PRELIMINARY ASSESSMENT/SITE INVESTIGATION FOR NAVAL AIR STATION KEFLAVIK, ICELAND

REWAI Project 87040

Volume I
Chapters 1 through 6

Presented to

Atlantic Division
Naval Facilities Engineering Command

By

R. E. WRIGHT ASSOCIATES, INC.
3240 Schoolhouse Road
Middletown, PA 17057

March 1989

Respectfully submitted,

Kent V. Littlefield, P.G.
Project Director

Ned E. Wehler, P.G.
Executive Vice President

r.e. wright associates, inc.

REFERENCES

Icelandic Meteorological Office, Precipitation Records.

Ingimarsson, J. et al, 1978. Evaluation of Groundwater Level and Maximum Yield of Wells in a Fresh Water Lens in Svartsengi South-West Iceland.

Petura, John C., April 1981. Trichloroethylene and Methyl Chloroform in Groundwater: A problem Assessment, Journal AWWA.

Smith, Leverett R. and James Dragun, 1984, Degradation of Volatile Chlorinated Aliphatic Priority Pollutants in Groundwater, from Environment International, Pergamon Press Ltd., Vol. 10, pp. 291-298.

Todd, D. K., 1979. Groundwater Hydrology, Wiley International Edition, pp. 235-246.

Verschueren, Karel, 1977. Handbook of Environmental Data on Organic Chemicals, Litton Educational Publishing.

ACKNOWLEDGEMENTS

R. E. Wright Associates, Inc. (REWAI) is grateful to the many individuals and organizations which have been instrumental in providing assistance in data gathering and compilation for the Preliminary Assessment/Site Investigation. In addition to the Government of Iceland and the U. S. Navy (LANTDIV), the following experts have enhanced the value of this document by their willingness to share their knowledge and expertise:

Haukur Tomasson, Director - Orkustofnun, Hydro Power Division

Birgir Jonsson, Head of Engineering Geology - Orkustofnun, Hydro Power Division

Bjorn A. Hardarson, Engineering Geologist - Orkustofnun, Hydro Power Division

Magnus H. Grudjonsson, Managing Director - Sudurnes Public Health Control

Snorri P. Snorrason, Geologist - Sudurnes Public Health Control

Torkell Johannesson, Professor and Head - University of Iceland

Ford Stryker, Commander and Public Works Officer - NAS Keflavik

James R. Bailey, Contract Officer - U. S. Navy Atlantic Division

Special Acknowledgment is given for the late
Einar Asgrimsson, P.E., Public Works Engineer - NAS Keflavik who gave generously of his time and lent expert assistance in this investigation.

TABLE OF CONTENTS

Page

REFERENCES..... Preceding Text

ACKNOWLEDGEMENTS..... Preceding Text

EXECUTIVE SUMMARY.....ES-1

1.0 INTRODUCTION..... 1-1

1.1 Project Background..... 1-1
1.2 Preliminary Assessment/Site Investigation Work Scope..... 1-3

1.2.1 Obtain and Evaluate Available Existing Data..... 1-4
1.2.2 Examine Material and Waste-Handling Activities..... 1-4
1.2.3 Site Operations Plan..... 1-5
1.2.4 Laboratory QA/QC Plan..... 1-5
1.2.5 Health and Safety Plan..... 1-5
1.2.6 Collection and Analysis of Groundwater Samples..... 1-5
1.2.7 Groundwater Contour Map..... 1-6

1.3 PA/SI Report Contents..... 1-6

2.0 SIGNIFICANT FINDINGS AND CONCLUSIONS..... 2-1

2.1 Introduction..... 2-1
2.2 Groundwater Chemistry..... 2-1
2.3 Groundwater Hydrology..... 2-6
2.4 Potential Sources of Contamination..... 2-8

2.4.1 Building 885 Drainage Area..... 2-9
2.4.2 Former Camp Davis Laundry..... 2-9
2.4.3 Day Care Center..... 2-10
2.4.4 Former Iceland Salvage Facility..... 2-10
2.4.5 Tank Bottom Disposal Area..... 2-10
2.4.6 Fire Training Area..... 2-11
2.4.7 Former Municipal Landfill..... 2-11
2.4.8 Concrete Plant Mound..... 2-12
2.4.9 Former Defense Force Landfill..... 2-12
2.4.10 Incinerator..... 2-12
2.4.11 Seaweed Area..... 2-13
2.4.12 Building 832 Drainage Area..... 2-13
2.4.13 Buildings 830 and 832 Drainage Area..... 2-13
2.4.14 Buildings 796 and 798 Drainage Area..... 2-14
2.4.15 Building 781 Drainage..... 2-14
2.4.16 Taxiway K Tank Bottom Disposal Area..... 2-14
2.4.17 Former Camp Geck Area..... 2-15
2.4.18 West End Complex..... 2-15

3.0 BACKGROUND..... 3-1

3.1 History..... 3-1
3.2 Site Geology..... 3-3

3.2.1 Bedrock..... 3-3
3.2.2 Structure..... 3-3
3.2.3 Soil and Morphology..... 3-6

3.3 Site Hydrology..... 3-6

3.3.1 Aquifer Description..... 3-6
3.3.2 Groundwater Recharge and Use..... 3-8

3.4 Groundwater Quality..... 3-10

3.4.1 Significance of VOC Contamination..... 3-10
3.4.2 Properties of Detected VOCs..... 3-14
3.4.3 Inorganic Chemicals..... 3-17

4.0 MATERIAL AND WASTE HANDLING..... 4-1

4.1 Introduction..... 4-1
4.2 Fuel Storage and Handling..... 4-1

4.2.1 On the Agreed Area..... 4-1

4.2.1.1 Fuel Storage and Handling..... 4-1
4.2.1.2 Refueling..... 4-5
4.2.1.3 Waste Disposal Practices..... 4-5
4.2.1.4 Spills..... 4-6

4.2.2 Off of the Agreed Area..... 4-9

4.3 Dry Cleaning Operations..... 4-11

4.3.1 Introduction..... 4-11
4.3.2 On the Agreed Area..... 4-11
4.3.3 Off Agreed Area..... 4-13

4.4 Vehicle Maintenance..... 4-15

4.4.1 On Agreed Area..... 4-15

4.4.1.1 Transportation..... 4-15
4.4.1.2 Auto Hobby Shop..... 4-16
4.4.1.3 Icelandic Contractors..... 4-18

4.4.1.3.1 Icelandic Prime Contractors..... 4-18
4.4.1.3.2 Keflavik Contractors..... 4-19

4.5 Aircraft Maintenance..... 4-19

4.5.1 Defense Force..... 4-19

4.5.1.1 Locations..... 4-19
4.5.1.2 Oils and Solvents..... 4-22
4.5.1.3 Disposal..... 4-23

4.5.2 Icelandair..... 4-24

4.5.2.1 Location..... 4-24
4.5.2.2 Oils and Solvents..... 4-24
4.5.2.3 Disposal..... 4-24

4.6 Landfills..... 4-25
4.7 Hospitals..... 4-25
4.8 Polychlorinated Biphenyls..... 4-27
4.9 Printing Shop..... 4-28

5.0 GROUNDWATER..... 5-1

5.1 Chemistry..... 5-1

5.1.1 Introduction..... 5-1
5.1.2 May 1988 Sampling..... 5-1
5.1.3 June 1988 Sampling..... 5-4
5.1.4 July 1988 Sampling..... 5-7
5.1.5 August 1988 Sampling..... 5-7
5.1.6 September 1988 Sampling..... 5-9
5.1.7 October 1988 Sampling..... 5-12
5.1.8 Municipal Wellfield Water Quality..... 5-12
5.1.9 Time Variations of Concentrations..... 5-15
5.1.10 Summary..... 5-21

5.2 Hydrology..... 5-26

5.2.1 Introduction..... 5-26
5.2.2 Groundwater Monitoring..... 5-27

5.2.2.1 Data Acquisition and Reduction..... 5-27
5.2.2.2 Hydrograph Analysis..... 5-29
5.2.2.3 Pumping Influences on Groundwater Levels..... 5-32
5.2.2.4 Weather Influences..... 5-33

5.2.2.5 Tidal Influences on Groundwater Elevation..... 5-35
5.2.2.6 Hydrograph Types..... 5-38

5.2.3 Groundwater Contour Map..... 5-44
5.2.4 Hydrologic Budget..... 5-49
5.2.5 Aquifer Discharge Rates..... 5-51
5.2.6 Groundwater Flow Velocity..... 5-53
5.2.7 Groundwater Contaminant Transport..... 5-53

6.0 POTENTIAL SOURCE AREAS FOR GROUNDWATER CONTAMINATION.. 6-1

6.1 Introduction..... 6-1
6.2 Accelerated RI/FS Sites..... 6-1

6.2.1 Building 885 Drainage Area..... 6-1
6.2.2 Former Camp Davis Laundry..... 6-6
6.2.3 Day Care Center..... 6-8
6.2.4 Former Icelandic Salvage..... 6-8
6.2.5 Tank Bottom Disposal Area..... 6-11
6.2.6 Fire Training Area..... 6-13
6.2.7 Former Municipal Landfill..... 6-15
6.2.8 Concrete Plant Mound..... 6-15

6.3 RI/FS Sites..... 6-18

6.3.1 Former Defense Force Landfill..... 6-18
6.3.2 Incinerator..... 6-20
6.3.3 Seaweed Area..... 6-22
6.3.4 Building 832 Drainage..... 6-24
6.3.5 Buildings 830 and 832 Drainage..... 6-26
6.3.6 Buildings 796 and 798 Drainage..... 6-26
6.3.7 Building 781 Drainage..... 6-28
6.3.8 Taxiway K Tank Bottom Disposal Area..... 6-31
6.3.9 Former Camp Geck Area..... 6-33
6.3.10 West End Complex..... 6-33

LIST OF FIGURES

Figure 1-1, Location Map..... 1-2

Figure 2-1, Accelerated RI/FS Sites..... 2-2

Figure 2-2, RI/FS Sites 2-3

Figure 2-3, Groundwater Contour Map Averaged Over 28 Days (October 18 - November 15, 1988)..... 2-7

Figure 3-1, World War II Site Layout..... 3-2

Figure 3-2, Location Map..... 3-4

Figure 3-3, Location Map of Shield Volcanoes..... 3-5

Figure 4-1, World War II Bulk Storage Locations..... 4-2

Figure 4-2, Present Bulk Storage Locations..... 4-4

Figure 4-3, Location Map of Fuel Spills..... 4-8

Figure 4-4, Location Map of Military Laundry Facilities..... 4-12

Figure 4-5, Location Map of Civilian Laundry Facilities..... 4-14

Figure 4-6, NAS-Keflavik Vehicle Maintenance Location Map... 4-17

Figure 4-7, World War II Aircraft Maintenance Facilities Map..... 4-20

Figure 4-8, NAS-Keflavik Aircraft Maintenance Facilities Map..... 4-21

Figure 4-9, Landfill Location Map..... 4-26

Figure 5-1, Groundwater Sampling Wells..... 5-2

Figure 5-2, New Wellfield Location..... 5-16

Figure 5-3, TCE Average Concentrations, May 1988 through October 1988..... 5-22

Figure 5-4, PCE Average Concentrations, May 1988 through October 1988..... 5-24

Figure 5-5, 1,1,1-TCE Average Concentrations and Conceptual Plume Locations, May 1988 through October 1988.. 5-25

Figure 5-6, Groundwater Monitoring Wells..... 5-28

Figure 5-7, Meteorologic Data, October 18 - November 15, 1988..... 5-31

Figure 5-8, Type 1: Example of Tidally Dominated Groundwater Hydrograph..... 5-41

Figure 5-9, Type 2: Example of Smooth Response Groundwater Hydrograph..... 5-42

Figure 5-10, Type 3: Example of Rough Response Groundwater Hydrograph..... 5-43

Figure 5-11, Type 4: Example of Spent Heating Water Infiltration Dominated Groundwater Hydrograph.. 5-45

Figure 5-12, Groundwater Contour Map (October 18 - November 1, 1988)..... 5-46

Figure 5-13, Groundwater Contour Map (October 18 - November 15, 1988)..... 5-47

Figure 5-14, Location of Groundwater Drainage Basins Utilized in Hydrologic Budget Estimates..... 5-50

Figure 6-1, Accelerated RI/FS Sites..... 6-2

Figure 6-2, RI/FS Sites..... 6-3

Figure 6-3, Building 885 Drainage Area Location Map..... 6-4

Figure 6-4, Former Camp Davis Laundry Location Map..... 6-7

Figure 6-5, Day Care Center Location Map..... 6-9

Figure 6-6, Former Icelandic Salvage Location Map..... 6-10

Figure 6-7, Tank Bottom Disposal Area Location Map..... 6-12

Figure 6-8, Fire Training Area Location Map..... 6-14

Figure 6-9, Former Municipal Landfill Location Map..... 6-16

Figure 6-10, Concrete Plant Mound Location Map..... 6-17

Figure 6-11, Former Defense Force Landfill Location Map..... 6-19

Figure 6-12, Incinerator Location Map..... 6-21

Figure 6-13, Seaweed Area Location Map..... 6-23

Figure 6-14, Building 832 Drainage Location Map..... 6-25

Figure 6-15, Buildings 830 & 832 Drainage Location Map..... 6-27

Figure 6-16, Building 796 & 798 Drainage Area Location Map.. 6-29

Figure 6-17, Building 781 Drainage Location Map..... 6-30

Figure 6-18, Taxiway K Tank Bottom Disposal Area Location Map..... 6-32

Figure 6-19, Former Camp Geck Area Location Map..... 6-34

Figure 6-20, West End Complex Location Map..... 6-35

LIST OF TABLES

Table 3-1, Well Specifications..... 3-9

Table 3-2, Relevant Guidelines, Goals and Maximum Contaminant Limits (MCLs) for Volatile Organic Chemicals (VOCs) in Drinking Water..... 3-14

Table 5-1, PA/SI Collection of Water Samples..... 5-3

Table 5-2, Summary of Wells Where VOC Analyses Revealed Chemicals Above Detection Limits, First PA/SI Sampling Results, May 26, 1988..... 5-5

Table 5-3, Summary of Wells Where VOA Analyses Revealed Chemicals Above Detection Limits, Second PA/SI Sampling Results, June 23, 1988..... 5-6

Table 5-4, Summary of Wells Where VOA Analyses Revealed Chemicals Above Detection Limits, Third PA/SI Sampling Results, July 28, 1988..... 5-8

Table 5-5, Summary of Wells Where VOA Analyses Revealed Chemicals Above Detection Limits, Fourth PA/SI Sampling Results, August 30, 1988..... 5-10

Table 5-6, Summary of Wells Where VOA Analyses Revealed Chemicals Above Detection Limits, Fifth PA/SI Sampling Results, September 27, 1988..... 5-11

Table 5-7, Summary of Wells Where VOA Analyses Revealed Chemicals Above Detection LImits, Sixth PA/SI Sampling Results, October 25, 1988..... 5-13

Table 5-8, Six Month Summary of Laboratory Analyses..... 5-17

Table 5-9, Data Editing..... 5-30

Table 5-10, Effective Porosity Estimates..... 5-36

Table 5-11, Tidal Estimate of Transmissivity (T) from 28-Day Monitoring Hydrographs..... 5-39

EXECUTIVE SUMMARY

As a result of the detection of volatile organic chemicals (VOCs) in the groundwater at the United States Naval Air Station (NAS) and nearby communities of Keflavik and Njardvik, Iceland, a Preliminary Assessment/Site Investigation (PA/SI) was initiated by the United States Navy.

The presence of VOCs in the groundwater is widespread in the vicinity of NAS-Keflavik, and the chlorinated solvents trichloroethylene (TCE), tetrachloroethylene (PCE), and 1,1,1-trichloroethane (1,1,1-TCA) are the most common contaminants. As groundwater is the water supply for NAS-Keflavik and the surrounding communities, the presence of VOCs constitutes a potential health hazard.

The purpose of the PA/SI was to develop a data base on which the presence, extent, and significance of VOC contamination may be evaluated and the nature of the problem understood prior to undertaking a more full-scale Remedial Investigation/Feasibility Study (RI/FS), to be followed by corrective actions. The objectives of the PA/SI were to verify existing groundwater quality, evaluate available information on past and present waste disposal practices, delineate the generalized groundwater flow directions and use, and identify any data requirements for succeeding remedial investigations.

To meet these objectives, REWAI performed a background investigation; documented the practices involving both current and past storage, handling, and disposal of materials potentially containing VOCs; collected and analyzed 124 groundwater samples from 24 wells; and determined the generalized groundwater flow directions. The response of groundwater to tidal, meteorological, and pumping influences was also evaluated.

The PA/SI determined that fuel and solvent storage, use, and disposal are common at NAS-Keflavik and in the surrounding communities. Fuel spills were documented as having occurred in several areas both on and off NAS-Keflavik. The largest documented fuel spill occurred in late 1987, when an estimated 20,000 gallons of diesel fuel leaked from an underground pipeline in the Nickel Area. No large-scale spills of solvents have been documented.

Groundwater occurs as a 100- to 200-foot-thick freshwater lens within a heterogeneous anisotropic tholeiitic basalt bedrock. The bedrock aquifer consists of the tholeiitic basalt which is relatively high in hydraulic conductivity. Based upon the monitoring results, a groundwater divide is present on the eastern third of the peninsula. Groundwater flow is generally eastward in the areas of Keflavik, Njardvik, and the eastern portion of NAS-Keflavik; and westward to southward in the remaining parts of NAS-Keflavik.

Maximum Contaminant Limits (MCLs) established by the U. S. Environmental Protection Agency (EPA) and guidelines set by the World Health Organization (WHO) for VOCs generally range from as low as 5 micrograms per liter (ug/l) (parts per billion [ppb]) for TCE to as much as 200 ug/l for 1,1,1-TCA. Even though the solubility of many of these solvents in water is low, their presence in groundwater often exceed these drinking water standards and thereby constitute a potential long-term health hazard. Therefore, a relatively small quantity of solvents may result in concentrations of significant concern. Based on the estimate of aquifer storage, the measured concentrations of VOCs measured in groundwater through the study area may be

attributable to a total quantity of solvents which range from 50 to 500 gallons. The effects of highly variable aquifer parameters, tidally and meteorologically controlled changes in groundwater levels and relatively high groundwater flow velocities combine to potentially cause substantial mixing of contaminants within the groundwater flow system.

Six potential VOC contaminant plumes (areas of contamination) appear to exist within the groundwater flow system. Three of these plumes are located in the southeastern portion of NAS-Keflavik and the Njardvik North Wellfield; they appear to coalesce in some areas. The other three plumes occur in the West End Complex, the Nickel Area, and the Keflavik North Wellfield. Groundwater samples taken from five wells within the study area--NAS 35, 36, 8, MW-1, and the Njardvik North Wellfield--exceeded the MCLs for VOCs during the PA/SI.

Based upon the information gathered during the PA/SI, 18 potential VOC source areas were identified. Eight of these warranted immediate-response investigations which were undertaken during an Accelerated Remedial Investigation (RI) conducted from September to December 1988. The eight priority sites included:

- Building 885 Drainage Area;
- Camp Davis Laundry;
- Day Care Center;
- Nickel Tank Bottom Disposal Area;
- Former Icelandic Salvage Facility;
- Former Municipal Landfill;
- Fire Training Area; and
- Concrete Plant Mound.

The other 10 sites were recognized as potential groundwater contaminant sources; they included:

- Former Defense Force Landfill;
- Incinerator Area;
- Seaweed Area;
- Building 832 Drainage Area;
- Building 830 and 831 Drainage Area;
- Building 781 Drainage Area;
- Building 796 and 798 Drainage Area;
- Taxiway K Tank Bottom Area;
- West End Complex; and
- Camp Geck Area.

Identification of these potential source areas was based on the accounts of storage, handling, and disposal practices; groundwater flow directions; and measured impacts to water quality in wells located downgradient. Information obtained during the PA/SI has laid a sufficient foundation for proceeding with the formal RI/FS. The RI/FS is necessary to determine whether the identified potential source areas actually constitute groundwater contaminant sources and to acquire additional groundwater hydrology and groundwater quality information necessary for formal evaluation of corrective action alternatives.

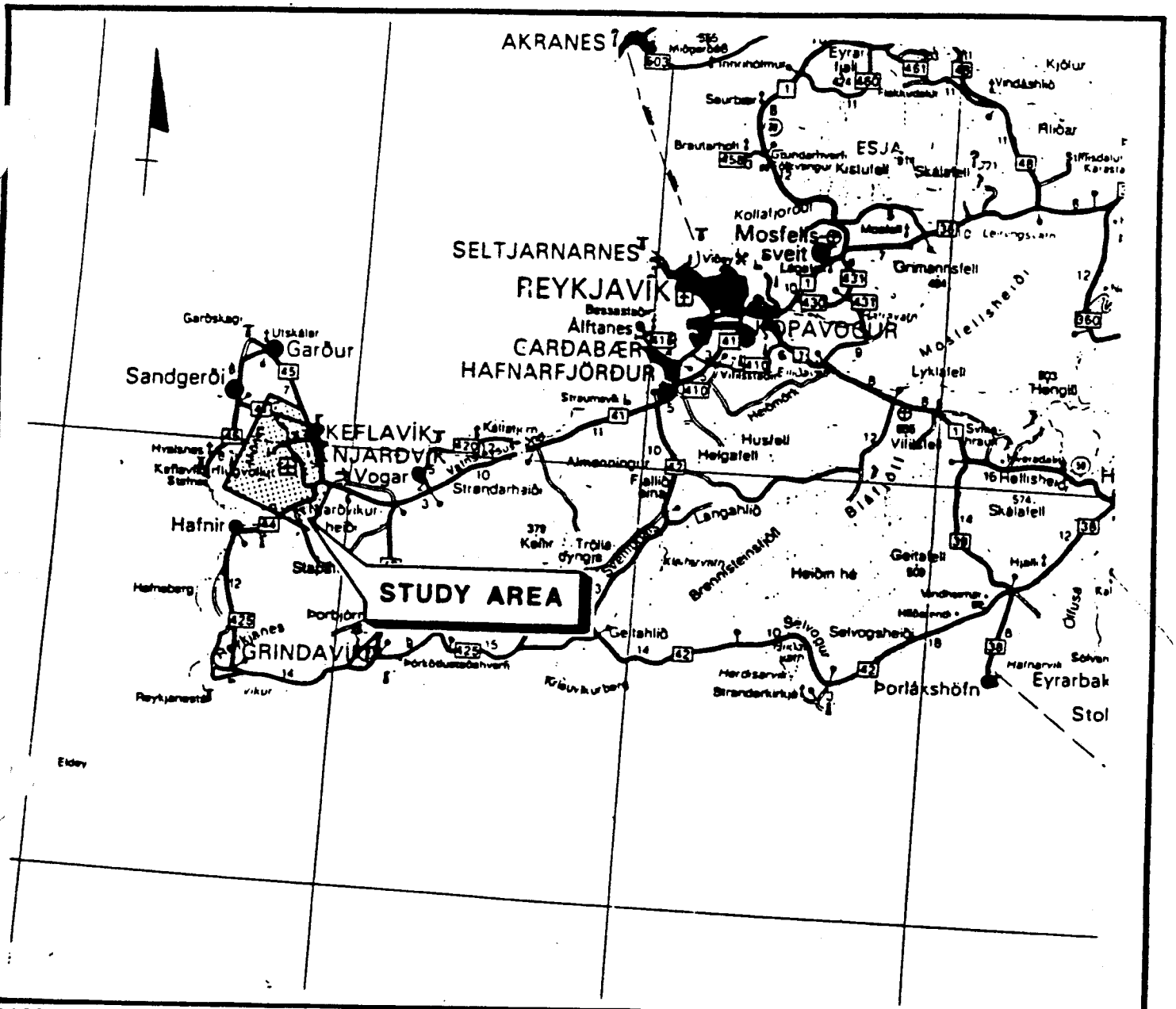
1.0 INTRODUCTION

1.1 Project Background

As a result of volatile organic chemicals (VOCs) being detected in groundwater samples collected from water supply wells at the United States Naval Air Station (NAS), Keflavik, Iceland, a groundwater quality study was initiated by the United States Navy. Since groundwater is the water supply for NAS and surrounding communities of Keflavik and Njardvik, the presence of VOCs constitutes a potential health hazard. VOCs are constituents of materials which are commonly used by industry and consumers such as fuels, cleaning fluids, paints and thinners; and until recently, the environmental and health impacts of improper disposal of these materials were not known. In order to effectively clean up VOCs in the groundwater, source(s) of the VOC contamination need to be defined, and removal or isolation of the source from the environment needs to be implemented. Figure 1-1 shows the location of NAS-Keflavik and the surrounding communities.

The study to define the nature and extent of VOCs in the groundwater, assess the potential environmental impacts from the measured VOC concentrations, and develop and undertake appropriate control and remedial actions, as necessary, was defined as follows:

- Phase I, Preliminary Assessment/Site Investigation (PA/SI);
- Phase II, Remedial Investigation/Feasibility Study (RI/FS); and
- Phase III, Remedial Measures (RM).



BASE MAP: PREPARED FROM MAP PUBLISHED BY LANDMEALINGAR ISLANDS (ICELAND GEODETIC SURVEY-1986)

SCALE 1:500,000

FIGURE 1-1

NAVY - NAS KEFLAVIK, ICELAND		
LOCATION MAP		
RAM	JLW	Drawing no.
JLW	1-23-89	87040-068-AA
r. e. wright associates, inc. earth resources consultants		

Located on the Rosmhvalanes Peninsula of the Reykjanes Peninsula in southwest Iceland, the study area is comprised of the U. S. Naval Air Station (NAS-Keflavik) and the municipalities of Keflavik and Njardvik (Figure 1-1). NAS-Keflavik is part of what is known as the "Agreed Area," which is the land area set aside by the Icelandic government for the operation of the NATO facility, also known as the "Defense Force." Primary access to the study area from outside of Iceland is through the Keflavik International Airport, located within the Agreed Area. The study area is located 27 miles south and west of the capital city of Reykjavik on Route 41.

R. E. Wright Associates, Inc. (REWAI) was contracted by the U. S. Navy, Atlantic Division, Naval Facilities Command, to implement the PA/SI in cooperation with Icelandic subcontractors from the Sudurnes Public Health Control (SPHC), Orkustofnun (Icelandic National Energy Authority [NEA]), the University of Iceland, and Thoris (Instrument Supplier/Subcontractor). A joint committee comprised of individuals designated by the government of Iceland and the U. S. Navy oversaw the progress of the PA/SI. REWAI conducted the PA/SI between May and November of 1988. In August 1988, an Accelerated RI/FS was undertaken to address the VOC contamination in the Njardvik North and Keflavik North Wellfields. This report addresses the PA/SI; the Accelerated RI/FS has been addressed in a previous report. Work tasks completed for the PA/SI are outlined and briefly described below.

1.2 Preliminary Assessment/Site Investigation Work Scope

The PA/SI was implemented to form a basis from which the significance of the VOC contamination detected may be evaluated

and the nature of the problem understood prior to undertaking corrective actions. The objectives of the PA/SI were to:

1. Verify the existing groundwater quality data by collecting a complete, statistically sound, and quality assured set of groundwater analyses;

2. evaluate available information on past and present waste disposal practices potentially impinging on groundwater quality;

3. delineate the generalized groundwater flow directions and use; and

4. identify any data requirements.

1.2.1 Obtain and Evaluate Available Existing Data

All available data, records, reports, and files relative to groundwater quality and hydrogeologic conditions for NAS-Keflavik and the surrounding communities were collected, reviewed, and summarized by REWAI and the NEA (Appendix A).

1.2.2 Examine Material and Waste-Handling Activities

Past and present industrial and maintenance operations, disposal practices, and waste-handling activities for NAS-Keflavik and the surrounding communities were investigated by REWAI and SPHC personnel. REWAI and SPHC interviewed key personnel associated with the preceding activities and visited the sites of potential contamination (Appendix B).

1.2.3 Site Operations Plan

REWAI prepared a Site Operations Plan (SOP) for Phase I of the groundwater investigation (Appendix C). The SOP was designed to be amended as needed for site-specific work associated with additional phases of the investigation.

1.2.4 Laboratory QA/QC Plan

REWAI developed a laboratory quality assurance/quality control plan (QA/QC) for Phase I of the groundwater investigation (Appendix D). The QA/QC plan was designed to be amended as needed for additional phases of the investigation.

1.2.5 Health and Safety Plan

REWAI prepared a Health and Safety Plan (HASP) for the groundwater investigation (Appendix E). The HASP was designed to be amended as needed for site-specific conditions which may be encountered during additional phases of the investigation.

1.2.6 Collection and Analysis of Groundwater Samples

REWAI and SPHC personnel collected groundwater samples from water supply wells and monitoring wells within the study area. The groundwater samples were collected once a month, from May 1988 through October 1988. The groundwater samples were preserved and shipped with chains-of-custody to Wright Lab Services, Inc.

(WLSI) in Middletown, Pennsylvania, United States, for analysis. Analytical procedures specified by U. S. Environmental Protection Agency (EPA) Method 624 were followed by the laboratory.

During the June 23, 1988 sampling event, a representative from the University of Iceland observed the sampling procedures. In September 1988, a representative of the University of Iceland observed the laboratory procedures at WLSI. Laboratory analysis and reports from the University of Iceland are included in Appendix F.

1.2.7 Groundwater Contour Map

A series of hourly groundwater levels was collected from 18 wells in the study area, during the period from October 18, 1988 to November 15, 1988. The wells were equipped by REWAI and NEA personnel with pressure transducers and data loggers purchased from Thoris. Data recovered from the data loggers were downloaded into the NEA's computer for interpretation. Average daily groundwater contour maps and graphs of the data logger readings are included in Appendix G. Hourly groundwater contour maps are presented in sequential order on a videotape.

1.3 PA/SI Report Contents

In this report, the significant findings and conclusions from the PA/SI are presented in Chapter 2.0. Detailed information supporting Chapter 2.0 is provided in the later chapters. Chapter 3.0 describes the study area's general history and general geology and a background on the chemicals detected in the groundwater. Chapter 4.0 describes the materials and waste-handling practices. Groundwater chemistry and hydrology

are described in detail in Chapter 5.0. Chapter 6.0 identifies potential source locations for groundwater quality degradation.

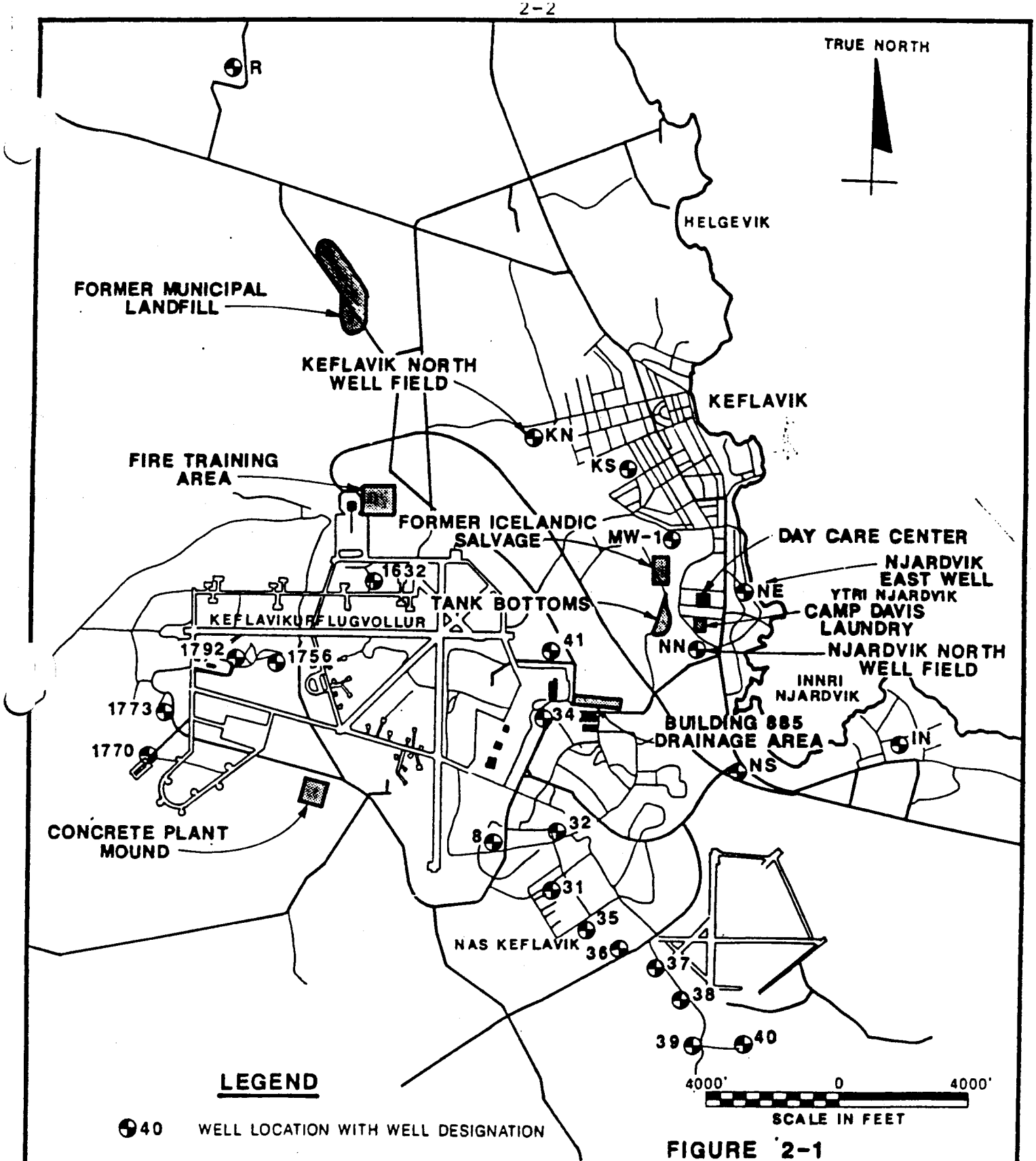
2.0 SIGNIFICANT FINDINGS AND CONCLUSIONS

2.1 Introduction

This chapter summarizes the more significant findings and conclusions of the Preliminary Assessment/Site Investigation (PA/SI) study which was conducted for NAS-Keflavik and the surrounding municipalities. Groundwater chemistry and hydrogeology are discussed in Sections 2.2 and 2.3, respectively. Thereafter, significant findings and conclusions are presented for individual sites which are potential sources for volatile organic compounds (VOCs) in the groundwater within the study area. The sites are divided into two groups. The first group includes the eight sites which were recommended for the Accelerated RI/FS (Figure 2-1); the second group consists of 10 other potential VOC source areas (Figure 2-2).

2.2 Groundwater Chemistry

Groundwater samples were collected and analyzed for VOCs from 22 individual wells and two municipal wellfields during the PA/SI. Of the VOCs that were detected in the groundwater, trichloroethylene (TCE), tetrachloroethylene (PCE) and 1,1,1-trichloroethane (1,1,1-TCA) appear most widespread. TCE was measured in 14 of the sampling locations with average concentrations that ranged from 58 micrograms per liter (ug/l) in NAS Well 35 to 1.0 ug/l in NAS Well 1632. PCE was detected in five of the sampling locations, and the average concentrations ranged from 6.6 ug/l at the Njardvik North Wellfield to 1.0 ug/l at the Keflavik North Wellfield. 1,1,1-TCA was detected in five of the sampling locations, and the average concentration ranged from 65 ug/l at NAS Well 35 to 1.3 ug/l at NAS Well 34.



LEGEND

40 WELL LOCATION WITH WELL DESIGNATION

FIGURE 2-1

NAVY - NAS
KEFLAVIK, ICELAND

ACCELERATED RI/FS SITES

drawn MEPE	approved JLW	drawing no. 87040-105-AA
checked JLW	date 3-25-89	

r. e. wright associates, inc.
earth resources consultants

BASE MAP: PREPARED FROM MAP PUBLISHED BY LANDMAELINGAR ISLANDS (ICELAND GEODETIC SURVEY) AND DMAHTC U.S.A.

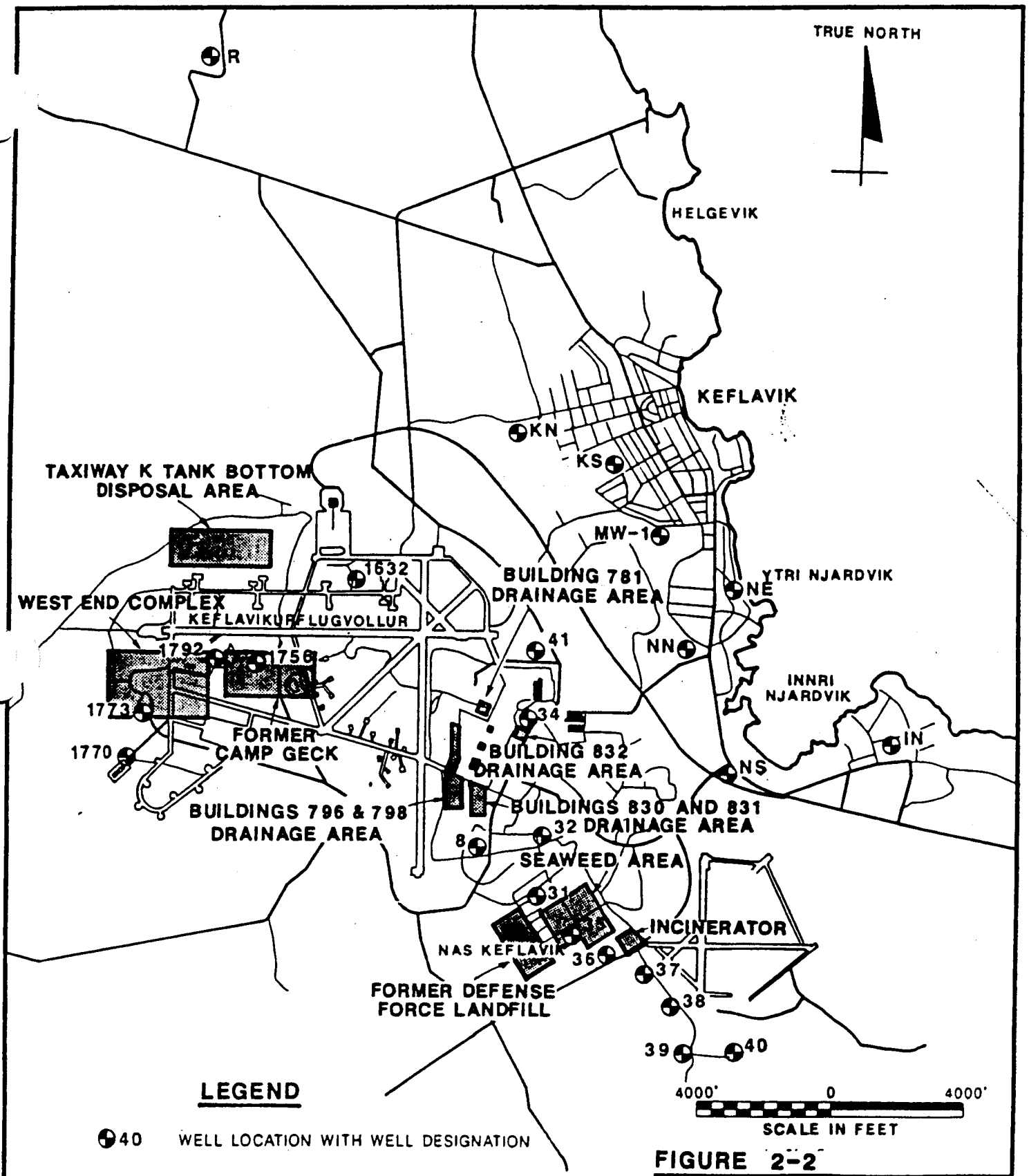


FIGURE 2-2

NAVY - NAS
KEFLAVIK, ICELAND

RI/FS SITES

drawn MEK	approved JLW	drawing no. 87040-106-AA
checked JLW	date 8-23-89	

r. e. wright associates, inc.
earth resources consultants

BASE MAP: PREPARED FROM MAP PUBLISHED BY LANDMAELINGAR

Of the 14 locations where TCE was measured, six of the locations--NAS Wells 8, 31, 32, 34, 35, and 36--are south of Building 885 and east of Buildings 830, 831, and 832. In addition, five sampling locations--NAS Wells 1632, 1756, 1770, 1773, and 1792--are south and southwest of the New International Air Terminal. The last three wells which contained TCE are NAS Well MW-1 in the Nickel Area, the Njardvik North Wellfield, and the Njardvik East Well, which are located northwest of Building 885.

PCE was detected in three different areas. The first area, south of Building 885, includes NAS Wells 34 and 32. The second area, located northeast of Building 885, is the Njardvik North Wellfield and the Njardvik East Well. Northwest of the New International Air Terminal, PCE was detected in the Keflavik North Wellfield.

1,1,1-TCA was detected in NAS Wells 8, 32, 34, 35, and 36. These wells are located south of Building 885 and east of Buildings 830, 831, and 832 where TCE contamination occurs.

Other VOCs were detected sporadically including carbon tetrachloride (CTC), 1,1-dichloroethane (1,1-DCA), 1,1-dichloroethylene (1,1-DCE), cis-1,2-dichloroethylene (c-1,2-DCE), trans-1,2-dichloroethylene (t-1,2-DCE), bromoform, dibromochloromethane, dichlorobromomethane, and toluene. The limited occurrence and distribution of these chemicals with respect to those discussed above may be due to their relatively limited use, more rapid degradation, or poorer mobility of these compounds in the groundwater flow system.

Groundwater quality in three sampling locations consistently exceeded World Health Organization (WHO) or U. S. Environmental Protection Agency (EPA) Maximum Contaminant Limits (MCLs) for TCE. These locations were the Njardvik North Wellfield, NAS Well 35, and MW-1. NAS Well 36 had TCE at concentrations greater than the MCL during most of the PA/SI and NAS Well 8 had 1,1-DCA above the MCL in May 1988.

The pattern of groundwater quality indicates that at least six plumes of VOC-contaminated groundwater are present, each of which could have resulted from one or more sources. The plumes appear to encompass the following areas:

1. A TCE, PCE, and 1,1,1-TCA plume in the area of NAS Wells 34, 32, and 8.

2. A TCE and PCE plume in the area of the Njardvik North Wellfield which could be related to similar plumes in Wells 34 and the Njardvik East well.

3. A TCE and 1,1,1-TCA plume concentrated around NAS Well 35 and also detected in NAS Wells 31 and 36.

4. A TCE plume in NAS Wells 1770, 1773, 1792, 1756, and 1652 in the West End Complex.

5. A TCE and CTC plume in the Nickel Area which might also contribute to TCE in the Njardvik East Well.

6. A PCE plume affecting the water quality of the Keflavik North Wellfield.

During the PA/SI, groundwater quality measured in 24 wells in the study area appeared to improve. This observation may be due to variations in rainfall, seasonal groundwater stage or flow direction, or pumping rates during the monitoring period.

Limited groundwater sampling and laboratory analysis has been performed for inorganic chemicals within the study area and none was done during the PA/SI. Laboratory analyses were found for wells operated by NAS-Keflavik. No laboratory analysis for inorganics was found for wells operated by the local municipalities. Analytical results for 1986 indicated that there are no inorganic concentrations above the MCLs established by the EPA in groundwater.

2.3 Groundwater Hydrology

Knowledge of the groundwater hydrology is necessary to estimate potential contaminant transport direction and speed in groundwater. The groundwater producing aquifer is a 100- to 200-foot-thick freshwater lens in a heterogeneous and anisotropic tholeiitic basalt. In order to determine groundwater flow characteristics, a groundwater contour map (Figure 2-3) was generated by averaging hourly groundwater elevations for the time period from October 18 to November 15, 1988. This map shows a groundwater divide which separates the eastern third of the study area from the western two-thirds. Macro-scale groundwater flow directions are generally east on the east side of the divide and west on the west side of the divide. However, localized groundwater flow directions are expected to vary. Such variations are attributable to micro-scale flow channels that could not be identified or evaluated with the available data due

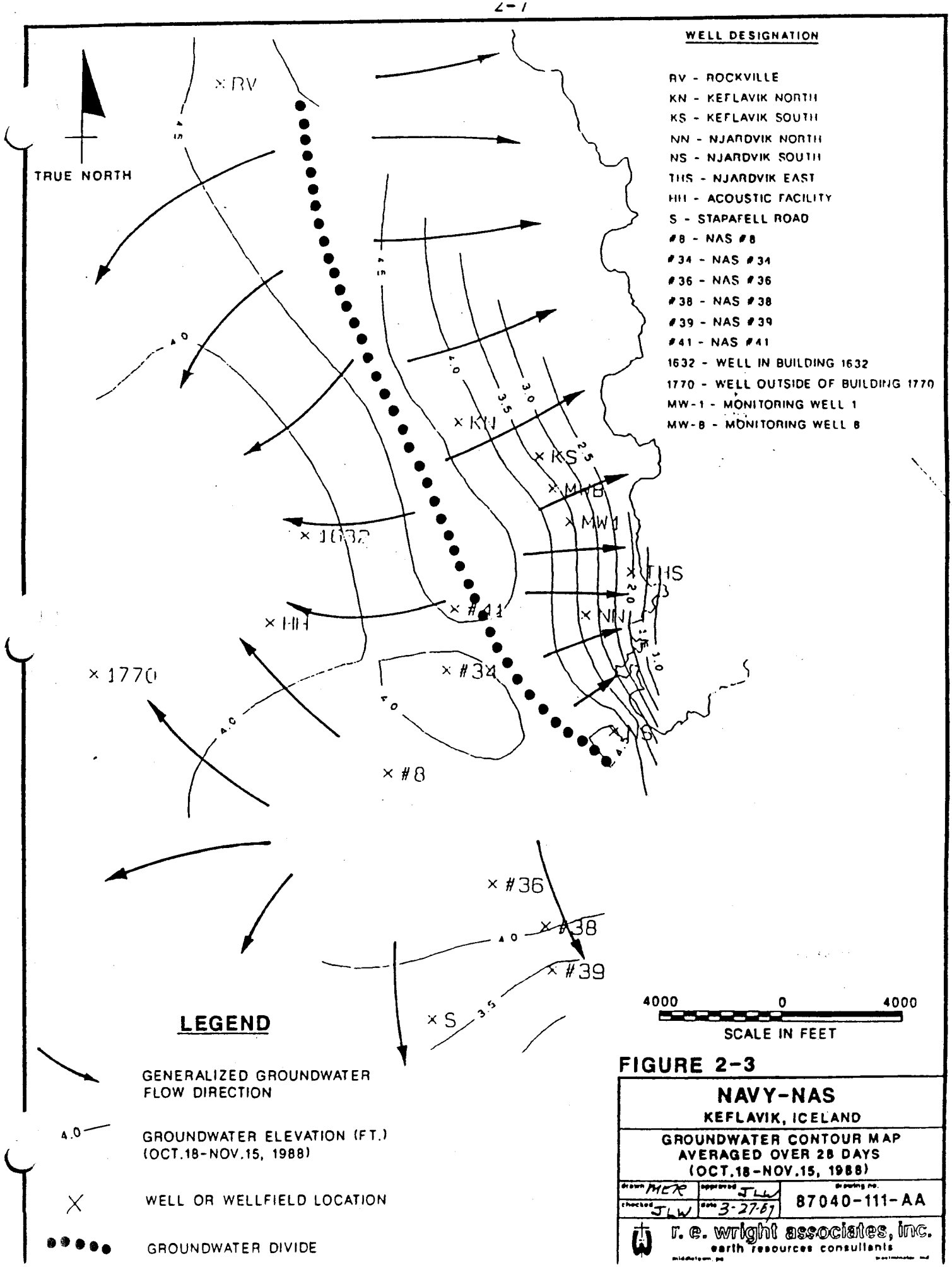


FIGURE 2-3

NAVY-NAS
KEFLAVIK, ICELAND

GROUNDWATER CONTOUR MAP AVERAGED OVER 28 DAYS (OCT.18-NOV.15, 1988)

drawn MER	approved JLW	drawing no. 87040-111-AA
checked JLW	date 3-27-89	

r. e. wright associates, inc.
earth resources consultants

to the wide variations in aquifer characteristics, the potential effects of localized structures, and the limited work scope.

