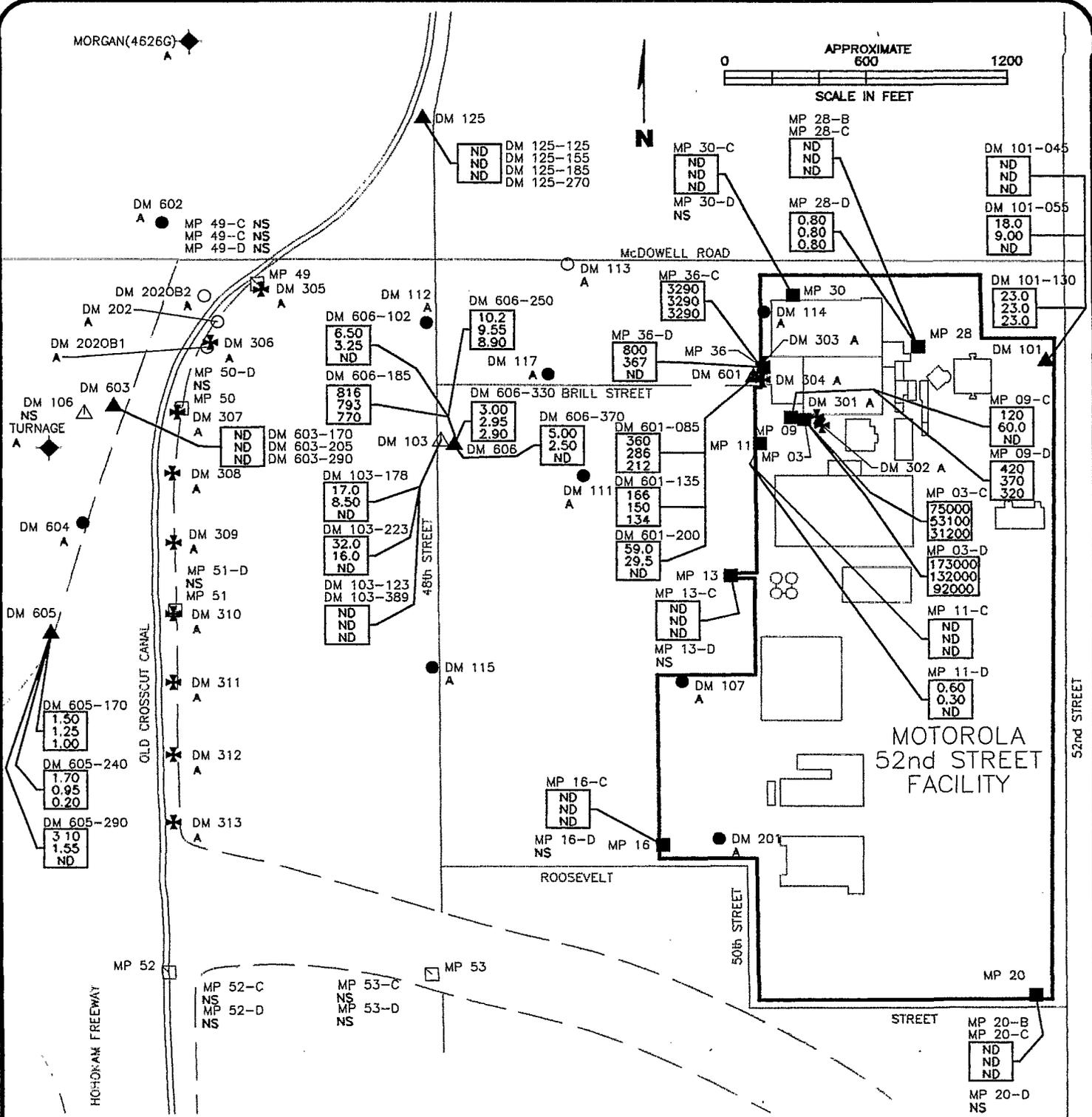
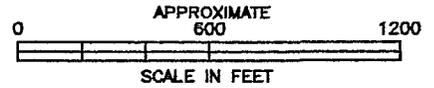
**NOTES:**

1. All units are ppb.
2. Data presented in Appendix E6.
3. See Attachment SW for discussion of solvent concentrations observed in DM 201.

**1991 TCA+DCE CONCENTRATIONS IN ALLUVIUM (NEAR-PLANT WELLS)**

**Figure 4.13**  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992

MORGAN(4626G) A



**LEGEND:**

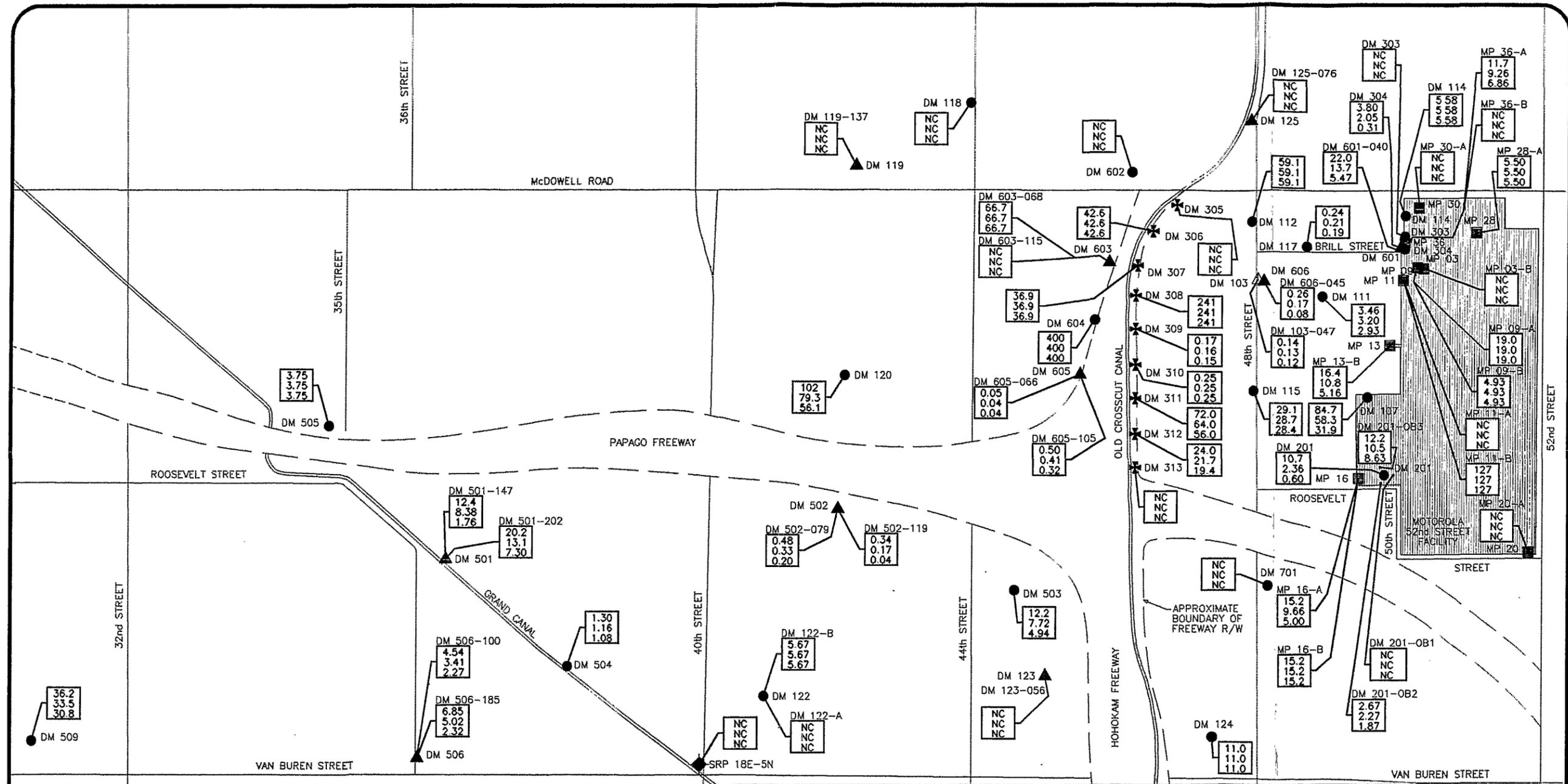
WELL TYPE	EXISTING	ABANDONED
WESTBAY	▲	△
CONVENTIONAL	●	○
MP	■	□
PRIVATE	◆	◇
EXTRACTION	✱	N/A
● DM 506	NAME OF WELL	
1170	MAXIMUM	
944	MEAN	
710	MINIMUM	
NS	NOT SAMPLED	
ND	NOT DETECTED	
A	ALLUVIUM ONLY	

**NOTES:**

1. All units are ppb.
2. Data presented in Appendix E6.
3. See Attachment SW for discussion of solvent concentrations observed in DM 201.

**1991 TCA+DCE CONCENTRATIONS IN BEDROCK (NEAR-PLANT WELLS)**

Figure 4.14  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992



**LEGEND:**

WELL TYPE	EXISTING	ABANDONED
WESTBAY	▲	△
CONVENTIONAL	●	○
MP	■	□
PRIVATE	◆	◇
EXTRACTION	✱	N/A
● DM 504	NAME OF WELL	
1170	MAXIMUM	
944	MEAN	
710	MINIMUM	
NC	NOT CALCULABLE	
ND	NOT DETECTED	

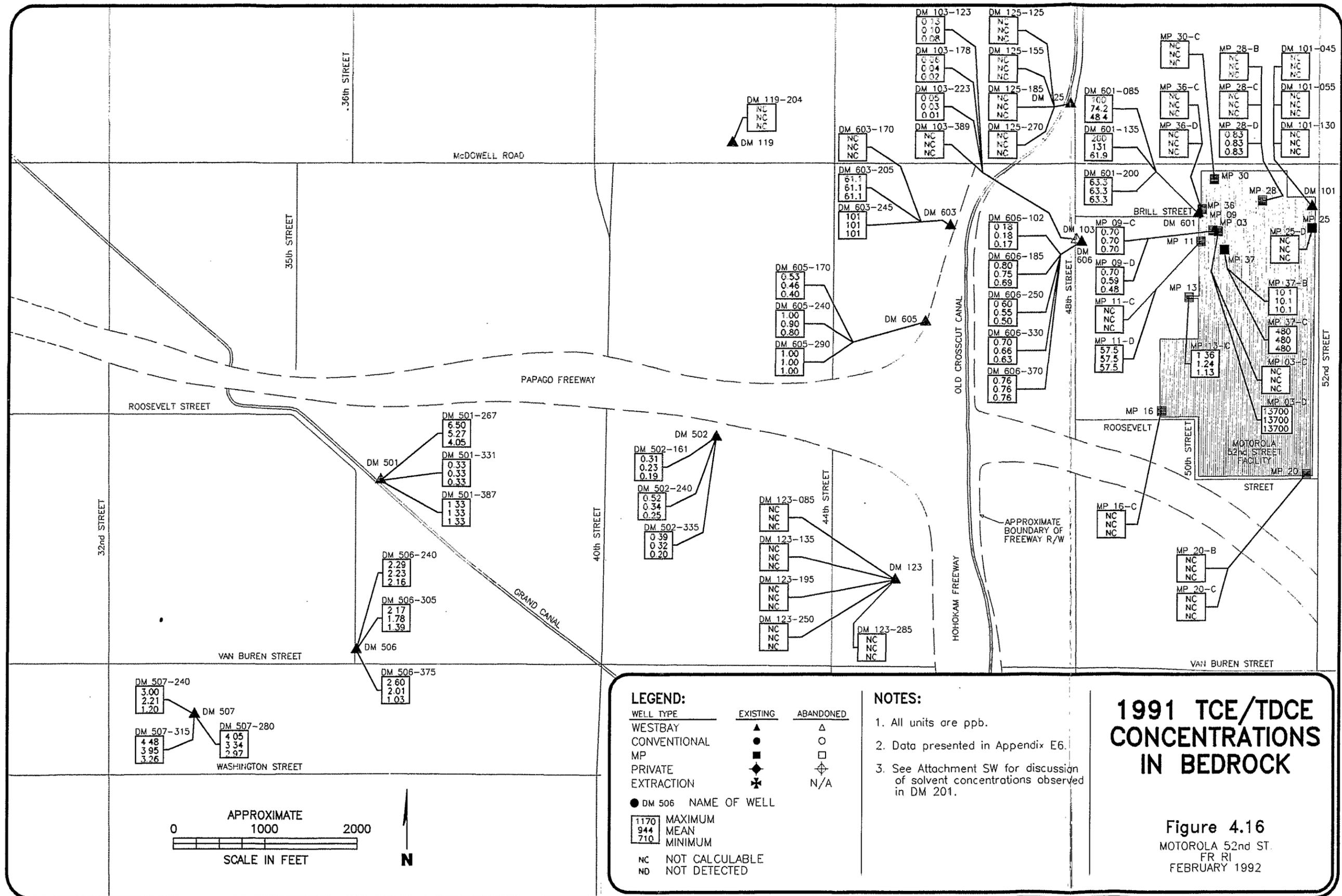
**NOTES:**

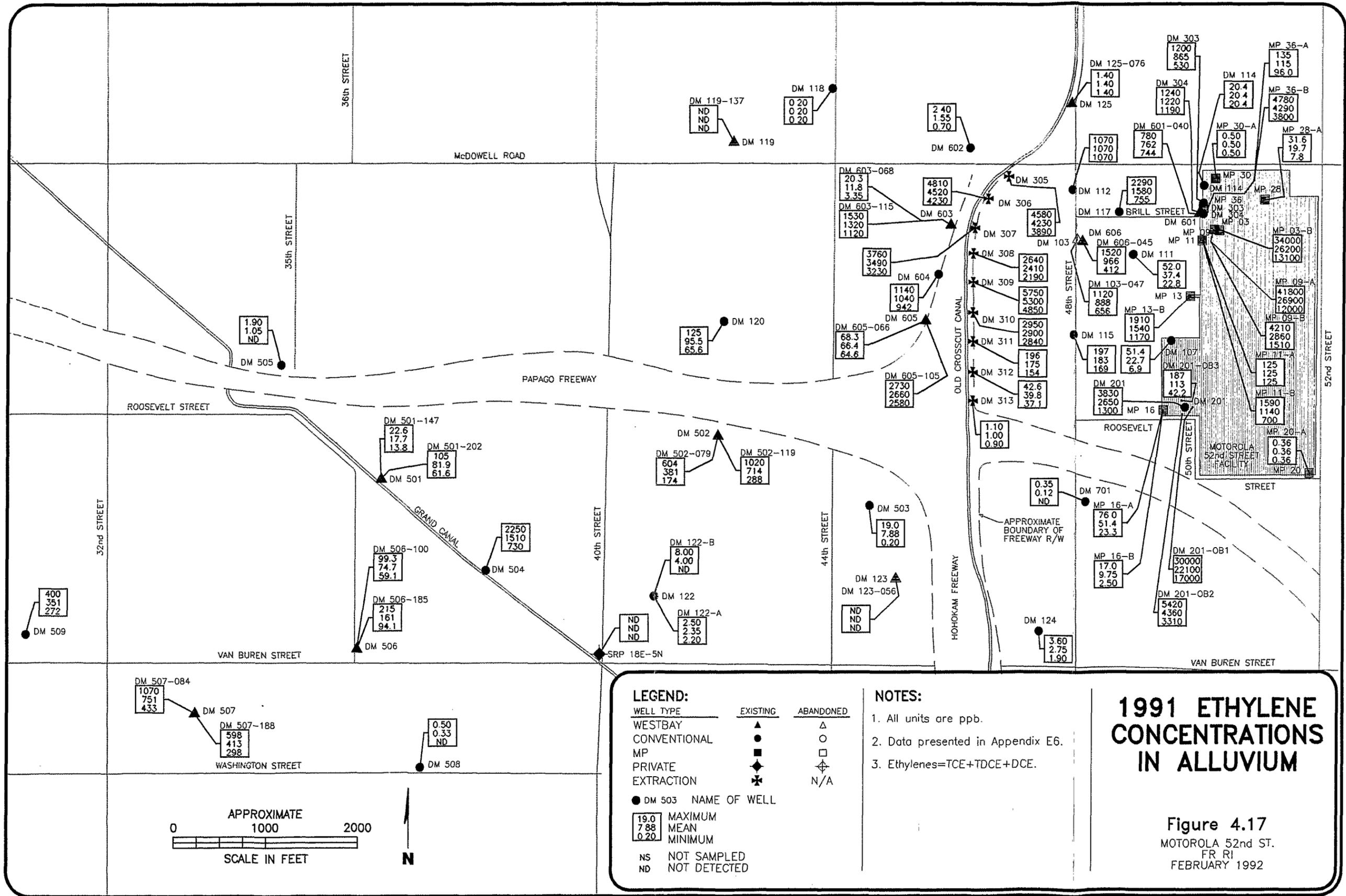
- All units are ppb.
- Data presented in Appendix E6.
- See Attachment SW for discussion of solvent concentrations observed in DM 201.

**1991 TCE/TDCE CONCENTRATIONS IN ALLUVIUM**

**Figure 4.15**  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992







**LEGEND:**

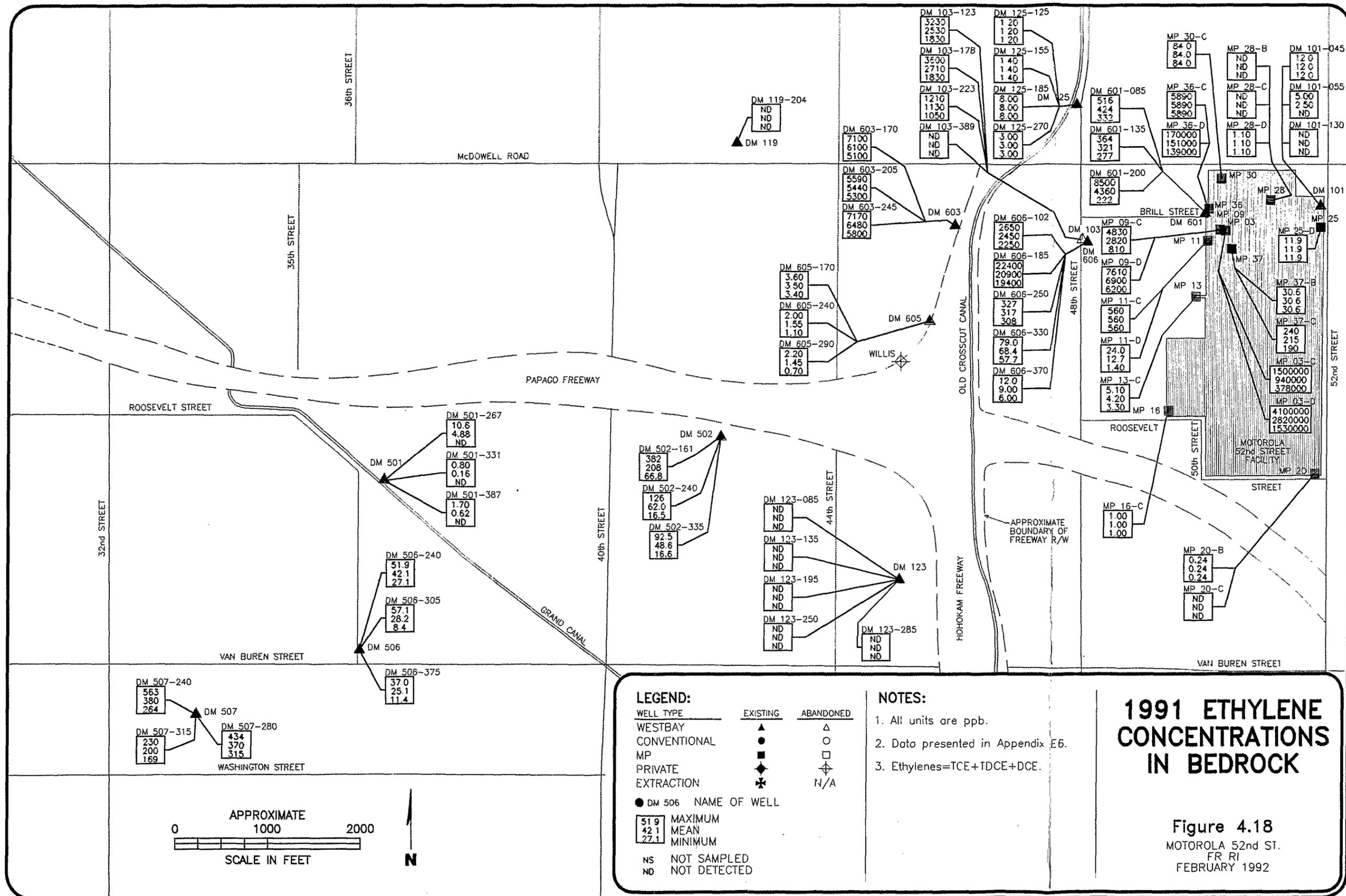
WELL TYPE	EXISTING	ABANDONED
WESTBAY	▲	△
CONVENTIONAL	●	○
MP	■	□
PRIVATE	◆	◇
EXTRACTION	✱	N/A
● DM 503	NAME OF WELL	
19.0	MAXIMUM	
7.88	MEAN	
0.20	MINIMUM	
NS	NOT SAMPLED	
ND	NOT DETECTED	

**NOTES:**

- All units are ppb.
- Data presented in Appendix E6.
- Ethylenes=TCE+TDCE+DCE.

# 1991 ETHYLENE CONCENTRATIONS IN ALLUVIUM

**Figure 4.17**  
 MOTOROLA 52nd ST.  
 FR RI  
 FEBRUARY 1992



**LEGEND:**

WELL TYPE	EXISTING	ABANDONED
WESTBAY	▲	△
CONVENTIONAL	●	○
MP	■	□
PRIVATE	◆	◇
EXTRACTION	✱	N/A
● DM 506	NAME OF WELL	

51.9	MAXIMUM
42.1	MEAN
27.1	MINIMUM

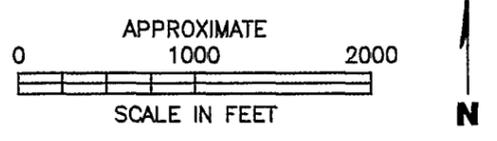
NS NOT SAMPLED  
ND NOT DETECTED

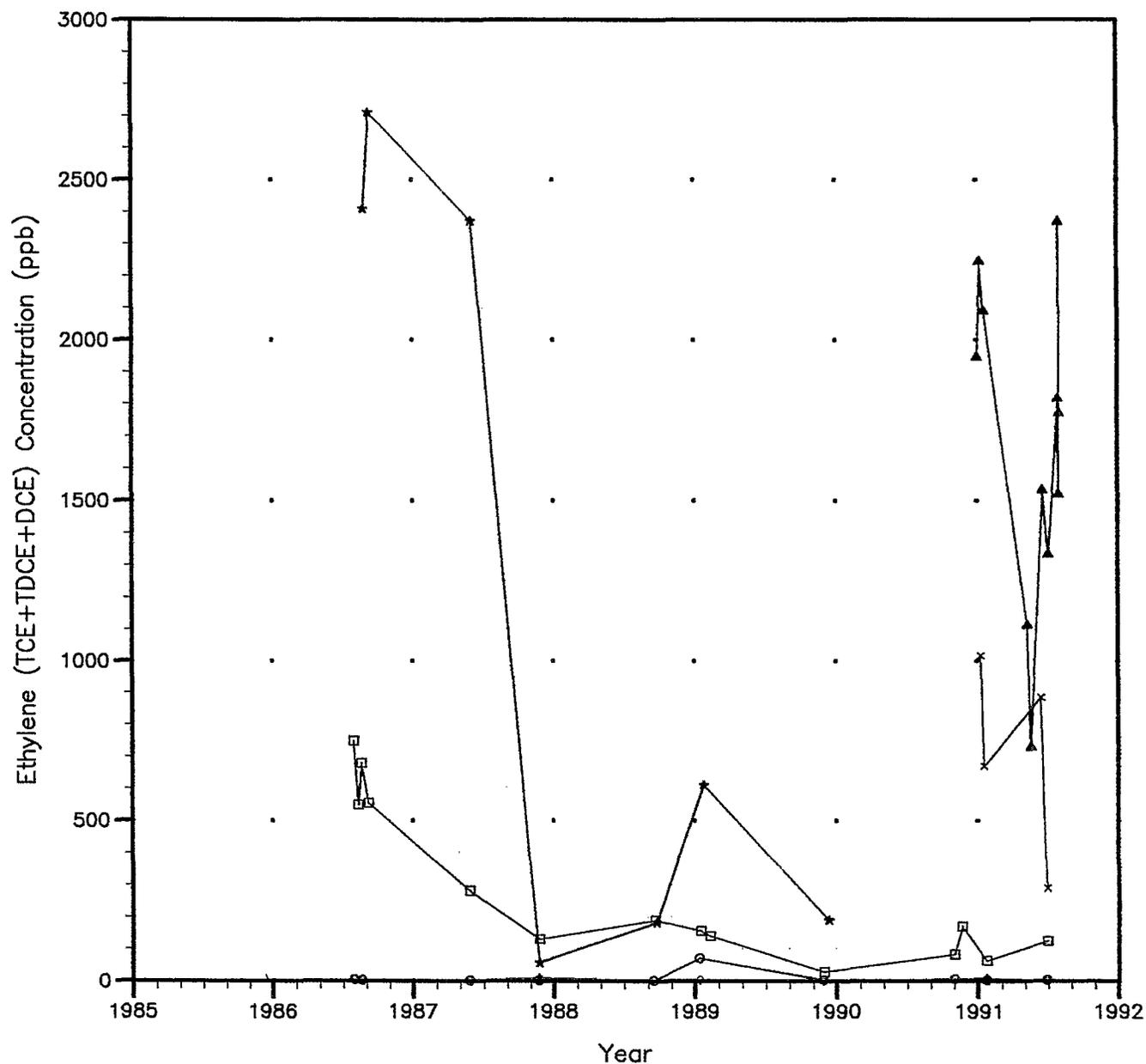
**NOTES:**

- All units are ppb.
- Data presented in Appendix E6.
- Ethylenes=TCE+TDCE+DCE.

# 1991 ETHYLENE CONCENTRATIONS IN BEDROCK

Figure 4.18  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992





**LEGEND:**

- DM 122-A
- ▲—▲—▲ DM 504
- DM 120
- ◇—◇—◇ DM 122-B
- ★—★—★ DM 121-125
- ×—×—× DM 502-119

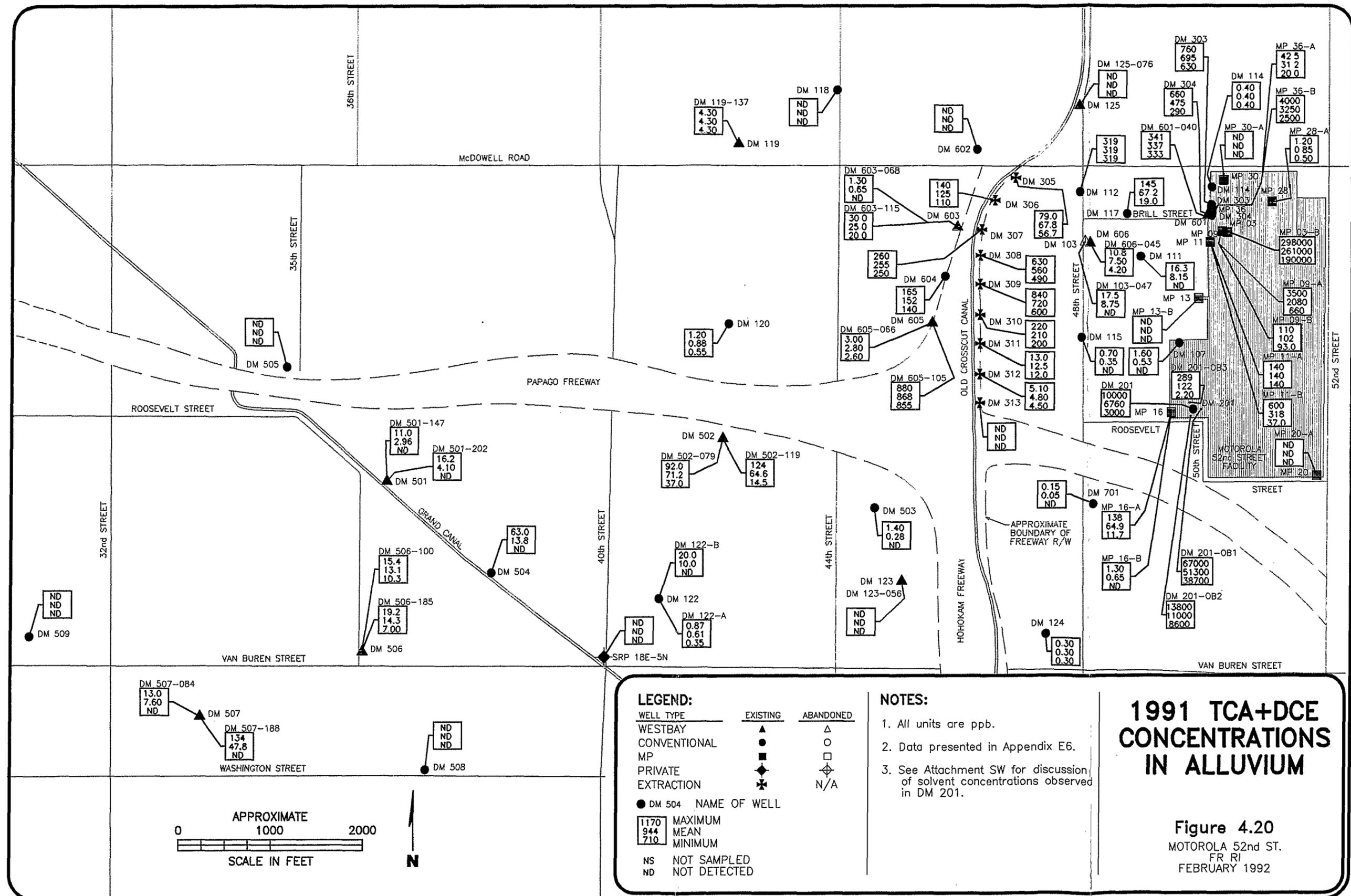
**NOTE:**

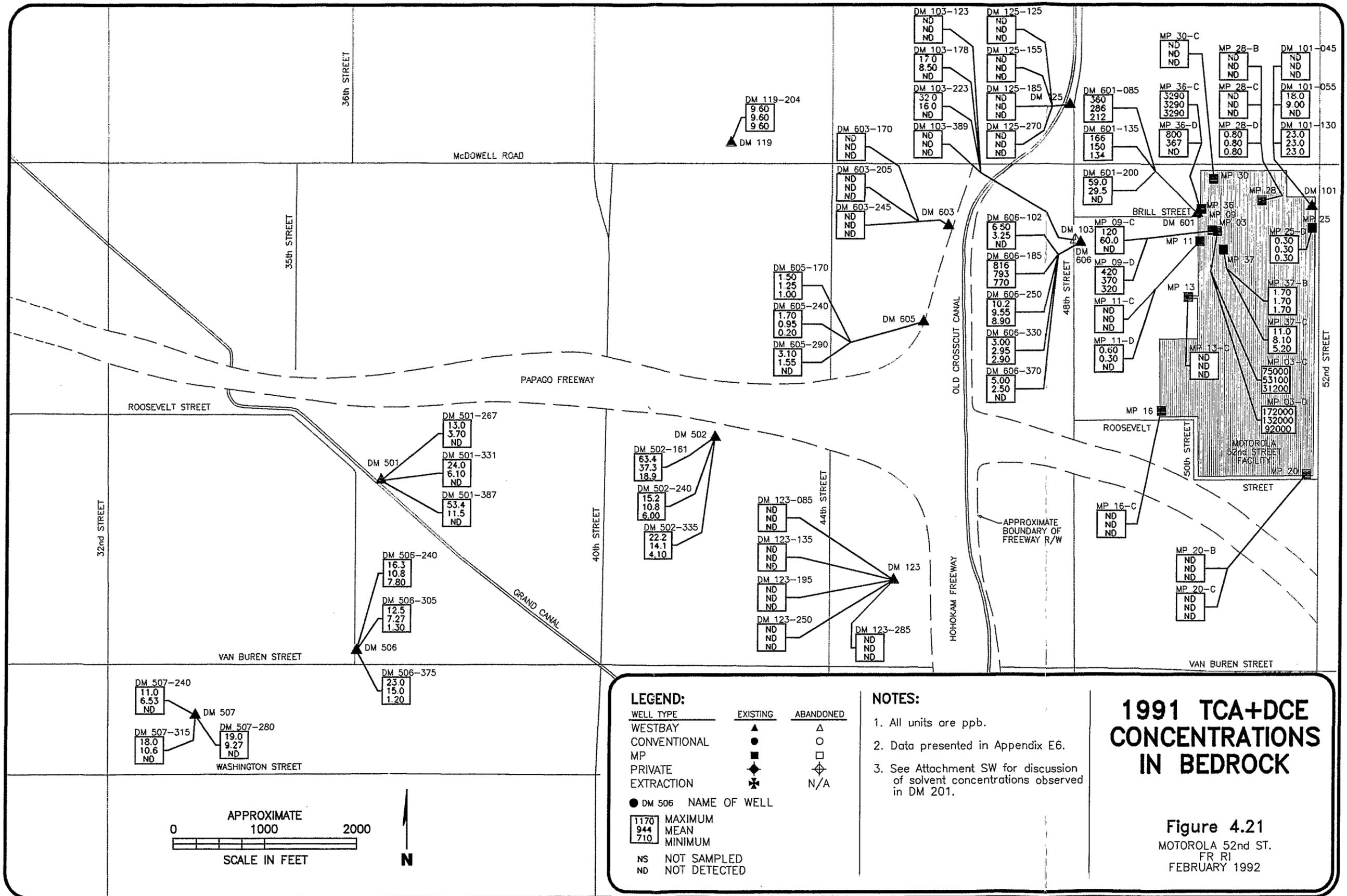
Data presented in Appendix E

## ETHYLENE CONCENTRATIONS VS. TIME (SELECTED FAR-FIELD WELLS)

**Figure 4.19**

MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992





**LEGEND:**

WELL TYPE	EXISTING	ABANDONED
WESTBAY CONVENTIONAL	▲	△
MP PRIVATE	■	□
EXTRACTION	◆	◇
	✱	N/A

● DM 506 NAME OF WELL

1170	MAXIMUM
944	MEAN
710	MINIMUM

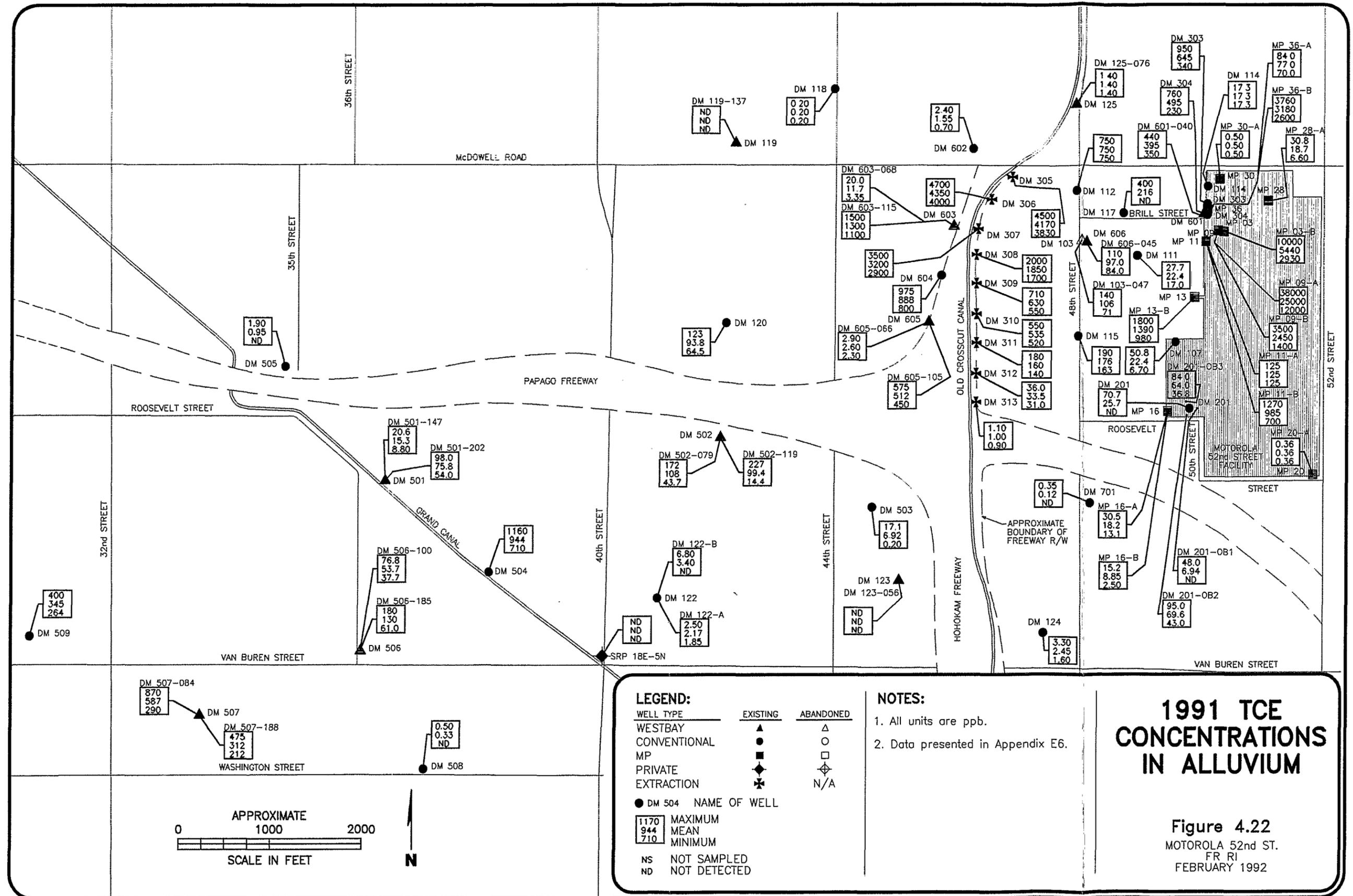
NS NOT SAMPLED  
ND NOT DETECTED

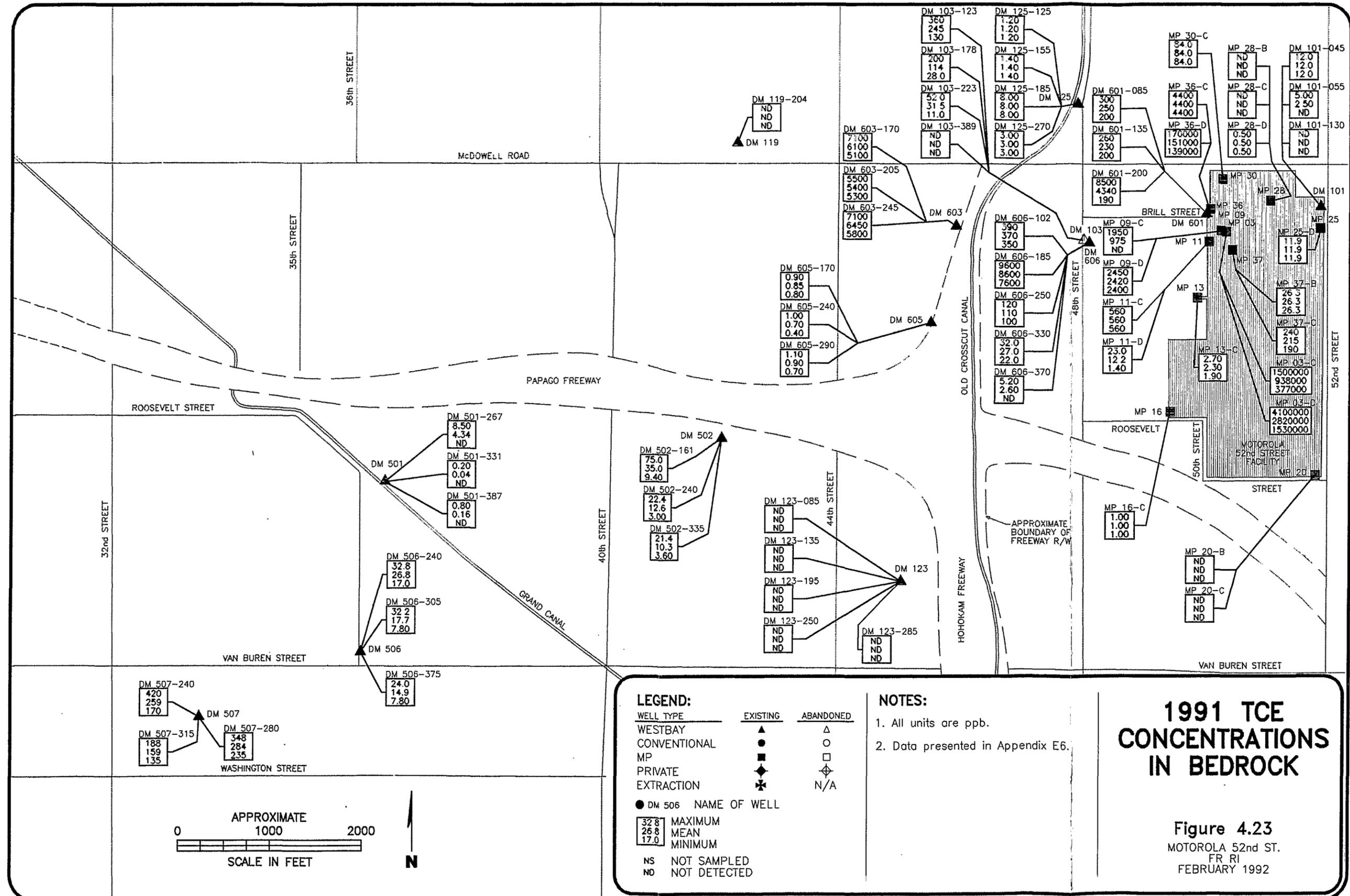
**NOTES:**

- All units are ppb.
- Data presented in Appendix E6.
- See Attachment SW for discussion of solvent concentrations observed in DM 201.

# 1991 TCA+DCE CONCENTRATIONS IN BEDROCK

**Figure 4.21**  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992





**LEGEND:**

WELL TYPE	EXISTING	ABANDONED
WESTBAY	▲	△
CONVENTIONAL	●	○
MP	■	□
PRIVATE	◆	◇
EXTRACTION	✱	N/A

● DM 506 NAME OF WELL

32.8	MAXIMUM
26.8	MEAN
17.0	MINIMUM

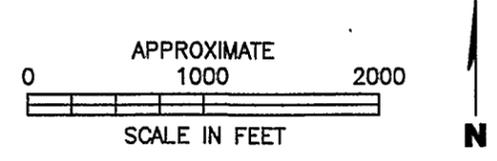
NS NOT SAMPLED  
ND NOT DETECTED

**NOTES:**

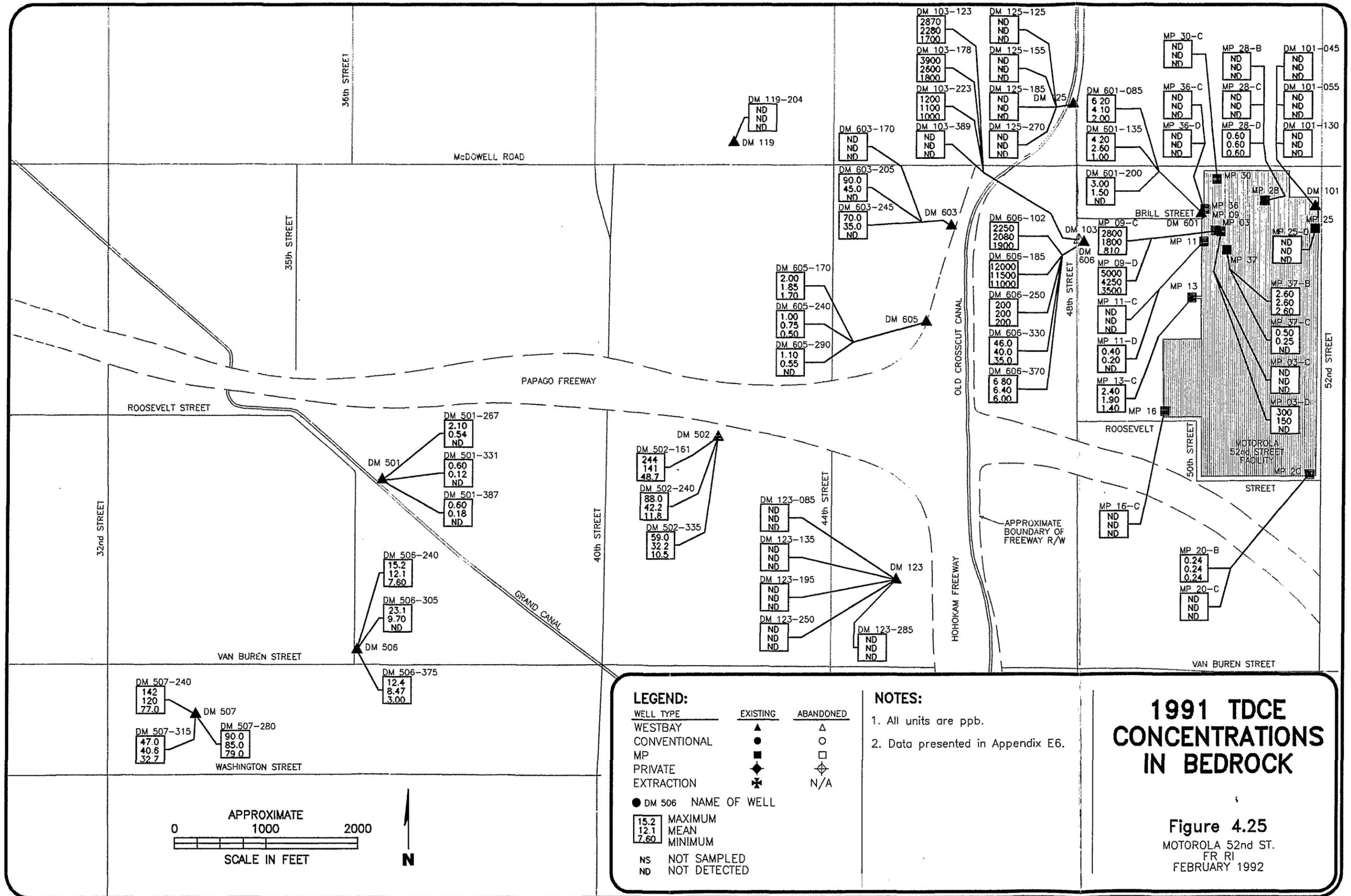
- All units are ppb.
- Data presented in Appendix E6.

# 1991 TCE CONCENTRATIONS IN BEDROCK

**Figure 4.23**  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992







**LEGEND:**

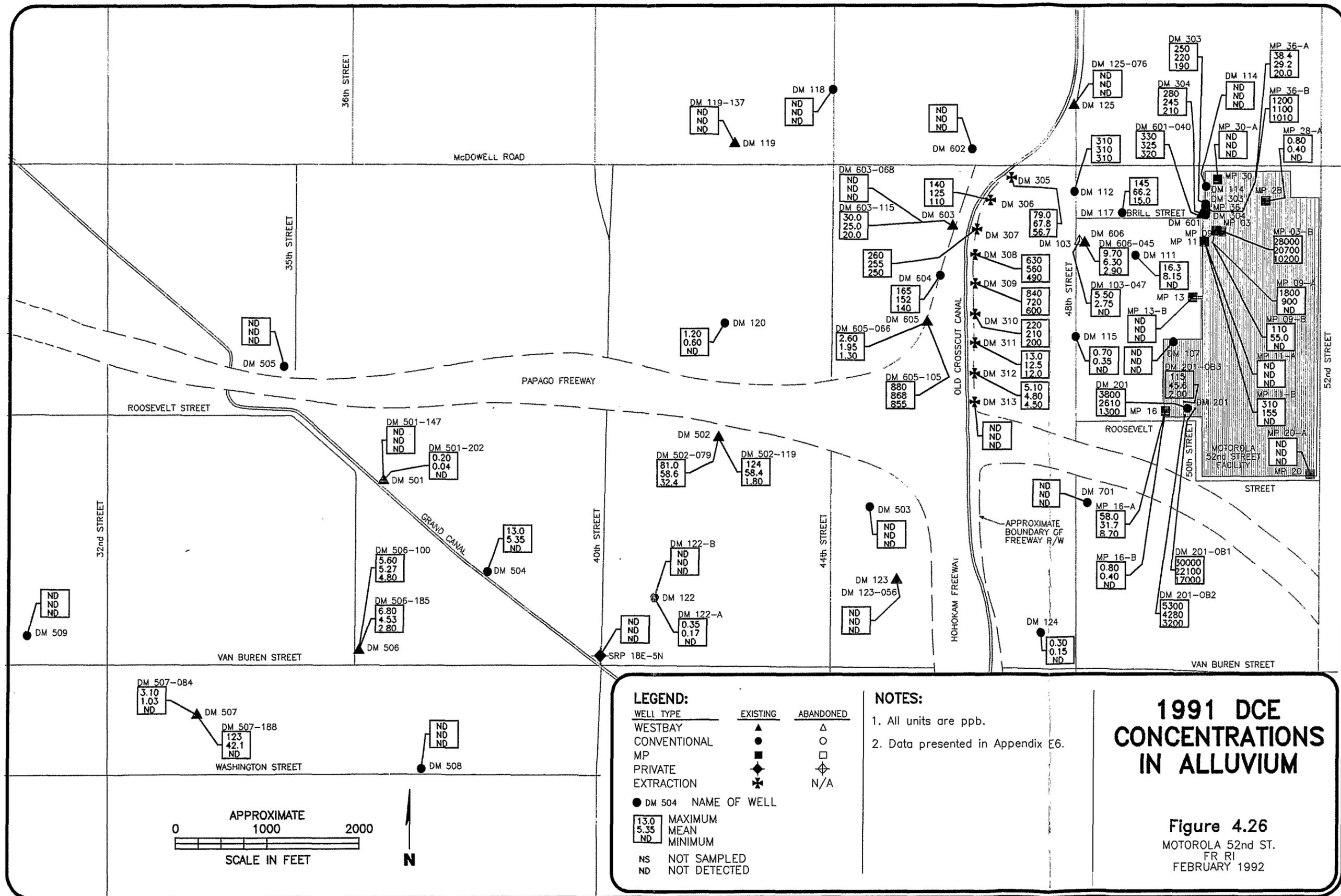
WELL TYPE	EXISTING	ABANDONED
WESTBAY	▲	△
CONVENTIONAL	●	○
MP	■	□
PRIVATE	◆	◇
EXTRACTION	✱	N/A
● DM 506	NAME OF WELL	
15.2	MAXIMUM	
12.1	MEAN	
7.60	MINIMUM	
NS	NOT SAMPLED	
ND	NOT DETECTED	

**NOTES:**

1. All units are ppb.
2. Data presented in Appendix E6.

**1991 TDCE CONCENTRATIONS IN BEDROCK**

**Figure 4.25**  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992



**LEGEND:**

WELL TYPE	EXISTING	ABANDONED
WESTBAY	▲	△
CONVENTIONAL	●	○
MP	■	□
PRIVATE	◆	◇
EXTRACTION	✱	N/A

● DM 504 NAME OF WELL

13.0	MAXIMUM
5.35	MEAN
ND	MINIMUM

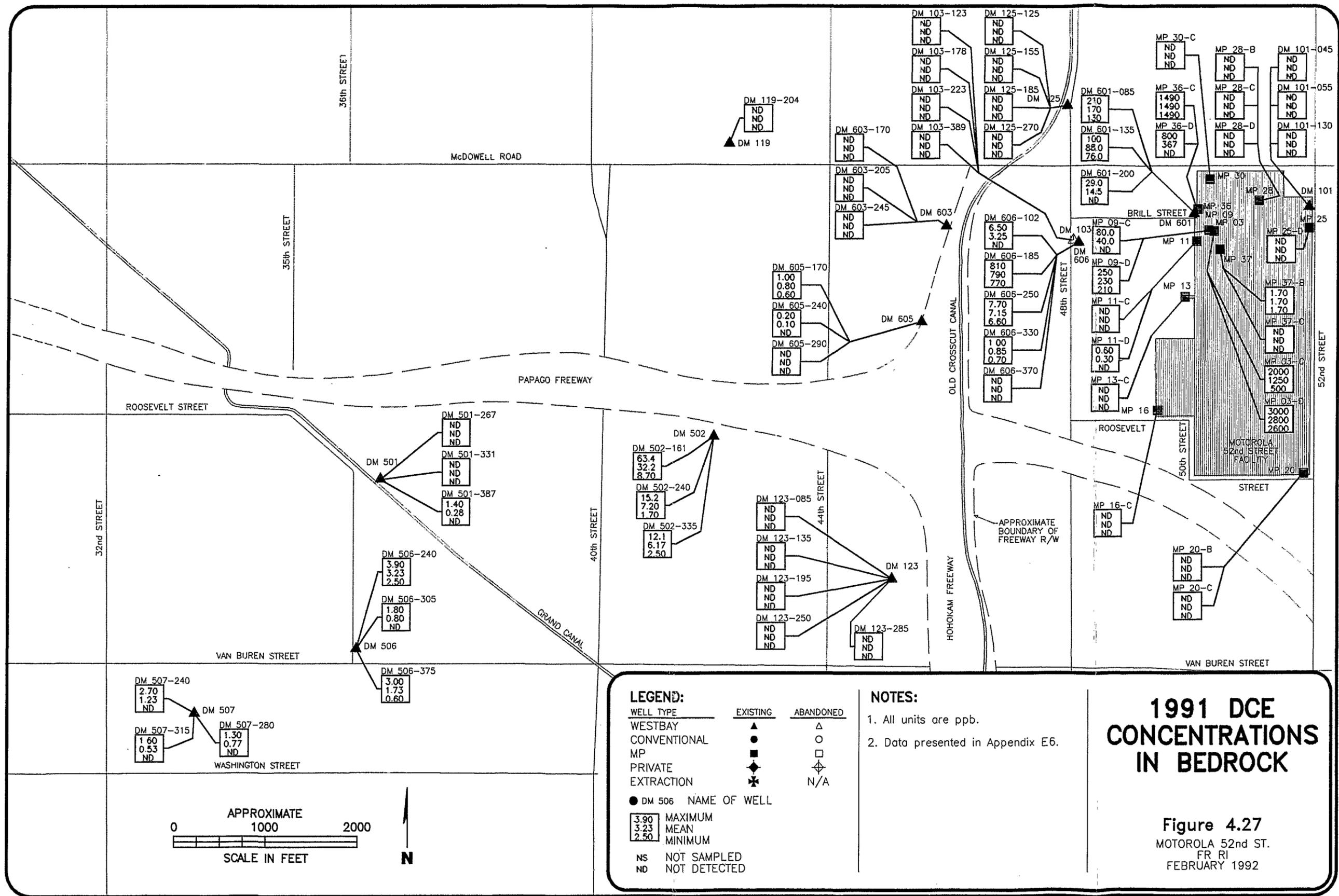
NS NOT SAMPLED  
ND NOT DETECTED

**NOTES:**

- All units are ppb.
- Data presented in Appendix E6.

# 1991 DCE CONCENTRATIONS IN ALLUVIUM

**Figure 4.26**  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992



**LEGEND:**

WELL TYPE	EXISTING	ABANDONED
WESTBAY	▲	△
CONVENTIONAL	●	○
MP	■	□
PRIVATE	◆	◇
EXTRACTION	✱	N/A
● DM 506 NAME OF WELL		
3.90	MAXIMUM	
3.23	MEAN	
2.50	MINIMUM	
NS	NOT SAMPLED	
ND	NOT DETECTED	

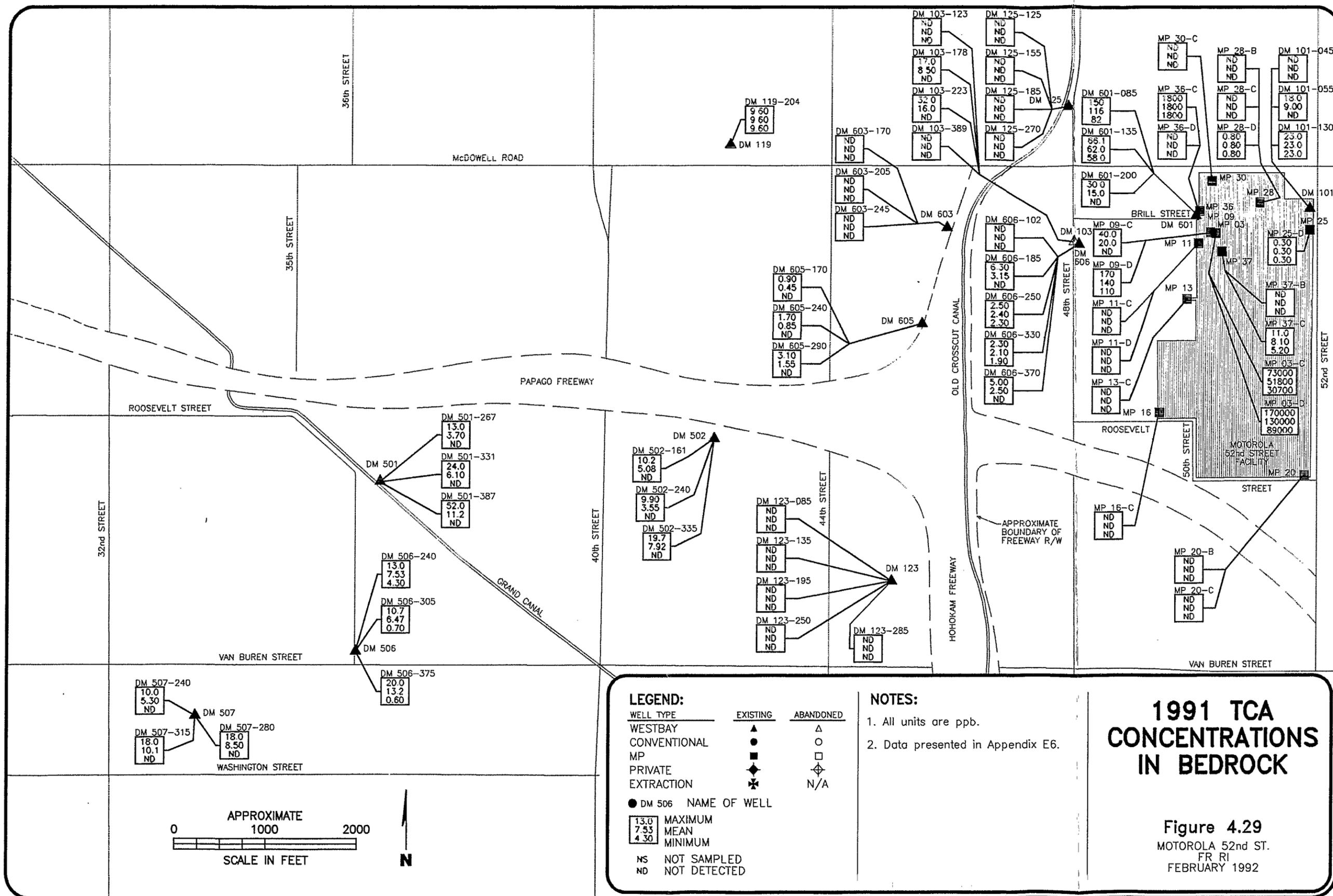
**NOTES:**

1. All units are ppb.
2. Data presented in Appendix E6.

**1991 DCE CONCENTRATIONS IN BEDROCK**

**Figure 4.27**  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992





**LEGEND:**

WELL TYPE	EXISTING	ABANDONED
WESTBAY	▲	△
CONVENTIONAL	●	○
MP	■	□
PRIVATE	◆	◇
EXTRACTION	✱	N/A
● DM 506	NAME OF WELL	
13.0	MAXIMUM	
7.53	MEAN	
4.30	MINIMUM	
NS	NOT SAMPLED	
ND	NOT DETECTED	

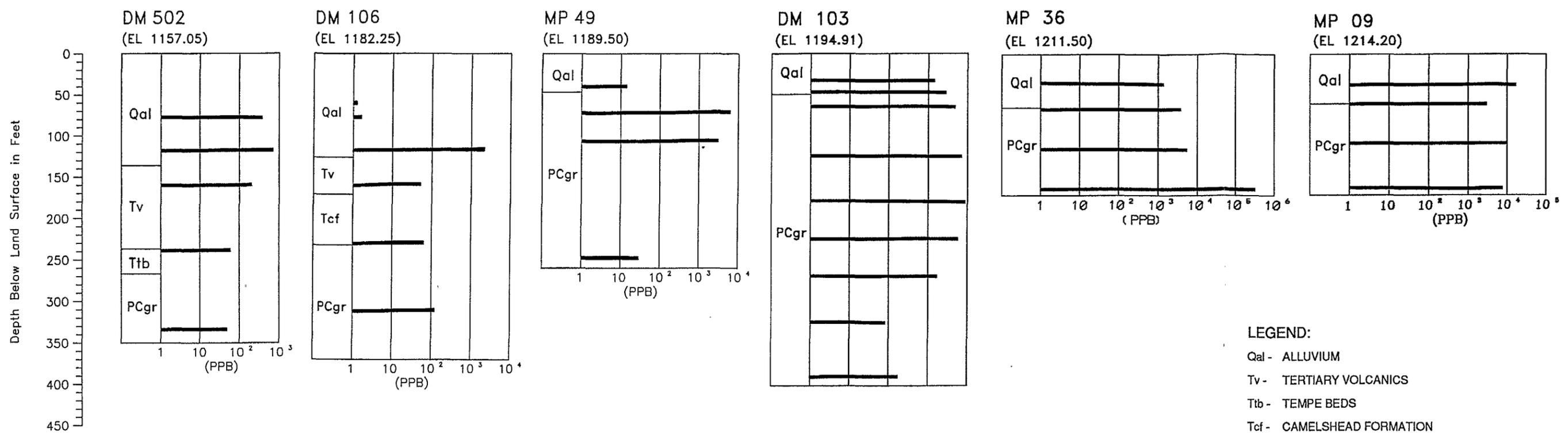
**NOTES:**

1. All units are ppb.
2. Data presented in Appendix E6.

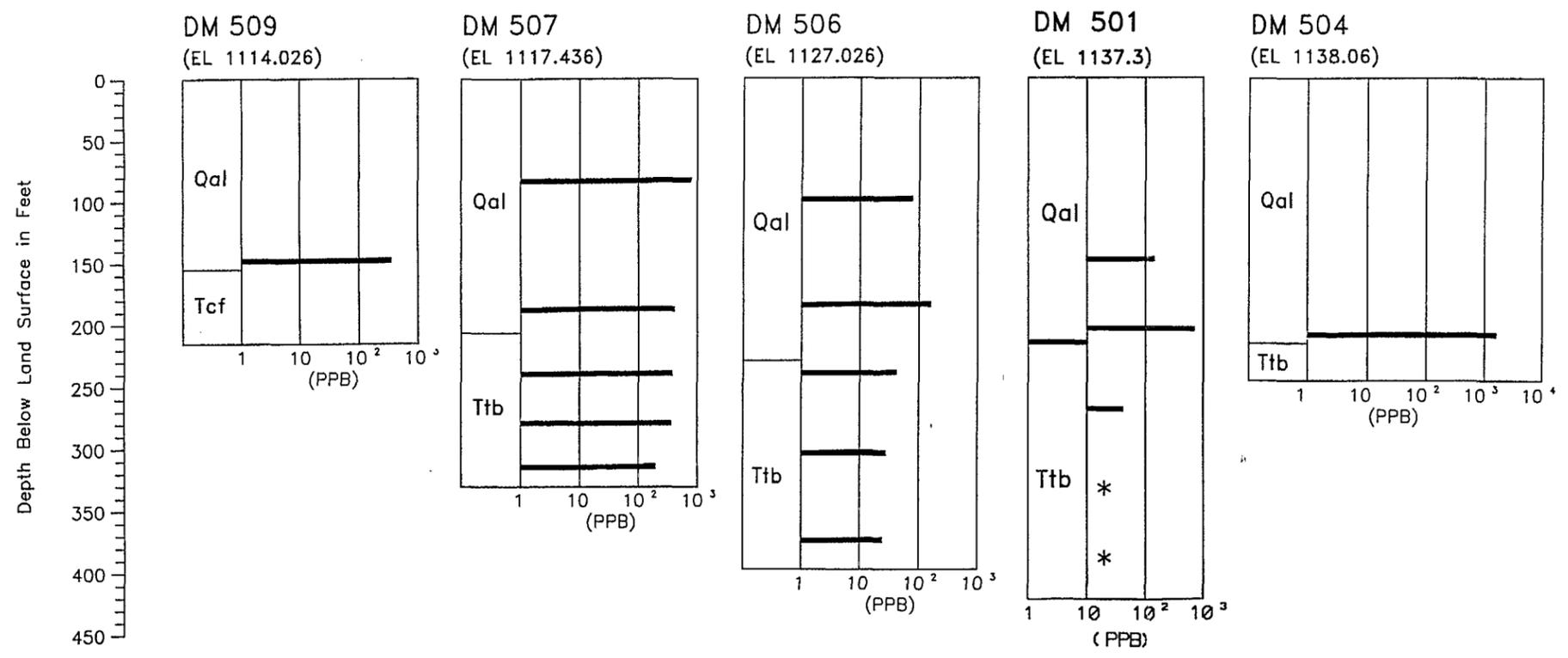
**1991 TCA CONCENTRATIONS IN BEDROCK**

**Figure 4.29**  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992

← DOWN GRADIENT DIRECTION



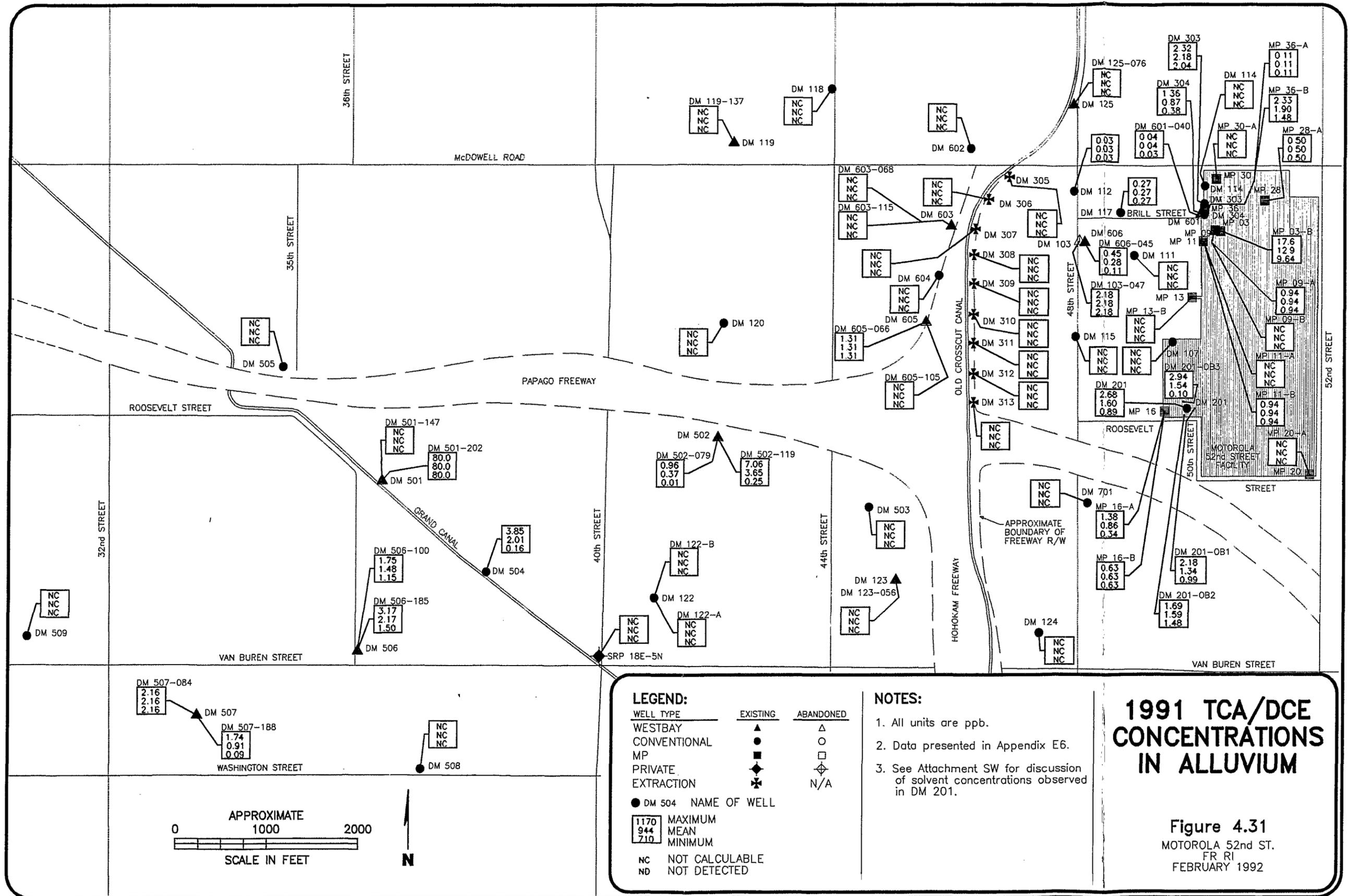
← DOWN GRADIENT DIRECTION

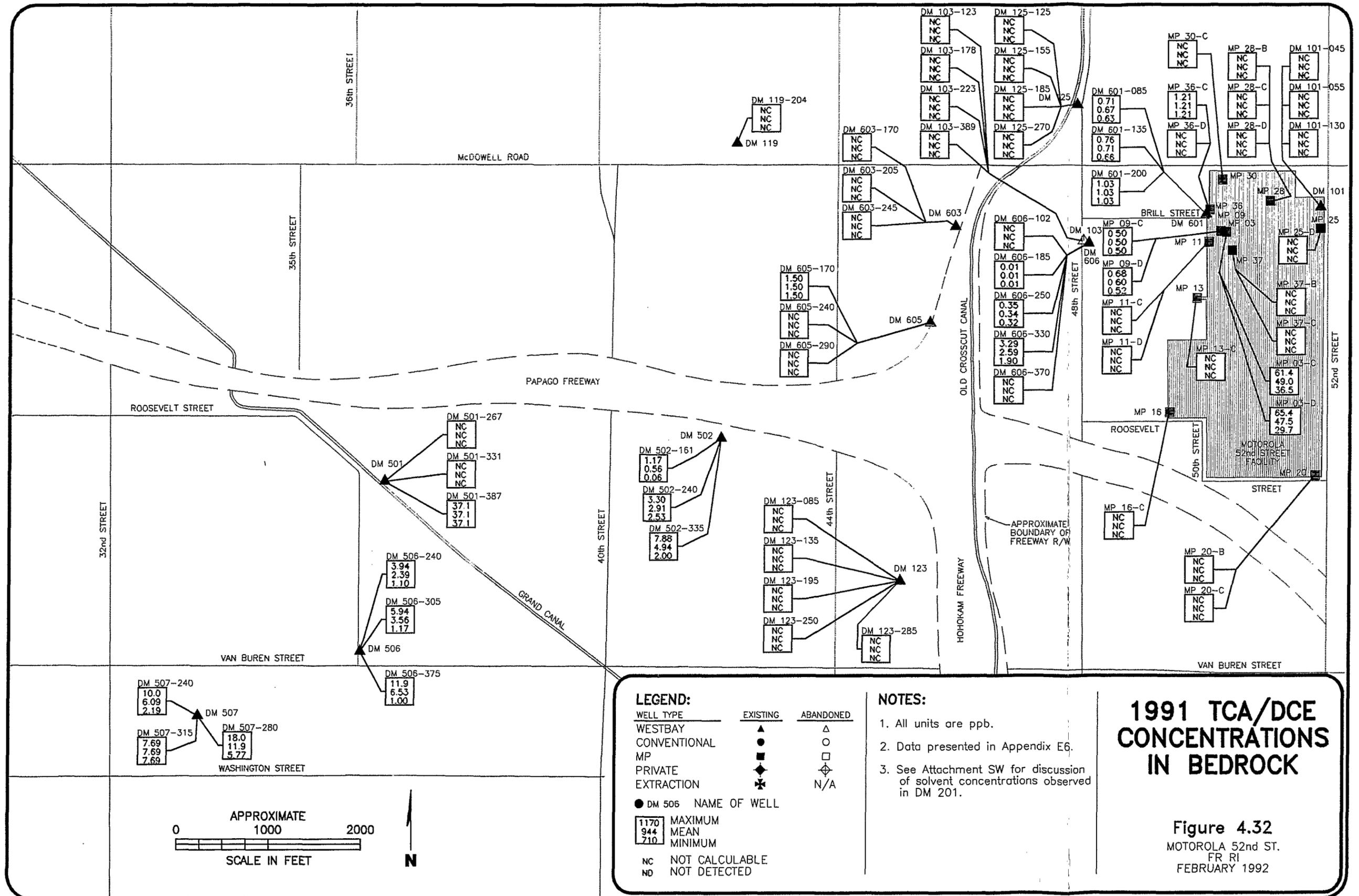


**LEGEND:**  
 Qal - ALLUVIUM  
 Tv - TERTIARY VOLCANICS  
 Ttb - TEMPE BEDS  
 Tcf - CAMELSHEAD FORMATION  
 PCgr - PRECAMBRIAN GRANITE  
 \* CONCENTRATION LESS THAN 1 PPB  
 — HORIZONTAL LINE INDICATES MEAN POST-RI ETHYLENE CONCENTRATION (TCE + TDCE + DCE) (LENGTH OF LINE)

**NOTES:**  
 REFER TO CROSS-SECTIONS IN CHAPTER 2  
 DATA PRESENTED IN APPENDIX E6  
 ELEVATIONS IN FEET ABOVE MEAN SEA LEVEL

**VERTICAL DISTRIBUTION OF ETHYLENES (TCE+TDCE+DCE)**  
 Figure 4.30  
 MOTOROLA 52nd ST.  
 FR RI  
 FEBRUARY 1992





**LEGEND:**

WELL TYPE	EXISTING	ABANDONED
WESTBAY	▲	△
CONVENTIONAL	●	○
MP	◆	◻
PRIVATE	◆	◻
EXTRACTION	✱	N/A

● DM 506 NAME OF WELL

1170	MAXIMUM
944	MEAN
710	MINIMUM

NC NOT CALCULABLE  
ND NOT DETECTED

**NOTES:**

- All units are ppb.
- Data presented in Appendix E6.
- See Attachment SW for discussion of solvent concentrations observed in DM 201.

# 1991 TCA/DCE CONCENTRATIONS IN BEDROCK

**Figure 4.32**  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992

## 5.0 INORGANIC GROUND-WATER QUALITY

### 5.1 INTRODUCTION

Inorganic ground-water quality was investigated as part of the 1987 Draft RI. Fifty-nine samples from 58 wells were collected in 1985 and 1986 and analyzed for a suite of inorganic constituents. Since 1986, an additional 230 samples have been collected from more than 30 wells in the area which has been expanded to west of the Grand Canal (see Figure 3.1 for monitor well locations). The current inorganic ground-water quality database therefore contains analytical results from approximately 290 samples in an area extending from the Motorola 52nd St. Facility west to about 30th Street and from Van Buren Street north to just south of Oak Street.

Inorganic constituents occur naturally in ground water making it difficult to define the extent and degree of inorganic contamination from man-made sources. The results of the 1987 Draft RI indicated that 1) background levels of many inorganic constituents are variable, and often exceed water quality standards, and 2) concentrations of most inorganic constituents were found to be about twice as high in alluvium as compared to bedrock.

Two areas of apparent inorganic contamination that could be attributed to historical activities on the Motorola 52nd St. Facility were identified in the 1987 Draft RI. One area occurs in the vicinity of the Courtyard associated with Source 14, an acid spill in Building J (now demolished). A second area of inorganic contamination of ground-water was identified in the vicinity of the Southwest Parking Lot (SWPL). The cause of the contamination in this area was not clear.

The results of inorganic water quality sampling conducted since completion of the 1987 Draft RI are summarized in this chapter. The inorganic chemistry in the study area is characterized with respect to background inorganic water quality and the influence of known source areas on the local inorganic ground-water composition.

### **5.1.1 Objective**

The objectives of the present investigation are to characterize ground-water quality and to identify areas of ground-water contamination related to the Motorola 52nd St. Facility.

Wells screened in the alluvium and in the bedrock were sampled and analyzed for inorganic constituents during the FR RI investigation. The largest concentrations of inorganic constituents occurred in alluvial monitor wells. As a consequence, the focus of this discussion is inorganic water quality in alluvium.

### **5.1.2 Collection of Data**

Objectives of the investigation and the general approach were presented in the Draft Inorganic Task Specification (Dames & Moore, 1990e) and in the Draft FR Work Plan (Dames & Moore, 1990i). Sample collection and analysis procedures are described in the following documents:

- Draft Sample Collection and Analysis Plan (Dames & Moore, 1990j),
- Task Specification for Water Sampling and Analysis, (Dames & Moore, 1985m), and
- Task Specification for the Long-Term Ground-Water Sampling Program, (Dames & Moore, 1987a).

About 290 samples collected from more than 30 wells were analyzed for inorganic constituents as part of this investigation. A general description of the ground-water monitoring

well network is provided in Chapter 4.0. Details of well construction methods are provided in Appendix A. A complete listing of all ground-water monitoring wells included in this investigation is provided in Appendix C1.

### 5.1.3 Presentation of Data

Inorganic water quality analytical data measurements are provided in Appendices E3 and E4. Field measurements included static water level, pH, specific conductance, temperature, and dissolved oxygen and are included in Appendices E3 and E4. Procedures used and data analyzed to conduct the laboratory and field quality assurance/quality control (QA/QC) programs are presented in Appendix E5. Specific analytical results have been qualified with regard to their applicability based on the QA/QC review; the qualifications are noted in Appendix E4.

Mean concentrations of inorganic constituents at individual wells are presented in Appendix E7. Abbreviations of inorganic constituents used in this chapter are as follows:

Inorganic Constituents	Abbreviations	Inorganic Constituents	Abbreviations
Sodium	Na	Arsenic	As
Potassium	K	Barium	Ba
Calcium	Ca	Boron	B
Magnesium	Mg	Selenium	Se
Chloride	Cl	Lead	Pb
Bicarbonate	HCO <sub>3</sub>	Manganese	Mn
Carbonate	CO <sub>3</sub>	Iron	Fe
Sulfate	SO <sub>4</sub>	Nickel	Ni
Nitrate	NO <sub>3</sub>	Cadmium	Cd
Phosphate	PO <sub>4</sub>	Silver	Ag
Fluoride	F	Thallium	Th

Inorganic Constituents	Abbreviations	Inorganic Constituents	Abbreviations
Total Dissolved Solids	TDS	Cyanide	CN
Chromium	Cr		

Mean concentrations of major ions in selected wells are represented graphically using Stiff (1951) diagrams on Figure 5.1 and plotted on a trilinear diagram on Figure 5.2. Wells that were not sampled or sampled only once are not shown in order to simplify presentation in areas with closely spaced wells. Wells not shown include DM 202, DM 202OB1, DM 202OB2, and SW 1. Monitor wells DM 202, DM 202OB1, and DM 202OB2 were located along the Old Crosscut Canal, near MP 49, and had inorganic water quality similar to MP 49. These wells, including MP 49, were abandoned during 1990, as explained in Appendix A. Monitor well SW-1 is located in the Courtyard, near MP 3, and has water quality that is similar to MP 3. The location of both MP 3 and MP 49 are shown on the figures.

The Stiff diagrams shown on Figure 5.1 were plotted by converting concentrations of major ions from parts per million (ppm) to milliequivalents per liter (meq/l). Concentrations of Na+K, Ca, Mg, and NO<sub>3</sub> are plotted to the left, and Cl, HCO<sub>3</sub>, SO<sub>4</sub>, and carbonate (CO<sub>3</sub>) are plotted to the right of a vertical axis that represents zero concentration. Stiff diagrams are used in the qualitative comparison of major ion concentrations. The area of the Stiff diagram is an indication of total ionic content. Waters of different concentrations are identified by differences in the width of the Stiff diagram, and waters of different compositions are identified by differences in shape.

Mean ion concentrations are plotted on Figure 5.2 using the trilinear diagram method developed by Piper (1944). The trilinear diagram consists of two ternary fields (triangles) for plotting percentages of cations (left triangle) and anions (right triangle), and a central diamond-shaped composite field for plotting cations and anions together. Each well is represented on Figure 5.2 by one point located in each of the three fields. The trilinear diagram

on Figure 5.2 is used to classify the ground water in the area, evaluate downgradient changes in major ion composition, and identify waters from different sources. Figures 5.3 through 5.10 present mean concentration data plotted at each well location for the inorganic constituents Cl, SO<sub>4</sub>, TDS, As, F, NO<sub>3</sub>, Cr, Pb, Se, Ba, Fe, Mn, Ni, and CN. These figures include pie charts comparing the mean concentrations to water quality standards including Primary Drinking Water Standards (PDWS), Secondary Drinking Water Standards (SDWS), or Health Based Guidance Levels (HBGL) for each constituent. Figures 5.11 through 5.16 are plots of mean concentrations for As, F, and NO<sub>3</sub> in relation to the ground-water flow direction as represented by water table elevation contour lines. The following sections provide an evaluation of these figures. Tables 5.1, 5.2, and 5.3 provide statistical information for observations of As, F, and NO<sub>3</sub>, respectively. Each table includes the maximum, mean, and minimum concentration values, the standard deviation, and the number of observations. The tables are useful for interpretation of the statistical significance of the mean values for As, F, and NO<sub>3</sub> presented in Figures 5.5, 5.6, and 5.11 through 5.16.

## 5.2 CHARACTERIZATION OF INORGANIC GROUND-WATER QUALITY

Inorganic constituents occur naturally in ground water; therefore, inorganic contamination is identified by comparison of observed concentrations to: 1) background concentrations, and 2) water quality standards. Background concentrations can vary considerably by location and with time as the result of complex and changing natural processes and human activities. Water quality standards, however, are fixed by state and federal agencies. At many locations, including the area of the Motorola 52nd St. Facility, background concentrations of many inorganic constituents may exceed water quality standards. In the following sections, major ion concentrations are characterized and then compared to water quality standards. The definition of water quality standards and a description of the development of standards are presented in Section 5.2.2.

### 5.2.1 Characterization of Major Ions in Study Area

Major ions detected in all samples include Ca, Mg, Na, K, Cl, SO<sub>4</sub>, and HCO<sub>3</sub>. Variations in the width and shape of the Stiff diagrams and the degree of scatter of points in the three fields of the trilinear diagram on Figures 5.1 and 5.2, respectively, indicate that both the total concentration and composition of major ions are variable in the study area.

The widest Stiff diagrams on Figure 5.1 are located in the Courtyard and SWPL areas of the Motorola 52nd St. Facility and in an area that extends downgradient from the SWPL. The larger concentrations of TDS within and near the Motorola 52nd St. Facility and downgradient from the SWPL may be due to onsite sources of inorganic contamination, as discussed in Section 5.3.

### 5.2.2 Inorganic Water Quality Standards

The trilinear 'Piper' diagram depicted in Figure 5.2 illustrates the wide variability of inorganic ground-water chemistry found throughout the study area. In general, the ground water is of the Na-Cl-SO<sub>4</sub> type. The variability observed in the trilinear diagram may be due to any or all of the following factors:

1. local changes to inorganic chemistry due to lawn fertilization and irrigation,
2. changes induced by natural geologic variability of the alluvial or bedrock matrix,
3. mixing of ground water derived from deep bedrock structures with existing water in the alluvial aquifer, and
4. inorganic water quality changes induced by activities, including discharges, in the Motorola Courtyard and SWPL areas.

In the area of the Motorola 52nd St. Facility, these processes combine making interpretation of inorganic water quality difficult. Inorganic contaminants are probably introduced

into ground water by all of these processes. Distinguishing contamination from any one source is therefore problematic. Regardless of the source, however, field data can be used to define areas of the aquifer where State and Federal Water Quality Standards are exceeded. Water quality standards applicable to ground water are discussed in this section. Also, in Section 5.2.3, comparisons of data are used to ascertain whether observed concentrations exceed background concentrations.

Two categories of water quality standards have been established by state and federal agencies for inorganic constituents. Drinking water quality standards were developed to protect consumers from potential health effects. Aesthetic water quality standards were developed to protect consumers from potentially undesirable physical properties.

According to Hem (1985), the first drinking water standards were established in 1914 by the U.S. Public Health Service. These were subsequently modified, but were legally applicable only to water used in interstate commerce. Primary drinking water standards (PDWSs), applicable to public drinking water supplies, were established by the 1974 Federal Safe Drinking Water Act and became effective in 1977 (USEPA, 1976 and 1986a). During 1990, the State of Arizona adopted the PDWSs and made them applicable to all aquifers in the state in accordance with Aquifer Water Quality Standard Rules (Title 18, Environmental Quality, Chapter 11, Article 4, R18-11-401 through R18-11-407). This statute classifies all aquifers in the state for drinking water protected use, regardless of whether they are used for drinking water purposes (A.R.S. 49-223, and A.R.S. 49-224).

Secondary drinking water standards (SDWSs), according to Hem (1985), were established in 1962 by the U.S. Public Health Service (USPHS, 1962). The SDWSs were specified by the EPA (1986b) on the basis of aesthetic properties. Aesthetic properties include color, taste, odor, and potential for undesirable effects such as staining and precipitation.

Draft human health-based guidance levels (HBGLs) for contaminants in drinking water and soil were developed for 230 chemicals by the Office of Risk Assessment and Investigation of the Arizona Department of Health Services (ADHS) under supervision of the Arizona Department of Environmental Quality (ADEQ). HBGLs are not legally enforceable drinking water standards. According to the ADEQ (1990), the HBGLs "...represent human ingestion levels that are unlikely to result in deleterious health effects during long-term exposure; they are estimated to be preventative of a toxic dose by a systemic toxicant and protective to the 1 in 1 million cancer risk level for carcinogenic compounds." HBGLs are also referred to as AHBGLs because the guidelines were issued by Arizona agencies for use in Arizona.

As discussed in Chapter 1.0, the standards discussed in this chapter are for comparison to observed concentrations only.

#### **5.2.2.1 Inorganic Ground-Water Quality Exceedances**

Figure 5.3 through 5.10 provide a graphic comparison between mean inorganic water quality concentrations and water quality standards. Mean inorganic concentrations were calculated using data collected from 1984 through 1991. The mean values have been used to characterize inorganic water quality because they provide approximation of average ground-water conditions over the entire (6+ years) span of this investigation. Maximum, mean, and minimum value of F and As concentrations measured in 1991 are illustrated in Appendix E7, Figures E7.7, E7.8, E7.9, and E7.10. Monitor wells where mean concentrations exceed water quality standards are shown on the following figures: Figures 5.3 and 5.4 for Cl, SO<sub>4</sub>, and TDS; Figures 5.5 and 5.6 for As, F, and NO<sub>3</sub>; Figures 5.7 and 5.8 for Cr, Pb, Se, and Ba; and Figures 5.9 and 5.10 for Fe, Mn, Ni, and CN. Not shown on Figures 5.3 through 5.10 are Ag, Cd, and Th. Exceedances occurred in only one well for Ag (MP 30B) and Th (DM 115). Exceedances occurred in only two wells for Cd (DM 121-210 and MP 9A).

### **5.2.3 Background Inorganic Ground-Water Quality**

To identify areas of inorganic contamination due to the activities at the Motorola 52nd St. Facility, background inorganic concentrations must first be established. Background, or ambient water quality characteristics, are caused primarily by natural processes, but may be affected by land use such as agricultural irrigation.

To distinguish background inorganic water quality from ground water considered to be contaminated with inorganics, water quality trends and characteristics are examined in detail in the following sections.

#### **5.2.3.1 Geologic Factors**

The presence of shallow bedrock in the area of the Motorola 52nd St. Facility may have a direct influence on inorganic ground-water quality. Faults and fractures provide conduits for the movement of deep bedrock ground water. Ground water derived from bedrock sources may contain high concentration of inorganic parameters because ground water moves more slowly through bedrock. Minerals dissolved into the ground water over time increase the concentrations of inorganic compounds. The relative concentrations of inorganic compounds is highly dependent on the local composition of bedrock.

At several monitor wells, an inorganic black suspension in ground-water samples has been associated with the smell of hydrogen sulfide gas. Specifically, black suspensions have been noted in wells DM 103, DM 117, DM 119, DM 125, and DM 504. At DM 504, the black suspended material and associated hydrogen sulfide smell was observed in a sample collected in June 1991. The black suspension in the sample quickly settled out of solution allowing isolation of the material. A sample of the black suspension was analyzed by SEM/TEC Laboratories, Inc. using x-ray diffraction to identify its mineral composition. The results indicated that the black

material contains a considerable amount of iron either as iron oxide or iron sulfide (letter from SEM/TEC Laboratories dated June 3, 1991).

Iron precipitates from solution when the oxidation potential (Eh) or pH change from oxygen-poor and/or low pH conditions to oxygen-rich and/or high pH conditions (Hem, 1985). The presence of sulfur- and iron-reducing bacteria can catalyze iron precipitation (Hem, 1985). The black material and hydrogen sulfide smell observed in wells DM 103, DM 117, DM 119, DM 125, and DM 504 indicates that conditions in or near the well favor iron and/or sulfur precipitation. These observations support the assertion that locally, inorganic contamination observed in the vicinity of the Motorola facility could be related to bedrock sources.

It is important to note that prevalent areas of VOC biodegradation occur near wells DM 103, DM 117 and DM 504 (see Section 4.3 for a discussion of VOC biodegradation). VOC biodegradation is enhanced where ground water is reduced and anaerobic bacteria flourish. These conditions are likely where iron and sulfur occur in high concentrations as indicated by the black precipitate and hydrogen sulfide odor.

#### **5.2.3.2 Cultural Factors**

High concentrations of nitrate and other inorganic constituents of ground water can be caused by agricultural irrigation and fertilization. The area of the Motorola 52nd St. Facility was originally citrus orchards as indicated by areal photographs presented by GPI (1984). Locally, high nitrate concentrations may have been contributed by agricultural activities prior to development of the area of the 1950s and 1960s.

### 5.2.3.3 Evaluation of Background Inorganic Water Quality

Figures 5.11 through 5.16 present mean concentrations of As, F, and NO<sub>3</sub>. Included on each figure are arrows indicating the direction of ground-water flow. These figures can be used to distinguish upgradient or offgradient monitor wells from monitor wells located downgradient of the Motorola 52nd St. Facility.

Monitor wells DM 101, MP 28, MP 30, and MP 20 are located upgradient of known source areas at the Motorola 52nd St. Facility. These wells are considered upgradient because measured water level elevations exceed water table elevations observed at the Courtyard and SWPL areas of the Motorola 52nd St. Facility. Offgradient monitor wells are located in areas of the aquifer peripheral to the known area of VOC contamination and include wells DM 118, DM 119, DM 124, DM 125, and the Morgan Well. Inorganic water quality measured in the upgradient and offgradient wells can be compared to measurements made in wells located downgradient of the Courtyard and SWPL source areas. The results of this comparison were used to evaluate the relative impact of Motorola inorganic sources on downgradient areas of the aquifer.

In Figures 5.11 and 5.12, mean arsenic concentrations have been plotted for each well. The drinking water quality standard for arsenic is 0.05 ppm. Mean arsenic concentrations only occasionally exceed the drinking water standards. The results do not indicate any large areas of arsenic contamination associated with the Motorola 52nd St. Facility.

Mean fluoride concentrations have been plotted on Figures 5.13 and 5.14. The primary drinking water standard of 4 ppm for fluoride is widely exceeded in the area including wells described above as being upgradient or offgradient of the Motorola 52nd St. Facility. The highest mean concentrations occur in the Courtyard (MP 03 at 46.0 ppm) and in the SWPL (MP 16 at 16.0 ppm). Other high fluoride concentrations occur throughout the study area, both in downgradient wells (DM 104 at 10.1 ppm; DM 313 at 9.55 ppm; and DM 504 at 8.0 ppm)

and in upgradient or offgradient wells (MP 20 at 6.20 ppm; DM 118 at 7.14 ppm; and DM 125 at 5.00 ppm). The widespread occurrence of high fluoride concentrations may indicate the presence of elevated background concentrations of fluoride. The contribution of fluoride from onsite sources to fluoride concentrations in downgradient areas is uncertain but seems to be restricted to the immediate vicinity of the Motorola 52nd St. Facility.

Figures 5.15 and 5.16 present the distribution of mean nitrate concentrations. The primary drinking water standard for nitrate is 10 ppm. Exceedances of this standard occur in one upgradient well (DM 101 at 24 ppm), in several onsite wells including MP 03 (83.5 ppm), MP 09 (28 ppm, MP 36 (89 ppm), DM 107 (68 ppm), and DM 201 (43 ppm). Exceedance of the nitrate drinking water standard also occurs in several downgradient wells including DM 115 (34 ppm), DM 120 (15 ppm), DM 701 (14 ppm), DM 312 (19 ppm), and DM 313 (10 ppm). As discussed previously (Section 5.2.3.2), elevated nitrate concentrations could be related to historical agricultural land use in this area as well as from sources located at the Motorola 52nd St. Facility. Historical land use may help explain the elevated nitrate concentration in upgradient well DM 101. The area of highest nitrate concentrations is located primarily upgradient of the off-site extraction well system along the Old Crosscut Canal.

### 5.3 AREAS OF INORGANIC CONTAMINATION

Areas of potential inorganic contamination from the Motorola 52nd St. Facility were delineated by identifying wells where large exceedances of water quality standards occur.

The principal areas of inorganic contamination include the areas of the Courtyard and the SWPL, as presented in the 1987 Draft RI Report (Dames & Moore, 1987b). Each are reviewed below.

### 5.3.1 Inorganic Contamination in the Courtyard Area

The following observations of mean concentrations of inorganic constituents in, and near the Courtyard indicate contamination of ground water due to Motorola activities:

- TDS ranges from 3,000 to more than 4,000 ppm;
- SO<sub>4</sub> ranges from 800 to more than 1,100 ppm;
- Cl ranges from 300 to more than 800 ppm;
- NO<sub>3</sub> ranges from 8 to more than 80 ppm;
- F ranges from 12 to more than 14 ppm; and
- Arsenic (As) ranges from 0.02 to 1 ppm.

Areas of potential contamination from these constituents are indicated by Stiff diagrams on Figure 5.1 and by the locations of exceedances on Figures 5.3 through 5.10.

Although large concentrations of TDS, SO<sub>4</sub>, Cl, NO<sub>3</sub>, and F were observed in wells located within the Courtyard, these large concentrations do not appear to extend downgradient to wells located offsite, west of the Courtyard. As noted in Section 5.2.3.3, fluoride and nitrate concentrations are observed to exceed water quality standards, even in wells upgradient or offgradient of the facility (Figures 5.13 and 5.15, respectively). Fluoride concentrations may exceed 7 ppm, and nitrate occurs as high as 24 ppm in upgradient or offgradient wells. Immediately west (or downgradient) of the Courtyard, fluoride concentrations range from 6 to 8 ppm. Nitrate ranges from 6 to 18 ppm.

Mean As concentrations exceed the PDWSs as far downgradient as monitor well DM 117 which is located less than 1,000 feet downgradient from the west side of the Courtyard. Mean concentrations of Ba, Fe, and Mn also exceeded the PDWSs and SDWSs at DM 117. The only exceedance of the PDWSs for Ba occurred in DM 117.

Mean concentrations of Ni, Cr, Pb, Se, and Cd exceed water quality standards at scattered wells located east of the Old Crosscut Canal and in the Courtyard. However, the locations of these exceedances, except for Se in monitor well MP 51 and Cr in monitor well DM 115, are limited to wells located within the Courtyard. The locations of the exceedances of these metals do not form an obvious pattern.

Potential sources of inorganic contamination in the Courtyard were discussed in the 1987 Draft RI Report. These included the disposal or spillage of hydrofluoric acid, ammonium fluoride, and nitric acid underneath Building J. This was identified as Source 14 (see discussion in Chapter 1.0).

### 5.3.2 Inorganic Contamination in the SWPL Area

The following observations indicate ground-water contamination by inorganic constituents in the SWPL, and an area downgradient from the SWPL:

- TDS ranges from 2,000 to more than 3,000 ppm;
- SO<sub>4</sub> is greater than 1,000 ppm;
- Cl ranges from 500 to more than 1,000 ppm; and
- NO<sub>3</sub> ranges from 20 to more than 30 ppm.

Areas of potential contamination by these constituents are indicated by Stiff diagrams on Figure 5.1 and by the locations of exceedances on Figures 5.3 through 5.5.

In the SWPL, concentrations of TDS range from 3,132 ppm in monitor well MP 16A to 5,460 ppm in monitor well DM 107. Concentrations of TDS in excess of 2,000 ppm extend as far downgradient as monitor well DM 503, which is located more than 3,500 feet southwest of DM 107.

This is the same pattern of apparent TDS contamination (concentrations greater than 2,000 ppm) shown in the 1987 Draft RI Report, specifically Figure 4.35. Concentrations of SO<sub>4</sub> have a similar pattern with the largest concentrations (1,786 ppm) occurring in DM 107 and concentrations in excess of 1,000 ppm occurring, in a relatively narrow band, as far downgradient as DM 503. Well DM 503 is located approximately 3,500 feet southwest of the SWPL. Similar patterns were also observed for Cl and NO<sub>3</sub> concentrations.

#### 5.4 SUMMARY AND CONCLUSIONS

Inorganic ground-water quality was evaluated through analysis of approximately 290 samples collected from more than 30 monitor wells. Background inorganic ground-water concentrations were estimated by comparison of water quality data with respect to the known direction of ground-water flow and the known location of source areas within the Motorola 52nd St. Facility. Background concentrations of TDS, F, Cl, NO<sub>3</sub>, Fe, and Mn were found to locally exceed water quality standards. Areas of inorganic ground-water contamination exceeding background levels are restricted to the Courtyard area and an area downgradient from the Southwest Parking Lot.

The source of inorganic contamination in the Courtyard is believed to be attributed primarily to the acid leak at the former location of Building J (designed Source No. 14). Other sources in the Courtyard (see Chapter 1.0) may contribute to local inorganic contamination.

The cause of observed inorganic contamination in the Southwest Parking Lot is uncertain. It is believed that the source of inorganic contamination in the Southwest Parking Lot may be related to land use practices before Motorola occupied the area.

Ground water in the study area is not presently used for drinking. Evaluation of inorganic water quality data confirm that background concentrations of inorganic constituents make ground water in the study area nonpotable.

**Table 5.1**

**STATISTICAL EVALUATION OF ARSENIC OBSERVATIONS: 1985-1991**

Well	Alluvium/ Interface/ Bedrock	Maximum	Mean	Minimum	Standard Deviation	Number of Observations
4626G	A	0.008	0.00375	0	0.00435	4
AZSLD	A	0.008	0.00533	0	0.00462	3
DM 101-102	B	0	0	0	NC	1
DM 101B	A	0	0	0	NC	1
DM 102-048	A	0.036	0.034	0.032	0.00283	2
DM 102-082	B	0.024	0.024	0.024	NC	1
DM 102-104	B	0.01	0.01	0.01	NC	1
DM 102-144	B	0	0	0	NC	1
DM 102-299	B	0	0	0	NC	1
DM 104-079	A	0.23	0.23	0.23	NC	1
DM 104-146	B	0	0	0	NC	1
DM 107	A	0.24	0.15	0.09	0.04677	9
DM 111	A	0.041	0.03356	0.02	0.0068	9
DM 112	A	0.034	0.03167	0.03	0.00208	3
DM 113	A	0.04	0.036	0.032	0.00566	2
DM 114	A	0.048	0.04367	0.039	0.00451	3
DM 115	A	0.033	0.0308	0.026	0.00295	5
DM 117	A	0.36	0.265	0.03	0.10886	10
DM 118	A	0.012	0.00775	0	0.00532	4
DM 119-137	I	0	0	0	NC	1
DM 119-244	B	0	0	0	NC	1
DM 120	A	0.024	0.01191	0	0.01152	11
DM 121-125	I	0	0	0	NC	1
DM 121-219	B	0	0	0	NC	1
DM 122A	A	0.022	0.01975	0.017	0.00206	4
DM 122B	I	2.3	0.34187	0.02	0.79621	8

\*The data presented in the table are calculated from tests with various detection limits. The numbers are presumed to be accurate to no more than 2 or 3 significant figures.

NC = Not calculable.

**Table 5.1 (Continued)**

Well	Alluvium/ Interface/ Bedrock	Maximum	Mean	Minimum	Standard Deviation	Number of Observations
DM 123-056	I	0	0	0	NC	1
DM 124	A	0.052	0.03975	0.025	0.01115	4
DM 125-076	I	0	0	0	NC	1
DM 125-270	B	0	0	0	0	2
DM 126	A	0	0	0	NC	1
DM 201	A	0.13	0.082	0.046	0.04327	3
DM 202	A	0.012	0.00733	0	0.00643	3
DM 202OB1	A	0.009	0.009	0.009	NC	1
DM 202OB2	A	0.015	0.015	0.015	NC	1
DM 301	A	0.17	0.068	0.007	0.06072	5
DM 302	A	0.044	0.0248	0	0.01583	5
DM 303	A	0.068	0.059	0.052	0.00779	4
DM 304	A	0.084	0.073	0.059	0.01128	4
DM 305	A	0.017	0.017	0.017	NC	1
DM 306	A	0.009	0.009	0.009	NC	1
DM 307	A	0.006	0.006	0.006	NC	1
DM 308	A	0.006	0.006	0.006	NC	1
DM 309	A	0.018	0.018	0.018	NC	1
DM 310	A	0.052	0.052	0.052	NC	1
DM 311	A	0.18	0.18	0.18	NC	1
DM 312	A	0.012	0.012	0.012	NC	1
DM 313	A	0.07	0.07	0.07	NC	1
DM 503	A	0.044	0.0242	0.01	0.01638	5
DM 504	A	0.021	0.011	0.007	0.00668	4
DM 505	A	0	0	0	0	4
DM 508	A	0.015	0.015	0.015	NC	1
DM 509	A	0.012	0.01	0.008	0.00283	2
DM 601-085	B	0.009	0.009	0.009	NC	1

\*The data presented in the table are calculated from tests with various detection limits. The numbers are presumed to be accurate to no more than 2 or 3 significant figures.

NC = Not calculable.

**Table 5.1 (Continued)**

Well	Alluvium/ Interface/ Bedrock	Maximum	Mean	Minimum	Standard Deviation	Number of Observations
DM 601-200	B	0.006	0.006	0.006	NC	1
DM 602	A	0.0135	0.01225	0.011	0.00177	2
DM 603-115	I	0	0	0	NC	1
DM 603-245	B	0	0	0	NC	1
DM 604	A	0.032	0.024	0.016	0.01131	2
DM 605-105	I	0	0	0	NC	1
DM 605-290	B	0	0	0	NC	1
DM 606-045	I	0	0	0	NC	1
DM 606-370	B	0.006	0.006	0.006	NC	1
DM 701	A	0.017	0.017	0.017	NC	1
MP 03B	I	0.031	0.01913	0	0.01246	8
MP 03C	B	0.04	0.02556	0.011	0.00834	9
MP 03D	B	0.032	0.02229	0	0.01153	7
MP 09A	A	0.35	0.1072	0	0.08924	15
MP 09B	I	0.046	0.03433	0.025	0.00855	6
MP 09C	B	0.024	0.01633	0.012	0.00532	6
MP 09D	B	0.037	0.03475	0.0325	0.00318	2
MP 11A	A	0.17	0.05644	0.028	0.04414	9
MP 11B	I	2.6	0.57749	0	0.90461	13
MP 11C	B	0.027	0.02533	0.022	0.00289	3
MP 11D	B	0.033	0.0305	0.028	0.00354	2
MP 13A	A	0	0	0	NC	1
MP 13B	I	0.045	0.0374	0.023	0.00838	5
MP 13C	B	0.012	0.011	0.01	0.00141	2
MP 13D	B	0	0	0	NC	1
MP 16A	A	0.053	0.02822	0	0.01553	9
MP 16B	I	0.086	0.086	0.086	NC	1
MP 16C	B	0.032	0.0275	0.023	0.00636	2

\*The data presented in the table are calculated from tests with various detection limits. The numbers are presumed to be accurate to no more than 2 or 3 significant figures.

NC = Not calculable.

**Table 5.1 (Continued)**

Well	Alluvium/ Interface/ Bedrock	Maximum	Mean	Minimum	Standard Deviation	Number of Observations
MP 16D	B	0	0	0	NC	1
MP 20A	I	0.044	0.03033	0.018	0.01305	3
MP 20B	B	0.1	0.0935	0.087	0.00919	2
MP 20C	B	0	0	0	0	3
MP 25D	B	0.018	0.018	0.018	NC	1
MP 28A	I	0.01	0.005	0	0.00707	2
MP 28B	B	0.011	0.007	0	0.00608	3
MP 28C	B	0.01	0.01	0.01	0	2
MP 28D	B	0.005	0.00167	0	0.00289	3
MP 30A	A	0.04	0.032	0.026	0.00721	3
MP 30B	I	0.11	0.11	0.11	NC	1
MP 30C	B	0.023	0.023	0.023	NC	1
MP 30D	B	0.015	0.0075	0	0.01061	2
MP 36A	A	0.097	0.04693	0.018	0.03112	10
MP 36B	I	1.2	0.1734	0.08	0.28454	15
MP 36C	B	0.076	0.055	0.042	0.01472	4
MP 36D	B	0.0335	0.01863	0.013	0.00996	4
MP 37C	B	0.027	0.0245	0.022	0.00354	2
MP 48D	B	0	0	0	NC	1
MP 49A	A	0.013	0.0125	0.012	0.00071	2
MP 49B	I	0.024	0.019	0.014	0.005	3
MP 49C	B	0.052	0.052	0.052	NC	1
MP 49D	B	0.006	0.003	0	0.00424	2
MP 50A	A	0.013	0.013	0.013	NC	1
MP 50B	A	0.015	0.0075	0	0.01061	2
MP 50D	B	0	0	0	NC	1
MP 51A	A	0.014	0.014	0.014	NC	1
MP 51B	A	0.063	0.03657	0.026	0.01299	7

\*The data presented in the table are calculated from tests with various detection limits. The numbers are presumed to be accurate to no more than 2 or 3 significant figures.

NC = Not calculable.

**Table 5.1 (Continued)**

Well	Alluvium/ Interface/ Bedrock	Maximum	Mean	Minimum	Standard Deviation	Number of Observations
MP 51D	B	0	0	0	NC	1
MP 52B	I	0.008	0.00229	0	0.0039	7
MP 52C	B	0	0	0	NC	1
MP 53B	I	0.09	0.0885	0.087	0.00212	2
MP 53D	B	0.027	0.027	0.027	NC	1
PZ 01	A	0.046	0.046	0.046	NC	1
PZ 02	A	0.02	0.02	0.02	NC	1
PZ 03	A	0	0	0	NC	1
PZ 04	A	0.03	0.03	0.03	NC	1
PZ 05	A	0.16	0.16	0.16	NC	1
PZ 06	A	0.04	0.04	0.04	NC	1
PZ 07	A	0.29	0.29	0.29	NC	1
PZ 08	A	0	0	0	NC	1
PZ 09	A	0.14	0.14	0.14	NC	1
PZ 10	A	0.07	0.07	0.07	NC	1
SW-1	I	2.6	0.3286	0	0.80909	10
WILLIS	A	0.007	0.007	0.007	NC	1

\*The data presented in the table are calculated from tests with various detection limits. The numbers are presumed to be accurate to no more than 2 or 3 significant figures.

NC = Not calculable.

**Table 5.2**

**STATISTICAL EVALUATION OF FLUORIDE OBSERVATIONS: 1985-1991**

Well	Alluvium/ Interface/ Bedrock	Maximum	Mean	Minimum	Standard Deviation	Number of Observations
16.9E6N	A	1.1	1.1	1.1	NC	1
40&VB	A	4.92	4.92	4.92	NC	1
4626G	A	6.1	3.15	0.2	4.17193	2
AZSLD	A	4.8	4.8	4.8	NC	1
DM 101-102	B	0.5	0.5	0.5	NC	1
DM 102-048	A	8.27	7.19	5.6	1.40616	3
DM 102-082	B	4.85	4.85	4.85	NC	1
DM 102-104	B	3.34	3.34	3.34	NC	1
DM 102-144	B	6.5	6.5	6.5	NC	1
DM 102-299	B	14.38	14.38	14.38	NC	1
DM 104-079	A	10.1	10.1	10.1	NC	1
DM 104-146	B	10.1	10.1	10.1	NC	1
DM 107	A	4.9	4.0529	2	0.97565	7
DM 111	A	10.9	7.7643	6	1.66567	7
DM 112	A	6.5	6.5	6.5	NC	1
DM 113	A	4.69	4.145	3.6	0.77075	2
DM 114	A	2.4	2.4	2.4	NC	1
DM 115	A	4.48	4.28	4.1	0.19079	3
DM 117	A	6.17	5.3137	2.3	1.25308	8
DM 118	A	7.2	7.145	7.09	0.07778	2
DM 119-137	I	3.5	3.5	3.5	NC	1
DM 119-244	B	5.4	5.4	5.4	NC	1
DM 120	A	7.5	6.5388	3.1	1.45017	8
DM 121-125	I	7.6	7.6	7.6	NC	1
DM 121-219	B	3.8	3.8	3.8	NC	1
DM 122A	A	5.6	5.5	5.4	0.14142	2

\*The data presented in the table are calculated from tests with various detection limits. The numbers are presumed to be accurate to no more than 2 or 3 significant figures.

NC = Not calculable.

**Table 5.2 (Continued)**

Well	Alluvium/ Interface/ Bedrock	Maximum	Mean	Minimum	Standard Deviation	Number of Observations
DM 122B	I	6.7	5.23	4.6	0.69544	7
DM 123-056	I	4.3	4.3	4.3	NC	1
DM 124	A	4.06	3.83	3.6	0.32527	2
DM 125-076	I	5	5	5	NC	1
DM 125-270	B	4.8	4.55	4.3	0.35355	2
DM 126	A	0.3	0.3	0.3	NC	1
DM 201	A	4.8	4.8	4.8	NC	1
DM 202	A	5	4.6333	4.22	0.39209	3
DM 202OB1	A	5.32	5.32	5.32	NC	1
DM 202OB2	A	4.23	4.23	4.23	NC	1
DM 301	A	18	8.136	1.34	7.28812	5
DM 302	A	25.9	14.54	3.3	8.00581	5
DM 303	A	12.9	12.9	12.9	NC	1
DM 304	A	18.2	18.2	18.2	NC	1
DM 305	A	3.42	3.42	3.42	NC	1
DM 306	A	4.45	4.45	4.45	NC	1
DM 307	A	5.775	5.775	5.775	NC	1
DM 308	A	6.54	6.54	6.54	NC	1
DM 309	A	4.62	4.62	4.62	NC	1
DM 310	A	6.3	6.3	6.3	NC	1
DM 311	A	8.78	8.78	8.78	NC	1
DM 312	A	7.73	7.73	7.73	NC	1
DM 313	A	9.55	9.55	9.55	NC	1
DM 503	A	6.18	6.18	6.18	0	2
DM 504	A	8.08	8.01	7.94	0.09899	2
DM 505	A	2.39	2.375	2.36	0.02121	2
DM 508	A	2.91	2.91	2.91	NC	1
DM 509	A	0.4	0.38	0.36	0.02828	2

\*The data presented in the table are calculated from tests with various detection limits. The numbers are presumed to be accurate to no more than 2 or 3 significant figures.

NC = Not calculable.

**Table 5.2 (Continued)**

Well	Alluvium/ Interface/ Bedrock	Maximum	Mean	Minimum	Standard Deviation	Number of Observations
DM 601-085	B	5.21	5.21	5.21	NC	1
DM 601-200	B	2.64	2.64	2.64	NC	1
DM 602	A	7.52	7.45	7.38	0.09899	2
DM 603-115	I	4.34	4.34	4.34	NC	1
DM 603-245	B	2.45	2.45	2.45	NC	1
DM 604	A	5.98	5.22	4.46	1.0748	2
DM 605-105	I	3.88	3.88	3.88	NC	1
DM 605-290	B	4.34	4.34	4.34	NC	1
DM 606-045	I	6.18	6.18	6.18	NC	1
DM 606-370	B	5.54	5.54	5.54	NC	1
DM 701	A	4.03	4.03	4.03	NC	1
MP 03A	A	46	46	46	NC	1
MP 03B	I	17.4	15.0167	12.5	1.87874	6
MP 03C	B	6.49	4.5757	3.81	0.8785	7
MP 03D	B	6.26	4.86	3.76	0.91845	5
MP 09A	A	19.7	14.3985	9.68	2.63768	13
MP 09B	I	12.81	9.705	7.47	1.98393	6
MP 09C	B	9.95	8.6857	6.443	1.5431	4
MP 09D	B	6.5	6.4925	6.485	0.01061	2
MP 11A	A	7	4.4229	2.9	1.54995	7
MP 11B	I	25	7.9545	2.64	7.3125	11
MP 11C	B	11.6	11.6	11.6	NC	1
MP 11D	B	11.4	11.3	11.2	0.14142	2
MP 13A	A	5.5	5.5	5.5	NC	1
MP 13B	I	6	4.6633	2.6	1.81274	3
MP 13D	B	3.2	3.2	3.2	NC	1
MP 16A	A	13.06	9.1071	7.1	2.02103	7
MP 16B	I	16	16	16	NC	1

\*The data presented in the table are calculated from tests with various detection limits. The numbers are presumed to be accurate to no more than 2 or 3 significant figures.

NC = Not calculable.

**Table 5.2 (Continued)**

Well	Alluvium/ Interface/ Bedrock	Maximum	Mean	Minimum	Standard Deviation	Number of Observations
MP 16D	B	16	16	16	NC	1
MP 20A	I	6.2	6.2	6.2	NC	1
MP 20C	B	2.2	2.2	2.2	NC	1
MP 28B	B	3.8	3.8	3.8	NC	1
MP 28D	B	3.2	3.2	3.2	NC	1
MP 30A	A	5	4.5	4	0.70711	2
MP 30D	B	5	5	5	NC	1
MP 36A	A	10.7	7.5857	6.4	1.546	7
MP 36B	I	30	21.9118	17.9	4.28686	11
MP 36C	B	9.2	9.2	9.2	NC	1
MP 36D	B	4.93	4.93	4.93	NC	1
MP 37C	B	11.7	11.105	10.51	0.84146	2
MP 48D	B	4	4	4	NC	1
MP 49A	A	2.97	2.885	2.8	0.12021	2
MP 49B	I	6.18	4.76	2.5	1.97859	3
MP 49C	B	13.5	13.5	13.5	NC	1
MP 49D	B	6.45	5.125	3.8	1.87383	2
MP 50A	A	7.64	7.64	7.64	NC	1
MP 50B	A	7	6.57	6.14	0.60811	2
MP 50D	B	4	4	4	NC	1
MP 51A	A	9.13	9.13	9.13	NC	1
MP 51B	A	10.67	8.3629	3.3	2.54158	7
MP 51D	B	4.1	4.1	4.1	NC	1
MP 52B	I	3.9	3.4357	2.4	0.53441	7
MP 52C	B	2.2	2.2	2.2	NC	1
MP 53B	I	7.27	6.885	6.5	0.54447	2
MP 53D	B	4.6	4.6	4.6	NC	1
PZ 01	A	4.7	4.7	4.7	NC	1

\*The data presented in the table are calculated from tests with various detection limits. The numbers are presumed to be accurate to no more than 2 or 3 significant figures.

NC = Not calculable.

**Table 5.2 (Continued)**

Well	Alluvium/ Interface/ Bedrock	Maximum	Mean	Minimum	Standard Deviation	Number of Observations
PZ 02	A	3	3	3	NC	1
PZ 03	A	2	2	2	NC	1
PZ 04	A	14	14	14	NC	1
PZ 05	A	7.1	7.1	7.1	NC	1
PZ 06	A	12	12	12	NC	1
PZ 07	A	8.4	8.4	8.4	NC	1
PZ 08	A	7.1	7.1	7.1	NC	1
PZ 09	A	7.1	7.1	7.1	NC	1
PZ 10	A	10	10	10	NC	1
SW-1	I	25.1	14.7882	9	4.56078	11
WILLIS	A	4.2	4.2	4.2	NC	1

\*The data presented in the table are calculated from tests with various detection limits. The numbers are presumed to be accurate to no more than 2 or 3 significant figures.

NC = Not calculable.

**Table 5.3**

**STATISTICAL EVALUATION OF NITRATE OBSERVATIONS: 1985-1991**

Well	Alluvium/ Interface/ Bedrock	Maximum	Mean	Minimum	Standard Deviation	Number of Observations
16.9E6N	A	55.45	55.45	55.45	NC	1
40&VB	A	46.4	46.4	46.4	NC	1
4626G	A	4.9	3.65	2.4	1.7678	2
AZSLD	A	3.2	3.2	3.2	NC	1
DM 101-102	B	0	0	0	NC	1
DM 101B	A	24	24	24	NC	1
DM 102-048	A	0	0	0	0	3
DM 102-082	B	0	0	0	NC	1
DM 102-104	B	0	0	0	NC	1
DM 102-144	B	0	0	0	NC	1
DM 102-299	B	0	0	0	NC	1
DM 104-079	A	7	7	7	NC	1
DM 104-146	B	0	0	0	NC	1
DM 107	A	90	67.5857	35	19.3037	7
DM 111	A	19	8.7571	3.8	5.2012	7
DM 112	A	6.4	6.4	6.4	NC	1
DM 113	A	5.1	4.85	4.6	0.3536	2
DM 114	A	2.9	2.9	2.9	NC	1
DM 115	A	57	33.6667	12	22.5462	3
DM 117	A	2.82	0.855	0	0.8954	8
DM 118	A	4.6	4.25	3.9	0.495	2
DM 119-137	I	0.2	0.2	0.2	NC	1
DM 119-244	B	0	0	0	NC	1
DM 120	A	73	15.1512	6	23.3843	8
DM 121-125	I	6.3	6.3	6.3	NC	1
DM 121-219	B	1.5	1.5	1.5	NC	1

\*The data presented in the table are calculated from tests with various detection limits. The numbers are presumed to be accurate to no more than 2 or 3 significant figures.

NC = Not calculable.