Although no specific testing of the aquifer parameters has been completed at NAS-Keflavik, estimates of transmissivity range from 0.5 to 3 million gallons per day per foot (Mgpd/ft) of aquifer width under a unit gradient. The aquifer storage coefficient, estimated at 0.01 from a test in the vicinity, suggests the aquifer is unconfined, but localized characteristics may vary. An aquifer porosity range of 0.01 to 0.10 or greater results in an estimated groundwater storage volume of 10 to 100 billion gallons beneath the 25 square mile study area. Annualized groundwater recharge is approximately 16 billion gallons (42 Mgpd), and use is 1.5 billion gallons per year (4 Mgpd).

The groundwater flow system on the Rosmhvalanes Peninsula is very dynamic and responds readily to tidal variations even at great distances from the nearest coastal water body. Response to precipitation is rapid and dramatic. Groundwater flow velocities are variable but relatively high, ranging from less than 1 to better than 50 feet per day. The effects of highly variable aquifer characteristics, the dynamic response to tide and precipitation, and relatively high groundwater flow rates combine to potentially cause dramatic mixing of VOCs where present within the groundwater flow system.

2.4 Potential Sources of Contamination

As determined by the PA/SI interviews, historic and current solvent use and disposal practices may have resulted in the groundwater contamination detected on the Rosmhvalanes Peninsula. Based on the documented activities, groundwater quality analyses,

and general groundwater flow directions, the following areas are suspected as potential sources of VOCs to the groundwater and represent areas where further hydrogeologic and geochemical investigations are warranted.

2.4.1 Building 885 Drainage Area

Floor drains in Building 885 and drains in the apron around Building 885 are discharged to an area east of Building 885. Oils and solvents spilled into these drains could be potential sources for their introduction into the groundwater. The Building 885 Drainage Area lies across the apparent groundwater divide. Groundwater transport from this area may be east toward the Njardvik North Wellfield and west toward NAS Well 34. Both the wellfield and Well 34 contain VOCs, TCE, and PCE. In addition, Well 34 contains 1,1,1-TCA. Because of former solvent use and disposal practices, the groundwater flow directions, and the presence of VOCs in the groundwater downgradient, this area could be the source for the VOCs in the groundwater.

2.4.2 Former Camp Davis Laundry

The former Camp Davis Laundry was the site of a World War II dry cleaning operation which used PCE as a cleaning solvent. The disposal practices of waste products from this laundry facility were not known. Improper use and disposal in this area may have introduced VOCs into the groundwater, and groundwater flow from this area would have taken the plume generally toward the east. However, whether groundwater flow from this area is induced to the Njardvik North Wellfield by pumping is undefined. Thus, the former Camp Davis Laundry could be a source for the PCE in the Njardvik North Wellfield. Groundwater transport of solvents from

this area may be induced to enter the Njardvik East Well, causing the sporadic impairment of water quality documented during the PA/SI.

2.4.3 Day Care Center

Currently, a day care center is located north of the former Camp Davis Laundry, possibly in the area where storage drums were stockpiled at the end of World War II. It is believed that the majority of the drums in this area contained White Spirits, a non-chlorinated petroleum distillate. However, one drum was analyzed around 1947 by the University of Iceland, and that drum contained what was termed "tetrachlor," which is presumably PCE. Transport of groundwater from this area, is generally east. The Njardvik East Well might be affected by VOCs originating from this area.

2.4.4 Former Iceland Salvage Facility

The former Icelandic Salvage facility which was located in the Nickel Area was destroyed by fire in 1964. Reports indicate that at the time of the fire, at least one of the buildings contained petroleum products. Groundwater contamination by TCE and CTC appears to originate in this area as suggested by MW-1. Groundwater flow direction in this area is generally east causing the adverse impact to the water quality in the Njardvik East Well as observed in the PA/SI.

2.4.5 Tank Bottom Disposal Area

The Tank Bottom Disposal Area located in the Nickel Area was used during the 1960s and 1970s. Potential groundwater contamination

from this area would be from petroleum hydrocarbons and lead. Groundwater flow direction from this area is generally east, and could influence both the North Njardvik Wellfield and the Njardvik East Well. No VOCs or fuel constituents were detected in either of these wellfields; however, inorganic data were not acquired by the PA/SI.

2.4.6 Fire Training Area

The Fire Training Area, located east of the New International Air Terminal, was used between 1955 and 1983 by the fire department for training. Waste oils and solvents collected from NAS operations were used as fuel sources for the fires. Groundwater flow direction in this area is generally west, although localized flow directions have not yet been well delineated. VOCs potentially introduced into the groundwater from the Fire Training Area activities may, through groundwater transport, be the source of adverse water quality detected by the PA/SI in NAS Wells 1632, 1770, 1773, 1756, and 1792.

2.4.7 Former Municipal Landfill

The former Municipal Landfill located north of the Fire Training Area was used by the local municipalities until 1979. This area lies on the apparent groundwater divide, allowing groundwater flow from this area to be both east and west. Disposal of solvents in the landfill may potentially affect groundwater quality. Groundwater transport along some as yet undelineated structural conduit may have caused the water quality impact observed in the Keflavik North Wellfield by the PA/SI.

2.4.8 Concrete Plant Mound

The concrete plant mound is an area where an unknown substance was reported to have been buried in the early 1960s. Information concerning the specific wastes buried at this area is not available at this time. Groundwater flow direction in this area is generally west, toward NAS Well 1770.

2.4.9 Former Defense Force Landfill

The former Defense Force Landfill, located south of the main NAS-Keflavik installation, was used until 1983. Although localized groundwater flow directions are not well delineated, groundwater flow directions in this area are generally southeast. VOCs potentially arising from the landfill are presently impairing NAS Wells 35 and 36. NAS Well 37 exhibits free-phase oil. NAS Wells 38, 39, and 40 are also southeast and potentially threatened by groundwater transport of VOCs and oil.

2.4.10 Incinerator

The Incinerator, located east of the former Defense Force Landfill, has been in use since 1979. Scrap metal and other nonburnable refuse has been stockpiled at this site. Groundwater flow direction in this area is generally southeast, and may be affecting NAS Well 36 as observed in the PA/SI. NAS Well 37 exhibits free-phase oil potentially from this area, and NAS Wells 38, 39, and 40 are also potentially at risk of water quality degradation.

2.4.11 Seaweed Area

The Seaweed Area, located between the former Defense Force Landfill and the Incinerator, is the area used by Icelandic Prime Contractors (IPC), Keflavik Contractors (KC), and the current Iceland Salvage storage facility. Waste oils and solvents stored in these areas could potentially degrade groundwater quality to the degree detected in NAS Wells 31 and 35 during the PA/SI. Groundwater flow in this area is generally southeast, and groundwater transport from this area could also be adversely impacting NAS Wells 36 and 37. NAS Wells 38, 39, and 40 are also at risk of water quality degradation.

2.4.12 Building 832 Drainage Area

Until 1975, the floor drains in Building 832 discharged to an area east of the building. During aircraft maintenance and repair, oils and solvents that were spilled on the floor were washed into the drains. The drainage area is located directly south of NAS Well 34, and VOCs potentially introduced to the groundwater in this area could be adversely influencing the water quality of that well, as measured during the PA/SI.

2.4.13 Buildings 830 and 832 Drainage Area

Floor drains in Buildings 830 and 831 discharged into the ground south of Building 831. During maintenance and repair of aircraft, oils and solvents which were spilled on the floor were washed into the drain system. Groundwater flow direction for this area appears to be generally north or south. However, localized flow directions in this area have not yet been well defined. If VOCs in the groundwater originated from this area,

they could potentially impair the water quality of NAS Wells 8, 31, and 32 to the degree observed in the PA/SI.

2.4.14 Buildings 796 and 798 Drainage Area

Floor drains in Building 796 and 798 discharge into the ground west and south of the two buildings. In addition, the parking area for aircraft also drains into the ditch west of the apron. During maintenance and repair of aircraft, solvents and oils which were spilled on the floor of the buildings or on the aircraft parking apron were washed into this drainage area. This drainage area is immediately west of the Building 830 and 831 drainage area. Groundwater flow in this area appears to be generally south and southwest. VOCs introduced to the groundwater in this area may be adversely impacting the groundwater quality of NAS Well 8.

2.4.15 Building 781 Drainage

Floor drains in Building 781 discharge into the ground west of the building. Solvents used in this building include paint thinners, strippers, and methyl ethyl ketone. Spills are washed into floor drains. Groundwater transported from this area is generally east and west. The degraded water quality measured in NAS Well 34 potentially originated from this area. Alternatively, the water quality of the Accoustic Facility well (AF or HH) may be threatened from this potential source.

2.4.16 Taxiway K Tank Bottom Disposal Area

A tank bottom disposal area was reported west of the new International Air Terminal and north of Taxiway K. Disposal of

tank bottoms in this area could potentially cause introduction of petroleum hydrocarbons and lead into the groundwater. Groundwater flow direction in this area is generally west toward NAS wells 1756, 1770, 1773, and 1792. No VOCs or hydrocarbons were detected in these wells; however, no inorganic analyses were performed by the PA/SI.

2.4.17 Former Camp Geck Area

The former Camp Geck area, located south of the Taxiway K Tank Bottom Disposal Area, was used during World War II by the British for aircraft maintenance and repair. Disposal practices of waste solvents and oils from the aircraft maintenance are not known. Groundwater flow direction in this area appears to be generally west toward NAS Wells 1756, 1770, 1773, and 1792, and could be causing the VOCs detected in these wells during the PA/SI.

2.4.18 West End Complex

The West End Complex, located west of the former Camp Geck area, is used for the maintenance and repair of aircraft. Floor drains within the buildings at this complex discharge into the ground. Waste oils and solvents that were spilled within these buildings were washed into the floor drains. The groundwater flow direction in this area is generally west toward NAS Wells 1770, 1773, and 1792, which may be adversely impacted by VOCs introduced to the groundwater from this area.

3.0 BACKGROUND

3.1 History

Prior to World War II, activities in the study area centered around the fishing towns of Keflavik and Njardvik and included farming and sheep ranching outside the towns.

The presence of the defense force in the study area began in the early 1940s, when the British built Meeks Field and Camp Geck (Figure 3-1). The U. S. military presence in Iceland began in 1942. During World War II, the U. S. Army Air Force constructed Patterson Field and was the primary military force in the Keflavik area; the British were primarily in Reykjavik.

In 1947, the British and U. S. military forces departed Iceland, leaving a private company, the American Overseas Airlines, as the caretaker of Meeks and Patterson Fields at Keflavik. American Overseas Airlines operated these airfields until 1952.

When Iceland joined NATO in 1952, a NATO base was established at Meeks and Patterson Airfields. The NATO agreement specified that the United States would operate the facility. The area set aside for the NATO operation has been designated as the Agreed Area. From 1952 to 1961, the U. S. Air Force operated the NATO facility. In 1961, the U. S. Navy assumed the responsibility of operating the NATO facility.

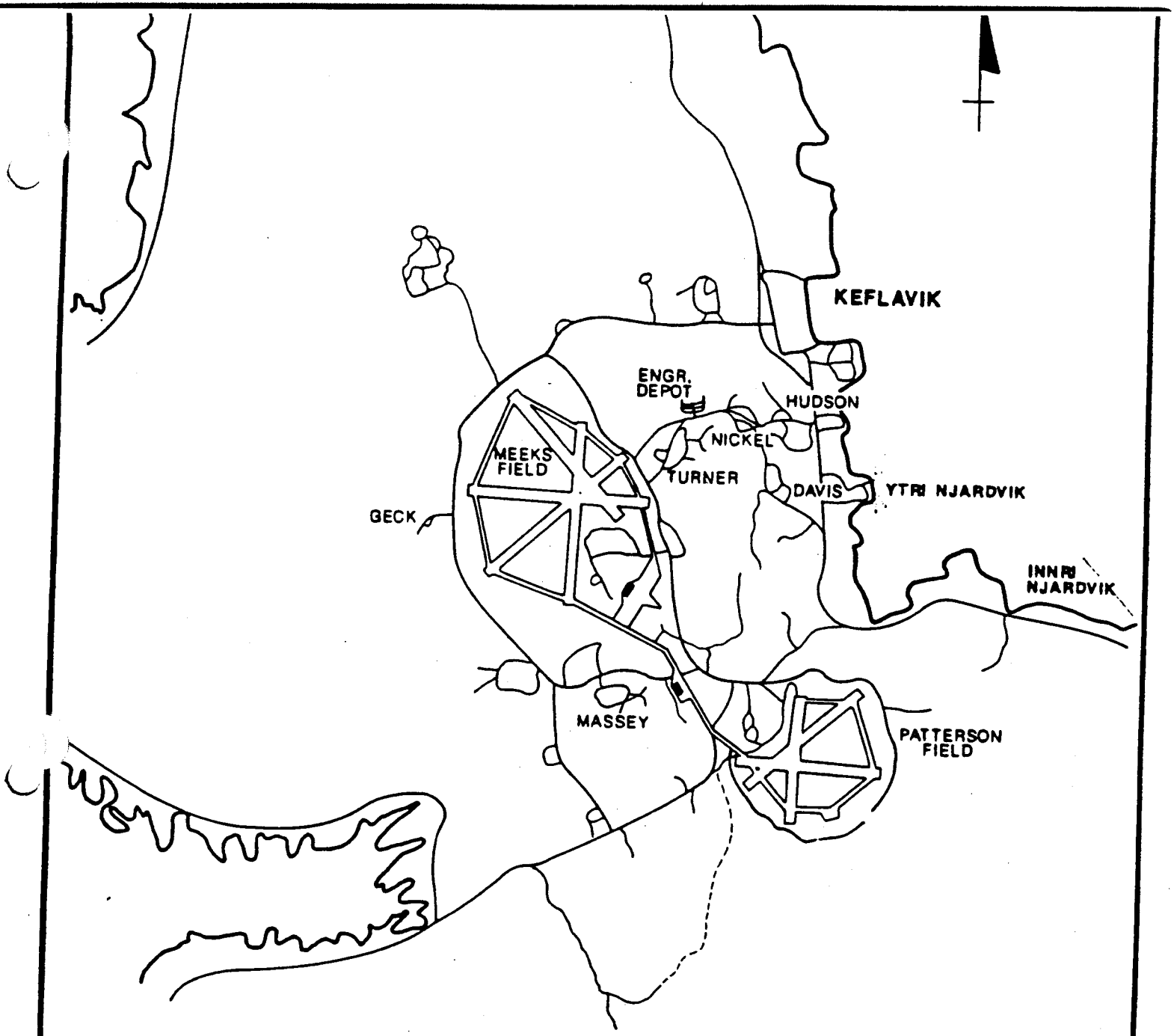


FIGURE 3-1

NAVY - NAS
KEFLAVIK, ICELAND

WORLD WAR II SITE LAYOUT

RAM	JLW	87040-069-AA
JLW	2-8-89	

r. e. wright associates, inc.
earth resources consultants

BASE MAP: PREPARED FROM 1944 MAP FROM THE OFFICE OF ENGINEERING, KEFLAVIK 824th ENGR. BN.

3.2 Site Geology

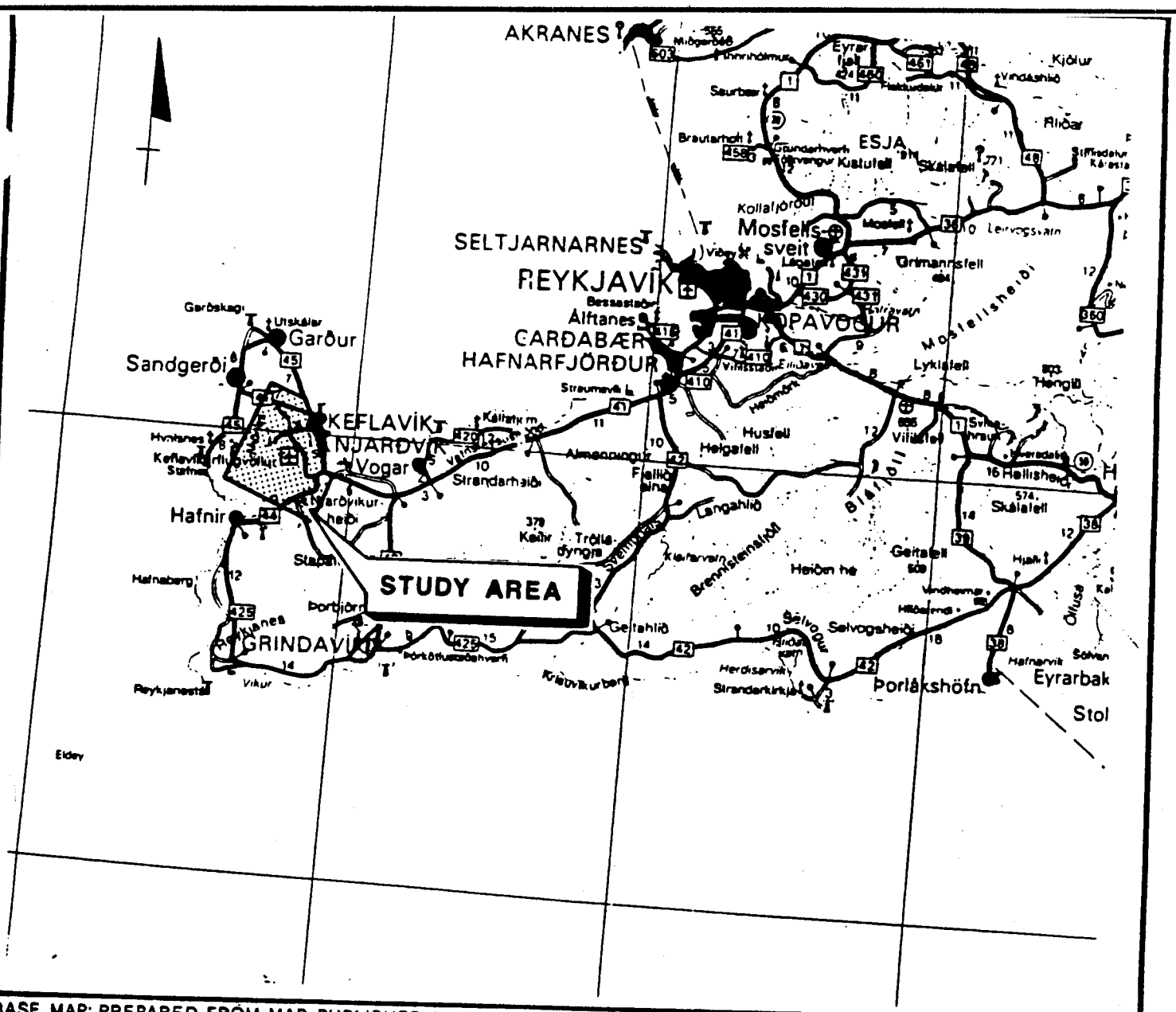
3.2.1 Bedrock

Iceland is located along the mid-Atlantic ridge in the Northern Atlantic Ocean. The project study area, comprised of the U.S. Naval Air Station (NAS Keflavik) and the municipalities of Keflavik and Njardvik, is located on the Rosmhvalanes Peninsula of the Reykjanes Peninsula in southwest Iceland (Figure 3-2).

The bedrock formations of the Reykjanes Peninsula are volcanic in origin and of Neo-pleistocene Age. Within the study area, the surficial bedrock is olivine tholeiite basalt derived from one or more shield volcanoes of the interglacial period. The former volcanic craters were located near Rockville, Haaleiti, and Vogastapi (Figure 3-3). Lithologic types in the study area vary from relatively dense basalt to highly porous vesicular basalt (containing entrained gas bubbles) and scoria (broken basalt). Lithologic types vary greatly laterally and vertically, resulting in a heterogeneous and anisotropic character in the bedrock.

3.2.2 Structure

Bedrock structure is sheet-like with a general regional dip to the west. Due to the great lithologic variation, correlation of individual sets of lava flows or interbedded scoria pockets is not possible. Dikes and lava tubes (voids in the solidified lava) are also potentially present in the subsurface. The tectonic pattern of the Reykjanes Peninsula consists of extensional lineations oriented southwest/northeast. No detailed



BASE MAP: PREPARED FROM MAP PUBLISHED BY LANDMEALINGAR ISLANDS (ICELAND GEODETIC SURVEY-1986)

SCALE 1:500,000

FIGURE 3-2

NAVY - NAS

KEFLAVIK, ICELAND

LOCATION MAP

drawn RAM	designed LW	drawing no. 87040-068-AA
checked LW	date 1-23-89	

r. e. wright associates, inc.
earth resources consultants

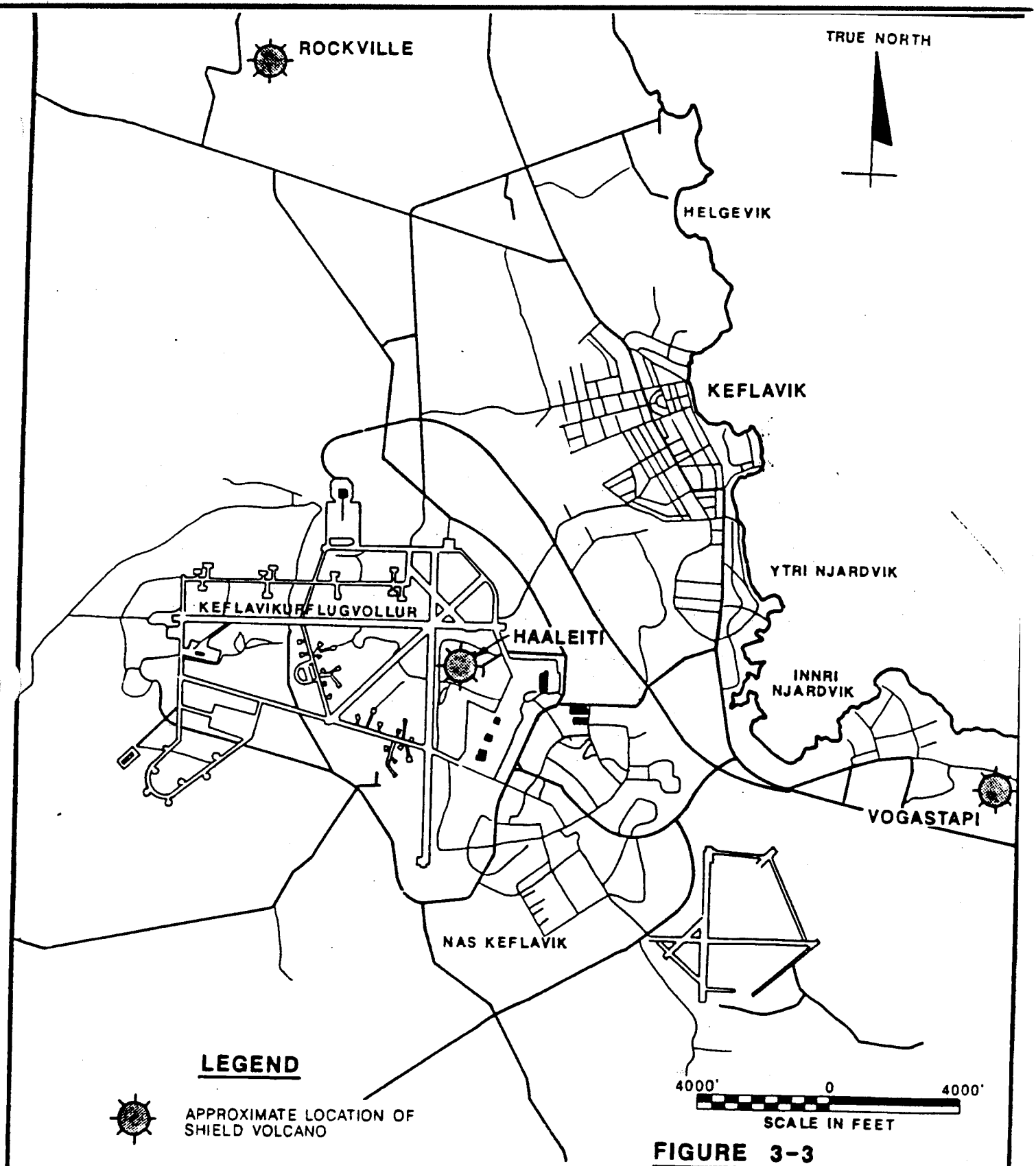


FIGURE 3-3

NAVY - NAS
KEFLAVIK, ICELAND

LOCATION MAP OF SHIELD VOLCANOES

Drawn RAM	Approved JLW	Drawing No. 87040-070-AA
Checked LW	Date 2-3-89	

r. e. wright associates, inc.
earth resources consultants

BASE MAP: PREPARED FROM MAP PUBLISHED BY LANDMAELINGAR ISLANDS (ICELAND GEODETIC SURVEY) AND DMAHTC USA.

mapping of fissures or faults has been carried out in the study area.

3.2.3 Soil and Morphology

Soil cover in the study area is thin, ranging from zero to eight feet in test pits dug on the site. The soil consists of washed ground moraine, from the last period of glaciation. This soil is well graded and consists of moderate reddish to yellowish-brown fine sand and silt liberally interspersed with a large percentage of pebbles, cobbles, and boulders.

The undisturbed surface morphology of the study area is described in local terms as "Moi." This terrain is characterized by a lava flow topography of mounds and closed depressions, vegetated by mosses and grasses.

3.3 Site Hydrology

3.3.1 Aquifer Description

The predominant groundwater producing unit (aquifer) is that portion of the basaltic bedrock which contains a freshwater "lens," which ranges from 100 to 200 feet thick, overlying a saltwater bearing strata. The aquifer character appears to be dominated by the porous nature of the bedrock and the interconnection of voids. The porosity of the bedrock ranges between one and ten percent (Ingimarsson et al, 1978). Consequently, the aquifer generally has a high hydraulic conductivity. As a result, groundwater yields to wells are very

high, although no estimates of specific capacities are given in the literature.

Estimates of aquifer transmissivity (T) derived from a pumping test at Sandgerdi indicate magnitudes which are very high, on the order of five to seven million gallons per day per foot (Mgpd/ft). Storativity coefficients from that test were also relatively high at 0.01, which suggests an unconfined aquifer in that location. The parameters produced by this test may not be entirely representative of the aquifer in other portions of the peninsula due to the heterogeneous and anisotropic character of the bedrock.

A pumping test was performed in the Nickel Area on monitoring well MW-11 during the investigation of the October 1987 fuel spill. Due to the high transmissivities and a pumping rate restriction, set by the Icelandic Government, of 200 gallons per minute (gpm), the test did not draw the aquifer down enough to obtain an accurate analysis of the aquifer coefficient transmissivity and storativity. However, tidal influenced groundwater fluctuation recorded during the test were used to calculate the ratio of transmissivity versus storativity (T/S) (Todd 1979). Based on the observed tidal time lag and amplitude attenuation between the coastal waters and the aquifer, the calculated T/S ratio is 6,740 square feet per minute (ft^2/min) (Appendix G). Based on this ratio and assuming that the aquifer storativity coefficient equals 0.01, the transmissivity solved by the calculation is approximately 7.26×10^5 gpd/ft.

3.3.2 Groundwater Storage, Recharge, and Use

The study area occupies approximately 25 square miles of the Rosmhvalanes Peninsula. The freshwater lens is estimated to range from between 100 and 200 feet thick. Based on the range of porosities provided by the literature (0.01 to 0.10) and an average lens thickness, between 10 and 100 billion gallons of fresh groundwater underlies the study area.

Rainfall on the Reykjanes Peninsula ranges from 32 to 54 inches per year (Icelandic Meteorological Office), and evapotranspiration is estimated at 16 inches per year (Ingimarsson et al, 1978). Runoff is considered negligible. Estimated infiltration and groundwater recharge of the aquifer is 35 inches per year (1.7 Mgpd/miles^2) (Ingimarsson et al, 1978). In the 25 square mile (mi^2) study area, this recharge amounts to approximately 16 billion gallons per year.

Water use on the Rosmhvalanes Peninsula is concentrated in the populated areas, including the Keflavik and Njardvik wellfields located along the eastern coast of the peninsula, and the NAS Keflavik Wellfield located in the southern portion of the peninsula. Together, these wellfields pump 1.5 billion gallons per year (4 Mgpd) of groundwater from the aquifer. Specifications on the wells in the study area are listed in Table 3-1.

The Keflavik wellfields consist of the north and south wellfields. The Keflavik North Wellfield employs three wells ranging in depth from 140 to 158 feet. These wells are all generally 14 inches in diameter and the individual yield of each well is not known. The combined yield for the Keflavik North

Table 3-1

NAS-Keflavik, Iceland
Well Specifications

Well Location	Approximate Grade Elevation** (ft ASL)	Depth** (ft)	Casing** Depth (ft)	Casing** Diameter (inches)	Approximate Static Water Elevation (ft ASL)	Approximate** Pumping Rate (gpm)
Keflavik North No. 3 (KN)	108.6	157.5	6.6	18.625	3.4*	1390a
Keflavik South No. 5 (KS)	NA	101.7	9.8	8	3.2*	208a
Njardvik North No. 2 (NN)	23.0	32.8	NA	6	2.5*	208a
Njardvik East (NE)	NA	69.0	NA	6	1.5*	NA
Njardvik South (NS)	NA	65.6	9.8	8	4.3*	NA
Nickel Area MW-1	46.6	223.1	19.7	8.625	2.8*	0
Nickel Area MW-8	66.3	98.4	18.4	8.625	3.0*	0
Rockville (R)	108.3	NA	NA	6	3.8*	NA
Stapafell No. 1 (S)	51.5	101.7	4.3	10	3.5*	NA
Accoustic Facility (AF or HH)	NA	157.5	9.8	16.5	3.4*	NA
NAS No. 8	146.53	181.1	163.0	20	3.7*	NA
NAS No. 31	113.03	NA	124.0	6	4.3**	180
NAS No. 32	140.27	NA	156.5	6	3.6**	180
NAS No. 34	157.20	NA	179.7	6	3.7*	180
NAS No. 35	110.44	NA	137.5	8	0.66**	150
NAS No. 36	96.20	NA	134.0	8	3.4*	80
NAS No. 37	81.50	NA	120.0	8	3.0**	150
NAS No. 38	70.70	107.9	107.9	8	3.4*	180
NAS No. 39	58.80	NA	96.0	8	2.8*	150
NAS No. 41	156.0	NA	184.1	8	3.6*	200
NAS No. 47 (1632)	139.8	NA	NA	NA	3.5*	150
NAS 1770	NA	NA	NA	NA	3.0*	NA
NAS 1792	86.6	NA	NA	NA	4.3**	NA
NAS 1773	NA	NA	NA	NA	NA	NA
NAS 1756	NA	NA	NA	NA	NA	80

NA - Information Not Available
* - Mean Low Water Elevation During PA/SI Monitoring
** - Appendix A, Table 1
a - Wells are not indiviudally metered, only approximate combined flow available.

Wellfield is two Mgpd. The Keflavik South Wellfield consists of two wells, 95 and 102 feet in depth. Wells are 12 and 8 inches in diameter and combined they yield 0.3 Mgpd. Individual well yields for the Keflavik South Wellfield is not known.

The Njardvik wellfields consist of the Njardvik North, Njardvik East, and the Njardvik South wellfields. The Njardvik North Wellfield consists of five wells ranging in depth from 43 to 63 feet. These wells range from 6 to 17.5 inches in diameter and the yield for each well is not known. The combined yield for the Njardvik North Wellfield is 0.7 Mgpd. The Njardvik East Wellfield consists of one well, 69 feet deep, and 6 inches in diameter. Yield for this well is unknown. The Njardvik South Wellfield consists of one well 66 feet in depth. This well is 8 inches in diameter and its yield is unknown.

NAS Keflavik employs 9 wells for supply, and these range from 59 to 156 feet in depth. The combined NAS groundwater use is approximately one Mgpd. Individual well yields are not known for all wells, as testing was inconsistently performed (Appendix A).

3.4 Groundwater Quality

3.4.1 Significance of VOCs

The groundwater at NAS Keflavik and surrounding communities has been degraded by volatile organic chemicals (VOCs). The most widespread and potentially serious groundwater degradation has occurred as a result of a class of VOCs which are chlorinated solvents. Non-chlorinated hydrocarbons, derived from spilled fuels, are also present in the groundwater, but pose less

potential impact due to their limited areal extent and relatively lower toxicity.

In order to provide a reference for assessing the water quality impacts potentially resulting from spills or improper disposal of these compounds in the study area, it is important to delineate the significance of the detected VOCs. During and since World War II, many of the detected VOCs have had widespread uses both in industry and in the home as solvents and cleaning agents. Industrial utilization of these materials in the study area is frequent and varied as summarized in Section 4.0. Because of the previously unknown toxic effects of the materials and lack of suitable disposal facilities, their improper disposal has resulted in their introduction into the groundwater system. Consumer products such as spot removers, rug cleaners, textile treatments, and automotive products also contain the VOCs detected in the groundwater in the study area. Although assessment of the by-products of household use of solvents was not part of the study, the effects of improper disposal from household use may have resulted in some of the VOCs detected in municipal wellfields.

The United States Environmental Protection Agency (EPA) Office of Drinking Water has established Maximum Contaminant Limits (MCLs) for most of the VOCs degrading groundwater quality in the study area. MCLs were established for drinking water from toxicological data projected for long-term exposures in the context of economic or technological feasibility of treatment. The value presented by the MCLs indicates the level of a contaminant in drinking water at which adverse health effects would not be anticipated, with a margin of safety. Water quality guidelines for VOCs have been established by the World Health

Organization (WHO). These criteria are similar to the MCLs established by the EPA except that WHO has a criteria for PCE and EPA has set goal (MCLG) for that substance. The relevant guidelines and criteria for the VOCs detected in the groundwater of the study area are listed in Table 3-2.

Relatively small quantities of solvents can degrade large volumes of groundwater to concentrations exceeding the MCLs. For example, 1 gallon of TCE can contaminate nearly 300 million gallons of water to the MCL concentration of 5 micrograms per liter (ug/l). For the purposes of perspective, the equivalent of 34 to 340 gallons of TCE dissolved and evenly distributed in the estimated 10 to 100 billion gallons of groundwater in the study area would be required to to exceed the MCL.

The mobility of VOCs in the groundwater flow system is relatively high, but the degree is dependent on their solubility in water, sorption to organic materials in the aquifer, volatilization rate, and degradation rate. In general, mobility is greater with substances which are relatively high in solubility. Sorption of VOCs to soil/rock surfaces depends on the organic carbon content in the aquifer and the affinity of the solvent for organic carbon with respect to water solubility. The degree of sorption influences both the velocity of migration and the concentration of the solute in transport in the groundwater flow system. Where water containing VOCs is exposed to air, loss of organics reduces the concentrations in transport. The rate of volatilization from groundwater is dependent on the vapor pressure and the water solubility as stated by Henry's Law. Degradation of VOCs occurs by microbial dehalogenation and hydrolysis or oxidation. High degrees of chlorination, low concentrations, and low temperatures tend to limit microbial metabolization rates, which are

7040

Table 3-2

Relevant Guidelines, Goals and Maximum Contaminant Limits (MCLs) for Volatile Organic Chemicals (VOCs) in Drinking Water (all units ug/l)

Parameter	World Health Organization (WHO)	U. S. Environmental Protection Agency (EPA)
Bromoform	100.0a	100.0a
Carbon Tetrachloride (CTC)	5.0	5.0
Chlorodibromomethane	100.0a	100.0a
Dichlorobromomethane	100.0a	100.0a
1,1-Dichloroethane (1,1-DCA)	5.0	5.0
1,1 Dichloroethylene (1,1-DCE)	7.0	7.0
Cis-1,2 Dichloroethylene (C-1,2-DCE)	70.0	70.0
Tetrachloroethylene (PCE)	10.0	5.0b
Toluene	2000.0b	2000.0b
1,1,1-Trichloroethane (1,1,1-TCS)	200.0	200.0
Trichloroethylene (TCE)	5.0	5.0

a = Total Trihalomethanes not to exceed 100 ug/l

b = MCL goal

NA = Not Assigned

relatively slow. Hydrolysis or oxidation rates tend to be slower degradation mechanisms than microbial (Smith and Dragun, 1984).

3.4.2 Properties of Detected VOCs

Trichloroethylene (TCE), which possesses the most notably high concentrations at the site, has many uses. These uses include metal degreasing, dry cleaning, solvents for grease, refrigerants and heat exchange liquids, organic synthesis, and even the removal of caffeine from coffee.

TCE is a colorless, volatile liquid with a high specific gravity which is 1.46 times that of water. Its solubility in water is 1,100 mg/l at 25 °C, with increasing solubility at lower temperatures such as those observed in the groundwater at the site (Verschueren, 1977). As a result of the limited solubility and high specific gravity, this compound, when introduced into the groundwater system in high concentrations, would tend to sink to the bottom of the aquifer (Petura, 1981). During its infiltration, some of the compound would be carried into solution in the groundwater.

TCE in solution in groundwater at the concentrations observed on-site would not migrate by a density differential as would the pure substance. The difference in specific gravity between pure water and the solution of dissolved TCE in groundwater is insignificant and the solution would migrate by groundwater transport. TCE in solution with water in the study area is highly mobile because of its relatively high solubility and the low organic carbon content of the aquifer. The degradation products of TCE may include cis-1,2-dichloroethylene (cis-1,2,-DCE), trans-1,2-dichloroethylene (t-1,2-DCE), and

vinyl chloride (VC) (Smith and Dragun, 1984). Vinyl chloride has not been detected in the groundwater of the study area.

1,1,1-trichlorethane (1,1,1-TCA) has been used in the study area as a degreasing solvent. This solvent can be substituted for TCE because of its similar degreasing capabilities and relatively lower toxicity. 1,1,1-TCA is a colorless volatile liquid with a solubility in water of 4,400 mg/l at 20°C, and a specific gravity 1.35 times that of water (Verschueren, 1977). The behavior of 1,1,1-TCA in the groundwater system is similar to that of TCE except for its higher solubility in water and accompanying higher mobility. Degradation products of 1,1,1-TCA may include acetic acid, 1,1-dichloroethane (1,1-DCA), 1,1-dichloroethylene (1,1-DCE), chloroethane, c-1,2-DCE, and VC (Smith and Dragun, 1984). Chloroethane has not been detected in the groundwater of the study area.

Tetrachloroethylene, also known as perchloroethylene (PCE), is a dry cleaning and a metal degreasing solvent. PCE is a colorless, volatile liquid with a specific gravity of 1.63 and a solubility in water of 150 mg/l at 20°C. The high solubility of PCE in water accounts for its high mobility in the groundwater system. Degradation products from PCE may include TCE, c-1,2-DCE, t-1,2-DCE, and VC.

Carbon tetrachloride (CTC) is a cleaning and degreasing solvent. It is a colorless volatile liquid with a specific gravity of 1.59 at 20°C and solubility in water of 1,160 mg/l at 25°C. CTC is very mobile in the groundwater system because of its high solubility. Degradation products of CTC are chloroform,

methylene chloride, and methyl chloride, none of which were detected on-site.

Dichloroethylene (DCE) is a solvent used in various manufacturing processes, but is not documented to be in use in the study area. However, the compound may be found in trace concentrations (less than one percent) as a degradation product or an impurity in industrial grade TCE and PCE. DCE has three isomers: 1,1-dichloroethylene (1,1-DCE), cis-1,2-dichloroethylene (c-1,2-DCE), and trans-1,2-dichloroethylene (t-1,2-DCE). DCEs are clear, colorless, highly volatile liquids with specific gravities and solubilities of 1.22 and 2,500 mg/l at 20°C, respectively, for 1,1-DCE, 1.28 and 800 mg/l at 20°C for c-1,2-DCE, and 1.26 and 600 mg/l at 20°C for t-1,2-DCE. Their relatively high solubilities may be responsible for the high mobility of DCE in the groundwater. Of the DCE isomers, t-1,2-DCE was not detected in the groundwater in the study area.

Dichloroethane (DCA) has major industrial uses as a chemical intermediate, and as a degreasing and extraction solvent. Although no use of this solvent is documented in the study area, DCA may be a degradation product of or found in trace quantities (less than one percent) in industrial-grade 1,1,1-TCA. Dichloroethane (DCA) has two isomers: 1,1-dichloroethane (1,1-DCA) and 1,2-dichloroethane (1,2-DCA). Of the isomers of DCA, 1,2-DCA has not been detected in the study area groundwater. 1,1-DCA is a colorless, volatile liquid with a specific gravity of 1.17 and a solubility in water of 5,500 mg/l at 20°C. The high solubility of DCA is responsible for its high mobility in the groundwater system.

Bromoform, dichlorobromomethane, and chlorodibromomethane are grouped into a family of organic chemicals known as trihalomethanes. Trihalomethanes are typically formed as

accessories with chloroform during the chlorination process of drinking water disinfection. Trihalomethanes are very mobile in the groundwater flow system due to their high solubilities, and they have been detected in the study area groundwater.

Toluene is used as a solvent for paints and coatings, adhesives, resins, rubber, and vinyl organols, and is a component of gasoline. Toluene is soluble in water to 515 mg/l at 20°C and the specific gravity is 0.87. Toluene will float on the water table because of its lighter gravity. It is not as mobile in the groundwater system because it has an affinity for adsorption to soil and rock surfaces. Toluene is degradable in the subsurface, and the end products are eventually CO_2 and water. However, the intermediate products are not well documented in the literature. Toluene was detected in study area groundwater.

In summary, the widespread applications and use of the solvents in the study area, particularly in operations requiring cleaning and degreasing, constitute a significant risk of accidental groundwater contamination. This fact in combination with the relatively high mobility of VOCs, the small quantity required to obtain concentrations in groundwater exceeding relevant guidelines and criteria, and the relatively slow rates of degradation serve to illustrate the risk of VOC contamination of groundwater.

3.4.3 Inorganic Chemicals

On the Rosmhvalanes Peninsula, groundwater sampling has occurred intermittently over the last 30 years. During the 1980s, sampling frequently has been more regular and consistent than in the past. Inorganic analyses of groundwater samples for the NAS wells have been performed by a variety of laboratories, and limited information is available regarding the historic inorganic

quality of the municipal wellfields. Because of potential inconsistencies from one laboratory to another, a comprehensive assessment of groundwater quality impairment by inorganic chemicals would require a more systematic quality assured sampling and analysis program. Therefore, historical data on inorganic chemicals in groundwater from the NAS wells should remain suspect until adequately resampled, and results verified.

The PA/SI was conducted specifically to assess the occurrence of VOCs in groundwater. Therefore, no groundwater samples were obtained or analyzed for inorganics. Based upon the information available (Appendix A), five inorganic chemicals have been detected in the groundwater in excess of the National Primary and Secondary Drinking Water standards set by the EPA. Iron content (secondary standard 0.3 mg/l) was exceeded in water from NAS Well 20 (1973, 3.400 mg/l) and NAS Well 1975 (1971, 0.304 mg/l). Neither of these wells has been resampled. Also, unacceptable quality for Iron was detected in NAS Wells 38 (1958, 0.60 mg/l and 1971, 0.535 mg/l) and Well 39 (1971, 1.21). Both Wells 38 and 39 were later resampled and shown to have acceptable water quality with regard to iron content. No information is available regarding whether any remedial activities were undertaken to affect this reduction.

The secondary drinking water standard for copper (1.0 mg/l) was exceeded in Well 37 (1984, 127 mg/l). This sample's laboratory report is somewhat questionable because it was unsigned and in a handwritten form, while other laboratory reports of the same time period were signed by the lab manager and typed. This same analysis showed elevated levels of zinc, arsenic, and mercury, all well above relevant standards. Subsequent sampling and laboratory analysis (1986) resulted in more realistic findings for these wells which were within EPA standards. Similar suspect laboratory reports for Wells 34, 36, and 37 were found. In each

case, elevated zinc, arsenic and mercury were reported on handwritten, unsigned laboratory reports. Wells 34 and 37 have subsequently been resampled with acceptable results. However, Well 36 was not resampled, and the results remain unsupported.

4.0 MATERIAL AND WASTE HANDLING

4.1 Introduction

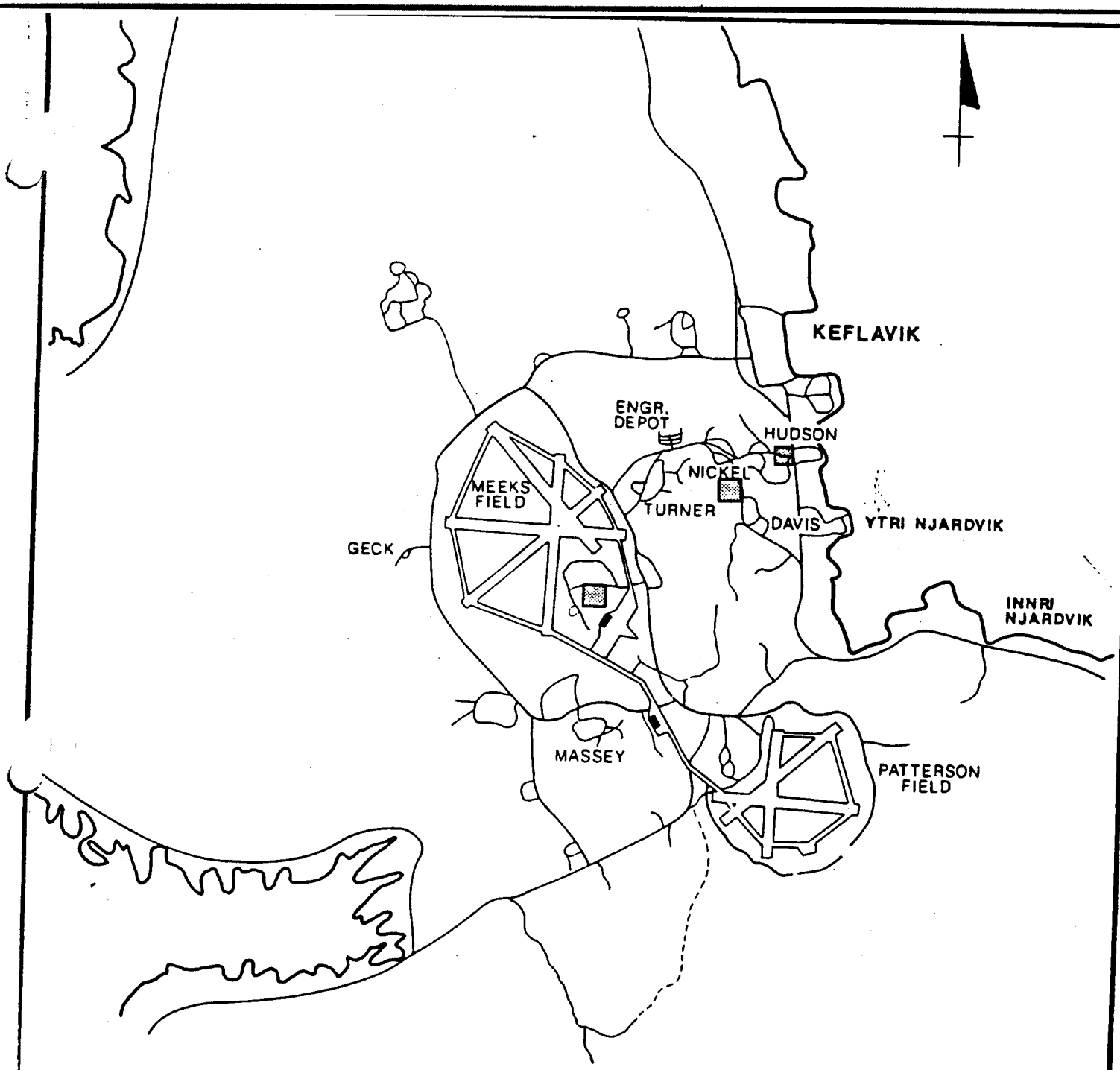
This chapter contains detailed information gathered by REWAI and SPHC during Work Task 2 of the PA/SI. Interview questionnaires and summaries used to produce this chapter are included in Appendix B.