**Table 5.3 (Continued)**

Well	Alluvium/ Interface/ Bedrock	Maximum	Mean	Minimum	Standard Deviation	Number of Observations
DM 122A	A	7.5	7.3	7.1	0.2828	2
DM 122B	I	10.6	8.6857	7.3	1.2253	7
DM 123-056	I	0	0	0	NC	1
DM 124	A	7.7	7	6.3	0.9899	2
DM 125-076	I	3.2	3.2	3.2	NC	1
DM 125-270	B	4.6	3	1.4	2.2627	2
DM 126	A	4.3	4.3	4.3	NC	1
DM 201	A	43	43	43	NC	1
DM 202	A	3.8	3.0667	2.2	0.8083	3
DM 202OB1	A	8.3	8.3	8.3	NC	1
DM 202OB2	A	2	2	2	NC	1
DM 301	A	64.8	45.92	27.1	17.1702	5
DM 302	A	96.5	84.84	73.1	10.5189	5
DM 303	A	37	37	37	NC	1
DM 304	A	66	66	66	NC	1
DM 305	A	8.6	8.6	8.6	NC	1
DM 306	A	7.9	7.9	7.9	NC	1
DM 307	A	6.3	6.3	6.3	NC	1
DM 308	A	11	11	11	NC	1
DM 309	A	4.1	4.1	4.1	NC	1
DM 310	A	4.3	4.3	4.3	NC	1
DM 311	A	8.5	8.5	8.5	NC	1
DM 312	A	19	19	19	NC	1
DM 313	A	10.2	10.2	10.2	NC	1
DM 503	A	9.1	7.85	6.6	1.7678	2
DM 504	A	5.8	4.7	3.6	1.5556	2
DM 505	A	0.8	0.61	0.42	0.2687	2
DM 508	A	4.4	4.4	4.4	NC	1

\*The data presented in the table are calculated from tests with various detection limits. The numbers are presumed to be accurate to no more than 2 or 3 significant figures.

NC = Not calculable.

**Table 5.3 (Continued)**

Well	Alluvium/ Interface/ Bedrock	Maximum	Mean	Minimum	Standard Deviation	Number of Observations
DM 509	A	1.9	1.185	0.47	1.0112	2
DM 601-085	B	16	16	16	NC	1
DM 601-200	B	4	4	4	NC	1
DM 602	A	3.6	3.5	3.4	0.1414	2
DM 603-115	I	1.5	1.5	1.5	NC	1
DM 603-245	B	1.32	1.32	1.32	NC	1
DM 604	A	6.2	5.5	4.8	0.9899	2
DM 605-105	I	1.9	1.9	1.9	NC	1
DM 605-290	B	11	11	11	NC	1
DM 606-045	I	1.245	1.245	1.245	NC	1
DM 606-370	B	0.16	0.16	0.16	NC	1
DM 701	A	13.9	13.9	13.9	NC	1
MP 03A	A	8.3	8.3	8.3	NC	1
MP 03B	I	104	83.5	54	19.2847	6
MP 03C	B	5.7	2.7629	0	2.5878	7
MP 03D	B	31.4	8.904	0	12.7414	5
MP 09A	A	83	25.8077	0	32.1608	13
MP 09B	I	78	28.1833	0	28.522	6
MP 09C	B	2.25	0.5625	0	1.125	4
MP 09D	B	3.3	1.925	0.55	1.9445	2
MP 11A	A	60	21.85	0	21.0258	6
MP 11B	I	74	13.04	0	23.034	10
MP 11C	B	3.7	3.7	3.7	NC	1
MP 11D	B	2.91	2.755	2.6	0.2192	2
MP 13B	I	2.3	1.375	0.45	1.3081	2
MP 13D	B	2.1	2.1	2.1	NC	1
MP 16A	A	53	34.7714	12.6	17.4338	7
MP 16B	I	2.5	2.5	2.5	NC	1

\*The data presented in the table are calculated from tests with various detection limits. The numbers are presumed to be accurate to no more than 2 or 3 significant figures.

NC = Not calculable.

**Table 5.3 (Continued)**

Well	Alluvium/ Interface/ Bedrock	Maximum	Mean	Minimum	Standard Deviation	Number of Observations
MP 16D	B	0	0	0	NC	1
MP 20A	I	3.3	3.3	3.3	NC	1
MP 20C	B	2.2	2.2	2.2	NC	1
MP 28B	B	3.9	3.9	3.9	NC	1
MP 28D	B	3.9	3.9	3.9	NC	1
MP 30A	A	3.03	2.015	1	1.4354	2
MP 30D	B	2.2	2.2	2.2	NC	1
MP 36A	A	37.7	23.8667	3.4	13.5301	6
MP 36B	I	113	89.1	67	14.2467	10
MP 36C	B	3.4	3.4	3.4	NC	1
MP 36D	B	16	16	16	NC	1
MP 37C	B	2.27	1.51	0.75	1.0748	2
MP 48D	B	2.3	2.3	2.3	NC	1
MP 49A	A	1.83	1.33	0.83	0.7071	2
MP 49B	I	8	6.7883	4.9	1.6571	3
MP 49C	B	7.6	7.6	7.6	NC	1
MP 49D	B	6.3	5.2	4.1	1.5556	2
MP 50A	A	4.7	4.7	4.7	NC	1
MP 50B	A	11	6.65	2.3	6.1518	2
MP 50D	B	5	5	5	NC	1
MP 51A	A	27.7	27.7	27.7	NC	1
MP 51B	A	11	6.5557	2.8	2.5896	7
MP 51D	B	7.2	7.2	7.2	NC	1
MP 52B	I	16	10.7286	7.1	3.1993	7
MP 52C	B	5	5	5	NC	1
MP 53B	I	13.2	8.2	3.2	7.0711	2
MP 53D	B	6.6	6.6	6.6	NC	1

\*The data presented in the table are calculated from tests with various detection limits. The numbers are presumed to be accurate to no more than 2 or 3 significant figures.

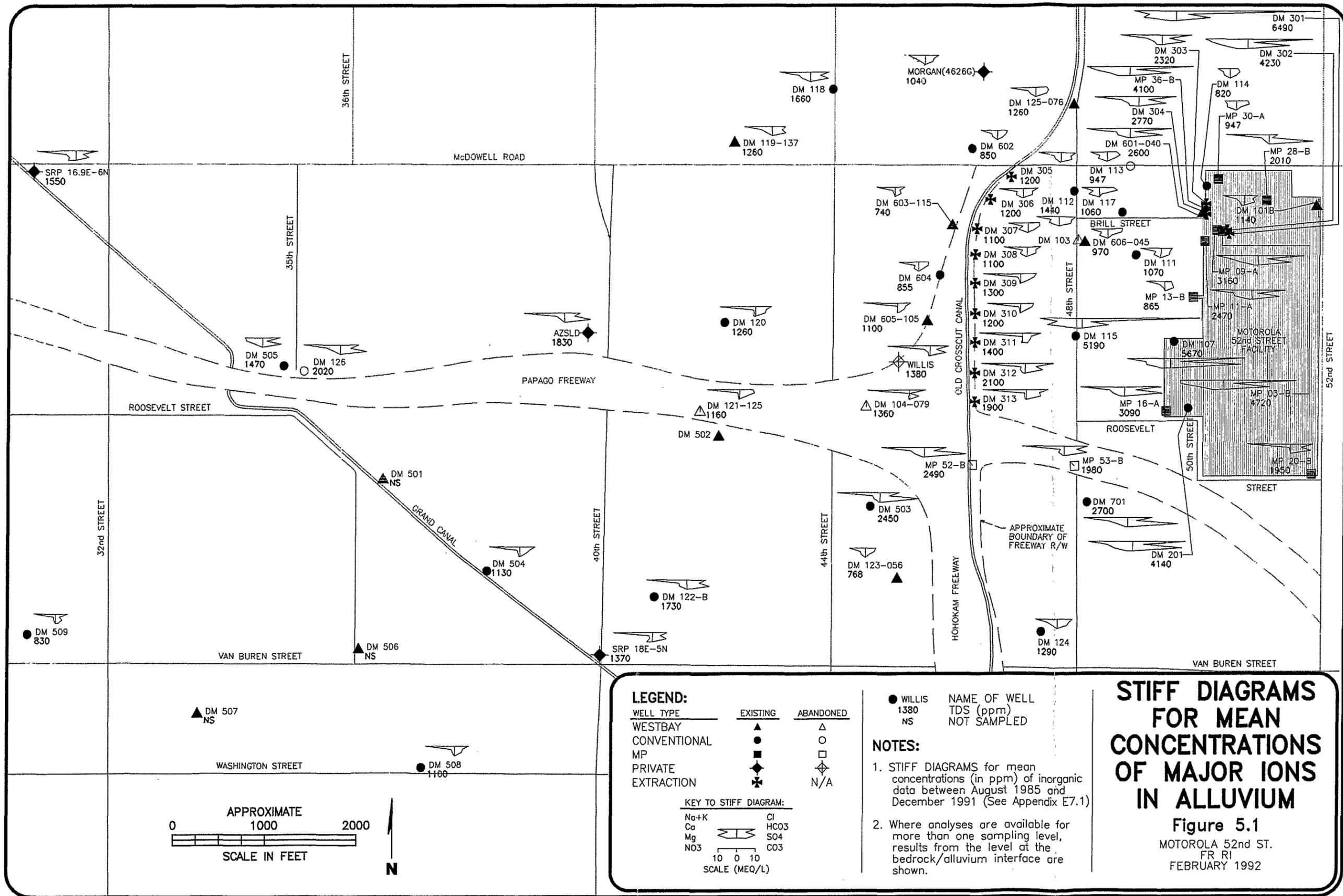
NC = Not calculable.

**Table 5.3 (Continued)**

Well	Alluvium/ Interface/ Bedrock	Maximum	Mean	Minimum	Standard Deviation	Number of Observations
SW-1	I	102	14.96	0	32.2519	10
WILLIS	A	9.3	9.3	9.3	NC	1

\*The data presented in the table are calculated from tests with various detection limits. The numbers are presumed to be accurate to no more than 2 or 3 significant figures.

NC = Not calculable.



**LEGEND:**

WELL TYPE	EXISTING	ABANDONED
WESTBAY	▲	△
CONVENTIONAL	●	○
MP	■	□
PRIVATE	◆	◇
EXTRACTION	✱	N/A

**KEY TO STIFF DIAGRAM:**

Na+K	CI
Ca	HCO3
Mg	SO4
NO3	CO3

SCALE (MEQ/L)

● WILLIS  
1380  
NS  
NAME OF WELL  
TDS (ppm)  
NOT SAMPLED

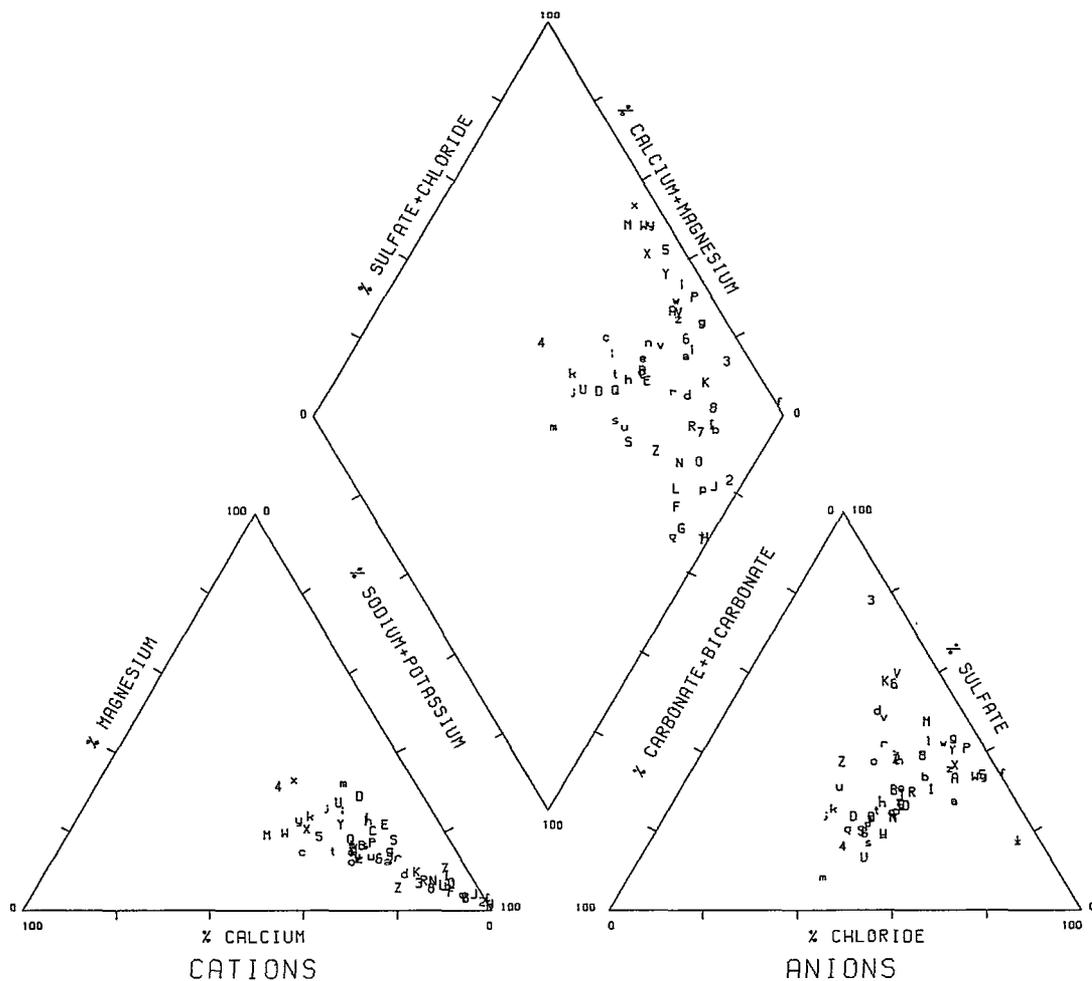
**NOTES:**

1. STIFF DIAGRAMS for mean concentrations (in ppm) of inorganic data between August 1985 and December 1991 (See Appendix E7.1)
2. Where analyses are available for more than one sampling level, results from the level at the bedrock/alluvium interface are shown.

**STIFF DIAGRAMS FOR MEAN CONCENTRATIONS OF MAJOR IONS IN ALLUVIUM**

**Figure 5.1**  
MOTOROLA 52nd ST.  
FR R1  
FEBRUARY 1992





**LEGEND:**

a	16.9E6N	A	DM304
b	40&VB	B	DM305
c	4626G	C	DM306
d	AZSLD	D	DM307
e	DM101B	E	DM308
f	DM104-079	F	DM309
g	DM107	G	DM310
h	DM111	H	DM311
i	DM112	I	DM312
j	DM113	J	DM313
k	DM114	K	DMS03
l	DM115	L	DMS04
m	DM117	M	DMS05
n	DM118	N	DMS08
o	DM119-137	O	DMS09
p	DM120	P	DM601-040
q	DM121-125	Q	DM602
r	DM122-8	R	DM603-115
s	DM123-056	S	DM604
t	DM124	T	DM605-105
u	DM125-076	U	DM606-045
v	DM126	V	DM701
w	DM201	W	DMPO3-B
x	DM301		
y	DM302		
z	DM303		

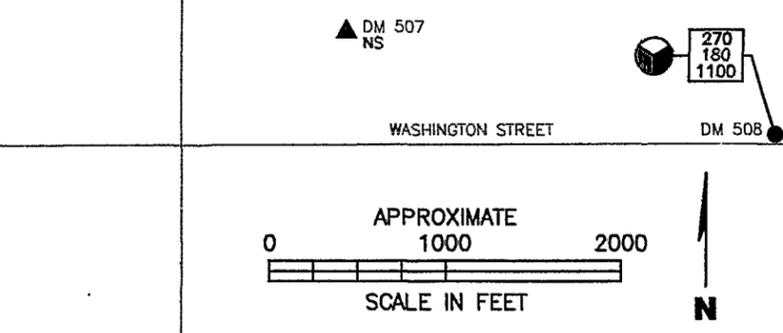
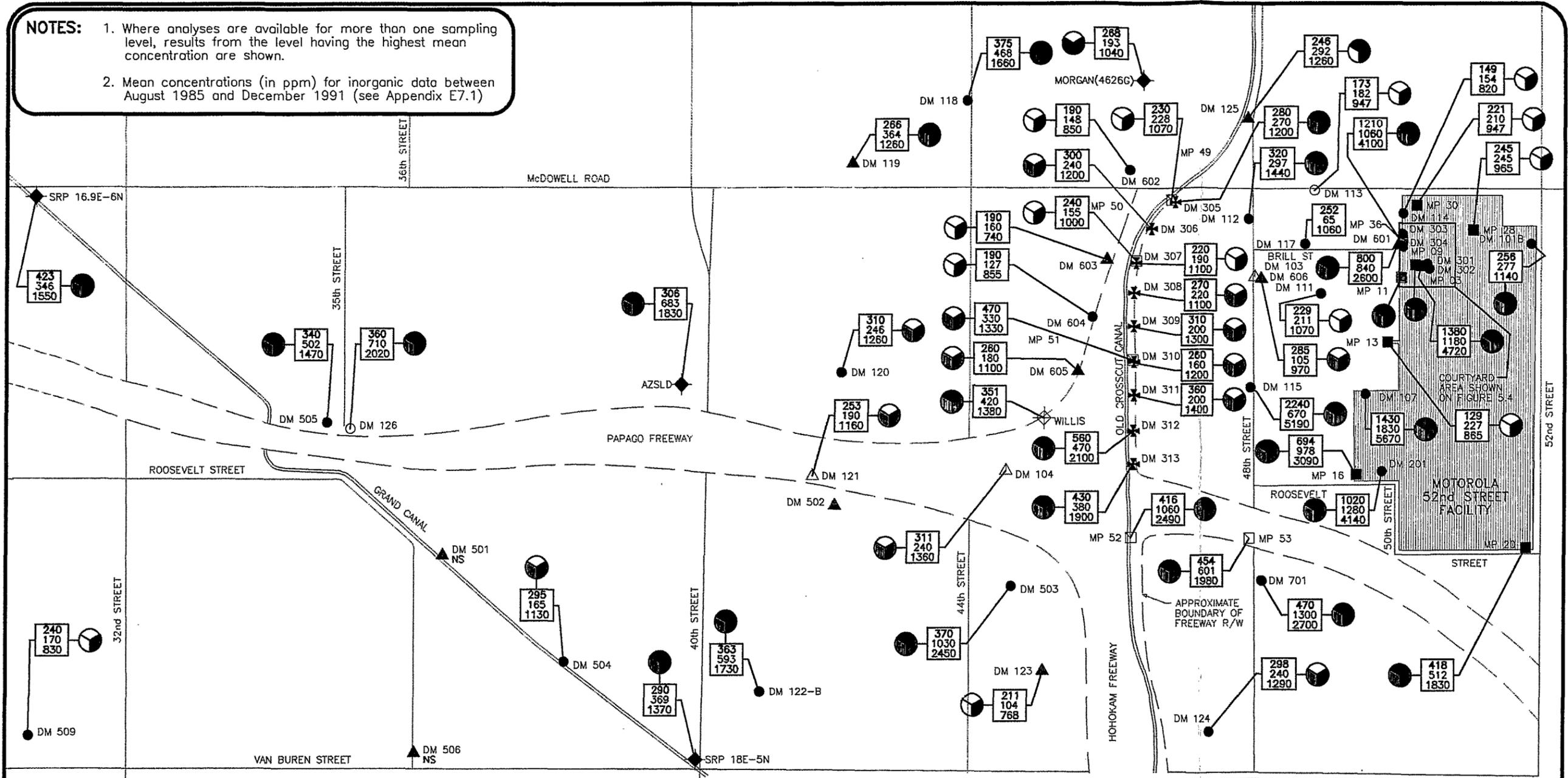
**TRILINEAR DIAGRAM OF  
MEAN CONCENTRATIONS  
OF MAJOR IONS  
IN THE ALLUVIUM**

**Figure 5.2**

MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992

**NOTES:**

- Where analyses are available for more than one sampling level, results from the level having the highest mean concentration are shown.
- Mean concentrations (in ppm) for inorganic data between August 1985 and December 1991 (see Appendix E7.1)



**LEGEND:**

WELL TYPE	EXISTING	ABANDONED
WESTBAY	▲	△
CONVENTIONAL	●	○
MP	■	□
PRIVATE EXTRACTION	◆	N/A

● DM 509 NS NAME OF WELL NOT SAMPLED

240  
170  
830  
SO<sub>4</sub>  
Cl TDS

MEAN CHLORIDE CONCENTRATION (ppm)  
 MEAN SULFATE CONCENTRATION (ppm)  
 MEAN TOTAL DISSOLVED SOLID CONCENTRATION (ppm)

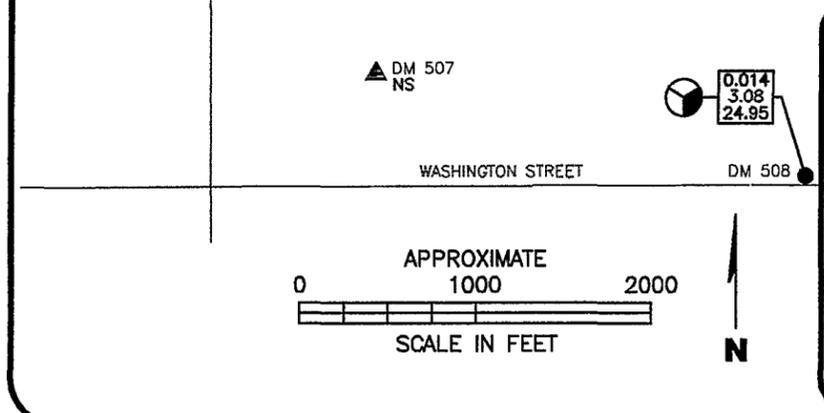
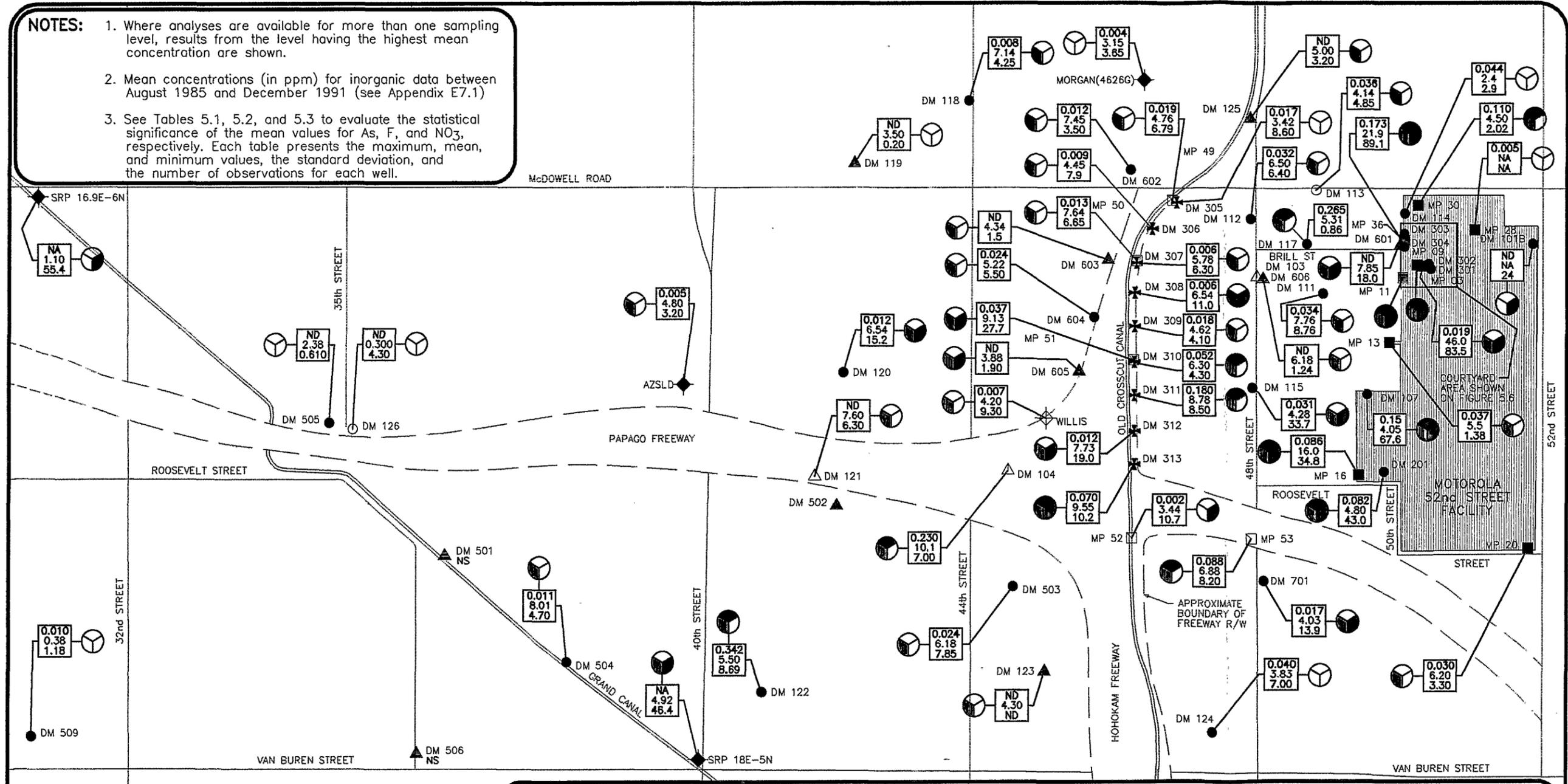
A SHADED THIRD INDICATES THAT THE PARTICULAR PARAMETER MEETS OR EXCEEDS THE FOLLOWING \*SDWS's:  
 Cl, 250 PPM; SO<sub>4</sub>, 250 PPM; TDS, 500 PPM.  
 \*SDWS IS SECONDARY DRINKING WATER STANDARDS.

**Cl, SO<sub>4</sub>, AND TDS  
IN THE ALLUVIUM**  
**Figure 5.3**  
 MOTOROLA 52nd ST.  
 FR RI  
 FEBRUARY 1992



**NOTES:**

- Where analyses are available for more than one sampling level, results from the level having the highest mean concentration are shown.
- Mean concentrations (in ppm) for inorganic data between August 1985 and December 1991 (see Appendix E7.1)
- See Tables 5.1, 5.2, and 5.3 to evaluate the statistical significance of the mean values for As, F, and NO<sub>3</sub>, respectively. Each table presents the maximum, mean, and minimum values, the standard deviation, and the number of observations for each well.



**LEGEND:**

WELL TYPE	EXISTING	ABANDONED
WESTBAY	▲	△
CONVENTIONAL	●	○
MP	◆	◇
PRIVATE	◆	◇
EXTRACTION	✱	N/A

● DM 509 NAME OF WELL

**0.03**  
3.69  
8.2

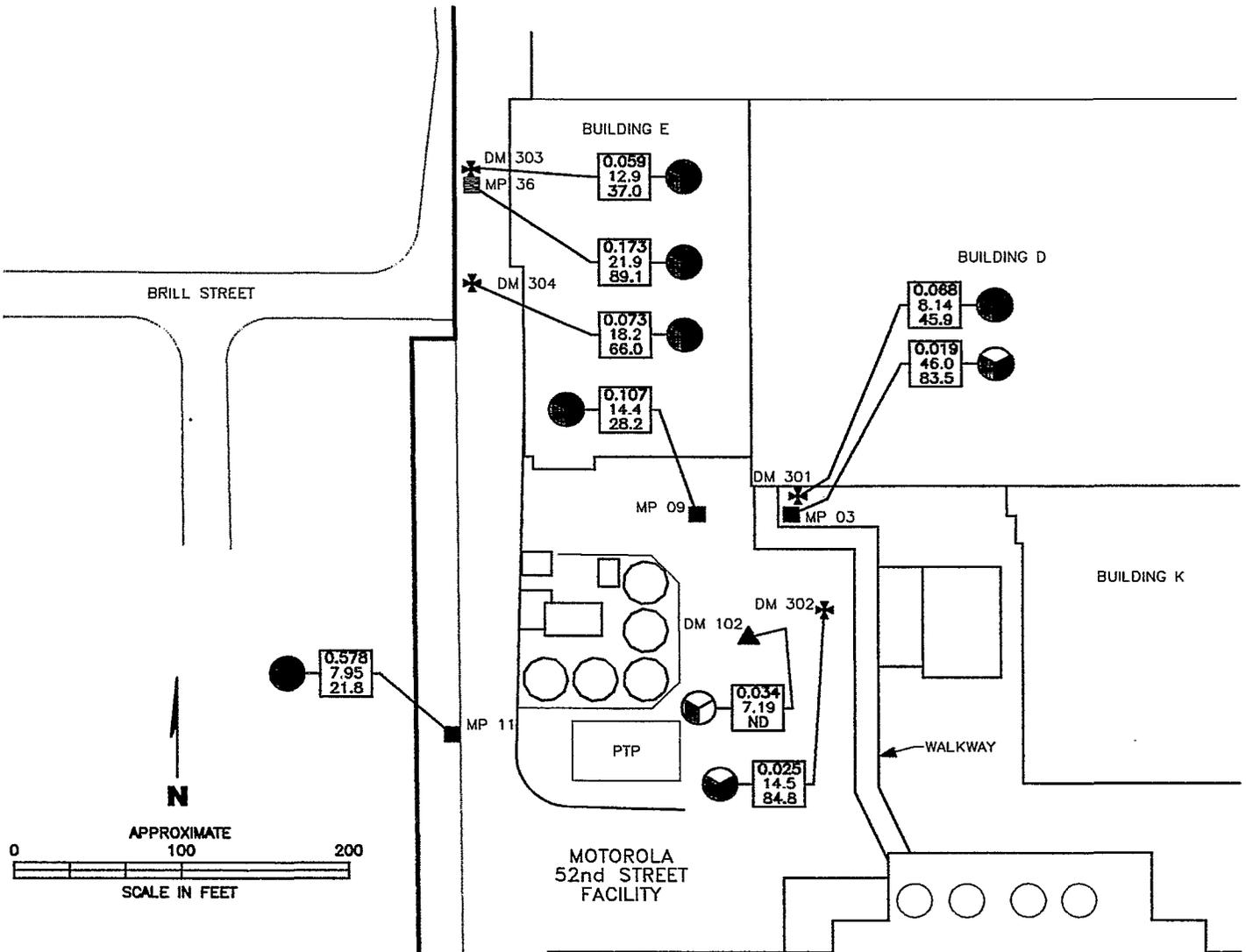
As  
F  
NO<sub>3</sub>

MEAN ARSENIC CONCENTRATION (ppm)  
MEAN FLUORIDE CONCENTRATION (ppm)  
MEAN NITRATE CONCENTRATION (ppm)  
NA = NOT ANALYZED  
ND = NOT DETECTED  
NS = NOT SAMPLED

A SHADED THIRD INDICATES THAT THE PARTICULAR PARAMETER MEETS OR EXCEEDS THE FOLLOWING \*SDWS's:  
As, 0.05 PPM; F, 4.0 PPM; NO<sub>3</sub>, 10 PPM.  
\*SDWS IS SECONDARY DRINKING WATER STANDARDS.

**As, F, AND NO<sub>3</sub>  
IN THE ALLUVIUM**

**Figure 5.5**  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992



**LEGEND:**

WELL TYPE	EXISTING
MP	■
EXTRACTION	⊕
WESTBAY	▲

■ MP 11 NAME OF WELL  
 [ 240 ] MEAN ARSENIC CONCENTRATION (ppm)  
 [ 170 ] MEAN FLUORIDE CONCENTRATION (ppm)  
 [ 830 ] MEAN NITRATE CONCENTRATION (ppm)  
 ND = NOT DETECTED

As  
 F NO<sub>3</sub>  
 A SHADED THIRD INDICATES THAT THE PARTICULAR PARAMETER MEETS OR EXCEEDS THE FOLLOWING \*PDWS's:  
 As, 0.05 PPM; F, 4.0 PPM; NO<sub>3</sub>, 10 PPM.  
 \*PDWS IS PRIMARY DRINKING WATER STANDARDS.

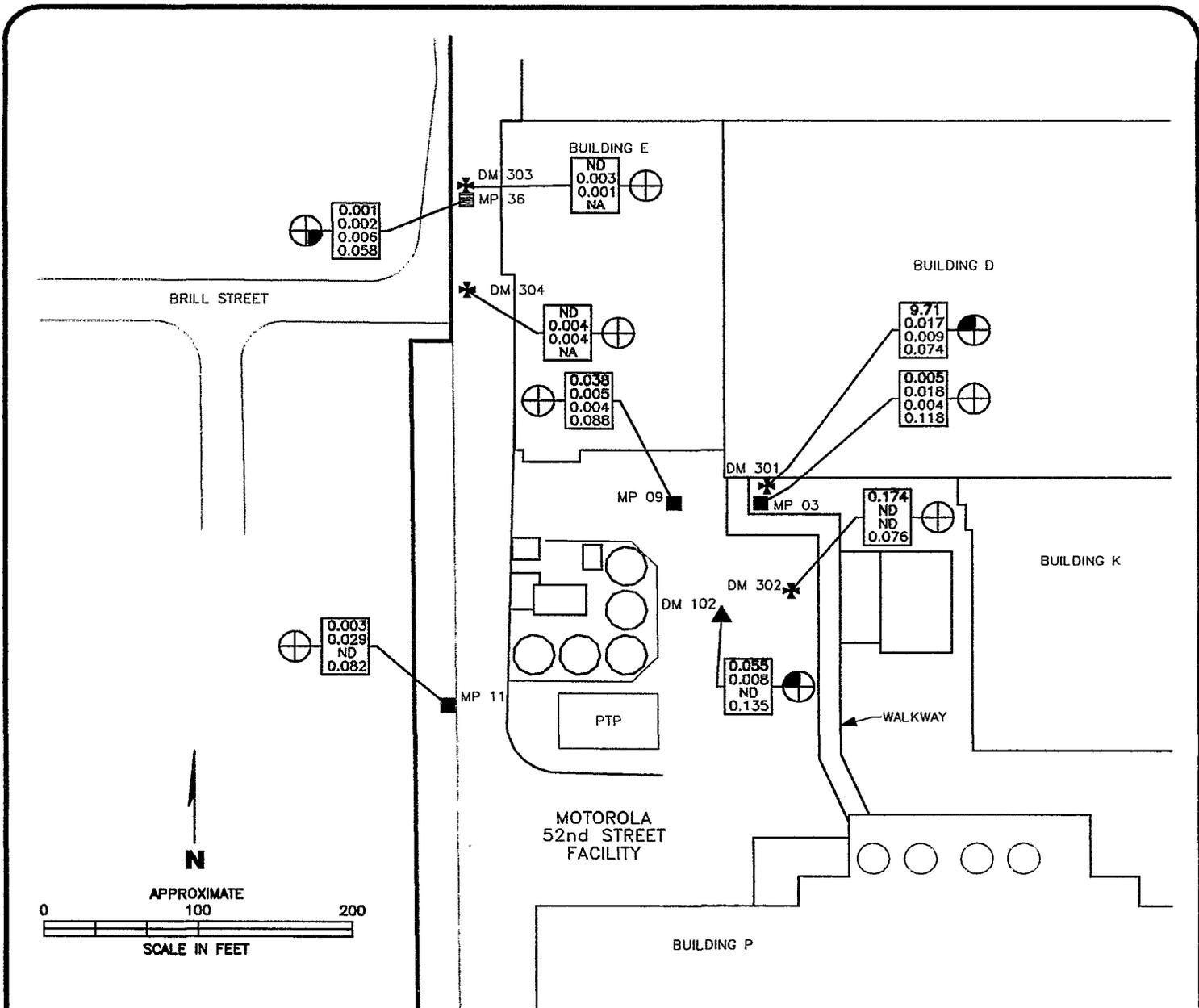
**NOTES:**

1. Where analyses are available for more than one sampling level, results from the level having the highest mean concentration are shown.
2. Mean concentrations (in ppm) for inorganic data between August 1985 and December 1991 (see Appendix E7.1)
3. See Tables 5.1, 5.2, and 5.3 to evaluate the statistical significance of the mean values for As, F, and NO<sub>3</sub>, respectively. Each table presents the maximum mean, and minimum values, the standard deviation, and the number of observations for each well.

**As, F,  
AND NO<sub>3</sub> IN  
THE COURTYARD  
ALLUVIUM**

**Figure 5.6**  
 MOTOROLA 52nd ST.  
 FR RI  
 FEBRUARY 1992





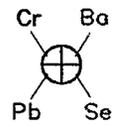
**LEGEND:**

WELL TYPE	EXISTING
MP	■
EXTRACTION WESTBAY	✦
	▲

■ MP 11 NAME OF WELL  

0.02
0.003
0.01
0.05

 MEAN CHROMIUM CONCENTRATION (ppm)  
 MEAN LEAD CONCENTRATION (ppm)  
 MEAN SELENIUM CONCENTRATION (ppm)  
 MEAN BARIUM CONCENTRATION (ppm)  
 ND = NOT DETECTED



A SHADED THIRD INDICATES THAT THE PARTICULAR PARAMETER MEETS OR EXCEEDS THE FOLLOWING \*SDWS's: Cr, 0.05 PPM; Pb, 0.05 PPM; Se, 0.01 PPM; Ba, 1.0 PPM.  
 \*SDWS IS SECONDARY DRINKING WATER STANDARDS.

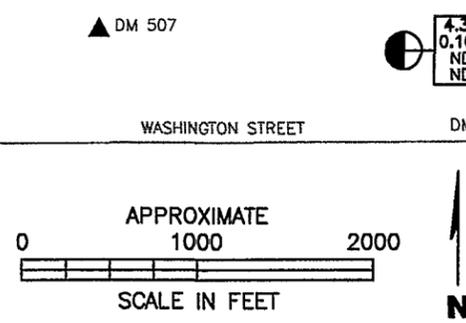
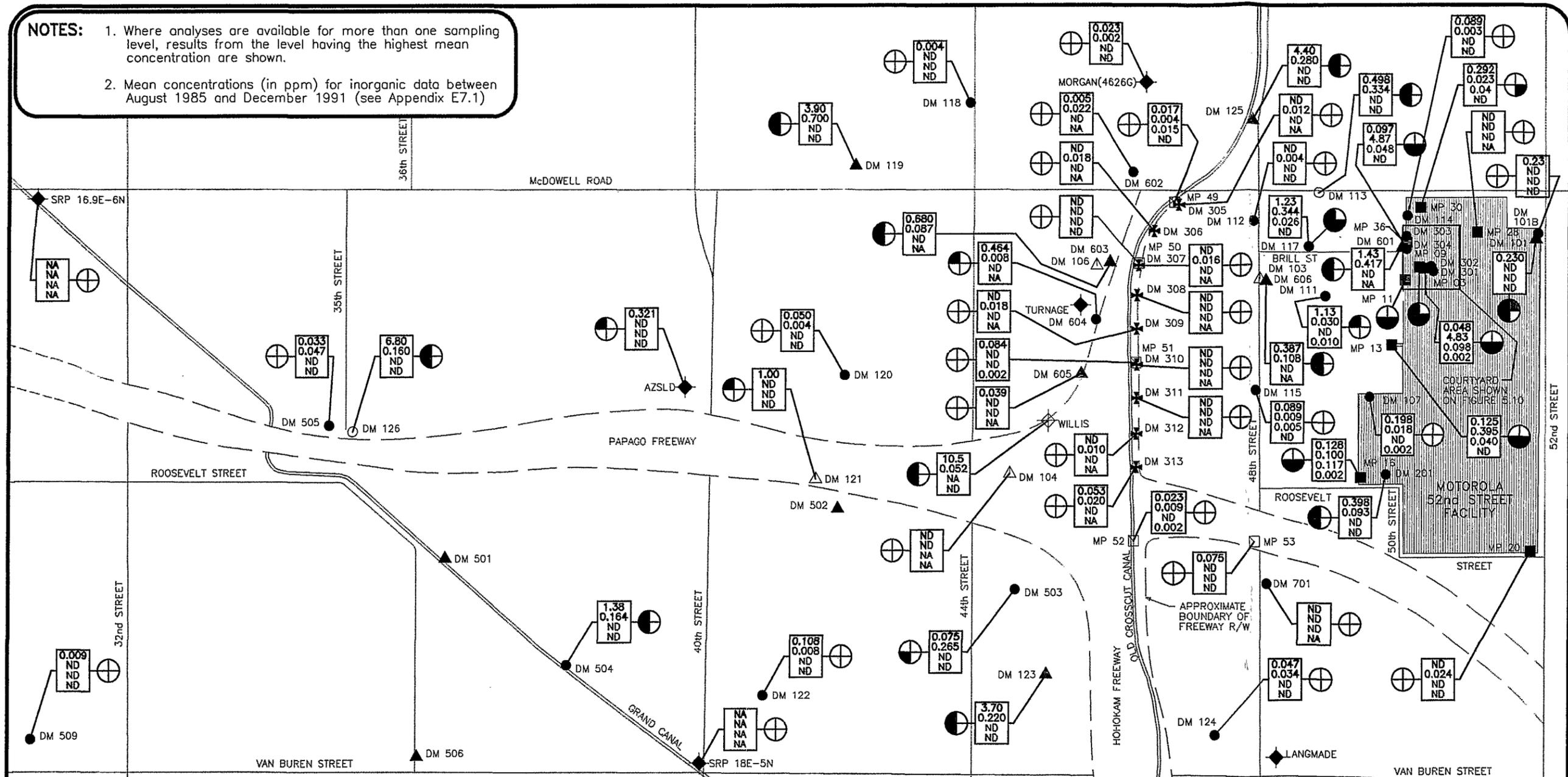
**NOTES:**

- Where analyses are available for more than one sampling level, results from the level having the highest mean concentration are shown.
- Mean concentrations (in ppm) for inorganic data between August 1985 and December 1991 (see Appendix E7.1)

**Cr, Pb,  
Se, AND Ba IN  
THE COURTYARD  
ALLUVIUM**  
  
**Figure 5.8**  
 MOTOROLA 52nd ST.  
 FR RI  
 FEBRUARY 1992

**NOTES:**

- Where analyses are available for more than one sampling level, results from the level having the highest mean concentration are shown.
- Mean concentrations (in ppm) for inorganic data between August 1985 and December 1991 (see Appendix E7.1)



**LEGEND:**

WELL TYPE	EXISTING	ABANDONED
WESTBAY	▲	△
CONVENTIONAL	●	○
MP	■	□
PRIVATE	◆	◇
EXTRACTION	✱	N/A

● DM 509 NAME OF WELL

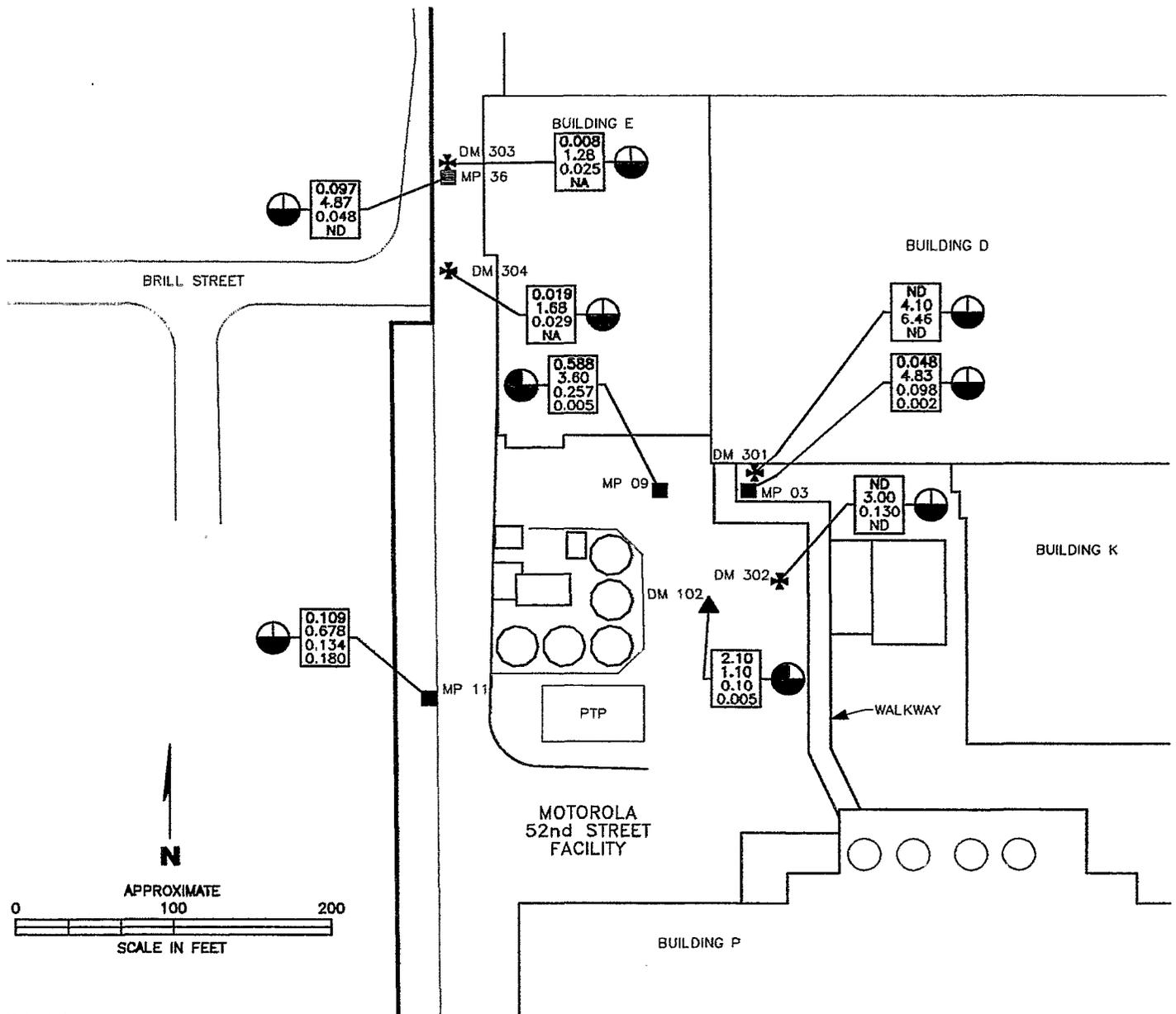
0.29	MEAN IRON CONCENTRATION (ppm)
0.10	MEAN MANGANESE CONCENTRATION (ppm)
0.11	MEAN NICKEL CONCENTRATION (ppm)
0.01	MEAN CYANIDE CONCENTRATION (ppm)

NA = NOT ANALYZED  
ND = NOT DETECTED

A SHADED THIRD INDICATES THAT THE PARTICULAR PARAMETER MEETS OR EXCEEDS THE FOLLOWING SDWS's \* : Fe, 0.3 PPM; Mn, 0.05 PPM; Ni, 0.01 PPM; CN, 0.2 PPM.  
\* SDWS is Secondary Drinking Water Standards.

# Fe, Mn, Ni, AND CN IN THE ALLUVIUM

**Figure 5.9**  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992



**LEGEND:**

WELL TYPE	EXISTING
MP	■
EXTRACTION WESTBAY	✱
	▲

■ MP 11 NAME OF WELL  
 0.29 MEAN IRON CONCENTRATION (ppm)  
 0.10 MEAN MANGANESE CONCENTRATION (ppm)  
 0.11 MEAN NICKEL CONCENTRATION (ppm)  
 0.01 MEAN CYANIDE CONCENTRATION (ppm)  
 ND = NOT DETECTED  
 NA = NOT ANALYZED

A SHADED THIRD INDICATES THAT THE PARTICULAR PARAMETER MEETS OR EXCEEDS THE FOLLOWING SDWS's\* AND HBGL's\*: Fe, 0.05 PPM; Mn, 0.05 PPM; Ni, 0.01 PPM; Cn, 0.2 PPM.  
 \*SDWS IS SECONDARY DRINKING WATER STANDARDS.  
 \*HBGL IS HEALTH-BASED GUIDANCE LEVELS

**NOTES:**

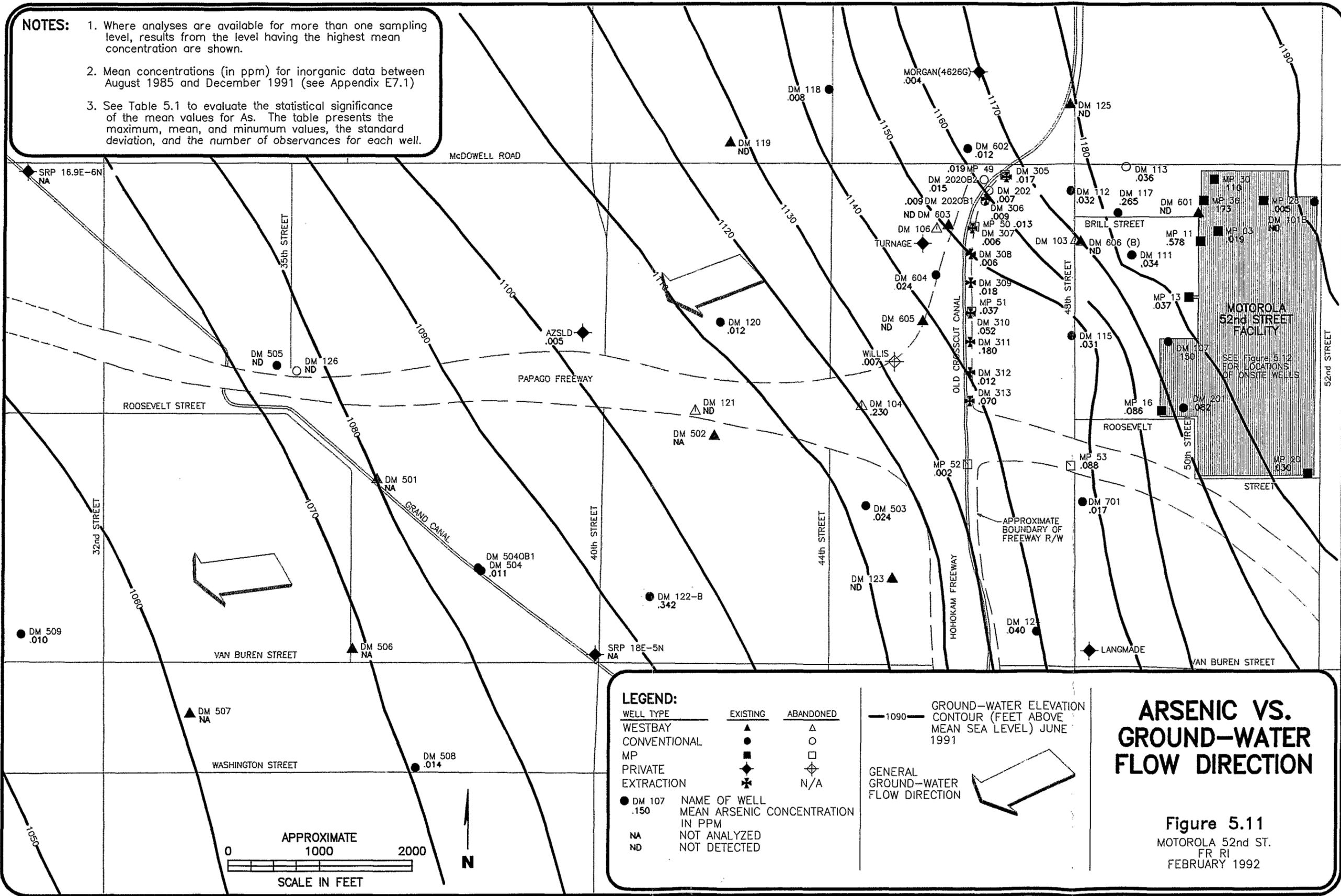
- Where analyses are available for more than one sampling level, results from the level having the highest mean concentration are shown.
- Mean concentrations (in ppm) for inorganic data between August 1985 and December 1991 (see Appendix E7.1)

**Fe, Mn, Ni, AND CN IN THE COURTYARD ALLUVIUM**

**Figure 5.10**  
 MOTOROLA 52nd ST.  
 FR RI  
 FEBRUARY 1992

**NOTES:**

1. Where analyses are available for more than one sampling level, results from the level having the highest mean concentration are shown.
2. Mean concentrations (in ppm) for inorganic data between August 1985 and December 1991 (see Appendix E7.1)
3. See Table 5.1 to evaluate the statistical significance of the mean values for As. The table presents the maximum, mean, and minimum values, the standard deviation, and the number of observations for each well.



**LEGEND:**

WELL TYPE	EXISTING	ABANDONED
WESTBAY CONVENTIONAL	▲	△
MP PRIVATE EXTRACTION	●	○
	◆	◇
	✱	N/A

● DM 107 .150 NAME OF WELL  
MEAN ARSENIC CONCENTRATION IN PPM

NA NOT ANALYZED  
ND NOT DETECTED

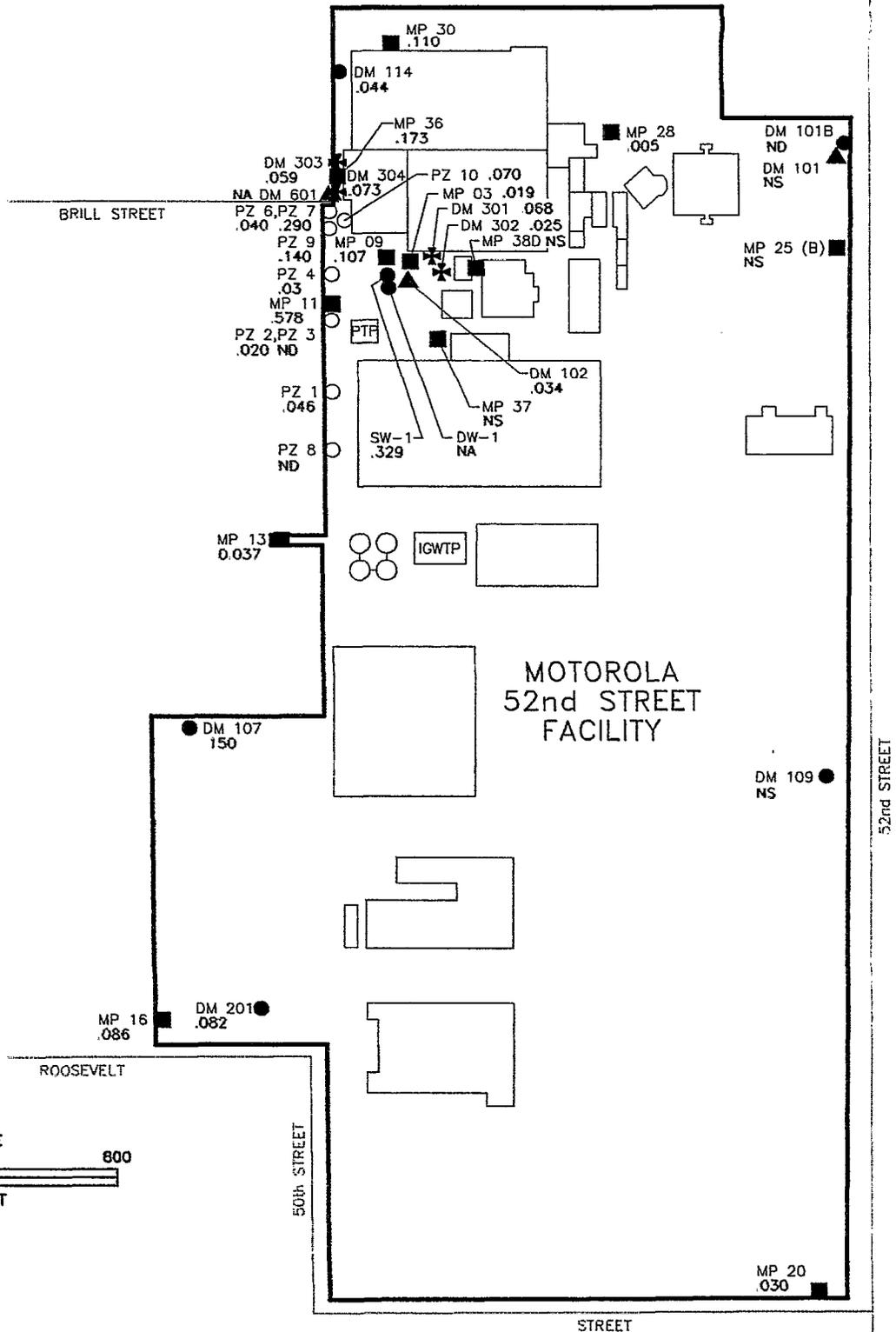
—1090— GROUND-WATER ELEVATION CONTOUR (FEET ABOVE MEAN SEA LEVEL) JUNE 1991

GENERAL GROUND-WATER FLOW DIRECTION

## ARSENIC VS. GROUND-WATER FLOW DIRECTION

**Figure 5.11**  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992





**LEGEND:**

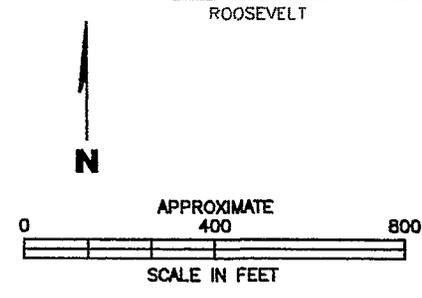
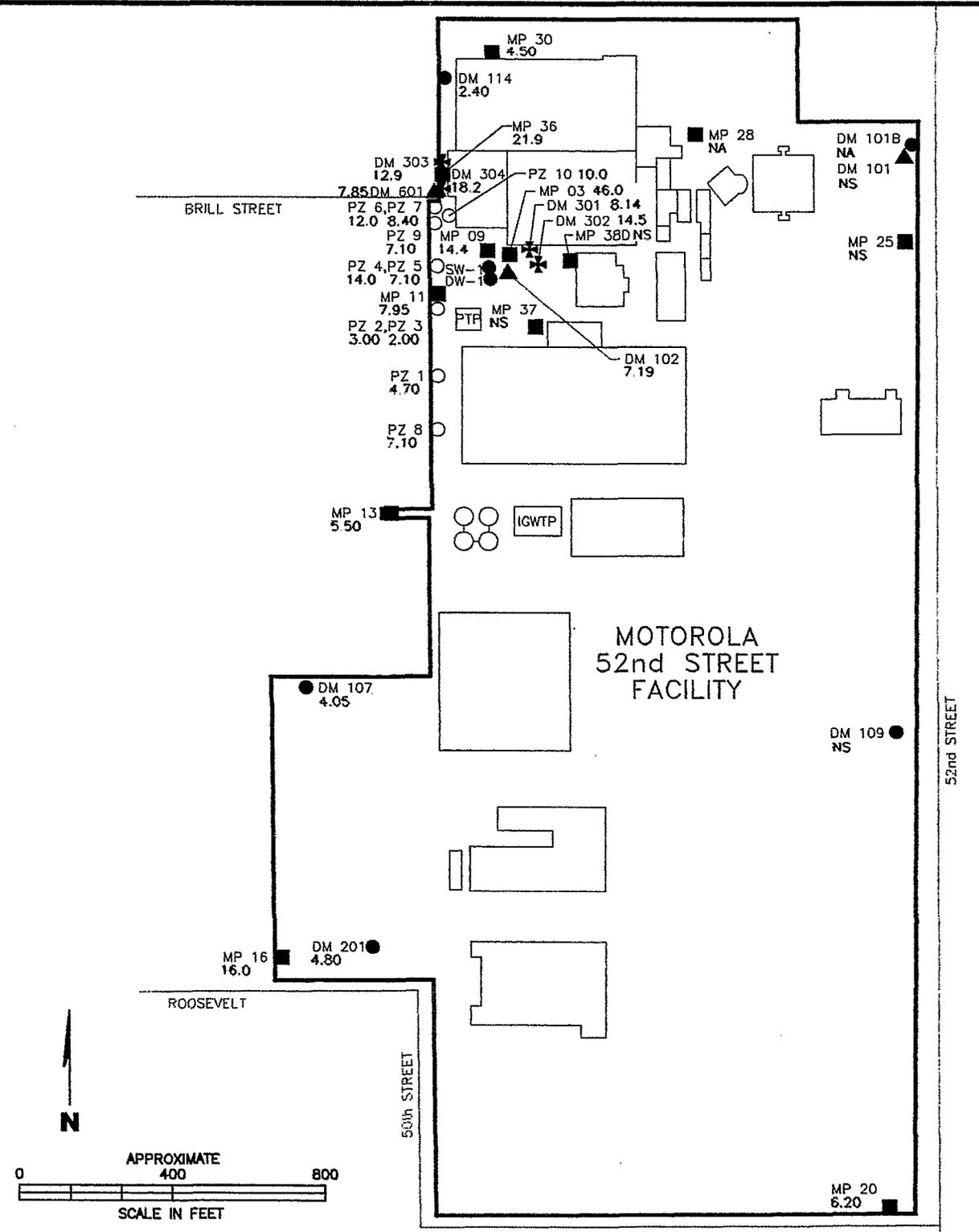
WELL TYPE	EXISTING	
WESTBAY	▲	
CONVENTIONAL	●	
MP	■	
PRIVATE	◆	
EXTRACTION	✱	
PIEZOMETER	○	
● DM 107		NAME OF WELL
.150		MEAN CONCENTRATION (ppm)
NA		NOT ANALYZED
ND		NOT DETECTED
NS		NOT SAMPLED

**NOTES:**

1. Where analyses are available for more than one sampling level, results from the level having the highest mean concentration are shown.
2. Mean concentration (in ppm) for inorganic data between August 1985 and December 1991 (see Appendix E7.1)
3. See Table 5.1 to evaluate the statistical significance of the mean values for As. The table presents the maximum, mean, and minimum values, the standard deviation, and the number of observations for each well.

**ARSENIC IN  
ONSITE ALLUVIUM**

**Figure 5.12**  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992



**LEGEND:**

WELL TYPE	EXISTING
WESTBAY CONVENTIONAL	▲
MP	●
PRIVATE EXTRACTION	◆
PIEZOMETER	○

● DM 201	NAME OF WELL
4.80	MEAN CONCENTRATION (ppm)
NA	NOT ANALYZED
ND	NOT DETECTED
NS	NOT SAMPLED

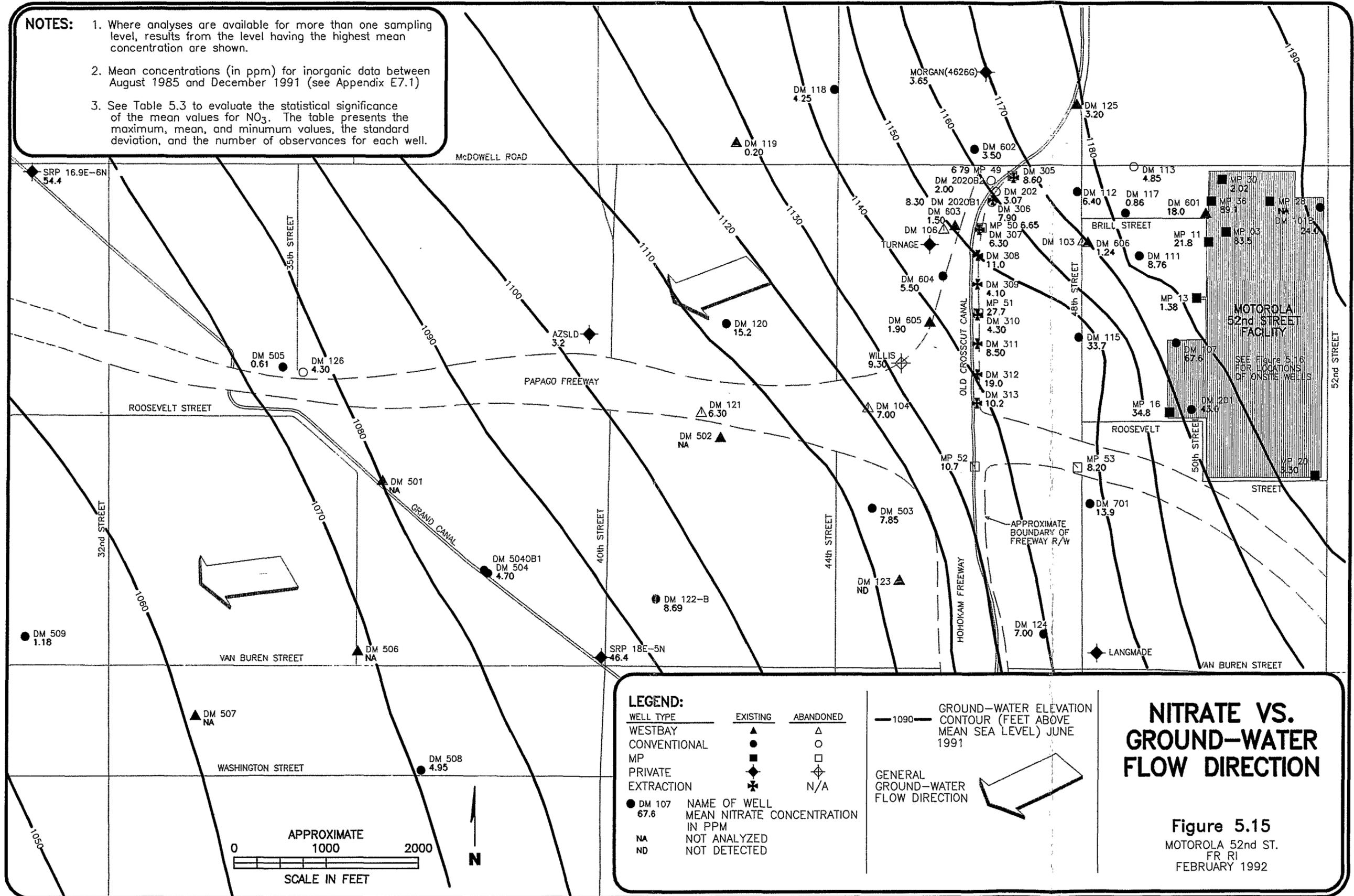
**NOTES:**

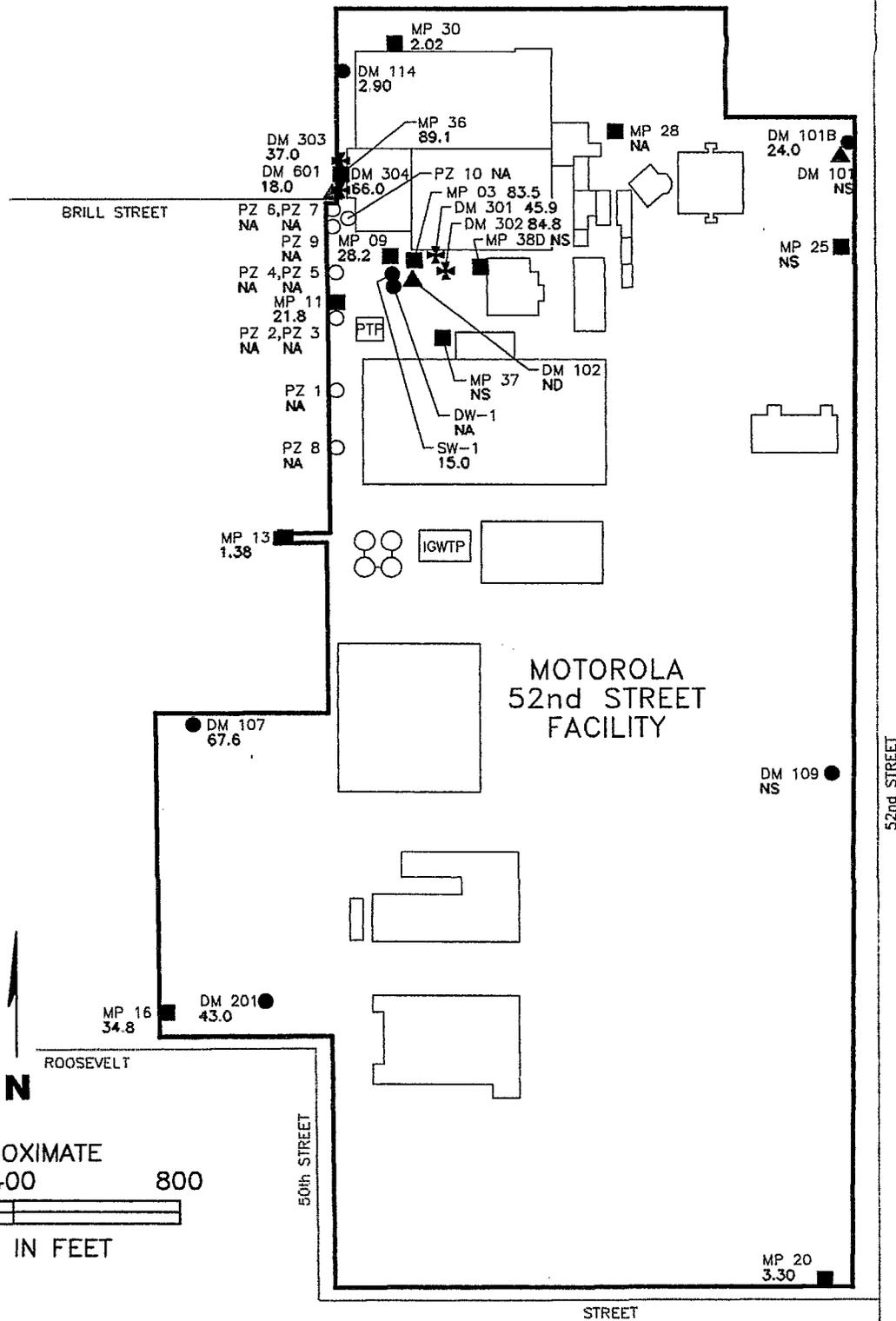
- Where analyses are available for more than one sampling level, results from the level having the highest mean concentration are shown.
- Mean concentration (in ppm) for inorganic data between August 1985 and December 1991 (see Appendix E7.1)
- See Table 5.2 to evaluate the statistical significance of the mean values for F. The table presents the maximum, mean, and minimum values, the standard deviation, and the number of observations for each well.

**FLUORIDE IN ONSITE ALLUVIUM**

**Figure 5.14**  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992

- NOTES:**
1. Where analyses are available for more than one sampling level, results from the level having the highest mean concentration are shown.
  2. Mean concentrations (in ppm) for inorganic data between August 1985 and December 1991 (see Appendix E7.1)
  3. See Table 5.3 to evaluate the statistical significance of the mean values for NO<sub>3</sub>. The table presents the maximum, mean, and minimum values, the standard deviation, and the number of observations for each well.





**LEGEND:**

WELL TYPE	EXISTING
WESTBAY	▲
CONVENTIONAL	●
MP	■
PRIVATE EXTRACTION	◆
PIEZOMETER	○

WELL NAME	MEAN CONCENTRATION (ppm)
DM 303	37.0
NA	NOT ANALYZED
ND	NOT DETECTED
NS	NOT SAMPLED

**NOTES:**

- Where analyses are available for more than one sampling level, results from the level having the highest mean concentration are shown.
- Mean concentration (in ppm) for inorganic data between August 1985 and December 1991 (see Appendix E7.1)
- See Table 5.3 to evaluate the statistical significance of the mean values for NO<sub>3</sub>. The table presents the maximum, mean, and minimum values, the standard deviation, and the number of observations for each well.

**NITRATE IN ONSITE ALLUVIUM**

**Figure 5.16**  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992

## **6.0 GROUND-WATER FLOW AND TRANSPORT MODELING**

### **6.1 INTRODUCTION**

Since 1983, model predictions have been used to assist in locating monitor wells, define ground-water contamination, and aid in evaluating alternative remediation measures. The 1987 Draft RI Report contains Chapter 5.0 and Appendix F describing the model development and predictions (Dames & Moore, 1987b). The present investigation has utilized previous modeling studies to provide a sound basis for the expanded three-dimensional ground-water model.

The three-dimensional flow and transport model presented in the 1987 Draft RI has been modified as part of this Final Remedy Remedial Investigation (FR RI) to provide numerical predictions of the extent of contamination. Observed ground-water flow characteristics and measured contaminant concentrations are compared with predictions of the model. These comparisons have been used to evaluate the accuracy of model predictions.

The relationship between current work and the 1987 Draft RI predictions is discussed in Section 6.1, and the modeling approach is reviewed in 6.2. Model assumptions are described in Section 6.3, and the sensitivity of variable canal recharge is discussed in Section 6.4. Section 6.5 includes a description of calibration of the model to water quality observations and the source. The conclusions are presented in Section 6.6.

#### **6.1.1 Purpose**

The ground-water flow and transport model was developed for the FR RI to predict the downgradient extent of ground-water contamination. The FR RI model utilizes field data obtained as part of this as well as previous investigations. Additionally, the three-dimensional

ground-water model is intended to provide a basis for evaluation of remedial alternatives during the FR Feasibility Study (FS).

### 6.1.2 Previous Modeling Work

The results of modeling presented in this chapter are the culmination of examining several ground-water flow and transport models which have been developed by Dames & Moore since 1983. The models were developed sequentially such that each successive model was expanded to incorporate additional downgradient data generated by field programs.

The model domain areas used in each of the previous ground-water models is shown on Figure 6.1. Also included on Figure 6.1 is the domain for the three-dimensional model which is the subject of this chapter.

The 1983 model was expanded and updated in 1985 and 1986 with additional data collected for the Draft RI/FS (Dames & Moore, 1987b). A three-stage modeling approach was used. The Stage 1 model was designed to assist in the placement of downgradient monitor wells. The Stage 2 model, with a total of 20,757 calculation cells, provided the basis for the conclusions reached in the RI Report. The Stage 3 model was used to evaluate remedial alternatives presented in the Draft FS Report.

The assumptions used in the Stage 2 model are documented in the Draft RI Report (Dames & Moore, 1987b, Sections 5.4.3.1 and 5.4.3.2), and are based on extensive field and laboratory data. Sensitivity analyses were used to test input assumptions (Draft RI Report, 1987b, Section 5.4.4). The Stage 2 model input assumptions were the basis for development of the FR RI ground water model. The Stage 1 and Stage 2 models are collectively referred to as the "1987 Draft RI" model in this report.

## 6.2 APPROACH

The approach to development of the FR RI ground-water model, presented graphically in Figure 6.2, is similar to the approach used in the 1987 Draft RI. A three-dimensional model was chosen for the FR RI and previous models for a number of reasons including:

- a) The depth of observed contamination (greater than 300 feet at several wells) and the stratigraphy present in the area precludes the use of a horizontal plane, two-dimensional model;
- b) The existence of point contamination sources (for example the dry well, Source 2, in the Courtyard Area); and
- c) The need to define the areal extent of contamination.

In addition, this model was developed to anticipate its eventual use to evaluate potential remediation scenarios for the FR FS.

The flow interaction between bedrock and alluvium within the study area necessitated the vertical distribution of materials with different hydraulic properties. The three-dimensional numerical model can accommodate these requirements and is more flexible with respect to definition of boundary conditions than a simple analytical solution. The integrated finite-difference code TARGET™ has been used for all previous modeling studies and was therefore selected for the present investigation. Appendix K of the 1987 Draft RI provides a description of the governing equations, inherent assumptions, numerical formulation and solution procedures for TARGET™.

The FR RI model, as with previous models, was developed to predict concentrations of TCE represented by observations of total ethylenes (TCE + DCE + TDCE) because high concentrations of the DCE isomers are associated with TCE throughout the

observed extent of the plume. The DCE isomers are degradation products of TCE. Degradation is not a process that can be simulated by the model. Therefore, TCE was selected as the source VOC in the model and compared to the sum of the ethylenes, TCE + TDCE + DCE.

### 6.2.1 Model Framework

The FR RI model is a three-dimensional model extending 21,000 feet in a southwest-northeast direction, 12,000 feet in a northwest-southeast direction, and 420 feet in depth. The model domain is illustrated in Figure 6.1, and sections through the calculation mesh are shown in Figure 6.3. There are 53 calculations cells in the southwest-northeast direction, 33 calculations cells in the northwest-southeast direction and 17 layers for a total of 29,733 cells. The cells vary in size from 200 feet by 200 feet by 15 feet thick below the plant site to 1,000 feet by 1,000 feet by 50 feet thick at the edges of the model. The dimensions of the calculation cells were selected to avoid extreme aspect ratios and maintain sensible cell Peclet numbers. These design criteria limit the artificial dispersion of the contaminant (known as "numerical dispersion").

The cell aspect ratios influence model convergence and numerical dispersion. Ideally, this ratio should be one, although ratios as high as 10:1 are acceptable. The aspect ratio is calculated by comparing the product of a cell dimension and the hydraulic conductivity in the direction of a given model axis (e.g. the x-axis) with the same product along another axis (e.g. the y-axis). Cell aspect ratios in the FR RI model range from one to five.

It is also recommended that the cell dimensions between adjacent cells should not vary by a factor of more than two, although factors of up to five can be used in regions of low interest. The largest change in dimensions between adjacent cells in the FR RI model is 1.5.

Cell Peclet numbers also influence model convergence and numerical dispersion. Acceptable Peclet numbers for the TARGET™ model range from 1 to 10. In the primary area

of interest, from the Motorola 52nd St. Facility to just west of the Grand Canal, the Peclet number ranges from 2 to 4.

The flow direction in the model domain varies from west to southwest with the predominant flow direction being to the southwest. The orientation of the model grid coincides with the predominant flow direction to minimize numerical dispersion and to better approximate anisotropic dispersivity.

### **6.2.2 Site-Specific Data**

Input data required for ground-water models include initial conditions, boundary conditions, site stratigraphy, hydraulic property distributions, and source data. Input assumptions incorporated in the 1987 Draft RI were used for the FR RI unless more recent data warranted modification. The following discussion focuses on input assumptions which were modified based on new data.

#### **Alluvium**

The geologic framework of the model is based on a two-layer system of alluvium unconformably overlying bedrock. The alluvium was subdivided into six materials, each with a different hydraulic conductivity based on field measurements or literature review. Two materials were used to simulate bedrock geologic units. The distribution of the alluvial materials and the assigned hydraulic conductivities for each material are shown in plan view just above the bedrock on Figure 6.4. Cross sections A-A' and B-B' (identified on Figure 6.4) through the model are shown on Figure 6.5, and show the vertical distribution of alluvial and bedrock materials.

Alluvium thins to the east and is unsaturated in several areas around the Motorola 52nd St. Facility (Section B-B'). The observed saturated thickness of the alluvium is

depicted on Figure 3.4. Alluvium thickens to over 150 feet to the west. Aquifer tests have shown the alluvium to have variable hydraulic conductivity.

Drilling in 1991 revealed the presence of a coarse, sandy gravel in the upper portion of the alluvium west of approximately 44th Street. This coarse gravel may have been deposited from the Salt River which is approximately one mile south of the Motorola 52nd St. Facility. The fluvial gravel extends from near the surface to a depth of approximately 100 feet and is composed of well-rounded cobbles and boulders of variable composition (see Section 3.2 for a more complete description). In appearance, the fluvial gravels are similar to gravels which occur in the Salt River channel and therefore, are likely to have hydraulic properties similar to Salt River alluvium. The FR RI model was developed with this fluvial gravel unit added in the upper portion of the alluvium extending horizontally from just east of well DM 502 (near coordinates 12,000 to 14,000 feet on Figure 6.5) to the western end of the model. The hydraulic properties of this unit were assigned values (100 ft/day) consistent with published hydrogeologic data for similar sediments.

Alluvium underlying the fluvial gravel unit is comprised of clayey, silty, poorly sorted gravel with large subangular clasts and cobbles of granite and metarhyolite. The lower alluvial unit is interpreted to have been derived from erosion of local bedrock during the Tertiary Period. The hydraulic properties of the lower alluvial unit have been measured using pumping tests at wells DM 202 and DM 504 and by rising head tests in multiport Westbay™ wells. The results of these tests are discussed in Appendix F and in Section 3.4. The measured hydraulic conductivity of the lower alluvial unit ranges from 36 ft/day to 54 ft/day. In the ground-water model, an average value of 40 ft/day was chosen. There was assumed to be no horizontal anisotropy. The vertical hydraulic conductivity was assumed to be 4 ft/day, one-tenth the horizontal value.

## **Bedrock**

The bedrock in the model domain is composed of five units: Precambrian metarhyolite, Precambrian granite, Tertiary Camels Head Formation, Tertiary Tempe Beds, and Tertiary volcanics. A map of the bedrock geology is presented in Figure 2.2 and a map of the bedrock topography is shown in Figure 2.6. A discretized bedrock surface contour map is shown in Figure 6.6.

Features of the bedrock topography include: (1) a bedrock trough below the Courtyard trending to the northwest, (2) a bedrock high west of the Courtyard, (3) a downward slope of the bedrock to the west, and (4), an apparent bedrock mound west of the Grand Canal. The distribution of hydraulic conductivities in the bedrock was evaluated through a combination of rising head test data, geophysical data and drill core evaluation. Figure 6.5 shows the vertical distribution of hydraulic properties in two cross sections through the model domain.

Drilling data have revealed that the bedrock surface appears to rise west of the Grand Canal in the vicinity of wells DM 507 and DM 509. The bedrock high appears to be comprised of Tertiary Camels Head Formation, although in appearance it is similar to the overlying alluvial material. The bedrock in this area was represented using two materials to simulate a gradational decrease in hydraulic conductivity with depth; this decrease was indicated by rising head test data. The upper portion of the Camels Head Formation was assigned a hydraulic conductivity value of 2 ft/day while the lower portion was assigned a value of 0.05 ft/day (see Section A-A' at coordinates 6,000 to 8,000 on Figure 6.5).

## **Hydraulic Conditions**

The ground-water flow regime supplied as initial conditions for the model is depicted in Figure 3.3, which is based on the June 1991 water level contour map. The June 1991 data include several wells located west of the Grand Canal that were not previously available.

The hydraulic gradient depicted in Figure 3.3 is assumed to be representative of the average annual conditions through the area encompassed by the ground-water model. It is known that west of about 24th Street, the hydraulic gradient is seasonally influenced by regional irrigation pumping. The seasonal influence increases with distance to the west due to the presence of numerous irrigation wells in the western portion of Phoenix. Seasonal changes in flow direction are negligible throughout the model domain because few irrigation wells are present in the immediate area of the model. Historic ground-water level measurements also support the assertion that the hydraulic gradient in this area is not significantly influenced by seasonal pumping. Further discussion of ground-water level trends is provided in Chapter 3.0.

Vertical hydraulic gradients have been measured in the multiport wells and are illustrated in Figure 3.6. Upward and downward vertical gradients have been measured throughout the model domain and are most readily apparent between bedrock and alluvium. Within the model, upward and downward vertical gradients are induced by supplying a fixed pressure head throughout the bottom of the model. A comparison of observed and predicted vertical gradients is illustrated in Figure 6.7. Figure 6.8 presents a vertical cross section through the model domain illustrating predicted flow direction vectors. In general, the model simulates upward and downward gradients where they have been observed to occur. Downward gradients were observed most often near the Motorola 52nd St. Facility. Toward the west, upward gradients predominate.

The boundaries of the model were simulated using fixed head cells (Figure 6.9). The values of fixed head were derived by interpretation of water-table elevations (Figure 3.3).

### **Recharge**

Recharge to the model was supplied using fixed-flux boundary cells. In general, the areas of recharge and values of the infiltration flux rate were the same as that reported in the 1987 Draft RI model. Exceptions included:

- 1) the addition of turf irrigation at Pierce Park and Gerard High School, both of which were outside of the 1987 Draft RI model domain;
- 2) the Old Crosscut Canal (OCC) was extended from the limits imposed by the 1987 Draft RI model domain; and
- 3) the infiltration rate of the Grand Canal was varied to test the sensitivity of variable recharge suggested by data from the ADWR.

The recharge sensitivity tests are described in more detail in Section 6.3.1. Figure 6.10 illustrates the distribution of recharge to the model. It is important to note that the OCC is now lined (1991), but was not for the period of modeling.

### Source Description

The source rate of TCE supplied to the model in the Courtyard area was increased by a factor of four to compensate for the increase of the source cell dimensions between the 1987 Draft RI model and the FR RI model. The cell dimensions were increased to allow expansion of the model without creating a cumbersome number of calculation cells. The source cells used in the 1987 Draft RI model have dimensions of 100 feet by 100 feet by 15 feet, and 100 feet by 100 feet by 30 feet in alluvium and bedrock, respectively. In the FR RI model, the alluvium and bedrock source cells were increased to 200 feet by 200 feet by 15 feet, and 200 feet by 200 feet by 30 feet, respectively. The TARGET™ code computes the contaminant concentration in a cell based on the mass concentration of adjacent cells. Therefore, in an attempt to maintain a VOC concentration in the source area generally equivalent to the 1987 Draft RI model, the source rate was increased by a factor of four to compensate for the larger volume of saturated alluvium or bedrock, in each source cell. The sensitivity of the source rate and a comparison of the 1987 Draft RI and FR RI models are discussed in Sections 6.3 and 6.4

The vertical location of source cells was not changed from the 1987 Draft RI; the higher source is positioned at the bedrock/alluvium interface beneath the Courtyard area, and a the lower, second source is located 150 feet below the ground surface in the bedrock.

### 6.3 ASSUMPTIONS

Input assumptions to the numerical ground-water model were made to allow simplification of the complex hydrogeologic system. Hydrodynamic and transport assumptions were necessary to calibrate the flow and contaminant transport portion of the model, respectively. Each are described in the following sections.

#### 6.3.1 Hydrodynamic Conditions

The major hydrodynamic assumptions used in the FR RI model have not changed significantly from the 1987 Draft RI model. The assumptions are described below with a discussion of changes incorporated into the FR RI model.

1. The 1987 Draft RI model was calibrated using September 1987 static water levels to represent hydraulic gradients and ground-water levels throughout the period of contaminant migration. Although the ground-water level measurements in June 1991 are lower than the elevations observed in September 1986, the measured hydraulic gradients are approximately the same (Figure 3.3). The overall decline in ground-water levels has not significantly reduced the overall saturated thickness of the alluvial aquifers. June 1991 ground-water levels are therefore assumed to be representative of hydraulic gradients and ground-water levels throughout the period of model simulation (1962-1991).
2. Seasonal fluctuations in ground-water levels across the model domain do not significantly influence mass transport. It has been observed that the ground-water levels vary uniformly across the study area (Figure 3.5); therefore horizontal hydraulic gradients across the domain have also not been observed to vary seasonally.

3. Long-term variations in horizontal hydraulic gradients are negligible within the model domain. The influence of pumping in the Courtyard area as part of Pilot Treatment Plant (PTP) operation is assumed to be negligible for far-field downgradient predictions given the large model area and the large cell sizes used to represent the Courtyard area.
4. Historical variations in recharge distribution and quantities are not significant to the prediction of contaminant transport with the exception of recharge from the Grand Canal. The importance of this assumption was investigated through sensitivity analyses in the 1987 Draft RI model (Dames & Moore, 1987, Section 5.4.4). Grand Canal recharge is different and has varied based upon data provided by the ADWR and SRP. In particular, the Grand Canal within the model domain was reported to be unlined until 1987 when SRP installed a concrete lining. Therefore, the infiltration from the Grand Canal may have decreased significantly after 1987. The sensitivity of recharge from the Grand Canal was investigated using the ADWR/SRP data (Section 6.4).
5. Evaporation of ground water from the ground-water table is negligible. This assumption is appropriate because the depth to the ground-water table is greater than 20 feet throughout the model domain.
6. Flow and transport in the bedrock may be represented by flow in an equivalent porous medium with heterogeneous and/or anisotropic hydraulic conductivity (See Dames & Moore, 1987b, Section 5.4.3.1).

### 6.3.2 Transport Factors

The major transport assumptions used in the FR RI model analyses were:

1. At the concentrations observed in the ground water, ethylenes are soluble and can be treated as a solute for the purpose of transport calculations. This assumption is valid except in the neighborhood of solvent sources (see Assumption 2).
2. The presence of free-phase TCE has been found in the saturated zone and inferred historically in the unsaturated zone in the Courtyard. It is assumed that the undissolved TCE may be treated as a continuous source of ground-water contamination, the rate of which is dependent on local ground-water

flow rates and the rate of molecular diffusion of TCE into water. A range of dissolution rates for the source were evaluated during model calibration.

3. The free-phase source of TCE is assumed to be stationary. Dissolved TCE related to the free-phase source is assumed to emanate from both the bedrock/alluvial interface and in the bedrock at a depth of 150 feet below ground surface. The locations of the sources were selected from physical chemical considerations. Interfacial tension at the alluvium/bedrock interface, and differential fracturing will immobilize a fraction of the disposed TCE.
4. It is expected that the dissolution rate of TCE from the free phase source will decay with time as the source diminishes. It is assumed that the decay rate is unimportant for the time period considered in the FR RI modeling analyses.
5. The dry well in the Courtyard (designated Source 2 in the 1987 Draft RI and shown on Figure 1.2) is estimated to be the source of nearly 90 percent of TCE disposed at the plant site. It is assumed that the location of the dry well may be used as the sole source (alluvium/bedrock interface and in the bedrock) of TCE for modeling purposes.
6. Adsorption of TCE may be neglected. As described in Chapter 2 of the 1987 Draft RI, measurements of adsorption of TCE by site soils indicate that adsorption is small for the finest fraction of soil samples tested, and zero for the bulk samples of both soil and rock.
7. Dispersivity effectively increases with the distance of contaminant transport (Anderson, 1979). It is assumed that dispersivity may be estimated, through sensitivity analyses, at the scale of observed ground-water contamination. The sensitivity of dispersivity was evaluated using the 1987 Draft RI model and is discussed in Section 5.4.4.2 of the 1987 Draft RI report (Dames & Moore, 1987b).
8. Solvent sources in the unsaturated zone may be neglected for purposes of modeling TCE transport and migration. The presence of undissolved TCE was not encountered in source studies conducted for the 1987 Draft RI.
9. Vapor-phase transport, resulting in evaporation at the ground surface or solvent transport to the water table, may be neglected. Soil-gas concentration profiles around Source 2 indicate that concentrations are elevated in close proximity to the source, and the profile is representative of one-dimensional diffusion. Therefore, it can be inferred that vapor-phase

transport is diffusion controlled and of limited extent. Loss of TCE due to vapor-phase transport is assumed to be negligible for the purpose of ground-water modeling.

10. In the model used in this analysis, density and viscosity effects couple the flow and transport calculations. It is assumed that local density and viscosity of mixtures of solvent and ground water follow a linear approximation for dilute solutions (Perry and Chilton, 1973) and are independent of accompanying chemical species. This assumption is appropriate because the density and viscosity effects for TCE are small at dissolved concentrations.
11. Degradation is believed to occur at the site because degradation isomers of TCE (DCE and TDCE) were not used or disposed at the plant site, but are observed in water samples (see discussion in Chapter 4.0). It is widely acknowledged that the mechanisms governing degradation are not well understood and, therefore, cannot be modeled accurately (Schwartz and Milne-Home, 1987). Consequently, it is assumed that predicted TCE concentrations may be interpreted in terms of a combination of TCE and DCE isomers. This assumption is practical because TCE, TDCE and DCE have similar physical chemistry properties and the transport and cleanup of TCE include the DCE isomers. Furthermore, the observed ground-water concentration distributions are more readily understood if the combination of TCE, TDCE, and DCE is examined.
12. Interactions between solvents disposed at the same time do not affect the migration and transport of TCE. The greatest potential for synergistic effects consists of competitive adsorption. Since laboratory experiments show that minimal adsorption occurs, competitive adsorption is unimportant to the prediction of TCE transport. Laboratory experiments show that solvent solubility limits vary with the concentration of accompanying solvents; at the concentrations found in ground-water samples, this effect is insignificant, except near source areas. Similarly, the diffusion, dispersion and advection of TCE are not expected to be affected by the presence of solvents other than TCE.
13. TCA, although present in high concentrations at the Courtyard, was not included as a source because: 1) the leaking TCA subsurface tank in the Courtyard (Source 25) acted as a source over a shorter period of time than the Courtyard dry well (Source 2); and 2) TCA originating from the leaking underground tank would have had a minimal impact on the downgradient extent of ethylene contamination. For reference, see the preliminary estimate of sources reiterated in Chapter 1.0.

## 6.4 SENSITIVITY ANALYSES

Sensitivity analyses are used to test the predictions of the model to variations in parameters such as hydraulic conductivity, recharge, hydraulic gradient, source rate, adsorption, and dispersivity. The FR RI model is based on the assumptions used in the 1987 Draft RI model. Therefore, most of the sensitivity analyses conducted with the 1987 Draft RI model are applicable to the FR RI model. Sensitivity analyses which were evaluated with the FR RI model focused on the variation of two input assumptions: 1) the source rate to the model, and 2) recharge from the Grand Canal.

The source rate of TCE dissolution was varied to calibrate predictions of the model to observed ethylene concentrations. The results of the calibration runs are discussed in Section 6.5.2 and, therefore, the sensitivity of the source rate is not discussed here. The discussion in this section focuses on recharge to the Grand Canal. The results of sensitivity analyses for other input parameters are described in Section 5.4.4 of the 1987 Draft RI Report, pages 5-23 (Dames & Moore, 1987b).

The ADWR recently completed development of the Salt River Valley (SRV) ground-water model (ADWR, in preparation, 1991). Development of the model included compilation of canal infiltration rates to ground water. The database developed for the SRV model was compiled from a variety of sources including data from SRP, the USGS, and the U.S. Bureau of Reclamation. The data generated by ADWR were provided to Dames & Moore (S. Correll, personal communication, 1991).

The ADWR database indicates that, within the FR RI model domain, the Grand Canal was lined in 1987. Data from SRP included in the ADWR database indicates that recharge from an unlined canal ranges from 0.25 to 0.52 cubic feet per square foot per day ( $\text{ft}^3/\text{ft}^2/\text{day}$  or  $\text{ft}/\text{day}$ ). The rate of recharge from the Grand Canal assumed for the 1987 Draft RI model was 0.028  $\text{ft}/\text{day}$  and was derived by assuming that the bottom of the canal has a hydraulic

conductivity of  $1.0 \times 10^{-5}$  cm/sec and that the hydraulic gradient was equal to 1.0. No specific field measurements were provided to support the higher recharge rates described in the ADWR/SRP database; therefore, the values for Grand Canal recharge reported in the ADWR/SRP database could not be independently checked. A sensitivity test of the impact of the higher canal recharge rates was conducted using the FR RI model to evaluate the importance of this input assumption.

The seepage rate for the Grand Canal was applied to the model by first calculating the amount of water that would infiltrate into the model domain in one day from the Grand Canal and then distributing that amount of water throughout the modeled area of the canal. In this case, the cell widths were approximately 400 feet, much wider than the actual width of the canal (approximately 50 feet).

The unlined canal seepage rate (0.41 ft/day) was derived by averaging the rates reported by SRP. SRP reported that the rates declined with time (see Section 3.5). The model was run from 1962 to 1988 using the unlined canal seepage rate of 0.41 ft/day. After 1987, the Grand Canal infiltration rate was changed in the model to the SRP-reported average lined-canal seepage rate of 0.05 ft/day. The transient run was then continued to June 1991. This sensitivity test was designated Run 25. As discussed in Section 6.5, Model Run 24 was developed as an "initial base case" from the Draft RI Stage 2 model using the assumptions stated in Section 6.3. (Please note that the numerical designation for each model run is arbitrary and bears no relationship to the 1987 Stage 2 model unless stated herein).

The predicted results from Run 25 were compared to the initial base case, Run 24, in which the Grand Canal was simulated using the seepage rate assumed for the 1987 Draft RI model (0.028 ft/day). Other assumptions used in Run 24 were identical to the assumptions used in Run 25. Figures 6.11 and 6.12 present a comparison for alluvium and bedrock, respectively, between Runs 24 and 25. On each figure, the dashed contour lines are predictions from Run 25, while solid lines represent predictions from Run 24.

The results indicate that the higher Grand Canal seepage rates (Run 25) shorten the predicted western extent of the 100 ppb total ethylene concentration contour line by approximately 1,000 feet. This reduction downgradient of the Grand Canal is attributed to dilution of the contaminant plume by the introduction of water from the canal. The predicted 10 ppb contour line in Run 25 lies north of the 10 ppb contour line by approximately 700 feet in Run 24 in the vicinity of the Grand Canal. This shift in orientation is related to changes in the hydraulic gradient and flow direction as a result of the increased recharge rate along the Grand Canal.

Observation of historic water levels in SRP wells 18E-5N and 16.9E-6N, (Figure 3.6) do not indicate a significant decline in water levels after 1987. The model (Run 25) predicts a reduction in ground-water level of approximately five feet along the canal. This observation suggests that the lining of the Grand Canal in 1987 did not significantly alter the rate of infiltration along the canal assumed for the model prior to 1987. Therefore, it is concluded that the unlined- and lined-canal rates of infiltration along the Grand Canal are similar.

The relatively small differences in predicted ethylene distribution between Runs 24 and 25 indicate that the variation of the rate of Grand Canal recharge does not significantly impact the predicted extent of contaminant migration. Additionally, observations of historical ground-water levels in SRP wells along the canal suggest the unlined- and lined-canal recharge rates are not significantly different. Predictions of model Run 24 match the observed ethylene concentrations in the Grand Canal more closely than predictions of model Run 25. Therefore, for the FR RI model, the rate of Grand Canal recharge is assumed to equal the rate estimated for the 1987 Draft RI model (0.028 ft/day).

## 6.5 MODEL CALIBRATION

Model calibration is accomplished by systematically varying input assumptions and comparing the predicted results with observations. The model is calibrated

when the predictions are found to match the observations within acceptable levels of tolerance. Sensitivity analyses are used to guide the calibration, and observed conditions are used to assess the applicability of the calibrated model.

### 6.5.1 Hydrodynamic Factors

The hydrodynamic calibration of the FR RI model began with the assignment of fixed head values to boundary cells and the input of fixed pressure head values throughout the bottom layer of the model. The fixed head input data were derived from analysis of the water table elevation contour map shown in Figure 3.3. The contours shown on the figure were interpolated using June 1991 water level measurements. Pressure head values were derived by calculating the hydraulic head at the bottom layer of the model using measured vertical hydraulic gradients from multiport wells and observed hydraulic heads at the bedrock/alluvium interface. The hydraulic head data were then converted to pressure head data for input to the model.

Several hydrodynamic calibration runs were conducted and are described in Appendix D. Calibration of the FR RI model necessitated modification of the boundary conditions used in the 1987 Draft RI model. Widely scattered wells, including water-level measurements from wells located outside the model domain, were used to develop the water-level contour map shown in Figure 3.3. The local hydraulic gradient and flow direction is apparent on Figure 3.3. The water table map was then used to estimate the values of hydraulic head to be assigned to each fixed-head cell along the model boundary. From these initial conditions, the TARGET™ model computes hydraulic heads at each cell within the model domain. The model boundaries were chosen to be a sufficient distance from the primary area of interest that model predictions in the main area of interest would not be influenced by the boundaries. For this reason, model predictions within approximately 1,000 feet of the boundaries should be regarded as less accurate than in other areas of the model domain.

Predicted and observed hydraulic heads for the alluvium are compared in Figure 6.13 for model Run 24, the initial base case. A plot of predicted versus observed hydraulic heads is shown graphically on Figure 6.14. The correlation coefficient comparing observed and predicted heads equals 0.99. Predicted heads are generally within several feet of observed heads.

Figure 6.15 illustrates the correlation between predicted (Run 24) and observed alluvium saturated thickness. A comparison of measured and predicted vertical hydraulic gradients is depicted in Figure 6.7 and is discussed in Section 6.2.2.

Run 24, as the initial base case, had a flow mass imbalance of less than 2 percent, and was therefore used as the basis for the model transport calibration.

### 6.5.2 Transport Factors

The ground-water model transport predictions can be calibrated by variation of the source rate to yield predicted ethylene concentrations that best match observations. The source rate is varied because it is an input assumption which cannot be field measured or tested, yet it has a major effect on the transport predictions.

The dissolution of TCE to ground water varies with the size of the source area, the local hydraulic gradient, ground-water temperature, and other chemical and physical parameters that are difficult to quantify. Therefore, the source rate must be estimated by comparing predictions of contaminant concentrations in the model with observations of downgradient concentrations. As stated previously, the predictions are compared with ethylene concentrations, or the sum of TCE, TDCE and DCE.

The source rate used in this model is reported in units of gallons of free-phase TCE per year. The TARGET™ model code mixes the specified amount of source in a specified

source cell producing a dissolved mass concentration of TCE. It is this dissolved concentration that is used in the model to calculate downgradient concentrations with increasing time.

As discussed in Section 6.2.3, the size of the source cell specified in the FR RI models was increased by a factor of four from the 1987 Draft RI model. The increase was necessary to allow expansion of the model domain without creating a cumbersome number of calculation cells. To maintain the equivalent concentration of ethylene in the source cell, the source rate supplied to the model was increased. The following table presents a comparison of the source rates used in FR RI model Run 24 and the 1987 Draft RI model.

Source	1987 Draft RI Model (gal/year)	Run 24 FR RI Model (gal/year)
Alluvium	136	544
Bedrock	78	312

To assess differences between the two models, a comparison was made using 1986 predictions. Figures 6.16 and 6.17 present the observed and predicted 1986 alluvium and bedrock ethylene concentrations, respectively for Run 24. The dashed lines on the figure illustrate results from the 1987 Draft RI model for 1986.

By comparing the 1,000 ppb contour line for each prediction, two differences are apparent: 1) the FR RI model (Run 24) predicts that ethylene concentrations in excess of 1,000 ppb extend approximately 800 feet farther than predictions from the 1987 Draft RI model; and 2) the center of the plume predicted using the Run 24 is approximately 500 feet north of the center predicted using the 1987 Draft RI model. These differences increase west of the Grand Canal.

The difference in extent of the 1,000 ppb concentration contour line is attributed to model design changes such as modification of the boundary conditions. The Run 24 predicted

plume lies north of the 1987 Draft RI model plume as a result of calibration of the model to the ground-water table surface illustrated in Figure 3.3. Additional monitor wells installed for the FR RI have provided a more complete network of wells west of the Grand Canal from which interpretation of hydraulic gradient and flow direction have been made. The new data and resultant interpretations are incorporated in the model boundaries and indicate ground-water flows to the southwest, east of the Grand Canal, and to the west-southwest, west of the Grand Canal. In general, the observed differences do not significantly influence the predicted versus observed calibration presented for the 1987 Draft RI. The observed 1986 concentrations used in the 1987 Draft RI model are included on Figures 6.16 and 6.17 for comparison. The FR RI model Run 24 provides a reasonably good calibration to the 1987 Draft RI model and in places improves the predictions (note the observed and predicted concentrations at DM 126, DM 122, and DM 121 in the downgradient portion of the plume). From this analysis, it is concluded that the FR RI model, Run 24, provides predictions approximately the same as the 1987 Draft RI model.

The next step toward calibrating the FR RI model was to compare 1991 predicted ethylene concentrations with recent measured ethylene concentrations. Figures 6.18 and 6.19, illustrate the predictions for 1991 from Run 24 and include post-RI/FS maximum mean ethylene concentrations for comparison. (The maximum mean ethylene concentration is the greatest mean value in either the alluvium or bedrock, and was used conservatively for comparison with predictions in the 1987 Draft RI). The data used for the post-RI/FS mean includes Sample Rounds No. 8 (May 1987) through No. 15 (June 1991). At multi-port wells, the maximum mean value is reported for alluvium (Figure 6.18) and bedrock (Figure 6.19). A comparison of individual monitoring points is presented graphically on Figure 6.20.

The comparison of predicted and observed (mean post-RI) ethylene concentrations presented in Figures 6.18, 6.19, and 6.20 indicate that the source rate assumed for Run 24 results in an overestimation of ethylene concentrations for most wells, particularly wells in the near-field area from the Motorola 52nd St. Facility to the OCC. A comparison between predictions and observations at all alluvial and bedrock monitor wells is shown on a log-log plot on Figure 6.20.

Figure 6.20 includes a diagonal, solid line and dashed lines above and below. A data point falling on the solid line indicates a perfect correlation between predicted and observed ethylene concentrations. The dashed lines distinguish predictions that are within one order-of-magnitude of observations (within the dashed lines) and predictions that exceed one order-of-magnitude when compared to observations (outside of the dashed lines). Many points on Figure 6.20 fall above the uppermost dashed line indicating predictions exceed observations by more than a factor of 10. The correlation coefficient calculated using the plotted data equals 0.77.

The evaluation of historical water quality trends indicates that at most monitoring locations within the contaminant plume, ethylene concentrations have declined since completion of the 1987 Draft RI. The decline in observed ethylene concentrations between 1986 and 1991 is discussed in Section 4.3. The declines were evaluated by comparison of mean RI and Post-RI ethylene concentrations in alluvium and bedrock. Each monitoring location was evaluated with respect to its location relative to the center of the plume. From this evaluation and observations cited in Chapter 4.0, it is concluded that the observed declines are related to three phenomena:

- 1) the artificial decrease in local ethylene concentrations resulting from installation of monitor wells;
- 2) an overall reduction in source rate; and/or
- 3) mass reduction within portions of the plume due to biodegradation.

To provide a better comparison of predicted and observed ethylene concentrations, the source rate of TCE was reduced by a factor of four. As noted in Chapter 4.0 (Section 4.3), comparison of mean RI and mean post-RI ethylene concentrations indicated an average decline by a factor of approximately four. The model run with a source rate reduction of four was designated Run 23. The predicted results from Run 23 are compared to post-RI/FS maximum mean ethylene concentrations on Figures 6.21 and 6.22 for alluvium and bedrock, respectively.

A graphical comparison of predicted versus observed concentrations is presented on Figure 6.23. The results of Run 23 provide a better match of predicted and observed ethylene concentrations than the results obtained from Run 24. The correlation coefficient for the comparison presented in Figure 6.23 is 0.81. Table 6.2 lists the mean ethylene concentrations observed in 93 wells or monitoring ports for the 1987 RI data, the post-1987 RI data, the data collected in 1991, and a mean for all of the data. For comparison, the model predictions for each monitoring interval are listed in Table 6.2 for Model Runs 23 and 24.

Figure 6.24 presents a comparison of predicted and observed post-RI/FS mean ethylene concentrations along the approximate centerline of the plume for both Runs 23 and 24. Figure 6.25 illustrates the vertical distribution of predicted and observed ethylenes for selected wells along the length of the plume. Predicted concentrations near the source area exceed observations for both runs; however, Run 23 predictions more closely match post-RI observations.

In the downgradient portion of the plume, west of the Grand Canal, the model predictions from Runs 23 and 24 are both less than the observed mean ethylene concentrations in wells DM 504, DM 507, and DM 509. These comparisons are also indicated in Figures 6.20 and 6.23, plots of predicted versus observed concentrations for Runs 24 and 23, respectively. In each figure, monitor wells have been identified.

Monitor wells DM 501 through DM 509 were installed between November 1990 and June 1991. As described in Chapter 4.0, historical ground-water quality data suggest that there is an association between vigorous pumping in a monitor well and an increase in measured VOC concentrations. Vigorous pumping occurs during installation of a new monitor well. Therefore, it is possible that the high observed versus predicted concentrations in wells near the Grand Canal are associated with the relatively recent installation of the wells. In that case, Model Run 23 should be considered a simulation of long-term contaminant levels, rather than concentrations currently being measured.

At well DM 504, model Run 24 provides a good prediction of observed ethylene concentration. The mean ethylene concentration in DM 504 is 1,570 ppb and the predicted ethylene concentration in Run 24 is 1,202 ppb. In Run 23, the predicted ethylene concentration at well DM 504 is 292 ppb. Therefore, based on the modeling analyses, the ethylene concentrations in well DM 504 are predicted to decline eventually to approximately 300 ppb. A decline has been observed in well DM 504 between January and June 1991 (Figure 4.6). This decline appears to have been interrupted by agitation of the aquifer during the pumping test conducted in July. During the test, ethylene concentrations increased to as high as 2,300 ppb.

The same analysis provided above for well DM 504 may be applied to wells DM 507 and DM 509. It has been concluded in Chapter 4 (Section 4.4) that the observed VOC concentrations in wells DM 507 and DM 509 may be anomalous. The predictions of Run 24 indicate the highest mean "short-term" (Model Run 24) concentrations in wells DM 507 and DM 509 should be approximately 300 and 100 ppb, respectively. The observed means are higher: 750 ppb for DM 507 and 350 ppb for DM 509. The influence of other sources of contamination in the local areas of DM 507 and DM 509 could explain these anomalies.

The ethylene concentrations observed at well DM 506 are anomalously low compared to the predictions of Run 24 but are consistent with predictions from Run 23. The cause of this anomaly is unclear. The well is located immediately downgradient of the Grand Canal; therefore, recharge from the Grand Canal may influence concentrations in the local area. The model, however, does not indicate a significant amount of local dilution even with high estimates of canal recharge (see Section 6.2.5).

## 6.6 SUMMARY AND CONCLUSIONS

A ground-water flow and contaminant transport model (the FR RI model) was developed for the downgradient portion of the Motorola 52nd St. Facility plume. The model was developed using many of the input assumptions used for the 1987 Draft RI model (Dames

& Moore, 1987b). The FR RI model was extended downgradient and has been calibrated using recently obtained field data including bedrock lithology and depth, hydraulic conductivity measurements, water level data, and piezometric pressure measurements from multi-port wells.

The sensitivity of important input parameters were evaluated in the 1987 Draft RI. One input assumption was tested with the FR RI model, seepage from the Grand Canal. The model was calibrated to observed 1991 hydraulic heads. Calibration of the contaminant transport predictions was accomplished by: 1) comparing predictions of the 1987 Draft RI model with predictions of the FR RI model (Run 24) for 1986 and, 2) comparing predictions of the model for 1991 (Run 23) with mean post-1987 RI/FS ethylene concentrations.

The best approximation of post-RI/FS data is provided by Run 23. The run resulted in a correlation coefficient of 0.81 between predicted and observed ethylene concentrations. The source reduction associated with Run 23 can be supported by the observation that contaminant concentrations in monitor wells installed for the 1987 RI/FS have declined significantly.

Run 23 is recommended for use as the "best fit" to predict the extent of downgradient contamination in 1991. Run 24, however, provides a valuable comparison to evaluate ethylene observations from wells installed in 1991. Concentrations measured in wells installed during 1990-1991 should, according to historical trends, match predictions from Run 24. Predictions from Run 23 represent long-term average concentrations and are therefore considered more representative of actual ground-water ethylene concentrations.

**Table 6.1****MODEL INPUT DATA**

Parameter	Colluvium/Alluvium	Precambrian Granite	Precambrian Metarhyolite	Tertiary Bedrock
<b>HYDROLOGY</b>				
Horizontal hydraulic conductivity (ft/day)	2 to 100 <sup>a</sup>	0.005 <sup>a</sup>	0.05 <sup>a</sup>	0.005 <sup>a</sup>
Vertical hydraulic conductivity (ft/day)	1 to 10 <sup>a</sup>	0.005 <sup>a</sup>	0.05 <sup>a</sup>	0.005 <sup>a</sup>
Storativity (1)	5.0 x 10 <sup>-3a</sup>	1.0 x 10 <sup>-5a</sup>	1.0 x 10 <sup>-5a</sup>	1.0 x 10 <sup>-5a</sup>
Specific Yield (1)	0.21 to 0.22	---	---	---
Surface Recharge	Based on estimated recharge rates for urban flood irrigation (1.15 ft/yr), seepage from irrigation laterals (4 acre ft/yr) and the Old Crosscut Canal (39 acre ft/yr), plant losses (25 to 50 af/yr) natural recharge (100 to 150 af/yr) and the Grand Canal (91-2111 acre ft/yr). See Chapter 3.0, 1987 Draft RI Report.			
Boundary head data	Based on observed heads June 1991			
Vertical hydraulic gradient	Based on most recent available vertical gradients between uppermost saturated port and lowermost port in multi-completion wells. Inferred heads at 800 ft. AMSL supplied as base boundary condition.			
<b>GEOLOGY</b>				
Unit geometry	As described in Chapter 3.0, 1987 Draft RI Report.			
Porosity (1)	0.28 - 0.30	0.01	0.01	0.01
<b>CONTAMINATION</b>				
Longitudinal dispersivity (ft)	100.0 <sup>b</sup>	100.0 <sup>b</sup>	100.0 <sup>b</sup>	100.0 <sup>b</sup>
Transverse dispersivity (ft)	10.0 <sup>b</sup>	10.0 <sup>b</sup>	10.0 <sup>b</sup>	10.0 <sup>b</sup>
Adsorption distribution coefficient (ml/g)	0.0 <sup>c</sup>	0.0 <sup>c</sup>	0.0 <sup>c</sup>	0.0 <sup>c</sup>
Source data	TCE at Courtyard Source in alluvium and bedrock cells. Source active from 1962 onward. <sup>d</sup> Source rates remain constant in each model run. Various source rates were used for sensitivity analysis			
Specific gravity of TCE (1)	1.46 at 20°C			
Viscosity of TCE (cp)	0.58 at 20°C			
Background water quality	Uncontaminated with VOCs. <sup>f</sup>			
<p>Notes:</p> <p>a Aquifer test results (See Appendix F, FR RI Report, 1991 and Chapter 3.0, 1987 Draft RI Report)</p> <p>b Inferred during the course of model calibration.</p> <p>c Batch and column test results (See Chapter 2.0, 1987 Draft RI Report)</p> <p>d See Chapter 6.0, Draft FR RI Report, 1991 about source rates applied in model</p> <p>e Laboratory test results (See Chapter 2.0, 1987 Draft RI Report)</p> <p>f Assumed</p> <p>1 Unitless</p>				

**Table 6.2**

**COMPARISON OF OBSERVED AND PREDICTED  
ETHYLENE (TCE + TDCE + DCE) CONCENTRATIONS<sup>(1)</sup>**

Well	Alluvium/ Interface/ Bedrock	Draft RI Mean <sup>(2)</sup> (ppb)	Post RI Mean <sup>(3)</sup> (1987-1991) (ppb)	1991 Mean or Most Recent Analysis (ppb)	Total Mean (ppb) (1985-1991)	Model Run 23 (ppb)	Model Run 24 (ppb)
16.9E6N	A	.	0	0	0		
40&VB	A	0.46	0	0	0.35		
4626G	A	0.29	0.24	0	0.26		
48&VB	B	9.27	.	.	9.27		
AZNGD	A	12.68	.	.	12.68		
AZNGD N	A	6.44	.	.	6.44		
AZNGD S	B	17.71	.	.	17.71		
AZSLD	A	1.78	0.65	0.80	1.33		
DM 101-025	A	.	.	.	.		
DM 101-045	B	35.5	12	12	32.14	0	0
DM 101-055	B	47.33	1.31	2.5	15.12	0	0
DM 101-070	B	27.7	.	.	27.7		
DM 101-094	B	55.93	.	.	55.93		
DM 101-102	B	8.6	.	.	8.6		
DM 101-114	B	27.5	.	.	27.5		
DM 101-130	B	113	0	0	37.67	0	0
DM 101-140	B	39.31	.	.	39.31		
DM 101B	A	179.37	.	.	179.37		
DM 102-026	A	.	.	.	.		
DM 102-048	A	563.35	.	.	563.35		
DM 102-065	I	104.41	.	.	104.41		
DM 102-082	B	987.14	.	.	987.14		
DM 102-104	B	291.84	.	.	291.84		
DM 102-119	B	4652.42	.	.	4652.42		

(1) The data presented in the table are calculated from tests with various detection limits. The numbers are presumed to be accurate to no more than 2 or 3 significant figures.

(2) Data obtained prior to 1987 and used as the basis for the evaluation presented in the 1987 Draft RI.

(3) Data obtained from 1987 through 1991 inclusive.

. = Not analyzed.

0 = Not detected.

**Table 6.2 (Continued)**

Well	Alluvium/ Interface/ Bedrock	Draft RI Mean <sup>(2)</sup> (ppb)	Post RI Mean <sup>(3)</sup> (1987-1991) (ppb)	1991 Mean or Most Recent Analysis (ppb)	Total Mean (ppb) (1985-1991)	Model Run 23 (ppb)	Model Run 24 (ppb)
DM 102-144	B	1676.4	.	.	1676.4		
DM 102-159	B	725.72	.	.	725.72		
DM 102-186	B	.	.	.	.		
DM 102-191	B	479.82	.	.	479.82		
DM 102-213	B	.	.	.	.		
DM 102-233	B	147.04	.	.	147.04		
DM 102-253	B	.	.	.	.		
DM 102-273	B	75.5	.	.	75.5		
DM 102-299	B	171.96	.	.	171.96		
DM 102-319	B	24.66	.	.	24.66		
DM 102-344	B	.	.	.	.		
DM 102-354	B	11.99	.	.	11.99		
DM 102-377	B	26.5	.	.	26.5		
DM 102-388	B	.	.	.	.		
DM 102-404	B	36.75	.	.	36.75		
DM 102-427	B	.	.	.	.		
DM 102-454	B	114.87	.	.	114.87		
DM 102-469	B	.	.	.	.		
DM 102-489	B	35.78	.	.	35.78		
DM 103-032	A	1059.53	1228.96	780	1165.43	1920	10768
DM 103-047	I	6246.24	2623.32	888.25	4016.75	2558	10676
DM 103-064	B	5642.42	4171.44	1338.5	4973.79	3714	15537
DM 103-079	B	7163.75	.	.	7163.75		
DM 103-103	B	7682.77	.	.	7682.77		
DM 103-123	B	13060.78	6883.94	2530	9531.16	8587	35963
DM 103-148	B	7977.13	.	.	7977.13		
DM 103-163	B	13121.53	.	.	13121.53		

(1) The data presented in the table are calculated from tests with various detection limits. The numbers are presumed to be accurate to no more than 2 or 3 significant figures.

(2) Data obtained prior to 1987 and used as the basis for the evaluation presented in the 1987 Draft RI.

(3) Data obtained from 1987 through 1991 inclusive.

. = Not analyzed.

0 = Not detected.

Table 6.2 (Continued)

Well	Alluvium/ Interface/ Bedrock	Draft RI Mean <sup>(2)</sup> (ppb)	Post RI Mean <sup>(3)</sup> (1987-1991) (ppb)	1991 Mean or Most Recent Analysis (ppb)	Total Mean (ppb) (1985-1991)	Model Run 23 (ppb)	Model Run 24 (ppb)
DM 103-178	B	27564.29	8693.15	2714	17499.68	9383	39200
DM 103-203	B	13489.67	.	.	13489.67		
DM 103-223	B	3193.25	5814.79	1131.5	4940.94	9229	38477
DM 103-243	B	580.77	.	.	580.77		
DM 103-269	B	226.65	1388.78	95.0	923.93	8591	35723
DM 103-289	B	122.08	.	.	122.08		
DM 103-304	B	300.2	.	.	300.2		
DM 103-324	B	141.56	81.2	30.0	108.64	7669	31788
DM 103-344	B	199.38	.	.	199.38		
DM 103-364	B	153.95	.	.	153.95		
DM 103-389	B	233.17	151.93	0	189.42	7154	29609
DM 104-040	A	3.97	2.13	0.91	3.23		
DM 104-052	A	17.83	13	13.0	17.23		
DM 104-079	A	170.07	129.42	166	153.13		
DM 104-101	I	18.87	55.3	55.3	23.42		
DM 104-124	B	.	0	0.00	0		
DM 104-146	B	0.56	3.9	0	1.95		
DM 104-158	B	1.22	0	0	0.97		
DM 104-175	B	.	0	0	0		
DM 104-191	B	1.41	0	0	1.21		
DM 104-221	B	2.01	0	0	1.61		
DM 104-241	B	0.75	0	0	0.64		
DM 104-261	B	0.61	0	0	0.49		
DM 104-281	B	0.95	0	0	0.63		
DM 104-293	B	0	0	0	0		
DM 106-040	A	32.65	1.01	0.5	16.83		
DM 106-062	A	69.75	1.26	0.9	46.92		

(1) The data presented in the table are calculated from tests with various detection limits. The numbers are presumed to be accurate to no more than 2 or 3 significant figures.

(2) Data obtained prior to 1987 and used as the basis for the evaluation presented in the 1987 Draft RI.