4.2 Fuel Storage and Handling

4.2.1 On the Agreed Area

4.2.1.1 Fuel Storage and Handling - During World War II, the U. S. Army Air Force provided and distributed fuels and oils for aircraft, vehicles, and heating. Gasoline, diesel fuel, and aviation gasoline were stored in aboveground bulk storage tanks near Camp Hudson, Camp Nickel, and Building 832 (Figure 4-1). The bulk storage tanks at each location were bolted together. Seams of the tanks were sealed with rubber gaskets. A total of 23 tanks were used during World War II, with each tank having a 165,000-gallon capacity.

In 1947, Oliufelagid Hf. (Esso) began operating the bulk storage facilities. Sixteen of the bolted tanks were replaced in 1949 and 1950 with four aboveground welded tanks. The remaining seven bolted tanks were replaced with five aboveground welded tanks in 1952 and 1953. In 1954, five underground tanks were constructed in the Nickel Area to provide storage for aviation gasoline. Four additional underground tanks were constructed in 1955 to provide additional storage for aviation fuel. All of the



LEGEND

BULK FUEL STORAGE LOCATIONS

BASE MAP: PREPARED FROM 1944 MAP FROM THE OFFICE OF ENGINEERING, KEFLAVIK 824th ENGR. BN.

FIGURE 4-1

NAVY - NAS
KEFLAVIK, ICELAND

WORLD WAR II BULK STORAGE LOCATIONS

drawn DLB	approved JLW	drawing no 87040-096-AA
checked KVL	date 3-15-89	

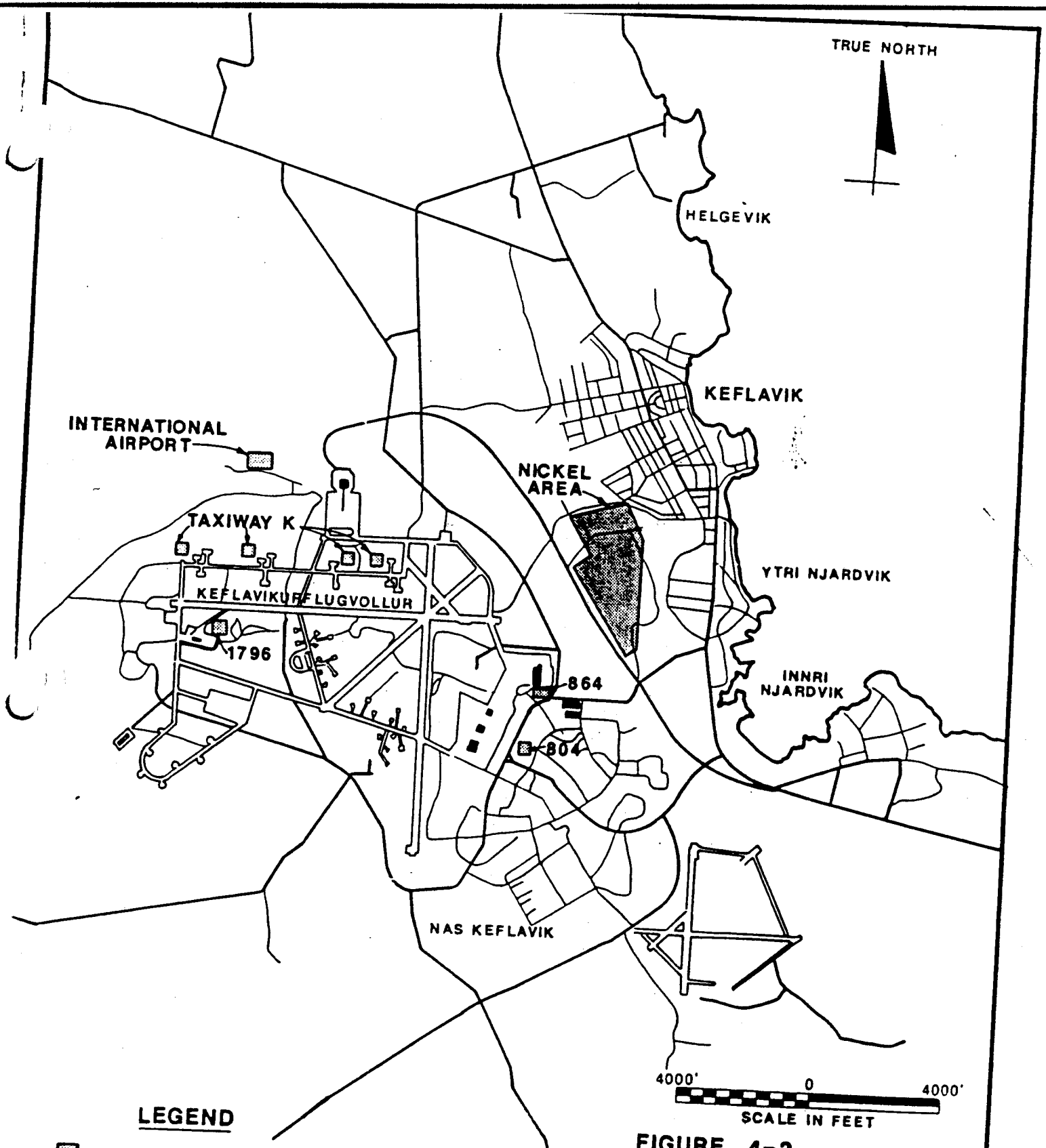
r. e. wright associates, inc.
earth resources consultants
middletown, pa

underground tanks and four of the aboveground tanks in the Nickel Area are still in use.

Additional bulk storage tanks were built in the 1950s and include: two 50,000-gallon underground tanks near Building 893 used for gasoline, JP-4 and JP-5; four 50,000-gallon and one 25,000-gallon underground JP-4 tanks at Taxiway K; three 25,000-gallon underground JP-4 and JP-5 tanks near Building 1796; three 25,000-gallon aboveground JP-4 and JP-5 tanks near Building 864; and four 25,000-gallon aboveground gasoline tanks near Building 804 (Figure 4-2). With the exception of the tanks at Taxiway K, all of these tanks are still in use.

Esso operated the Nickel Area tank farm until 1958. From 1958 to 1961, the U. S. Air Force operated the Nickel Area tank farm. In 1961, BP took over operations of the tank farm and operated the tank farm until 1967. Esso has operated the tank farm since 1967.

Leak detection and prevention practices include weekly visual inspections of all aboveground storage tanks and distribution lines. Underground storage tanks are cleaned and inspected on a five- to seven-year cycle. In addition, monthly inventory control is used for leak detection purposes. Inventory control is a comparison of the amount of fuel received, amount of fuel distributed, and volume of fuel in each tank and distribution line. Inventory control can be inaccurate due to the changes in stored fuel volume expansions and contractions caused by temperature.



LEGEND

BULK STORAGE LOCATIONS

FIGURE 4-2

NAVY - NAS
KEFLAVIK, ICELAND

PRESENT BULK STORAGE LOCATIONS

drawn DLB	approved TLW	drawing no. 87040-097-AA
checked TLW	date 3-15-89	

r. e. wright associates, inc.
earth resources consultants

ASE MAP: PREPARED FROM MAP PUBLISHED BY LANDMAELINGAR ISLANDS (ICELAND GEODETIC SURVEY) AND DMAHTC U.S.A.

Presently, a new bulk storage facility is being constructed at Helgevik. When completed, this facility will replace the aboveground storage tanks in the Nickel Area. Leak detection systems are being installed during the construction of the tanks. The new underground distribution lines for this facility are of double-wall construction, which allows for leak detection of the distribution lines.

4.2.1.2 Refueling - Refueling of military aircraft was carried out by the military during World War II. Esso refueled military aircraft from 1952 until 1958. From 1958 to 1967, military personnel were responsible for the refueling of their aircraft. Since 1967, Esso has been refueling the military aircraft at NAS-Keflavik.

Commercial aircraft at NAS-Keflavik have been refueled by Esso personnel, except for the period from 1961 to 1964 when BP refueled Icelandair aircraft. The JP-1 storage tanks and refueling system at Building 804 have always been owned and operated by Esso (Figure 4-2). A new storage and refueling system has been constructed at the International Airport. This system consists of 3 surface tanks and associated underground fuel distribution pipelines which is operated by a joint venture of the local petroleum companies.

4.2.1.3 Waste Disposal Practices - Various waste disposal practices have been used by the petroleum operations on the Agreed Area. Waste fuel and oils were either given to the fire department for fire training or they were sent to Reykjavik. Fire training consisted of pouring the waste onto the ground at the fire-training area and burning it. Tank-bottom water (water which collects as condensate in the bottom of storage tanks) was

drained onto the ground and allowed to infiltrate until approximately 20 years ago. In the past 20 years, tank-bottom water has been pumped into trucks and discharged through an oil-water separator, which removed the residual fuels. The treated water infiltrated into the ground. An unknown volume of tank-bottom sludge (material cleaned from the bottom of petroleum storage tanks) has been spread on the ground in the Nickel Area and Taxiway K area or containerized and sent to Reykjavik. Currently, all of the waste fuels, oils, and tank-bottom sludges are sent to Reykjavik for disposal. Disposition of the waste in Reykjavik is not known.

4.2.1.4 Spills - Spills have occurred during refueling of aircraft. Esso personnel estimated that the average quantity lost when a refueling spill occurs has been approximately 25 gallons. Until 1985, the spills were washed off the pavement onto the ground by the fire department. Since 1985, spills have been contained by diking and cleaned up by the Hazardous Waste Department of Public Works. To minimize the fire hazard around the old air terminal building, a drain system was installed in 1972 along the east edge of the aircraft parking and loading area. Spills were washed into this drain system and through an oil-water separator. The treated water was then allowed to infiltrate into the ground. At the new air terminal, a drain system has been installed where the aircraft are refueled. This system contains oil-water separators to collect fuel which is spilled during refueling. Treated water discharged from the oil-water separators infiltrates into the ground.

Incidents of fuel and oil storage, handling, and dispensing spills on the Agreed Area were described to REWAI and SPHC personnel by Icelandic and U. S. military personnel during the

interviewing process (Appendix B). Incidents were checked as closely as possible by interviewing people involved with the spills or cleanups. Figure 4-3 shows the location of confirmed spills.

In 1968, a report of spillage of JP-4 occurred during the filling of the tanks at Building 1796. At this time, the U. S. Air Force was operating the system. The spill could not be confirmed by the current Fuels Officer, and no loss amount could be found for this spillage. The water well at Building 1792 was reported to contain fuel from this spill, but analysis of water from the well did not detect fuel constituents.

In 1972, Esso reported a leak in Storage Tank 1311 in the Nickel Area. Between 200 and 300 gallons of diesel fuel were estimated to be spilled. No cleanup was performed in response to this spill.

Also in 1972, a tanker truck was involved in a traffic accident at the corner of Flugvallarbraut and Vesturbraut, on the Agreed Area. An estimated 5,500 gallons of JP-1 were spilled at this site. No cleanup was performed in response to this spill.

During a 1984 test of the rapid refueling system, on the apron west of the old air terminal, a leak occurred when a four-inch high-pressure pipeline broke. An estimated 200 to 300 gallons were spilled before the system was shut off. The spilled fuel was washed into the drain and collected in the oil-water separator.

In 1987, an estimated 20,000 gallons of diesel fuel leaked from an underground pipeline in the Nickel Area. Fuel soaked soil was

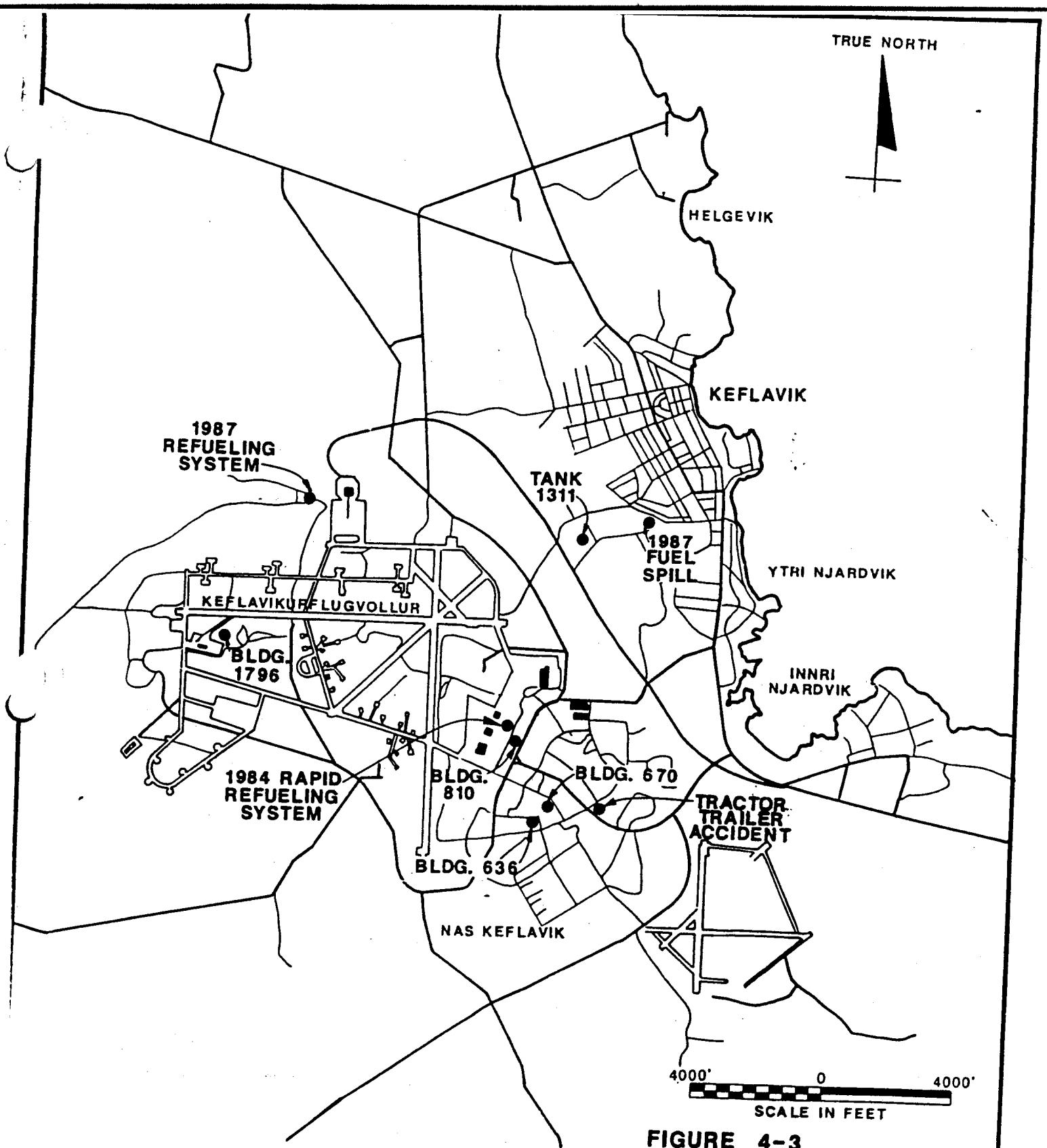


FIGURE 4-3

LEGEND

● LOCATION OF SPILL

BASE MAP: PREPARED FROM MAP PUBLISHED BY LANDMAELINGAR ISLANDS (ICELAND GEODETIC SURVEY) AND DMAHTC U.S.A.

NAVY - NAS KEFLAVIK, ICELAND		
LOCATION MAP OF FUEL SPILLS		
drawn DLB	approved	drawing no. 87040-098-AA
checked	date 3-15-89	

r. e. wright associates, inc.
earth resources consultants
middletown, pa. — westminster, md.

removed and taken to the landfill near Dye-5, a communications facility approximately 2 miles west of the West End Complex where it was spread out to aerate. The fuel which reached the groundwater is currently being recovered from wells drilled in response to the spill using automatic hydrocarbon recovery equipment.

Also in 1987, during the test of the refueling system at the new air terminal, a loss of 150 to 330 gallons of jet fuel occurred in a valve pit. The fuel drained into the ground and no cleanup was done.

Before the heating systems in the buildings were converted to geothermal hot water, three underground fuel oil tanks were located at Buildings 810, 670, and 636. These tanks were suspected to have leaked, because the fuel oil usage at these buildings was significantly higher than at other buildings. However, leakage from these tanks was never confirmed. The tanks were replaced by Esso, but the dates of replacement were not known.

4.2.2 Off of the Agreed Area

Three oil companies are operating in the study area. Osk is the largest and has been operating since 1938. Olis, the middle-sized company of the three, began operating in 1965; and Skeljunjur Hf., the smallest of the local oil companies, opened its Njardvik office in 1960.

Bulk storage facilities for Osk and Olis are centered at the Keflavik Harbor, while the Skeljunjur Hf facility is located in Njardvik Harbor. All three oil companies use aboveground tanks

without any secondary containment basins. Diesel fuel for the fishing industry is the primary storage volume.

Between 1942 and 1976, the oil companies also supplied heating oil to the residents and businesses in the area. After the completion of the geothermal heating system--Hitaveita Sudurnesja (Sudurnes Heating Service)--in 1976, heating oil tanks were removed from all houses and most of the businesses.

Local gasoline stations receive gasoline deliveries by tanker truck from Reykjavik. All of the stations use underground tanks to store the gasoline and diesel fuel. Leak detection practices at the stations and bulk storage facilities consist of inventory control.

In general, waste fuels and oil are collected by the oil companies and sent to Reykjavik. However, in some cases, the waste oil has been poured onto the ground, down the drain, or put into the garbage.

Three measurable spills have been reported by the oil companies. Two spills occurred at Skeljungur in 1987. They were both between 13 and 26 gallons and resulted from the malfunctioning of automatic shutoff valves in tanked trucks. The third spill occurred between 1968 and 1970 at Adalstodin Gas Station, where an estimated 26 to 80 gallons of gasoline were lost. Again, this spill was the result of a malfunctioning automatic shutoff valve. The local fire departments were called to clean up all three spills. Methods used by the fire department to clean up the spills are not known.

4.3 Dry Cleaning Operations

4.3.1 Introduction

Dry cleaning processes utilize organic solvents such as tetrachloroethylene (PCE) as a cleaning media. Due to its common use and potentially inappropriate disposal, PCE contamination of soil and groundwater is suspect for dry cleaning operations.

4.3.2 On the Agreed Area

Dry cleaning operations on the Agreed Area have been limited to two sites. During World War II and until 1949, the dry cleaning facility was located at Camp Davis. Since 1949, the facility has been located in Building 632 (Figure 4-4).

The Camp Davis Laundry operated dry cleaning machines that used PCE which was shipped and stored in five-gallon containers. No information was available on how many machines were used or the method of disposal for any waste products. Typically, waste products include water, sludge, and used air filters--all of which can contain PCE.

The current laundry facility, located in Building 632, operates dry cleaning machines which use PD-680, a Type 2 dry cleaning solvent which is an odorless mineral spirit (non-chlorinated petroleum distillate). Prior to the current machines, the laundry used a PCE machine which was moved from the Camp Davis facility. The PCE machine was used until approximately 1954.

Presently, the laundry is installing a new dry cleaning machine for cleaning leather and silk. The new machine will use

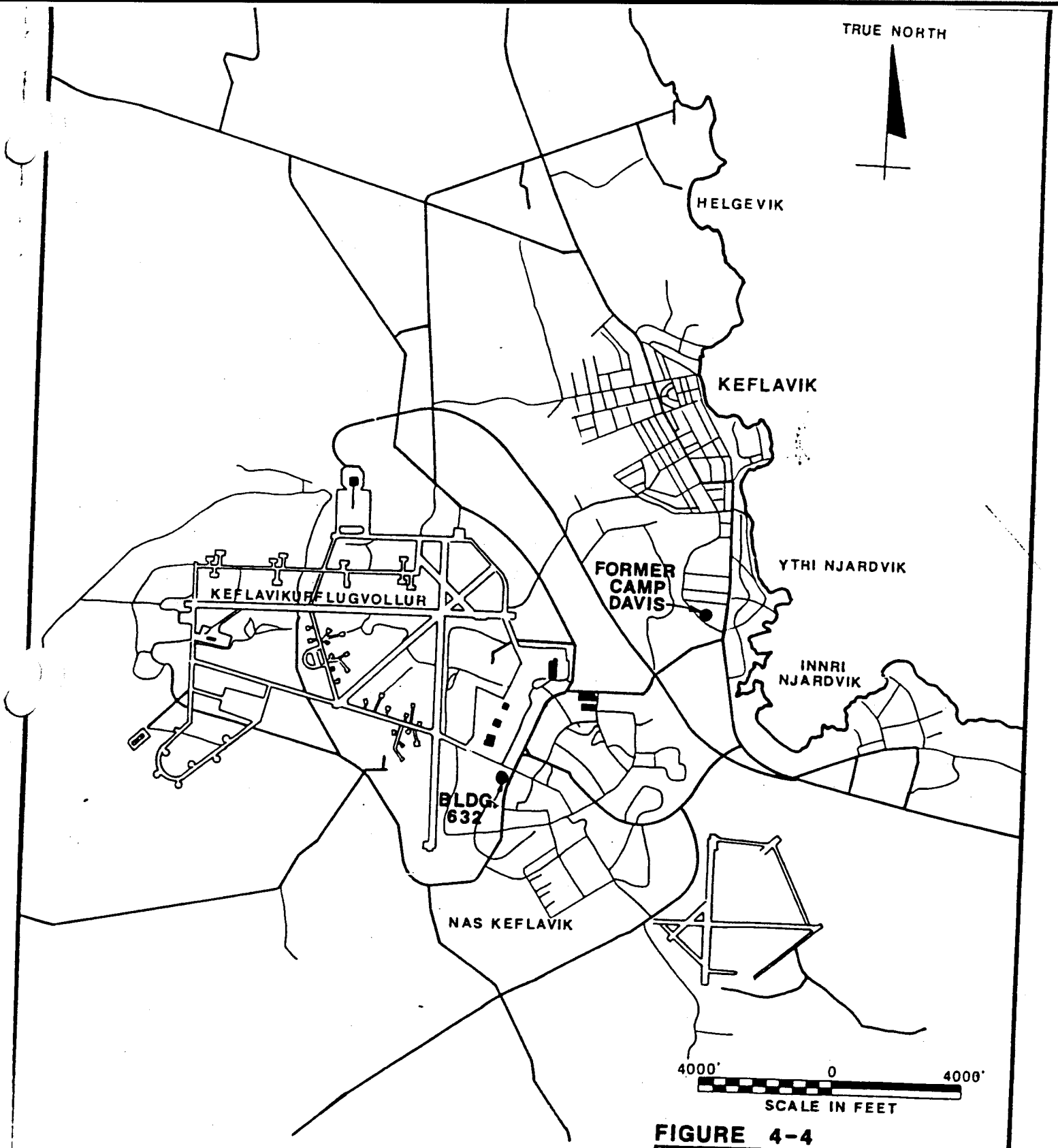


FIGURE 4-4

NAVY - NAS
KEFLAVIK, ICELAND

LOCATION MAP OF MILITARY LAUNDRY FACILITIES

drawn DLB	approved	drawing no. 87040-099-AA
checked	date 3-15-89	

r. e. wright associates, inc.
earth resources consultants
middletown, pa. — westminster, md

LEGEND

● MILITARY LAUNDARY FACILITY

BASE MAP: PREPARED FROM MAP PUBLISHED BY LANDMAELINGAR ISLANDS (ICELAND GEODETIC SURVEY) AND DMAHTC U.S.A.

Another business, located at Hafnargata 30 since 1984, uses PCE as the dry cleaning solvent. At this location PCE is shipped and stored in 55-gallon drums. The dry cleaning machine is a closed system which distills and recirculates the PCE solvent. Approximately 55 gallons of PCE are added to the system each month to replace liquid lost from the system, presumably by evaporation. Waste sludge and air filters are sent to the incinerator for disposal. Wastewater is discharged through the sewer system.

4.4 Vehicle Maintenance

4.4.1 On Agreed Area

4.4.1.1 Transportation - During World War II, most of the vehicle maintenance was done at Camp Massey. No information was available concerning the operations, such as use and disposal practices of solvents, cleaners, and oils at this facility.

After World War II, maintenance of the heavy equipment used to construct the current base was performed where the equipment was working. Waste oils and cleaners were poured onto the ground at these sites.

Presently, the Public Works Transportation Department is responsible for cleaning, repairing, and maintaining the vehicles belonging to the U. S. military stationed at NAS-Keflavik. Most of the mechanical maintenance operations are carried out in Building 501. The paint and body shop is located in Building 534. The wash rack and a tire shop are located in Buildings 507

and 508, respectively. The diesel repair shop is located in Building 546 (Figure 4-6).

Various oils, lubricants, cleaners, solvents, and paints are used and stored by the transportation department. In Building 501, where maintenance of vehicles occurs, motor oils, hydraulic oils, and PD-680 cleaning solvent are used. The paint and body shop uses various acrylic and enamel paints, paint thinners, isopropyl alcohol, toluene, naphtha, ethylene glycol, sulfuric acid, and PD-680. Soap and PD-680 are used at the tire shop. The diesel shop uses SD-2 (a petroleum solvent) and a carbon-removing compound. No information is available about solvents used before PD-680, and no chemical composition is available for the carbon-removing compound.

Prior to 1986, waste disposal practices of the transportation department varied. At times, the waste products were collected and used by the fire department for training. Some of the times, the waste oils and lubricants were containerized and transferred to Military Disposal and were then sold to Icelandic Salvage. At other times, the waste products were disposed of at the Defense Force landfill where they were either burned in pits or placed in the landfill. There appeared to be no uniform policy or methodology for disposal of the waste products in the past--just a random use of the three different methods. Currently, waste oils and solvents are collected by the Public Works Hazardous Materials Office and transferred to Military Disposal. Military Disposal sells the waste to Icelandic Salvage or local companies designated by Icelandic Salvage.

4.4.1.2 <u>Auto Hobby Shop</u> - The auto hobby shop, located in Building 520 (Figure 4-6), is used by Defense Force personnel to

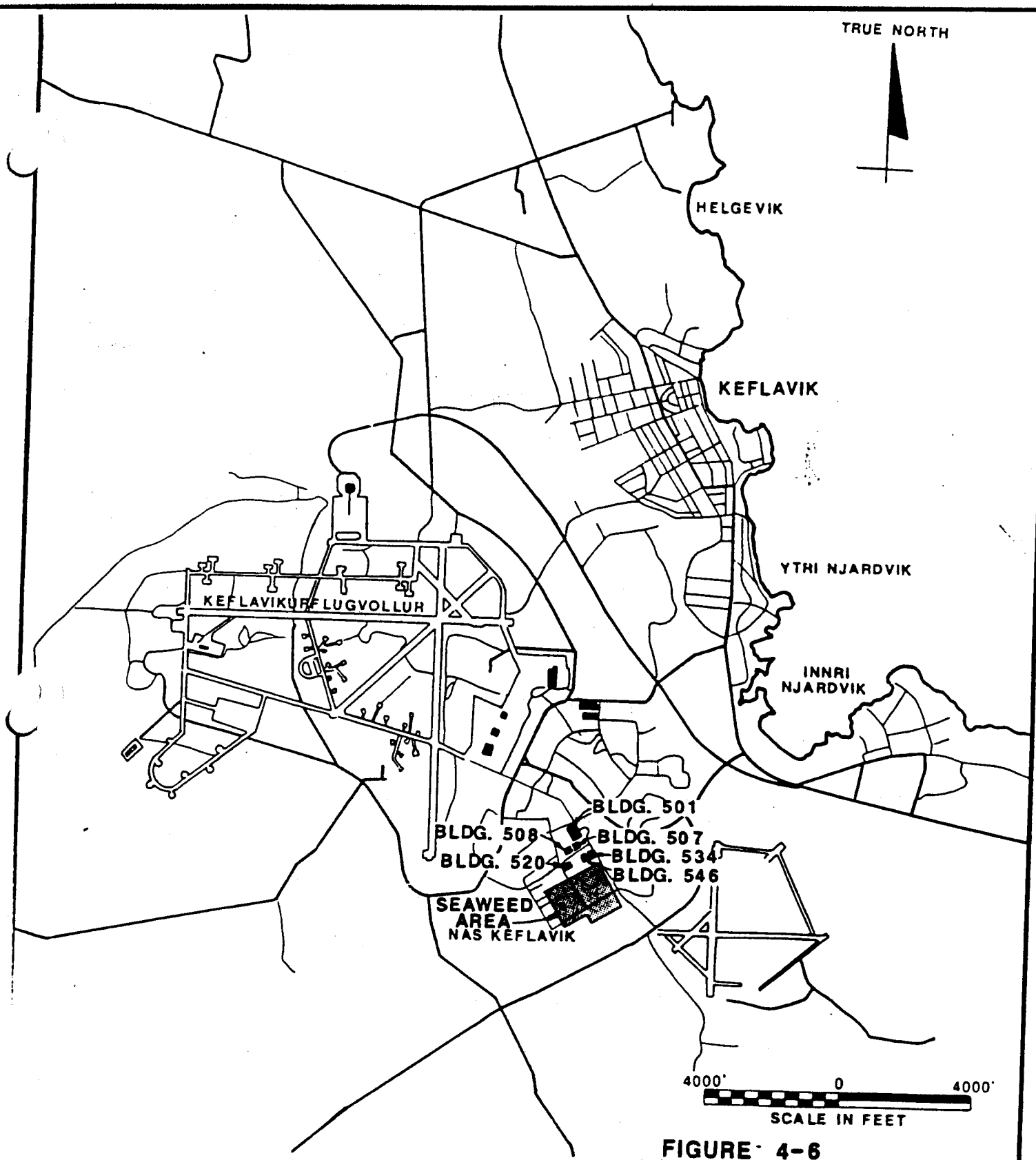


FIGURE 4-6

NAVY - NAS

KEFLAVIK, ICELAND

NAS KEFLAVIK VEHICLE MAINTENANCE LOCATION MAP

drawn DLB	approved JLW	drawing no. 87040-101-AA
checked JLW	date 3-15-89	

r. e. wright associates, inc.
earth resources consultants

BASE MAP: PREPARED FROM MAP PUBLISHED BY LANDMAELINGAR ISLANDS (ICELAND GEODETIC SURVEY) AND DMAHTC U.S.A.

maintain privately owned vehicles. Solvents currently used at this facility include PD-680, methyl ethyl ketone, and 1,1,1-trichloroethane. Waste oils and solvents generated at this facility are stored in drums and tanks. The waste is collected by the Public Works Hazardous Materials Branch and turned over to Military Disposal for sale. Staining of the ground around the waste storage tanks was observed. Information was not available on past storage or disposal of solvents and waste oils at this facility.

4.4.1.3 Icelandic Contractors

4.4.1.3.1 Icelandic Prime Contractors - Icelandic Prime Contractors (IPC) maintenance operations are located in the Seaweed Area (Figure 4-6). IPC also operates and maintains fuel storage tanks for refueling its vehicles and construction equipment. The only solvents which IPC representatives recalled using include white spirits, Sator (an ethylene oxide used in steam cleaning), and trichlorotrifluoroethane. Used lubricating and hydraulic oils and associated filters are also generated by vehicle maintenance.

For the last two years, IPC has collected waste oils and solvents which were then sold to Icelandic Salvage. Prior to that time, IPC collected and sold the waste oils and solvents to Esso, fish factories, and private individuals.

Only minor spills of the solvents, oils, of fuels have occurred and no cleanup was performed according to IPC representatives. Fuel spillage appeared to occur while refueling the storage tanks. Staining of the ground around the refueling area was observed.

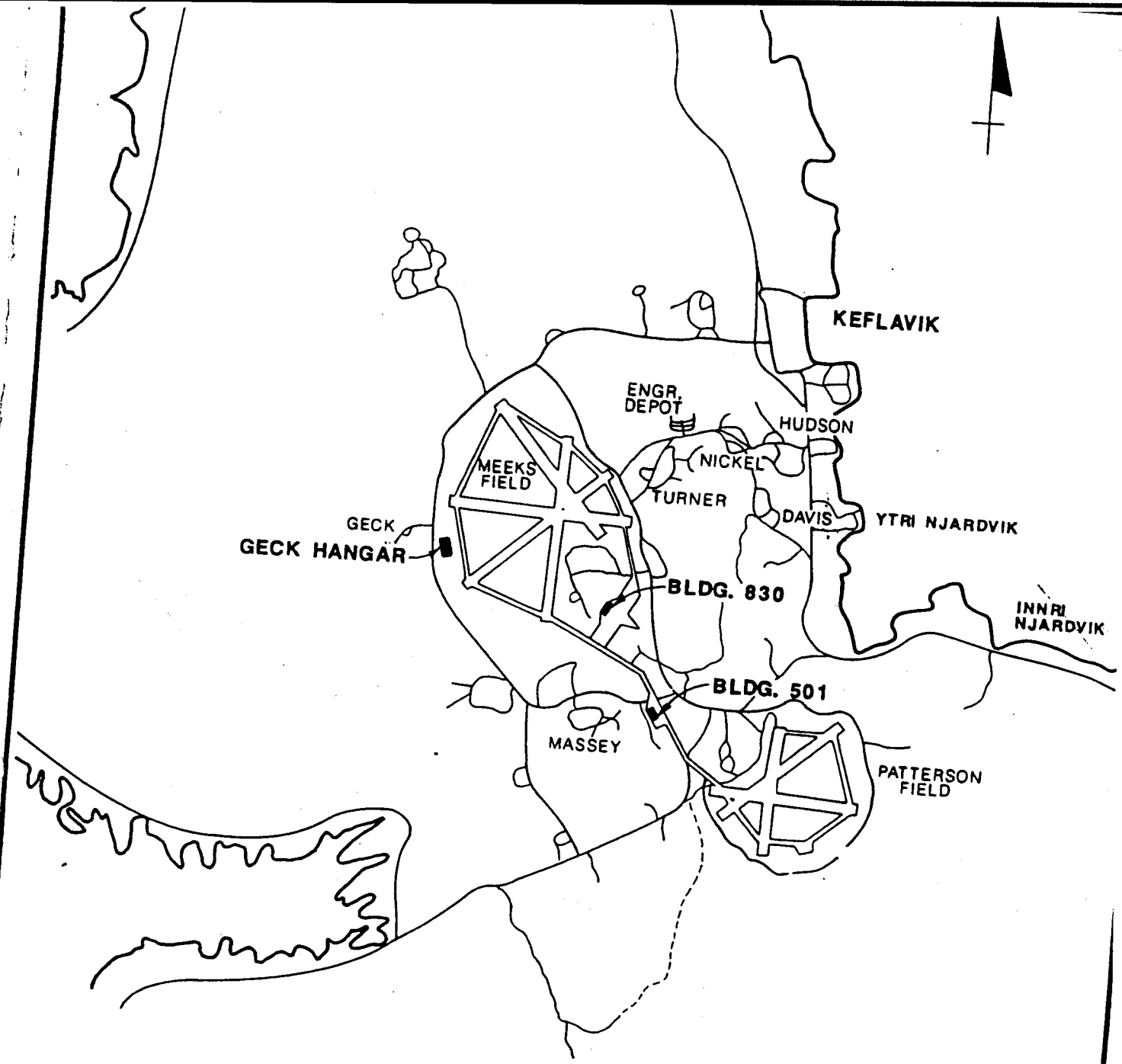
4.4.1.3.2 Keflavik Contractors - Keflavik Contractors (KC) perform maintenance and repair of vehicles and construction equipment in the Seaweed Area (Figure 4-6). Solvents currently used by KC are white spirits and trichlorotrifluoroethane. KC representatives did not recall using any other solvents. Waste solvents generated by KC are poured down drains. Waste lubricating and hydraulic oils are containerized and sold to Icelandic Salvage.

4.5 Aircraft Maintenance

4.5.1 Defense Force

4.5.1.1 Locations - Aircraft maintenance operations performed by Defense Force personnel have occurred in numerous facilities (Figure 4-7). During World War II, the Camp Geck hangar, Building 501, and Building 830 were the primary maintenance facilities used by the British and United States forces. After World War II, as other facilities were being built, the Camp Geck hangar and Building 501 were no longer used for aircraft maintenance. The Camp Geck hangar became the facility where runway deicing and snow removal equipment was stored. Building 501 became the transportation maintenance facility.

Since the early 1950s, aircraft maintenance has been conducted in Buildings 830, 831, 832, and 885 (Figure 4-8). In addition, buildings west of Building 832 have been used to repair engines and electrical components. Ground support equipment used on the flight line has been located in Building 633. In 1982, a corrosion control facility was constructed at Building 781.



LEGEND

■ MAINTENANCE FACILITY

BASE MAP: PREPARED FROM 1944 MAP FROM THE OFFICE OF ENGINEERING, KEFLAVIK 824th ENGR. BN.

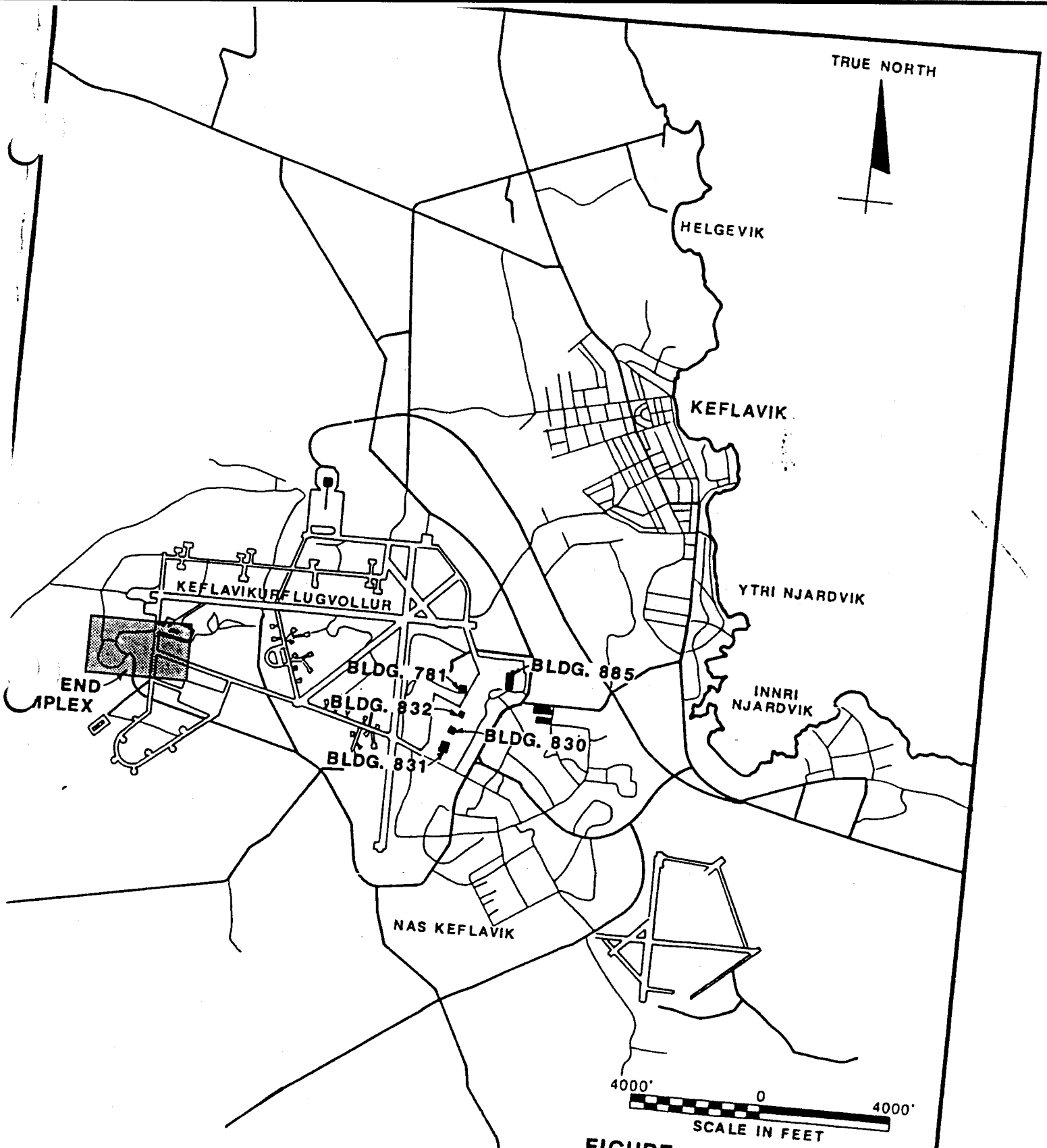
FIGURE 4-7

NAVY - NAS
KEFLAVIK, ICELAND

WORLD WAR II AIRCRAFT MAINTENANCE FACILITIES MAP

drawn DLB	approved	drawing no.
checked	date 3-16-89	87040-102-AA

r. e. wright associates, inc.
earth resources consultants
middletown, pa. westminster, md



LEGEND

■ MAINTENANCE FACILITY

MAP: PREPARED FROM MAP PUBLISHED BY LANDMAELINGAR ISLANDS (ICELAND GEODETIC SURVEY) AND DMAHTC U.S.A.

FIGURE 4-8

NAVY - NAS

KEFLAVIK, ICELAND

NAS-KEFLAVIK AIRCRAFT MAINTENANCE FACILITIES MAP

drawn DLB	approved	drawing no.
checked	date 3-15-89	87040-103-AA

r. e. wright associates, inc.
earth resources consultants
middletown, pa.

Aircraft corrosion control was performed in Buildings 830, 831, 832, and 885.

Currently, maintenance of fighter aircraft is conducted in facilities at the West End Complex (buildings west of the runway layout). These buildings include the Alert Facility, Building 1775, and the aircraft shelters.

4.5.1.2 Oils and Solvents - Various lubricating oils, hydraulic oils, and solvents have been used for the maintenance and repair of military aircraft. Information for the types of solvents used during World War II was not available.

In the early 1970s, solvents usage which consisted predominantly of TCE and PCE was discontinued. PCE and TCE still constitute 5 to 30 percent concentrations in solvents used at NAS-Keflavik. In one instance, TCE is currently used at its technical grade by Naval Weapons, whose inventory contains one 5-gallon can of TCE used for cleaning electrical connections.

Currently, solvents used at NAS-Keflavik include, but are not limited to, 1,1,1-trichloroethane (1,1,1-TCA), toluene, xylene, isopropyl alcohol, PD-680, methyl ethyl ketone, trichloro-trifluoroethane, paint strippers and thinners, and solvents containing between 5 and 30 percent TCE and PCE. All of the aircraft maintenance locations discussed in Section 4.5.1.1 are areas where any of these solvents could have been used.

Glycol (Navy stock #8243D) is used for deicing aircraft and is reportedly used sparingly on the runways, taxiways, and aprons. Urea (ammonium nitrate), however, is the primary deicing agent for the runways.

4.5.1.3 Disposal - As with previous operations at NAS-Keflavik, disposal practices of waste oils and waste solvents generated by aircraft maintenance are varied. At times, the waste oils and solvents were containerized and given to the fire department for training. At other times, the wastes were containerized and turned over to Military Disposal, who in turn sold the wastes to Icelandic Salvage.

An area approximately 20 feet west of the northwest corner of Hangar 885 and across the apron was also used for disposal of waste oils and solvents until 1970. Because the accumulation of this waste posed a potential fire hazard, it was cleaned up by excavating the contaminated soil, containerizing it, and sending the containers to the Defense Force landfill. The quantity of soil removed was undocumented. The excavation was filled in with sand, after which no further dumping of wastes oils and solvents was done at this site.

Spills of oils and solvents inside the maintenance hangars were washed into the floor drains which in turn infiltrated into the ground. In the mid-1970s, oil-water separators were installed in the floor drain system of Building 830, and in 1979, an oil-water separator was installed in the floor drain system in Building 885. The floor drains in Building 832 were connected to the sanitary sewer line in 1975. Oil-water separators were also installed in the floor drains for the building complex west of Hangar 832. The floor drains in Hangar 832 do not have oil-water separators installed. The corrosion control facility (Building 781) has an oil-water separator connected to the floor drains. Floor drains at the West End Complex have oil-water separators installed. All of the oil-water separators are

maintained on a routine basis by the Public Works Department Hazardous Materials Division. Drainage for the oil-water separators discussed above is by infiltration into the ground.

4.5.2 Icelandair

4.5.2.1 Location - Building 885 is used for routine safety checks and emergency maintenance by Icelandair, a private air carrier.

4.5.2.2 Oils and Solvents - Used lubricating and hydraulic oils are generated by Icelandair in performing routine safety checks and emergency maintenance on their aircraft. Detergents are used in cleaning both the interior and exterior of the aircraft. Solvents currently used by Icelandair are acetone, white spirits, toluene, paint thinners, and paint strippers. PCE was used in Building 885 by Icelandair before 1975. Thereafter, methyl ethyl ketone was used until 1985.

Glycol was used as a deicer by Icelandair until 1980. Since 1980, Icelandair has used a product called Kilfrost as a deicer. Manufacturer specifications for Kilfrost (Appendix B) showed it contained greater than 50 percent glycol monopropylene.