(3) Data obtained from 1987 through 1991 inclusive.

. = Not analyzed.

0 = Not detected.

Table 6.2 (Continued)

Well	Alluvium/ Interface/ Bedrock	Draft RI Mean <sup>(2)</sup> (ppb)	Post RI Mean <sup>(3)</sup> (1987-1991) (ppb)	1991 Mean or Most Recent Analysis (ppb)	Total Mean (ppb) (1985-1991)	Model Run 23 (ppb)	Model Run 24 (ppb)
DM 106-079	A	18.38	1.6	0.5	13.59		
DM 106-101	A	2308.81	.	.	2308.81		
DM 106-118	I	3456	2169.65	1400	3088.47		
DM 106-140	B	53.24	.	.	53.24		
DM 106-160	B	291.02	52.65	29.10	222.91		
DM 106-180	B	95.6	.	.	95.6		
DM 106-205	B	149.24	.	.	149.24		
DM 106-231	B	725.76	64.6	28.70	536.86		
DM 106-252	B	104.3	.	.	104.3		
DM 106-267	B	246.67	.	.	246.67		
DM 106-292	B	28.2	.	.	28.2		
DM 106-312	B	18.08	122.9	122.9	39.04		
DM 106-332	B	21.91	.	.	21.91		
DM 106-347	B	65.22	.	.	65.22		
DM 106-357	B	.	.	.	.		
DM 107	A	298.67	250.42	22.7	262.48	9.41	35
DM 109	A	.	.	.	.		
DM 111	A	2275	266.16	37.4	814.03	18847	80984
DM 112	A	3690	1116.35	1072.7	2660.54	5670	24297
DM 113	A	1199.33	858.74	2159.3	986.46	6848	29713
DM 114	A	4.88	14.8	20.4	8.85	4.85	157.74
DM 115	A	1070.3	147.87	183	399.45	78.4	330.66
DM 117	A	22937.97	3088.1	1577.5	7668.84	11903	50121
DM 118	A	0	3.4	0.2	2.04	0.004	0.018
DM 119-072	A	0.09	.	.	0.09		
DM 119-098	A	0	.	.	0		
DM 119-137	I	0.16	0.06	0	0.08	0	0.002

(1) The data presented in the table are calculated from tests with various detection limits. The numbers are presumed to be accurate to no more than 2 or 3 significant figures.

(2) Data obtained prior to 1987 and used as the basis for the evaluation presented in the 1987 Draft RI.

(3) Data obtained from 1987 through 1991 inclusive.

. = Not analyzed.

0 = Not detected.

**Table 6.2 (Continued)**

Well	Alluvium/ Interface/ Bedrock	Draft RI Mean <sup>(2)</sup> (ppb)	Post RI Mean <sup>(3)</sup> (1987-1991) (ppb)	1991 Mean or Most Recent Analysis (ppb)	Total Mean (ppb) (1985-1991)	Model Run 23 (ppb)	Model Run 24 (ppb)
DM 119-182	B	.	.	.	.		
DM 119-204	B	0	1.1	0	0.86	0	0.001
DM 119-230	B	.	.	.	.		
DM 119-244	B	0	.	.	0		
DM 119-270	B	.	.	.	.		
DM 119-284	B	0.09	.	.	0.09		
DM 120	A	730.62	137.68	95.53	307.09	71	168
DM 121-043	A	116.45	55	55	95.97	27.5	2198
DM 121-084	A	148.65	106.35	152	127.5	27.3	2682
DM 121-125	I	2559.25	681.91	190	1218.29	26.9	2054
DM 121-146	B	.	.	.	.		
DM 121-159	B	294.5	47.4	25	170.95	17.5	1133
DM 121-185	B	.	.	.	.		
DM 121-219	B	387.5	54.81	89.15	149.87	7.62	507
DM 121-248	B	.	.	.	.		
DM 121-284	B	141.1	85.39	0.00	99.32	3.22	183
DM 122-A	A	2.7	10.45	2.35	8.9	69.9	289
DM 122-B	I	1.22	2.94	4	2.56	70.5	291
DM 123-056	I	0.09	0	0	0.06	0	0.001
DM 123-085	B	0	0	0	0	0	0.001
DM 123-111	B	.	.	.	.		
DM 123-135	B	0	0	0	0	0	0.001
DM 123-156	B	.	.	.	.		
DM 123-195	B	0	0	0	0	0	0.001
DM 123-226	B	.	.	.	.		
DM 123-250	B	0	0	0	0	0	0.001
DM 123-285	B	0	0	0	0	0	0

(1) The data presented in the table are calculated from tests with various detection limits. The numbers are presumed to be accurate to no more than 2 or 3 significant figures.

(2) Data obtained prior to 1987 and used as the basis for the evaluation presented in the 1987 Draft RI.

(3) Data obtained from 1987 through 1991 inclusive.

. = Not analyzed.

0 = Not detected.

**Table 6.2 (Continued)**

Well	Alluvium/ Interface/ Bedrock	Draft RI Mean <sup>(2)</sup> (ppb)	Post RI Mean <sup>(3)</sup> (1987-1991) (ppb)	1991 Mean or Most Recent Analysis (ppb)	Total Mean (ppb) (1985-1991)	Model Run 23 (ppb)	Model Run 24 (ppb)
DM 124	A	4.8	14.8	2.75	10.8	0	0
DM 125-046	A	0.11	0	0	0.03	295	1279
DM 125-076	I	0.46	0.65	1.4	0.61	92.4	400
DM 125-125	B	19.55	1.3	1.2	6.51	53.4	222
DM 125-155	B	10.85	3.06	1.4	4.79	47.6	197
DM 125-185	B	15.3	5.7	8	7.83	33.9	140
DM 125-211	B	.	.	.	.		
DM 125-236	B	.	.	.	.		
DM 125-270	B	10.95	1.65	3	3.71	16	65
DM 126	A	24.37	1.01	1.25	8.02		
DM 201	A	273.6	2536.72	2650.88	2466.00		
DM 201-OB1	A	.	22065.76	22065.76	22065.76		
DM 201-OB2	A	.	4364.16	4364.16	4364.16		
DM 201-OB3	A	.	113.18	113.18	113.18		
DM 202	A	.	282.15	519	282.15		
DM 202-OB1	A	.	2757	3110	2757		
DM 202-OB2	A	351	390.67	539	380.75		
DM 301	A	69711.73	.	.	69711.73		
DM 302	A	242099.8	.	.	242099.8		
DM 303	A	.	1287.5	865	1287.5		
DM 304	A	.	1740	1215	1740		
DM 305	A	.	4234.5	4234.5	4234.5		
DM 306	A	.	4522	4522	4522		
DM 307	A	.	3494.25	3494.25	3494.25		
DM 308	A	.	2414.15	2414.15	2414.15		
DM 309	A	.	5300	5300	5300		
DM 310	A	.	2895	2895	2895		

(1) The data presented in the table are calculated from tests with various detection limits. The numbers are presumed to be accurate to no more than 2 or 3 significant figures.

(2) Data obtained prior to 1987 and used as the basis for the evaluation presented in the 1987 Draft RI.

(3) Data obtained from 1987 through 1991 inclusive.

. = Not analyzed.

0 = Not detected.

Table 6.2 (Continued)

Well	Alluvium/ Interface/ Bedrock	Draft RI Mean <sup>(2)</sup> (ppb)	Post RI Mean <sup>(3)</sup> (1987-1991) (ppb)	1991 Mean or Most Recent Analysis (ppb)	Total Mean (ppb) (1985-1991)	Model Run 23 (ppb)	Model Run 24 (ppb)
DM 311	A	.	175	175	175		
DM 312	A	.	39.85	39.85	39.85		
DM 313	A	.	1	1	1		
DM 501-147	A	.	15.08	17.67	15.08	104	427
DM 501-202	I	.	68.87	81.94	68.87	107	438
DM 501-267	B	.	4.07	4.88	4.07	76.3	312
DM 501-331	B	.	0.13	0.16	0.13	42.4	173
DM 501-387	B	.	0.52	0.62	0.52		
DM 502-079	A	.	381.02	381.02	381.02	723	3021
DM 502-119	I	.	714.48	714.48	714.48	540	2291
DM 502-161	B	.	208.12	208.12	208.12	283	1175
DM 502-240	B	.	61.98	61.98	61.98	120	495
DM 502-335	B	.	48.6	48.6	48.6	19.1	78.6
DM 503	A	.	7.88	7.88	7.88	0.65	2.7
DM 504	A	.	1570.47	1507.77	1570.47	292	1202
DM 504OB1	A	.	.	.	.		
DM 505	A	.	1.05	1.05	1.05	4.62	18.8
DM 506-100	A	.	74.67	74.67	74.67	156	6.36
DM 506-185	I	.	161.13	161.13	161.13	158	644
DM 506-240	B	.	42.13	42.13	42.13	105	428
DM 506-305	B	.	28.17	28.17	28.17	51.9	210
DM 506-375	B	.	25.07	25.07	25.07		
DM 507-084	A	.	751.03	751.03	751.03	81.6	332
DM 507-188	I	.	413.13	413.13	413.13	27.8	111
DM 507-240	B	.	379.9	379.9	379.9	19.7	78.7
DM 507-280	B	.	370.1	370.1	370.1	13.3	52.9
DM 507-315	B	.	199.77	199.77	199.77	13.3	52.9

(1) The data presented in the table are calculated from tests with various detection limits. The numbers are presumed to be accurate to no more than 2 or 3 significant figures.

(2) Data obtained prior to 1987 and used as the basis for the evaluation presented in the 1987 Draft RI.

(3) Data obtained from 1987 through 1991 inclusive.

. = Not analyzed.

0 = Not detected.

**Table 6.2 (Continued)**

Well	Alluvium/ Interface/ Bedrock	Draft RI Mean <sup>(2)</sup> (ppb)	Post RI Mean <sup>(3)</sup> (1987-1991) (ppb)	1991 Mean or Most Recent Analysis (ppb)	Total Mean (ppb) (1985-1991)	Model Run 23 (ppb)	Model Run 24 (ppb)
DM 508	A	.	0.33	0.33	0.33	0.71	2.88
DM 509	A	.	351.27	351.27	351.27	24.5	110
DM 601-040	I	.	762	762	762		
DM 601-085	B	.	424.1	424.1	424.1		
DM 601-135	B	.	320.6	320.6	320.6		
DM 601-200	B	.	4361	4361	4361		
DM 602	A	.	1.55	1.55	1.55		
DM 603-068	A	.	11.83	11.83	11.83		
DM 603-115	I	.	1325	1325	1325		
DM 603-170	B	.	6100	6100	6100		
DM 603-205	B	.	5445	5445	5445		
DM 603-245	B	.	6485	6485	6485		
DM 604	A	.	1041	1041	1041		
DM 605-066	A	.	66.45	66.45	66.45		
DM 605-105	I	.	2655	2655	2655		
DM 605-170	B	.	3.5	3.5	3.5		
DM 605-240	B	.	1.55	1.55	1.55		
DM 605-290	B	.	1.45	1.45	1.45		
DM 606-045	I	.	965.8	965.8	965.8		
DM 606-102	B	.	2448.25	2448.25	2448.25		
DM 606-185	B	.	20890	20890	20890		
DM 606-250	B	.	317.15	317.15	317.15		
DM 606-330	B	.	68.35	68.35	68.35		
DM 606-370	B	.	9	9	9		
DM 701	A	.	0.12	0.12	0.12		
DW-1	B	33730.6	.	.	33730.6		
MP 01-A	B	.	.	.	.		

- (1) The data presented in the table are calculated from tests with various detection limits. The numbers are presumed to be accurate to no more than 2 or 3 significant figures.
- (2) Data obtained prior to 1987 and used as the basis for the evaluation presented in the 1987 Draft RI.
- (3) Data obtained from 1987 through 1991 inclusive.

. = Not analyzed.  
0 = Not detected.

**Table 6.2 (Continued)**

Well	Alluvium/ Interface/ Bedrock	Draft RI Mean <sup>(2)</sup> (ppb)	Post RI Mean <sup>(3)</sup> (1987-1991) (ppb)	1991 Mean or Most Recent Analysis (ppb)	Total Mean (ppb) (1985-1991)	Model Run 23 (ppb)	Model Run 24 (ppb)
MP 01-B	B	.	.	.	.		
MP 03-A	A	15961.25	.	.	15961.25		
MP 03-B	I	68262.5	22913.33	26176.67	41053	48914	216169
MP 03-C	B	1801300	1093167	939750	1649557	115271	455666
MP 03-D	B	1630175	2378633	2817950	1802896	275836	978208
MP 09-A	A	55477.31	16938.13	26900	40795.71	45009	197810
MP 09-B	I	28334.5	2860	2860	23239.6		
MP 09-C	B	24190.75	9267.99	2820	16729.37	171260	625637
MP 09-D	B	31963.33	6905	6905	25698.75		
MP 11-A	A	3197.85	1293.57	125	2413.74	30327	132491
MP 11-B	I	684.05	1207.01	1145	916.48	32181	140695
MP 11-C	B	435.37	662.43	560	548.9	92058	466456
MP 11-D	B	149.06	12.7	12.7	114.97		
MP 13-A	A	36.96	.	.	36.96		
MP 13-B	I	3876.48	1592.5	1540	2962.88	46.6	162
MP 13-C	B	113.28	11.78	4.2	62.53	398	1363
MP 13-D	B	48.04	.	.	48.04		
MP 16-A	A	72.33	38.7	51.45	51.31		
MP 16-B	I	13.74	9.75	9.75	12.85		
MP 16-C	B	37.56	6.63	1	18.53		
MP 16-D	B	134.55	.	.	134.55		
MP 20-A	I	157.67	0.18	0.36	118.3	0	0
MP 20-B	B	82.42	0.12	0.24	61.85	0	0
MP 20-C	B	74.59	0	0	55.94	0	0
MP 20-D	B	.	.	.	.		
MP 25-A	I	17.04	.	.	17.04		
MP 25-B	B	12.81	.	.	12.81		

- (1) The data presented in the table are calculated from tests with various detection limits. The numbers are presumed to be accurate to no more than 2 or 3 significant figures.
- (2) Data obtained prior to 1987 and used as the basis for the evaluation presented in the 1987 Draft RI.
- (3) Data obtained from 1987 through 1991 inclusive.

. = Not analyzed.  
0 = Not detected.

Table 6.2 (Continued)

Well	Alluvium/ Interface/ Bedrock	Draft RI Mean <sup>(2)</sup> (ppb)	Post RI Mean <sup>(3)</sup> (1987-1991) (ppb)	1991 Mean or Most Recent Analysis (ppb)	Total Mean (ppb) (1985-1991)	Model Run 23 (ppb)	Model Run 24 (ppb)
MP 25-C	B	.	.	.	.		
MP 25-D	B	19.47	14.7	11.9	18.11	0	0
MP 28-A	I	15.56	34.8	19.7	22.78	0	0
MP 28-B	B	28.43	1.2	0	21.62	0	0
MP 28-C	B	45.6	12.63	0	34.61	0	0
MP 28-D	B	21.56	0.55	1.1	16.31	0	0.001
MP 30-A	A	21.08	3.3	0.5	16.64	0.68	1.81
MP 30-B	I	60.32	9.8	9.8	51.9	0.6	1.6
MP 30-C	B	189.45	71.8	84	160.04	0.26	0.8
MP 30-D	B	79.16	6.1	6.1	66.98	0.111	0.42
MP 36-A	A	14865.5	1153.96	115.3	8370.56	31824	140134
MP 36-B	I	18578	3598.85	4287.5	11088.42	34171	150688
MP 36-C	B	31251.67	4892.88	5890	16189.5	29524	142528
MP 36-D	B	115658.3	261210	151366.7	206628.1	26896	140921
MP 37-A	I	.	.	.	.		
MP 37-B	B	.	30.6	30.6	30.6		
MP 37-C	B	179.25	215.25	215.25	188.25		
MP 38-A	B	.	.	.	.		
MP 38-D	B	.	.	.	.		
MP 48-C	B	5326.6	.	.	5326.6		
MP 48-D	B	21898.71	.	.	21898.71		
MP 48-E	B	12302.44	.	.	12302.44		
MP 49-A	A	1001.89	13.65	8.8	642.53		
MP 49-B	I	5854.96	6285	5440	6055.65		
MP 49-C	B	4224.48	3132.18	2980	3714.74		
MP 49-D	B	874.8	30.13	4.7	593.24		
MP 50-A	A	67.67	103.03	44.7	78.28		

(1) The data presented in the table are calculated from tests with various detection limits. The numbers are presumed to be accurate to no more than 2 or 3 significant figures.

(2) Data obtained prior to 1987 and used as the basis for the evaluation presented in the 1987 Draft RI.

(3) Data obtained from 1987 through 1991 inclusive.

. = Not analyzed.

0 = Not detected.

**Table 6.2 (Continued)**

Well	Alluvium/ Interface/ Bedrock	Draft RI Mean <sup>(2)</sup> (ppb)	Post RI Mean <sup>(3)</sup> (1987-1991) (ppb)	1991 Mean or Most Recent Analysis (ppb)	Total Mean (ppb) (1985-1991)	Model Run 23 (ppb)	Model Run 24 (ppb)
MP 50-B	A	206.54	532.92	655	295.55		
MP 50-C	I	.	.	.	.		
MP 50-D	B	1248.77	1950	1740	1404.6		
MP 51-A	A	617.34	28.33	16.6	440.64		
MP 51-B	A	466.41	419.5	308	444.76		
MP 51-C	I	2419.81	2670.8	2810	2516.35		
MP 51-D	B	7.72	0.07	0.0	5.63		
MP 52-A	A	.	.	.	.		
MP 52-B	I	15.87	1.12	0.0	9.55		
MP 52-C	B	61.5	.	.	61.5		
MP 52-D	B	.	.	.	.		
MP 53-A	A	.	.	.	.		
MP 53-B	I	96.18	0.03	0.20	54.98		
MP 53-C	B	333.13	0.58	2.10	190.61		
MP 53-D	B	36.4	0.65	0.30	24.48		
PZ01	A	391.43	.	.	391.43		
PZ02	A	296.55	.	.	296.55		
PZ03	A	1066.47	.	.	1066.47		
PZ04	A	697.72	.	.	697.72		
PZ05	A	1929.85	.	.	1929.85		
PZ06	A	9493.5	.	.	9493.5		
PZ07	A	32632.5	.	.	32632.5		
PZ08	A	161.8	.	.	161.8		
PZ09	A	12700	.	.	12700		
PZ10	A	21553	.	.	21553		
SW-1	I	11540.81	.	.	11540.81		
TOVREA	A	.	.	.	.		

- (1) The data presented in the table are calculated from tests with various detection limits. The numbers are presumed to be accurate to no more than 2 or 3 significant figures.
- (2) Data obtained prior to 1987 and used as the basis for the evaluation presented in the 1987 Draft RI.
- (3) Data obtained from 1987 through 1991 inclusive.

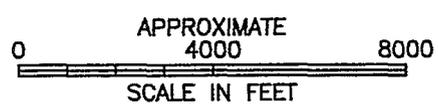
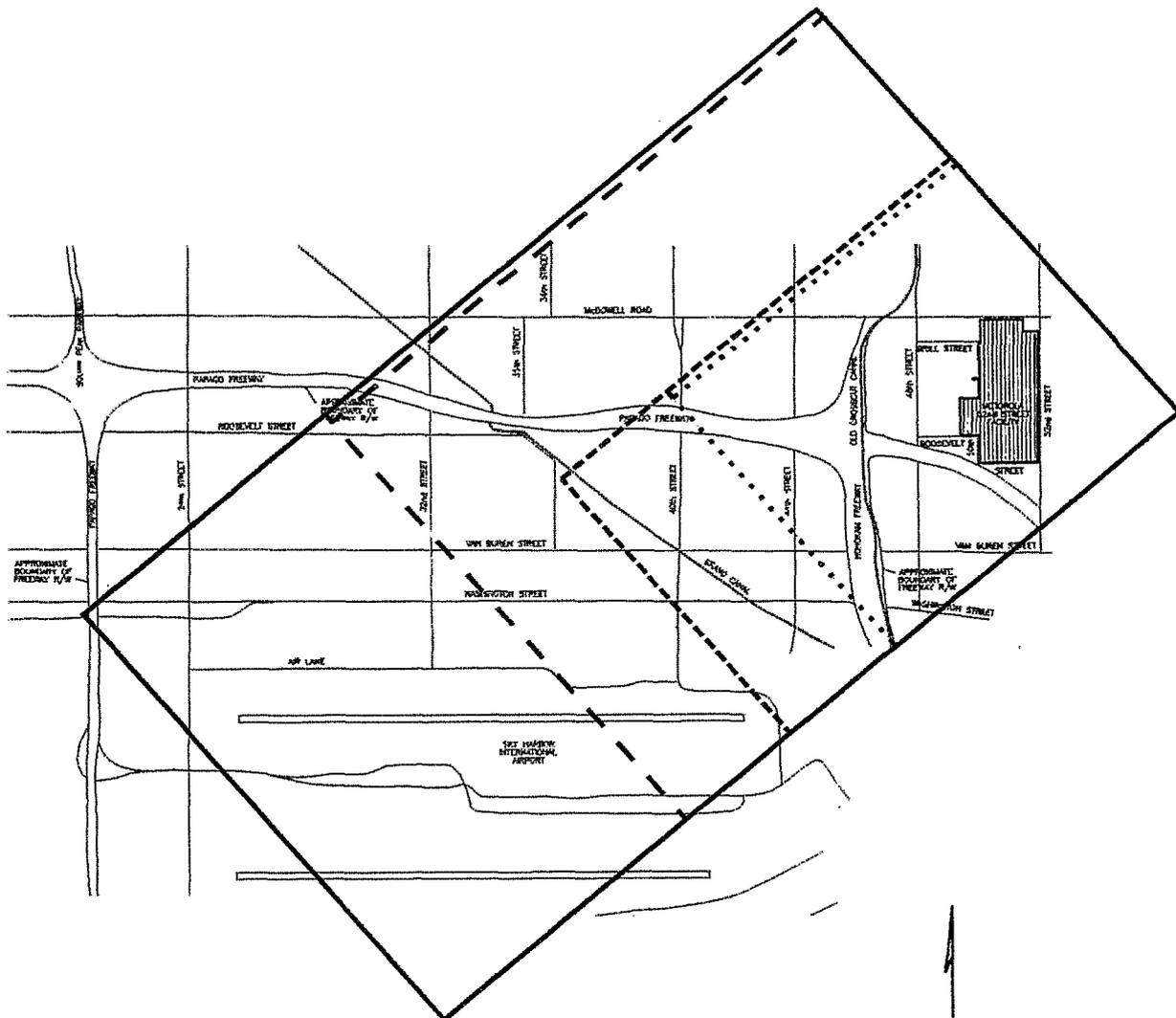
. = Not analyzed.  
0 = Not detected.

**Table 6.2 (Continued)**

Well	Alluvium/ Interface/ Bedrock	Draft RI Mean <sup>(2)</sup> (ppb)	Post RI Mean <sup>(3)</sup> (1987-1991) (ppb)	1991 Mean or Most Recent Analysis (ppb)	Total Mean (ppb) (1985-1991)	Model Run 23 (ppb)	Model Run 24 (ppb)
TURNA	A	3751.45	.	.	3751.45		
WILLIS	A	957.33	870	951.5	935.5		

- (1) The data presented in the table are calculated from tests with various detection limits. The numbers are presumed to be accurate to no more than 2 or 3 significant figures.
- (2) Data obtained prior to 1987 and used as the basis for the evaluation presented in the 1987 Draft RI.
- (3) Data obtained from 1987 through 1991 inclusive.

. = Not analyzed.  
0 = Not detected.

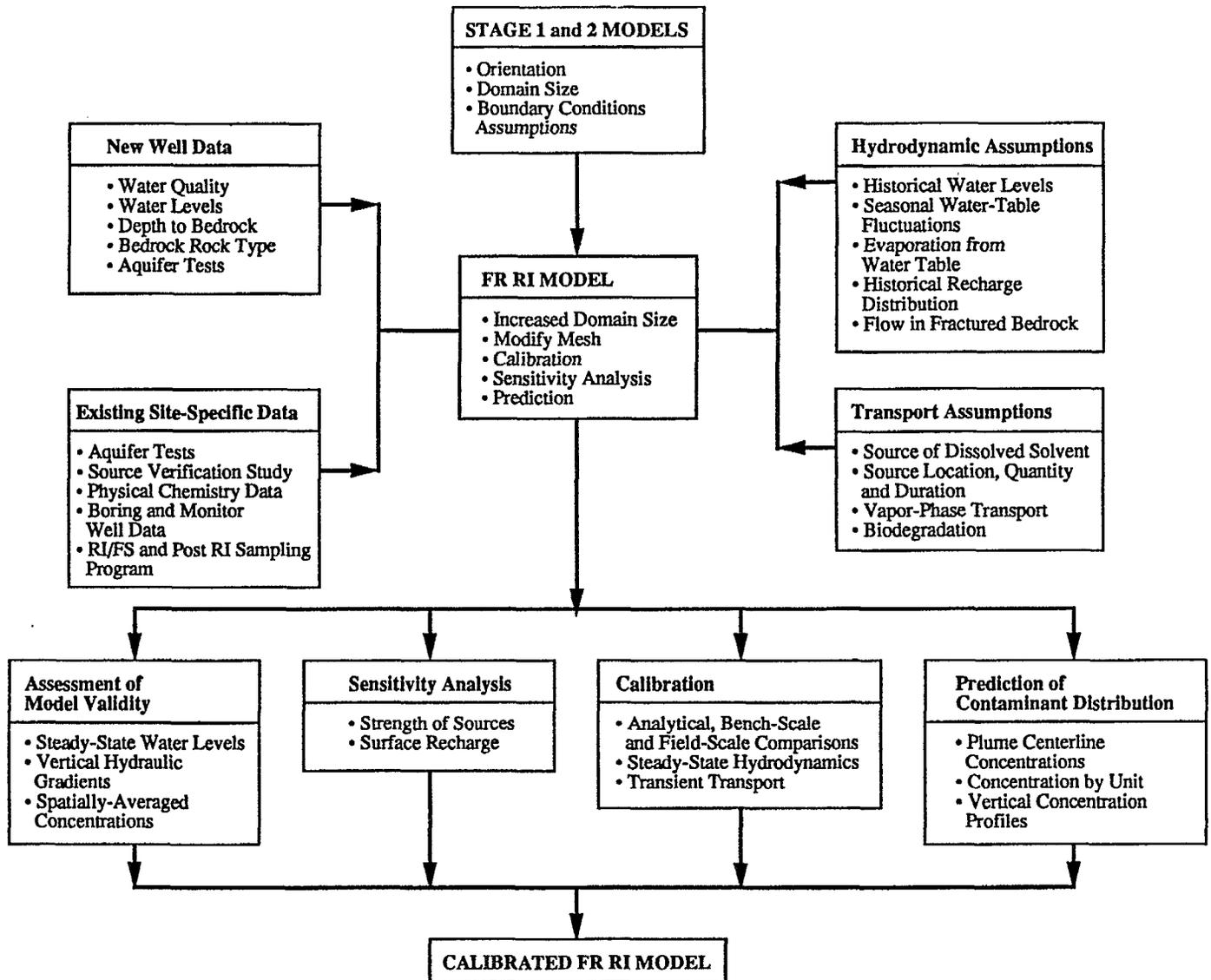


- LEGEND:**
- ..... BOUNDARY OF STAGE1, 3D MODEL
  - - - - BOUNDARY OF STAGES 2 & 3, 3D MODEL
  - · - · - BOUNDARY OF STAGE 3, 2D MODEL
  - BOUNDARY OF FR RI, 3D MODEL

**REFERENCE:**  
 1987 Draft RI, Chapter 5  
 Ground-water Modeling.

## MODEL CALCULATION DOMAINS

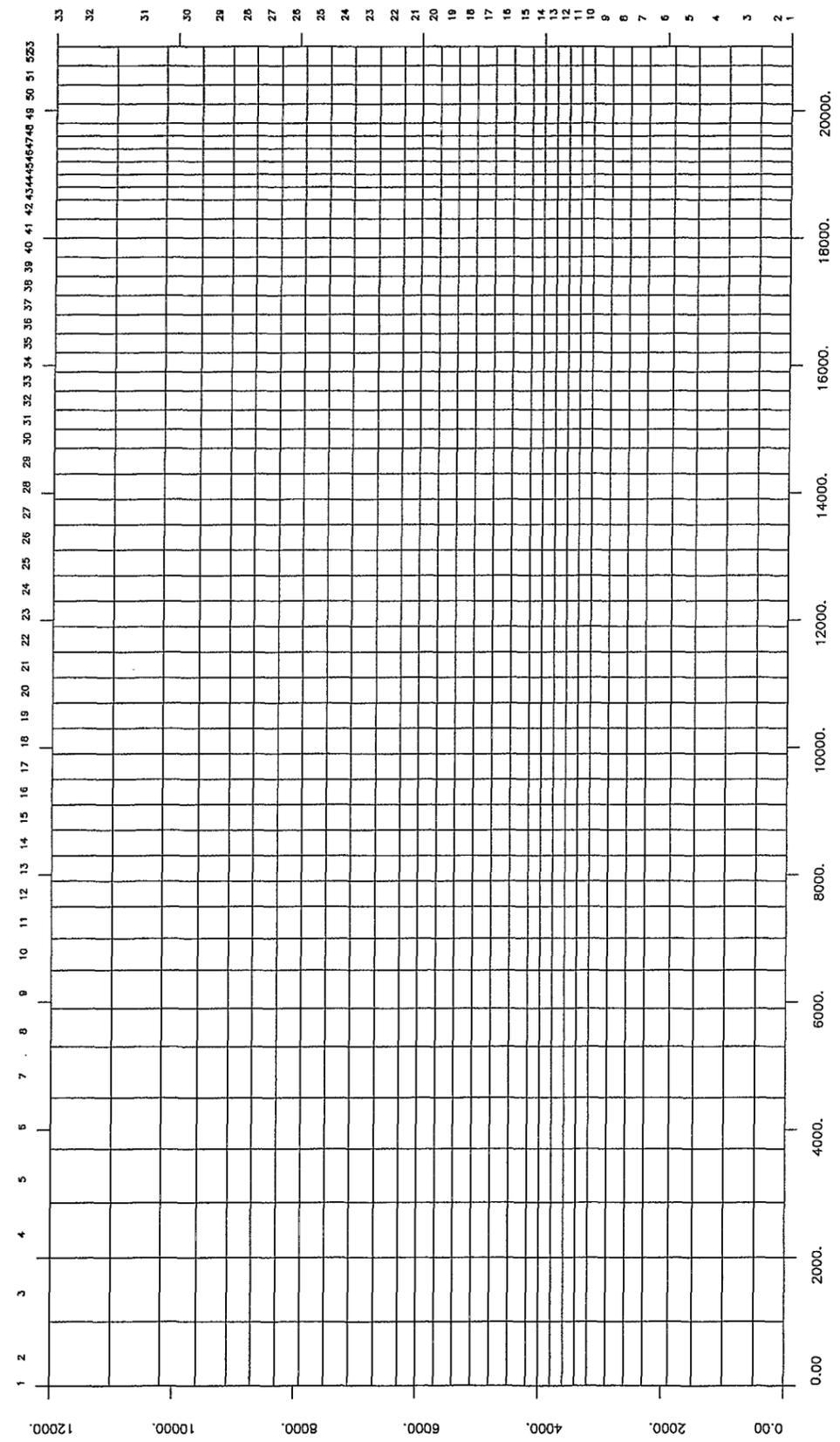
**Figure 6.1**  
 MOTOROLA 52nd ST.  
 FR RI  
 FEBRUARY 1992



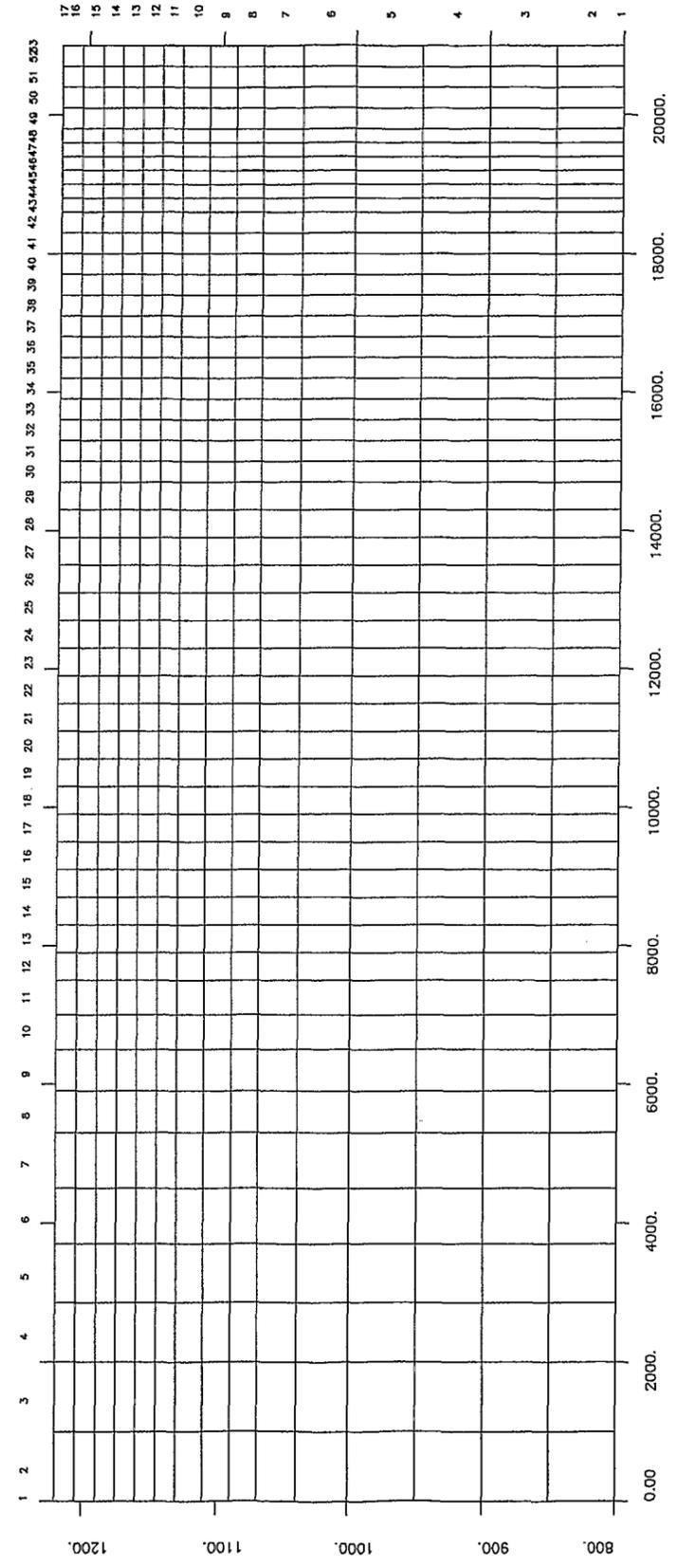
## FINAL REMEDY REMEDIAL INVESTIGATION MODEL APPROACH

Figure 6.2

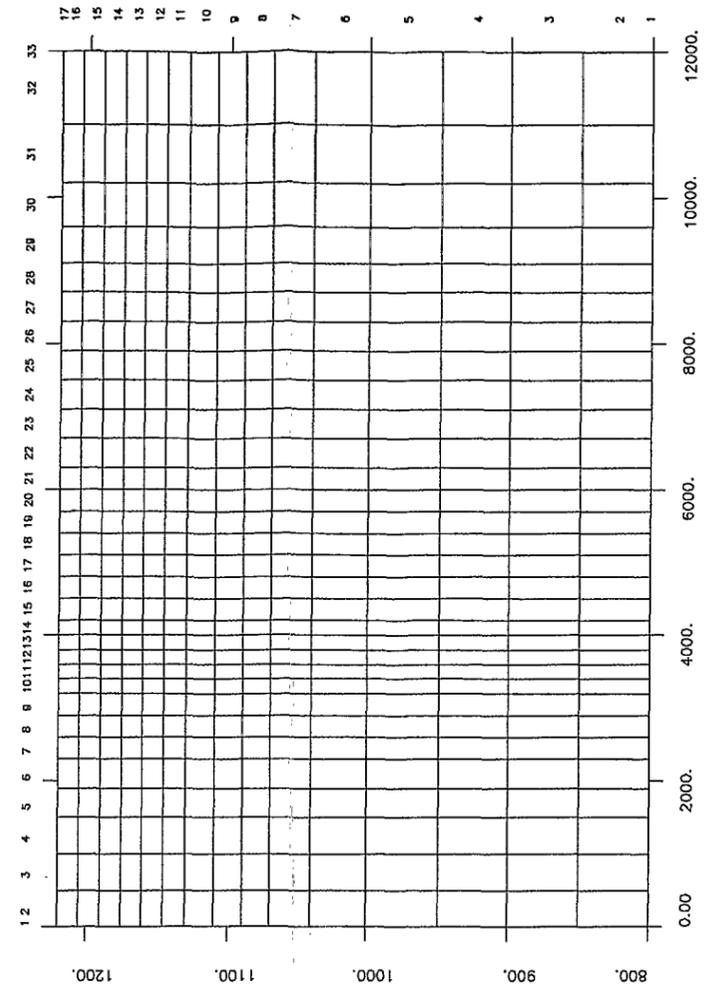
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992



HORIZONTAL PLANE



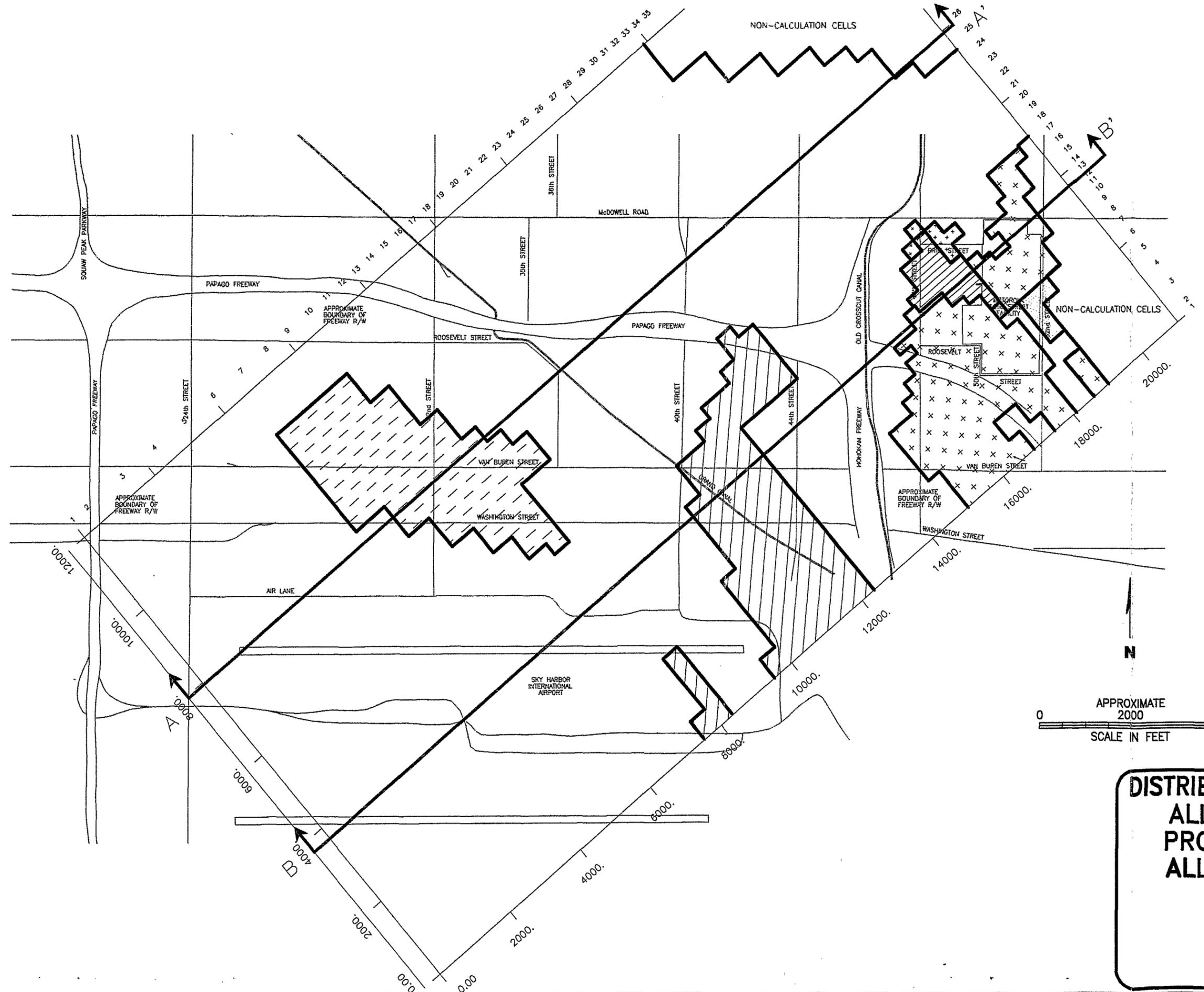
SW-NE VERTICAL PLANE



SE-NW VERTICAL PLANE

**SECTION THROUGH  
MODEL CALCULATION  
MESH**

Figure 6.3  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992



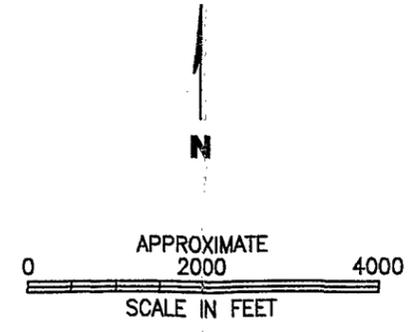
**LEGEND:**

HYDRAULIC CONDUCTIVITY

-  100 FEET/DAY
-  40 FEET/DAY
-  30 FEET/DAY
-  20 FEET/DAY
-  10 FEET/DAY
-  2 FEET/DAY

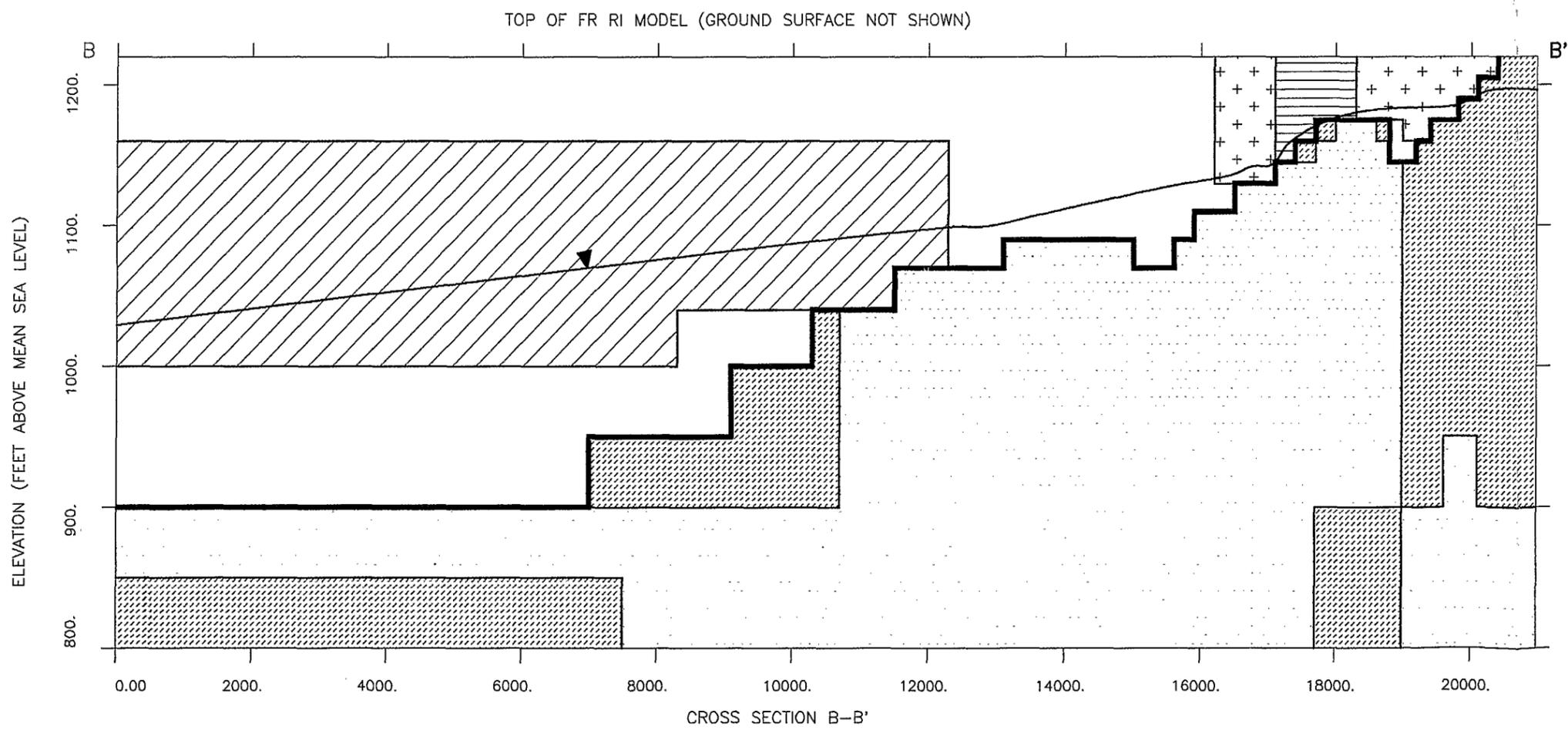
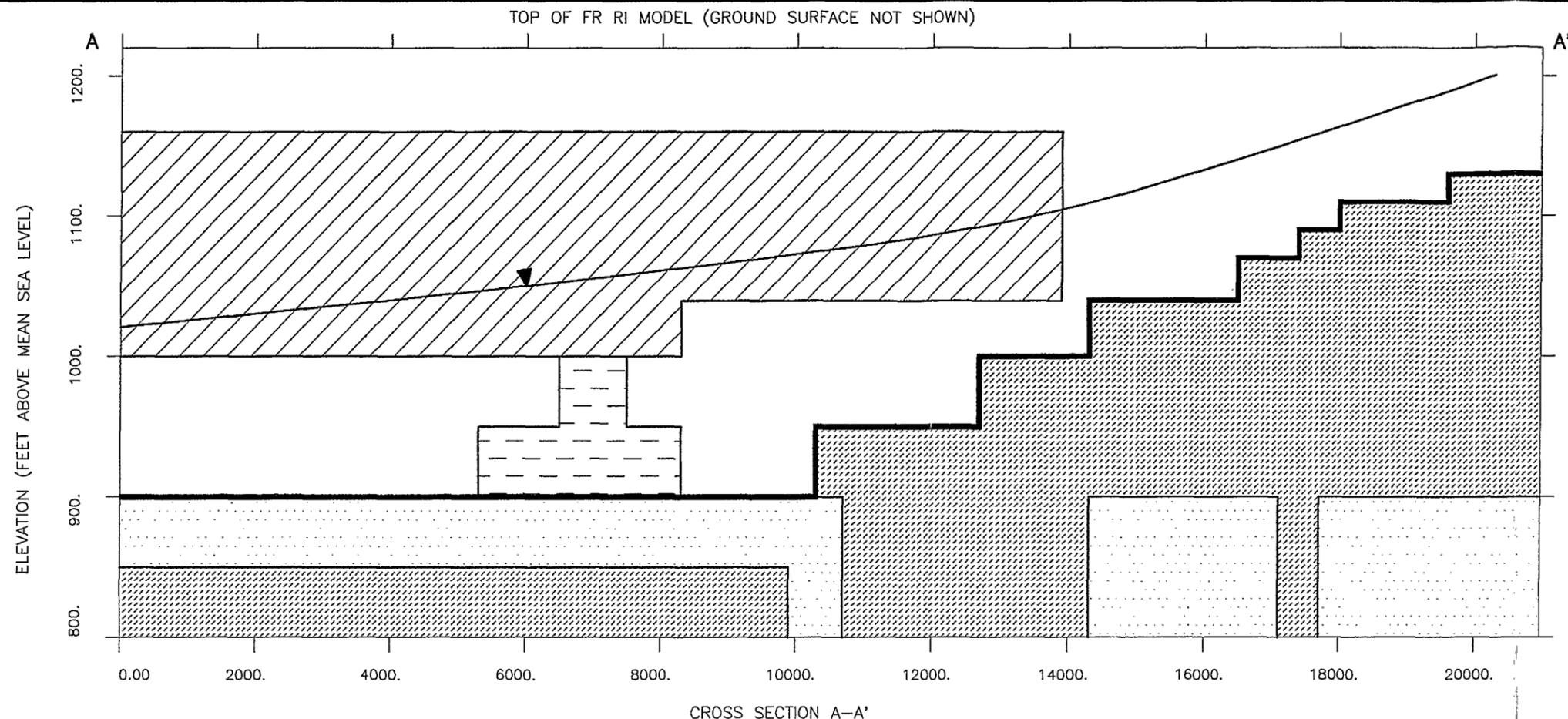
A ——— A' CROSS-SECTION LOCATIONS  
 B ——— B'

**NOTE:**  
 Cross sections shown on Figure 6.5



**DISTRIBUTION OF SIMULATED ALLUVIAL MATERIAL PROPERTIES AT THE ALLUVIUM/BEDROCK INTERFACE**

Figure 6.4  
 MOTOROLA 52nd ST.  
 FR RI  
 FEBRUARY 1992



**LEGEND:**

ALLUVIUM:

HYDRAULIC CONDUCTIVITY

- 100 FEET/DAY
- 40 FEET/DAY
- 30 FEET/DAY
- 20 FEET/DAY
- 2 FEET/DAY

BEDROCK:

HYDRAULIC CONDUCTIVITY

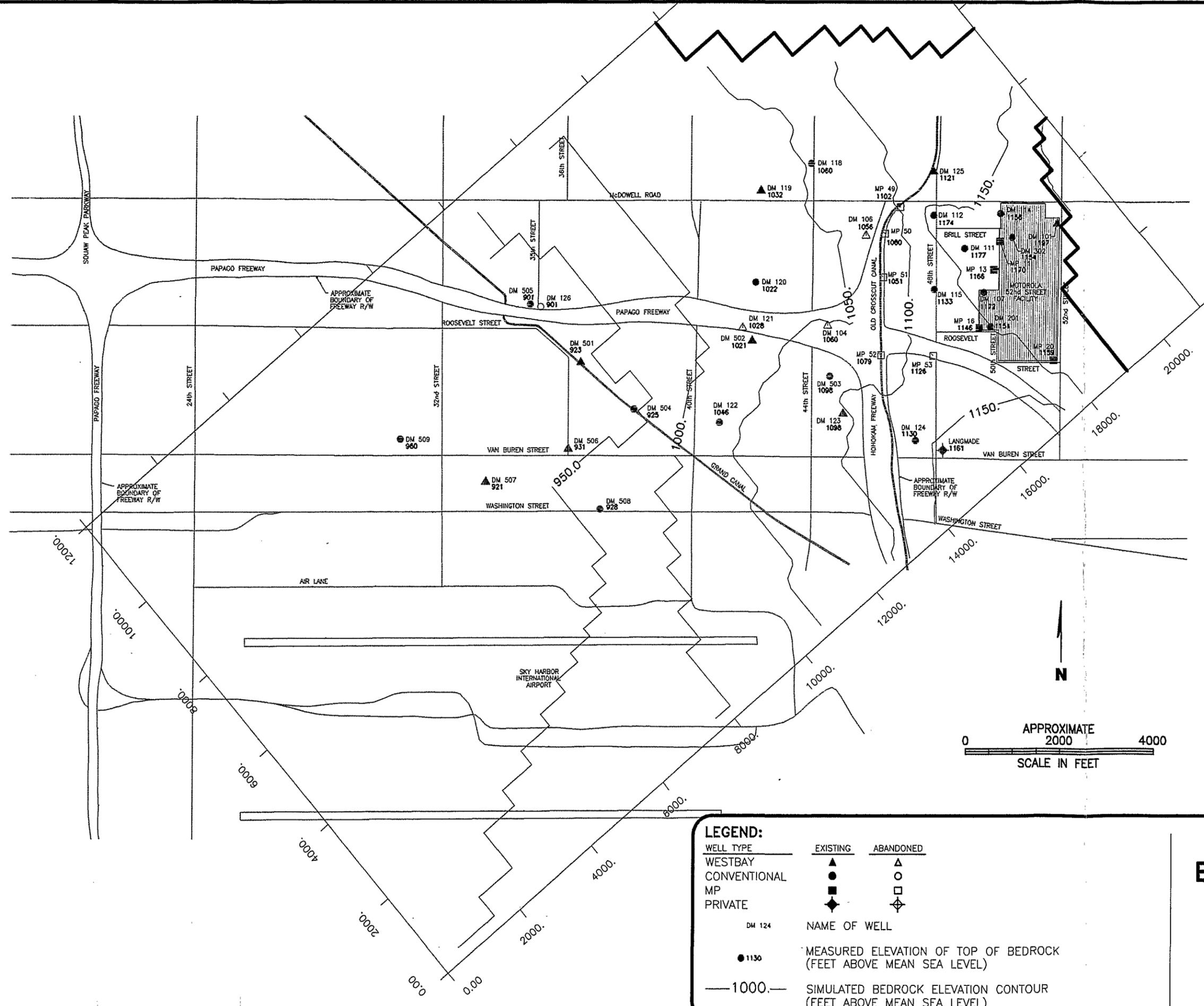
- 0.05 FEET/DAY
- 0.005 FEET/DAY

- PREDICTED WATER TABLE (JUNE 1991)
- BEDROCK/ALLUVIUM INTERFACE

- NOTES:**
1. locations of cross-sections shown on Figure 6.4.
  2. Vertical exaggeration = 20.

**DISTRIBUTION OF  
HYDROGEOLOGIC  
UNITS IN  
CROSS SECTIONS**

Figure 6.5  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992



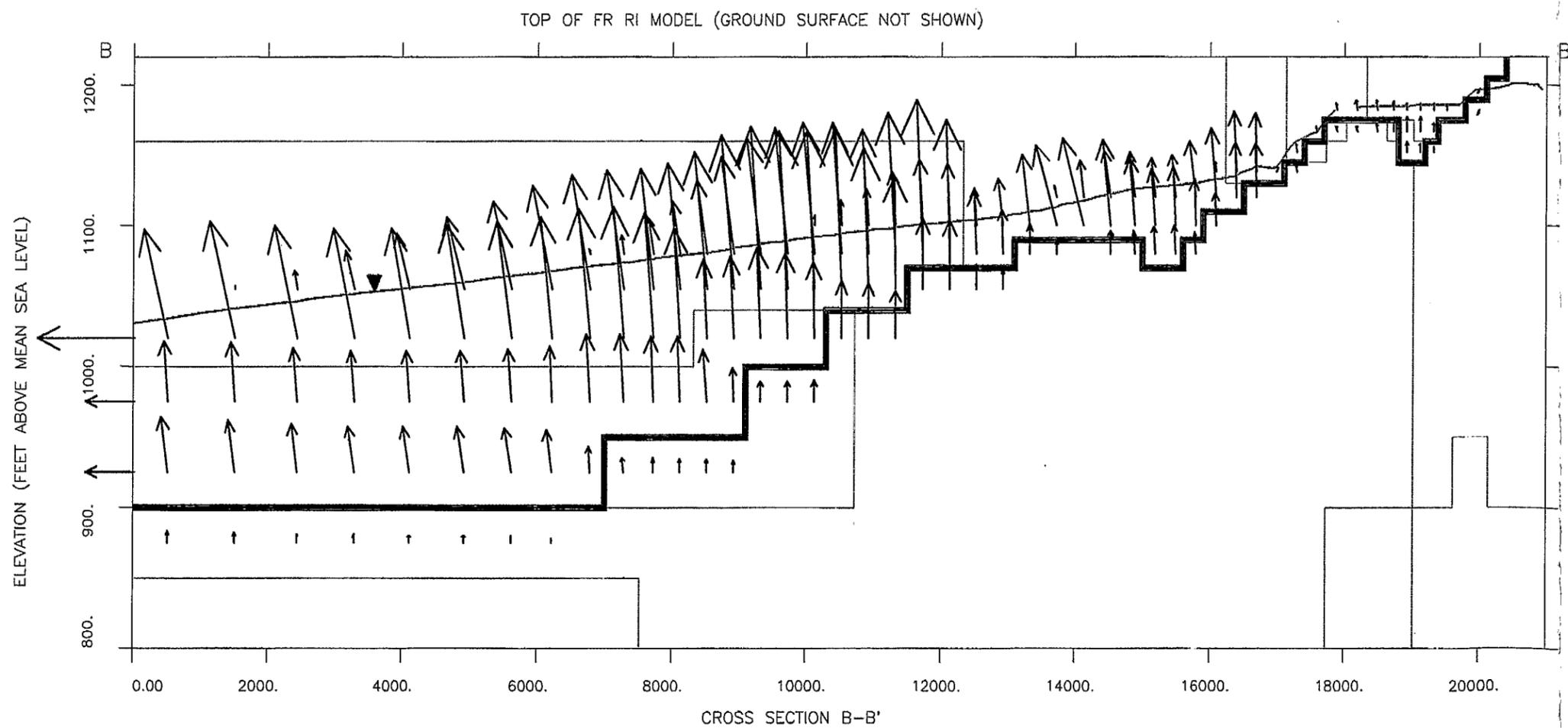
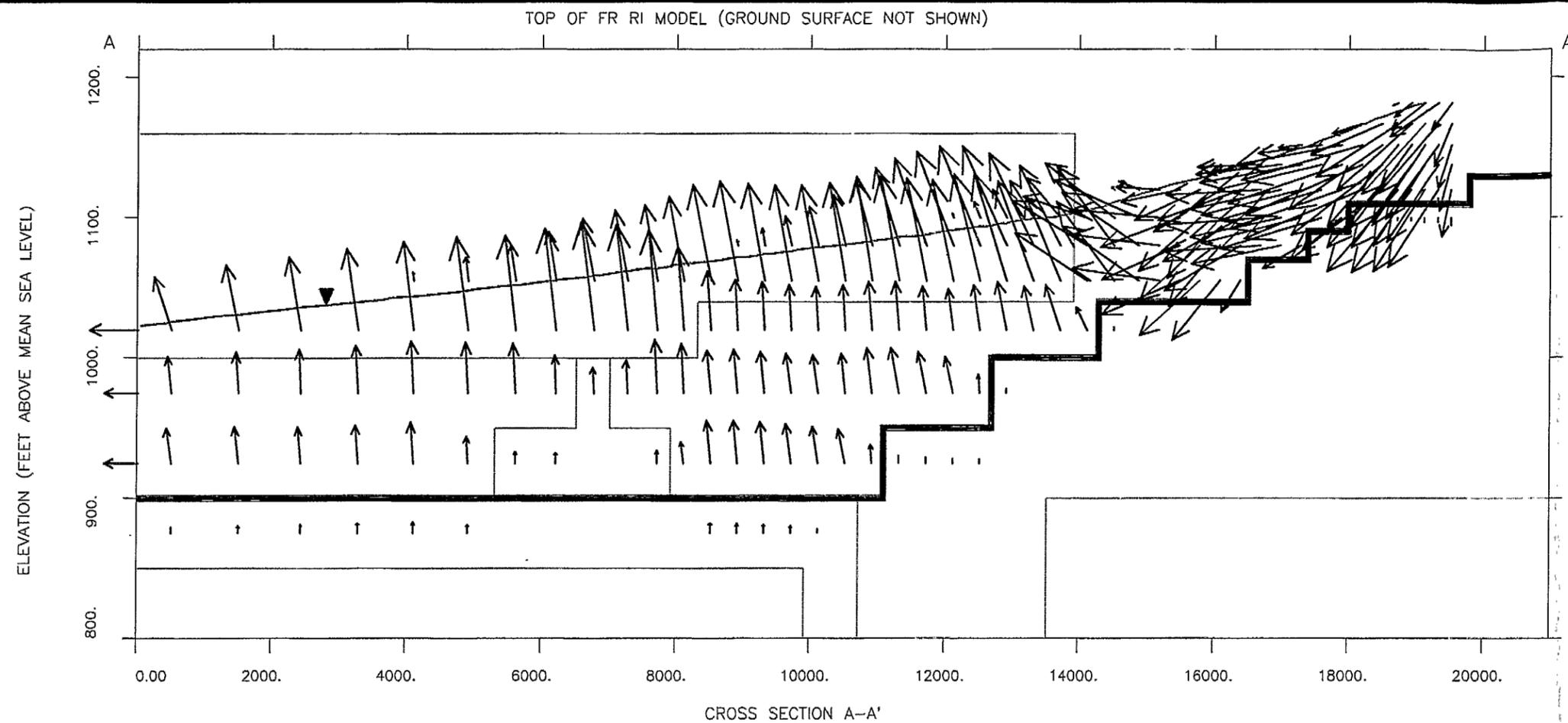
**LEGEND:**

WELL TYPE	EXISTING	ABANDONED
WESTBAY	▲	△
CONVENTIONAL	●	○
MP	■	□
PRIVATE	◆	◇
DM 124	NAME OF WELL	
● 1130	MEASURED ELEVATION OF TOP OF BEDROCK (FEET ABOVE MEAN SEA LEVEL)	
—1000.—	SIMULATED BEDROCK ELEVATION CONTOUR (FEET ABOVE MEAN SEA LEVEL)	

**EXTRAPOLATED  
BEDROCK  
TOPOGRAPHY**

Figure 6.6  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992





**LEGEND:**

▼ PREDICTED WATER TABLE (JUNE 1991)

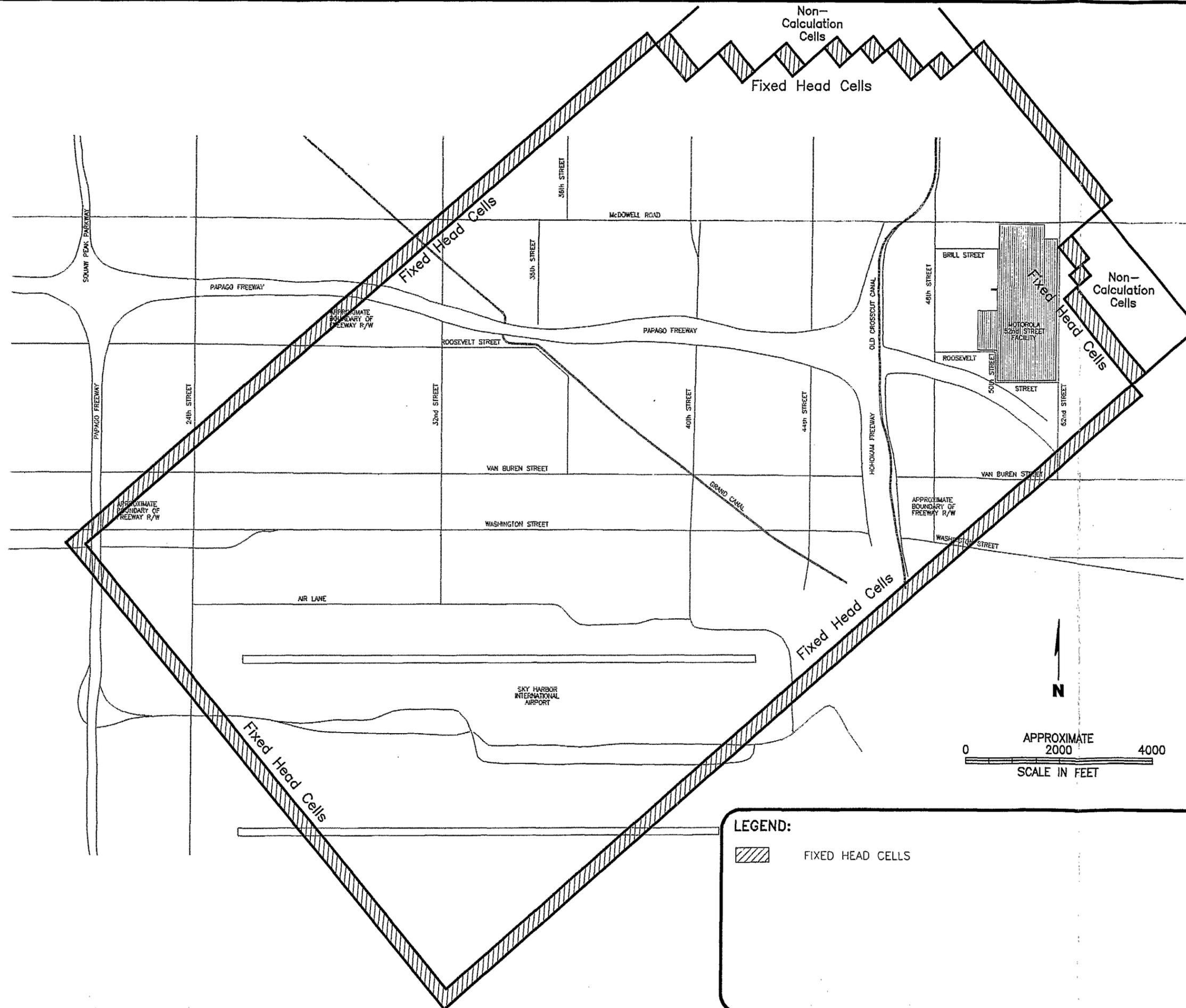
— BEDROCK/ALLUVIUM INTERFACE

← VELOCITY VECTORS REPRESENTING FLOW DIRECTION AND VELOCITY. =0.8 FEET/DAY

- NOTES:** 1. Locations of cross-sections shown on Figure 6.4.  
2. Vertical exaggeration = 20.