4.5.2.3 Disposal - Waste oils and solvents are stored in barrels outside of Building 885. When the fire training area was in use, the waste oils and solvents generated by Icelandair were given to the fire department to be burned for training at the fire-training area. Since 1985, the waste oils and solvents have been sent to Reykjavik for disposal. Oils and solvents spilled inside of Building 885 have been washed into the floor drains.

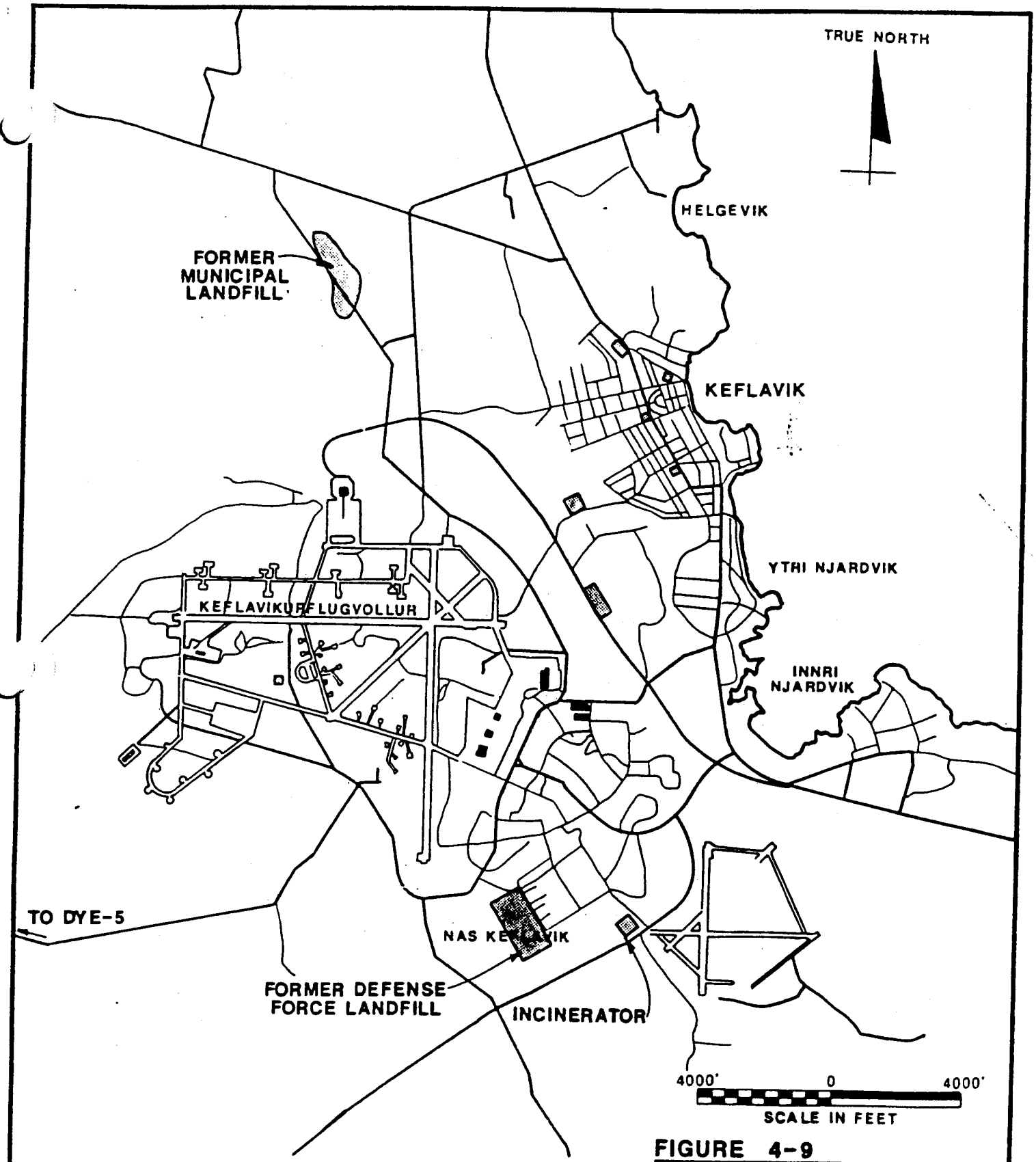
4.6 Landfills

Ten active and inactive landfills have been identified within the study area (Figure 4-9). Two of the landfills, which received the majority of the refuse within the study area, are the municipal landfill north of the International Airport and the Defense Force landfill southwest of the Seaweed Area. The municipal landfill was used by Keflavik and Njardvik until 1979, and the Defense Force landfill was used by NAS-Keflavik until 1983. Of the other landfills, four were located in Keflavik, two in the Nickel area, one at Camp Geck, and the other at DYE-5. These landfills were used for short periods of time, and are presently inactive. Information about the types of materials deposited in these landfills suggest that they were used for construction waste.

In 1979, an incinerator was constructed southeast of the Seaweed Area (Figure 4-9), and it has been operated and used by the local municipalities in the area. The Defense Force has used the incinerator for disposal of burnable wastes since 1983. A new landfill was opened in 1985 northwest of the Dye-5 complex. This landfill has been used by NAS-Keflavik and the local municipalities for the disposal of bulky nonburnable refuse, which includes scrap metal and items too large to put into the incinerator. Until the Dye-5 landfill was opened, bulky nonburnable refuse was stockpiled at the incinerator.

4.7 Hospitals

Wastes from the NAS-Keflavik Hospital and the Keflavik Hospital are currently sent to the incinerator for disposal. Prior to the incinerator, NAS-Keflavik Hospital disposed the waste at the



LEGEND

LANDFILL

BASE MAP: PREPARED FROM MAP PUBLISHED BY LANDMAELINGAR ISLANDS (ICELAND GEODETIC SURVEY) AND DMAHTC U.S.A.

FIGURE 4-9

NAVY - NAS
KEFLAVIK, ICELAND

LANDFILL LOCATION MAP

Drawn DLB	Approved JLW	Drawing No. 87040-104-AA
Checked JLW	Date 3-15-89	

r. e. wright associates, inc.
earth resources consultants

NAS-Defense Force landfill and the Keflavik Hospital disposed waste at the municipal landfill.

4.8 Polychlorinated Biphenyls

Polychlorinated biphenyls (PCBs) are contained in some cooling oils for electric transformers. The communities within the study area have checked transformer serial numbers with manufacturers to determine if any of the transformers contain PCB oil. To date, no PCB oil transformers have been found by the municipalities. All transformers on NAS-Keflavik have been tested for PCB oils. Transformers found containing PCB oils have been taken out of service, the oil drained, and the oil returned to the United States for disposal.

One spill of PCB oil from a transformer has been recorded at NAS-Keflavik. The spill occurred on September 3, 1985, at a transformer outside of Building 927. Soils containing the spilled PCB oil were containerized and sent to the United States for disposal.

During the PA/SI inspection of the Icelandic Salvage storage yard, in the Seaweed Area, nine electrical transformers were found. These transformers were tested by the Public Works Hazardous Materials Division, during 1988, and one of the transformers was found to contain PCB oil. The Hazardous Materials Division drained the PCB oil from the transformer and sent the oil to the United States for disposal. An attempt was made to determine the source of the transformers; however, the attempt was unsuccessful.

4.9 Printing Shop

PCE was used at the printing shop for NAS-Keflavik, which was located in Building 732. The PCE was used to dampen rags which are used to clean the print rollers. The dirty rags were thrown into the trash and taken to the Defense Force landfill before 1983. Since 1983, the dirty rags have been taken to the incinerator.

5.0 GROUNDWATER

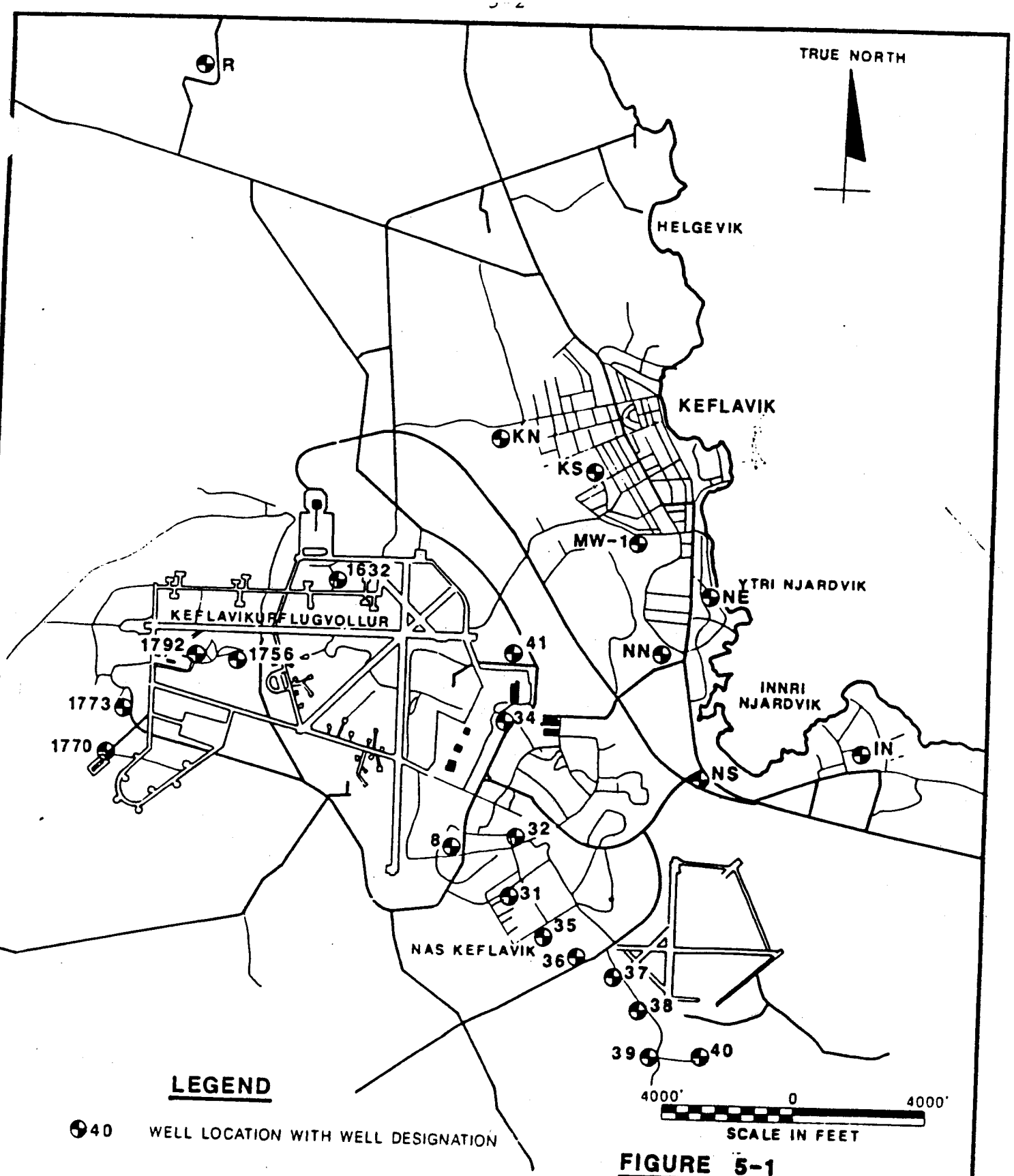
5.1 Chemistry

5.1.1 Introduction

Work Task 6 of the PA/SI involved collection and analyses of groundwater samples from the study area in order to determine the nature and extent of VOC contamination in the groundwater. Groundwater samples were collected by REWAI and SPHC personnel during a six-month period starting in May 1988. In total, 24 locations within the study area (Figure 5-1) were sampled to areally define groundwater quality, to delineate locations of measured or suspect contamination, and to assess impairment to water supplies. Twenty-two of the sampling locations were individual wells. Two of the sampling locations, Keflavik North (KN) and Njardvik North (NN), were wellfields where composite groundwater samples were collected. Groundwater samples were collected, preserved, and shipped according to procedures outlined and contained in Appendix C. Laboratory analysis was by EPA Method 624 (Appendix D), which is capable of determining the concentrations of most common chlorinated solvents, such as TCE, PCE, and 1,1,1-TCA, and some non-chlorinated hydrocarbon fuel constituents, such as toluene and benzene. Table 5-1 summarizes the monthly groundwater sample schedule. Complete laboratory analyses are presented in Appendix F.

5.1.2 May 1988 Sampling

Groundwater samples were collected and analyzed from 19 wells during the May 26, 1988 sampling event. In addition, two field duplicates from the same well and one field blank (a quality



LEGEND

40 WELL LOCATION WITH WELL DESIGNATION

FIGURE 5-1

NAVY - NAS
KEFLAVIK, ICELAND

GROUNDWATER SAMPLING WELLS

drawn MEH	approved JLW	drawing no 87040-107-AA
checked JLW	date 3-23-89	

T. R. wright associates, inc
earth resources consultants

BASE MAP: PREPARED FROM MAP PUBLISHED BY LANDMAELINGAR ISLANDS (ICELAND GEODETIC SURVEY) AND DMAHTC U.S.A.

7040T5

Table 5-1

PA/SI Collection of Water Samples

Well	Month					
	May	June	July	August	September	October
NAS #8	X	X	X	X	X	X
NAS #31	X	X	X			
NAS #32	X	X				
NAS #34	X	X	X	X	X	X
NAS #35	X	X	X	X	X	X
NAS #36	X	X	X	X	X	X
NAS #37	X	X	X	X		
NAS #38	X	X	X	X	X	X
NAS #39	X	X	X	X		
NAS #40	X	X	X	X		X
NAS #41	X	X	X	X	X	X
#1632	X	X	X	X	X	X
#1756			X	X	X	X
#1770				X	X	X
#1773			X	X	X	X
#1792		X	X	X	X	X
MW-1	X	X	X	X	X	X
Rockville	X	X	X	X	X	X
Keflavik North	X	X	X	X	X	X
Keflavik South	X	X	X	X	X	X
Njardvik East	X	X	X	X	X	X
Njardvik North	X	X	X	X	X	X
Njardvik South	X		X	X	X	X
Innri Njardvik		X	X	X	X	X
Field Blank	X	X	X	X		X
Trip Blank		X	X		X	X

X - Groundwater sample collected.

control sample prepared in the field with deionized water) were collected.

VOCs were measured above detection limits in nine groundwater samples collected during the May 1988 sampling (Table 5-2). Eight of the groundwater samples had detectable concentrations of TCE ranging from 70 micrograms per liter (ug/l) at NAS Well 35 to 1.9 ug/l at NAS Well 31. Four of the samples had measurable concentrations of PCE ranging from 9.9 ug/l at NAS Well 34, to 1.2 ug/l at the Keflavik North Wellfield. In four samples, 1,1,1-TCA was measured ranging from 76 ug/l at NAS Well 35, to 3.9 ug/l at NAS Well 36. Monitoring Well MW-1, in the Nickel Area, had CTC at 2.9 ug/l. In the groundwater sample collected from NAS Well 8, 1,1-DCA and 1,1-DCE were detected.

5.1.3 June 1988 Sampling

Twenty sampling locations, one field blank, and one trip blank were collected and analyzed for the June 23, 1988 sampling event. NAS Well 1792 was added to the wells which were sampled in May, and the Innri Njardvik Well (IN) was sampled instead of the Njardvik South Well. A representative from the University of Iceland observed the June 23, 1988 groundwater sampling.

Ten groundwater samples had VOCs measured above the detection limits (Table 5-3). TCE was detected in nine of the samples collected during the June 1988 sampling. Concentrations of TCE ranged from 64 ug/l at NAS Well 35, to 1.8 ug/l at NAS Well 31. Five groundwater samples had measurable concentrations of PCE ranging from 6.7 ug/l at NAS Well 34, to 1.0 ug/l at the Keflavik North Wellfield. In five groundwater samples, 1,1,1-TCA was measured. The concentrations of 1,1,1-TCA ranged from 73 ug/l at NAS Well 35, to 1.5 ug/l at NAS Well 32. Monitoring well MW-1

Table 5-2

Summary of Wells Where VOA Analyses Revealed Chemicals Above Detection Limits - EPA Method 624
First PA/SI Sampling Results
May 26, 1988

(all values are reported as ug/l)

	WHO Established	United States EPA Established	Well NAS 35	Well NAS 31	Well NAS 31	Well NAS 32	Well NAS 8	Well NAS 8	Well NAS 34	Well NAS 36	Well NAS MW-1	Well Keflavik North	Well Njardvik North
	Maximum Concen-tration Limit	Maximum Concen-tration Limit	Sample 201	Sample 202	Sample 202dup	Sample 203	Sample 204	Sample 205	Sample 206	Sample 213	Sample 216	Sample 217	Sample 221
Carbon Tetrachloride (CTC)	5.0	5.0	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	2.9	ND(<1)	ND(<1)
1,1-Dichloroethane (1,1-DCA)	5.0	5.0	ND(<1)	ND(<1)	ND(<1)	ND(<1)	4.5	5.2	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)
1,1-Dichloroethylene (1,1-DCE)	7.0	7.0	ND(<1)	ND(<1)	ND(<1)	ND(<1)	1.9	2.1	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)
Tetrachloroethylene (PCE)	10.0	NA	ND(<1)	ND(<1)	ND(<1)	2.9	ND(<1)	ND(<1)	9.9	ND(<1)	ND(<1)	1.2	7.2
1,1,1-Trichloroethane (1,1,1-TCA)	200.0	200.0	76.0	ND(<1)	ND(<1)	7.2	51.0	50.0	ND(<1)	3.9	ND(<1)	ND(<1)	ND(<1)
Trichloroethylene (TCE)	5.0	5.0	70.0	2.1	1.9	3.1	3.4	3.4	2.1	4.5	13.0	ND(<1)	8.5

NA = Not Assigned

ND(<1) = Not Detected at Level ()

Tabl

Summary of Wells Where VOA Analyses Revealed Chemicals Above Detection Limits - EPA Method 624
Second PA/SI Sampling Results
June 23, 1988

(all values are reported as ug/l)

	WHO Established Maximum Concen-tration Limit	United States EPA Established Maximum Concen-tration Limit	Well NAS 35 Sample 302	Well NAS 31 Sample 303	Well NAS 32 Sample 301	Well NAS 8 Sample 304	Well NAS 34 Sample 305	Well NAS 36 Sample 309	Well NAS MW-1 Sample 316	Well Keflavik North Sample 317	Well Njardvik North Sample 320	Well Njardvik East Sample 319
Carbon Tetrachloride (CTC)	5.0	5.0	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<5)	ND(<5)	2.8	ND(<1)	ND(<1)	ND(<1)
Tetrachloroethylene (PCE)	10.0	NA	ND(<1)	ND(<1)	2.3	ND(<1)	6.7	ND(<5)	ND(<1)	1.0	6.6	1.4
1,1,1-Trichloroethane (1,1,1-TCA)	200.0	200.0	73.0	ND(<1)	1.5	47.0	1.9#	5.1	ND(<1)	ND(<1)	ND(<1)	ND(<1)
Trichloroethylene (TCE)	5.0	5.0	64.0	1.8	2.6	3.0	2.4#	5.8	13.0	ND(<1)	7.9	2.1
Toluene	2000.0[a]	2000.0[a]	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<5)	ND(<5)	8.7	ND(<1)	ND(<1)	ND(<1)

NA = Not Assigned

ND(<1) = Not Detected at Level ()

= Estimated vaue, below level of reasonable detection.

a = EPA established MCL goal.

had measurable concentrations of CTC and toluene at 2.8 ug/l and 8.7 ug/l, respectively.

5.1.4 July 1988 Sampling

Twenty-two groundwater samples, one field blank, and one trip blank were collected and analyzed for the July 28, 1988 sampling. NAS Wells 1756 and 1773 and the Njardvik South Well were added to the list of wells sampled. A sample was not collected from NAS Well 32 because the well pump had been disconnected for repair.

VOCs were measured above detection limits at 12 of the sampling locations (Table 5-4). Eleven locations had TCE concentrations ranging from 63 ug/l at NAS Well 35, to 1.1 ug/l at NAS Well 1792. PCE was measured in 3 samples ranging from 6.6 ug/l at the Njardvik North Wellfield, to 1.1 ug/l at the Keflavik North Wellfield. 1,1,1-TCA was measured at four sampling locations with ranges from 56 ug/l at NAS Well 35, to 1.5 ug/l at NAS Well 34. In addition, monitoring well MW-1 had measurable concentrations of CTC, NAS Well 8 had measurable concentrations of 1,1-DCA, NAS Well 1756 had measurable concentrations of c-1,2-DCE, and NAS Well 34 had measurable concentrations of bromoform, chlorodibromomethane, and dichlorobromomethane.

5.1.5 August 1988 Sampling

Twenty-two groundwater samples and one field blank were collected and analyzed for the August 30, 1988 sampling. NAS Well 1770 was added to the wells sampled, and NAS Well 31 was not sampled because of an inoperative pump.

7040TA

T- -4

Summary of Wells Where VOA Analyses Revealed Chemicals Above Detection Limits - EPA Method 624
Third PA/SI Sampling Results
July 28, 1988

(all values are reported as ug/l)

	WHO Established Maximum Concentration Limit	United States EPA Established Maximum Concentration Limit	Well NAS 31 Sample 401	Well NAS 35 Sample 402	Well NAS 1756 Sample 403	Well NAS 1756 Sample 403dup	Well NAS 1792 Sample 404	Well NAS 1773 Sample 405	Well NAS 8 Sample 406	Well NAS 34 Sample 407	Well NAS 36 Sample 415	Well NAS 36 Sample 415dup	Well Keflavik North Sample 417	Well Njardvik East Sample 419	Well Njardvik North Sample 420	Well NAS MW-1 Sample 423
Carbon Tetrachloride (CTC)	5.0	5.0	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	2.2
1,1-Dichloroethane (1,1-DCA)	5.0	5.0	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	1.6	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)
Tetrachloroethylene (PCE)	10.0	NA	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	4.2	ND(<1)	ND(<1)	1.1	ND(<1)	6.6	ND(<1)
1,1,1-Trichloroethane (1,1,1-TCA)	200.0	200.0	ND(<1)	56.0	ND(<1)	ND(<1)	ND(<1)	ND(<1)	18.0	1.5	5.0	5.0	ND(<1)	ND(<1)	ND(<1)	ND(<1)
Trichloroethylene (TCE)	5.0	5.0	1.6	63.0	8.1	7.8	1.1	4.4	1.2	2.8	7.0	7.3	ND(<1)	1.2	8.4	13.0
cis-1,2-Dichloroethylene (cis-1,2-DCE)	70.0[a]	70.0[a]	ND(<1)	ND(<1)	2.4	2.5	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)
Bromoform (BFM)	100.0[b]	100.0[b]	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	1.5	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)
Chlorodibromomethane (CDBM)	100.0[b]	100.0[b]	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	1.7	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)
Dichlorobromomethane (DCBM)	100.0[b]	100.0[b]	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	1.0	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)

NA = Not Assigned

ND(<1) = Not Detected at Level ()

a = EPA Established MCL Goal.

b = Total Halomethanes are Not to Exceed 100 ug/l

r. c. wright associates, inc.

VOCs were measured above detection limits in ten of the groundwater samples (Table 5-5). Ten samples had TCE concentrations which ranged from 53 ug/l at NAS Well 35, to 1.2 ug/l at NAS Well 8. PCE was measured in two samples--the North Njardvik Wellfield and NAS Well 34--at concentrations of 6.7 ug/l and 3.9 ug/l, respectively. 1,1,1-TCA was measured in three groundwater samples and ranged from 73 ug/l at NAS Well 35, to 1.6 ug/l at NAS Well 34. C-1,2-DCE was detected in NAS Wells 1756 and NAS Well 8. In addition, NAS Well 8 had 1,1-DCA detected. MW-1 had CTC detected and NAS Well 34 had bromoform and chlorodibromomethane detected.

A representative from the University of Iceland traveled to the United States and observed the procedures of Wright Lab Services, Inc. (WLSI) as it analyzed the August 1988 samples.

5.1.6 September 1988 Sampling

Groundwater samples from 19 wells and one trip blank were collected and analyzed for the September 27, 1988 sampling. NAS Wells 37, 39, and 40 were not sampled because they were undergoing repair.

VOCs were measured above the detection limits in 12 of the groundwater samples (Table 5-6). Eleven samples had measurable concentrations of TCE which ranged from 48 ug/l at NAS Well 35, to 1.1 ug/l in NAS Well 8. PCE was measured in four of the groundwater samples and ranged from 6.0 ug/l at the Njardvik North Wellfield, to 1.0 ug/l at the Keflavik North Wellfield. Three groundwater samples had detectable levels of 1,1,1-TCA which ranged from 47 ug/l at NAS Well 35, to 4.3 ug/l at NAS Well 36. In addition, Well MW-1 had CTC detected, NAS Well 1756

Tabl

Summary of Wells Where VOA Analyses Revealed Chemicals Above Detection Limits - EPA Method 624
Fourth PA/SI Sampling Results
August 30, 1988

(all values are reported as ug/l)

	WHO Established Maximum Concentration Limit	United States EPA Established Maximum Concentration Limit	Well NAS 34 Sample 503	Well NAS 34 Sample 503dup	Well NAS 8 Sample 504	Well NAS 1756 Sample 505	Well NAS 1792 Sample 506	Well NAS 1773 Sample 507	Well NAS 1770 Sample 509	Well NAS 35 Sample 510	Well Njardvik North Sample 515	Well Njardvik North Sample 515dup	Well NAS 36 Sample 518	Well NAS MW-1 Sample 523
Carbon Tetrachloride (CTC)	5.0	5.0	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	3.4
1,1-Dichloroethane (1,1-DCA)	5.0	5.0	ND(<1)	ND(<1)	1.2	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)
Tetrachloroethylene (PCE)	10.0	NA	3.8	3.9	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	6.6	6.7	ND(<1)	ND(<1)
1,1,1-Trichloroethane (1,1,1-TCA)	200.0	200.0	1.4	1.6	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	73.0	ND(<1)	ND(<1)	8.2	ND(<1)
Trichloroethylene (TCE)	5.0	5.0	3.1	3.1	1.2	10.3	1.3	4.4	4.5	53.0	8.7	8.9	10.3	14
cis-1,2-Dichloroethylene (cis-1,2-DCE)	70.0[a]	70.0[a]	ND(<1)	ND(<1)	2.4	2.7	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)
Bromoform (BFM)	100.0[b]	100.0[b]	1.2	1.2	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)
Chlorodibromomethane (CDBM)	100.0[b]	100.0[b]	1.5	1.4	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)

NA - Not Assigned

ND(<1) - Not Detected at Level ()

a - EPA Established MCL Goal.

b - Total Halomethanes are Not to Exceed 100 ug/l

Table

Summary of Wells Where VOA Analyses Revealed Chemicals Above Detection Limits - EPA Method 624
Fifth PA/SI Sampling Results
September 27, 1988

(all values are reported as ug/l)

	WHO Established Maximum Concentration Limit	United States EPA Established Maximum Concentration Limit	Well Keflavik North Sample 602	Well Njardvik East Sample 604	Well Njardvik North Sample 605	Well NAS 36 Sample 609	Well NAS 35 Sample 610	Well NAS 1773 Sample 611	Well NAS 1770 Sample 612	Well NAS 1756 Sample 613	Well NAS 1792 Sample 614	Well NAS 8 Sample 615	Well NAS 34 Sample 616	Well NAS MW-1 Sample 619
Carbon Tetrachloride (CTC)	5.0	5.0	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	1.6
Tetrachloroethylene (PCE)	10.0	NA	1.0	2.1	6.0	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	3.4	ND(<1)
1,1,1-Trichloroethane (1,1,1-TCA)	200.0	200.0	ND(<1)	ND(<1)	ND(<1)	4.3	47.0	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)
Trichloroethylene (TCE)	5.0	5.0	ND(<1)	3.1	7.9	11.0	48.0	4.6	4.4	12.0	1.3	1.1	3.0	12.0
cis-1,2-Dichloroethylene (cis-1,2-DCE)	70.0[a]	70.0[a]	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	1.4	ND(<1)	ND(<1)	ND(<1)	ND(<1)
Chlorodibromomethane (CDBM)	100.0[b]	100.0[b]	ND(<1)	ND(<1)	ND(<1)	ND(<1)	1.0	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)

NA = Not Assigned

ND(<1) = Not Detected at Level ()

a = EPA Established MCL Goal.

b = Total Halomethanes are Not to Exceed 100 ug/l

had c-1,2-DCE detected, and NAS Well 35 had chlorodibromomethane detected.

5.1.7 October 1988 Sampling

Groundwater samples from 20 wells, one trip blank, and one field blank were collected and analyzed for the October 25, 1988 sampling. NAS Well 40 was sampled; however, NAS Wells 37 and 39 were still under repair and not sampled.

VOCs were measured above the detection limits in eleven of the groundwater samples (Table 5-7). Eleven samples contained concentrations of TCE which ranged from 49 ug/l at NAS Well 35, to 1.1 ug/l at NAS Well 8. The Njardvik North Wellfield and NAS Well 34 had measurable concentrations of PCE--6.6 ug/l and 3.4 ug/l, respectively. 1,1,1-TCA was measured in 3 wells and ranged from 59 ug/l at NAS Well 35, to 1.1 ug/l at NAS Well 34. Monitoring Well MW-1 had measurable concentrations of CTC and NAS Well 1792 had measurable concentrations of c-1,2-DCE. In addition, NAS Well 35 had measurable concentrations of bromoform and chlorodibromomethane, and NAS Well 34 had measurable concentration of chlorodibromomethane.

5.1.8 Municipal Wellfield Water Quality

Groundwater quality impairment of the Keflavik North Wellfield has been predominantly caused by PCE, ranging in concentration from non-detected to 1.4 ug/l. During the six months of PA/SI sampling (May to October 1988), no TCE or other VOCs were detected. However, two samples of the Keflavik North Wellfield were previously taken by the SPHC: one in September 1987 and another in July 1988. The samples, analyzed by a Danish laboratory and reported at lower detection limits than PA/SI

Tabl

Summary of Wells Where VOA Analyses Revealed Chemicals Above Detection Limits - EPA Method 624
Sixth PA/SI Sampling Results
October 25, 1988

(all values are reported as ug/l)

	WHO Established Maximum Concentration Limit	United States EPA Established Maximum Concentration Limit	Well NAS MW-1 Sample 701	Well Njardvik North Sample 706	Well NAS 36 Sample 709	Well NAS 35 Sample 713	Well NAS 1756 Sample 714	Well NAS 1792 Sample 715	Well NAS 1773 Sample 716	Well NAS 1773 Sample 716dup	Well NAS 1770 Sample 717	Well NAS 8 Sample 718	Well NAS 34 Sample 719	Well NAS 1632 Sample 721
Carbon Tetrachloride (CTC)	5.0	5.0	2.7	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)
Tetrachloroethylene (PCE)	10.0	NA	ND(<1)	6.6	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	3.4	ND(<1)
1,1,1-Trichloroethane (1,1,1,-TCA)	200.0	200.0	ND(<1)	ND(<1)	ND(<1)	59.0	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	13.0	1.1	ND(<1)
Trichloroethylene (TCE)	5.0	5.0	14.0	7.7	1.6	49.0	14.0	1.6	4.5	4.5	4.5	1.1	3.0	1.3
cis-1,2-Dichloroethylene (cis-1,2-DCE)	70.0[a]	70.0[a]	ND(<1)	ND(<1)	ND(<1)	ND(<1)	3.0	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)
Bromoform (BFM)	100.0[b]	100.0[b]	ND(<1)	ND(<1)	ND(<1)	1.0	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)
Chlorodibromomethane (CDBM)	100.0[b]	100.0[b]	ND(<1)	ND(<1)	ND(<1)	1.6	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	1.0	ND(<1)

NA - Not Assigned

ND(<1) - Not Detected at Level ()

a - EPA Established MCL Goal.

b - Total Halomethanes are Not to Exceed 100 ug/l

analyses, detected PCE at 1.6 ug/l in September 1987. The July 1988 analyses detected PCE at 1.6 ug/l and TCE at 0.27 ug/l. The July 1988 sample was the only one which detected a compound other than PCE in the Keflavik North Wellfield.

VOCs were not detected in groundwater samples taken from the Keflavik South Wellfield, during the May to October 1988 PA/SI monthly groundwater sampling. This was supported by the September 1987 and July 1988 sampling by the SPHC, which also did not detect VOCs. Therefore, it appears that the Keflavik South Wellfield has no VOC-related groundwater quality problems.

Water quality samples taken from the Njardvik North Wellfield from May to October 1988 provided a representation of the types and degree of water quality impairment by VOCs at this location. The character of the VOCs detected in the Njardvik North Wellfield was different from that detected at the Keflavik North Wellfield. TCE and PCE were detected in the July 1988 SPHC samples at peak values of 12 ug/l and 9.7 ug/l, respectively. TCE and PCE were detected in PA/SI samples at peak concentrations of 8.9 ug/l in August 1988 and 7.2 ug/l in May 1988, respectively.

The Njardvik East Wellfield has occasionally experienced degradation in its groundwater quality in the form of TCE at 2.1 ug/l and PCE at 1.4 ug/l. Although still of concern, this problem has less of an adverse impact on the municipal supply than does the degraded water quality at the Njardvik North Wellfield due to the relatively lower concentrations and lower pumping rates at the Njardvik East Wellfield.

Neither the PA/SI nor the SPHC studies detected VOCs in the Njardvik South Wellfield. Therefore, it appears that this wellfield has no VOC-related groundwater quality problems.

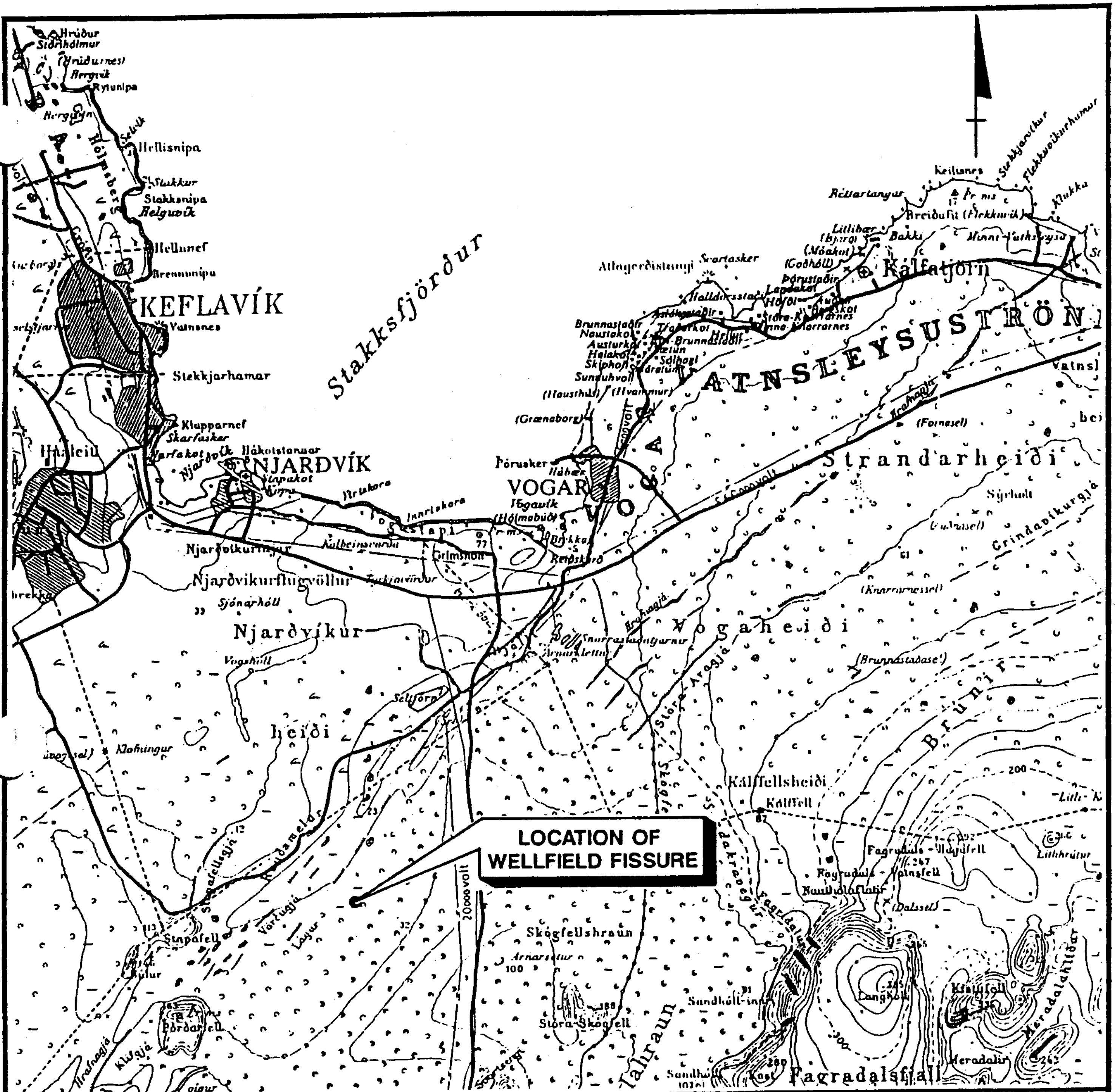
The replacement water supply wellfield has been located approximately 4.7 miles (7.5 km) south-southeast of Njardvik. The water will be pumped from a fissure, labeled as Gjd (HSK-100) on Figure 5-2. This fissure will provide potable water for Njardvik, Keflavik, and NAS-Keflavik.

The well field is located between areas of recent volcanic activity. The fissures were formed primarily from this extrusive activities, as well as intrusive activities.

5.1.9 Time Variations of Concentrations

Significant variations in VOC concentrations were observed in eight of the wells during the six months of sampling (Table 5-8). In general, the water quality variations over time appear to reflect the dynamics of the groundwater flow system due to pumping or seasonal changes in flow direction.

VOC concentrations in NAS Well 8 were highest in May and June when the well was being pumped and decreased when it was not being pumped. The changes in VOC concentrations appear to coincide with usage of NAS Well 8 and suggest that pumping the well changes the direction of groundwater transport of VOCs (plume). When the well is not being pumped, the VOC plume may move away from the well under the natural hydraulic gradient. Alternatively, the change in groundwater quality may be in response to natural seasonal or weather-induced variations in groundwater flow directions. PCE was not detected in any groundwater samples of NAS Well 8 indicating that this well may



BASE MAP: PREPARED FROM MAP PUBLISHED BY LANDMAELINGER ISLANDS (ICELAND GEODETIC SURVEY) AND DMATC U.S.A.

FIGURE 5-2

NAVY - NAS

KEFLAVIK, ICELAND

NEW WELLFIELD LOCATION

drawn RAM	approved	drawing no.
checked	date 12-7-90	87040-115-AA

r. e. wright associates, inc.
earth resources consultants
middletown, pa. westminster, md.

Table 5-8

Six Month Summary of Laboratory Analyses
(all values are reported as ug/l)

Well	Chemical	Month May	June	July	August	September	October
NAS #8	Trichloroethylene (TCE)	3.4	3.0	1.2	1.2	1.1	1.1
	1,1,1-Trichloroethane (1,1,1-TCA)	50.0	47.0	18.0	ND(<1)	12.0	13.0
	1,1-Dichloroethane (1,1-DCA)	5.2	ND(<1)	1.6	1.2	ND(<1)	ND(<1)
	1,1-Dichloroethylene (1,1-DCE)	2.1	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)
	cis-1,2-Dichloroethylene (cis-1,2-DCE)	ND(<1)	ND(<1)	ND(<1)	2.4	ND(<1)	ND(<1)
NAS #31	Trichloroethylene (TCE)	2.1	1.8	1.6	NS	NS	NS
NAS #32	Trichloroethylene (TCE)	3.1	2.6	NS	NS	NS	NS
	Tetrachloroethylene (PCE)	2.9	2.3	NS	NS	NS	NS
	1,1,1-Trichloroethane (1,1,1-TCA)	7.2	1.5	NS	NS	NS	NS
NAS #34	Trichloroethylene (TCE)	2.1	2.4	2.8	3.1	3.0	3.0
	Tetrachloroethylene (PCE)	9.9	6.7	4.2	3.9	3.4	3.4
	1,1,1-Trichloroethane (1,1,1-TCA)	ND(<1)	1.9	1.5	1.6	ND(<1)	1.1
	Bromoform (BFM)	ND(<1)	ND(<1)	1.5	1.2	ND(<1)	ND(<1)
	Chlorodibromomethane (CDBM)	ND(<1)	ND(<1)	1.7	1.5	ND(<1)	1.0
	Dichlorobromomethane (DCBM)	ND(<1)	ND(<1)	1.0	ND(<1)	ND(<1)	ND(<1)
NAS #35	Trichloroethylene (TCE)	70.0	64.0	63.0	53.0	48.0	49.0
	1,1,1-Trichloroethane (1,1,1-TCA)	76.0	73.0	56.0	73.0	47.0	59.0
	Bromoform (BFM)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	1.0
	Chlorodibromomethane (CDBM)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	1.0	1.6
NAS #36	Trichloroethylene (TCE)	4.5	5.8	7.3	10.3	11.0	1.6
	1,1,1-Trichloroethane (1,1,1-TCA)	3.9	5.1	5.0	8.2	4.3	ND(<1)
NAS #1632	Trichloroethylene (TCE)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	ND(<1)	1.3
NAS #1756	Trichloroethylene (TCE)	NS	NS	8.1	10.3	12.0	14.0
	cis-1,2-Dichloroethylene (cis-1,2-DCE)	NS	NS	2.5	2.7	1.4	3.0
NAS #1770	Trichloroethylene (TCE)	NS	NS	NS	4.5	4.4	4.5
NAS #1773	Trichloroethylene (TCE)	NS	NS	4.4	4.4	4.6	4.5
NAS #1792	Trichloroethylene (TCE)	NS	ND(<5)	1.1	1.3	1.3	1.6

Table 5-

Six Month Summary of Laboratory Analyses
(all values are reported as ug/l)

Well	Chemical	Month May	June	July	August	September	October
NAS MW-1	Trichloroethylene (TCE)	13.0	13.0	13.0	14.0	12.0	14.0
	Carbon Tetrachloride (CTC)	2.9	2.8	2.2	3.4	1.6	2.7
Keflavik North	Tetrachloroethylene (PCE)	1.2	1.0	1.1	ND(<1)	1.0	ND(<1)
Njardvik North (Bolafotur)	Trichloroethylene (TCE)	8.5	7.9	8.4	8.9	7.9	7.7
	Tetrachloroethylene (PCE)	7.2	6.6	6.6	6.7	6.0	6.6
Njardvik East (Thorustigur)	Trichloroethylene (TCE)	ND(<1)	2.1	1.2	ND(<1)	ND(<1)	ND(<1)
	Tetrachloroethylene (PCE)	ND(<1)	1.4	ND(<1)	ND(<1)	1.0	ND(<1)

ND(<1) = Not Detected at Level ()

NS = Not Sampled

be outside the plume containing that species. Other VOCs--such as 1,1-DCE, c-1,2-DCE, and 1,1-DCA--were also sporadically detected in this well. The current data base is not sufficient to test this "seasonal" hypothesis.

NAS Well 31 was not a pumping well during the six-month time frame while NAS Well 32 was used as a water supply well during the months of May and June but was taken out of service thereafter. The samples which were obtained from Well 31 in May, June, and July and from Well 32 in May and June indicate a decrease in VOC concentrations in these two wells over time. Groundwater samples from Well 31 contained only TCE, while samples from Well 32 contained TCE in addition to PCE and 1,1,1-TCA during the period sampled. The non-detection of PCE and 1,1,1-TCA in Well 31 indicates that it may be outside of the plume of those species detected in Well 32.

NAS Well 34 was used as a water supply well during the last four months of the six-month sampling period. Concentrations of TCE, in general, increased with time, but the increase was insignificant (1 ug/l). During the same period, concentrations of PCE decreased with time. The concentrations of 1,1,1-TCA varied, but showed a general decrease with time. The variation in water quality produced by this well may be related to either pumping or seasonal changes.

TCE and 1,1,1-TCA concentrations in NAS Well 35, a non-pumping well during the six-month sampling period, appeared to decrease over time indicating either plume transport away from the area or a seasonal variation in groundwater flow direction. The potential cessation of control on groundwater VOC transport by nearby Wells 8 and 32, having been shut down in June and July respectively, may also have caused the concentration reduction

observed. During the entire period, Well 35 was free of PCE as was Well 31, suggesting the absence of a PCE plume in the vicinity of these wells.

NAS Well 36 was used as a water supply well during the six-month period. Pumping of Well 36 was continuous through August but in September became intermittent when repairs were being conducted to the well house and the pump. TCE concentrations in Well 36 generally increased until the month of October when a sharp decline was observed. In addition, 1,1,1-TCA concentrations in Well 36 generally increased until the month of September when a sharp decline was observed. The increase in VOC concentration at Well 36 suggests transport or spreading of the plume to that well over time. An explanation for the sharp decrease in concentrations in October has not been postulated.

Samples from water wells located at the west end of NAS-Keflavik contained only TCE during the six-month period except for NAS Well 1756 which additionally contained c-1,2-DCE. NAS Wells 1756 and 1792 experienced a slight increase in VOC concentrations over time, while the remaining wells at the west end appeared to have no change in VOC concentrations over time. Wells 1756, 1770, and 1773 were used for water supply during the six months of sampling. Pumping of the three wells was not continuous, as each well was supplying water to a pressure tank and only pumped to maintain pressure in the tanks. Well 1792 was not used during the six-month sampling period. Therefore, concentration changes in this area may be naturally influenced by groundwater stage or flow direction.

NAS Well MW-1 in the Nickel Area was a non-pumping well and did not experience changes in VOC concentrations over time. The Keflavik North Wellfield and the Njardvik North Wellfield were

both pumping during the entire sampling period. Changes in VOC concentrations over time were not observed in either of these well fields. Occasional detection of VOCs was observed in the Njardvik East (NE) Well which is used only on an as-needed basis. Consequently, the pumping occurs irregularly. The occasional detection of VOCs in the NE well could be due to the irregular pumping drawing in a nearby plume.