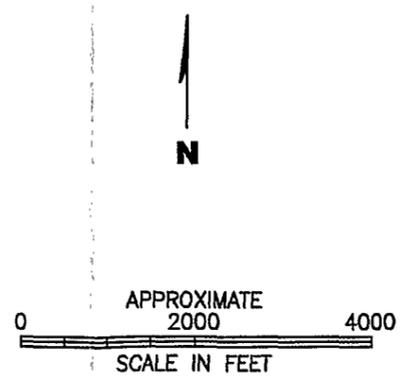
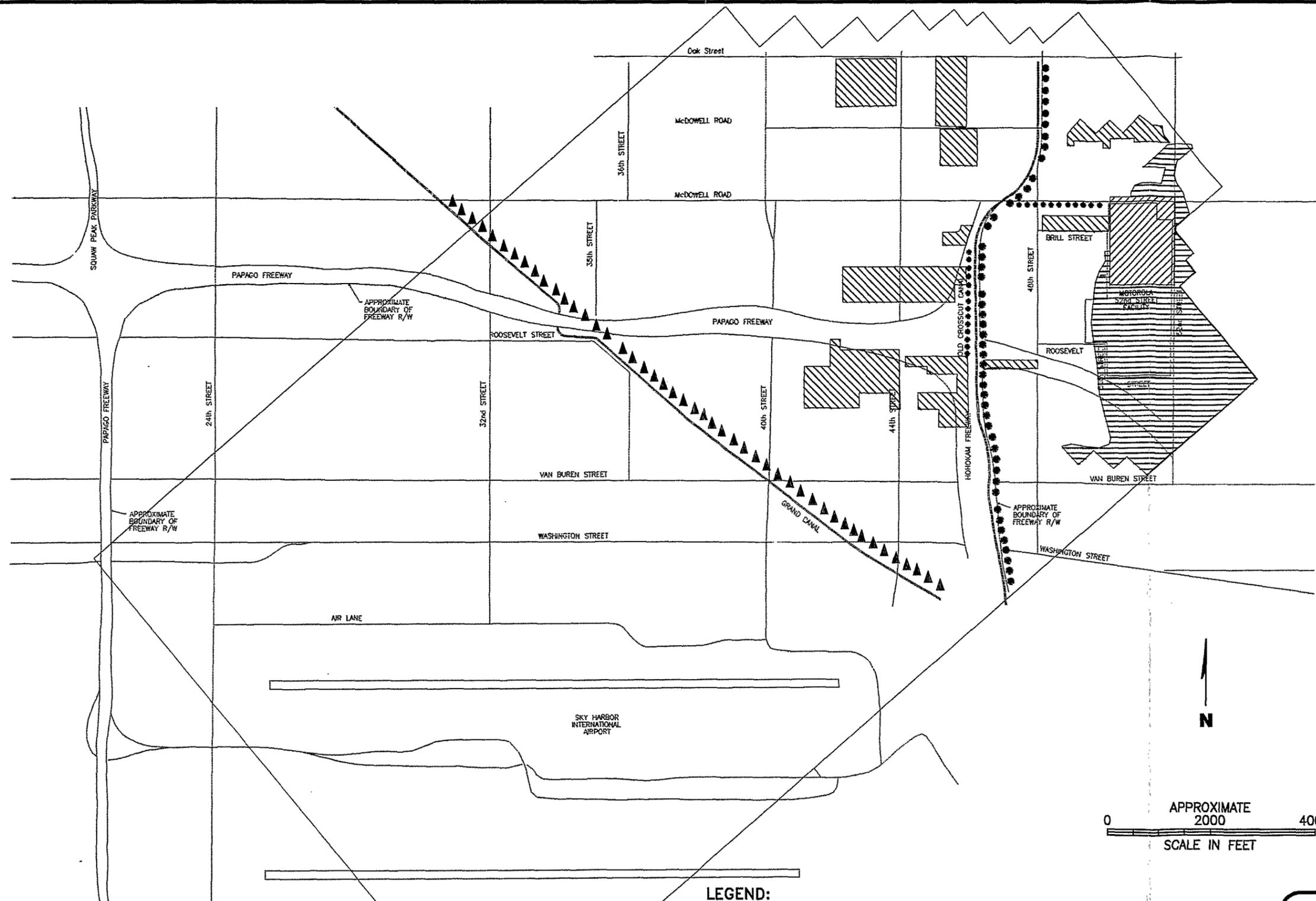
**VERTICAL  
CROSS-SECTION  
VELOCITY  
VECTORS**

**Figure 6.8**  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992



## BOUNDARY CONDITIONS

Figure 6.9  
 MOTOROLA 52nd ST.  
 FR RI  
 FEBRUARY 1992



**LEGEND:**

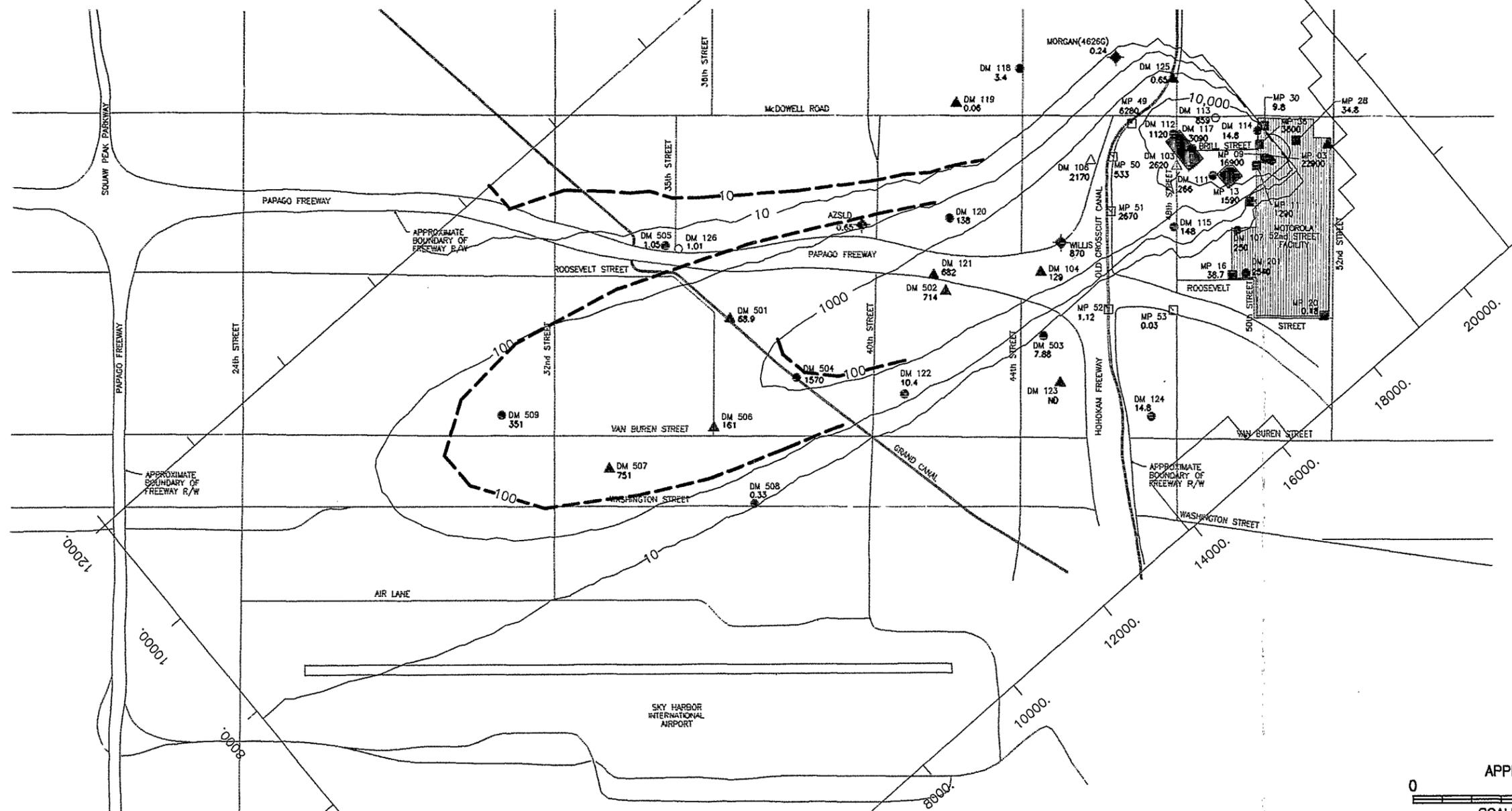
- RECHARGE FROM FLOOD IRRIGATION OF LAWNS (80 ACRE-FEET/YEAR)
- RECHARGE FROM THE CROSSCUT CANAL (39 ACRE-FEET/YEAR)
- RECHARGE FROM LATERALS (4 ACRE-FEET/YEAR)
- RECHARGE FROM MOTOROLA FACILITY SOURCES (41 ACRE-FEET/YEAR)
- RECHARGE FROM NATURAL PRECIPITATION AND RUNOFF (99 ACRE-FEET/YEAR)
- RECHARGE FROM THE GRAND CANAL (91 ACRE-FEET/YEAR)

**NOTES:**

1. Recharge amounts are estimates for calculation domain of ground-water model for 1991.
2. For purpose of ground-water modeling, recharge is assumed to occur uniformly over indicated areas.

**GROUND-WATER RECHARGE AREAS**

Figure 6.10  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992



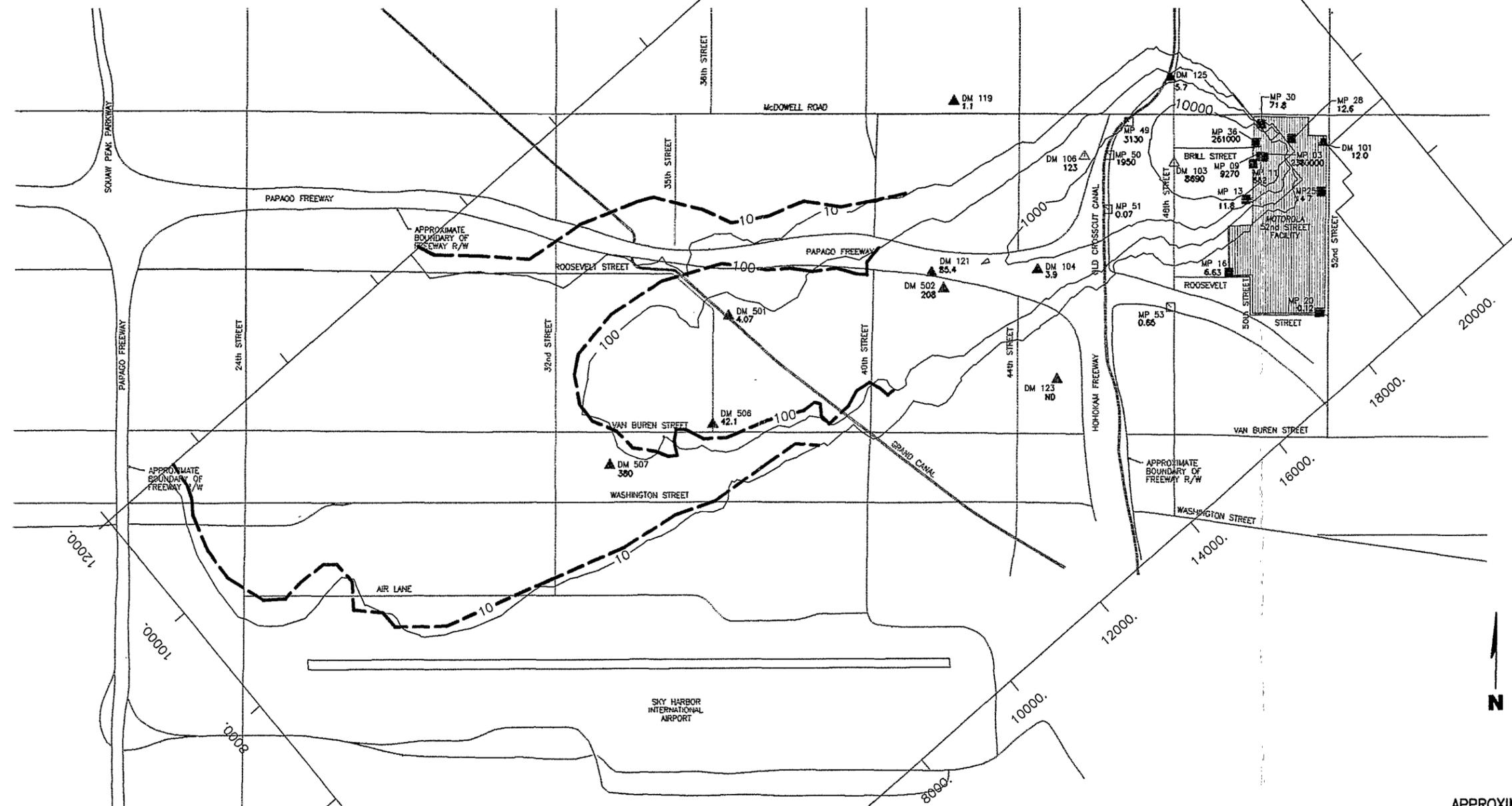
**LEGEND:**

- 14.8 OBSERVED MAXIMUM MEAN (POST RI) SUM OF TCE, DCE AND TDCE CONCENTRATIONS (in ppb)
- 10— PREDICTED TCE CONCENTRATION in ppb (JUNE 1991) Run 24
- - -10- - - PREDICTED TCE CONCENTRATION in ppb (JUNE 1991) Run 25
- ◆ INDICATES DRY ALLUVIUM
- DM 124 NAME OF WELL

WELL TYPE	EXISTING	ABANDONED
WESTBAY	▲	△
CONVENTIONAL	●	○
MP	■	□
PRIVATE	◆	◇

**NOTE:**  
 Run 24 used Grand Canal Recharge estimated for draft 1987 RI Model  
 Run 25 used ADWR estimates of Grand Canal Recharge for unlined (1962-1988) and lined (1988-1991) canal infiltration rates.

**GRAND CANAL RECHARGE RATE SENSITIVITY TEST RESULTS; COMPARISON OF MODEL RUNS 24 AND 25 1991-ALLUVIUM**  
 Figure 6.11  
 MOTOROLA 52nd ST.  
 FR RI  
 FEBRUARY 1992



**LEGEND:**

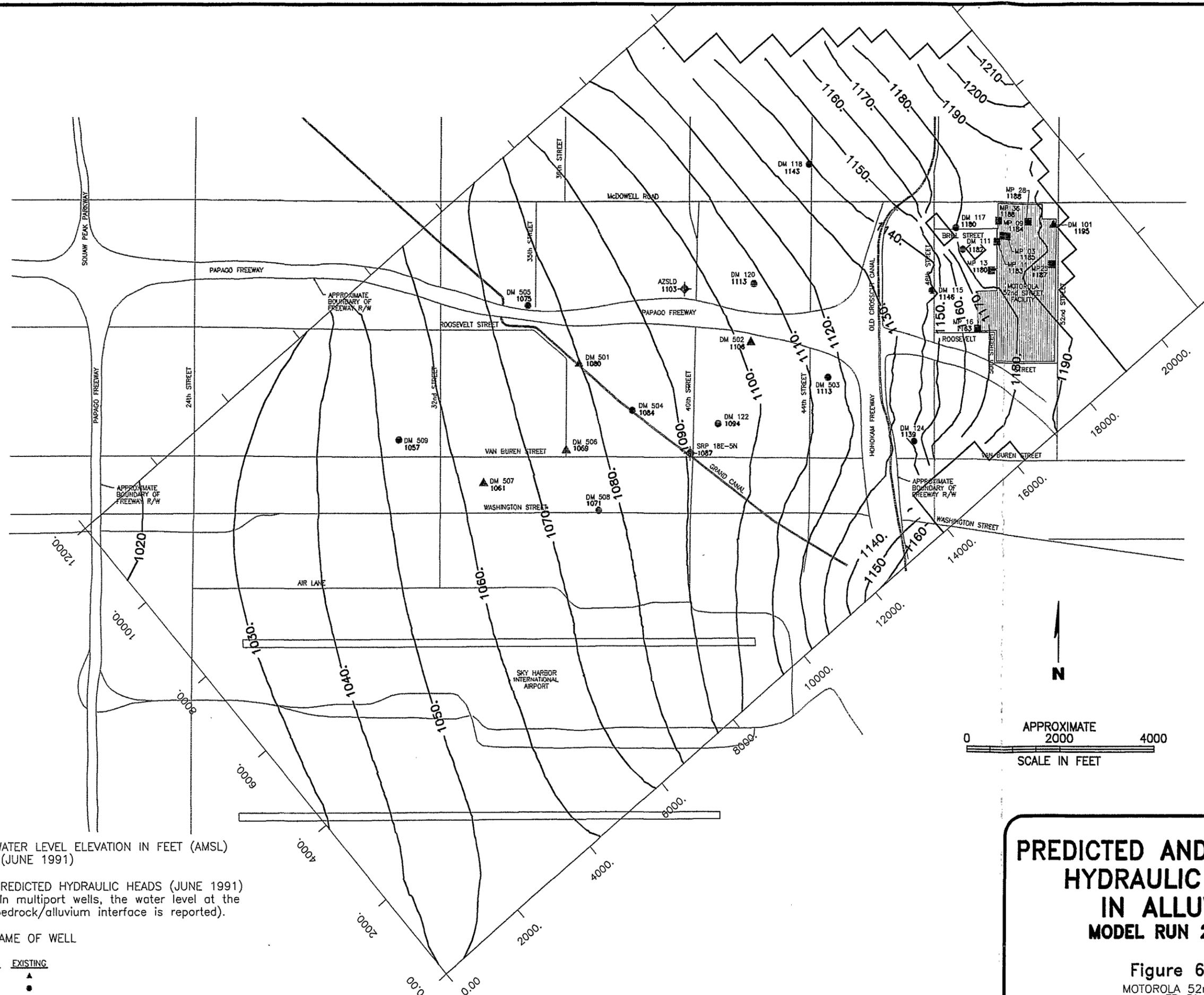
● 380 OBSERVED MAXIMUM MEAN (POST RI) SUM OF TCE, DCE AND TDCE CONCENTRATIONS (in ppb)  
 ND NOT DETECTED

—10— PREDICTED TCE CONCENTRATION in ppb (JUNE 1991) Run 24  
 - - -10 - - - PREDICTED TCE CONCENTRATION in ppb (JUNE 1991) Run 25

DM 507	NAME OF WELL	EXISTING	ABANDONED
▲	WESTBAY	▲	△
●	CONVENTIONAL	●	○
■	MP	■	□
◆	PRIVATE	◆	◇

**NOTE:**  
 Run 24 used Grand Canal Recharge estimated for 1987 draft RI Model  
 Run 25 used ADWR estimates of Grand Canal Recharge for unlined (1962-1988) and lined (1988-1991) canal infiltration rates.

**GRAND CANAL RECHARGE RATE SENSITIVITY TEST RESULTS; COMPARISON OF MODEL RUNS 24 AND 25 1991-BEDROCK**  
 Figure 6.12  
 MOTOROLA 52nd ST. FR RI  
 FEBRUARY 1992

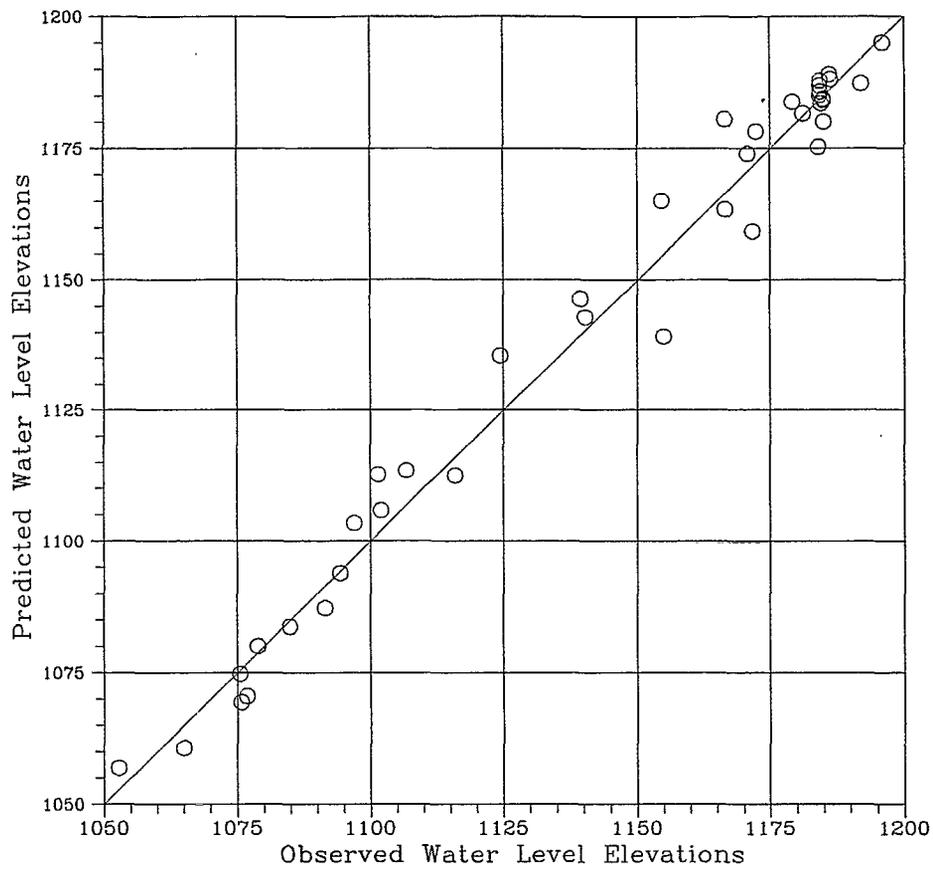


**LEGEND:**

- 714 WATER LEVEL ELEVATION IN FEET (AMSL)  
(JUNE 1991)
  - 1020— PREDICTED HYDRAULIC HEADS (JUNE 1991)  
(In multiport wells, the water level at the  
bedrock/alluvium interface is reported).
  - DM 503 NAME OF WELL
- | WELL TYPE    | EXISTING |
|--------------|----------|
| WESTBAY      | ▲        |
| CONVENTIONAL | ●        |
| MP           | ■        |
| PRIVATE      | ◆        |

**PREDICTED AND OBSERVED  
HYDRAULIC HEADS  
IN ALLUVIUM  
MODEL RUN 24-1991**

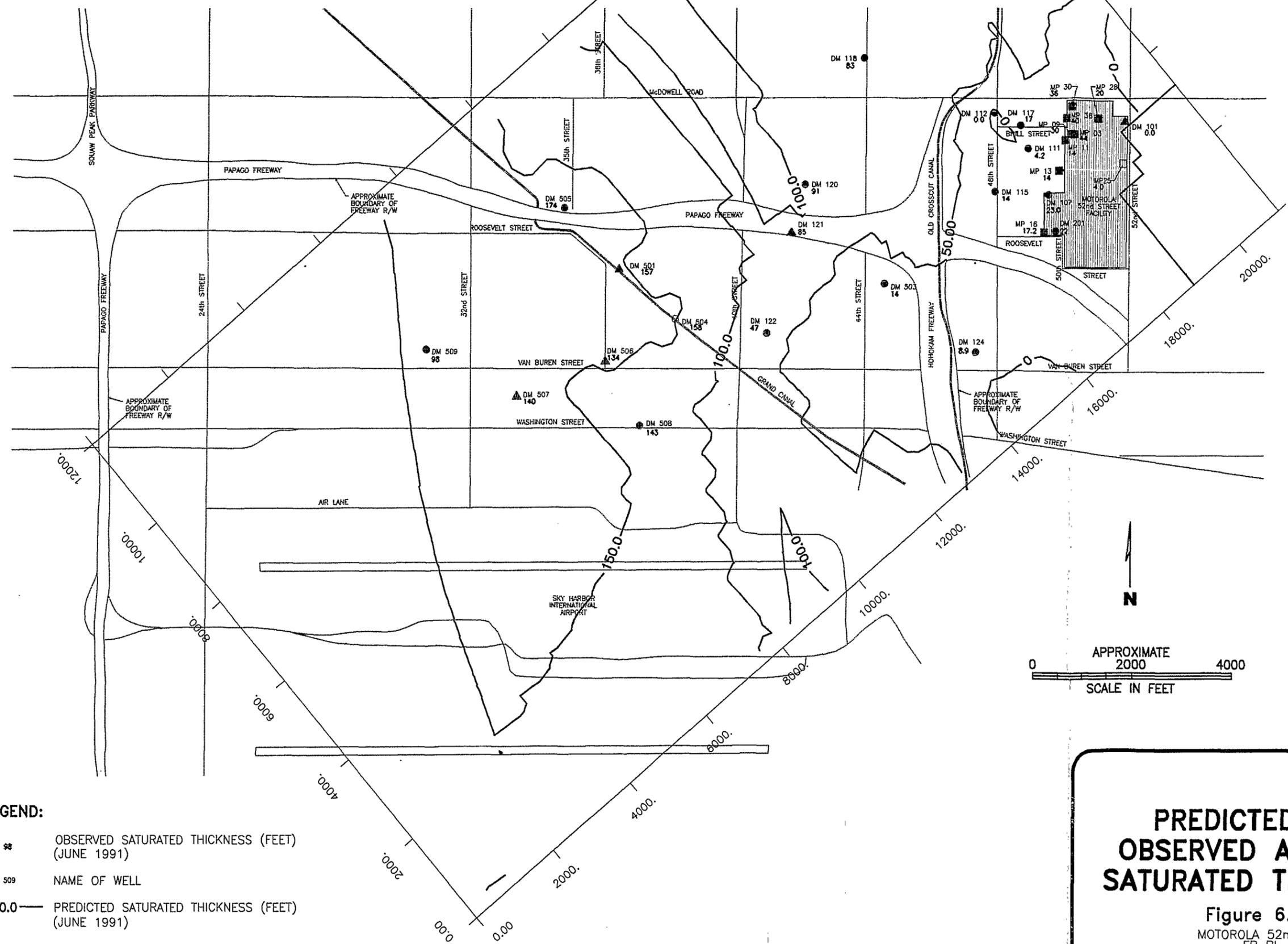
Figure 6.13  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992



**NOTE:**  
 Observed water levels measured in June 1991.  
 See Appendix G.

**PREDICTED VS. OBSERVED  
 WATER LEVEL ELEVATIONS:  
 TRANSPORT RUN 24**

**Figure 6.14**  
 MOTOROLA 52nd ST.  
 FR RI  
 FEBRUARY 1992



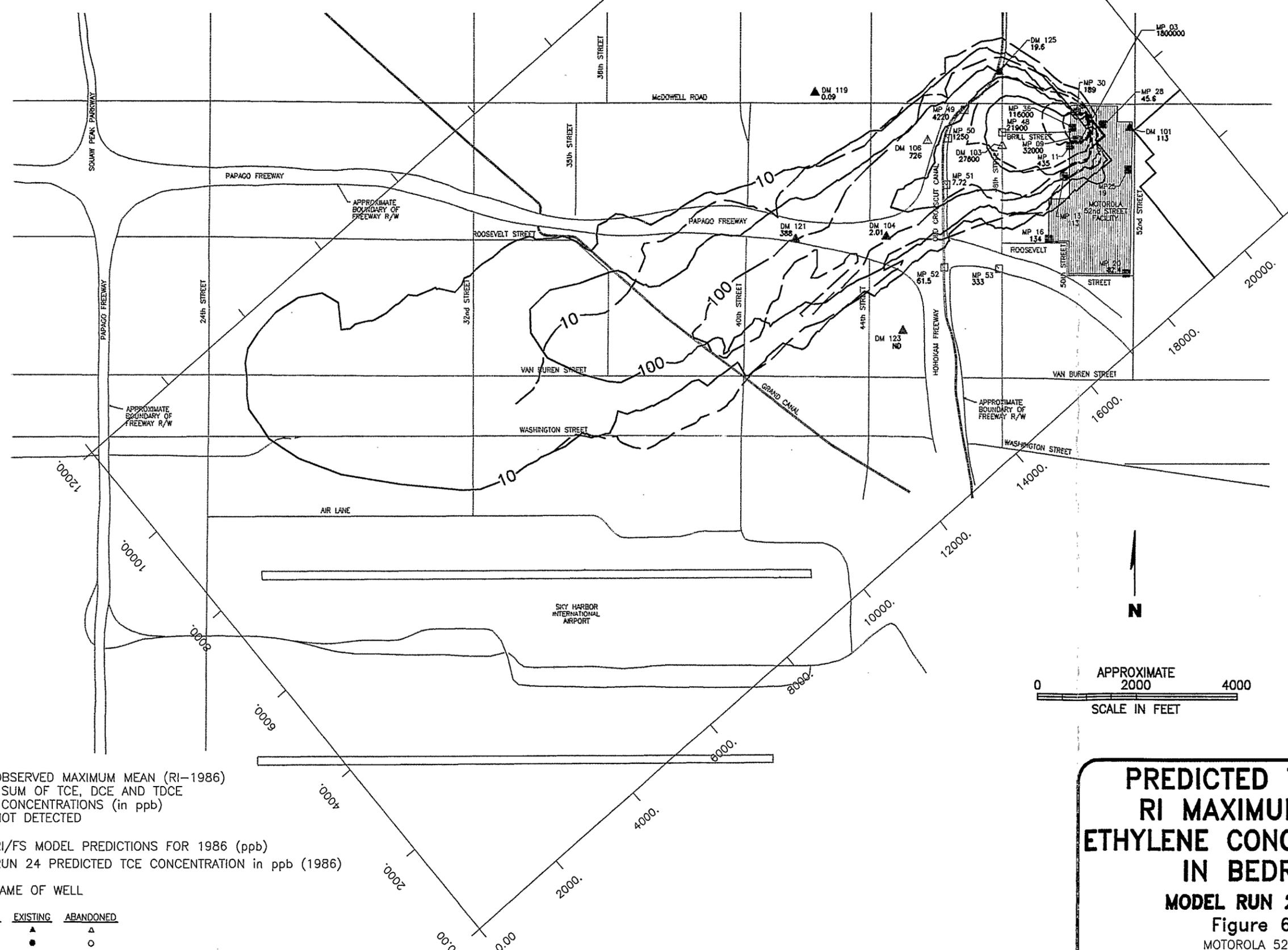
**LEGEND:**

- \* OBSERVED SATURATED THICKNESS (FEET)  
(JUNE 1991)
- DM 509 NAME OF WELL
- 100.0— PREDICTED SATURATED THICKNESS (FEET)  
(JUNE 1991)

**PREDICTED AND  
OBSERVED ALLUVIUM  
SATURATED THICKNESS**

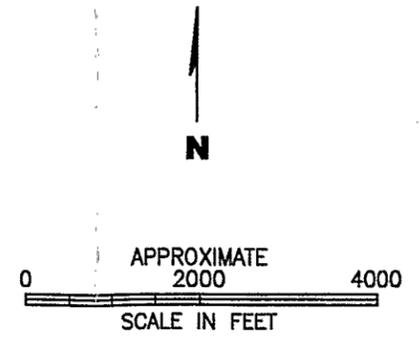
Figure 6.15  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992



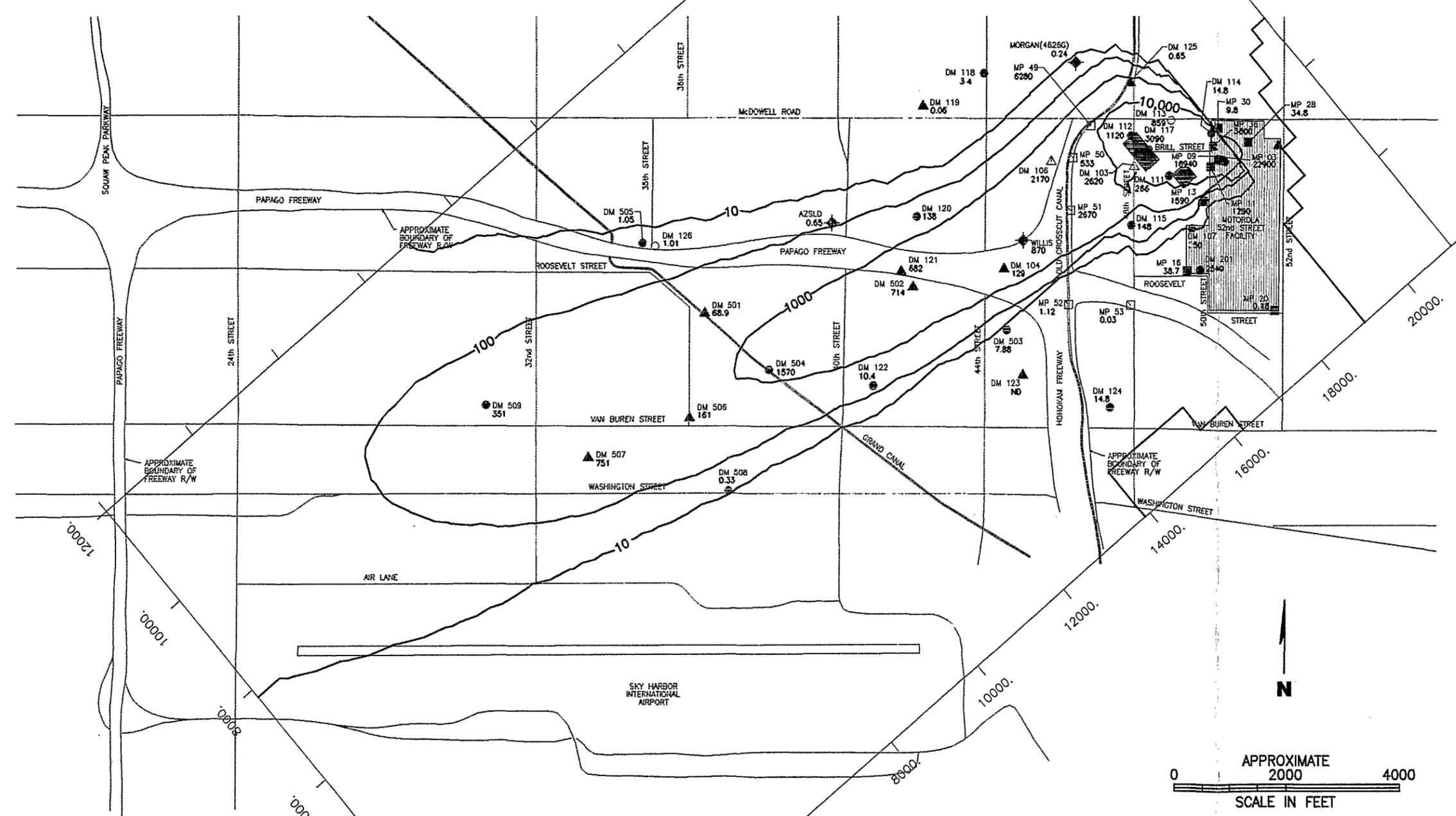


**LEGEND:**

- 388 OBSERVED MAXIMUM MEAN (RI-1986) SUM OF TCE, DCE AND TDCE CONCENTRATIONS (in ppb)
  - no NOT DETECTED
  - 10--- RI/FS MODEL PREDICTIONS FOR 1986 (ppb)
  - 10— RUN 24 PREDICTED TCE CONCENTRATION in ppb (1986)
  - DM 121 NAME OF WELL
- | WELL TYPE    | EXISTING | ABANDONED |
|--------------|----------|-----------|
| WESTBAY      | ▲        | △         |
| CONVENTIONAL | ●        | ○         |
| MP           | ■        | □         |
| PRIVATE      | ◆        | ◇         |



**PREDICTED TCE AND  
 RI MAXIMUM MEAN  
 ETHYLENE CONCENTRATIONS  
 IN BEDROCK**  
**MODEL RUN 24-1986**  
 Figure 6.17  
 MOTOROLA 52nd ST.  
 FR RI  
 FEBRUARY 1992



**LEGEND:**

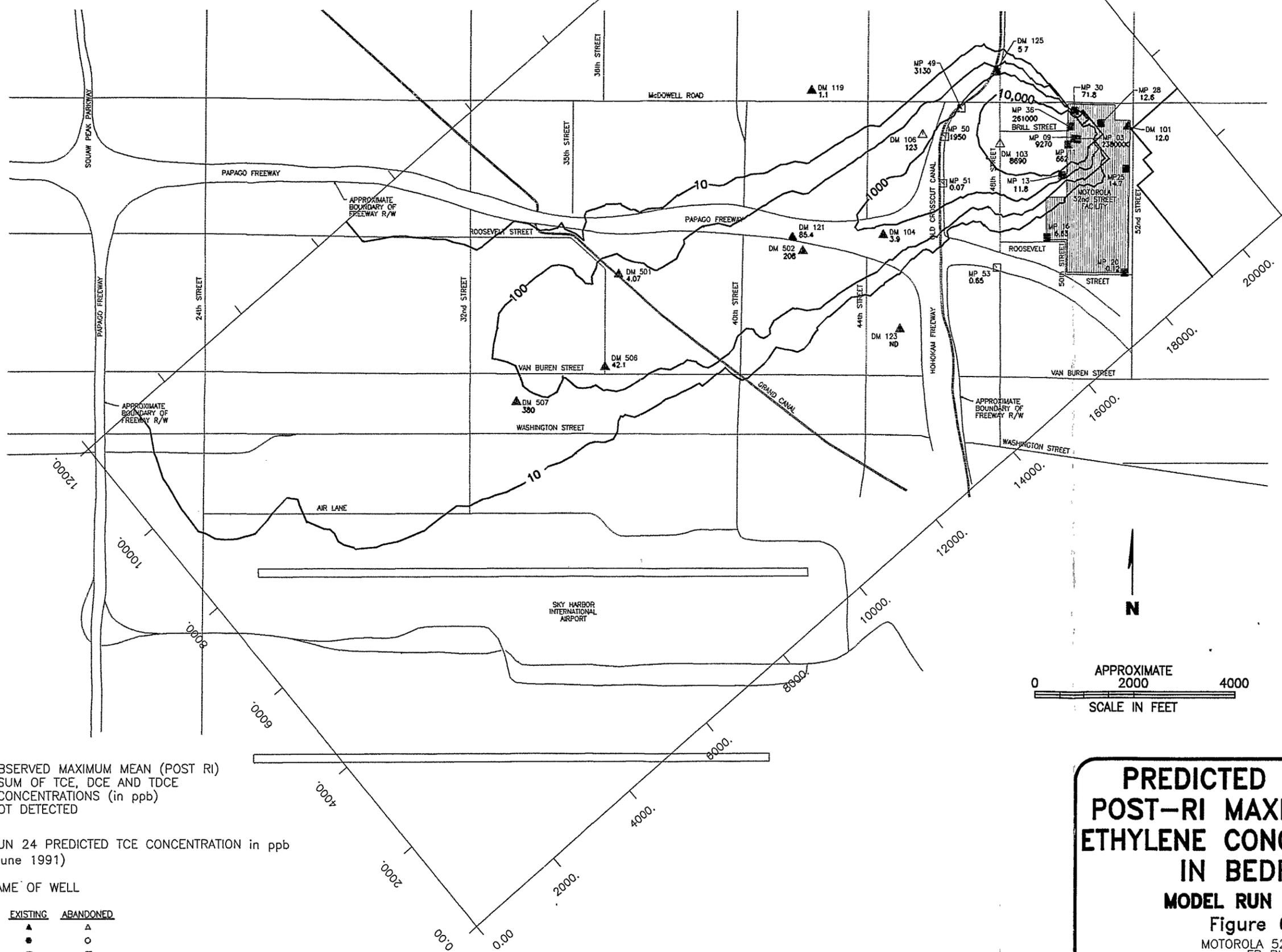
- 14.8 OBSERVED MAXIMUM MEAN (POST RI) SUM OF TCE, DCE AND TDCE CONCENTRATIONS (in ppb)
- ND NOT DETECTED
- 10— PREDICTED TCE CONCENTRATION in ppb (JUNE 1991)
- ◆ INDICATES DRY ALLUVIUM
- DM 114 NAME OF WELL

WELL TYPE	EXISTING	ABANDONED
WESTBAY	▲	△
CONVENTIONAL	●	○
MP	■	□
PRIVATE	◆	◇

**PREDICTED TCE AND  
POST-RI MAXIMUM MEAN  
ETHYLENE CONCENTRATIONS  
IN ALLUVIUM**

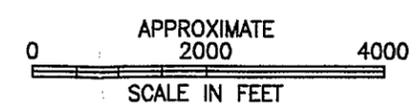
**MODEL RUN 24-1991**

Figure 6.18  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992

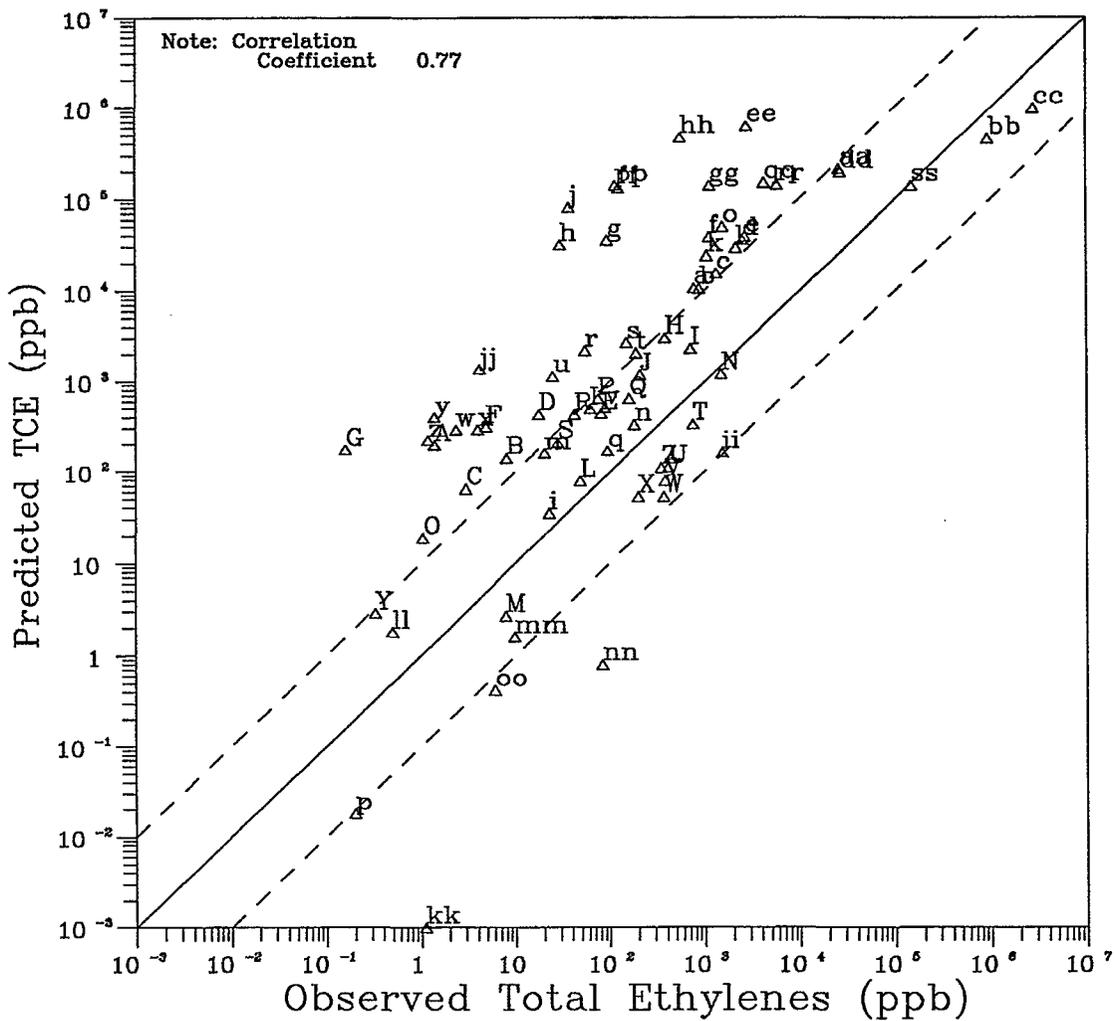


**LEGEND:**

- 1.1 OBSERVED MAXIMUM MEAN (POST RI) SUM OF TCE, DCE AND TDCE CONCENTRATIONS (in ppb)
  - NO NOT DETECTED
  - 10— RUN 24 PREDICTED TCE CONCENTRATION in ppb (June 1991)
  - DM 119 NAME OF WELL
- | WELL TYPE            | EXISTING | ABANDONED |
|----------------------|----------|-----------|
| WESTBAY CONVENTIONAL | ▲        | △         |
| MP                   | ●        | ○         |
| PRIVATE              | ◆        | ◇         |



**PREDICTED TCE AND  
POST-RI MAXIMUM MEAN  
ETHYLENE CONCENTRATIONS  
IN BEDROCK**  
**MODEL RUN 24-1991**  
 Figure 6.19  
 MOTOROLA 52nd ST.  
 FR RI  
 FEBRUARY 1992



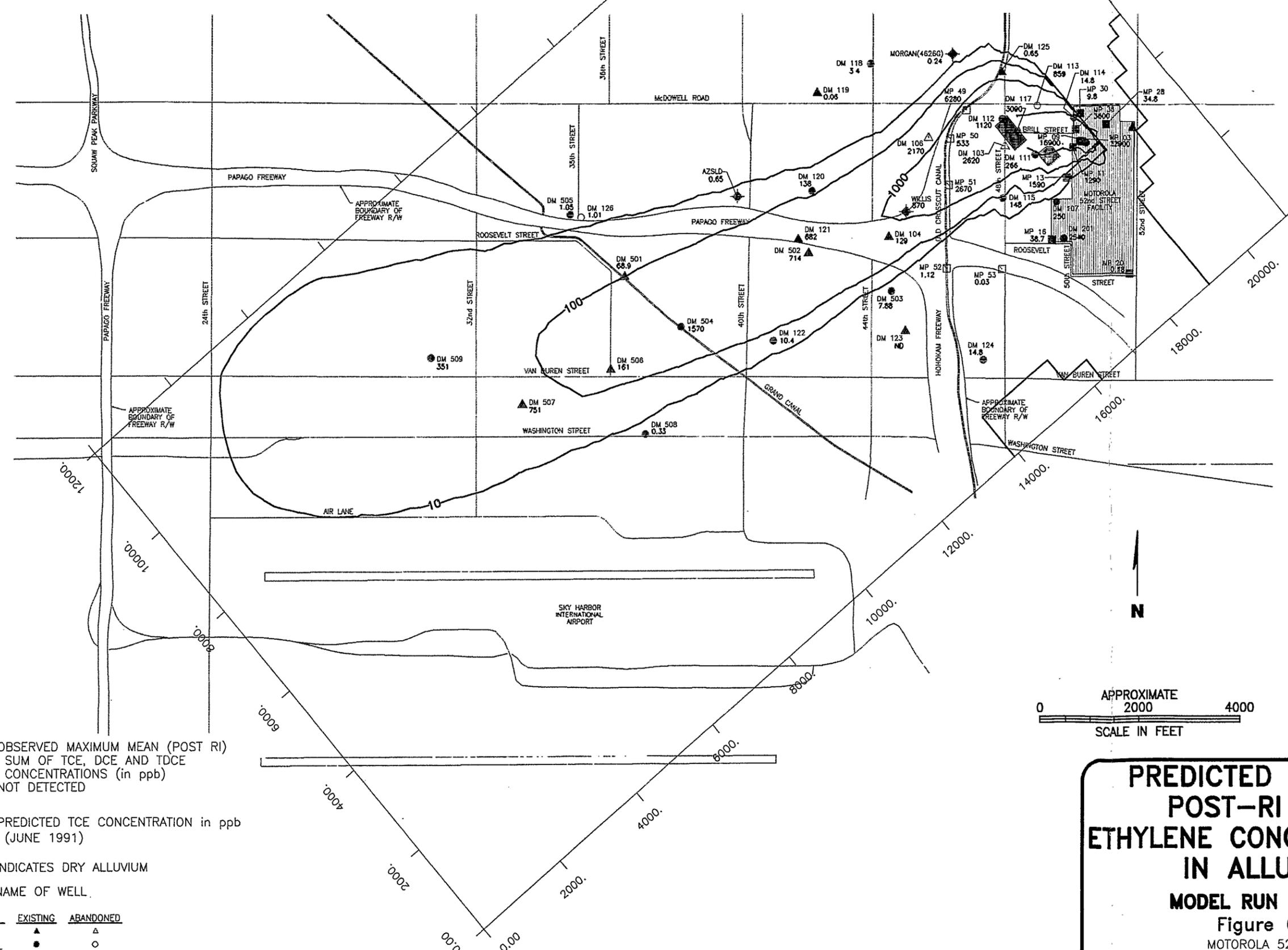
Predicted - TCE in ppb  
 Observed - Sum of TCE+TDCE+DCE in ppb (1991 mean or more recent data)

a - DM103-032	l - DM113	w - DM122-A	H - DM502-079	S - DM506-305	dd - MP09-A	pp - MP36-A
b - DM103-047	m - DM114	x - DM122-B	I - DM502-119	T - DM507-084	ee - MP09-C	qq - MP36-B
c - DM103-064	n - DM115	y - DM125-076	J - DM502-161	U - DM507-188	ff - MP11-A	rr - MP36-C
d - DM103-123	o - DM117	z - DM125-125	K - DM502-240	V - DM507-240	gg - MP11-B	ss - MP36-D
e - DM103-178	p - DM118	A - DM125-155	L - DM502-335	W - DM507-280	hh - MP11-C	
f - DM103-223	q - DM120	B - DM125-185	M - DM503	X - DM507-315	ii - MP13-B	
g - DM103-269	r - DM121-043	C - DM125-270	N - DM504	Y - DM508	jj - MP13-C	
h - DM103-324	s - DM121-084	D - DM501-147	O - DM505	Z - DM509	ll - MP30-A	
i - DM107	t - DM121-125	E - DM501-202	P - DM506-100	aa - MP03-B	mm - MP30-B	
j - DM111	u - DM121-159	F - DM501-267	Q - DM506-185	bb - MP03-C	nn - MP30-C	
k - DM112	v - DM121-219	G - DM501-331	R - DM506-240	cc - MP03-D	oo - MP30-D	

**NOTE:**  
 Observed total ethylene concentrations  
 in Appendix E.

## PREDICTED VS. OBSERVED ETHYLENE CONCENTRATIONS TRANSPORT RUN 24

Figure 6.20  
 MOTOROLA 52nd ST.  
 FR RI  
 FEBRUARY 1992

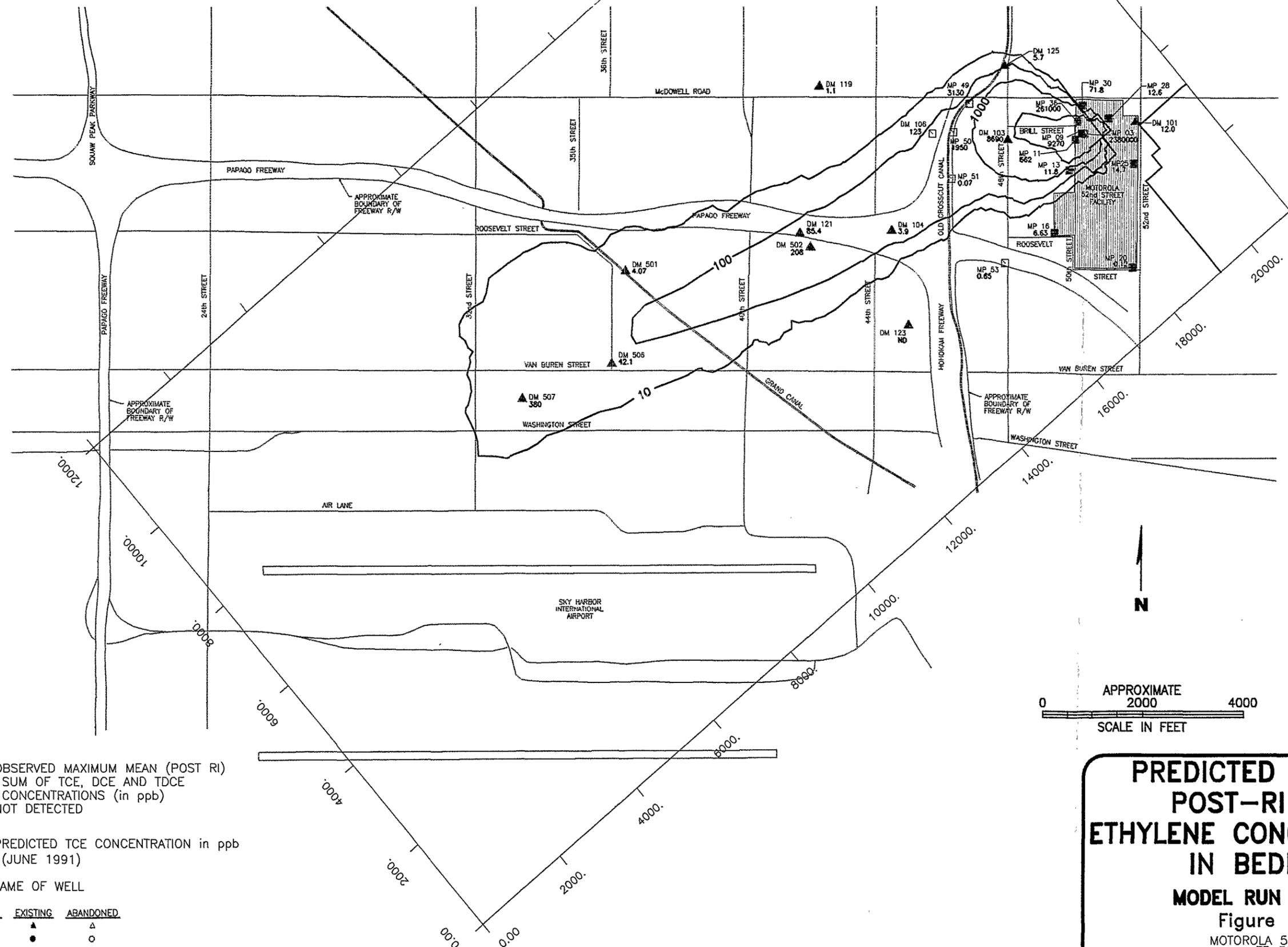


**LEGEND:**

- 14.8 OBSERVED MAXIMUM MEAN (POST RI) SUM OF TCE, DCE AND TDCE CONCENTRATIONS (in ppb)
- ND NOT DETECTED
- 10— PREDICTED TCE CONCENTRATION in ppb (JUNE 1991)
- ◆ INDICATES DRY ALLUVIUM
- DM 124 NAME OF WELL