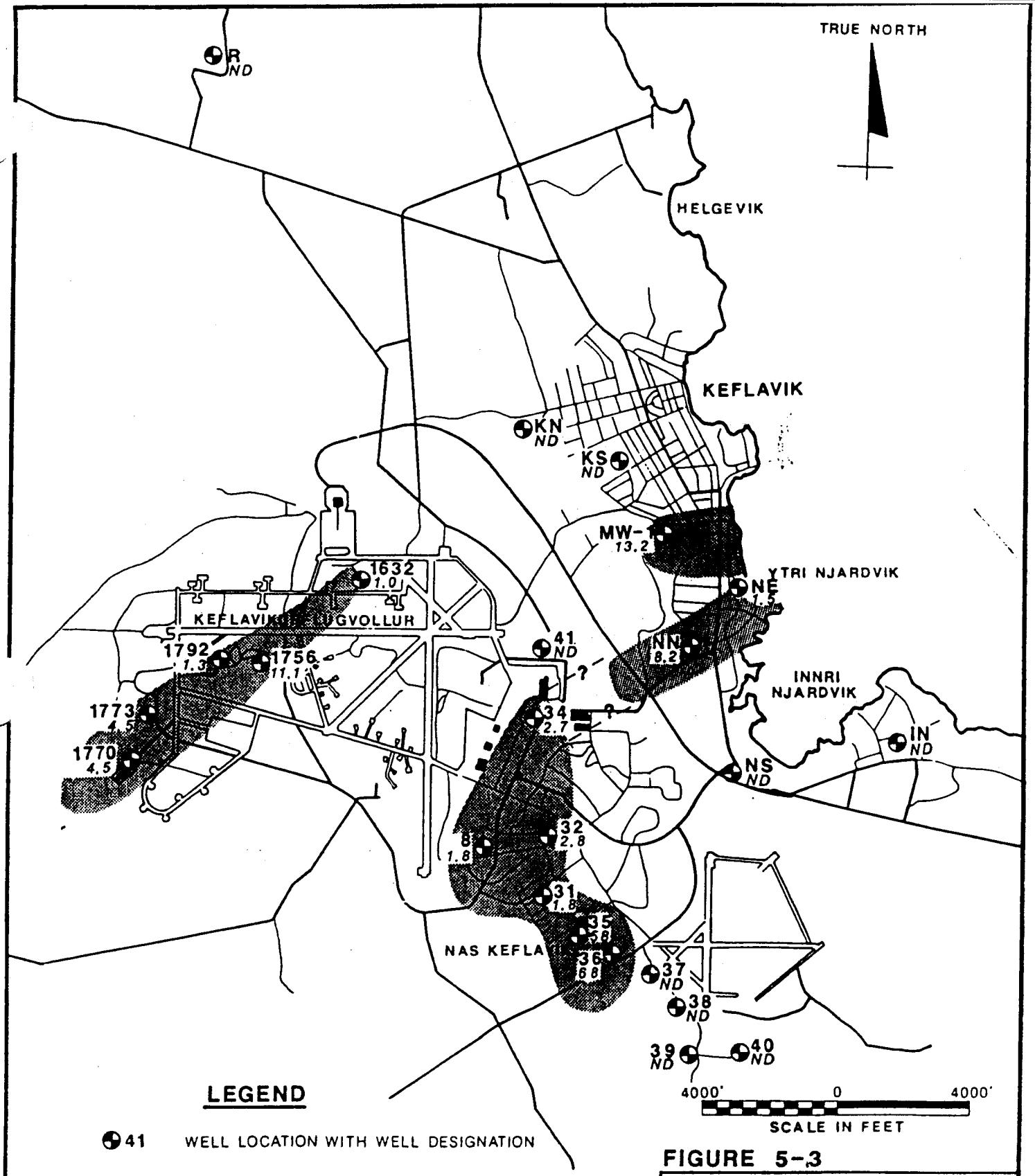
5.1.10 Summary

Average concentrations were calculated for TCE, PCE, and 1,1,1-TCA, over the six months PA/SI sampling with the following assumptions:

- When a parameter was detected intermittently but not detected during one or more of the months, a value of 0.9 ug/l was used for that time period in calculating the 6-month average concentration; and

- If a well was not sampled during a particular month or more, the period over which the average concentration was calculated was reduced by the respective number of months lacking data.

Of the contaminants detected in the groundwater of the study area, TCE, PCE, and 1,1,1-TCA appear most widely distributed. TCE was most widespread and was measured in 14 of the 22 wells sampled in concentrations ranging from 1.0 ug/l to 58 ug/l (Figure 5-3). The relative extent of this solvent may be due to its frequent widespread use over a relatively long time period. PCE was detected in samples from 5 of the locations in



LEGEND

41	WELL LOCATION WITH WELL DESIGNATION
4.5	TCE CONCENTRATION (ppb)
ND	NOT DETECTED ABOVE 1 ppb
	CONCEPTUAL PLUME LOCATION

BASE MAP: PREPARED FROM MAP PUBLISHED BY LANDMAELINGAR ISLANDS (ICELAND GEODETIC SURVEY) AND DMAHTC U.S.A.

FIGURE 5-3

NAVY - NAS

KEFLAVIK, ICELAND

TCE AVERAGE CONCENTRATIONS AND CONCEPTUAL PLUME LOCATIONS MAY 1988 THROUGH OCTOBER 1988

drawn MER	approved	drawing no 87040-114-AA
checked	date 3-30-89	

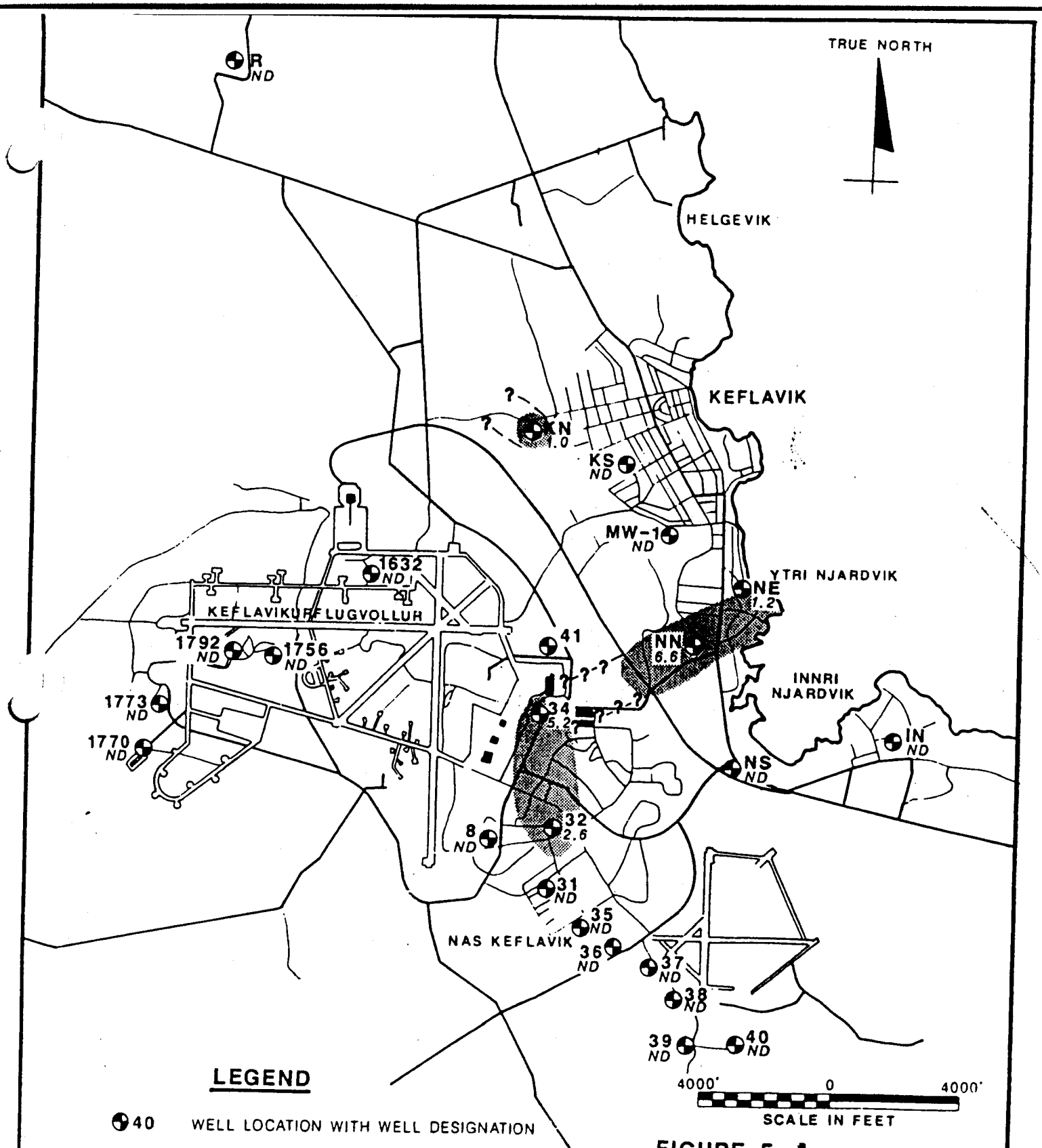
r. e. wright associates, inc.
earth resources consultants

concentrations ranging from 1 ug/l to 6.6 ug/l (Figure 5-4). This more limited distribution of PCE may be due to its less common use in the study area. 1,1,1-TCA was detected in samples from 5 locations in concentrations ranging from 13 ug/l to 65 ug/l (Figure 5-5). The limited extent of this solvent may be due to the shorter time period of use since its recent replacement of TCE.

Other organic chemicals were detected sporadically or in limited geographical areas. The more restricted occurrence of these other compounds may be due to the limited use, nonpersistence, and/or poor mobility in their groundwater flow system. Carbon tetrachloride is limited in occurrence and trihalomethanes (bromoform, dibromochloromethane, and dichlorobromomethane) are found in only one sample location, suggesting their limited use or nonpersistence. C-1,2-DCE, 1,1-DCE, and 1,1-DCA are only found sporadically and only in association with other more predominant VOCs. Their presence within the groundwater is probably a result of degradation of the more pervasive VOCs.

Although free-phase oil occurred in several wells in the Nickel Area and Well 37, toluene, a constituent of most fuels, was detected only once in MW-1. No evidence of volatile dissolved hydrocarbon constituents was detected in NAS Well 37. This may be due to the poor mobility and biodegradability or the relatively low solubility in the groundwater of the oil constituents.

The groundwater quality at three sampling locations consistently exceeded World Health Organization (WHO) and/or U. S. Environmental Protection Agency (EPA) Maximum Contaminant Limits (MCLs) for TCE. These locations were the Njardvik North Wellfield, NAS Well 35, and MW-1.



LEGEND

40	WELL LOCATION WITH WELL DESIGNATION
1.2	PCE CONCENTRATION (ppb)
ND	NOT DETECTED ABOVE 1 ppb
	CONCEPTUAL PLUME LOCATION

BASE MAP: PREPARED FROM MAP PUBLISHED BY LANDMAELINGAR ISLANDS (ICELAND GEODETIC SURVEY) AND DMAHTC U.S.A.

FIGURE 5-4

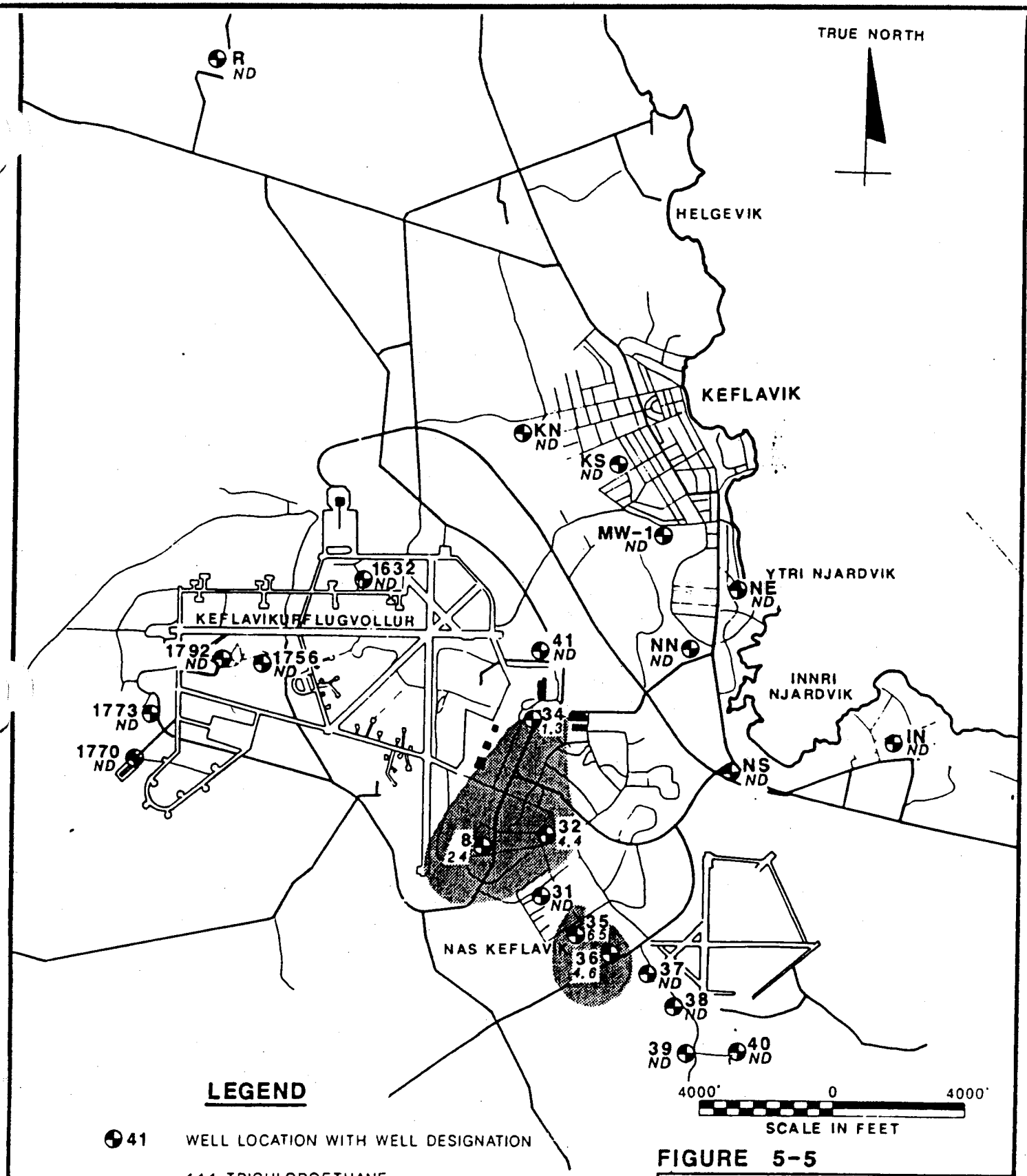
NAVY - NAS

KEFLAVIK, ICELAND

PCE AVERAGE CONCENTRATIONS AND CONCEPTUAL PLUME LOCATIONS MAY 1988 THROUGH OCTOBER 1988

drawn MEFC	approved KVL	drawing no 87040-108-AA
checked JLW	date 3-27-89	

r. e. wright associates, inc.
earth resources consultants



LEGEND

41	WELL LOCATION WITH WELL DESIGNATION
4.4	1,1,1-TRICHLOROETHANE CONCENTRATION (ppb)
ND	NOT DETECTED ABOVE 1 ppb
	CONCEPTUAL PLUME LOCATION

BASE MAP: PREPARED FROM MAP PUBLISHED BY LANDMAELINGAR ISLANDS (ICELAND GEODETIC SURVEY) AND DMAHTC U.S.A.

FIGURE 5-5

NAVY - NAS

KEFLAVIK, ICELAND

1,1,1-TCE AVERAGE CONCENTRATIONS AND CONCEPTUAL PLUME LOCATIONS MAY 1988 THROUGH OCTOBER 1988

drawn MEC	approved JLW	drawing no 87040-109-AA
checked JLW	date 3-28-89	

r. e. wright associates, inc.
earth resources consultants

Groundwater analytical results indicate that six different plumes of VOC degraded groundwater exist in the study area. Several of these plumes may have originated from one or more sources. First, NAS Wells 34, 32, and 8 appear similarly effected by TCE and 1,1,1-TCA. PCE is also a constituent of the plume detected in Wells 34 and 32 to the east of, but not in Well 8. This same TCE/PCE plume may also encompass the Njardvik North Wellfield; however, the data are insufficient to delineate whether this area may be impacted by a second plume as it does not contain 1,1,1-TCA present in the other wells. NAS Wells 31, 35, and 36 appear to share a third common plume which is concentrated around Well 35. The TCE in this plume may have resulted from the same source as Wells 8, 32, and 34. However, no 1,1,1-TCA was detected in Well 31, suggesting two separate plumes of that solvent. A fourth plume of TCE, which encompasses Wells 1632, 1756, 1792, 1773, and 1770, is present in the West End Complex. The Nickel Area has TCE and CTC degradation in the groundwater of MW-1. This fifth plume may impact the Njardvik East Wellfield. Finally, a PCE plume appears to be the predominant impairment to the Keflavik North Wellfield.

5.2 Hydrology

5.2.1 Introduction

Work Task 7 of the PA/SI was implemented to develop an understanding of the groundwater hydrology of the study area. Due to the dynamic nature of the groundwater surface, caused primarily by tidal influences, groundwater level elevations in 18 wells on the Rosmhvalanes Peninsula were monitored every hour for 28 days in October and November 1988. Hourly groundwater contour maps were plotted from the data and computer animated in

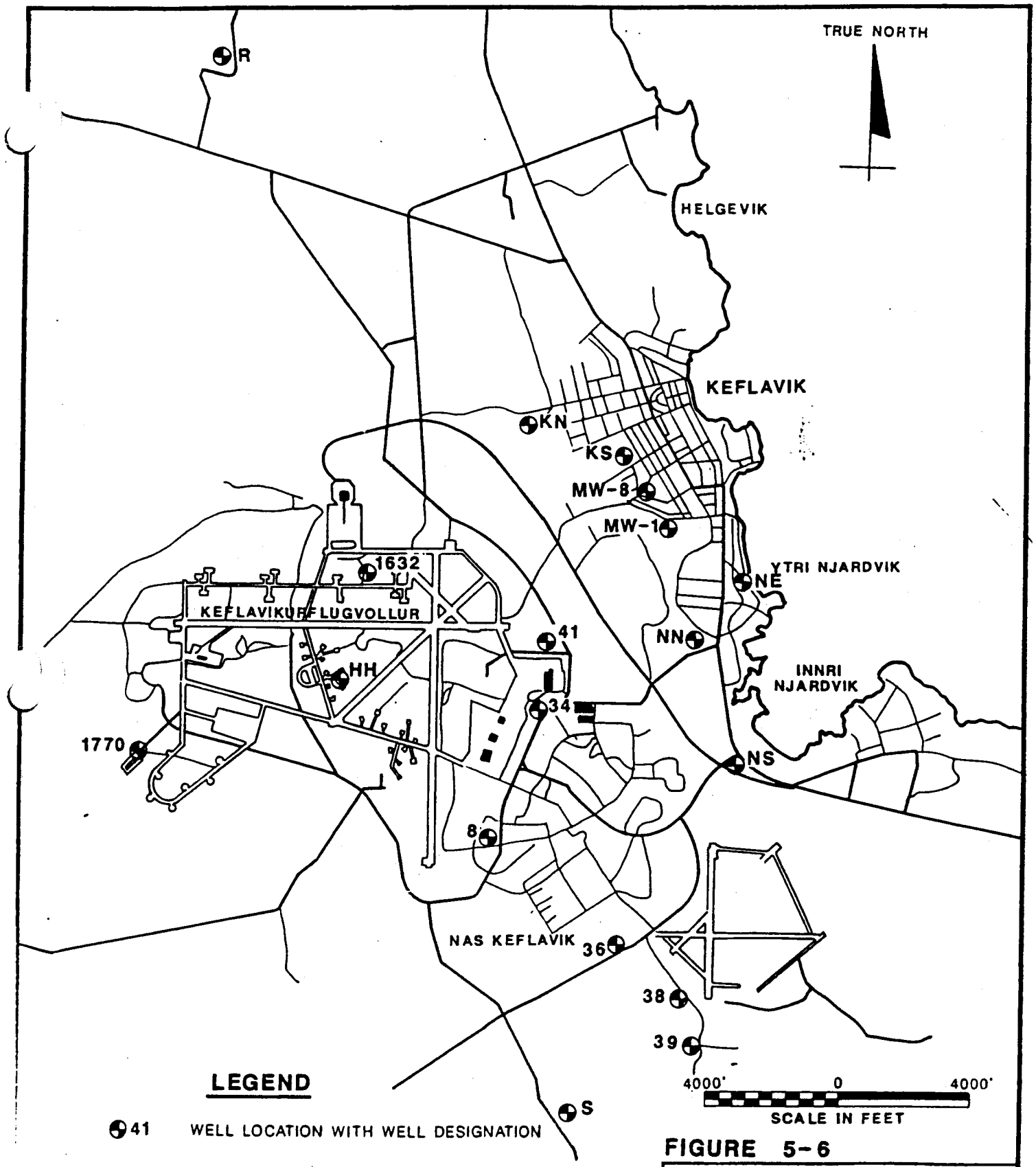
a video recording. In addition, hydrographs of in-well groundwater elevations, plots of precipitation and atmospheric pressure, and average daily and long-term groundwater contour maps were generated (Appendix G). Finally, a hydraulic budget and estimates of groundwater discharge (flux) and velocity were developed.

5.2.2 Groundwater Monitoring

5.2.2.1 Data Acquisition and Reduction - Twenty-one wells were identified and inspected by REWAI and NEA personnel for use as groundwater monitoring locations. NEA personnel surveyed the elevation and location of these 21 wells. Due to obstructions in NAS wells 31 and 32, and free-phase oil in NAS Well 37, monitoring equipment could not be installed. Therefore, the remaining 18 wells were used for groundwater monitoring (Figure 5-6).

Pressure transducers and automatic data loggers were purchased from Thoris and used to monitor the groundwater elevations in the 18 wells. REWAI and NEA personnel installed the monitoring equipment on October 18, 1988, according to procedures described in Appendix C. The data loggers were programmed to record groundwater elevations every hour.

On November 15, 1988, the information recorded by the data loggers was collected and transferred to the NEA's computer. Groundwater data were reduced, edited, and contoured by the NEA on an HP 9000/840 computer with a program called DDD developed by the Computer Science Center of the Department of Energy, Mines, and Resources, Canada. The program grids the irregularly distributed data into a rectangular grid (49 x 39 points). Water level data were corrected for well loss caused by pumping



LEGEND

41 WELL LOCATION WITH WELL DESIGNATION

FIGURE 5-6

NAVY - NAS
KEFLAVIK, ICELAND

GROUNDWATER MONITORING WELLS

drawn MEC	approved JLW	drawing no.
checked JLW	date 3-31-89	87040-113-AA

r. e. wright associates, inc.
earth resources consultants
middletown, pa. westminster, md

BASE MAP: PREPARED FROM MAP PUBLISHED BY LANDMAELINAR ISLANDS (ICELAND GEODETIC SURVEY) AND DMAHTC U.S.A.

as will be discussed in Section 5.2.2.3. All interpolation between wells was either linear or Cubic Bessel Interpolation. In order to be able to plot comparable maps for all measuring times, the data for some of the wells were extrapolated either forward or backward in time so that time series for all the wells covered the same time interval. Table 5-9 lists all editing of the data and available information on pumps and pumping in each well.

In order to aid in the interpolation of the contouring program by establishing boundary conditions, four offshore points with mean sea level values were arbitrarily added near Keflavik and Njardvik. In addition, three points were added close to the Njardvik South Well in order to limit the apparent influence on the computer-generated maps in the Njardvik South area by the infiltration of wastewater from the Sudurnes Heating Services. Data for these points were based on the average of the surrounding wells and the Njardvik South Well.

5.2.2.2 Hydrograph Analysis - Hydrographs of groundwater level elevations were plotted from the hourly measurements for each of the 18 wells monitored during the 28-day period. The resulting plots were analyzed for long-term transient effects due to pumping, tidal, and meteorological (precipitation and barometric) influences (Figure 5-7). Generalized groupings of wells displaying similar hydrographs were made and broad-based values of aquifer characteristics were estimated for comparison with hydraulic budget values.

In general, all hydrographs displayed two unique conditions. The first condition occurred in the period initiated upon start-up of the monitoring program, October 18, until the initiation of a series of significant storm events on November 2. During this

Table 5-9

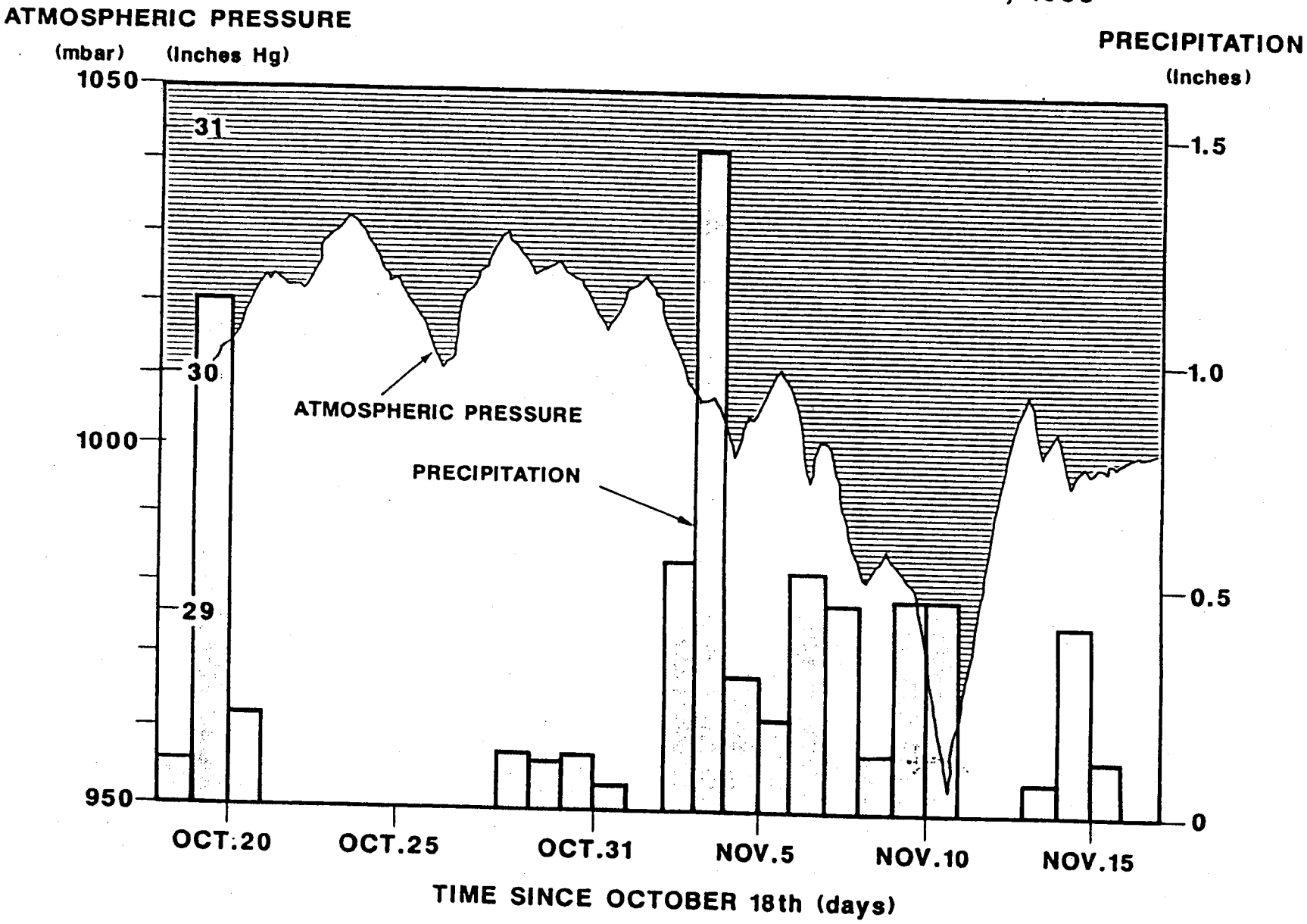
Data Editing

Well	Data Logger	Comments
1770	170	Pump in well, pumping unknown; data not changed; 4 points added at the end, linearly using the last 11 points as reference.
36	171	Constant pumping; spikes removed; 19 points added at the beginning (well 8 used as reference -0.04987 m); 3 points added at the end, linearly using the last 11 points as reference.
8	172	Pump in well, no pumping; data not changed; 4 points added at the end, linearly using the last 11 points as reference.
38	173	Unsteady pumping, not possible to correct; data from well 36 used instead.
34	174	Constant pumping except for 6 hours, data moved up to remove well effects; 4 points added at the end, linearly, using the last 11 points as reference.
AF	176	No pumping; data not changed; gaps (10/21/17 - 10/22/11) filled in using Bessel interpolation; 4 points added at the end, linearly using the last 11 points as reference.
41	177	Constant pumping except two short intervals; date moved up to remove well effects; 4 points added at the end, linearly using the last 11 points as reference.
R	178	Pump in well; pumping not known; data not changed; 1 point added at the end - same as the last one.
S	179	No pump in well; data not changed; 19 points added at the beginning; constant (same as the first data point); 3 points added to the end (same as the last one).
MW-1	180	No pump in well; data not changed; 1 point added at the end; same as the last one.
1632	181	Pump in well; most likely not used during monitoring; data not changed; gap (10/21/18-10/22/05) filled in using Bessel interpolation; 3 points added to the end (same as the last one).
MW-8	182	No pump in well; data not changed; 1 point added at the end, same as the last one.
39	184	Pump in well, used for short intervals; data corrected for well effects; 19 points added at the beginning; constant (same as the first point); 3 points added to the end (same as the last one).
NE	0222	Pump in well, not known if in use, most likely not; data not changed.
NS	0226	Constant pumping, inflow; data not changed; gap (10/20/13-10/21/16) filled in linearly; 5 points deleted at the beginning.
KN	1210	Constant pumping except for 6 hours; data moved up to remove well effects; 1 point added at the end; same as the last one.
NN	1211	No pump in well; data not changed.
KS	1216	Constant pumping except for 6 hours; data moved up to remove well effects; 1 point added at the end; same as the last one.

FIG 5-7

NAS-KEFLAVIK, ICELAND

METEOROLOGIC DATA OCTOBER 18-NOVEMBER 15, 1988



initial period, mean groundwater elevations remained essentially constant. This initial period was characterized by two minor water level recessions straddling a period of a slight rise which peaked on or about October 27. A relatively minor precipitation event occurred near the end of the initial period between October 28 and 31. This was a rainfall of just under 0.2 inches spread over a 4-day period which caused no response on the hydrographs.

The second half of the monitoring period was marked by the onset of a significant storm system characterized by extremely low atmospheric pressure of 28.3 inches of mercury (953 millibars). Rainfall of about one inch occurred in the first two days followed by a week of moderately consistent rainfall totaling an additional 1.2 inches. The monitoring period ended with a three-day absence of rainfall followed by an additional 0.25 inches of rain during the next three days.

5.2.2.3 Pumping Influences on Groundwater Levels - Of the wells monitored during the period, 11 were water supply wells which were pumped either continuously or periodically. In order to determine the effects on groundwater elevations caused by this pumping, the supply pumps were shut off for a six-hour period on the morning of October 29, 1988, and the response of groundwater levels to the cessation of pumping was recorded. In most of the pumping wells, the response to shutdown was relatively instantaneous recovery followed by relatively static groundwater levels. This response suggested the recovery of water level was from well entry frictional effects (well loss) rather than significant aquifer drawdown. In the Njardvik North Wellfield, a non-pumping well was monitored and displayed no response from shutdown of nearby pumping wells which could be discerned from the background tidal influence.

The response of pumping wells that showed only well loss and no residual drawdown (recovery) of the aquifer indicates that the supply wells are not causing aquifer drawdown at present pumping rates. It follows that, given the pumping rates produced from the wellfields, hydraulic conductivities are extremely high in the aquifer.

The effect of well loss in the pumping wells may be misleading in a hydraulic evaluation of the groundwater flow system which uses water level data from pumping wells. Therefore, before using the data in the analysis, drawdown attributed to well loss, as determined in the above exercise, was negated from the data where appropriate for assembling groundwater elevatation maps. This provided an approximation of groundwater elevations outside the well bore, but would not alter any other natural variation in groundwater elevation.

5.2.2.4 Weather Influences - In a confined aquifer (sealed from communication with the atmosphere), relatively significant variations in water levels of wells can result from changes in atmospheric pressure. The relationship between atmospheric pressure and well water level is inverse, such that a decrease in atmospheric pressure produces an increase in water level. As this effect occurs within the well bore only water levels respond relatively instantaneously with changes in atmospheric pressure. In general, greater magnitudes of atmospherically induced well bore water level changes occur with greater degrees of confinement of the aquifer.

The literature on the hydrogeology of the site indicates that the aquifer is unconfined. As an unconfined aquifer is, by definition, connected to the atmosphere, atmospheric pressure

changes are transmitted directly and equally to the water table in both the aquifer and the well. Therefore, significant water level fluctuations are not expected to be induced by barometric changes at this site.

An alternative mechanism of water table fluctuation which occurs on small permeable oceanic islands is caused by sea level changes in response to atmospheric pressure variations (Todd, 1979). The relationship of groundwater elevation to barometric pressure is also inverse such that a lower atmospheric pressure results in a sea and corresponding groundwater level rise. A sea level change would be reflected in both confined and unconfined aquifers inland. However, the effect is transmitted as a long-term tide to the water table with attenuation and time lag dictated by the aquifer character. As no monitoring of sea level changes was done during the monitoring period, the influence of this mechanism on groundwater levels could not be assessed.

In addition to the above meteorological phenomena, groundwater recharge from rainfall infiltration may raise the groundwater levels. During the 28 days of monitoring of late October and early November, approximately 3.6 inches of rain fell. Meteorological records maintained between 1953 and 1987 on the Rosmhvalanes Peninsula indicate precipitation averages for October and November are approximately 4.9 and 4.3 inches, respectively. Therefore, the monitoring period represents below average precipitation.

The response to rainfall is highly dependent on subsurface conditions of moisture content, specific retention, permeability, confinement, and depth to the water table. A nearly instantaneous response of shallow water tables to rainfall has been noted by some investigators (Todd, 1979) due to the pressure

increase of air trapped in the zone of aeration by infiltrating water. A lag in response to rainfall may be due to a deficiency in soil moisture content below the specific retention value. The water table will not respond to recharge from rainfall until the moisture deficiency has been satisfied.

In most of the hydrographs of site wells, a lack of response or a lag in groundwater response is noted for two precipitation events during the monitoring period. Commencing late on October 28 and ending on October 31, a rainfall of approximately 0.2 inches fell with no observed response in groundwater levels. On November 2, a significant rainfall of 2.2 inches occurred over 9 days. Response time by the aquifer either occurred immediately or lagged up to one day after the onset of the rain in various hydrographs of wells on the site.

The rise in groundwater level is the result of that portion of precipitation which recharges the groundwater table, divided by the aquifer's specific yield, which is relatively equal to the effective porosity or storativity in an unconfined aquifer. Literature estimates of the storativities for the site ranged from 0.01 to 0.10. Water level increases from the rain between November 2 and November 11 ranged between 2.2 and 4.3 feet in well hydrographs. Based on the assumption of infiltration of 72 percent of all rainfall (equal to the ratio of precipitation to groundwater recharge, Section 5.2.4), and an unconfined aquifer, the effective porosity was estimated in the vicinity of the monitoring wells. These estimates are presented in Table 5-10 and were within the range given by the literature.

5.2.2.5 <u>Tidal Influences on Groundwater Elevation</u> - The tidal amplitude in the Icelandic coastal waters ranges from 3.9 to 13.8 feet depending on the lunar phase. Most wells on the

Table 5-10

NAS-Keflavik, Iceland

Effective Porosity Estimates

Well	h	Effective Porosity (N) Estimate*
NE	2.5	0.03 - 0.05
MW-1	3.0	0.03 - 0.05
NN	3.5	0.02 - 0.04
MW-8	3.2	0.03 - 0.04
1770	3.6	0.02 - 0.04
38	3.7	0.02 - 0.04
8	3.7	0.02 - 0.04
KN	3.7	0.02 - 0.04
36	3.6	0.02 - 0.04
41	4.3	0.02 - 0.03
R	3.8	0.02 - 0.04
KS	2.3	0.03 - 0.06
34	2.6	0.03 - 0.05
1632	2.6	0.03 - 0.05
S	2.2	0.04 - 0.06
F (HH)	2.4	0.03 - 0.06
39	3.2	0.03 - 0.04
NS	2.5	0.03 - 0.05

* Based on groundwater recharge of h feet. November 2 through November 11, 1988. See Appendix G for calculations.

Rosmhvalanes Peninsula show varying degrees of groundwater level fluctuations due to tidal influences. Groundwater monitoring during the 28-day period of the PA/SI enabled the evaluation of the tide on the groundwater flow system. The periods of greatest tidal amplitude observed by groundwater monitoring occurred on October 25 and November 9 during the full moon and the new moon, respectively. A slight increase in mean aquifer water level elevations independent of rainfall occurred during the period of the full moon, as evidenced by nearly all the hydrographs acquired. Rainfall was occurring during the period of the new moon; therefore, any response of aquifer mean water levels to that event could not be evaluated.

Tidal amplitude is greatest near the coast as indicated by the groundwater level in the Njardvik East Well. This well is approximately 450 feet inland, and its water level oscillates with up to 4.5 feet of amplitude. Tidal amplitudes decrease inland from about 1 foot at MW-1 in the Nickel Area to about 0.1 foot at Well 1632 (2330 feet and 11,650 feet west from the coast, respectively).

Erratic tidal fluctuations may have been influenced by different tidal inputs (i.e. east and west coast tides) causing constructive and destructive interferences of wave sets. The Stapafell well was located between both the east and west coasts (12,800 feet and 8,700 feet distant, respectively) and had erratic tidal amplitudes which appeared to be dampened on some tidal cycles and boosted on others. NAS Well 39 had an erratically occurring tidal fluctuation which also may result from interferences between the tidal functions of both coasts.

A tidal amplitude of 0.5 feet was observed in NAS Well 1770 near the center of the peninsula at a distance of approximately

9,840 feet from the inlet to the southwest of that well. This relatively large tidal amplitude at such a great distance from the nearest coastal waters is thought to be a result of the constructive interference of tidal inputs from both coasts and the relatively transmissive aquifer character.

The tidal amplitude attenuation and time lag between coastal waters and groundwater levels in wells were used to estimate the ratio of the aquifer parameters transmissivity (T) and storativity (S). Hydrographs from the wells which displayed tidal fluctuation were analyzed for the T/S ratio based on an amplitude attenuation determined from the hydrographs and tide tables. Table 5-11 provides the results of this calculation and an estimate of T based on the effective porosities developed from rainfall response by the hydrographs discussed in Section 5.2.2.4.

The results of these estimates (Appendix G) indicate that the aquifer under the study area is highly transmissive. The large tidal amplitudes in groundwater elevations at great distances from coastal water supports this conclusion. Transmissivity estimates based on the analysis show a range of 0.42 Mgpd/ft to 35.6 Mgpd/ft. Some degree of variation in tidal response is present and may result from lithologic or structural features promoting localized orientation of groundwater flow. However, the general pattern suggests a decrease in transmissivity closer to the eastern coast. This pattern may result from a decrease in aquifer thickness or permeability near the coast.

5.2.2.6 <u>Hydrograph Types</u> - Four unique well hydrograph types were recognized from the monitoring data. The types are the result of and represent variable hydraulic conditions in the groundwater flow system such as differences in aquifer character

NAS-Keflavik, Iceland
Tidal Estimate of Transmissivity (T)
from 28-Day Monitoring Hydrographs

Well	Distance (x) from Coast (feet)	Tidal Amplitude (h) in Well (feet)	Tidal Amplitude (ho) from Tide Table (feet)	T/S Ratio (ft^2/M)	Effective Porosity Estimate (Table 5-11)	Range of T's** (Mgpd/ft)
1770	9840	0.25	7.22	28,950	0.02 - 0.04	0.98 - 1.95
NE	450	2.25	7.22	1282	0.03 - 0.05	0.42 - 0.69
MW-1	2330	0.50	7.22	6550	0.03 - 0.05	2.11 - 3.53
NN	1560	0.65	7.22	3600	0.02 - 0.04	1.16 - 1.94
MW-8	2760	0.35	7.22	7160	0.03 - 0.04	2.31 - 3.86
1770	9840	0.25	7.22	73680	0.02 - 0.04	15.9 - 31.7
38	8100	0.05	7.22	22850	0.02 - 0.04	4.92 - 9.84
8	9120	0.05	7.22	28950	0.02 - 0.04	6.24 - 12.5
KW	5280	0.05	7.22	4530	0.02 - 0.04	0.98 - 1.95
36	8040	0.05	7.22	22500	0.02 - 0.04	4.85 - 9.69
41	6350	0.15	7.22	23125	0.02 - 0.03	4.98 - 7.47
R	9350	0.10	7.22	41090	0.02 - 0.04	8.85 - 17.7
KS	2620	0.30	7.22	5850	0.03 - 0.06	1.89 - 3.78
34	6530	0.01	7.22	20050	0.03 - 0.05	6.48 - 10.8
1632	11650	0.05	7.22	47250	0.03 - 0.05	15.3 - 25.4
S	8700	0.15	7.22	43400	0.04 - 0.06	18.7 - 28.0
AF (HH)	10825	0.10	7.22	55075	0.03 - 0.06	17.8 - 35.6
39	9380	0.05	7.22	30625	0.03 - 0.04	9.90 - 13.2
NS	1150	0	7.22	--	0.03 - 0.05	--

Range 0.42 - 35.6 Mgpd/ft
Average 10.01 Mgpd/ft

** See Appendix G for Calculation
-- Not Calculated
Mgpd/ft - Million Gallons Per Day Per Foot

distance from tidal water bodies, and dominance by wastewater infiltration. Differentiation of hydrograph signatures was based on response to tide and meteorological influences.

The Type-1 hydrograph was tidally dominated, due to close proximity to coastal water bodies (Figure 5-8). The Njardvik East Well was the most influenced by tide such that other characteristics could not be discerned. The Njardvik North Wellfield, MW-1, and MW-8 (in the Nickel Area) also experienced relatively large tidal influences. However, their signatures resemble the second hydrograph type.

The Type-2 hydrograph was characterized by a relatively smooth groundwater level signature (even in the ones affected by tide) and a rapid and large increase in water level with the onset of the storm on November 2 (Figure 5-9). This hydrograph type appeared to inversely correlate with atmospheric pressure, but in some wells, the peaks in the water levels appeared to lag the extreme lows in barometric pressure by one-half to one day. Recession of water levels occurred immediately after weather events and was rapid. The wells displaying this hydrograph type were interpreted to have lower transmissivities and lower effective porosities than Type-3 wells by the methods discussed in Section 5.2.2.5. Some degree of confinement may be indicated by the wells with this hydrograph; however, the degree of confinement of the aquifer was not determined by this investigation.

The Type-3 hydrograph was characterized by a relatively rough signature (Figure 5-10). Water level increases in response to the storm events lagged the November 2 onset by at least one day. The peaks in groundwater levels also lagged the extremes in barometric lows by one-half to one day. Recession rates in

FIGURE 5-8

NAS-KEFLAVIK, ICELAND

TYPE 1: EXAMPLE OF TIDALLY DOMINATED GROUNDWATER HYDROGRAPH

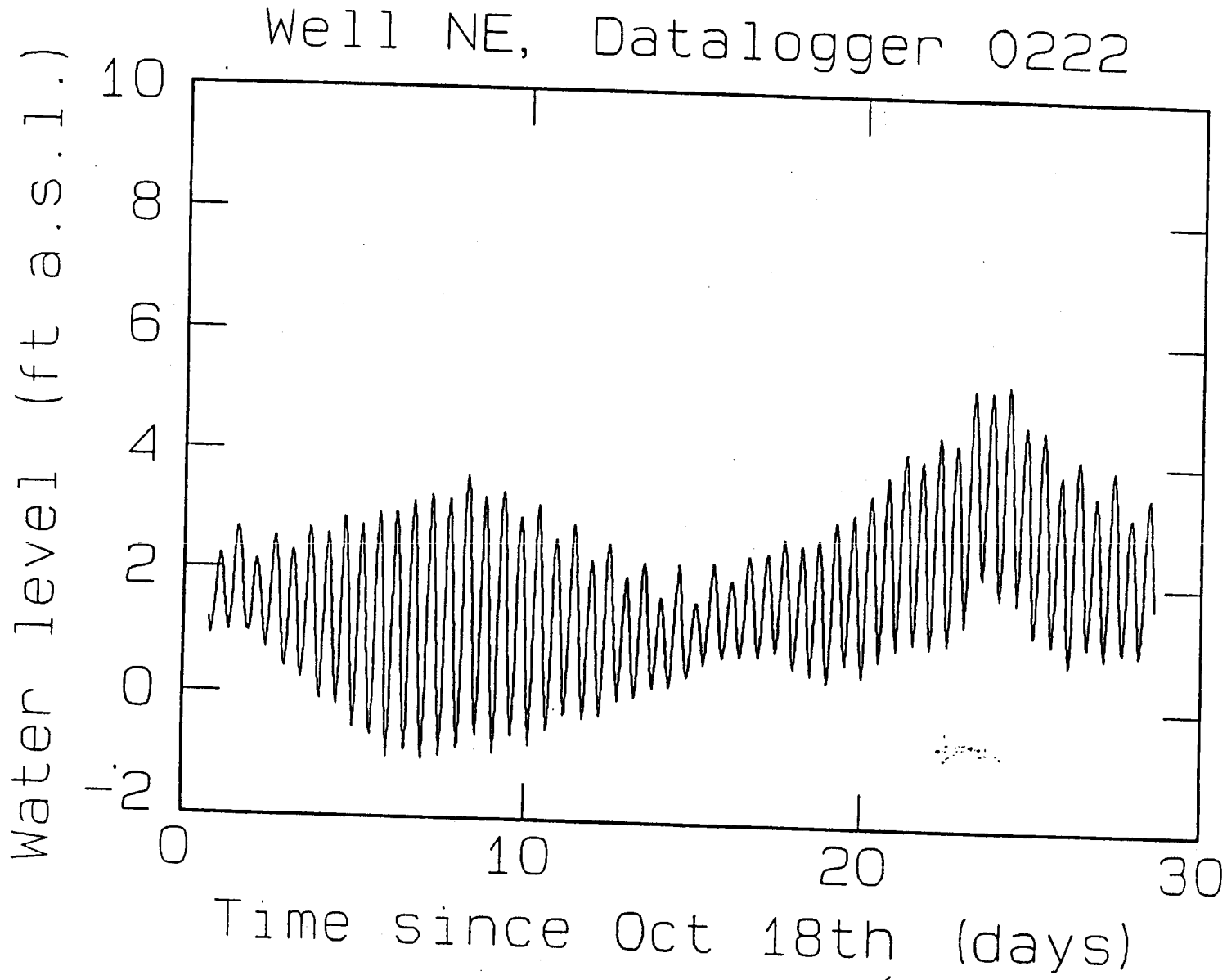


FIGURE 5-9

NAS-KEFLAVIK, ICELAND

TYPE 2: EXAMPLE OF SMOOTH RESPONSE GROUNDWATER HYDROGRAPH

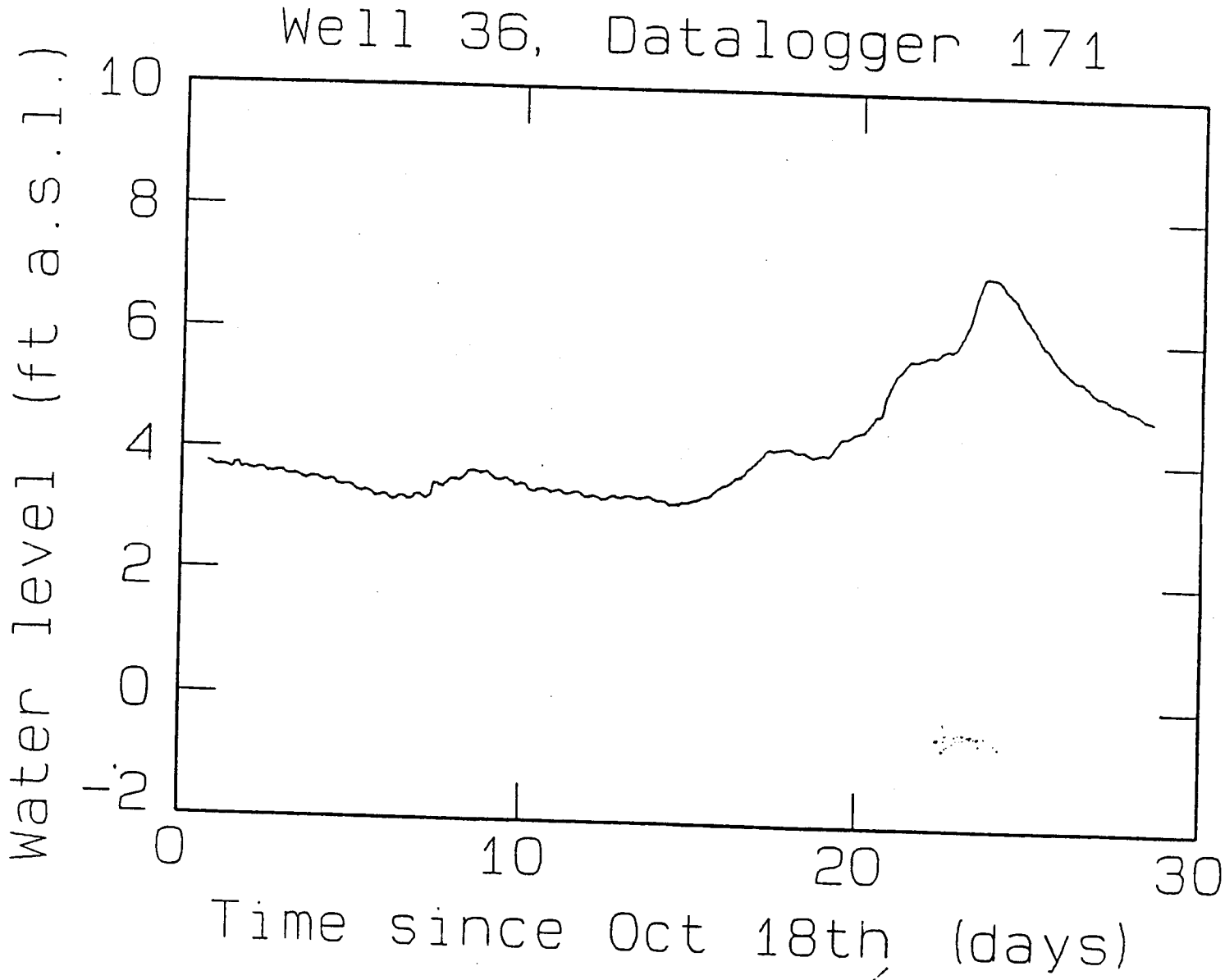
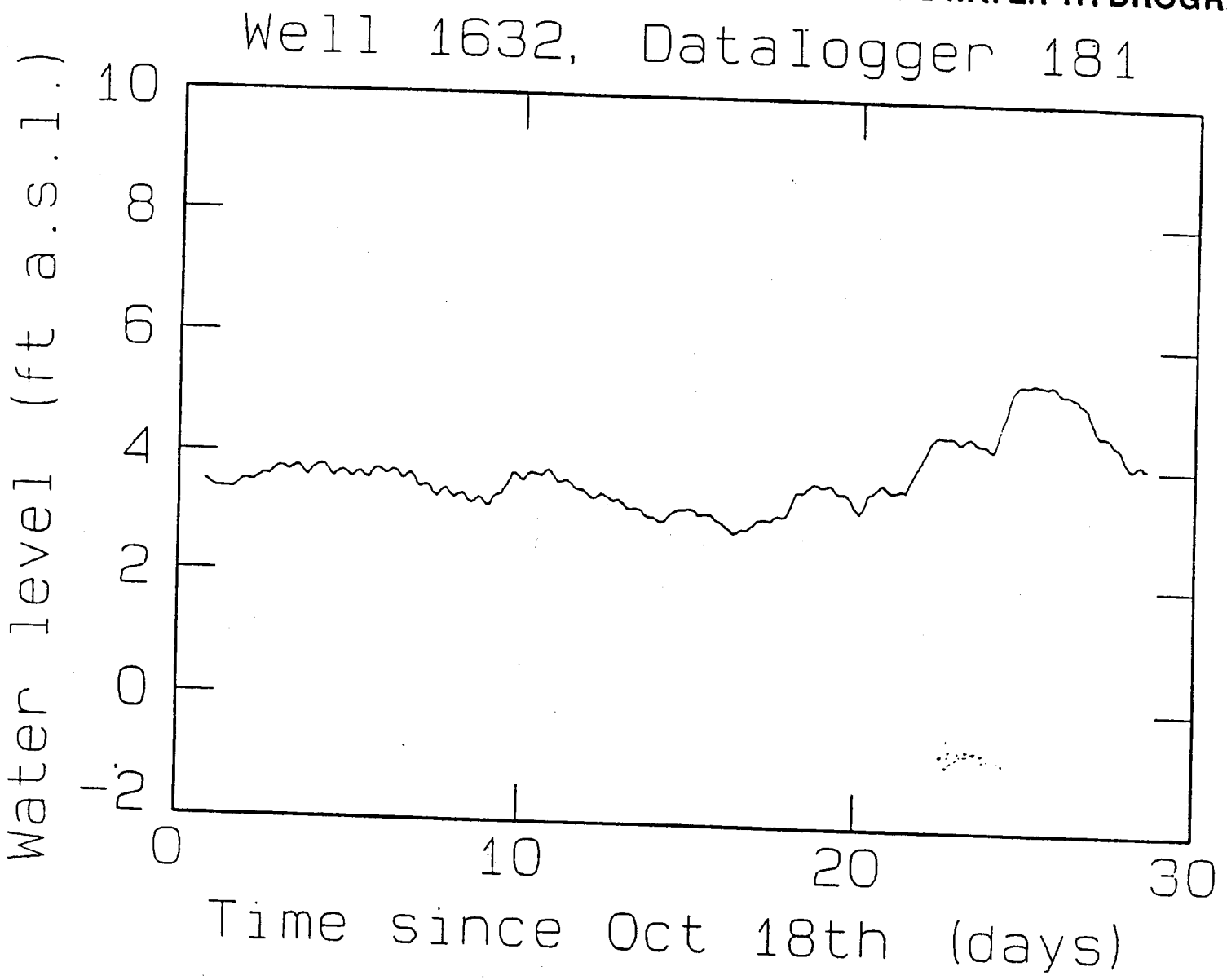


FIGURE 5-10

NAS-KEFLAVIK, ICELAND

TYPE 3: EXAMPLE OF ROUGH RESPONSE GROUNDWATER HYDROGRAPH



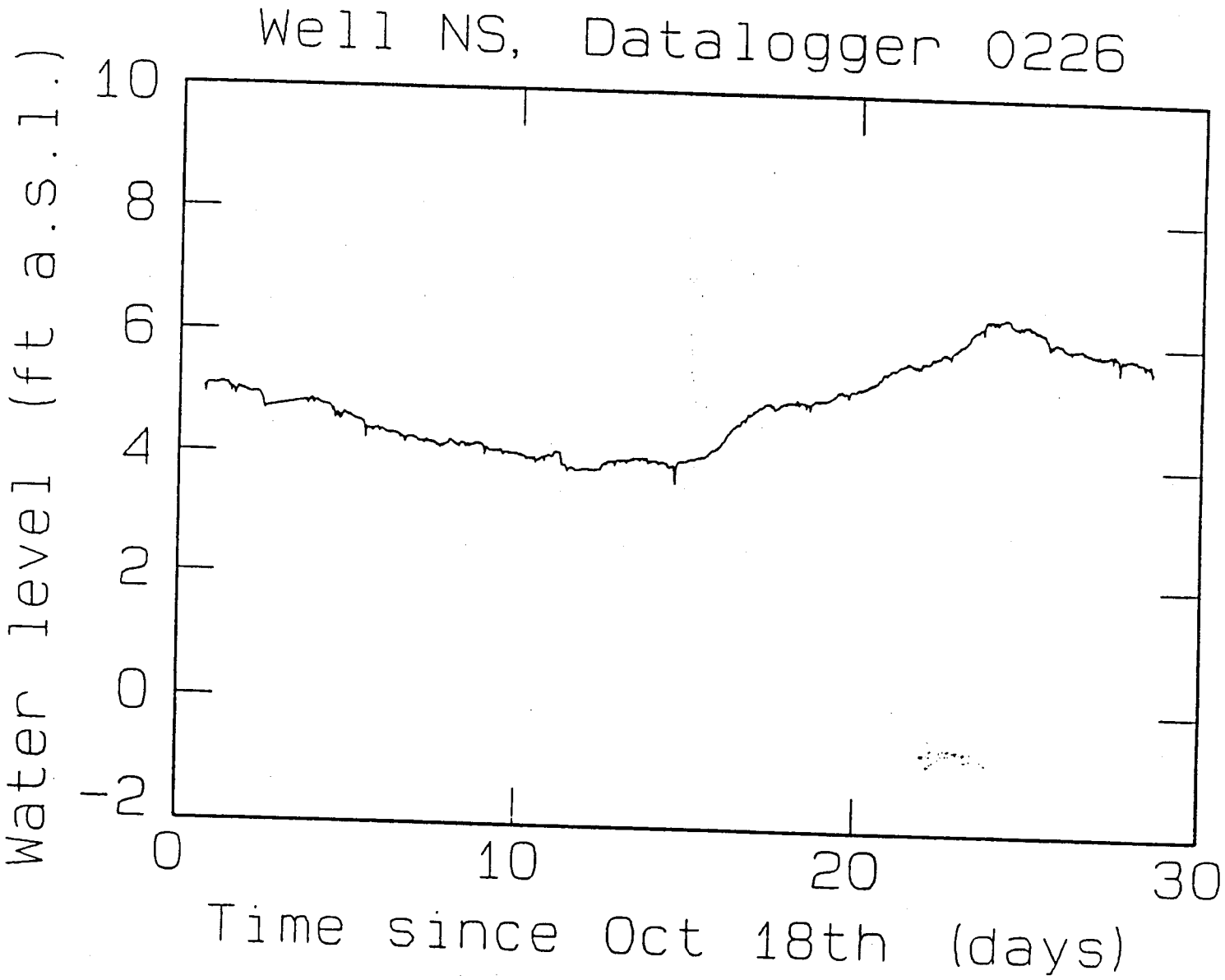
groundwater levels were relatively slow. The well displaying this type of hydrograph were interpreted to have relatively high transmissivities and effective porosities (Section 5.2.2.5). The slower and less dramatic response to rainfall in these hydrographs may be due to the relatively higher indicated effective porosities and transmissivities; however, the parameters of the aquifer penetrated by these wells were not verified by this study.

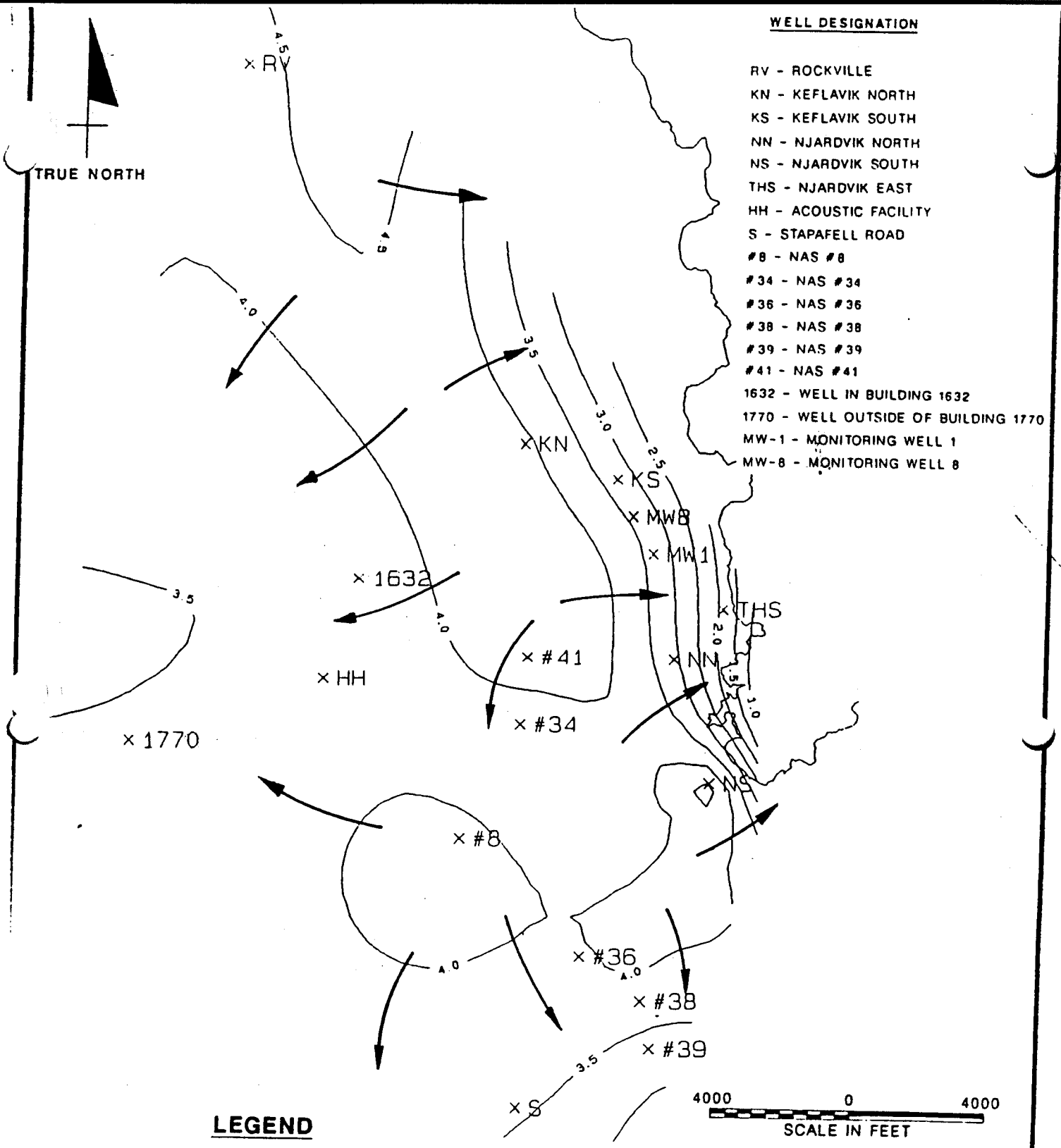
Finally, the fourth type of hydrograph was represented by the Njardvik South Well, which was dominated by the influence of injection by the Sudurnes Heating Authority in that vicinity (Figure 5-11). This well did show a one-day delay in rainfall response and calculations indicated a relatively high effective porosity of 0.07. No tidal influence was indicated by this well, even though it is located only 1,200 feet inland. Therefore, no estimate of transmissivity was calculated for this well.

5.2.3 Groundwater Contour Map

Six hundred seventy-one hourly groundwater contour maps were generated from the data collected during the 28-day monitoring period. In addition to the hourly groundwater contour maps, 29 groundwater contour maps were constructed using the daily average groundwater elevation for each well (Appendix G). Also, groundwater contour maps were generated using the average groundwater elevation for each well between October 18 and November 1 and over the entire monitoring period (Figures 5-12 and 5-13, respectively). Averaging of groundwater elevations enabled the removal of tide-induced changes in groundwater elevation, and the data collected enabled the development of a long-term average groundwater flow model.

FIGURE 5-11
NAS-KEFLAVIK, ICELAND
TYPE 4: EXAMPLE OF SPENT HEATING WATER INFILTRATION DOMINATED GROUNDWATER HYDROGRAPH





LEGEND

GENERALIZED GROUNDWATER FLOW DIRECTION

—4.0— GROUNDWATER ELEVATION (FT.) (DASHED WHERE INFERRED)

X WELL OR WELLFIELD LOCATION

NOTE: DATA AVERAGED BEFORE SIGNIFICANT METEOROLOGICAL INFLUENCES

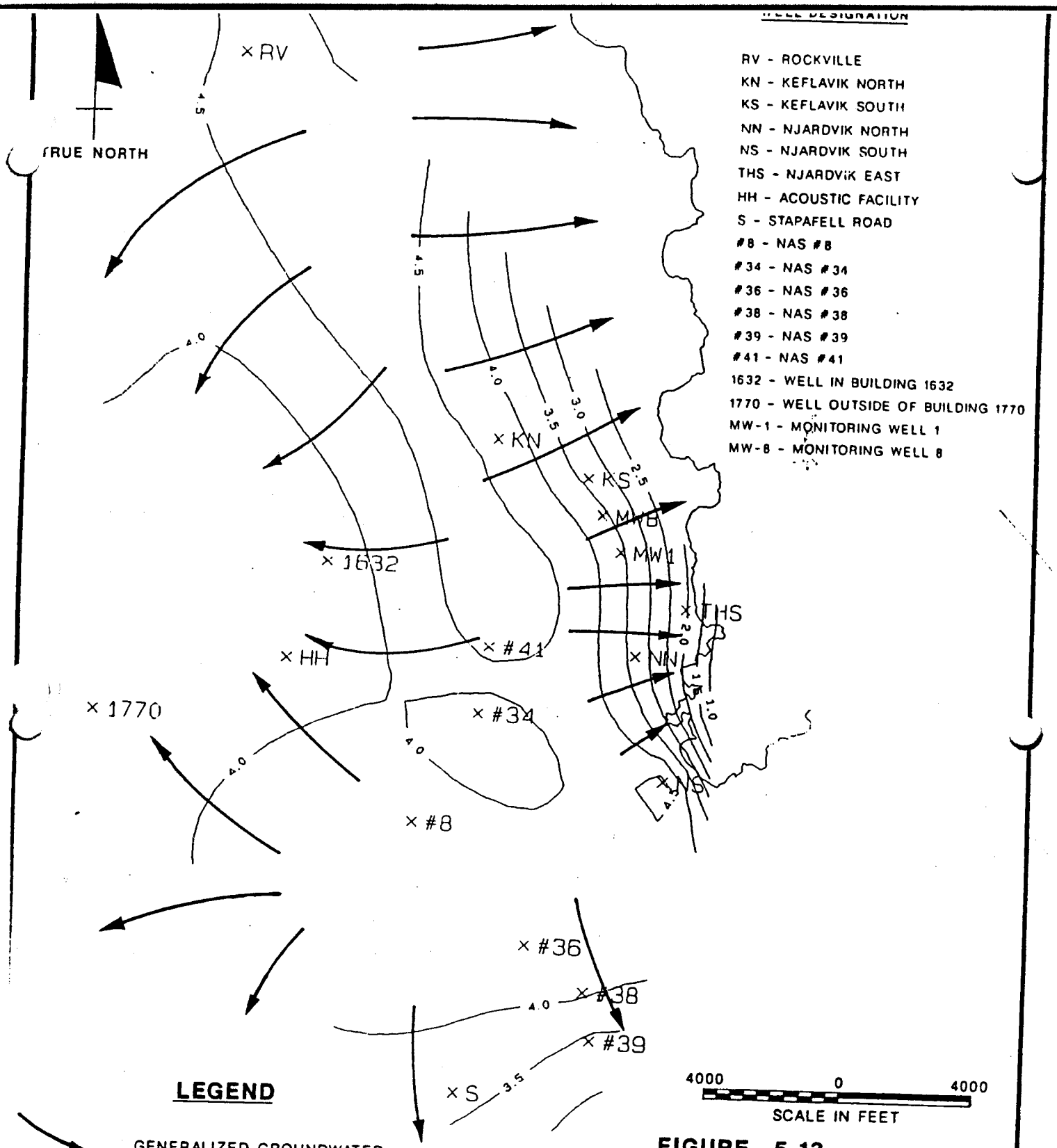
FIGURE 5-12

NAVY-NAS
KEFLAVIK, ICELAND

GROUNDWATER CONTOUR MAP
(OCT.18-NOV.1, 1988)

drawn MEK	approved JLW	drawing no. 87040-110-AA
checked JLW	date 3-27-89	

r. e. wright associates, inc.
earth resources consultants
middletown, pa. westminster, md



LEGEND

GENERALIZED GROUNDWATER FLOW DIRECTION

4.0 GROUNDWATER ELEVATION (FT.) (OCT.18-NOV.15, 1988)

X WELL OR WELLFIELD LOCATION

FIGURE 5-13

NAVY-NAS
KEFLAVIK, ICELAND

GROUNDWATER CONTOUR MAP AVERAGED OVER 28 DAYS (OCT.18-NOV.15, 1988)

drawn MER	approved	drawing no. 87040-111-AA
checked	date 3-27-89	

r. e. wright associates, inc.
earth resources consultants
middletown, pa. westminster, md

Weather-induced groundwater elevation changes are evident by comparison of contour maps. The only significant difference between the maps is the magnitude of the hydraulic gradient. The groundwater contour maps are similar with respect to generalized macro-scale groundwater flow directions in the study area.

The average contour maps indicate the study area is bisected by a hydraulic divide running approximately north-northwest/south-southeast along the eastern third of the peninsula. Groundwater elevations on this hydraulic divide during the monitoring averaged over 4.0 feet above mean sea level. On the eastern slope of the divide, the hydraulic gradient ranged between 0.0004 and 0.0007 toward the east coast. Hydraulic gradients on the western side of the divide were inadequately defined in some areas due to limited data, but appeared to range from 0.0001 to 0.0003, and the generalized flow is west and south. In the area of NAS Well 34, a low or closed depression in the groundwater table was dominant during the monitoring period. This may reflect the influence of the pumping of Well 34; however, the aquifer transmissivity also appears to be relatively high in this area with respect to surrounding wells, which may result in locally lower water levels.

Due to the wide variation in lithology and the resulting heterogeneous and anisotropic aquifer character, the distribution of water-bearing zones and the locations of preferred paths of groundwater flow are largely unpredictable. Structural elements such as the northeast-southwest tectonic trend; lava sheet dip; and the potential presence of scoria pockets, dikes, and lava tubes may have significant influences on the localized groundwater flow directions. Due to the limited background information and the limited scope of the investigation, delineation of the presence and most frequent orientations of

these structures, and their relative predominance over groundwater flow in the study area cannot be assessed. However, on a macro scale, the aquifer flow could generally be considered to migrate parallel to the hydraulic gradient.

A timing sequence error of 16 hours and 32 hours was identified in the data collected on October 21 and 22 for well 1632 and well HH, respectively. A time shift resulting from the error affected the hourly groundwater elevations in the western drainage basin after that date. However, a review of the sensitivity of the long-term average contour maps to this error indicated that the change in groundwater elevations for the two wells would not affect the interpretations of groundwater flow in the eastern drainage basin. In addition, the average groundwater contour maps were not significantly affected by the change in water elevations in the two wells, and the groundwater flow directions would generally be the same.

5.2.4 Hydrologic Budget

A hydrologic budget provides a generalized basis of describing the aquifer's flow and characteristics. A hydrologic budget was used to evaluate important components of the water passing through the eastern and western drainage basins (Figure 5-14). The 7.5 square mile (mi^2) eastern drainage basin contains the groundwater flow system influencing the Njardvik North Wellfield and the Keflavik North Wellfield. The 15.8 mi^2 western drainage basin contains the groundwater flow system of NAS-Keflavik.

The basic hydrologic budget supposes that the amount of water entering an aquifer is equal to the amount of water leaving it except for changes in storage. Some components are easily measured while others cannot be measured directly; thus, it is

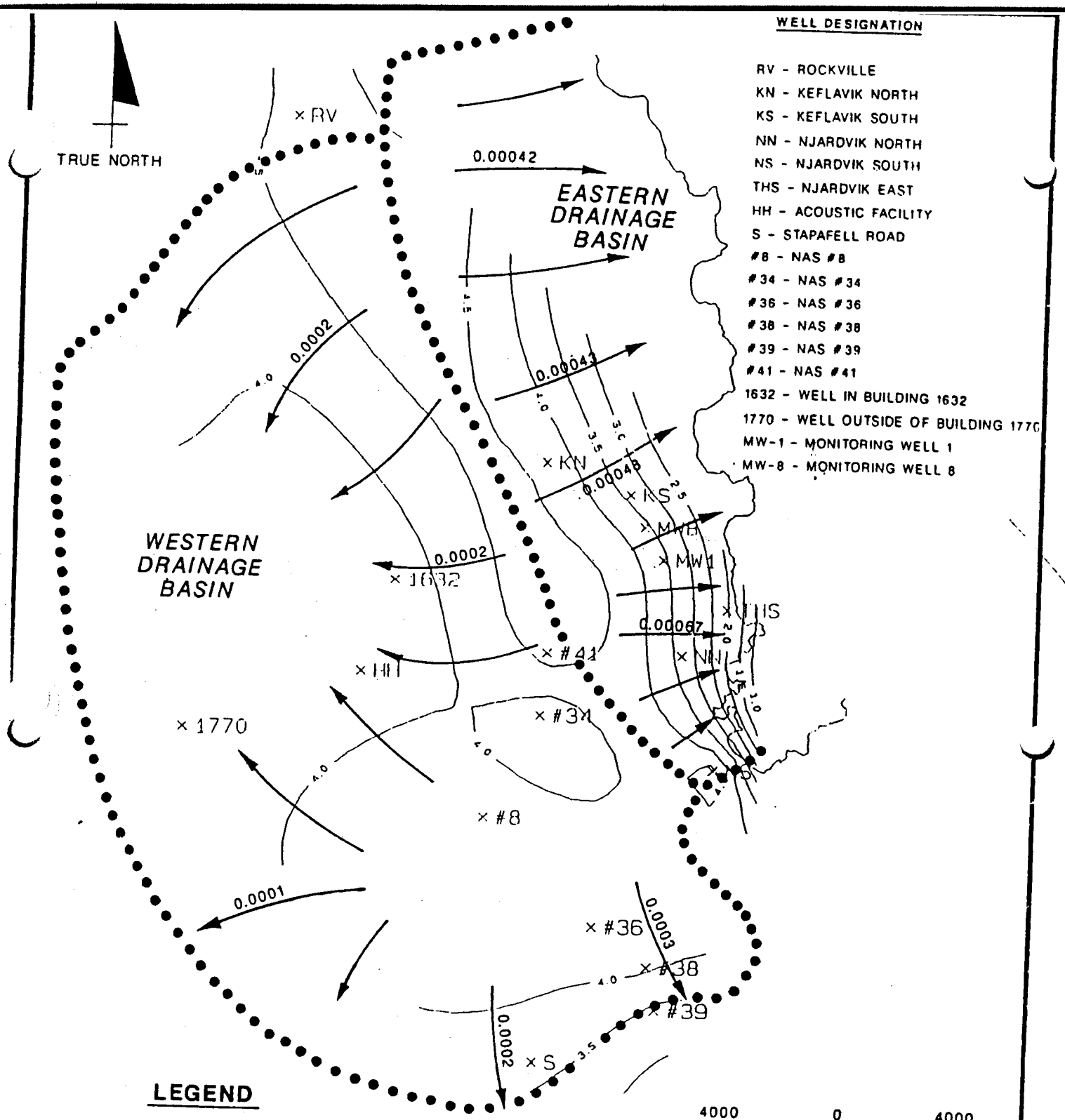


FIGURE 5-14

NAVY-NAS
KEFLAVIK, ICELAND

LOCATION OF GROUNDWATER DRAINAGE BASINS UTILIZED IN HYDROLOGIC BUDGET ESTIMATES

drawn MER	approved JLW	drawing no. 87040-072-AA
checked JLW	date 3-30-89	

r. e. wright associates, inc.
earth resources consultants
middletown, pa. westminster, md

important to understand the relations between the water cycle and the hydrologic budget. The water cycle begins with precipitation (P). Once on the ground, the water either runs over the surface of the ground to a stream and is transported away (R); is returned to the atmosphere by evaporation or transpiration (ET); or infiltrates the ground, percolates to the water table, and eventually recharges the aquifer (G). The following formula mathematically defines the basic hydrologic budget in terms of the individual components of the water cycle:

$$P = R + G + ET \pm S$$

Change in storage (S) refers to the change in the amount of water stored in the ground over time. Over an entire hydrologic cycle, this term is assumed to be zero. Due to the character of the Moi terrain, it is assumed that the stream runoff (R) in this area is zero. This assumption is supported by the literature and the lack of established stream channels on the peninsula. Evapotranspiration (ET) is quoted in the literature as being 16 inches per year, but is expected to be highly variable during the year. Balancing the hydrologic budget with an average precipitation of 43 inches per year (in/yr) requires that groundwater recharge (G) is 27 in/yr, which is approximately 8 in/yr less than other estimates in the literature. Because of this potential variation, a range of recharge values of 27 and 35 in/yr (G_L and G_H, respectively) was utilized in the hydrologic assessments.

5.2.5 Aquifer Discharge Rates

A technique known as the Area Discharge Method was used to estimate the annualized aquifer discharge from the eastern and western drainage basins. This technique employed the range of

groundwater recharge rates from the literature and the hydrologic budget discussed above (1.29 Mgpd to 1.7 Mgpd, respectively). The results of the analysis produced a range of equilibrium aquifer discharge rates of 6.7 Mgpd to 9.3 Mgpd from the eastern drainage basin and a range of 20.4 Mgpd to 26.8 Mgpd from the western drainage basin.

The volume of groundwater discharge laterally through a cross sectional area of the aquifer over time was also estimated using Darcy's Law. Calculations used an average hydraulic gradient of 0.0005 in the eastern drainage basin and 0.0002 in the western basin. The estimates employed the aquifer transmissivity of 7×10^6 gpd/ft from the Sandgerdi pumping test. The eastern drainage basin discharge of 88 Mgpd, calculated by this method (Appendix G) is approximately 10 times the entire groundwater recharge value for the basin. The western drainage basin discharge of 50 Mgpd by this calculation is about twice the recharge rate. This suggests that the aquifer transmissivity value estimated from the Sandgerdi pumping test is not representative of the average aquifer characteristics of the site.

Solving for T using the Darcy equation and the 6.7 Mgpd solved by the Area Discharge Method groundwater recharge rate in the eastern basin resulted in a transmissivity estimate of 0.5 Mgpd/ft for that basin. Similarly, the 19.4 Mgpd recharge rate in the western drainage basin results in a transmissivity estimate of 2.7 Mgpd/ft.

The estimated transmissivity values for the aquifer under the study area, ranging from approximately 0.5 Mgpd/ft (solved by the Area Discharge Method) to 35 Mgpd/ft (from the tidal influence calculations), reflect the potential variety of the bedrock

aquifer character at the site. Although a conservative transmissivity range on the order of 0.5 to 3.0 Mgpd/ft is considered most appropriate, use of these values in further assessment of the site must be done with caution.

5.2.6 Groundwater Flow Velocity

Interstitial (advective) groundwater flow velocity was calculated using Darcy's Law for the areas of the Keflavik and the Njardvik North wellfields and the Building 885 Drainage Area in the Eastern Drainage Basin and the Fire Training Area and southern portion of the Agreed Area in the western drainage basin. Based on the range of porosities given in the literature and the conservative range of transmissivities given above, the derived advective velocities for the aquifer in the eastern drainage basin range between 1 and 31 ft/d. The range of advective velocities in the western drainage basin is 2 to 54 ft/d.

A potential for a great range in advective velocities is due to the great diversity in aquifer character. Site-specific work is necessary to obtain more precise estimates of groundwater flow velocities in areas of interest.

5.2.7 Groundwater Contaminant Transport

The transport of spilled contaminants in the groundwater is a complex physio-chemical process controlled by the quantities and characteristics of the contaminant spilled, its interaction with the earth materials, the time period and area of the spill, and the characteristics of the groundwater flow system. The types and behavior of chlorinated organic chemicals which were the subject of the PA/SI are generally known. The quantities, time periods, and spill areas were not often recorded, although

general use patterns and locations were described to the investigators (Section 4.0). If introduced into the groundwater in large quantities, the chlorinated solvents would be expected to sink to the bottom of the aquifer. During infiltration, a residual quantity would adhere to the soil and rock particle surfaces which could potentially fully adsorb small quantity spills. As the solvents are somewhat soluble in water, infiltrating precipitation would then leach them from the soil to the groundwater in low concentrations over time.

Groundwater transport of contaminants requires a groundwater flow gradient and a migration pathway. During transport, it is expected that dispersion would result in some mixing of the contaminants within the aquifer. Flow through the diffuse types of aquifer materials will promote mixing and provide a means of lateral dispersion and dilution in the groundwater. The effects of dispersion of contaminants in transport within the groundwater is dependent on initial concentration, length of time of input, retardation or sorption factors, rate of degradation, groundwater flow velocity, and aquifer character. Initial concentrations and length of time of input are unknown. Due to the relatively low organic carbon content of the aquifer, the effect of retardation or slowing of the velocity of the transport of organic compounds by adsorption into the aquifer materials should be minimal. Degradation occurs and the rate is not well defined; however, the rate is expected to be slow based upon the relatively deep depths to groundwater and the relatively low temperatures. Due to the wide range of groundwater velocities and the diffuse types of aquifer materials, the undefined initial concentrations, and input times, the effects of dispersion could not be quantified.

The relatively low concentration of VOCs detected in the groundwater during the PA/SI could have resulted from several

scenarios. One possibility is that only a small quantity of solvents was spilled and only leaching by infiltrating precipitation is occurring. Another is that because of the long-time period since spillage occurred, the VOCs could have been largely diluted and transported away from the study area. A third possibility is that any large VOC introduction into the aquifer may have sunken to the bottom of the water column beneath the freshwater lens leaving behind a residuum on the soil and rock surfaces. This residual solvent could be slowly dissolving into the groundwater creating the concentrations measured on-site.

The time period of spillage appears to be undocumented; however, the on-site use of TCE was widespread and goes back to World War II. The long use period could result in the wide distribution of TCE in groundwater. Comparatively, 1,1,1-TCA--which, as a recent substitute for TCE, is used just as widely--has a smaller plume area.

Because a potentially long time has passed since the spillage of some VOCs, it appears that most of the VOCs remain on-site. This is demonstrated in the southeastern portion of NAS-Keflavik where the downgradient limits of the TCE and 1,1,1-TCA plume were established between NAS Wells 36 and 37. Alternatively, if the VOC plume impacting the Njardvik North Wellfield originated on the NAS facility, most of the contaminant in that plume has moved off-site.

Without further investigation, definition of whether the sources of VOCs to the groundwater are small areas of high concentrations leaching to the groundwater or whether the condition of the groundwater is the dissipated residuum of past practices cannot be determined.

6.0 POTENTIAL SOURCE AREAS FOR GROUNDWATER CONTAMINATION

6.1 Introduction

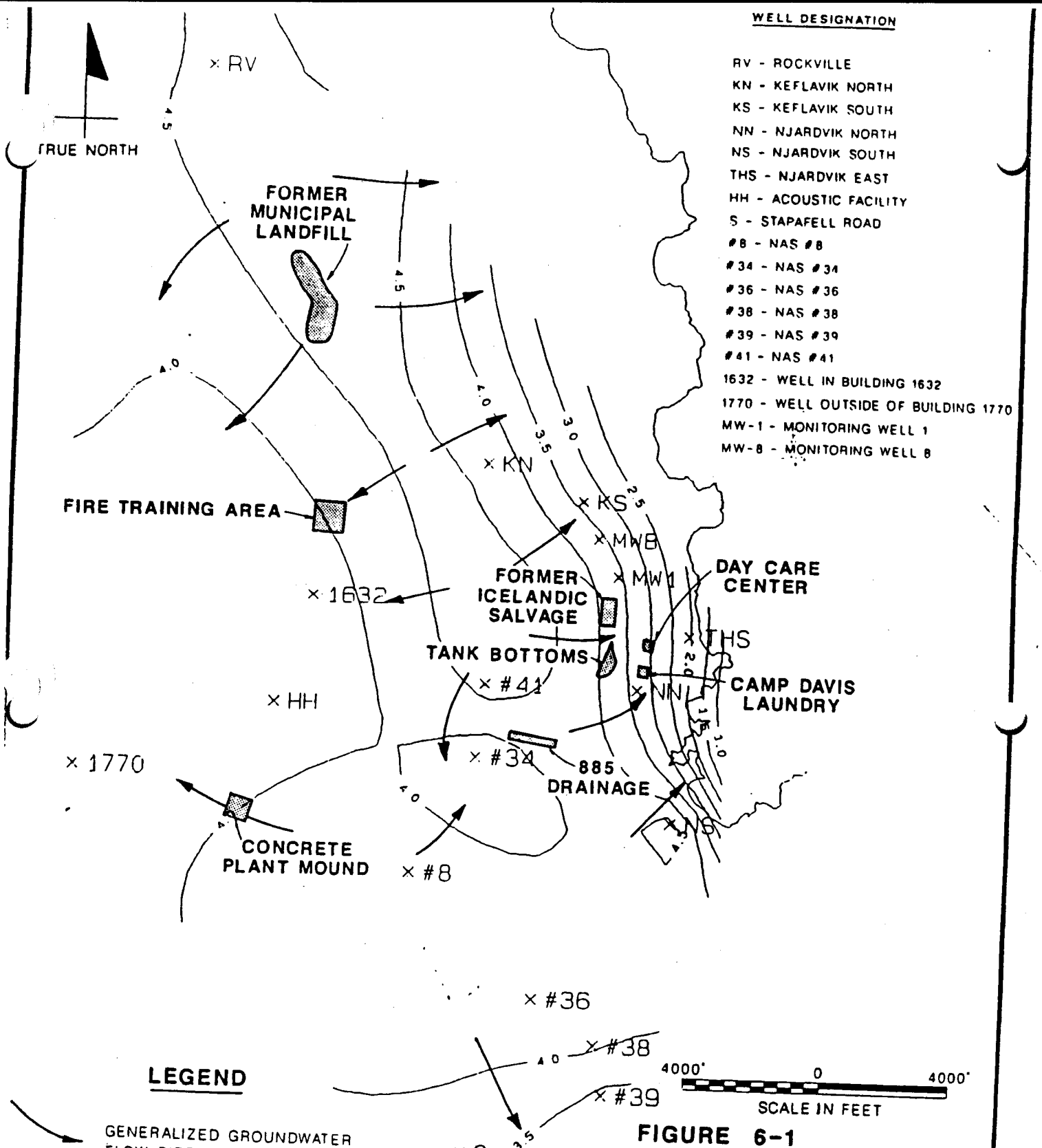
This chapter contains detailed descriptions of the 18 sites within the study area which were considered potential source areas for groundwater contamination as a result of the activities and solvent use, the groundwater flow direction, and water quality documented by the PA/SI. The sites were divided into two groups: The first group contains the eight sites chosen for the Accelerated RI/FS (Figure 6-1), and the second group contains 10 sites chosen for the RI/FS (Figure 6-2).

6.2 Accelerated RI/FS Sites

6.2.1 Building 885 Drainage Area

The Building 885 drainage area is located west of Building 885 and north of the Navy Exchange Building (Figure 6-3). Building 885 was constructed from 1954 to 1956 and has been used as an aircraft maintenance hangar since 1956. Military and civilian aircraft are repaired and maintained in this facility by military and Icelandair personnel, respectively.

When Building 885 was constructed, the floor drains within the building were constructed to drain into a pit east of the building. In addition, storm drains installed in the apron around the building were also constructed to drain into the same pit as the floor drains. In 1979, an oil-water separator was installed within the drainage pit and the drainage was routed east from the oil-water separator to the current drainage configuration. Oil, fuels, and solvents spilled within the hangar and on the apron around the hangar were generally washed



LEGEND

GENERALIZED GROUNDWATER FLOW DIRECTION

4.0 GROUNDWATER ELEVATION (FT) (OCT. 18-NOV. 15, 1988)

× WELL OR WELLFIELD LOCATION

4000' 0 4000'
SCALE IN FEET

FIGURE 6-1

NAVY - NAS
KEFLAVIK, ICELAND

ACCELERATED RI/FS SITES

drawn RAM	approved JLW	drawing no. 87040-076-AA
checked JLW	date 2-7-89	

r. e. wright associates, inc.
earth resources consultants

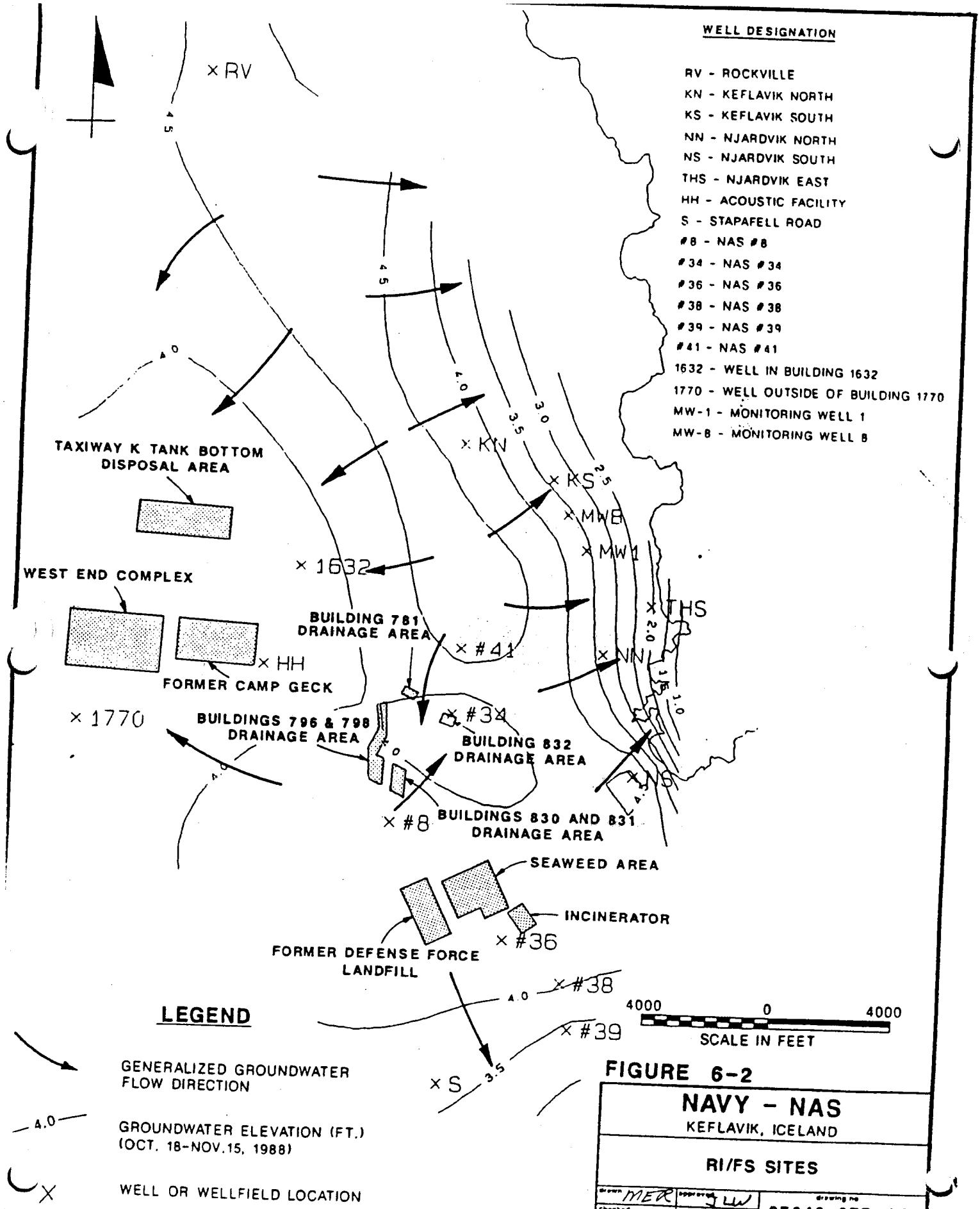


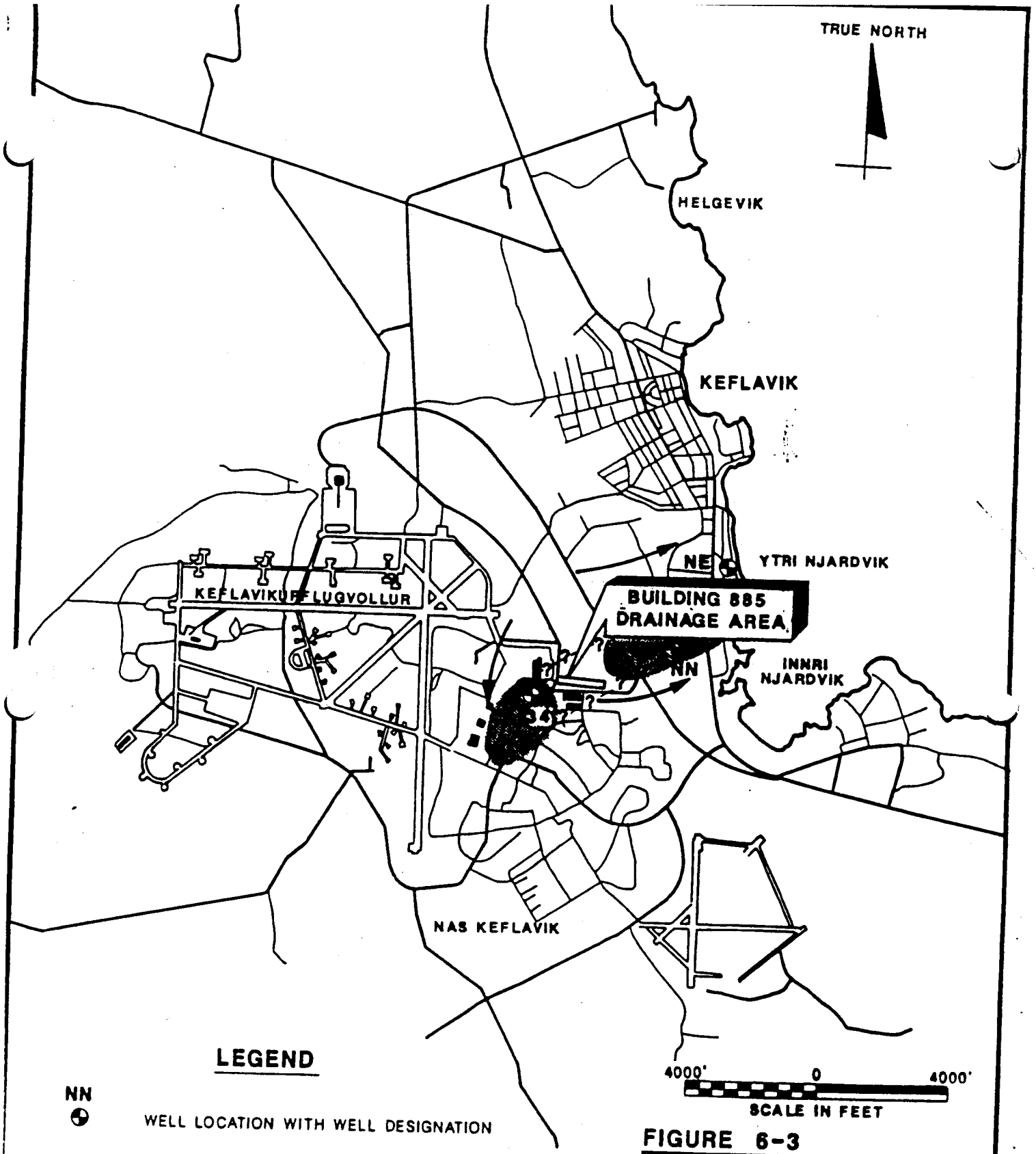
FIGURE 6-2

NAVY - NAS
KEFLAVIK, ICELAND

RI/FS SITES

drawn MER	approved JLW	drawing no 87040-077-AA
checked JLW	date 3-14-89	

r. e. wright associates, inc.
earth resources consultants



LEGEND

NN — WELL LOCATION WITH WELL DESIGNATION

GENERALIZED GROUNDWATER FLOW DIRECTION

CONCEPTUAL PLUME LOCATION

BASE MAP: PREPARED FROM MAP PUBLISHED BY LANDMAELINGAR ISLANDS (ICELAND GEODETIC SURVEY) AND DMAHTC U.S.A.