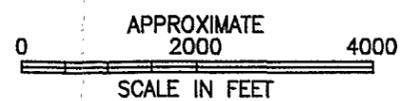
WELL TYPE	EXISTING	ABANDONED
WESTBAY	▲	△
CONVENTIONAL	●	○
MP	■	□
PRIVATE	◆	◇

**PREDICTED TCE AND  
 POST-RI MEAN  
 ETHYLENE CONCENTRATIONS  
 IN ALLUVIUM**  
**MODEL RUN 23-1991**  
 Figure 6.21  
 MOTOROLA 52nd ST.  
 FR RI  
 FEBRUARY 1992



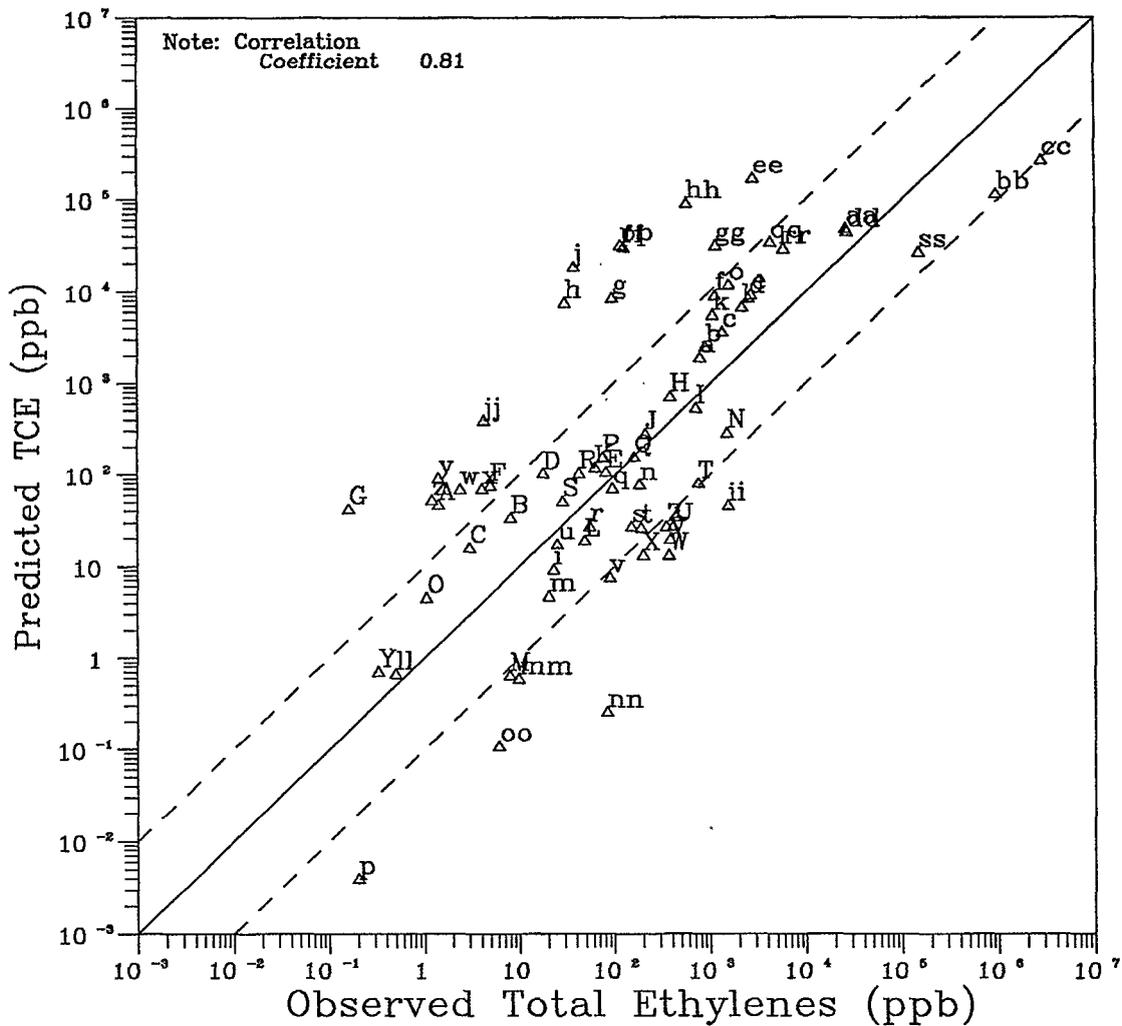
**LEGEND:**

- 380 OBSERVED MAXIMUM MEAN (POST RI) SUM OF TCE, DCE AND TDCE CONCENTRATIONS (in ppb)
  - ND NOT DETECTED
  - 10— PREDICTED TCE CONCENTRATION in ppb (JUNE 1991)
  - DM 507 NAME OF WELL
- | WELL TYPE    | EXISTING | ABANDONED |
|--------------|----------|-----------|
| WESTBAY      | ▲        | △         |
| CONVENTIONAL | ●        | ○         |
| MP           | ■        | □         |
| PRIVATE      | ◆        | ◇         |



**PREDICTED TCE AND  
POST-RI MEAN  
ETHYLENE CONCENTRATIONS  
IN BEDROCK**

**MODEL RUN 23-1991**  
Figure 6.22  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992



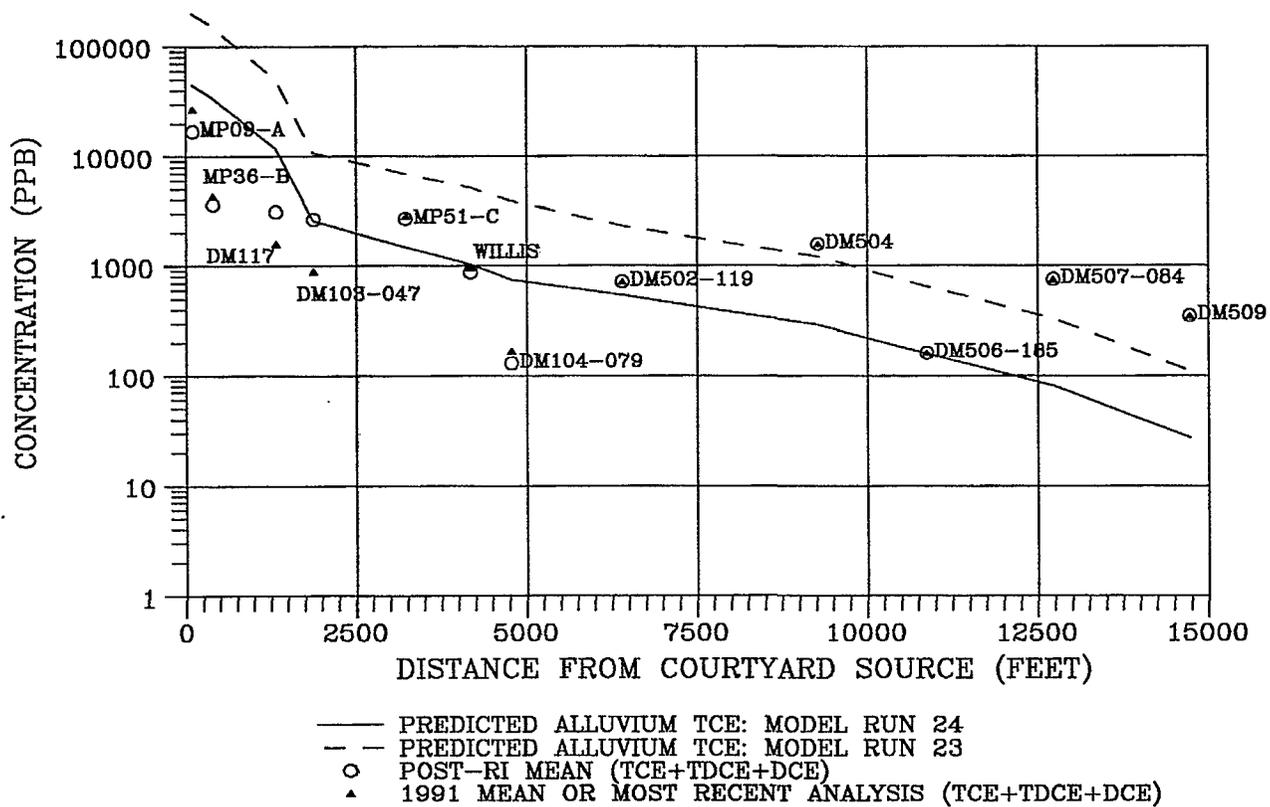
Predicted - TCE in ppb  
 Observed - Sum of TCE+TDCE+DCE in ppb (1991 mean or more recent data)

a - DM103-032	l - DM113	w - DM122-A	H - DM502-079	S - DM506-305	dd - MP09-A	oo - MP30-D
b - DM103-047	m - DM114	x - DM122-B	I - DM502-119	T - DM507-084	ee - MP09-C	pp - MP36-A
c - DM103-064	n - DM115	y - DM125-076	J - DM502-161	U - DM507-188	ff - MP11-A	qq - MP36-B
d - DM103-123	o - DM117	z - DM125-125	K - DM502-240	V - DM507-240	gg - MP11-B	rr - MP36-C
e - DM103-178	p - DM118	A - DM125-155	L - DM502-335	W - DM507-280	hh - MP11-C	ss - MP36-D
f - DM103-223	q - DM120	B - DM125-185	M - DM503	X - DM507-315	ii - MP13-B	
g - DM103-269	r - DM121-043	C - DM125-270	N - DM504	Y - DM508	jj - MP13-C	
h - DM103-324	s - DM121-084	D - DM501-147	O - DM505	Z - DM509	kk - MP28-D	
i - DM107	t - DM121-125	E - DM501-202	P - DM506-100	aa - MP03-B	ll - MP30-A	
j - DM111	u - DM121-159	F - DM501-267	Q - DM506-185	bb - MP03-C	mm - MP30-B	
k - DM112	v - DM121-219	G - DM501-331	R - DM506-240	cc - MP03-D	nn - MP30-C	

**NOTE:**  
 Observed total ethylene concentrations  
 in Appendix E.

## PREDICTED VS. OBSERVED ETHYLENE CONCENTRATIONS TRANSPORT RUN 23

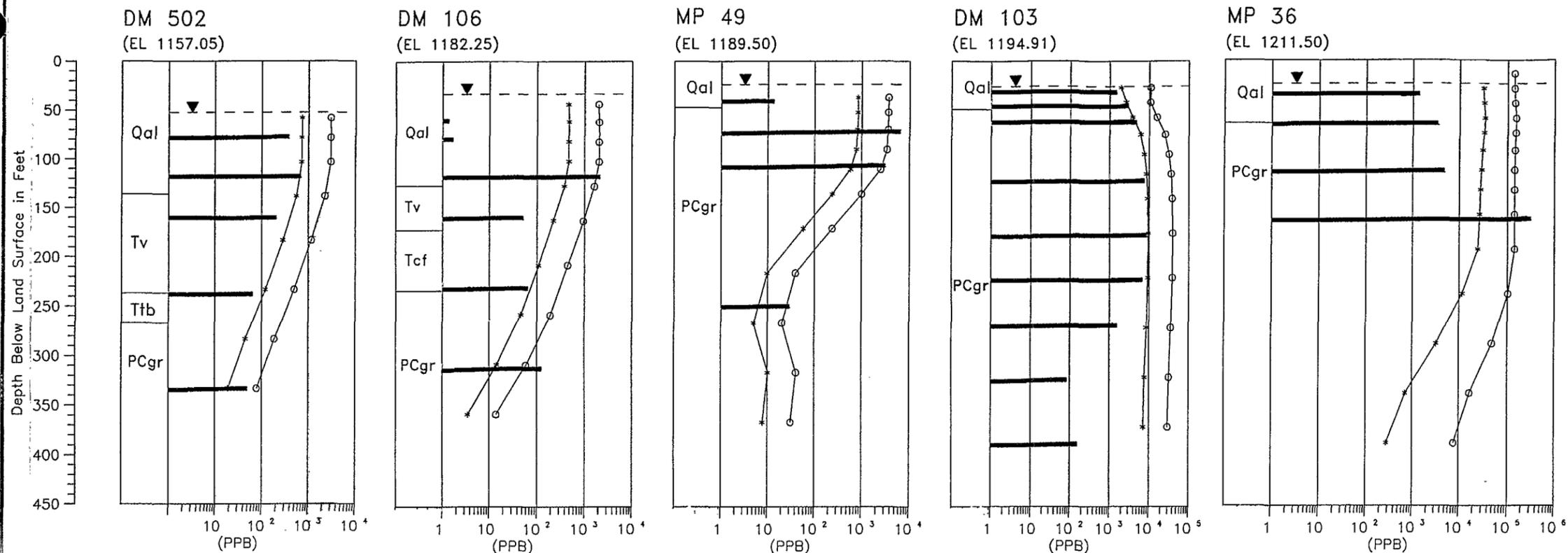
Figure 6.23  
 MOTOROLA 52nd ST.  
 FR RI  
 FEBRUARY 1992



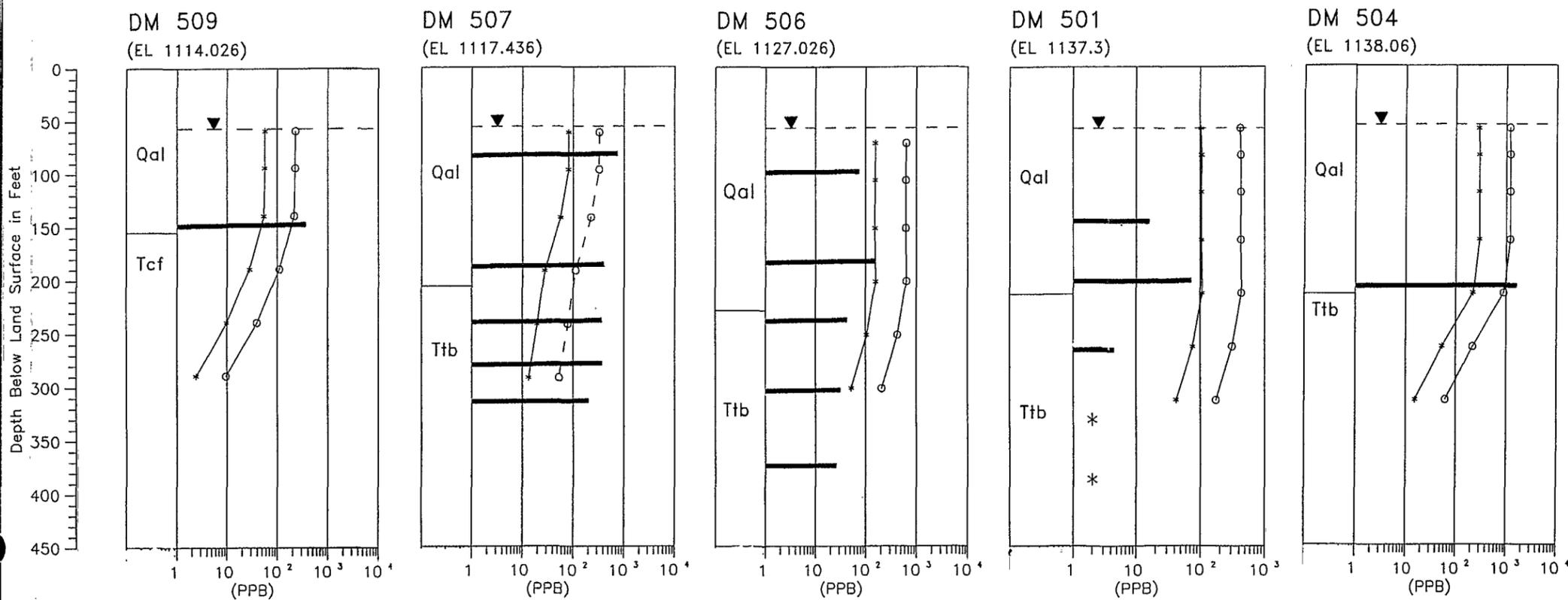
**PREDICTED AND OBSERVED  
ETHYLENE CONCENTRATIONS  
VS. DISTANCE FROM SOURCE**

**Figure 6.24**  
 MOTOROLA 52nd ST.  
 FR RI  
 FEBRUARY 1992

← DOWN GRADIENT DIRECTION



← DOWN GRADIENT DIRECTION



**LEGEND:**

- \* LESS THAN 1 PPB
- \*— PREDICTED TCE CONCENTRATION: RUN 23
- PREDICTED TCE CONCENTRATION: RUN 24
- ▼ WATER LEVEL ELEVATION (6 / 91)
- MEAN POST-RI ETHYLENE (TCE + TDCE + DCE) CONCENTRATION (LENGTH OF LINE)

**NOTES:**

REFER TO CROSS-SECTIONS  
IN CHAPTER 2  
DATA PRESENTED IN  
APPENDIX E6  
ELEVATIONS IN FEET ABOVE  
MEAN SEA LEVEL

**PREDICTED AND OBSERVED  
VERTICAL DISTRIBUTION OF  
ETHYLENES**

**Figure 6.25**  
MOTOROLA 52nd ST.  
FR RI  
FEBRUARY 1992

## 7.0 SUMMARY AND CONCLUSIONS

A Draft RI/FS Report was presented in 1987 that lead to a Draft Remedial Action Plan and formed the basis for a Consent Order between Motorola Inc. and the State of Arizona in 1989. The Motorola 52nd St. Consent Order includes provisions for implementation of an Operable Unit under the State's WQARF program, plus continued investigation of the extent of contaminant migration in ground water. This report contains the results of the Final Remedy Remedial Investigation. This chapter provides an overview of the conclusions reached in this investigation.

As shown on Figure 7.1, the series 500 monitor wells were installed downgradient of the Motorola 52nd St. Facility. Well DM 509 is located west of 32nd St., over 2.5 miles downgradient of the 52nd St. Facility. Model predications indicate potential VOC contamination of ground water as far west as 24th Street. Although new monitor wells have not been installed this far downgradient, the data from the 500 series wells are judged sufficient to calibrate against model predictions in this general area. As pointed out below, calibration west of 32nd St. is difficult in any case due to the documented presence of other potential sources of VOC discharges.

It was found that the hydrogeological framework and the predictions of contaminant migration are generally consistent with the conclusions reached in 1987. For inorganic contamination in ground water, the following conclusions were reached:

- Many inorganic constituents were found to exceed background concentrations and standards or guidelines (PDWS, SDWS or HBGLs).
- Evidence of contamination of ground water by inorganic constituents is found in the immediate vicinity of the Courtyard at the Motorola 52nd St. Facility, and downgradient of the Southwest Parking Lot. Although Courtyard area contamination can likely be attributed to Motorola's activities, the cause of unusually greater inorganic concentrations in ground water downgradient from the SWPL remains uncertain.

The evaluation of VOC contamination in ground water revealed that some conclusions reached in the 1987 work required revision. The most significant relates to the manner in which "representative" concentrations of ethylene contamination levels are estimated. This is important because mean concentrations are used to calibrate, or to judge the relative accuracy of model predictions.

As noted in Chapter 4.0, ethylene (TCE plus TDCE plus DCE) concentrations observed in recent ground-water sampling programs were found to be four (4) to ten (10) times lower than the maximum mean concentrations reported in the 1987 Draft RI Report. This apparent decline in observed concentrations was not expected because a continuous, constant rate of TCE dissolution from the source area into ground water has been a primary assumption for modeling contaminant migration. No chemical or physical evidence has been obtained to change that assumption. The evidence accumulated from over 30 ground-water monitor locations over an 8-year period, however, shows a decline at most monitor wells and at various depths by a factor of about four. This was illustrated by comparing mean ethylene concentrations between 1983 and 1986 to mean concentrations from the same wells between 1987 to 1991 (Post RI means). This overall decline in observed ethylene concentrations resulted in a reexamination of model predictions.

As described in Chapter 6.0, a larger size ground-water model was developed using previous assumptions supplemented by recent data, particularly in the expanded area of study. The updated hydrodynamic and contaminant transport models were evaluated through sensitivity programs, notably by varying surface recharge rates and the contaminant source term. The predictions of ethylene contamination were then compared to observed data, both the mean concentrations reported in 1987 and the mean values of data obtained between 1987 and 1991. The initial calibration (Run 24) was made against the base case used in 1987, and was found to over predict ethylene concentrations. The source term was then reduced by a factor of 4, and the results (Run 23) compared to observed data. This produced the highest correlation coefficient, 0.81, between observed and predicted concentrations at monitor well locations.

Therefore, Model Run 23 was selected as the "base case" best suited to predict contaminant transport for the FR RI.

The predicted TCE isoconcentration lines in alluvium for Run 23 are shown on Figure 7.1 relative to the Motorola 52nd St. Facility. Documented locations of other facilities that may be potential responsible parties in the East Washington WQARF area are also shown on Figure 7.1. Also shown are the locations of monitor wells recently (1991) installed to define the extent of ground-water contamination from the Motorola 52nd St. Facility, together with reported, historical ethylene concentrations observed previously at other locations where solvent disposal may have occurred. Figure 7.2 illustrates the Run 23 predictions at the same scale as Figure 7.1 relative to the locations of leaking underground storage tanks (ADEQ, 1991).

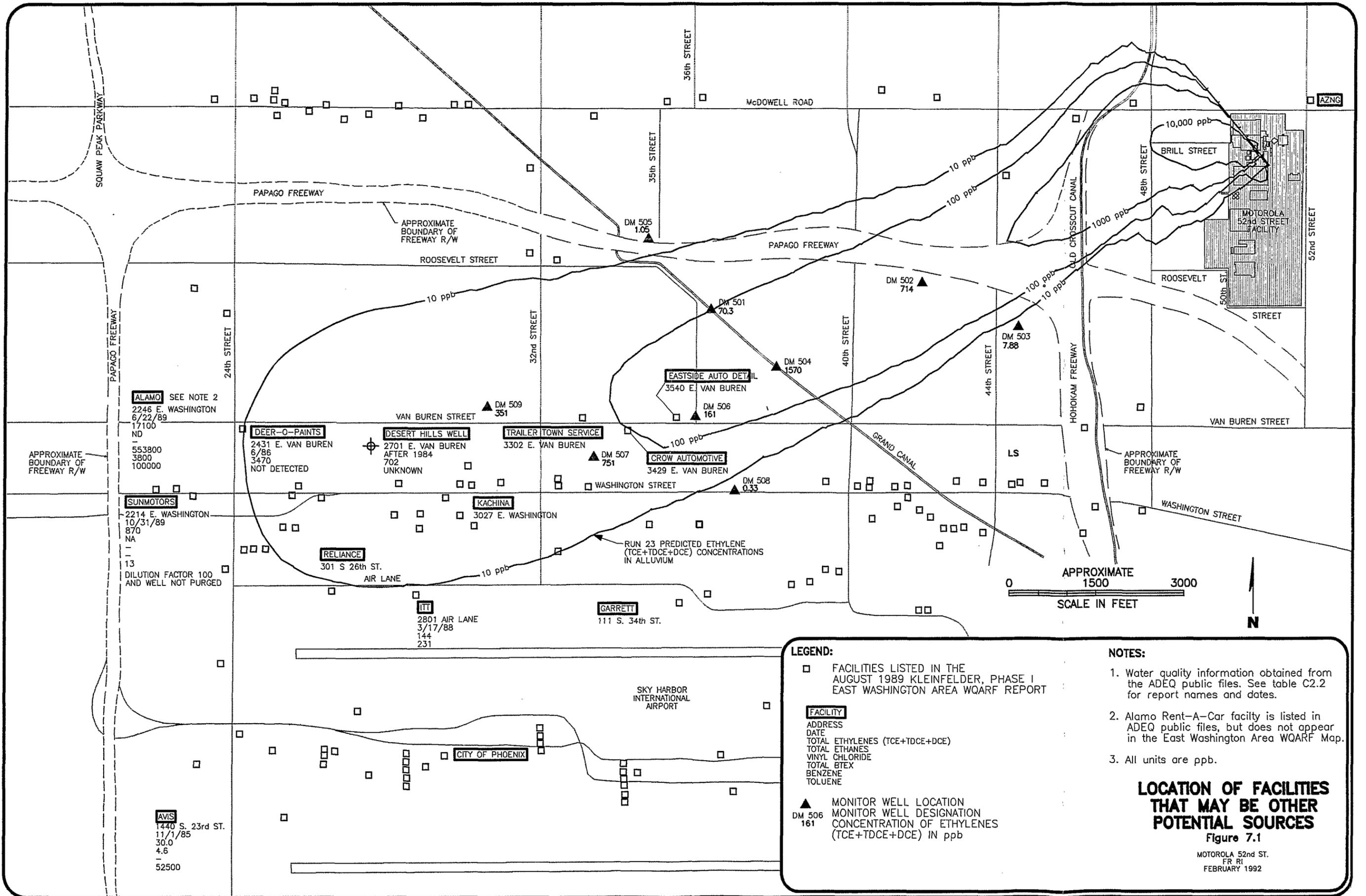
The evidence presented in this report and illustrated on Figures 7.1 and 7.2 lead to the following conclusions regarding VOC concentration:

1. VOC (primarily chlorinated ethylenes) contamination to the 10-ppb concentration in ground water is predicted to extend downgradient west-southwesterly from the Motorola 52nd St. Facility to the area near 24th St. and Washington St. The width of predicted contamination varies from about 3,000 feet downgradient of the Old Crosscut Canal to about a mile wide near 32nd Street.
2. Downgradient of 36th Street (near the location of DM 506), the model predictions cannot be calibrated closely with observed data, either at monitor wells DM 507 and DM 509, or concentrations from other locations. The predictions illustrate that ethylene contamination reported at Garrett (see Table C2.2, Appendix C2) located on Air Lane is probably not related to the "Motorola plume". This latter point is reinforced by a comparison of ethylene concentrations at Garrett (1,370 ppb) with those observed upgradient at monitor well DM 508 (less than 1 ppb).
3. The vertical distribution and relative magnitude of ethylene concentrations observed at monitor wells DM 507 (751 ppb) and DM 509 (351 ppb) suggest that contamination levels at these locations are anomalous (too high) with respect to Run 23 predictions. It is possible that other source(s) of

VOCs in the area of these monitor wells may be contributing to the detected contamination.

4. The density of LUSTs (Figure 7.2) and other potential sources of contamination (Figure 7.1) suggests a high probability of commingled contamination of ground water from numerous sources (of varied age, magnitude and type), particularly in the area west of 36th St.
5. Anamolously greater concentrations of TCA and DCE (believed to be degraded from TCA) have been observed recently (1990-1991) in soil-gas and ground water in the area of the SWPL. The area affected appears to be in the immediate vicinity of the Facility. Results of studies to date are presented in Attachment SW to this report. Further studies are being conducted and the results will be presented as they become available.

To conclude, TARGET™ model run 23 provides the "best fit" between observed and predicted ethylene concentrations in the ground-water plume. Run 23 provides a reasonably accurate correlation with observed data and, to the extent feasible, can be used to predict the extent of contaminant migration. It has been shown that other sources of VOC contamination probably obscure predictions in the downgradient area due to commingling of various plumes. Regardless, it is believed that the results of this FR RI can be used to proceed directly with the Final Remedy Feasibility Study.



**ALAMO** SEE NOTE 2  
 2246 E. WASHINGTON  
 6/22/89  
 17100  
 ND  
 553800  
 3800  
 100000

**SUNMOTORS**  
 2214 E. WASHINGTON  
 10/31/89  
 870  
 NA  
 13  
 DILUTION FACTOR 100  
 AND WELL NOT PURGED

**AVIS**  
 1440 S. 23rd ST.  
 11/1/85  
 30.0  
 4.6  
 52500

**DEER-O-PAINTS**  
 2431 E. VAN BUREN  
 6/86  
 3470  
 NOT DETECTED

**DESERT HILLS WELL**  
 2701 E. VAN BUREN  
 AFTER 1984  
 702  
 UNKNOWN

**TRAILER TOWN SERVICE**  
 3302 E. VAN BUREN

**CROW AUTOMOTIVE**  
 3429 E. VAN BUREN

**RELIANCE**  
 301 S 26th ST.  
 AIR LANE

**ITT**  
 2801 AIR LANE  
 3/17/88  
 144  
 231

**GARRETT**  
 111 S. 34th ST.

**CITY OF PHOENIX**

**LEGEND:**

- FACILITIES LISTED IN THE AUGUST 1989 KLEINFELDER, PHASE I EAST WASHINGTON AREA WQARF REPORT
- ▲ MONITOR WELL LOCATION

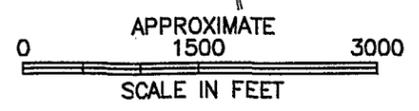
**FACILITY**  
 ADDRESS  
 DATE  
 TOTAL ETHYLENES (TCE+TDCE+DCE)  
 TOTAL ETHANES  
 VINYL CHLORIDE  
 TOTAL BTEX  
 BENZENE  
 TOLUENE

**DM 506 161**  
 MONITOR WELL DESIGNATION  
 CONCENTRATION OF ETHYLENES (TCE+TDCE+DCE) IN ppb

**NOTES:**

1. Water quality information obtained from the ADEQ public files. See table C2.2 for report names and dates.
2. Alamo Rent-A-Car facility is listed in ADEQ public files, but does not appear in the East Washington Area WQARF Map.
3. All units are ppb.

**LOCATION OF FACILITIES THAT MAY BE OTHER POTENTIAL SOURCES**  
 Figure 7.1  
 MOTOROLA 52nd ST.  
 FR RI  
 FEBRUARY 1992



RUN 23 PREDICTED ETHYLENE (TCE+TDCE+DCE) CONCENTRATIONS IN ALLUVIUM

10,000 ppb

100 ppb

100 ppb

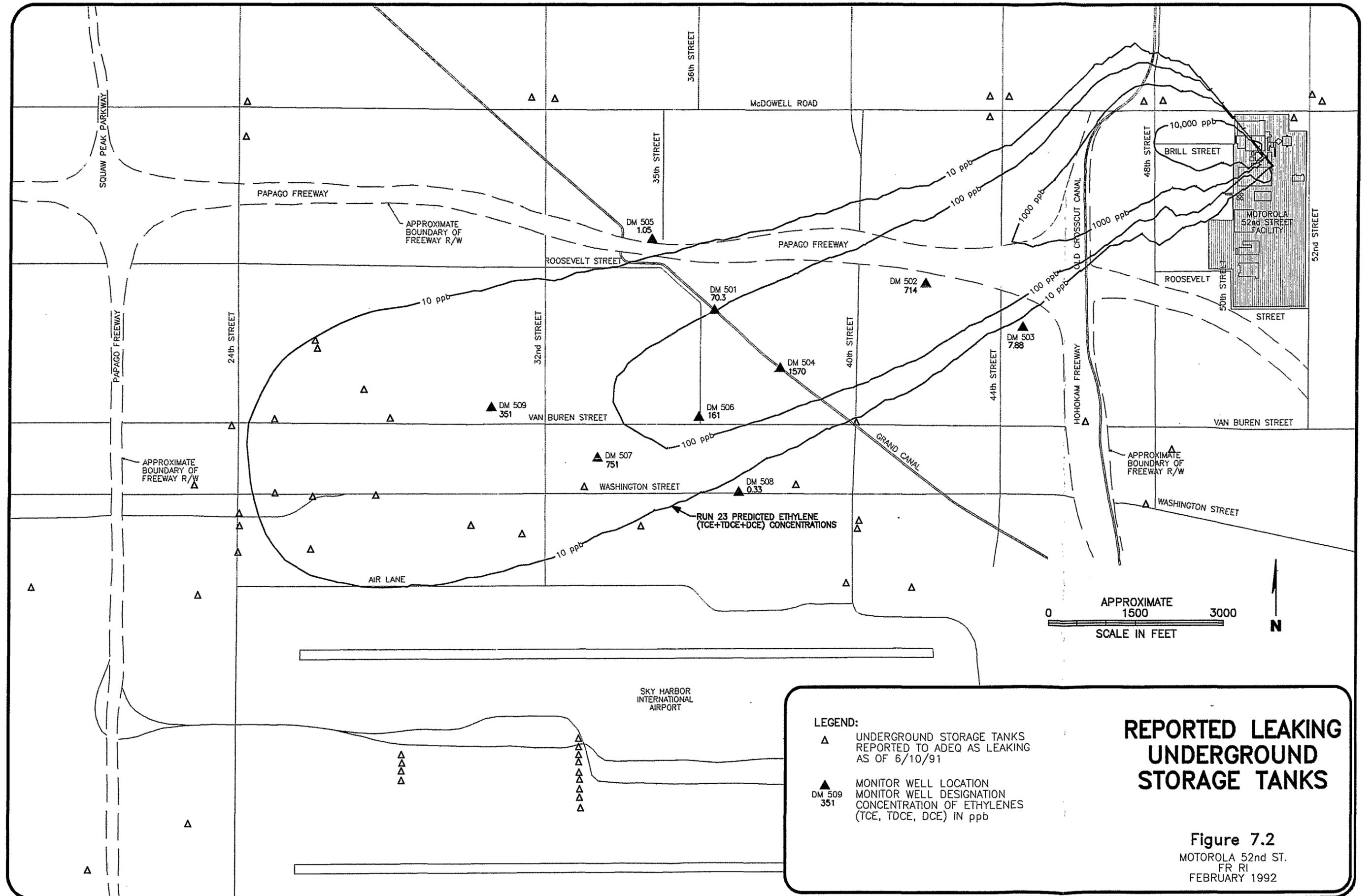
100 ppb

100 ppb

10 ppb

10 ppb

10 ppb



SQUAW PEAK PARKWAY

PAPAGO FREEWAY

APPROXIMATE BOUNDARY OF FREEWAY R/W

ROOSEVELT STREET

McDOWELL ROAD

35th STREET

PAPAGO FREEWAY

10 ppb

100 ppb

1000 ppb

1000 ppb

100 ppb

10 ppb

10,000 ppb

BRILL STREET

MOTOROLA 52nd STREET FACILITY

ROOSEVELT

STREET

52nd STREET

24th STREET

32nd STREET

40th STREET

44th STREET

HOHOKAM FREEWAY

VAN BUREN STREET

APPROXIMATE BOUNDARY OF FREEWAY R/W

DM 509  
351

DM 507  
751

WASHINGTON STREET

DM 508  
033

RUN 23 PREDICTED ETHYLENE  
(TCE+TDCE+DCE) CONCENTRATIONS

AIR LANE

10 ppb

GRAND CANAL

APPROXIMATE BOUNDARY OF FREEWAY R/W

WASHINGTON STREET

APPROXIMATE  
0 1500 3000  
SCALE IN FEET



SKY HARBOR INTERNATIONAL AIRPORT

▲  
▲  
▲  
▲

▲  
▲  
▲  
▲  
▲  
▲  
▲  
▲

## 8.0 REFERENCES

### CHAPTER 1.0 - INTRODUCTION & BACKGROUND

Attorney General's Office, 1989. 52nd St./Complaint, Consent Order and Settlement Agreement, Civil Action No. 89-16807. June 20, 1989.

Arizona Department of Environmental Quality, 1990. Comments on the "Draft Work Plan, Final Remedy RI/FS". November 6, 1990.

\_\_\_\_\_, 1992. Comments on the "Draft Final Remedy Remediation Investigation Report, Motorola 52nd St., September 1991". February 18, 1992.

Arizona Department of Water Resources, 1991. Poor Quality Groundwater Withdrawal Permit, No. 59-530577. May 19, 1991.

Dames & Moore, 1987b. Draft Remedial Investigation/Feasibility Study. June 11, 1987.

\_\_\_\_\_, 1990i. Draft Work Plan for FR RI/FS. September 20, 1990.

\_\_\_\_\_, 1991a. Hydrologic Report in Support of an Application for a PQGWWP, Motorola 52nd St. Operable Unit. January 3, 1991.

\_\_\_\_\_, 1991i. Draft Well Installation, Plume Definition Report. June 17, 1991.

\_\_\_\_\_, 1991n. Draft Final Remedy Remedial Investigation Report, Motorola 52nd St. September 30, 1991.

Morgan, Gerald, 1991. Letter to Karen Berry (ADWR) Requesting ADWR to Rescind PQGWWP No. 59-530577. October 21, 1991.

U.S. Public Health Service, Agency for Toxic Substances and Disease Registry (ATSDR), 1988. Health Assessment. May 2, 1988.

### CHAPTER 2.0 - GEOLOGIC SETTING

Arteaga, F.E., White, N.D., Cooley, M.E., and Suthener, A.F., 1968. Ground Water in Paradise Valley, Maricopa County, Arizona; Arizona State Land Department Water-Resources Report 35, 76 p.

- Bales, J., 1985. Environmental Geology of the Tempe Quadrangle, Maricopa County, Arizona: Part II, Unpublished Masters Thesis, Arizona State University. December 1985.
- Bureau of Reclamation, U.S. Dept. of the Interior, 1976. Central Arizona Project, Geology and Groundwater Resources Report, Maricopa and Pinal Counties, Arizona, Volume I.
- Dames & Moore, 1985h. Draft Report, Stratigraphic Borings/Monitoring Wells, Remedial Investigation/Feasibility Study. July 24, 1985.
- \_\_\_\_\_, 1987b. Draft Remedial Investigation/Feasibility Study. June 11, 1987.
- \_\_\_\_\_, 1990i. Draft Work Plan, Final Remedy RI/FS. September 20, 1990.
- \_\_\_\_\_, 1991a. Hydrologic Report in Support of an Application to Withdraw Poor Quality Ground Water (the PQGWWP Report), Motorola 52nd St. Facility, prepared by Dames & Moore for Motorola, Inc., January 3, 1991.
- \_\_\_\_\_, 1991b. Bedrock Data Report, Motorola 52nd St. Facility, Final Remedy RI/FS. February 8, 1991.
- Gutierrez-Palmenberg, Inc, (GPI), 1983, Preliminary Report, Chemical Leak Project (the GPI Report) prepared by Gutierrez-Palmenberg, Inc. for Motorola. December 9, 1983.
- Laney, R. L., and Hahn, M.E., 1986. Hydrogeology of the Eastern Part of the Salt River Valley Area, Maricopa and Pinal Counties, Arizona: U.S. Geological Survey Water-Resources Investigations Report 86-4147, 4 sheets.
- Lee, W.T., 1905. Underground Waters of the Salt River Valley: U.S. Geological Survey Water Supply and Irrigation Paper No. 136.
- McDonald, H.R., Wolcott, H.N. and Hem, J.D., 1947. Geology and ground water resources of the Salt River Valley area, Maricopa County and Pinal Counties, Arizona: U.S. Geological Survey Open-file report.
- Péwé, T.L., Wellendorf, C.S., Bales, J.T., 1986. Environmental geology of the Tempe Quadrangle, Maricopa County, Arizona (geologic maps), Geologic Investigation Series, Maps GI-20-A-B-C, Arizona Bureau of Geology and Mineral Technology.
- Pool, J.G., 1990. Personal Communication; Geology with the U.S. Geological Survey, Tucson, Arizona, Arizona Hydrological Society Meeting. October 4, 1990.
- Reynolds, S.J., 1985. Geology of the South Mountains, Central Arizona: Arizona Bureau of Geology and Mineral Technology, Bulletin 195.

- Shafiqullah, M., Damon, P.E., and Pierce, H.W., 1976. Late Cenozoic Tectonic Development of Arizona Basin and Range Province (abs): 25th International Geologic Congress, v. 1, p. 99.
- Schulten, C.S., 1979. Environmental Geology of the Tempe Quadrangle, Maricopa County, Arizona: Part I, unpublished thesis, Arizona State University. December 1979.
- Wilson, E.D., Moore, R.T., Pierce, H.W., 1957. Geologic Map of Maricopa County, Arizona: Arizona Bureau of Mines, University of Arizona, 1:375,000.

### SECTION 3.0 - HYDROGEOLOGY

- Dames & Moore, 1987b. Draft Remedial Investigation/Feasibility Study. June 1, 1987.
- ADWR, Compilation of Recharge Data from various sources including SRP, U.S. Bureau of Reclamation, and the U.S.G.S. 1991.
- Long, Mr. R., Niccoli, M.A., Hollander, R., and Watts, J.L., 1982. Final Report: Salt River Valley Cooperative Study Modeling Effort: Arizona Department of Water Resources, 53 pp.
- U.S. Bureau of Reclamation, 1989. U.S.G.S., 1980, pp 3-8.

### CHAPTER 4.0 - VOC CHARACTERIZATION

- Cline, P.V., and Delfino, J.J., 1989. Transformation kinetics of 1,1,1-trichloroethane to the stable product 1,1-dichloroethene in Biohazards of Drinking Water Treatment, R.A. Larson, Editor; Lewis Publishers, Inc., Chelsea, Michigan, pp. 47-56.
- Dames & Moore, 1985k. Well Evaluation Report, November 6, 1985.
- \_\_\_\_\_, 1985m. Draft Task Specification for Water Sampling and Analysis. November 27, 1985.
- \_\_\_\_\_, 1987a. Task Specification, Long-Term Ground Water Sampling Program for the Motorola Inc. 52nd St. RI/FS. May 12, 1987.
- \_\_\_\_\_, 1987b. Draft Remedial Investigation/Feasibility Study. June 1, 1987.
- \_\_\_\_\_, 1988a. Draft Remedial Action Plan. June 24, 1988.

- \_\_\_\_\_, 1990j. Draft Sample Collection and Analysis Plan, Final Remedy RI/FS, Motorola 52nd St. October 25, 1990.
- \_\_\_\_\_, 1991f. Task Specification, Ground-Water Investigation at the Southwest Parking Lot (SWPL). April 19, 1991.
- \_\_\_\_\_, Hydro Geo Chem, Inc., 1991. Soil Gas Survey of Motorola SWPL. April 10, 1991.

### CHAPTER 5.0 - INORGANIC WATER QUALITY

- Arizona Department of Environmental Quality, 1990. Human Health-based Guidance Levels for Contaminants in Drinking Water and Soil: Arizona Department of Environment. September 1990, 21 p.
- Back, W., 1961. Techniques for Mapping of Hydrochemical Facies: U.S. Geological Survey Professional Paper 424-D, p. 380-382.
- Brown, J.G. and Pool, D.R. Hydrogeology of the Western Part of the Salt River Valley Area, Maricopa County, Arizona: U.S. Geological Survey Water-Resources Investigations Report 88-4202, 5 sheets.
- Dames & Moore, 1985m. Draft Task Specification for Water Sampling and Analysis, Remedial Investigation/Feasibility Study, Motorola Inc., 52nd Street and McDowell Road, Phoenix, Arizona. November 27, 1985.
- \_\_\_\_\_, 1987a. Task Specification; Long-Term Ground-Water Sampling Program, 52nd Street RI/FS, for Motorola Inc. May 12, 1987.
- \_\_\_\_\_, 1987b. Draft Remedial Investigation/Feasibility Study. June 1, 1987.
- \_\_\_\_\_, 1990e. Draft Task Specification, Review of Potential Inorganic Contamination, Motorola 52nd Street Consent Order. April 16, 1990.
- \_\_\_\_\_, 1990i. Draft Work Plan, Final Remedy RI/FS, Motorola 52nd St., Phoenix, Arizona, for Motorola Inc. September 20, 1990.
- \_\_\_\_\_, 1990j. Draft Sample Collection and Analysis Plan, Final Remedy RI/FS, Motorola 52nd Street, Phoenix, Arizona, for Motorola Inc. October 25, 1990.
- Hem, J.D., 1985. Study and Interpretation of the Chemical Characteristics of Natural Water (3d. ed.): U.S. Geological Survey Water-Supply Paper 2254, 263 p.

- Lee, W.T., 1905. *Underground Waters of the Salt River Valley, Arizona*: U.S. Geological Survey Water-Supply Paper 136, Washington, D.C.
- Maricopa Association of Governments, 1978. *Groundwater Quality in the Major Basins of Maricopa County*: Maricopa Association of Governments, 208 Program, Phoenix, Arizona.
- Osterkamp, W.R., 1974. *Chemical Quality of Ground Water for Public Supply in the Phoenix Area, Arizona*: U.S. Geological Survey Miscellaneous Investigations Series Map I-845-F, 1 sheet.
- Piper, A.M., 1974. *A Graphic Procedure in the Geochemical Interpretation of Water Analyses*: American Geophysical Union Transactions, v. 25, p. 914-923.
- Robertson, F.N., 1991. *Geochemistry of Ground Water in Alluvial Basins of Arizona and Adjacent Parts of Nevada, New Mexico, and California*: U.S. Geological Survey Professional Paper 1406-C, 90 p.
- Smith, S.A., Small, G.G., Phillips, T.S., and Clester, M., 1982. *Water Quality in the Salt River Project*: Salt River Project, Water Resources Operations, Phoenix, Arizona.
- Stiff, H.A., Jr., 1951. *The Interpretation of Chemical Water Analysis by Means of Patterns*: Journal of Petroleum Technology, v. 3 no. 10, P. 15-17.
- U.S. Environmental Protection Agency, 1976. *National Interim Primary Drinking Water Regulations*: Environmental Protection Agency-570/9-76-003: Washington, D.C., U.S. Environmental Protection Agency Office of Water Supply.
- \_\_\_\_\_, 1986a. *Primary Drinking Water Standard, or MCL (Maximum Contaminant Level)*: U.S. EPA National Primary Drinking Water Regulations, 40 CFR 141. July 3, 1986.
- \_\_\_\_\_, 1986b. *Secondary Drinking Water Standard, or Secondary MCL*: U.S. EPA National Secondary Drinking Water Regulations, 40 CFR 143. July 3, 1986.
- U.S. Public Health Service, 1962. *Drinking Water Standards, 1962*: U.S. Public Health Service Publication 956, 61 p.

## CHAPTER 6.0 - MODELING

- Anderson, M.P. 1979. *Using models to simulate the movement of contaminants through groundwater flow systems*. Critical Reviews in Environmental Control, volume 9, issue 2.

Dames & Moore. 1983. Modeling analyses of subsurface contamination at the Motorola Discrete Semiconductor Facility. Phoenix, Arizona. Consultant's report for Gutierrez-Palmenberg, Inc. Phoenix, Arizona.

\_\_\_\_\_, 1987b. Draft Remedial Investigation/Feasibility Study. June 1, 1987.

Perry, R.H. and C.H. Chilton. 1973. Chemical engineers handbook. McGraw-Hill, Inc., New York, NY.

Salt River Valley GW Model, unpublished, ADWR.

### CHAPTER 7.0

Arizona Department of Environmental Quality, 1991. Reported Leaking Underground Storage Tank List. June 10, 1991.

## DAMES & MOORE SOURCE MATERIAL

- Dames & Moore, 1984a. Remedial Investigation/Feasibility Study Work Plan. October 1984.
- \_\_\_\_\_, 1984b. Draft Task Specification for Soil Gas Sampling, Remedial Investigation/Feasibility Study. October 24, 1984.
- \_\_\_\_\_, 1984c. Draft Task Specification - Stratigraphic Borings/Wells. October 19, 1984.
- \_\_\_\_\_, 1984d. Draft Quality Assurance Program Plan, Remedial Investigation/Feasibility Study. November 16, 1984.
- \_\_\_\_\_, 1984e. Final Task Specification - Stratigraphic Borings/Wells. November 30, 1984.
- \_\_\_\_\_, 1984f. Amendment No. 1 - Stratigraphic Borings/Wells Task Specification. November 30, 1984.
- \_\_\_\_\_, 1984g. Task Specification - Soil-Gas Sampling. December 7, 1984.
- \_\_\_\_\_, 1984h. Draft Task Specification for Aquifer Testing, Remedial Investigation/Feasibility Study. January 11, 1985.
- \_\_\_\_\_, 1985a. Draft Task Specification for Data Management, Remedial Investigation/Feasibility Study. January 23, 1985.
- \_\_\_\_\_, 1985b. Draft Task Specification for Ground-Water Level Monitoring, Remedial Investigation/Feasibility Study. March 18, 1985.
- \_\_\_\_\_, 1985c. Final Task Specification for Modeling of Ground-Water Contamination, Remedial Investigation/Feasibility Study. April 25, 1985.
- \_\_\_\_\_, 1985d. Draft Task Specification for Source Verification and Onsite Contamination Evaluation, Remedial Investigation/Feasibility Study. May 14, 1985.
- \_\_\_\_\_, 1985e. Final Task Specification for Aquifer Testing, Remedial Investigation/Feasibility Study. May 20, 1985.
- \_\_\_\_\_, 1985f. Final Task Specification for Ground-Water Level Monitoring, Remedial Investigation/Feasibility Study. May 24, 1985.

- \_\_\_\_\_, 1985g. Final Task Specification for Data Management, Remedial Investigation/Feasibility Study. June 25, 1985.
- \_\_\_\_\_, 1985h. Draft Stratigraphic Borings/Monitoring Wells, Remedial Investigation/Feasibility Study. July 24, 1985.
- \_\_\_\_\_, 1985i. Draft Report (Revised) Soil-Gas Investigation, Remedial Investigation/Feasibility Study. August 8, 1985.
- \_\_\_\_\_, 1985j. Final Task Specification for Source Verification Program, Remedial Investigation/Feasibility Study. September 16, 1985.
- \_\_\_\_\_, 1985k. Draft Well Evaluation Report, Remedial Investigation/Feasibility Study. November 6, 1985.
- \_\_\_\_\_, 1985l. Draft Aquifer Testing: A Preliminary Report. November 27, 1985.
- \_\_\_\_\_, 1985m. Draft Task Specification for Water Sampling and Analysis, Remedial Investigation/Feasibility Study. November 27, 1985.
- \_\_\_\_\_, 1985n. Final Community Relations Plan for Remedial Investigation/Feasibility Study. December 21, 1985.
- \_\_\_\_\_, 1986a. Task Specification for Additional Wells: First Phase, Remedial Investigation/Feasibility Study. January 9, 1986.
- \_\_\_\_\_, 1986b. Closure Inspection Report Building L. January 20, 1986.
- \_\_\_\_\_, 1986c. Source Sensitivity Stage 1 Model Results, Cases 17 through 23. February 27, 1986.
- \_\_\_\_\_, 1986d. Task Specification for Additional Borings and Wells: Second Phase, Remedial Investigation/Feasibility Study. March 28, 1986.
- \_\_\_\_\_, 1986e. Ground-Water Modeling Study for Motorola: Summary of Stage I (Preliminary) Model Investigations. April 1, 1986.
- \_\_\_\_\_, 1986f. Draft Task Specification for Courtyard Wells and Borings, Remedial Investigation/Feasibility Study. April 9, 1986.
- \_\_\_\_\_, 1986g. Draft Ground-Water Modeling Study for the Motorola 52nd Street Site: Summary of Stage 1 (Preliminary) Model Investigations. April 22, 1986.

- \_\_\_\_\_, 1986h. Draft Aquifer Testing: Second Report, Remedial Investigation/Feasibility Study. May 28, 1986.
- \_\_\_\_\_, 1986i. Draft Interim Summary Report, Remedial Investigation/Feasibility Study. June 24, 1986.
- \_\_\_\_\_, 1986j. Task Specification for Additional Wells: Third Phase, Remedial Investigation/Feasibility Study. July 2, 1986.
- \_\_\_\_\_, 1986k. Draft Screening Report, Remedial Investigation/Feasibility Study. August 1, 1986.
- \_\_\_\_\_, 1986l. Draft Source Verification Report, Remedial Investigation/Feasibility Study, August 13, 1986.
- \_\_\_\_\_, 1986m. Draft Physical Chemistry Investigation with Special Emphasis on Contaminant Transport Modeling for the Remedial Investigation/Feasibility Study. September 25, 1986.
- \_\_\_\_\_, 1987a. Task Specification Long Term Ground-Water Sampling Program for Motorola, Remedial Investigation/Feasibility Study. May 12, 1987.
- \_\_\_\_\_, 1987b. Draft Remedial Investigation/Feasibility Study. June 1, 1987.
- \_\_\_\_\_, 1987c. Results of the June, 1987 Ground Water Sampling, Remedial Investigation/Feasibility Study. July 14, 1987.
- \_\_\_\_\_, 1988a. Draft Remedial Action Plan, Motorola 52nd St. Facility. June 24, 1988.
- \_\_\_\_\_, 1989a. Statement of Work, Motorola 52nd St. Facility. August 9, 1989.
- \_\_\_\_\_, 1989b. Addendum No. 1 to Statement of Work, Motorola 52nd St. Facility. September 27, 1989.
- \_\_\_\_\_, 1990a. Transmittal of Geophysical Logs and Selected Aquifer Test Data. January 22, 1990.
- \_\_\_\_\_, 1990b. Analytical Data for December, 1989 and Field Data for June 1987 through December, 1989. January 30, 1990.
- \_\_\_\_\_, 1990c. Report: Review of Bedrock Issues. March 14, 1990.

- \_\_\_\_\_, 1990d. Draft Task Specification for Plume Definition. March 30, 1990.
- \_\_\_\_\_, 1990e. Draft Task Specification: Review of Potential Inorganic Contaminants. April 16, 1990.
- \_\_\_\_\_, 1990f. Draft Work Plan Outline and Revised Plume Definition Program FR RI/FS. July 3, 1990.
- \_\_\_\_\_, 1990g. Work Plan for Well Abandonment and Water Quality Sampling - Monitor Wells MP 49, DM 202, DM 202 OB1 and DM 202 OB2. July 3, 1990.
- \_\_\_\_\_, 1990h. Transmittal of QA/QC Data. July 13, 1990.
- \_\_\_\_\_, 1990i. Draft Work Plan for FR RI/FS. September 20, 1990.
- \_\_\_\_\_, 1990j. Draft Sample Collection and Analysis Plan FR RI/FS. October 25, 1990.
- \_\_\_\_\_, 1990k. Quality Assurance Program Plan, the Sampling Plan, and Health and Safety Plan. October 25, 1990.
- \_\_\_\_\_, 1990l. Revised Community Relations Plan. November 9, 1990.
- \_\_\_\_\_, 1990m. Draft Well Inventory FR RI/FS. November 21, 1990.
- \_\_\_\_\_, 1990n. Task Specification for Implementation of the SVE Pilot Treatment Plant Program. December 20, 1990.
- \_\_\_\_\_, 1991a. Hydrologic Report in Support of an Application for a PQGWWP, MI 52nd Street Operable Unit. January 4, 1991.
- \_\_\_\_\_, 1991b. Bedrock Data Report. February 8, 1991.
- \_\_\_\_\_, 1991c. Water Quality Results for the November, 1990 Sampling Round. February 15, 1991.
- \_\_\_\_\_, 1991d. Supplement No. 1 - Draft Work Plan FR RI/FS. March 27, 1991.
- \_\_\_\_\_, 1991e. Water Quality Data Useability - Sampling Rounds 8 through 14, FR RI/FS. April 19, 1991.
- \_\_\_\_\_, 1991f. Task Specification - Ground-Water Investigation SWPL. April 19, 1991.
- \_\_\_\_\_, 1991g. Operable Unit Monitor Well Task Specification. May 13, 1991.

- \_\_\_\_\_, 1991h. Aquifer Test Task Specification. June 17, 1991.
- \_\_\_\_\_, 1991i. Draft Well Installation Plume Definition Report. June 17, 1991.
- \_\_\_\_\_, 1991j. Draft Preliminary Ground Water Quality Results: Plume Definition Program. July 8, 1991.
- \_\_\_\_\_, 1991k. June Sampling Round and Interim Data Submittals. August 21, 1991.
- \_\_\_\_\_, 1991l. Transmittal of SWPL Soil Gas Data to Arizona Department of Health Services (ADHS). August 11, 1991.
- \_\_\_\_\_, 1991m. Draft Submittal #1 Task Specification - Ground-Water Quality Investigation, Southwest Parking Lot (SWPL). August 27, 1991.
- \_\_\_\_\_, 1991n. Draft Final Remedy Remedial Investigation Report, Motorola 52nd St. September 30, 1991.
- \_\_\_\_\_, 1990o. Water End Use Feasibility Study PQGWWP No. 59-530577, Motorola 52nd St. OU. December 30, 1991.

## 9.0 DEFINITION OF TERMS

The following is the definition of terms used in this report and other source documents listed in Chapter 8.0. Section 9.1 is a glossary, and Section 9.2 includes a definition of acronyms.

### 9.1 GLOSSARY

**Absorption.** The assimilation of gas, liquid, or solute into the internal structure of another substance.

**Adsorption.** The assimilation of gas, liquid, or solute onto the surface of another substance. In some cases, such as the assimilation by soil, both adsorption and absorption may occur. The term sorption is used when adsorption and absorption are not distinguished.

**Adsorptive or Absorptive Capacity.** The capacity of soil and rock to remove dissolved chemicals from water.

**Advection.** The process by which solutes are transported by the bulk motion of the flowing ground water.

**Air Stripping.** A mass transfer process in which a substance in solution in water is transferred to solution in a gas, usually air.

**Alkalinity.** Relating to the capacity of solutes in water and soluble salts in soil to neutralize acids. Quantitatively, alkalinity is expressed as an equivalent amount of calcium carbonate, even though several other soluble species contribute.

**Alluvium.** A general term for clay, silt, sand, gravel, or similar unconsolidated material deposited during comparatively recent geologic time by a stream or other body of running water as a sorted or semisorted sediment in the bed of the stream or on its floodplain or delta, or as a cone or fan at the base of a mountain slope.

**Anion.** A negatively charged ion, for example, chloride or sulfate.

**Annulus.** The space between the drill string or casing and the well of the borehole or outer casing.

**Aquiclude.** A saturated, but poorly permeable bed formation, or a group of formations that does not yield water freely to a well or spring. However, an aquiclude may transmit appreciable water to or from adjacent aquifers.

**Aquifers.** A formation, group of formations, or part of a formation that contain sufficient saturated permeable material to yield economical quantities of water to wells or springs.

**Aquifer Test.** A test in which measured quantities of water are withdrawn from or added to a well. The resulting changes in head in the aquifer both during and after the period of discharge or addition are measured to calculate the hydraulic properties of the aquifer.

**Aquitard.** A geologic formation, group of formations, or part of a formation through which virtually no water moves.

**Artesian Well.** A well deriving its water from a confined aquifer in which the water level stands above the ground surface.

**Artificial Recharge.** Recharge at a rate greater than natural, resulting from deliberate actions of man.

**Backwash (Water Treatment).** The process in which filter beds are subjected to water flow opposite to the service flow direction to loosen the bed and flush solid materials accumulated on the filter bed to waste.

**Backwash (Well Development).** The surging effect or reversal of water flow in a well. Backwashing removes fine-grained material from the formation surrounding the borehole and, thus, can enhance well yield.

**Basalt.** A general term for dark-colored iron-rich and magnesium-rich igneous rocks, commonly extrusive, but locally intrusive.

**Base Exchange.** The displacement of a cation bound to a site on the surface of a solid, as in silica-alumina clay-material packets, by a cation in solution.

**Bedrock.** A general term for the rock, usually solid, that underlies soil or other unconsolidated material.

**Bentonite.** A colloidal clay, largely made up of the mineral sodium montmorillonite, a hydrated aluminum silicate. Bentonite is widely used as a drilling fluid additive.