FIGURE 6-3

NAVY - NAS
KEFLAVIK, ICELAND

BUILDING 885 DRAINAGE AREA LOCATION MAP

drawn RAM	approved JLW	drawing no. 87040-078-AA
checked JLW	date 1-24-89	

r. e. wright associates, inc.
earth resources consultants

into the drain system. Since 1984, the Public Works Hazardous Materials Division has cleaned up spills on the apron with sorbent material.

Solvents currently used in and around Building 885 include 1,1,1-TCA, toluene, xylene, isopropyl alcohol, PD-680, methyl ethyl ketone, trichlorotrifluoroethane, paint strippers and thinners, and solvents containing between 5 and 30 percent TCE and PCE. Solvents previously used in Building 885 would include the preceding solvents and solvents containing higher concentrations of PCE and TCE. In addition, glycol is occasionally used to deice aircraft within the building.

Waste disposal practices at Building 885 have varied. At times, the waste oils and solvents were containerized and given to the fire department for training. At other times, the waste oils were containerized and turned over to military disposal, who in turn sold the wastes to Icelandic Salvage. In addition, an area north of Building 885 and 500 feet south of NAS Well 41 was used for disposal of waste oils and solvents. This area was excavated and the contaminated soil containerized. The contaminated soil was then sent to the Defense Force landfill for disposal. The excavation was filled in with sand, after which no further dumping of waste oils and solvents was done at this site.

Building 885 drainage area is located on the groundwater divide between the pumping influence of NAS Well 34, 0.2 miles west, and the natural easterly groundwater gradient. Being on the divide, this area may contribute groundwater flow west toward NAS Well 34 or east-northeast toward the Njardvik North Wellfield, just over 0.5 miles downgradient. Groundwater contamination resulting from improper use or disposal of solvents into the subsurface at

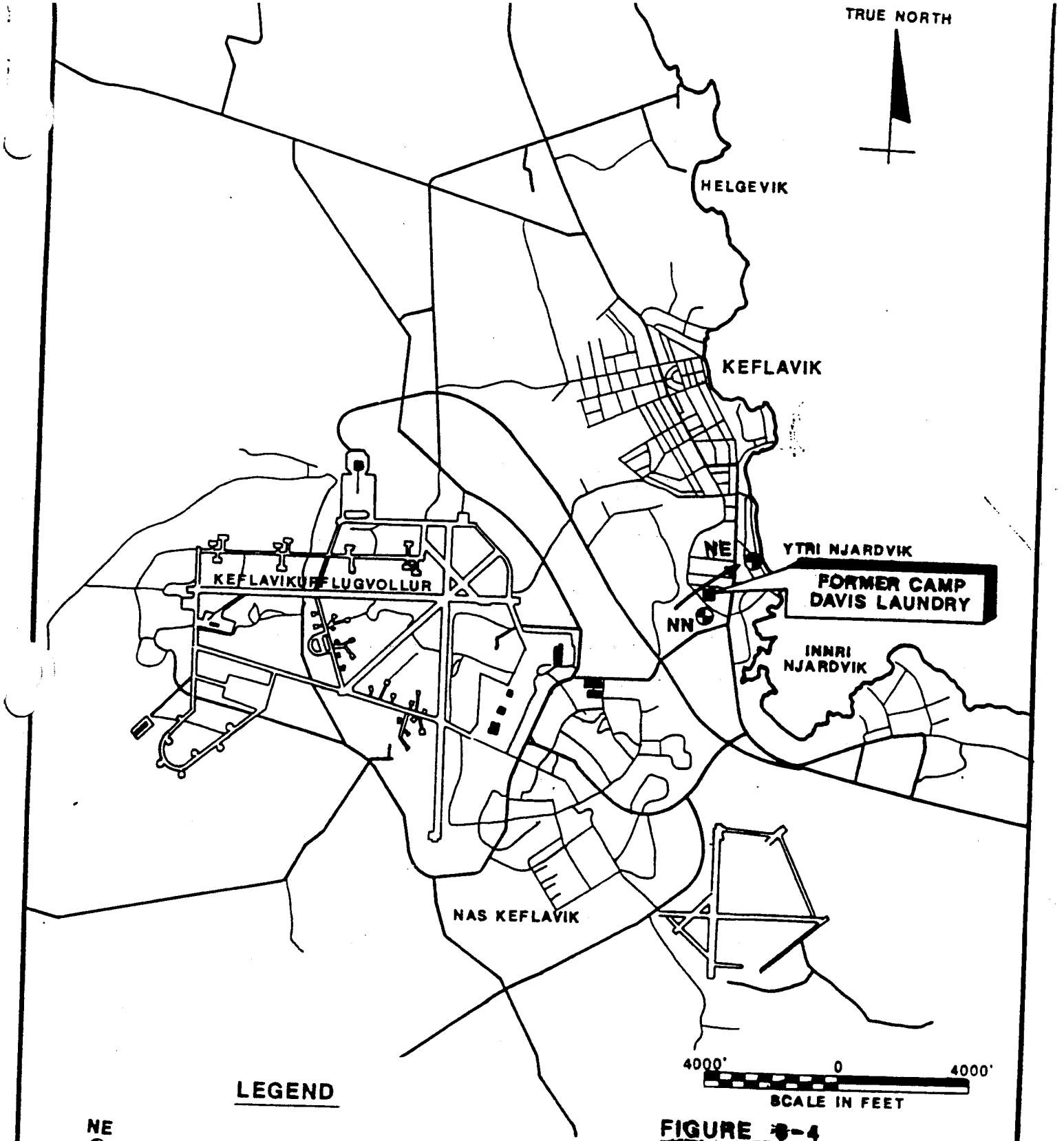
Building 885 could have resulted in the spread of a VOC plume both west and east as observed in groundwater quality data collected by the PA/SI at all of these wells. However, other sources may also potentially impact these wells to the degree observed in the PA/SI.

6.2.2 Former Camp Davis Laundry

Camp Davis was a U. S. Army quartermaster's camp during World War II. The laundry facility located in Camp Davis was the only military laundry facility during World War II (Figure 6-4) and was operated until 1949. Cleaning machines used at the laundry facility used PCE as the cleaning solvent. Waste disposal practices for the Camp Davis laundry are unknown.

After World War II, the laundry facility was closed and one of the dry cleaning machines, which used PCE, was moved to the current laundry which is located in Building 632. Usage of the Camp Davis area was returned to the Icelanders, and the former laundry building was used by the Icelanders as a fish processing plant and a warehouse for fishing supplies. The laundry building was demolished in September of 1988.

General groundwater flow direction at the former Camp Davis laundry is easterly. The former laundry is located 0.1 mile north of the Njardvik North Wellfield and 0.3 southwest of the Njardvik East Well Wellfield. It is not expected that groundwater flow from the former Camp Davis laundry would be drawn into the Njardvik North Wellfield due to the immeasurably small magnitude of drawdown effected by this wellfield; however, the area of its influence on the groundwater flow system has not been fully delineated.



LEGEND

NE — WELL LOCATION WITH WELL DESIGNATION

GENERALIZED GROUNDWATER FLOW DIRECTION

BASE MAP: PREPARED FROM MAP PUBLISHED BY LANDMAELINGAR ISLANDS (ICELAND GEODETIC SURVEY) AND DMAHTC U.S.A.

FIGURE 8-4

NAVY - NAS

KEFLAVIK, ICELAND

FORMER CAMP DAVIS LAUNDRY LOCATION MAP

drawn RAM	reviewed LW	drawing no. 87040-079-AA
checked LW	date 1-24-89	

r. e. wright associates, inc.
earth resources consultants

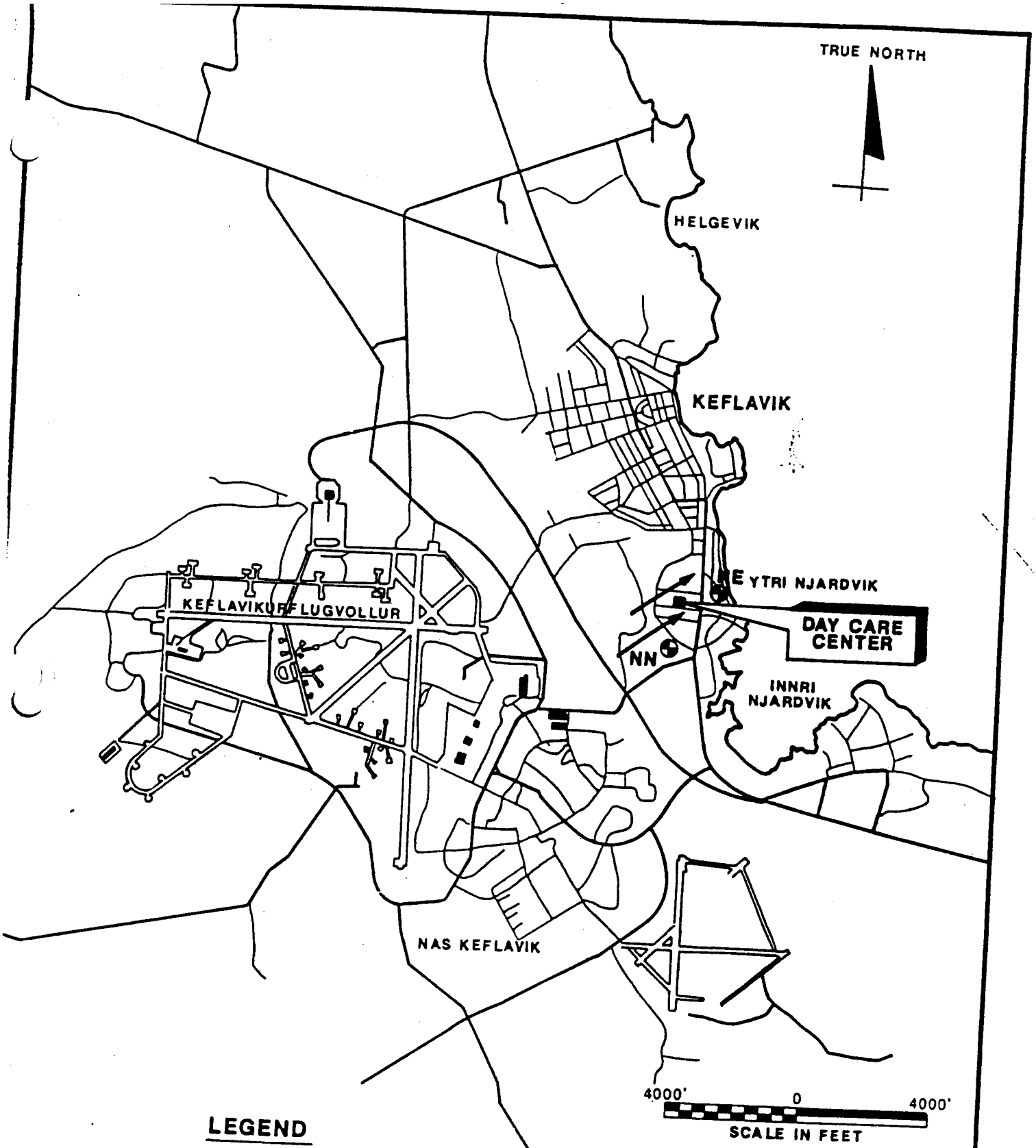
6.2.3 Day Care Center

The Day Care Center site, located 0.1 mile north of the former Camp Davis laundry, is the location of a suspected drum storage area from World War II (Figure 6-5). Drums were stored in this area during the mid to late 1940s. By 1950, most of the drums had been removed or decayed. Information gathered during the interviewing process indicated that most of the drums could have contained "white spirits." Esso reported purchasing approximately 30 barrels which were believed to have contained "white spirits." In one instance, contents from one drum was analyzed in 1947 by the University of Iceland. The analysis reported the contents as being termed "tetrachlor," which presumably is PCE. Copies of the analysis performed by the University of Iceland were not available.

Groundwater flow in the Day Care Center area appears to be generally east. As with the former Camp Davis laundry facility, the Day Care Center is located north of the Njardvik North Wellfield, and general groundwater flow is easterly. If improper use or disposal of solvents occurred at the Day Care Center, a plume of contaminated groundwater may have resulted. It is not expected that groundwater flow from the Day Care Center would impact the Njardvik North Wellfield.

6.2.4 Former Icelandic Salvage

The former Icelandic Salvage facility is located in the Nickel Area tank farm (Figure 6-6). Buildings used by Icelandic Salvage were used by the U. S. Air Force until 1957 to store building materials, plumbing materials, and spare parts for heavy



LEGEND

NN — WELL LOCATION WITH WELL DESIGNATION

→ GENERALIZED GROUNDWATER FLOW DIRECTION

SE MAP: PREPARED FROM MAP PUBLISHED BY LANDMAELINGAR ISLANDS (ICELAND GEODETIC SURVEY) AND DMAHTC U.S.A.

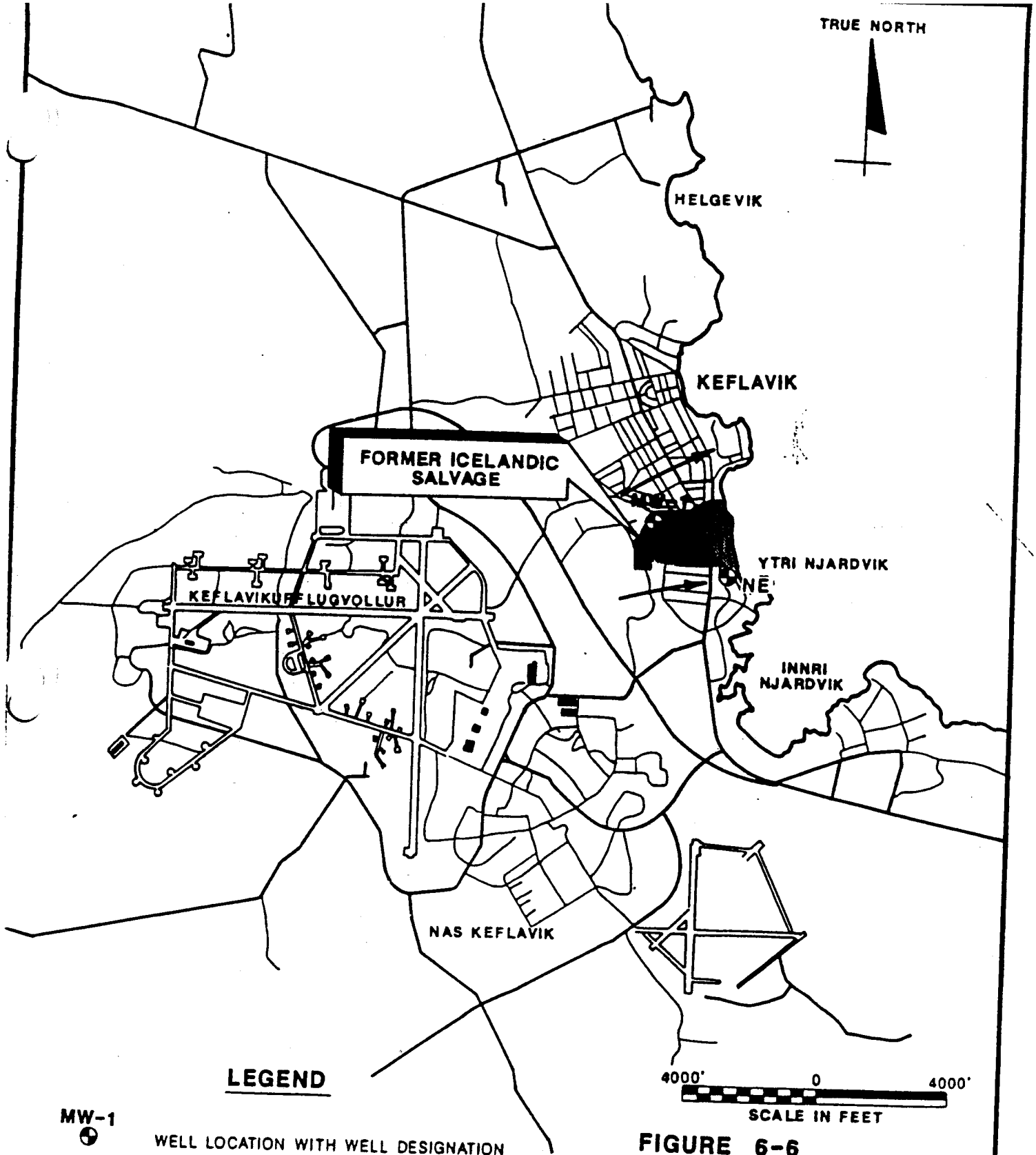
FIGURE 6-5

NAVY - NAS
KEFLAVIK, ICELAND

DAY CARE CENTER LOCATION MAP

drawn RAM	approved JLW	drawing no. 87040-080-AA
checked JLW	date 2-3-89	

r. e. wright associates, inc.
earth resources consultants



LEGEND

MW-1 — WELL LOCATION WITH WELL DESIGNATION

GENERALIZED GROUNDWATER FLOW DIRECTION

CONCEPTUAL PLUME LOCATION

BASE MAP: PREPARED FROM MAP PUBLISHED BY LANDMAELINGAR ISLANDS (ICELAND GEODETIC SURVEY) AND DMAHTC U.S.A.

FIGURE 6-6

NAVY - NAS
KEFLAVIK, ICELAND

FORMER ICELANDIC SALVAGE LOCATION MAP

Drawn RAM	Approved JLW	Drawing No. 87040-081-AA
Checked JLW	Date 1-24-89	

r. e. wright associates, inc.
earth resources consultants

equipment. Icelandic Salvage used the buildings from approximately 1960 until 1964, when a fire destroyed the buildings. In 1964, when the fire occurred, the buildings were reported to have contained mostly cars. One of the buildings was also reported to have contained aircraft oils and hydraulic fluid.

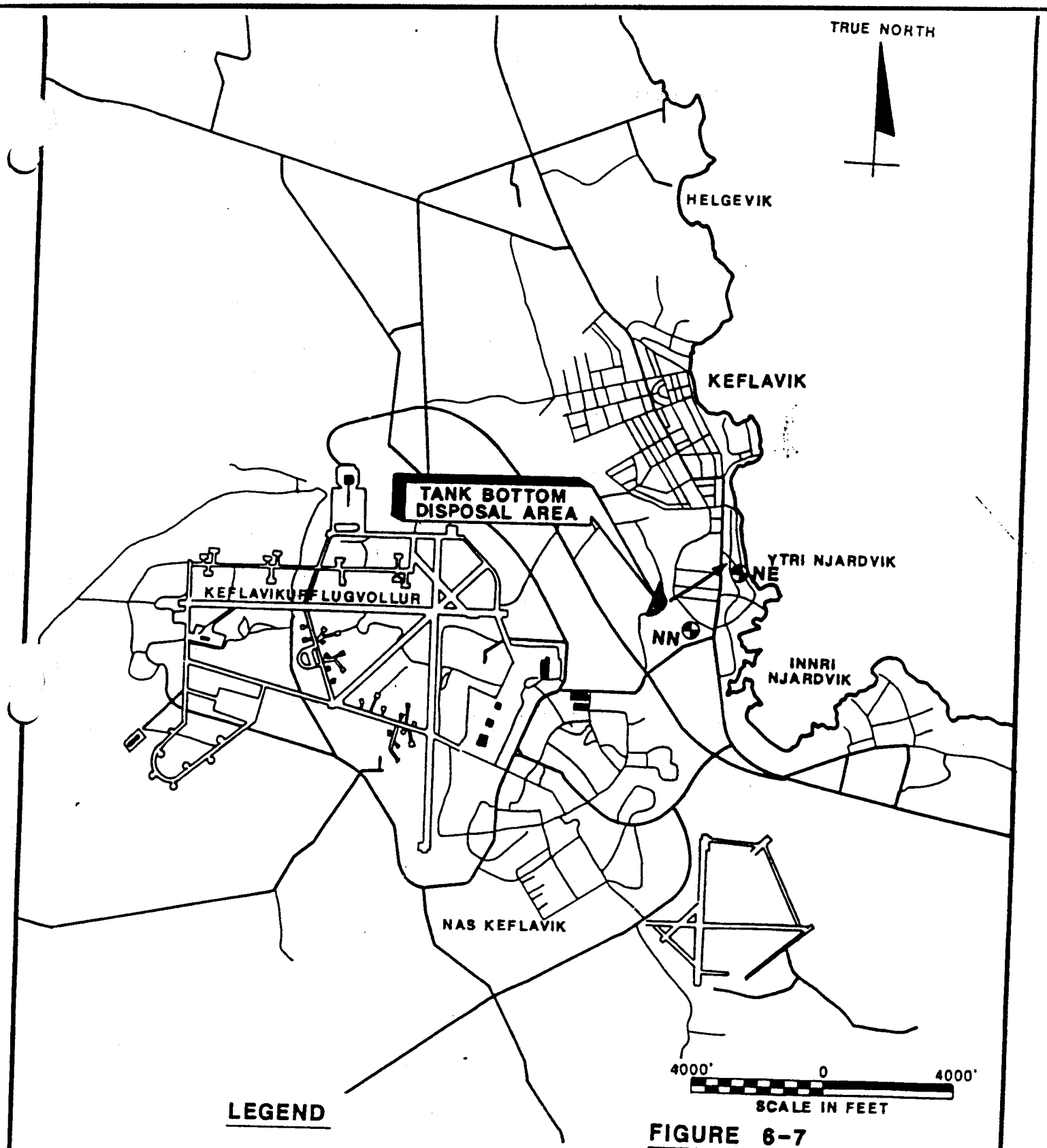
Groundwater flow in the former Iceland Salvage area is generally east and does not appear to contribute flow to the Njardvik North Wellfield. However, the former Icelandic Salvage facility may contribute flow to the Njardvik East Well which is located approximately 0.4 miles downgradient.

Groundwater contamination by TCE and CTC is indicated by MW-1. The source of this plume could be due to activities at Icelandic Salvage or as a result of spillage during the fire. The plume from this area migrates eastward and is potentially the cause of sporadic impairment of the Njardvik East Wellfield observed by the PA/SI.

6.2.5 Tank Bottom Disposal Area

The Tank Bottom Disposal Area is located 0.25 miles south of the former Icelandic Salvage facility (Figure 6-7). This area was used in the 1970s for the disposal of tank bottoms. The "tank bottoms" were spread over the ground to aerate and dry. The "tank bottoms" could have contained lead and petroleum hydrocarbons which may have leached into the ground and subsequently the groundwater.

Groundwater flow in the Tank Bottom Disposal Area is generally east. This area, which is located northwest of the Njardvik



LEGEND

WELL LOCATION WITH WELL DESIGNATION

GENERALIZED GROUNDWATER FLOW DIRECTION

BASE MAP: PREPARED FROM MAP PUBLISHED BY LANDMAELINGAR ISLANDS (ICELAND GEODETIC SURVEY) AND DMAHTC U.S.A.

FIGURE 6-7

NAVY - NAS
KEFLAVIK, ICELAND

TANK BOTTOM DISPOSAL AREA LOCATION MAP

drawn RAM	approved JLW	drawing no. 87040-082-AA
checked JLW	date 1-24-89	

r. e. wright associates, inc.
earth resources consultants

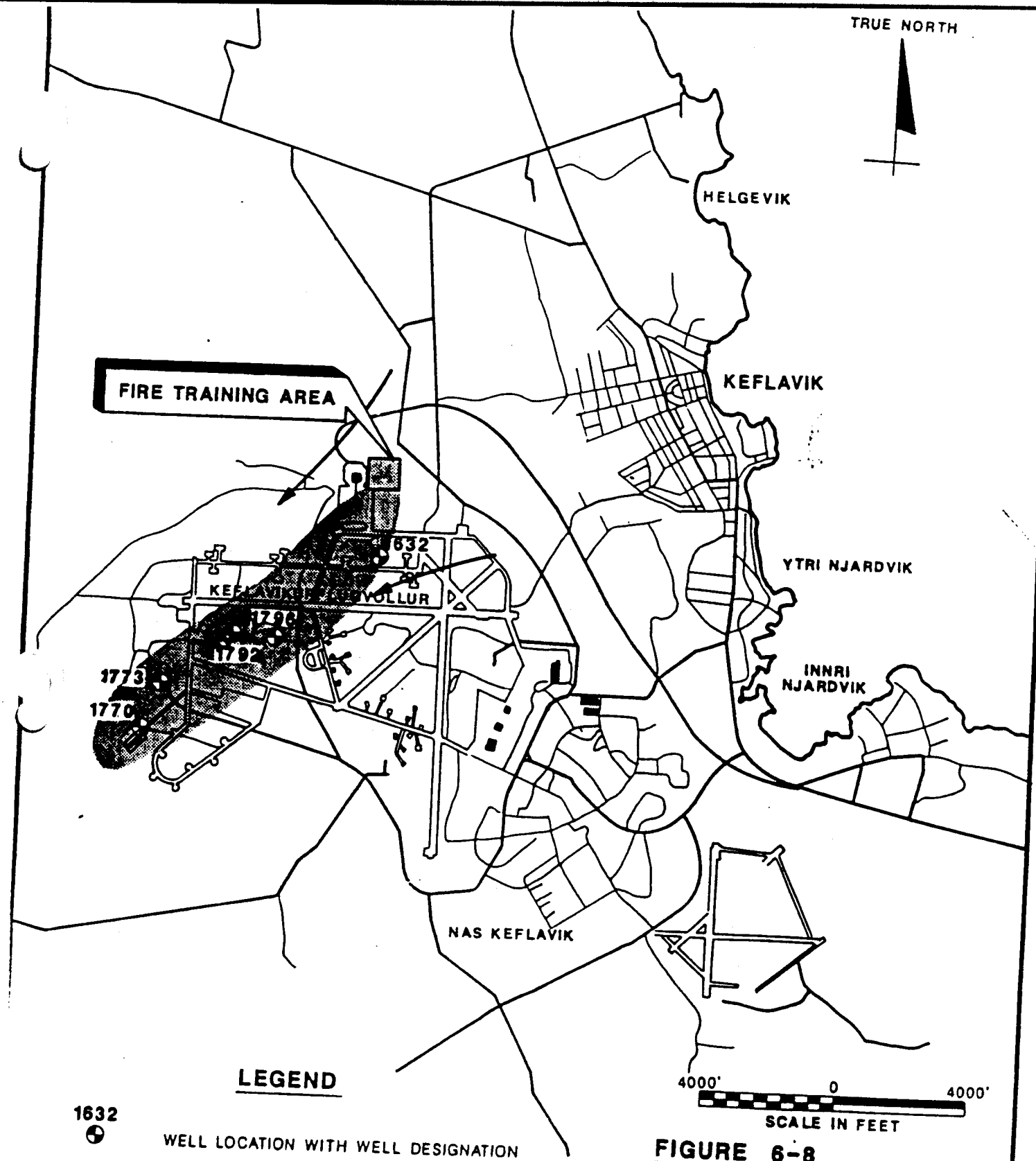
North Wellfield, may contribute to the water withdrawn from either the Njardvik North or East Wellfields.

6.2.6 Fire Training Area

The Fire Training Area is located directly east of the new International Air Terminal (Figure 6-8). Fire-fighting training began in this area in 1955 and continued until 1983 when construction of the International Air Terminal began. From 1955 until 1966, trenches were dug into the ground using a bulldozer, and waste oils and solvents collected from various activities at NAS-Keflavik were poured in the trenches and set on fire. In 1970, a concrete pad with a drain system which contained an oil-water separator was constructed for fire training. An underground storage tank and distribution line were also installed to provide bulk storage of the waste fuels and solvents and to transfer the waste products from the storage tank to the concrete pad. The waste oils and solvents could have contained any and all of the solvents and oils discussed in Chapter 4.0.

These activities potentially contribute to contamination of groundwater which would transport the contaminants with its flow.

The Fire Training area is located west of the groundwater divide and approximately one mile west of the Keflavik North Wellfield. Groundwater flow in this area appears to be westerly and as such would not appear to contribute flow to the Keflavik North Wellfield. PA/SI evidence of groundwater contamination and westerly transport of a plume from the Fire Training Area could be exhibited by TCE-degraded water quality in NAS Wells 1632, 1756, 1792, 1773, and 1770. However, other sources identified by the PA/SI, such as the West End Complex and Camp Geck area, could



LEGEND

1632 — WELL LOCATION WITH WELL DESIGNATION

GENERALIZED GROUNDWATER FLOW DIRECTION

CONCEPTUAL PLUME LOCATION

BASE MAP: PREPARED FROM MAP PUBLISHED BY LANDMAELINGAR ISLANDS (ICELAND GEODETIC SURVEY) AND DMAHTC U.S.A.

FIGURE 6-8

NAVY - NAS
KEFLAVIK, ICELAND

FIRE TRAINING AREA LOCATION MAP

Drawn RAM	Approved JLW	Drawing no. 87040-083-AA
Checked JLW	Date 1-24-89	

r. e. wright associates, inc.
earth resources consultants

also potentially impair these wells' water quality in whole or in part.

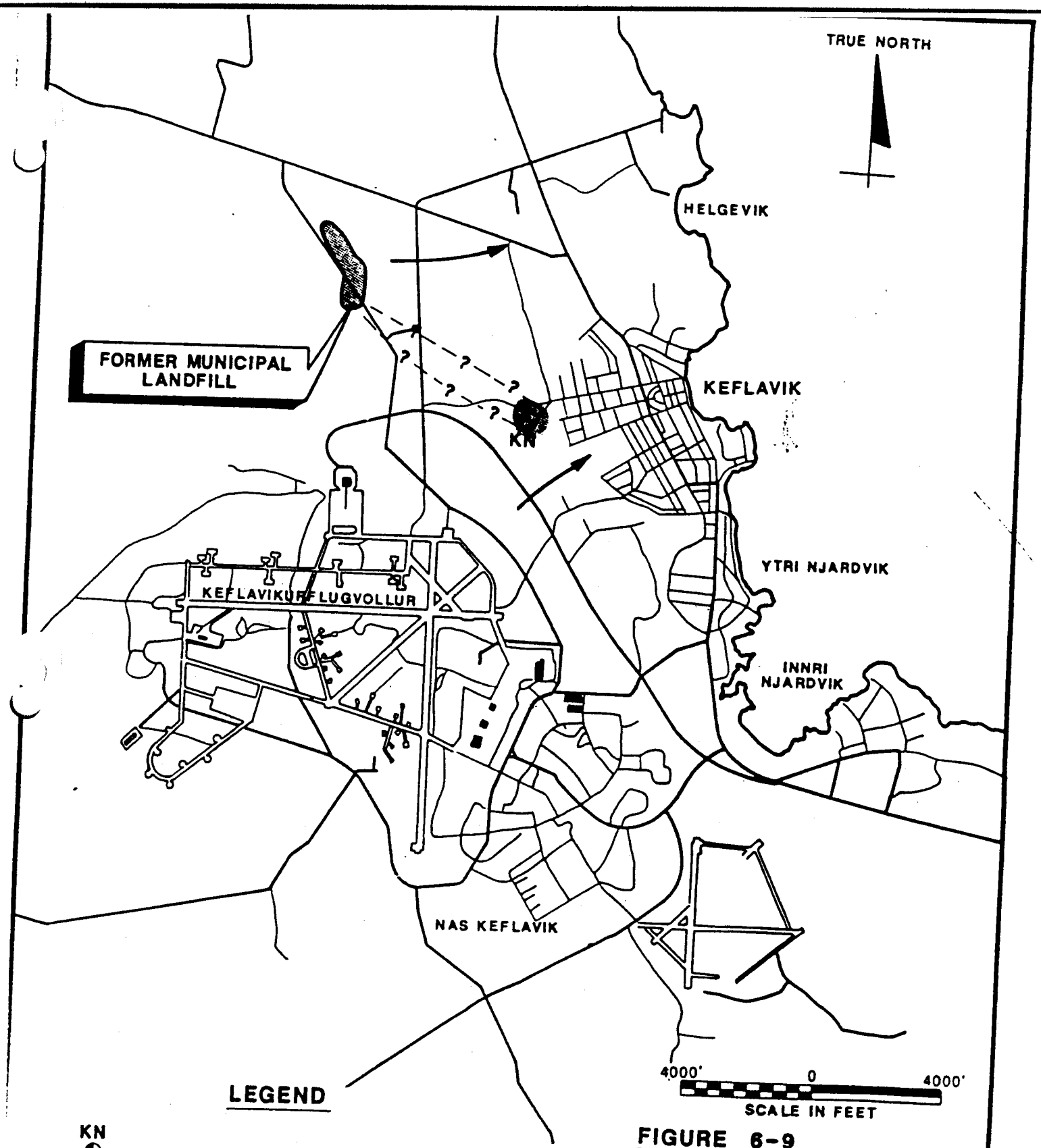
6.2.7 Former Municipal Landfill

The former Municipal Landfill is located approximately one mile north of the Fire Training Area (Figure 6-9). The landfill was used by the local municipalities for disposal of industrial and household waste until 1979 when the Incinerator became operable. It has been reported that some waste oils and solvents were disposed in the landfill. In addition, wastes from the Keflavik Hospital were also disposed of at the landfill.

The former Municipal Landfill, approximately 1.3 miles northwest of the Keflavik North Wellfield, straddles the groundwater divide. Groundwater flow appears to be predominantly east and west from that area; however, groundwater elevation data are extremely limited in this area. Because the presence of a structural feature providing a conduit for groundwater flow from the landfill to the Keflavik North Wellfield cannot be discounted by the present data, groundwater contamination arising from the disposal of solvents in the landfill may potentially be the source of water quality degradation observed at the Keflavik North Wellfield during the PA/SI. No other potential source for that impact was identified by the PA/SI.

6.2.8 Concrete Plant Mound

The concrete plant mound is located 1.7 miles south of the fire training area and directly west of the NAS-Keflavik concrete plant (Figure 6-10). REWAI, SPHC, and NEA personnel were informed during an interview that the possibility of waste



LEGEND

KN — WELL LOCATION WITH WELL DESIGNATION

GENERALIZED GROUNDWATER FLOW DIRECTION

CONCEPTUAL PLUME LOCATION

BASE MAP: PREPARED FROM MAP PUBLISHED BY LANDMAELINGAR ISLANDS (ICELAND GEODETIC SURVEY) AND DMAHTC U.S.A.

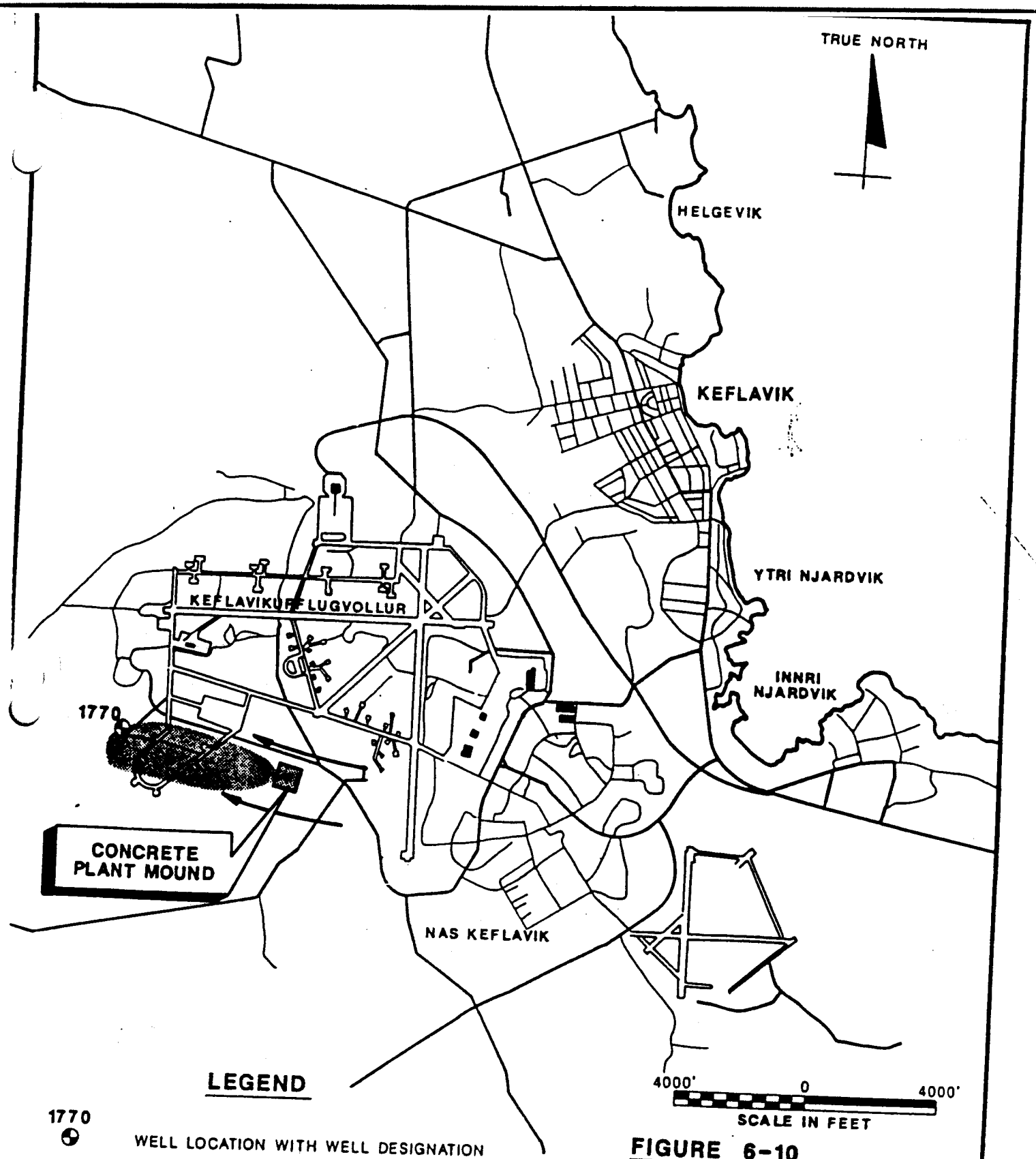
FIGURE 6-9

NAVY - NAS
KEFLAVIK, ICELAND

FORMER MUNICIPAL LANDFILL LOCATION MAP

Drawn RAM	Approved JLW	Drawing No. 87040-084-AA
Checked JLW	Date 1-24-89	

r. e. wright associates, inc.
earth resources consultants



LEGEND

1770 — WELL LOCATION WITH WELL DESIGNATION

GENERALIZED GROUNDWATER FLOW DIRECTION

CONCEPTUAL PLUME LOCATION

ASE MAP: PREPARED FROM MAP PUBLISHED BY LANDMAELINGAR ISLANDS (ICELAND GEODETIC SURVEY) AND DMAHTC U.S.A.

FIGURE 6-10

NAVY - NAS
KEFLAVIK, ICELAND

CONCRETE PLANT MOUND LOCATION MAP

drawn RAM	reviewed JLW	drawing no. 87040-085-AA
checked JLW	date 1-24-89	

r. e. wright associates, inc.
earth resources consultants

containers being buried at this location existed. During the interview, it was reported that in the early 1960s, a trench was dug using a bulldozer and unknown materials were buried in the trench. The bulldozer operator was informed by military personnel that the waste was "deadly poison" and that he should not enter the trench. The bulldozer operator reported that the covered waste could have been drums. An additional interview reported that in 1975, drums of asphaltic material were observed at this location.

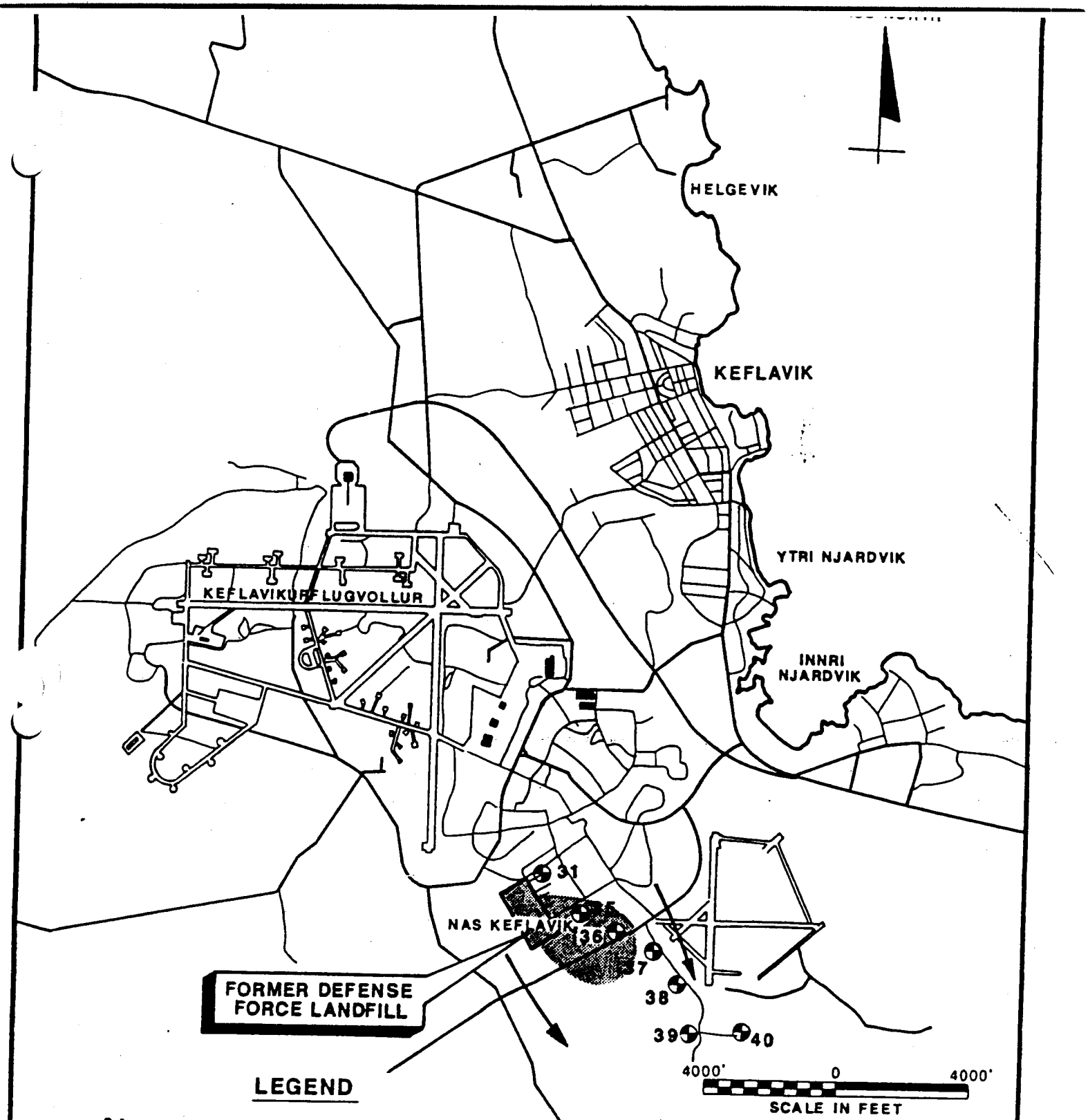
Upon inspection of this area during the Accelerated RI/FS, rusted remnants of drums were observed, and areas of asphalt-like material were observed around the barrel remnants. Further information concerning the contents of the mound was unavailable.

Groundwater flow in this area and any groundwater transport of contaminants that potentially infiltrated into this area appears to be generally west. NAS Well 1770 is west of the concrete plant mound and could potentially be adversely impacted by groundwater contamination originating from this area. However, other potential sources for the water quality degradation in that well were identified by the PA/SI such as the West End Complex, Camp Geck, or the Fire Training Area.

6.3 RI/FS Sites

6.3.1 Former Defense Force Landfill

The former Defense Force Landfill is located south of the main NAS-Keflavik complex (Figure 6-11). NAS-Keflavik used this landfill until 1983 as their primary disposal area for refuse which included household and industrial waste. Burning pits were



LEGEND

34 — WELL LOCATION WITH WELL DESIGNATION

GENERALIZED GROUNDWATER FLOW DIRECTION

CONCEPTUAL PLUME LOCATION

BASE MAP: PREPARED FROM MAP PUBLISHED BY ISLANDS (ICELAND GEODETIC SURVEY) AND DMAHTC U.S.A.