**Bit.** The cutting tool attached to the bottom of the drill stem.

**Braided Stream.** A stream that divides into or follows an interlacing or tangled network of several small branching and reuniting shallow channels separated from each other by branch islands or channel bars, resembling in plan the strands of a complex braid.

**Bridge.** An obstruction in the drill hole or annulus. A bridge is usually formed by caving of the wall of the well bore, by the intrusion of a large boulder, or by filter pack materials during well completion. Bridging can also occur in the formation during the well development.

**Caliche.** Soil or alluvium that has been cemented into a rock-like condition by chemical precipitates. The most common cementing material is calcium carbonate.

**Capillary Fringe.** The zone at the bottom of the vadose zone where ground water is drawn upward by capillary force.

**Cation.** An ion having a positive charge, for example, calcium or sodium.

**Cation Exchange.** Ion exchange process in which cations in solution are exchanged for other cations from an ion exchanger. Cation exchange occurs in ground water under natural conditions and is also used as a water treatment process.

**Cavitation.** A phenomena of cavity formation, or formation and collapse, especially in regard to pumps, when the absolute pressure within the water reaches the vapor pressure causing the formation of vapor pockets.

**Chloride (Cl<sub>2</sub>).** A gas composed of two chlorine atoms widely used in the disinfection of water and as an oxidizing agent.

**Coefficient of Storage.** The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head.

**Colloid.** Extremely small particles, 0.0001 to 1 micron in size, which will not settle out of a solution; intermediate in size between a dissolved molecule and a suspended particle which will settle out of solution.

**Colluvium-Alluvium.** Sediments consisting of mixtures of sand, gravel, silt, and clay which have been deposited by processes such as landslides (colluvium) or streams (alluvium).

**Cone of Depression.** A depression in the ground-water table or potentiometric surface that has the shape of an inverted cone and develops around a well from which water is being withdrawn. It defines the area of influence of a well.

**Confined Aquifer.** A formation in which the ground water is isolated from the atmosphere at the point of discharge by impermeable geologic formations; confined ground water is generally subject to pressure greater than atmospheric.

**Contamination.** The degradation of natural water quality as a result of man's activities. There is no implication of any specific limits, since the degree of permissible contamination depends upon the intended end use, or uses, of the water.

**Corrosion.** The act or process of dissolving or wearing away metals.

**Darcy's Law.** An empirical relation, describing the rate of laminar (viscous) flow of fluids through porous solids.

**Density.** A property of matter measured as mass per unit volume expressed in pounds per gallon (lb/gal), pounds per cubic foot (lb/ft<sup>3</sup>), and kilograms per cubic meter (kg/m<sup>3</sup>).

**Discharge Area.** An area in which ground water is flowing toward the ground surface and may escape as a spring into a surface water body or may escape by evaporation and transpiration. Pumping wells are man-made discharge areas.

**Dispersion.** The spreading and mixing of chemical constituents in ground water caused by diffusion and mixing due to microscopic variations in velocities within and between pores.

**Dissolution.** The process of dissolving; solvation.

**Dolomite.** A mineral composed of calcium magnesium carbonate.

**Drainage Basin.** The land area from which surface runoff drains into a stream channel or system of channels, or to a lake, reservoir, or other body of water.

**Drawdown.** The distance between the static water level and the surface of the cone of depression.

**Drill Pipe.** Special pipe used to transmit rotation from the rotating mechanism to the bit during well drilling. The pipe also transmits weight to the bit and conveys air or fluid which removes cuttings from the hole and cools the bit.

**Drilling Fluid.** A water- or air-based fluid used in well drilling operations to remove cuttings from the hole, to clean and cool the bit, to reduce friction between the drill string and the sides of the hole, and to seal the borehole.

**Effective Size.** The 90-percent-retained size of the sediment as determined from a grain-size analysis; therefore, 10 percent of the sediment is finer and 90 percent is coarser.

**Effluent.** A liquid discharge (often waste) from a manufacturing or treatment process, in its natural state or partially or completely treated, that discharges into the environment. Or, per ADWR, water which, after being withdrawn as ground water or diverted as surface water, has been used for domestic, municipal or industrial purposes and which is available for reuse for any purpose, whether or not the water has been treated to improve its quality.

**Equipotential Line.** A closed curve on the water table or potentiometric surface along which the pressure head of ground water in an aquifer is the same. Fluids flow is normal to these lines in the direction of decreasing fluid potential.

**Evaporation.** The process by which fluids change from the liquid to the vapor state.

**Exempt well.** A well having a pump with a maximum capacity of not more than 35 gallons per minute which is used to withdraw ground water pursuant to ARS 45-454.

**Extrusive Rocks.** Igneous rocks formed from magma that flows out on the Earth's surface. These rocks cool rapidly, producing a fine crystalline structure.

**Fault.** A fracture or a zone of fractures along which there has been displacement of the rocks or soil relative to one another.

**Field Capacity.** The amount of water held in the soil after the excess gravitational water has drained away and after the rate of downward movement of water has materially decreased.

**Filter Cake.** The suspended solids that are deposited on a porous medium during the process of filtration.

**Filtration.** The process of separating suspended solids from liquid by forcing the latter through a porous medium.

**Floodplain.** The surface or strip of relatively smooth land adjacent to a river channel, constructed by the present river and covered with water when the river overflows its banks. It is built of alluvium carried by the river during floods and deposited in the sluggish water beyond the influence of the swiftest current.

**Flow Lines.** Lines indicating the direction followed by ground water toward points of discharge. Flow lines are perpendicular to equipotential lines.

**Fouling.** The process in which undesirable foreign matter accumulates in a bed of filter media or ion exchanger, clogging pores and coating surfaces, and, thus, inhibiting or retarding the proper operation of the bed.

**Gas Chromatography.** A process by which different gases can be separated from a mixture. The separation is accomplished by passing the gaseous mixture through a volume containing liquid film. The different gases separate by way of successive sorption and desorption at different rates and leave the column in appropriate order of decreasing boiling point.

**Graded.** An engineering term pertaining to a soil or an unconsolidated sediment consisting of particles of several or many sizes or having a uniform or equable distribution of particles from coarse to fine.

**Grain per Gallon (gpg).** A common basis for reporting water analyses in the water-treatment industry in the United States and Canada. One grain per U.S. gallon equals 17.12 milligrams per liter.

**Gravel Pack.** Gravel that is placed in the annulus of the well between the borehole wall and the well screen to prevent formation material from entering the screen.

**Ground Water.** The subsurface water that occurs beneath the water table in soils and rocks that are saturated.

**Ground-Water Flow.** The movement of water through openings in soil and rock in the saturated zone in response to differences in hydraulic head, temperature, or chemical concentration.

**Grout.** A fluid mixture of Portland cement and water of a consistency that can be forced through a pipe and placed as required. Various additives, such as sand, bentonite, and hydrated lime, may be included in the mixture to meet certain requirements. Bentonite and water are sometimes used for grout. Neat cement grout is a mixture of water and Portland cement without additives.

**Grouting.** The operation by which grout is placed between the casing and the sides of the well bore to a predetermined height above the bottom of the well. This secures the casing in place and excludes water and other fluids from the well bore.

**Head.** Energy contained in a water mass, produced by elevation, pressure, or velocity.

**Head Loss.** The part of head energy which is lost because of friction as water flows.

**Heterogeneous.** Nonuniform in structure or composition throughout.

**Homogeneous.** Uniform in structure or composition throughout.

**Hydration.** The act by which a substance takes up water by absorption and/or adsorption.

**Hydraulic Conductivity.** The rate of flow of ground water under a unit hydraulic gradient at the prevailing temperature (ft/day). In the SI System the units are  $m^3/day/m^3$  or m/day.

**Hydraulic Gradient.** The rate of change in total head per unit of distance of flow in a given direction.

**Hydrogeology.** The study of interrelationships between ground water and geologic materials and processes.

**Hydrologic Cycle.** A continual sequence of conditions through which water passes, by processes such as precipitation and evaporation, from the atmosphere to the land or oceans and eventually back to the atmosphere.

**Igneous Rocks.** Rocks that solidified from molten or partially molten material, that is, from a magma.

**Infiltration.** The flow of water downward through the soil surface into the ground.

**Injection.** The pumping of liquid waste into the ground through wells for disposal.

**Interference.** The condition occurring when the area of influence of a water well comes into contact with or overlaps that of a neighboring well, as when two wells are pumping from the same aquifer or are located near each other.

**Intrusive Rocks.** Those igneous rocks forms from magma injected beneath the Earth's surface. Generally these rocks have large crystals caused by slow cooling.

**Ion.** An element or compound that has gained or lost an electron, so that it is no longer neutral electrically, but carries a charge.

**Isotropic.** Refers to a medium whose properties are the same in all directions.

**Laminar Flow.** Water flow in which the stream lines remain distinct and in which the flow direction at every point remains unchanged with time. It is characteristic of the movement of ground water.

**Leachate.** The liquid that is derived from water which has percolated through waste materials and has dissolved the soluble components of the waste.

**Limestone.** A sedimentary rock consisting chiefly of calcium carbonate, primarily in the form of the mineral calcite.

**Lost Circulation.** The results of drilling fluid escaping from the borehole into the formation by way of crevices or porous media.

**Metamorphic Rocks.** Any rock derived from pre-existing rocks by mineralogical, chemical, and/or structural changes, essentially in the solid state, in response to marked changes in temperature, pressure, shearing stress, and chemical environment, generally at depth in the Earth's crust.

**Monitor Well.** A well which is used to measure ground-water levels and obtain ground-water samples.

**Naturally Developed Well.** A well in which the screen is placed in direct contact with the aquifer materials; no filter pack is used.

**Nongraded.** An engineering term pertaining to a soil or an unconsolidated sediment consisting of particles of essentially the same size or having a range of sizes with some intermediate size missing.

**Observation Well.** A well drilled in a selected location for the purpose of observing parameters such as water levels and pressure changes.

**Partial Penetration.** When the intake portion of the well is less than the full thickness of the aquifer.

**Perched Water.** Unconfined ground water separated from an underlying main body of ground water by an unsaturated zone.

**Percolate.** The act of water seeping or filtering through the soil without a definite channel.

**Permeability.** The property or capacity of a porous rock, sediment, or soil for transmitting a fluid; it is a measure of the relative ease of fluid flow under pressure gradients. Hydraulic conductivity is proportional to permeability. Permeability is measured in units of area.

**pH.** A measure of the acidity or alkalinity of a solution, numerically equal to 7 for neutral solutions, increasing with increasing alkalinity and decreasing with increasing acidity. (Originally stood for the words potential of hydrogen and is equal to the negative logarithm of the hydrogen ion concentration.)

**Piezometer.** Device for measuring pressures in the ground water from which water-level elevations can be calculated.

**Porosity.** Related to the interstitial volume of bulk matter. It is the fraction of bulk volume not occupied by solid granular matter.

**Potentiometric Surface.** An imaginary surface representing the total head of ground water in a confined aquifer that is defined by the level to which water will rise in a well.

**Pumping Test.** A test that is conducted to measure aquifer or well characteristics. Frequently used synonymously with aquifer test.

**Radius of Influence.** The radial distance from the center of the pumping well to the point where there is no lowering of the water table or potentiometric surface (the edge of the cone of depression).

**Recharge.** The addition of water to the zone of saturation; also, the amount of water added.

**Recharge Area.** The portion of the land surface through which water seeps into the ground by infiltration or from another aquifer to recharge a particular aquifer.

**Relative Permeability.** Measure of the ease with which one liquid (e.g. oil) can move through soil or rock in the presence of another liquid (e.g. water) in variable proportions.

**Residual Drawdown.** The difference between the original static water level and the depth to water at a given instant during the recovery period after the pump has been shut off in a pumping well.

**Runoff.** That part of precipitation flowing to surface streams.

**Sandstone.** A sedimentary rock composed of abundant rounded or angular fragments of sand which may be set in a fine-grained matrix (silt or clay) and more or less firmly united by a cementing material.

**Safe Yield.** The amount of water which can be withdrawn from a ground-water basin on an annual basis without producing excessive drawdowns or other undesirable results. Cannot exceed mean annual recharge.

**Saturated Zone.** The area underground in which all available spaces are filled with water.

**Sedimentary Rocks.** Rocks resulting from the consolidation of loose sediment that has accumulated in layers.

**Shale.** A fine-grained sedimentary rock formed by the consolidation of clay, silt, or mud. It is characterized by finely laminated structure and is sufficiently indurated so that it will not fall apart on wetting.

**Semi-Volatile Organic Compound.** Any organic compound that cannot be effectively purged from a water solution by an inert gas. In particular, any chemical analyzed by EPA Methods No. 625 and No. 8270 are defined as semi-volatile.

**Slurry.** A thin mixture of liquid, especially water, and any of several finely divided substances, such as cement or clay particles.

**Solution Channel.** An underground opening or passage formed by the dissolving action of water on rocks as limestone or dolomite.

**Specific Capacity.** The rate of discharge of a water well per unit of drawdown, commonly expressed in gpm/ft or m<sup>3</sup>/day/m. It varies with duration of discharge.

**Specific Gravity.** The weight of a particular volume of any substance compared to the weight of an equal volume of water at a reference temperature.

**Specific Retention.** The ratio of the volume of water that a given body of rock or soil will hold against the pull of gravity to the volume of the body itself. It is usually expressed as a percentage.

**Specific Yield.** The ratio of the volume of water that a given mass of saturated rock or soil will yield by gravity to the volume of that mass. This ratio is stated as a percentage.

**Static Water Level.** The level of water in a well that is not being affected by withdrawal of ground water.

**Stratigraphy.** The study of rock strata, especially of their distribution, deposition, and age.

**Storage Coefficient.** The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. By definition, it is a dimensionless term.

**Surfactant.** A substance capable of reducing the surface tension of a liquid in which it is dissolved. Used in air-based drilling fluids to produce foam and during well development to disaggregate clays.

**Tortuosity.** Sinuosity of the actual flow path in porous medium; it is the ratio of the length of the flow path divided by the length of the sample.

**Total Dissolved Solids (TDS).** A term that expressed the quantity of dissolved material in a sample of water, either the residue on evaporation, dried at 356°F (180°C), or, for many waters that contain more than about 1,000 mg/l, the sum of the dissolved chemical constituents.

**Transmissivity.** The rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. Transmissivity values are given in gallons per day through a vertical section of an aquifer one foot wide and extending the full saturated height of an aquifer under a hydraulic gradient of one of the English Engineering system (gpd/ft); in the International System, transmissivity is given in cubic meters per day through a vertical section of an aquifer one meter wide and extending the full saturated height of an aquifer under a hydraulic gradient of one ( $m^2/d$ ).

**Transpiration.** The process by which water absorbed by plants, usually through the roots, is evaporated into the atmosphere from the plant surface.

**Turbulent Flow.** Fluid flow in which the flow lines are confused and heterogeneously mixed. It is typical of flow in surface-water bodies.

**Unconfined Aquifer.** An aquifer where the water table is exposed to the atmosphere through openings in the overlying materials.

**Unsaturated Zone.** An underground area containing water in the gas phase under atmospheric pressure, water temporarily or permanently under less than atmospheric pressure, and air or other gases.

**Vadose Zone.** The zone containing water under pressure less than that of the atmosphere, including soil water, intermediate vadose water, and capillary water. This zone is limited above by the land surface and below by the surface of the zone of saturation, that is, the water table.

**Viscosity.** The property of a substance to offer internal resistance to flow. Specifically, the ratio of the shear stress to the rate of shear strain.

**Void Ratio.** The pore volume of the soil, defined as the ratio between the volume of the voids and the volume of the solids.

**Volatile Organic Compound (VOC).** Any compound that can be purged from a water solution with an inert gas. The compounds that can be analyzed by EPA Method 624 are considered to be VOCs. As a useful guide, any organic liquid compound with a vapor pressure of the order of or greater than the vapor pressure of water may be considered to be a VOC.

#### **Water - Designations of Use in Arizona.**

**Commercial Use** - identical to domestic use except that water use occurs in a non-residential situation (i.e. gas station, office, steel plant, etc.).

**Domestic Use** - Uses related to the supply, service and activities of households and private residences and includes the application of water to less than two acres of land to produce plants or parts of plants for sale or human consumption, or for use as feed for livestock, range livestock or poultry, as such terms are defined in ARS 24-101.

**Industrial Use** - The use of water in the industrial process itself not covered by a specific use category (i.e. construction, cooling, processing).

**Irrigation Use** - The use of ground water on two more or more acres of land to produce plant or parts of plants for sale or human consumption, or for use as feed for livestock, range livestock or poultry, as such terms are defined in ARS 24-101.

**Water Table.** The surface between the vadose zone and the ground water; that surface of the body of unconfined ground water at which the pressure is equal to that of the atmosphere.

**Weathering.** The in situ physical disintegration and chemical decomposition of rock materials at or near the Earth's surface.

**Well Development.** Process by which obstructions such as silt and fine sand are removed from the surrounding aquifer prior to pumping. The use of brushes, compressed air, and water surging cleans the well screen and surrounding aquifer and allows water to enter the well more readily.

**Well Screen.** A filtering device used to keep sediment from entering a water well.

**Well Yield.** The volume of water discharged from a well in gallons per minute or cubic meters per day.

## 9.2 ACRONYMS

AG	Attorney General
ATSDR	Agency for Toxic Substances and Disease Registry
ATP	Acid Treatment Plant
ADOT	Arizona Department of Transportation
ADHS	Arizona Department of Health Services
ADWR	Arizona Department of Water Resources
AHBGL	Arizona Health Based Guidance Level
ARS	Arizona Revised Statutes
ATI	Analytical Technologies, Inc.
AZNG	Arizona National Guard
BOD	Biological Oxygen Demand
CERCLA	Comprehensive Environmental Response Compensation and Liability Act of 1980 (also known as the Superfund Act)
COP	City of Phoenix
CY	Courtyard area
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
HBGL	Health Based Guidance Level
LUST	Leaking Underground Storage Tank
OCC	Old Crosscut Canal
OU	Operable Unit
MCL	Maximum Contaminant Levels
ND	Non Detected
NS	Not Sampled
PDWS	Primary Drinking Water Standards
ppb	Parts per Billion
PQGWWP	Poor Quality Groundwater Withdrawal Permit

PTP	Pilot Treatment Plant
RAP	Remedial Action Plan
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
RQD	Rock Quality Designation
SDWS	Secondary Drinking Water Standards
SRP	Salt River Project
SRV	Salt River Valley
SWPL	Southwest Parking Lot
SWL	Static Water Level
ug/l	Micrograms per Liter
USBR	United States Bureau of Reclamation
USGS	United States Geologic Survey
VC	Vinyl Chloride
VOC	Volatile Organic Compound
WB	Westbay
WQARF	Water Quality Assurance Revolving Fund

9.3

CHEMICAL ABBREVIATIONS

<u>Proper Name</u>	<u>Abbreviation Used</u>
<b>ORGANIC COMPOUNDS</b>	
Acetone	ACT
Benzene	BNZ
Carbon tetrachloride	CCL4
Chlorobenzene	CB
Chloroform	CLFM
1,2-Dichlorobenzene	DCB2
1,3-Dichlorobenzene	DCB3
1,4-Dichlorobenzene	DCB4
1,1-Dichloroethane	DCA
1,1-Dichloroethylene	DCE
Ethyl Benzene	ETB
Methylene Chloride	MEC
Solvent Naptha	VMP
1,1,2,2-Tetrachloroethane	TET
Tetrachloroethylene	PCE
Toluene	TOL
1,1,1-Trichloroethane	TCA
1,1,2-Trichloroethane	TCA2
Trichloroethylene	TCE
1,2-Dichloroethane	DCA2
Trans- and Cis-1,2-Dichlorethylene	TDCE
Trichlorofluoromethane	TCFM
Trichlorotrifluoroethane	F-113
Vinyl Chloride	VC
Xylenes	XYL

(Source: 52ND ST. RI/FS, MOTOROLA, INC.,  
REMEDIAL INVESTIGATION, 1987)

<u>Proper Name</u>	<u>Abbreviation Used</u>
<b>INORGANIC CATIONS</b>	
Arsenic	As
Barium	Ba
Chromium	Cr
Copper	Cu
Lead	Pb
Nickel	Ni
Silver	Ag
Zinc	Zn
<b>INORGANIC ANIONS</b>	
Chloride	Cl
Cyanide	CN
Fluoride	F
Nitrate	NO <sub>3</sub>
Phosphorus	P
Phosphate	PO <sub>4</sub>
Sulfate	SO <sub>4</sub>
Total Dissolved Solids	TDS

(Source: 52ND ST. RI/FS, MOTOROLA, INC.,  
REMEDIAL INVESTIGATION, 1987)

ATTACHMENT A

**FR RI RESPONSES TO AGENCY COMMENTS**  
**(Letter to Motorola from ADEQ dated February 28, 1992)**

General Comments

1. A statement that groundwater in the study area is not controlled with regards to use. (The current report contains sections specifically stating or inferring that groundwater is not used and/or cannot be used for drinking water.

**The FR RI text (Chapter 1.0) has been modified to include a statement explaining the State's statutory limitations with regard to control of ground-water use. As noted, neither Motorola Inc. nor the State of Arizona currently has the legal authority to prohibit or control the use of ground water in the area as drinking water. As a practical matter, however, the ground water in the study area is too saline to use as drinking water without extensive treatment, and drinking water is piped to the area from outside the study area by the City of Phoenix.**

**It remains for further consideration, therefore, whether the legal means for the control and/or management of ground water in the area should be established as part of an overall remediation program. This alternative has been adopted at other Superfund sites, and will be evaluated in the Motorola 52nd St. FR Feasibility Study.**

2. Further analysis of anomalous water quality data in the farfield and Grand Canal area.

**Motorola intends to continue ground-water sampling in the far-field and Grand Canal areas and has indicated an interest to conduct further water quality sampling and/or participate in the upcoming ADEQ East Washington WQARF sampling program. A schedule of ground-water monitor wells to be included in future sampling events has been forwarded to the ADEQ (letter dated January 21, 1992).**

3. A Glossary of all acronyms used.

**A glossary and definition of terms has been included in Chapter 9 of the FR RI.**

4. Consistent language when referring to matters that relate to the Risk Assessment, such as "Chemicals of Potential Concern". (In addition, some aspects of the Risk Assessment should be incorporated into the report.)

**The Risk Assessment (RA) prepared by ADHS was to be included in the FR RI, however, Motorola has not received it as of March 1992.**

**Specific Comments**

1. Page 1-2, 1st paragraph - ADEQ, ADWR, and EPA provide regulatory oversight; ADHS has been contracted by ADEQ to perform the baseline risk assessment.

**ADHS did participate in regulatory oversight leading to preparation of the 1987 RI prior to establishment of the ADEQ in 1986. This sentence has been clarified.**

2. Page 1-3, 2nd paragraph - ADHS is not part of the review process other than as it pertains to human health and the risk assessment activities.

**The reference to ADHS has been deleted from the text.**

3. Page 1-3, 3rd paragraph - Section 1.1, Background, stated that: "Further study has not revealed any other potential sources,"

Please include references for this further study.

**Since preparation of the Draft FR RI (September, 1991), an additional source investigation has been conducted in the SWPL area. The text has been revised to indicate that "Further study ... has revealed an additional source of potential solvent discharge in the SWPL."**

4. Page 1-6, 2nd paragraph - "To the extent that information regarding groundwater use in the area has been developed since 1982, no known use of groundwater for drinking has been identified."

Jerry Morgan has reported to ADWR, ADEQ, ADHS, Dames and Moore and Motorola that his well has been used for domestic as well as swimming pool and irrigation water uses. The well is located in Section 31, T2N R4E and is registered with ADWR (registration number 55-650584). Please revise the report to reflect this information.

**The text has been modified to include a description of Mr. Morgan's well as referred to in Mr. Morgan's letter of October 21, 1991.**

5. Figure 1.3, Monitor Well Locations, Motorola 52nd Street, - The legend lists wells as "Westbay", "Conventional", "MP" and Private. Definitions are not given for these well types until Section 4.1. It would be helpful if, at least, on Figure 1.3 it was indicated that these were different types of well completions (in the case of Westbay, Conventional and MP).

**A glossary and list of acronyms has been presented in Chapter 9. Figure 1.3 has been modified to indicate that the "Westbay", "Conventional", "MP", "Private", and "Extraction" are Well Types.**

6. Figure 1.4A - Locations of OU Extraction and Monitor Wells Offsite and Figure 1.4B, Location of OU Extraction Wells Onsite - Well DM601 on Figure 1.4A and Well DM304 on Figure 1.4B appear to be located in the same location. If one of these well is a replacement of the other this should be explained.

**DM 601 and DM 304 are two separate wells, a monitor well and an extraction well, respectively. The wells are about 30 feet apart. DM 601 is offsite and is therefore shown on Figure 1.4A. Well DM 304 is onsite and is shown on Figure 1.4B. No modification of the figures was made.**

7. Page 2-2, list of documents - Full titles of all documents should be given.

**Full titles can be found in Chapter 8.0, References. The listed titles are used in later sections of the report. A reference to Chapter 8 has been included in the introduction to the list.**

8. Page 2-2, 2nd paragraph, Section 2.1.2 - "Installation of New Monitor Wells" - states that: "These new wells were installed from November 1990 through July 1991 and consist of 10 wells downgradient from the Old Crosscut Canal..."

None of the figures in this section or the previous section include an indication of the gradient direction. Please indicate on the pertinent figures, such as figure 2.1A and 2.1B, the direction of the groundwater gradient.

**Arrows have been added to Figures 2.2A and 2.2B to indicate the direction of the ground-water flow.**

9. Page 2-6, 1st paragraph, Section 2.2.3 - Tertiary Camels Head Formation, states that: "This unit is exposed in the Papago Park area..."

Please include a vicinity map which shows the locations of such features as Papago Park, Tovrea Castle Area, Papago Buttes, Barnes Buttes, and South Mountain in relation to the 52nd St. site, or show them on an existing Figure.

**A vicinity map, Figure 2.1 "Bedrock Outcrop Map", has been added showing the locations of the features listed in the comment.**

10. Page 2-7, 1st paragraph, Section 2.2.3 - Tertiary Camels Head Formation, states that : "The influence of the Camels Head Formation on the buried bedrock topography is

evident in the area between 48th Street and the Old Crosscut Canal, as shown on Figure 2.3."

Shouldn't the reference include Figure 2.6. Elevations of the Top of Bedrock (Base of Alluvium) in addition to Figure 2.3?

**The text has been corrected to refer to Figures 2.4 (Geologic Bedrock Map) and 2.7 (Elevations of the Top of Bedrock).**

11. Page 2-8, 1st paragraph, Section 2.2.5 Tertiary Volcanic - Tempe Butte is approximately 3 miles southeast of the facility.

**The text has been corrected.**

12. Page 3-2 2nd paragraph, Section 3.2.1, Alluvium - States that: "The shallow fluvial gravel was not noted in wells installed along the Old Crosscut Canal. The eastern limit of this unit is believed to be east of monitor well DM502. The unit has been encountered in all monitor wells installed to-date west of DM502".

If the eastern limit of this unit is believed to be east of monitor well DM 502, then the fluvial gravel must also have been encountered in DM502.

**The fluvial gravel was encountered in DM 502. The text has been clarified.**

13. Page 3-3, 4th paragraph - The general description of groundwater flow direction is too vague. The generalities regarding the effects of the Luke Sink area are misleading. A more specific discussion of flow direction and factors affecting flow direction should be included.

**Figure 3.3 has been updated using a more recent published water table map (Brown and Pool, 1989). Appendix G has been added which provides water table contour maps and a complete listing of water level measurements. The text has been clarified with regard to historical versus present ground-water flow patterns.**

14. Page 3-4, 1st paragraph, 2nd Sentence - Should this sentence be written to state that "The gradient gradually diminishes to approximately 0.005 ft/ft west of the Grand Canal"? If not, it would appear to be in conflict with the sentence: "The ground-water hydraulic gradient averages approximately 0.011 ft/ft east of the Grand Canal."

**The text has been corrected as suggested in the comment.**

15. Page 3-4, 3rd paragraph - Section 3.3, Flow Patterns states that: "The long term water level trends are represented by time histories for two SRP wells, 18E5N and 16.9E-6N.

Please define SRP.

**SRP is an acronym for Salt River Project. The text will be clarified and the acronym is included in a listing in Chapter 9.**

16. Page 3-4, 4th paragraph - The rationale for inferring vertical groundwater flow should be explained in more detail. If possible, references to other sites should be included.

**The referenced paragraph has been expanded to include a more complete discussion of vertical hydraulic gradients and how they are interpreted from pressure measurements in multi-port wells. Appendix G has been added which provides tables and figures showing water level data. Table 3.1 has been added to Chapter 3 providing a summary of the calculation of vertical hydraulic gradients.**

17. Page 3-6, 4th paragraph - Section 3.4.1, Alluvium states: "Well DM504 is located along the Grand Canal in what has been estimated to be the approximate center of the contaminant plume."

In what manner has well DM504 been determined to be in the approximate center of the plume? Provide references for this statement.

**The word "center" in this case refers to the approximate centerline or the middle of the width of the plume. The position of well DM 504 with respect to the center of the plume is based on evaluation of water quality and hydraulic gradient data from wells throughout the area. It is a subjective rather than a geometrically-precise modifier.**

18. Figure 3.1, Location of Monitor Wells - Please provide explanation of abbreviations such as AZSLD & SRP.

**AZSLD stands for the Arizona State Land Department and SRP stands for the Salt River Project. A glossary of acronyms has been included in Chapter 9.**

19. Page 3-12 - It may be best to use the appropriate infiltration rates for the appropriate time. Using the higher unlined rates may be preferred prior to 1987 (at which time the canal was lined).

**The recharge rate from the Grand Canal was evaluated using the ground-water flow model as discussed in Chapter 6. The model simulations indicated that the recharge rates from the Grand Canal have a negligible influence on the predicted movement**

of the contaminant plume. Additionally, mounding of ground water predicted by the model for the higher Grand Canal recharge rates was not observed in SRP wells located adjacent to the canal. The lining of the canal in 1987 did not produce a sudden drop in water levels in the SRP wells as would have been expected if the canal recharge was having a significant affect on the local water levels. Furthermore, the higher unlined rates were found to produce predicted concentrations of ethylenes where existing monitor wells indicate low or negligible concentrations of ethylenes are present today. The canal seepage rates reported by the SRP are system-wide estimates and not necessarily directly applicable to the Grand Canal reach within the study area. It was therefore concluded that the lower recharge rates produce a better approximation of observed water levels and water quality than the higher recharge rates.

20. Page 4-1, 2nd paragraph - Section 4.0, VOC Characterizations states: "The groundwater monitor well network is depicted on Figures 3.1 and 3.2 and consists of a total of 77 wells and 270 potential groundwater monitor locations."

Please define "potential groundwater monitor locations."

There are a total of 77 wells. Of these, there are numerous wells with more than one sampling interval. For instance, MP wells were usually constructed with as many as three to five discrete sampling zones. Westbay wells have from 5 to more than 20 individual sampling zones. If all of the individual sampling zones in the multiport wells are added together, the total number of sampling locations totals 270. The text will be clarified.

21. Page 4-5, 4th paragraph, 6th Sentence, Correct "TCE migration" to "TCA migration."

The text was corrected as indicated in the comment.

22. Page 4-6, 3rd paragraph - Please detail the development of the theory regarding the temporary increase in local VOC concentrations around a newly installed well. Please cite any observations or references at this or other sites.

The discussion in the text has been expanded to include observations made at wells DM 102 and DM 120 as well as DM 504 and MP 36. The association between well installation and/or renovation and observed concentration changes is based solely on observations made at this site.

23. Page 4-7, 2nd paragraph - The assertion that a well locally influences observed ethylene concentrations may be inappropriate with data generated in a pump test. The duration of the pumping may have an effect on ethylene concentrations. Please revise this portion of the report to explain the effects of new well placement vs. sustained pumping.

Evidence is presented in the text supporting the association of well pumping and an increase in ethylene concentrations (see response to Comment No. 23). Data collected during the pumping test in well DM 504 did not indicate an association between the duration of the pumping test and the observed change in ethylene concentration.

24. Page 4-8, 1st paragraph - "The rapid decrease" reported in the first sentence should actually be "The rapid increase".

Also the statement regarding the continued decline suggesting changes are occurring in the rate of TCE dissolution at the source was confusing. What source is being refined to?

The discussion of ethylene concentration changes with well pumping has been expanded to include additional field evidence (see response to Comment No. 23).

25. Page 4-9, 2nd paragraph - Motorola should test for oxidation potential at wells where degradation is suspected to be occurring and explain why wells downgradient from wells exhibiting low sic (**actually high**) ratios of DCE/TCA and DCE/TCE do not also show low sic (**actually high**) ratios. Ratios of DCE/TCA and DCE/TCE should be calculated and evaluated for each sampling round instead of evaluating just mean ratios. (Note: We actually look at the inverse, i.e., TCA/DCE etc.)

Dissolved oxygen and biological oxygen demand (BOD) have been measured in numerous wells to provide data useful for interpretation of the oxidation potential of site ground water. The dissolved oxygen and BOD data are presented in Figure 4.10, and discussed with respect to degradation in Section 4.3.6, "The Distribution of Solvent Degradation".

With regard to the presentation of ratios, Figure 4.31 and 4.32, plots of TCA/DCE, have been added to Chapter 4. The ratios have been derived by first taking the ratio of the VOC's of interest for each sample, then computing the sample mean.

The presentation of mean concentrations and sampling results for each sampling round has been discussed between Motorola, Dames & Moore, and ADEQ. Mean concentrations have been used to present the Motorola data for the following reasons:

- 1) The Motorola 52nd St. water quality database includes the results of more than 67,000 analyses from more than 2,300 ground-water samples. The use of mean results allow presentation of this large set of data in a way that can be easily understood. Presentation of each analyte by individual sampling round would result in a confusion of figures and would require the reader to

spend considerable time evaluating each in order to understand the ground-water quality implications.

2) Water quality trends are presented in the form of concentration time history plots for individual sampling locations. The reader can evaluate changes in ethylene concentrations with time for individual sampling locations. In multi-port wells, sampling zones are plotted together to allow interpretation of vertical variations.

3) Changes in vertical VOC concentrations can be evaluated from plots of ethylene concentrations versus time for multi-port wells and from the distinction of alluvium and bedrock in the presentation of plan-view mean concentration maps. Differences in concentrations between alluvium and bedrock ports have been presented using maximum-mean concentration values whereby the highest mean concentration from a port in alluvium or bedrock is reported on the appropriate alluvium or bedrock map. For each map illustrating the distribution of VOC concentrations in alluvium, a similar map has been prepared for the bedrock.

4) A comparison of the mean concentrations presented in the 1987 Draft RI report was important to this investigation so that the calibration of the 1987 Draft RI ground-water model could be checked and updated with data collected since 1986. Therefore, mean concentrations were developed for the data not included in the 1987 Draft RI and compared with the mean concentration included in the 1987 Draft RI. This comparison is the basis for calibration of the ground-water model discussed in Chapter 6.

As a result of the discussions held with ADEQ, additional figures have been prepared and presented in Chapters 4 and 7 illustrating the maximum, mean, and minimum values of TCE, TCA, TDCE, DCE, total ethylene Fluoride and Arsenic for samples collected in 1991.

The issue of data presentation will be discussed in future technical meetings between Motorola, Dames & Moore, ADWR, and ADEQ.

26. Page 4-10, 1st paragraph, Sentence 5 - States "TCE to TDCE ratios illustrated on Figure 4.13 for alluvium..." TCE to TDCE ratios for alluvium are illustrated on Figure 4.12 not Figure 4.13. This text should be corrected. The ratio of TCE/TDCE at well DM-103 is 0.07 ug/l on the map not 0.09 ug/l as stated in the text. Which concentration is correct? Either the text of figure should be corrected.

The text and figure have been corrected.

27. Page 4-12, 4th paragraph, Section 4.4 Water Quality Characteristics: Far-Field Area, States that: "The uppermost port at depth of 84 feet has a mean ethylene concentration of 751 ppb for 3 observation (see Table 4.2)."

Table 4.2 includes historic (pre 2/91) VOC concentration in DM201. What is the correct reference here?

**The text has been corrected to refer to Figure 4.30, "Vertical Distribution of Ethylenes".**

28. Page 4-13, 3rd paragraph, Section 4.4, Water Quality Characteristics: Far-Field Area - States that "...TCE biodegradation is most active in the vicinity of DM502 and DM504 (immediately upgradient of DM509)..."

DM504 is over 5000 feet northeast of DM509 and can hardly be described as "immediately upgradient" of DM509. Is this what is actually meant or has an error been made in this paragraph?

**The word "immediately" has been deleted from the text.**

29. Page 4-15, 2nd paragraph - Please give exact figures regarding pumping rates and total amounts of water extracted per year from DM 201 and DM 201OB1.

**The rate of pumping from these wells averages a total of approximately 6 gallons per minute for up to about 40 hours per week since mid-July. The discussion of the SWPL area has been moved from Chapter 4 to Attachment SW.**

30. Page 4-15, 4th paragraph, Section 4.5.2 - VOC Concentrations in Groundwater in SWPL Wells-States "Water quality data for detected VOCs obtained between October 1990 and August 1991 are presented in Table 4.4."

Table 4.4 presents the results of the March 1991 SWPL soil gas concentrations. Table 4.3 presents the summary of VOCs detected in SWPL wells.

**The text has been corrected and moved to Attachment SW.**

31. Page 4-17, 1st paragraph, Section 4.5.3 VOC Concentration in SWPL Soil Gas - States that; "Reported concentration of TCA, DCE, PCE, TCE, vinyl chloride (VC), and Freon-113 are listed in Table 4.5. Concentrations of TCA, DCE, PCE, and TCA + DCE are shown on Figure 4.24 through 4.27.

There is no Figure 4.5, Soil concentrations are given in Table 4.4. Concentrations are shown on Figures 4.25 through 4.28, not Figures 4.24 through 4.27.

**The text has been corrected and moved to Attachment SW.**

32. Page 4-17, last paragraph - The last paragraph on this page should be clarified. What is meant by "Soil-gas and water quality data indicate the possibility of offsite ground-water contamination from the southern area of the SWPL"? Does this indicate that the observed contamination of wells in the SWPL area may originate from a source other than Motorola? This is not likely given that groundwater flow direction is to the southwest, and any contamination from the southern portion of the parking lot would need to migrate against groundwater flow in order to affect wells that show the highest concentrations of contaminants (DM-201-OB1 and DM-201). Please update this part using newly reported information concerning releases of hazardous substances from Building A-D.

**The potential source of contamination has been identified since completion of the September 1991 Draft FR RI. The results of investigations conducted through 1991 are reported in Attachment SW.**

33. Page 4-19, 5th paragraph - The summary states "The decline in the magnitude of observed concentrations appears to be irrefutable and must be considered in predicting the extent of groundwater contamination through modeling or other techniques."

The decline in VOC concentrations should be examined and considered in predicting the extent of groundwater contamination. However, the data generated in the investigation have not been demonstrated to be irrefutable. Questions still exist regarding the adequacy of the current monitor well network to accurately characterize the study area. The plume still has not been fully characterized to the west, as is indicated in Farsight (sic) Model Run 23.

**The data base for the FR RI is believed to be adequate to calibrate with model predictions. Motorola and ADEQ are currently reviewing options to obtain additional water quality data in downgradient areas of predicted VOC contamination.**

34. Page 4-19 (sic), Section 5.0, Inorganic Water Quality - Assumptions regarding background inorganic quality are presented within this section. Conclusions were drawn as to the use of groundwater based upon these assumptions. No substantive data were reported in support these conclusions. Upgradient water quality data, a summary of historical cultural and environmental activities, and a summary of the effects current activities may have on groundwater quality should be included within this section. Please revise this section and resubmit for agency evaluation.

**Chapter 5 has been rewritten as per the comment. Figures 5.11 through 5.16 have been added to clarify the relationship between ground-water flow direction and the concentrations of arsenic, fluoride, and nitrate.**

35. Page 5-1, 4th paragraph - States that "Fluoride concentrations were found to exceed groundwater standards at several off-site wells, however, the high fluoride concentrations were concluded to occur naturally as is common in the Phoenix area."

Please detail the rationale used in formulating this determination. Please cite specific references in the response.

**The referenced sentence has been deleted. Chapter 5 has been rewritten.**

36. Page 5-9, 1st paragraph - The concept of projecting upgradient water quality data from data generated from the SRP well at 40th and Van Buren should be explained in detail for agency review.

**The section of the report on Cultural Factors (now Section 5.2.3.2) has been rewritten. The concept discussed in the comment has been deleted.**

37. Page 5-9, 1st paragraph - Should reference to location of SRP well 18 E 5N read "north side of Grand Canal" rather than "Arizona Canal"?

**Yes. The text has been corrected.**

38. Page 5-9, 3rd paragraph, Section 5.2.1.3 Background Water Quality in Study Area - States that : "Although the plotted locations on the trilinear diagrams indicate that most of the water is of the Na-Cl-SO<sub>4</sub> Type, the evolution from Ca-HCO<sub>3</sub> to Na-Cl-SO<sub>4</sub> as groundwater moves from recharge to down-gradient areas is evident on Figure 5.2."

More definition is needed of the diagrams presented on Figure 5.2. It is not clear how the authors have made the conclusion that most of the water is of the Na-Cl-SO<sub>4</sub> type, nor is it readily evident from these diagrams that the groundwater is evolving from Ca-HCO<sub>3</sub> to Na-Cl-SO<sub>4</sub> as the water moves from recharge to downgradient areas. How are the arrows from the areas labeled "recharge" determined on the two diagrams shown on Figure 5.2? How are the areas labeled recharge determined? If, as stated on page 5-7, groundwater in "recharge" areas is characterized by large concentrations of Ca and HCO<sub>3</sub>, why are the two recharge areas located in the low Calcium and low HCO<sub>3</sub> portions of the ternary diagrams?

**The trilinear diagram (Figure 5.2) has been simplified and updated with data collected since completion of the Draft FR RI. The figure no longer includes the**

**arrows and is used to simply characterize the ground water and to illustrate the variability in inorganic water quality observed in the study area.**

39. Page 5-10, 2nd paragraph, Section 5.2.1.3, Background Water Quality in Study Area - States that : "total concentrations of inorganic constituents are expected to be greater in downgradient versus upgradient areas."

Provide a reference or data that supports this statement.

**The section referenced in the comment has been significantly modified. The referenced statement has been deleted.**

40. Page 5-12, 3rd paragraph - Please reproduce and cite specific portions of the Osterkamp report, and explain how determinations regarding this site were derived from it.

**The reference to the Osterkamp report has been deleted from the discussion in Chapter 5.**

41. Page 5-12, 4th paragraph - The process of comparing upgradient and downgradient water quality data was determined to be impractical at this site. Please explain why no upgradient water quality data were included or compared to downgradient water quality data in this report.

**Upgradient and downgradient data are compared in Section 5.2.3.3, "Evaluation of Background Inorganic Water Quality" using Figures 5.11 through 5.16 illustrating the ground water flow direction through the area with respect to the concentrations of arsenic, fluoride, and nitrate.**

42. Page 5-14, 2nd paragraph - Please elaborate on the rationale used in determining that no relationship exists in the high levels of VOCs and high levels of inorganic contamination present in the Southwest Parking Lot.

**The referenced paragraph has been deleted. The relationship of VOC contamination and inorganic contamination in the SWPL is not discussed.**

43. Page 5-15, 3rd paragraph - Concentrations of fluoride exceeding MCLs exist downgradient of the facility. The disposal practices and spills of hydrofluoric acid and ammonium fluoride at the facility are listed as sources for fluoride contamination in the courtyard area. Please elaborate on the rationale used in determining that the discharge of fluoride compounds at the facility are not related to the high downgradient levels of fluoride found offsite.

**It is argued in Section 5.3, that greater concentrations of inorganic compounds observed in the Courtyard area do not seem to extend off site of the Motorola facility. Information from offgradient locations will be developed to provide a clearer comparison between background and MI 52nd St. concentrations.**

44. Page 5-16, 5th paragraph - States that: "... large concentrations of inorganic constituents in excess of background do not appear to extend downgradient of the courtyard." Please refer to comment above.

**See response to Comment No. 44.**

45. Page 5-17, 1st paragraph - States that: "Background concentrations of TDS, F, Cl, NO<sub>3</sub>, Fe and Mn were found to locally exceed water quality standards."

"Areas of inorganic groundwater contamination exceeding background levels are restricted to the courtyard area and an area downgradient from the Southwest Parking Lot."

Please refer to previous comments regarding the determination of background water quality concentrations.

**See response to Comment No. 44.**

46. Page 5-17, 3rd paragraph - The documentation of prior land uses occurring on the site should be included in this report.

**The land use history is best evaluated with the use of historical areal photographs presented in GPI (1984). These photos have not been included in the Final FR RI. A general description of past land use can be found in Attachment SW.**

47. Page 5-17, 4th paragraph - "Groundwater in the study area is not used for drinking. Evaluation of inorganic water quality data confirm that background concentrations of inorganic constituents preclude the use of ground water in the study area for human consumption."

While ground water in the study area is not known to be used for drinking at present, it has been in the past (recent past at 4626 E. Granada). Background concentrations of inorganic constituents do not preclude the use of groundwater in the study area for human consumption. Background water quality has not been documented in this report. Please review and revise this statement.

**The referenced paragraph has been modified to read: "Ground water in the study area is not presently used for drinking. Evaluation of inorganic water quality data**

confirm that background concentrations of inorganic constituents make ground water in the study area nonpotable."

48. Figure 5-7 -
- a. The symbol for DM 122 should be shaded for chromium.
  - b. The symbol for MP 13 should be shaded for lead.

**The figure has been corrected and updated.**

49. Figure 5-8 -
- a. The symbol for DM 303 should be shaded for lead.
  - b. The symbol for DM 304 should be shaded for selenium.
  - c. The symbol for MP 03 should be shaded for selenium.
  - d. No symbol for MP 9 exists, although chromium and selenium meet or exceed PDWS.

**The figure has been corrected and updated.**

50. Figure 5-9 -
- a. The manganese concentration is shaded for DM 122, but it is listed as being below SDWS's.
  - b. The symbol for DM 505 should be shaded for manganese.
  - c. The symbol for DM 120 should be shaded for manganese.
  - d. The symbol for MP 28 should be shaded for iron.
  - e. The symbol for MP 30 should be shaded for nickel.
  - f. The symbol for DM 114 should be shaded for nickel.
  - g. The symbol for DM 117 should be shaded for nickel.
  - h. The symbol for MP 13 should be shaded for nickel.
  - i. No symbol for MP 49 exists, although nickel exceeds SDWS's.

**The figure has been corrected and updated.**

51. Figure 5-10 -
- a. The symbol for MP 36 should be shaded for nickel.
  - b. The symbol for DM 303 should be shaded for nickel.
  - c. The symbol for DM 301 should be shaded for nickel.
  - d. The symbol for DM 304 should be shaded for nickel.
  - e. No symbol for MP 09 exists, although manganese and nickel exceed SDWS's.

**The figure has been corrected and updated.**

52. Page 6-8, 1st paragraph - In references to the sentence "Historic water level measurements support the assertion that the hydraulic gradient in this area is not significantly influenced by seasonal changes due to irrigation pumping."

Was the sentence meant to state that neither seasonal changes or irrigation pumping appear to influence the hydraulic gradient? Significant changes are seen when reviewing Deer-O-Paint data. How often does Motorola take water level measurements? Is this often enough to show these changes on a seasonal basis?

**The discussion of seasonal changes in hydraulic gradient has been expanded to indicate that seasonal changes are observed west of about 24th St. but that in the model domain, seasonal changes in hydraulic gradient are not observed due to the paucity of irrigation wells locally.**

Upward and downward gradients are indicated to occur within the model. Upward gradients are predominate toward the west, likely due to the presence of fluvial gravels, cobbles, and boulders deposited by the Salt River. A vertical cross-section of groundwater flow contours and velocity vectors would be helpful in illustrating this flow pattern. A groundwater flow velocity vector plot in the horizontal plane would better illustrate the distribution of contaminants in the bedrock and alluvium.

**A vertical cross section from the model illustrating vertical flow vectors has been included as Figure 6.8.**

If the hydraulic gradient is not affected by the seasonal changes and irrigation pumping, why are there long-term variations in horizontal hydraulic gradients?

**This comment seems to refer to a statement made in Section 6.3.1 "Hydrodynamic Calibration" which stated "The long-term variation in horizontal hydraulic gradient may be neglected." The statement has been changed to read: "Long-term variations in horizontal hydraulic gradients are negligible within the model domain."**

53. Page 6-14, paragraph 3, - States that: "No specific field measurements were provided to support the higher recharge rates described in the ADWR database; therefore, the values for Grand Canal recharge reported in the ADWR database could not be independently checked."

ADWR obtained the infiltration values from SRP, however these SRP infiltration values are not published and supportive data was not within SRP files. ADWR feels that the infiltration rates are SRP's preferred rates that SRP feels best represent their canal system.

**The rates provided by SRP are system-wide estimates and not necessarily applicable to the reach of the Grand Canal within the model domain. The sensitivity analysis**

using the ground-water model indicates that the SRP rates may not be good estimates of the leakage from the Grand Canal in this area. No changes were made to the text.

54. Page 6-22, 2nd paragraph, Section 6.5.2 Transport Factors States that: "In each figure, monitor well have been identified." Should this read "In each figure, monitor wells have been identified."

**The text has been corrected.**

55. Page 6-22, 3rd paragraph, - Explain how the installation of a monitor well could cause an artificial temporary increase in ethylene concentration in the local vicinity of the well. Correlating the increase to the installation of new wells is not acceptable. Data should be gathered to either support this postulation.

**The association of changes in ethylene concentrations and the pumping or installation of monitor wells is discussed in Chapter 4, Section 4.3.4, "Evaluation of Concentration Declines". Regardless of the cause of change, the data from 1986 and earlier do not match concentrations observed since 1986 for the area east of the Grand Canal. Concentrations have declined. Therefore, the model originally used in the 1987 Draft RI was revised to reflect these actual observations and trends. As a consequence, although the model is calibrated to more recent observations east of the Grand Canal, the predictions from the model appear too low west of the Grand Canal - when compared to recent data. The explanation provided is plausible. Future sampling from the wells west of the Grand Canal will provide evidence needed to support or refute the theory.**

56. Figure 6.20, - Why were monitor wells only installed to 30th Street, when the model predicted that the plume continued to 24th Street?

**Areas of known contamination exist west of about 30th St. In fact, the FR RI has indicated the possible presence of an additional source upgradient of the westernmost wells drilled as part of this investigation. As stated earlier, discussions are being held between Motorola, ADEQ, ADWR and EPA to evaluate the need for additional monitoring in this downgradient area of competing and/or overlapping indications of several sources of VOC discharges. The results of modeling have been used to predict the extent of contamination so that remedial action alternatives can be evaluated in the FR Feasibility Study.**

57. Page 7-1, 2nd paragraph, - States that "The FR RI study incorporated the entire area of potential contamination, however, the primary focus of the investigation was to define the nature and extent of VOC contamination." The FR RI did not incorporate the entire area of potential contamination. The nature and extent of VOC contamination was not defined.

Compliance wells, which would be outside (beyond) of the extent of the plume, will be required.

**See response to Comment No. 57.**

58. Page 7-1, 1st Bullet, - Exceedances of background concentrations being attributed to "greater background contamination" does not make sense. No substantive data on background concentrations are presented.

**See responses to Comments No. 35, 40, 42, 44, 45, and 46. The last sentence of the bullet has been deleted.**

59. Page 7-3, item 2, - What is the source of information on ethylene contamination reported at Garrett? Please supply a copy of this report or data source to ADEQ. Furthermore, there is considerable distance between DM507, DM509, DM508, and the Garrett facility on Air Lane. Additional monitor wells will be necessary to support this claim.

**The source of information for the Garrett facility is ADEQ and is referenced in Appendix C2 (see Table C2.2). The gradient can be deduced from the existing well network. Additionally, ADEQ has reported that Garrett is in the process of installing monitor wells on and/or near their property.**

60. Page 7-4, paragraph 1, - Additional water quality data should be gathered in the areas of anomalous higher concentrations of VOCs to support conclusions regarding additional sources of contamination.

**It is Motorola's intention to continue to monitor the existing plume definition wells.**

61. Page 7-4, item 3, - Reality rarely matches the computer model. The levels are anomalous (high) in regard to the other monitor point. However, additional data indicating other sources are indeed responsible for these high observations must be submitted.

**Comment noted.**

62. Page 7-4, item 4, - The potential is high for other potential sources to have contributed to groundwater contamination in this area. In any industrial setting, the potential for numerous sources is high. However, this does not diminish Motorola's responsibility to totally define the extent of the contamination in the groundwater which can be attributed to their facility.

**Comment noted. Also, see the response to Comment No. 57.**

63. Figure 7.1, - It would also be helpful to identify the facilities on Van Buren Street between monitoring wells DM507 and DM506 (listed in the August 1989 Kleinfelder, East Washington WQARF Report).

**The information from the Kleinfelder report is included in Appendix C2. The figure has been modified to include identification of the three upgradient facilities shown.**

64. Page A-112 (sic), A.3.2 Bedrock Drilling Methods, 1st paragraph, 2nd sentence, - It appears that "of" should be deleted so the sentence will read "One of three mud rotary drilling rigs was used to core the bedrock: 1) Gardner-Denver 2500, 2) Gardner-Denver 1500, or 3) Failing F-10."

**The text has been revised.**

65. Appendix B, page B-11, 3rd paragraph, Section B.4.1 Test methods, - States that: "One multi-well pump test was conducted in the bedrock (DW1) and three multi-well pump tests were conducted in the alluvium (SW1, DM201, and DM202)."

Please provide a Figure reference that shows the location of wells SW1 and DW1.

**Figure B.6B, "Locations of Hydraulic Conductivity Tests in Courtyard", has been included and illustrates the locations of the referenced wells.**

66. Appendix B, page B-19, 1st paragraph, Section B.4.3 Relationship Between Structure and Hydraulic Conductivity, States that: "Monitor well MP 9 (sic) was drilled to a depth of 252 feet. Fractures were described as occurring every 5 feet from about 88 to 120 feet and about every 20 feet from 120 to 260 feet (total depth of MP 9)."

MP 9 was drilled to a depth of 260 feet according to Figure B.10. Please explain the difference (exploration boring for geologic information vs. the monitor well).

**The well referenced in the comment should be 'MP 49'. Text has been corrected to agree with the total depth of 260 feet reported on Figure B.10.**

67. Page B-24, 3rd Paragraph, 4th Sentence - This sentence should read "Recovered core is reported to be extensively fractured with white and reddish-brown cemented fractures.

**Text has been corrected.**

68. Appendix B. pg B-27, last paragraph, Section B.6, Hydraulic Connection Between Alluvium and Bedrock, - States that: "During the test, water levels were measured in the alluvial and bedrock completion zones in MP3, MP9, MP11, and MP12. Water levels were also measured in bedrock monitor wells MP1 and MP37C and in alluvial

piezometers PZ5 and PZ7. These wells are all located in or near the Courtyard at the locations shown on Figure B.4".

Of these wells, only MP3, and MP9 are shown on Figure B.4. Please reference the correct figure number upon which all of these wells are shown.

**Figure B.6B has been added showing the locations of the referenced wells.**

69. Appendix C2, - Reference to "Potential Responsible Parties" may be acceptable coming from Motorola 52nd Street. However, ADEQ has elected not to use this label for "interested parties" in the WQARF Project Areas. "Other potential sources" is the preferred term.

**Comment noted.**

70. Appendix B6 (sic), VOC Water Quality, Figures E6.1 through E6.16 Comparison of Mean RI, Mean Post-RI, and Total Mean concentrations in Alluvium and Bedrock, - These figures would be much more useful if the total mean concentration of each figure were contoured.

**Figures 4.11 through 4.18, 4.20 through 4.29, 4.31, 4.32, and E7.7 through E7.10 have been modified and/or added to illustrate the distribution of VOCs measured in 1991. Each figure presents the maximum, mean and minimum 1991 concentration values for total ethylenes (TCE+TDCE+DCE), TCE, TDCE, DCE, TCA, fluoride, and arsenic.**

71. Figure E6.27, - Has it been determined that holding times, transportation time to lab, time to extraction, or time to analysis after extraction can not be correlated to the variation in levels observed? It may be that an expedited request for analysis and the subsequent shorter holding time resulted in the higher levels observed after installation of the new monitor wells rather than the actual installation of the wells.

**Holding times and purge volumes were investigated during sampling rounds conducted in 1990. The results did not indicate that holding times or purge volumes have a significant impact on observed concentrations.**

72. Appendix E, Table E3.1, page 17 of 74, - O, P-Xylene and M-Xylene was detected at significant concentrations at well DM117 on 05/27/87. Why were the analysis of these parameters discontinued at this well? These parameters should be added to the sampling list for DM117 and all nearby wells.

**EPA Method 602 has been added to the proposed sampling schedule provided to the ADEQ on January 21, 1992 for selected wells near McDowell Road.**

73. Appendix E. Table E3.1, page 22 of 74, - The Concentration of Chlorobenzene (sic) is reported at 12.5 ug/l for sample 03 on 12/12/89 and less than 12.5 ug/l for samples 01 and 02. Is this concentration a typographical error? Motorola must submit to ADEQ all laboratory analysis reports and chain of custody forms for all historical and future sampling events. Tabulation of data is acceptable in the reports, but the submittal of lab reports is necessary to allow the Department to review exceedances of holding times, varied detection limits, sample dilution, and table typos. Chain of custody procedures are used to maintain and document sample possession for enforcement purposes. Because of the potential evidentiary nature of sample collection investigations, the possession of samples must be traceable from the time they are collected until they are introduced as evidence. Since the samples at this site are physical evidence, completed chain of custody forms must be submitted with sampling results.

**Yes, it was a typo. The value for sample 03 is less than 12.5 ug/L. The table has been corrected.**

**Holding time exceedances are evaluated and reported in the QA/QC report Appendix E5. Motorola has agreed to a schedule for submittal of copies of all sample results and chain-of-custody records. A protocol will be established to submit copies of the requested documentation with future summaries of test results.**

74. Appendix E6, - The use of mean concentrations is not appropriate and should not be used. Numerous examples exist within the tables where a compound was detected during one sample round, but reported as non-detect during a subsequent sampling round due to sample dilution. A value of 0 is used to calculate the mean concentration when a less than value is reported. In fact the actual concentration of the parameter may have ranged from zero to the previous analyzed value or the detection limit. This type of averaging biases the calculated data. All figures depicting mean concentrations must be replaced with concentration contour maps for each sampling round for every major constituent of concern (TCA, TCE, DCE, Fluoride, Arsenic).

**See response to Comment No. 26. Figures E6.116 through E6.125 and E7.7 through E7.10 have been added. The maximum, mean and minimum concentration values for total ethylenes (TCE+TDCE+DCE), TCE, TDCE, DCE, TCA, fluoride, and arsenic are presented.**

75. Appendix E5, - Fluoride and Arsenic contamination at the site appears to be localized in the plant site area. However, fluoride has not been analyzed in a coordinated and consistent manner in both onsite and offsite wells for numerous sampling rounds. All Safe Drinking Water Act primary inorganic contaminants must be added to the list of analytical constituents in order to determine the extent of fluoride contamination.

**Fluoride will be added to future sampling analyses. Please refer to proposed sampling programs transmitted to ADEQ on January 21, 1992.**

76. Appendix F, Page F-8, 2nd paragraph, Section F.3.3.3 (sic) Analysis Methods and Results, - States that: "Figure F.9 presents a semi-log plot of residual drawdown versus T over T for well DM504 recovery data."

Please define residual drawdown. Discuss the significance of residual drawdown versus T/T. Throughout this section, or in an additional table, it would be helpful if each of the equations used for evaluating the aquifer test data were presented.

**The discussion has been clarified and expanded. Pertinent equations have been added to Appendix F.**