FIGURE 6-11

NAVY - NAS
KEFLAVIK, ICELAND

FORMER DEFENSE FORCE LANDFILL LOCATION MAP

Drawn RAM	Approved KVL	Drawing No. 87040-086-AA
Checked JLW	Date 1-24-89	

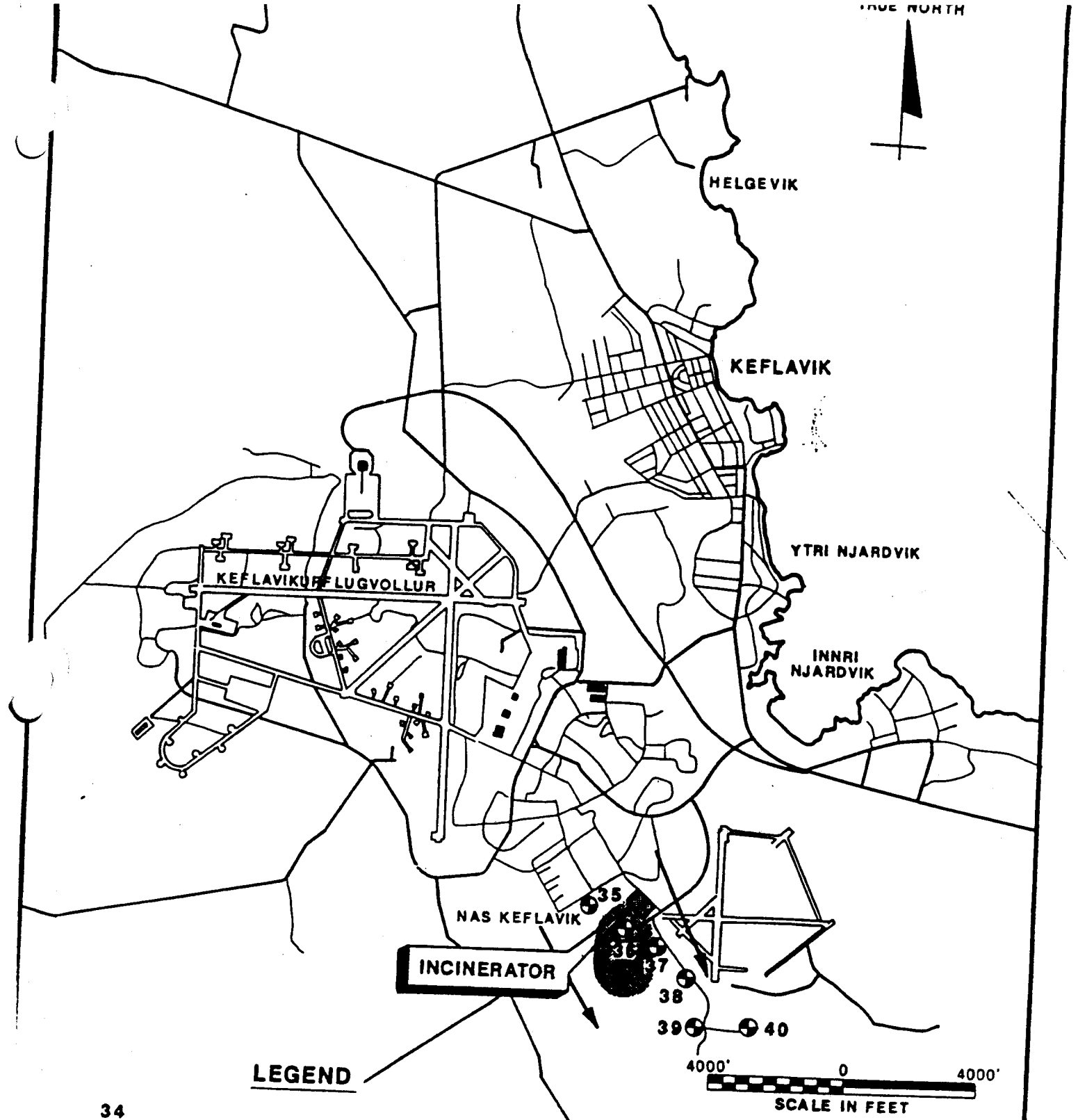
r. e. wright associates, inc.
earth resources consultants

used for the disposal of some of the trash while other waste was buried. Reports indicated that some waste oil, solvents, and hospital waste were disposed of in this landfill.

Disposal of solvents in this area may have degraded groundwater quality, and the groundwater flow direction in this area appears to be southeast. NAS Wells 35 and 36 are southeast of the former Defense Force Landfill and exhibited impaired water quality during the PA/SI. Groundwater transport from the landfill, the Incinerator, or the Seaweed Area may have resulted in the contamination of these wells. Other Wells 37, 38, 39, and 40 are also located southeast of the landfill, suggesting they may be threatened but were not impacted during the period of the PA/SI investigation.

6.3.2 Incinerator

The Incinerator site is located 0.5 miles east of the Defense Force landfill (Figure 6-12). Constructed in 1979, the incinerator is operated by the Sudurnes Incinerator Authority and is the disposal site currently used by NAS-Keflavik and the local municipalities for burning trash. From 1979 to 1985, scrap metal and other nonburnable trash was stockpiled at the Incinerator site. This stockpile is composed of materials which originated primarily from the municipalities since the Defense Force dump was used by the Defense Force until 1983. In 1985, a landfill was opened north of Dye-5 and nonburnable refuse from NAS-Keflavik and the local municipalities was sent to that landfill. The stockpile which had accumulated at the Incinerator has not been removed.



LEGEND

34 — WELL LOCATION WITH WELL DESIGNATION

GENERALIZED GROUNDWATER FLOW DIRECTION

CONCEPTUAL PLUME LOCATION

BASE MAP: PREPARED FROM MAP PUBLISHED BY LANDMAELINGAR ISLANDS (ICELAND GEODETIC SURVEY) AND DMAHTC U.S.A.

FIGURE 6-12

NAVY - NAS
KEFLAVIK, ICELAND

INCINERATOR LOCATION MAP

Drawn RAM	Approved	Drawing No. 87040-087-AA
Checked JLW	Date 1-24-89	

r. e. wright associates, inc.
earth resources consultants

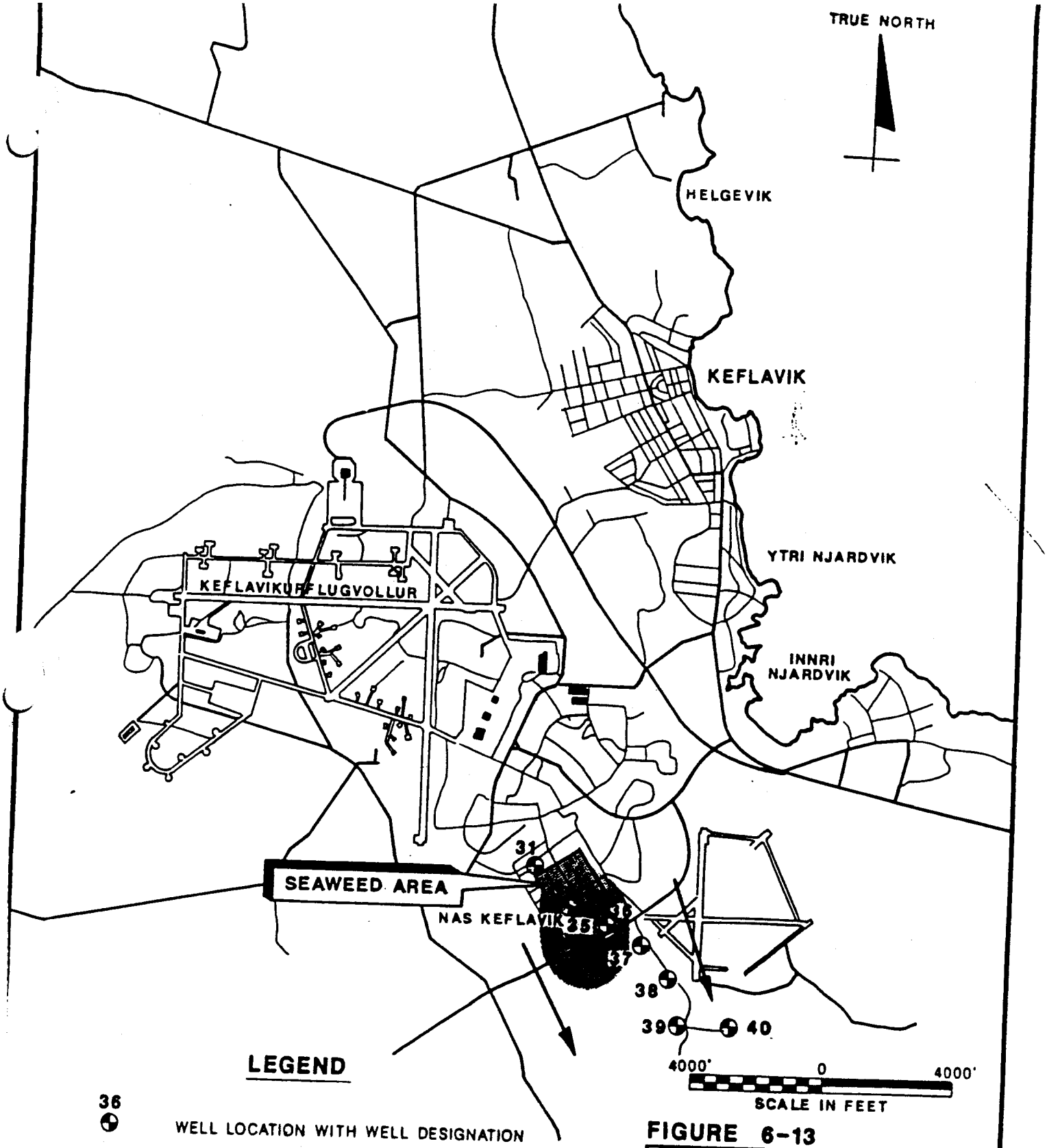
In September of 1985, concerns about the Incinerator resulted in the initiation of an environmental evaluation which identified TCE contamination in NAS Well 35. That environmental evaluation was the basis for originating the current groundwater contamination study.

Groundwater flow direction at the Incinerator appears to be southeast. If groundwater contamination has resulted from the Incinerator, groundwater flow from this area would probably not have impacted NAS Well 35. However, NAS Well 36 shows impairment which may have the Incinerator, the Defense Force Landfill, or the Seaweed Area as its source. NAS Wells 37, 38, 39, and 40 are also threatened by groundwater transport of contaminants from the Incinerator, Defense Force Landfill, or Seaweed Area.

6.3.3 Seaweed Area

The Seaweed Area is located between the former Defense Force landfill and the Incinerator (Figure 6-13). This area includes maintenance and storage facilities for IPC and KC, and the current storage yard for Icelandic Salvage. After interviewing personnel concerning this area and during inspections, numerous soil stains were observed throughout the Seaweed Area.

Waste disposal practices by IPC and KC were reported to have included the containerization of waste oils and solvents and giving them to the fire department for fire training; containerization of the waste oils/solvents and sending them to Reykjavik; containerization of the waste and selling it to Icelandic Salvage; or, in some minor instances, pouring the waste into drains or onto the ground.



LEGEND

36 — WELL LOCATION WITH WELL DESIGNATION

GENERALIZED GROUNDWATER FLOW DIRECTION

CONCEPTUAL PLUME LOCATION

BASE MAP: PREPARED FROM MAP PUBLISHED BY LANDMAELINGAR ISLANDS (ICELAND GEODETIC SURVEY) AND DMAHTC U.S.A.

FIGURE 6-13

NAVY - NAS
KEFLAVIK, ICELAND

SEAWEED AREA LOCATION MAP

Drawn RAM	Approved KVL	Drawing no. 87040-088-AA
Checked LW	Date 1-24-89	

r. e. wright associates, inc.
earth resources consultants

Icelandic Salvage receives waste oil and solvents and unused oil and solvents from the U. S. military. Also, they receive waste oil and solvents from IPC and KC. Icelandic Salvage stores the oils and solvents in the Seaweed Area until a buyer is found, at which time the material is removed.

During the PA/SI, NAS Wells 31 and 35, located on the boundaries of the Seaweed Area, displayed degraded water quality. Groundwater contamination potentially arising from activities in the Seaweed Area would flow to the southeast toward NAS Well 36, which is impaired, and toward Wells 37, 38, 39, and 40 which are potentially threatened.

6.3.4 Building 832 Drainage

Building 832 has been used an aircraft maintenance facility and is located approximately 0.3 miles southwest of Building 885 (Figure 6-14). Like Building 885, the floor drains in Building 832 infiltrated the ground. The drainage area was located between Buildings 848 and 822. In 1975, the floor drains for Building 832 were connected to the sanitary sewer. Solvents used in Building 832 have included, but are not limited to, 1,1,1-TCA, toluene, xylene, isopropyl alcohol, PD-680, methyl ethyl ketone, trichlorotrifluoroethane, paint strippers and thinners, and solvents containing between 5 and 100 percent TCE or PCE.

Waste disposal practices in Building 832 consisted primarily of containerizing the waste oils and solvents and either giving the waste to the fire department for training or sending it to Military Disposal. Spills which occurred in the hangar were generally washed into the floor drains.

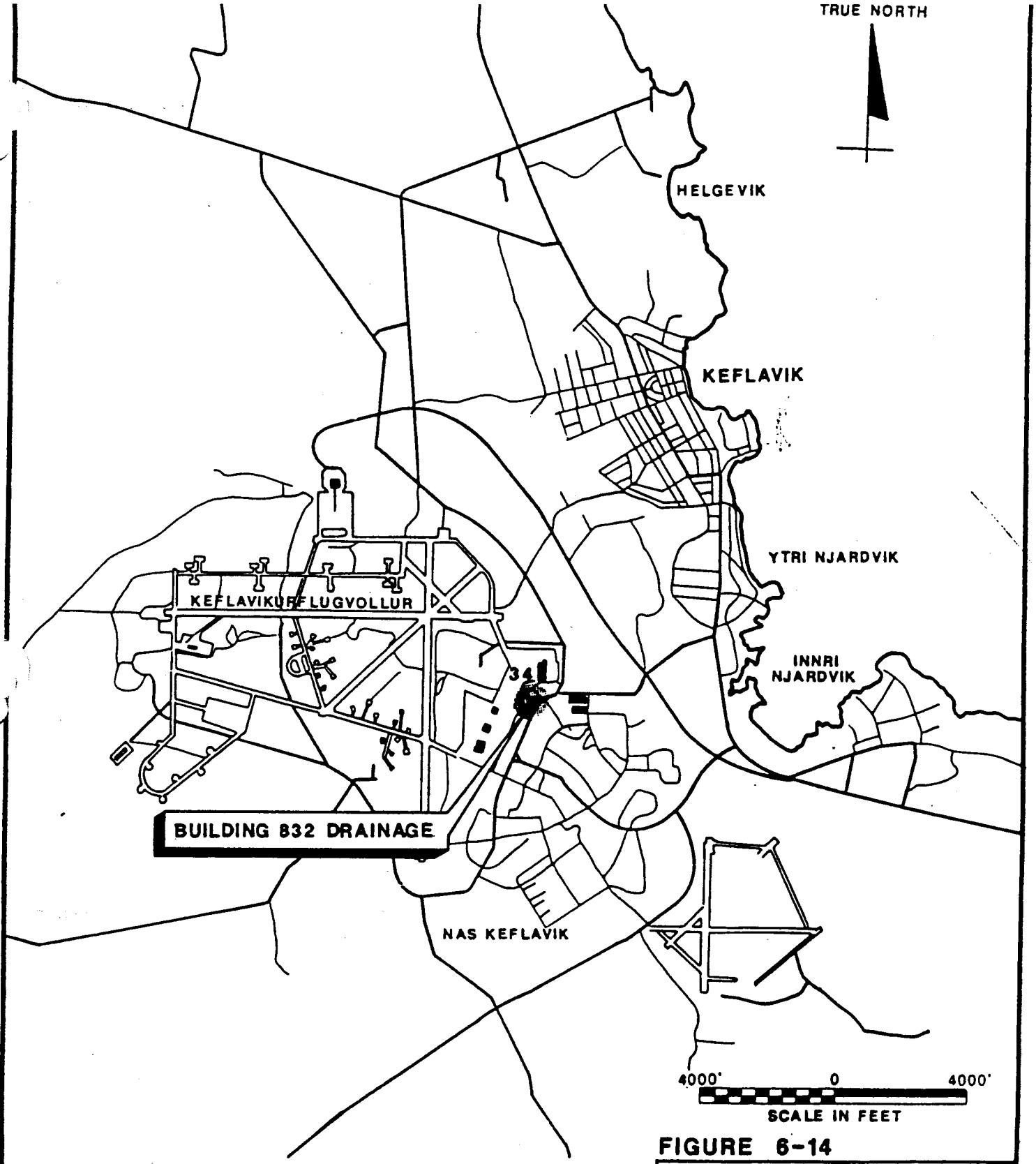


FIGURE 6-14

LEGEND

34 — WELL LOCATION WITH WELL DESIGNATION

CONCEPTUAL PLUME LOCATION

BASE MAP: PREPARED FROM MAP PUBLISHED BY LANDMAELINGAR ISLANDS (ICELAND GEODETIC SURVEY) AND DMAHTC U.S.A.

NAVY - NAS KEFLAVIK, ICELAND	
BUILDING 832 DRAINAGE LOCATION MAP	
drawn RAM; approved; checked; date 1-24-89	drawing no. 87040-089-AA
r. e. wright associates, inc. earth resources consultants	

Groundwater flow from Building 832 drainage appears to be flowing toward NAS Well 34. However, groundwater flow directions in this area are not well defined from the results of the 28-day groundwater monitoring due to undifferentiated pumping influences around NAS Well 34. Groundwater contamination which may have occurred from use or improper disposal of solvents in Building 832 are potentially being transported to and degrading the quality of NAS Well 34.

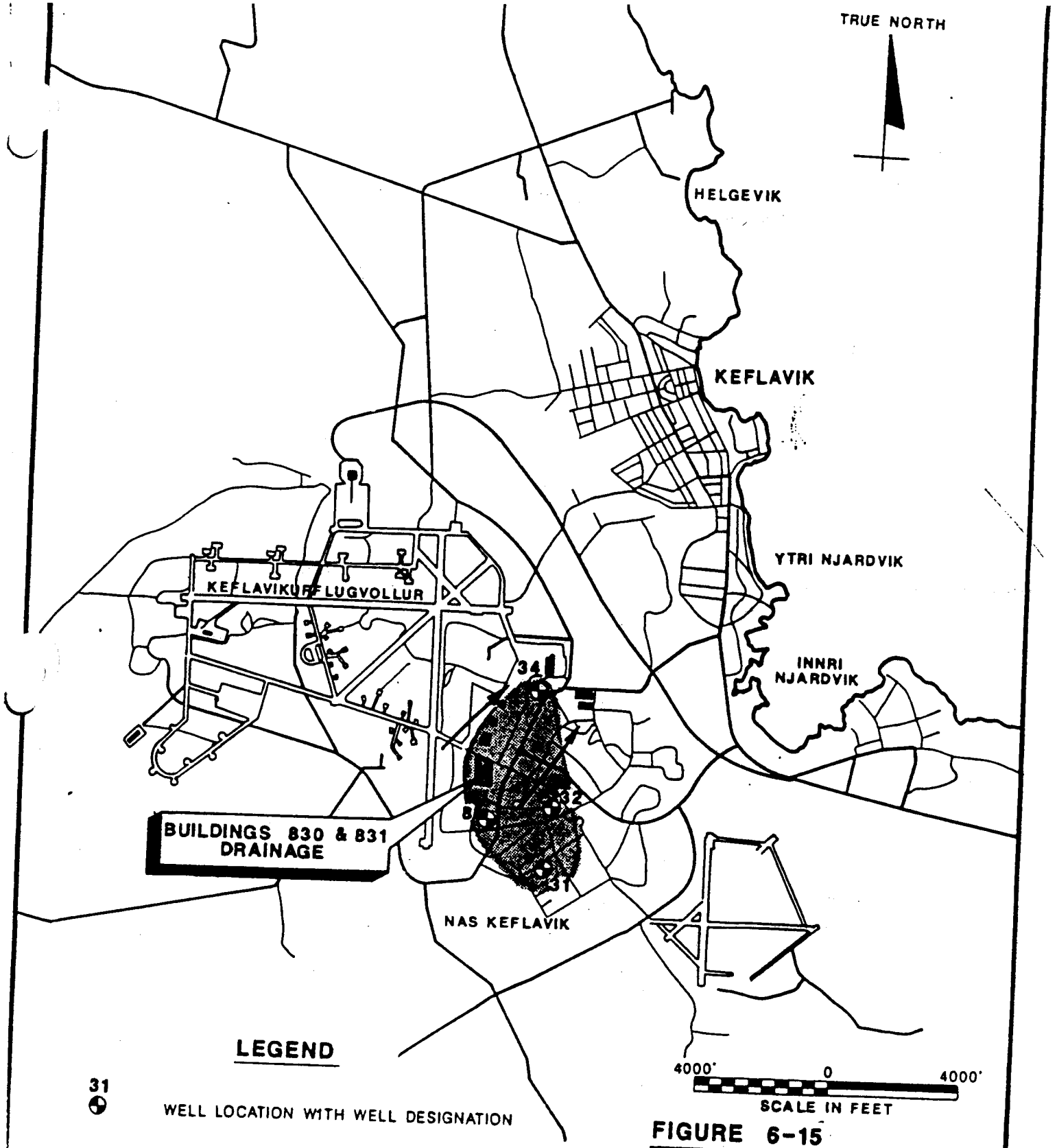
6.3.5 Buildings 830 and 831 Drainage

Buildings 830 and 831 are located directly south of Building 832, and the drainage from the floor drains in these two buildings is directly south of Building 832 into the ground (Figure 6-15). Usage of Buildings 830 and 831 has been primarily aircraft maintenance and repair. Usage and disposal of fuels, oils, and solvents in Buildings 830 and 831 have been similar to the practices which occurred in Building 832.

The groundwater flow direction in this area has not been well defined. In general, it appears that the groundwater flow in this area could be north toward NAS Well 34 or southerly toward NAS Wells 31 and 32. Degraded water quality is present in all of those wells. If groundwater contamination has occurred from activities at Building 830 and 831, this area is potentially a source for the degraded quality measured in those wells during the PA/SI.

6.3.6 Buildings 796 and 798 Drainage

The drainage area for the floor drains in Buildings 796 and 798 is located west of the drainage area for Buildings 830 and 831



LEGEND

31 — WELL LOCATION WITH WELL DESIGNATION

GENERALIZED GROUNDWATER FLOW DIRECTION

CONCEPTUAL PLUME LOCATION

BASE MAP: PREPARED FROM MAP PUBLISHED BY LANDMAELINGAR ISLANDS (ICELAND GEODETIC SURVEY) AND DMAHTC U.S.A.

FIGURE 6-15

NAVY - NAS
KEFLAVIK, ICELAND

BUILDINGS 830 & 831 DRAINAGE LOCATION MAP

drawn RAM	approved JLW	drawing no. 87040-090-AA
checked JLW	date 1-24-89	

r. e. wright associates, inc.
earth resources consultants

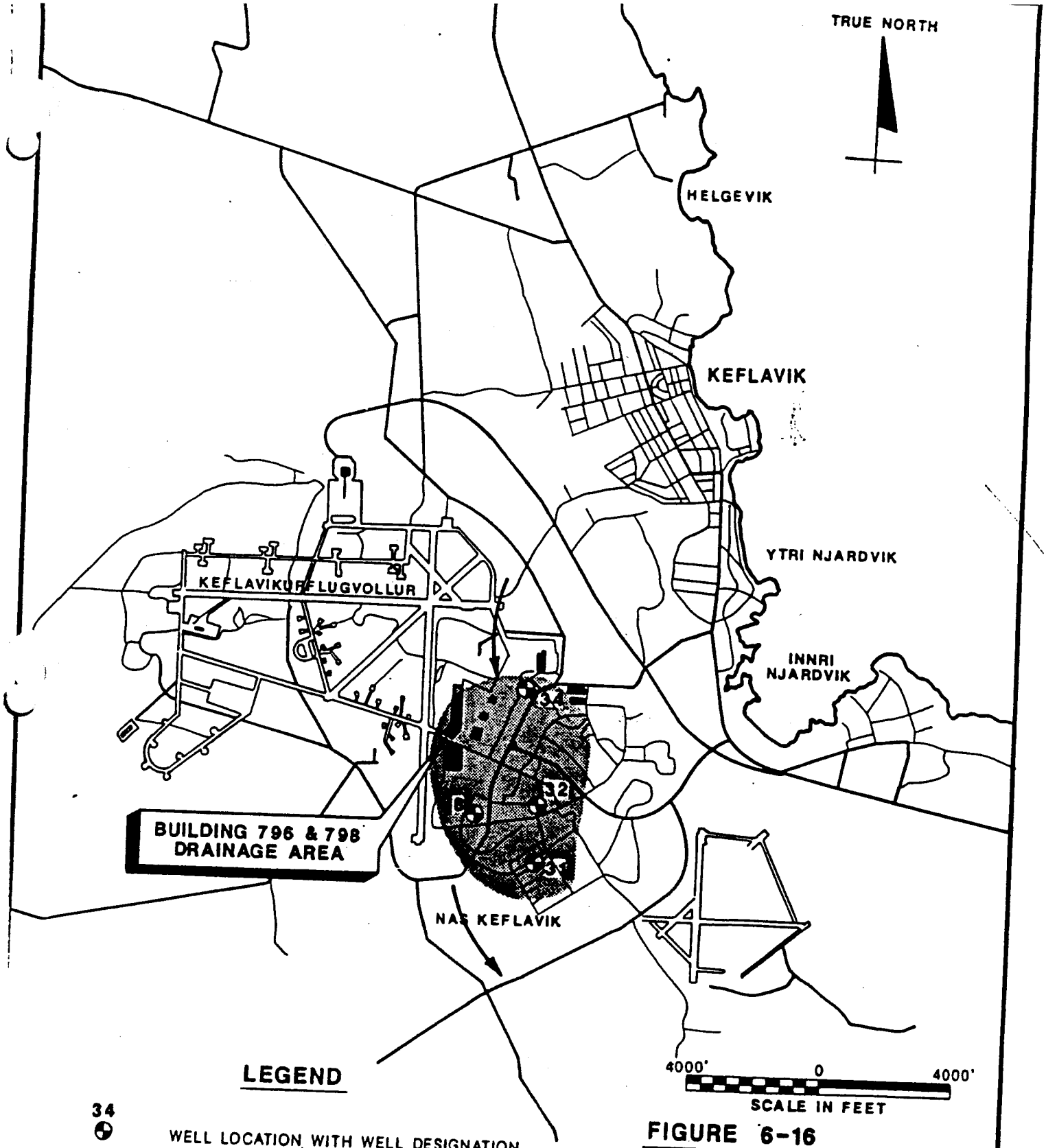
(Figure 6-16). Usage of Buildings 796 and 798 has been primarily aircraft maintenance, repair, and parking. As with the other aircraft maintenance facilities previously mentioned, the floor drains from these buildings drain into the ground. Oil-water separators have been installed in the floor drain system, but dates of installation were unknown. Fuels, oils, solvents, and waste disposal practices for these facilities were similar to the practices reported for Building 832. In addition to those practices, refueling of aircraft also occurred within these buildings.

Spills which occurred on the apron surrounding these buildings were washed into the drainage ditch west of the apron. This practice continued until 1985 when the Public Works Hazardous Materials Division was started. Since the start-up of the Hazardous Materials Division, spills which occur on the apron are contained and cleaned up with sorbent material which is then containerized and sent to Military Disposal.

Groundwater flow directions for this drainage area were not well defined due to undifferentiated pumping influences around NAS Well 34. However, the general groundwater flow directions appear to be to the southwest. The degraded groundwater quality measured in NAS Well 8 may arise from groundwater transport from this area.

6.3.7 Building 781 Drainage

Building 781 drainage area is located directly north of Building 832 (Figure 6-17). Constructed in 1982, Building 781 has been used by the military as an aircraft corrosion control



LEGEND

34 — WELL LOCATION WITH WELL DESIGNATION

GENERALIZED GROUNDWATER FLOW DIRECTION

CONCEPTUAL PLUME LOCATION

BASE MAP: PREPARED FROM MAP PUBLISHED BY LANDMAELINGAR ISLANDS (ICELAND GEODETIC SURVEY) AND DMAHTC U.S.A.

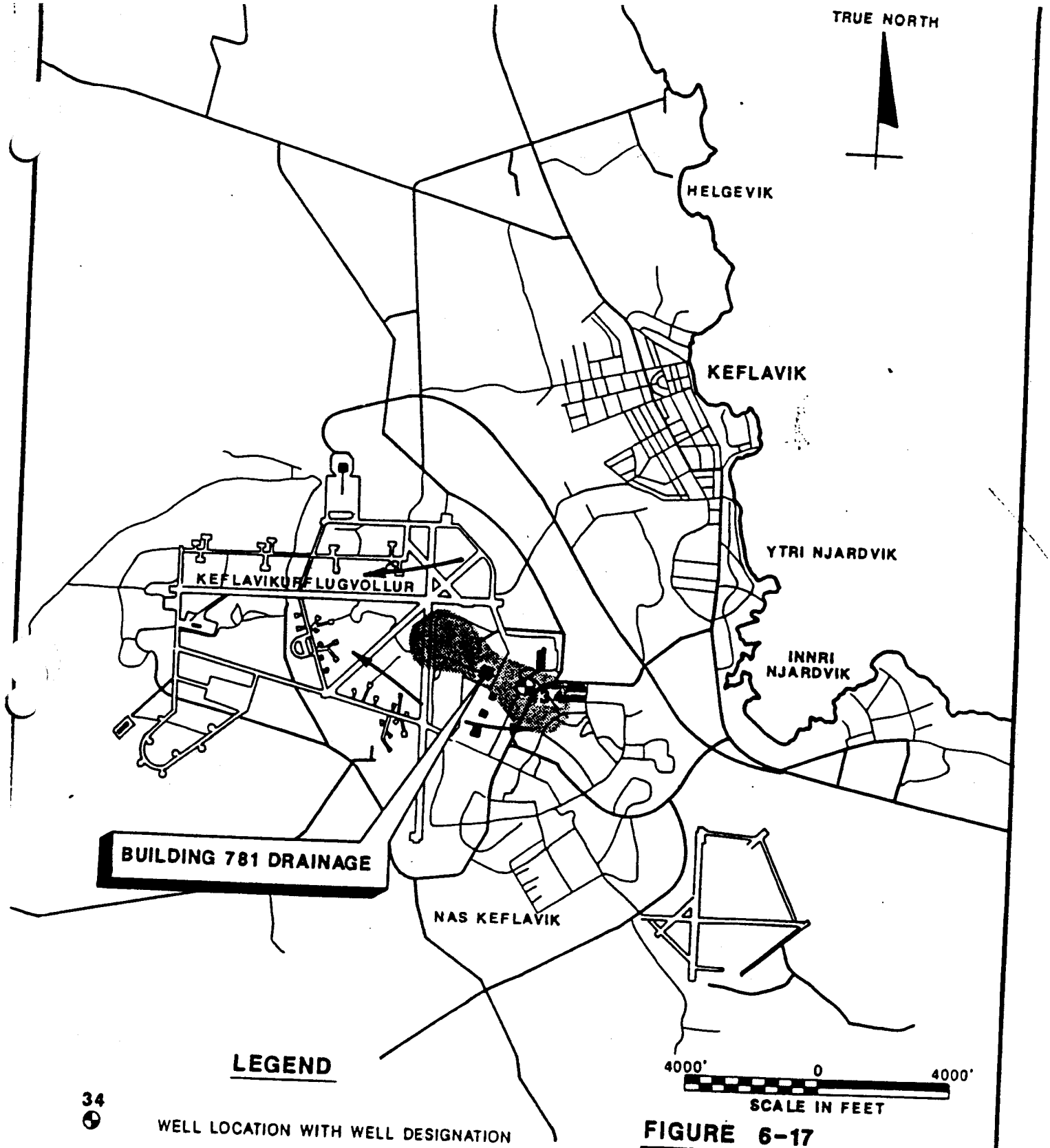
FIGURE 6-16

NAVY - NAS
KEFLAVIK, ICELAND

BUILDING 796 & 798 DRAINAGE AREA LOCATION MAP

drawn RAM	approved RW	drawing no. 87040-091-AA
checked LW	date 1-24-89	

r. e. wright associates, inc.
earth resources consultants



LEGEND

34 — WELL LOCATION WITH WELL DESIGNATION

GENERALIZED GROUNDWATER FLOW DIRECTION

CONCEPTUAL PLUME LOCATION

ASE MAP: PREPARED FROM MAP PUBLISHED BY LANDMAELINGAR ISLANDS (ICELAND GEODETIC SURVEY) AND DMAHTC U.S.A.

FIGURE 6-17

NAVY - NAS
KEFLAVIK, ICELAND

BUILDING 781 DRAINAGE LOCATION MAP

drawn RAM	approved KVL	drawing no. 87040-092-AA
checked JLW	date 1-24-89	

r. e. wright associates, inc.
earth resources consultants

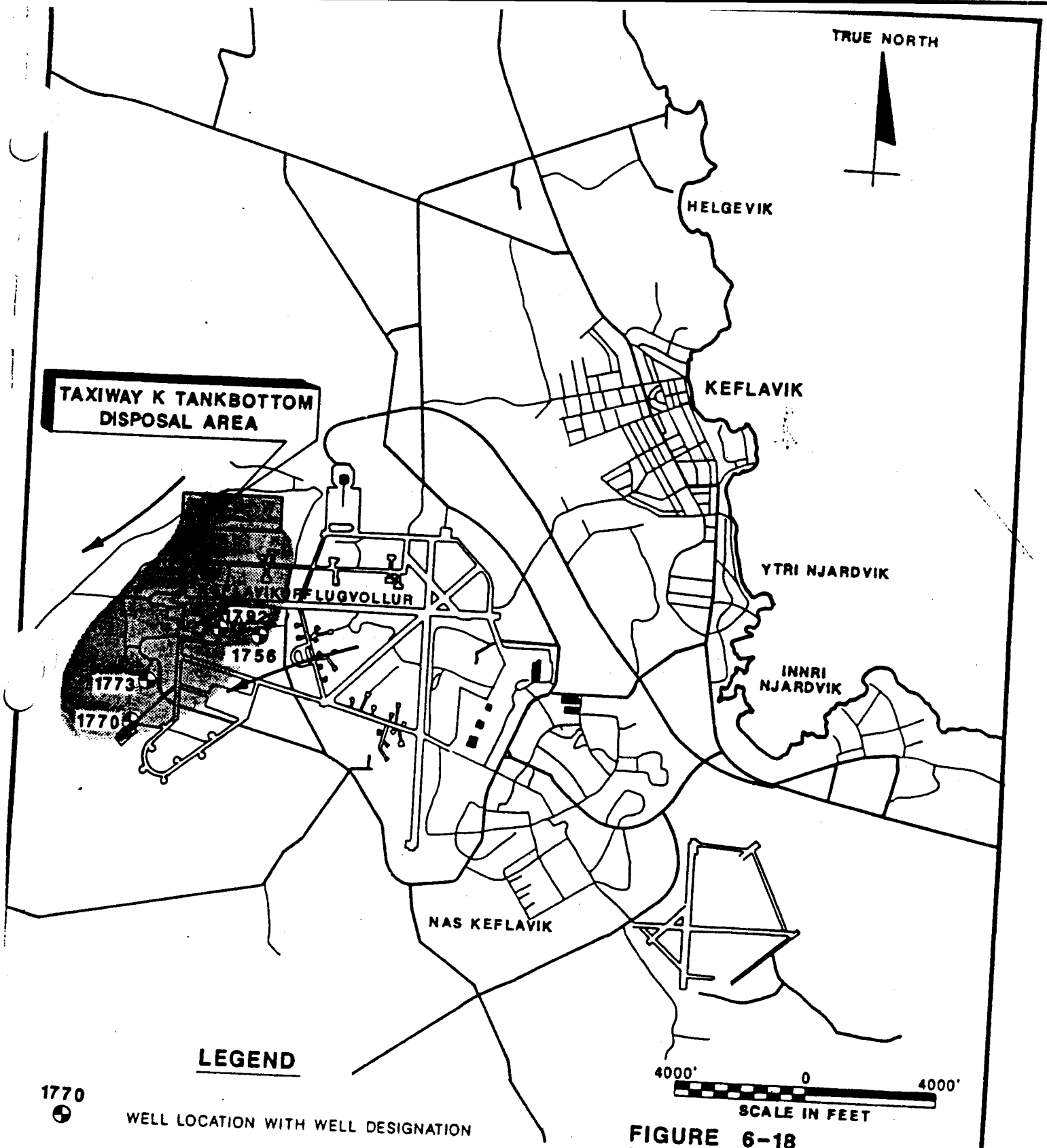
facility. Work within this building consists of cleaning and painting aircraft. Paint, paint thinners, paint strippers, and methyl ethyl ketone are used in this facility. The floor drains in the building drain through an oil water separator and discharge onto the ground west of the building. Spills which occur in this building are washed into the floor drains. Other waste products generated at this facility are containerized and sent to Military Disposal.

The groundwater flow direction in this area appears to be easterly toward NAS Well 34 or westerly toward the Accoustic Facility (AF or HH). If this location is resulting in groundwater quality degradation, both these wells are threatened by groundwater transport to this site.

6.3.8 Taxiway K Tank Bottom Disposal Area

This second tank bottom disposal area is located west of the International Air Terminal and north of Taxiway K (Figure 6-18). Use of this area was similar to the disposal area mentioned in Section 6.2.5. Tank bottoms were spread out in this area for disposal. Petroleum hydrocarbons and lead leached from the tank bottoms could potentially infiltrate to the groundwater in the area.

Groundwater flow direction in this area is generally west to southwest. If groundwater quality degradation has occurred, it would flow west to southwesterly. Presently, the supply wells which appear to be threatened in that area are NAS Wells 1756, 1770, 1773, and 1792.



LEGEND

1770 — WELL LOCATION WITH WELL DESIGNATION

GENERALIZED GROUNDWATER FLOW DIRECTION

CONCEPTUAL PLUME LOCATION

BASE MAP: PREPARED FROM MAP PUBLISHED BY LANDMAELINGAR ISLANDS (ICELAND GEODETIC SURVEY) AND DMAHTC U.S.A.

FIGURE 6-18

NAVY - NAS
KEFLAVIK, ICELAND

TAXIWAY K TANK BOTTOM DISPOSAL AREA LOCATION MAP

drawn RAM	approved JLW	drawing no. 87040-093-AA
checked JLW	date 1-24-89	

r. e. wright associates, inc.
earth resources consultants

6.3.9 Former Camp Geck Area

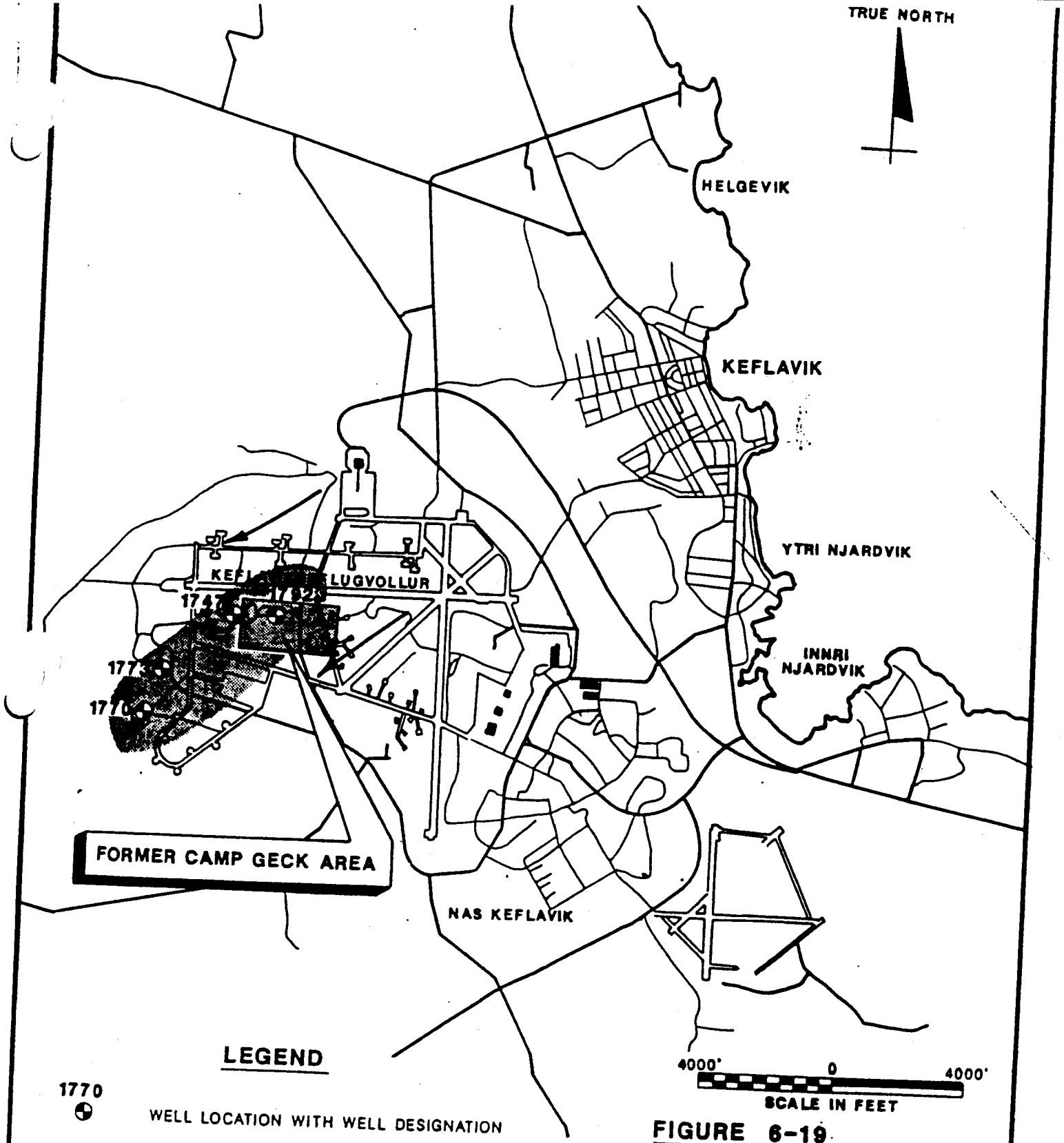
The former Camp Geck area, which includes the Camp Geck hangar, is located approximately one mile south of the International Air Terminal (Figure 6-19). Camp Geck was used during World War II by the British Air Force. Aircraft maintenance and repair were done inside the Geck hangar. Information about the types of oils and solvents the British used in the study area is unknown, but it was presumed that TCE may have been among them.

Waste disposal practices by the British at Camp Geck are unknown. However, during interviews it was reported that the British operated a landfill west of the Geck hangar.

Groundwater flow direction in the former Camp Geck area appears to be westerly. Activities in this area, as well as other potential source areas, may have resulted in degraded groundwater quality detected during the PA/SI in Wells 1792 and 1756. Groundwater transport of contaminants from those wells would also potentially impact NAS Wells 1773 and 1770.

6.3.10 West End Complex

The West End Complex, located west of the former Camp Geck area, includes the Alert Facility, an engine test cell facility, and aircraft shelters (Figure 6-20). Maintenance and repair of aircraft occur at the facilities in the West End Complex. Oils and solvents used are similar to those listed for Building 832. Floor drains in these facilities drain into the ground after passage through oil-water separators. Waste disposal practices at the West End Complex are similar to those listed for Building 832 (Section 6.3.4).



LEGEND

1770 — WELL LOCATION WITH WELL DESIGNATION

GENERALIZED GROUNDWATER FLOW DIRECTION

CONCEPTUAL PLUME LOCATION

BASE MAP: PREPARED FROM MAP PUBLISHED BY LANDMAELINGAR ISLANDS (ICELAND GEODETIC SURVEY) AND DMAHTC U.S.A.

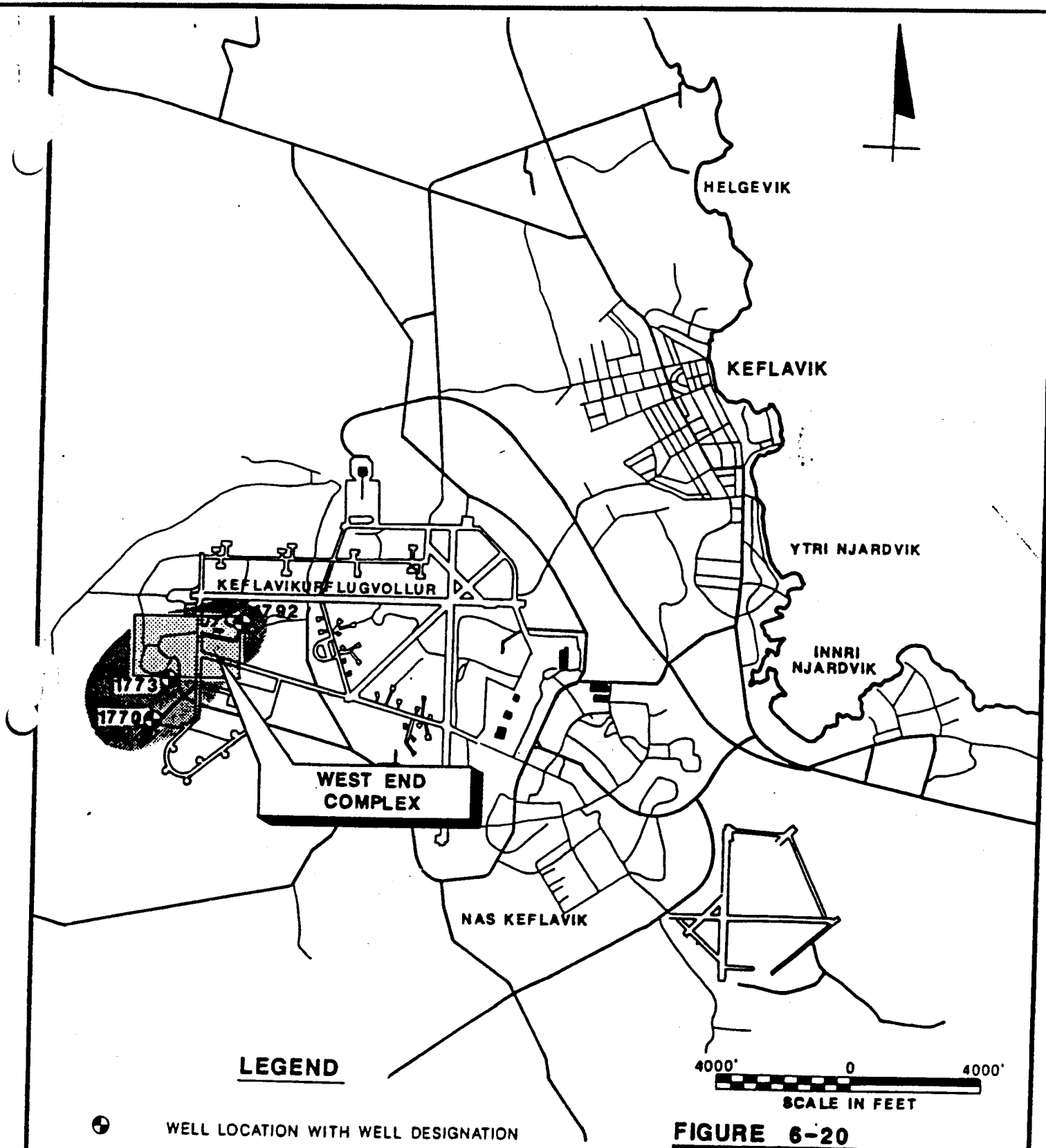
FIGURE 6-19

NAVY - NAS
KEFLAVIK, ICELAND

FORMER CAMP GECK AREA LOCATION MAP

RAM	KVC	
JLW	1-24-89	87040-094-AA

r. e. wright associates, inc.
earth resources consultants



LEGEND

- WELL LOCATION WITH WELL DESIGNATION
- GENERALIZED GROUNDWATER FLOW DIRECTION
- CONCEPTUAL PLUME LOCATION

BASE MAP: PREPARED FROM MAP PUBLISHED BY LANDMAELINGAR ISLANDS (ICELAND GEODETIC SURVEY) AND DMAHTC U.S.A.

FIGURE 6-20

NAVY - NAS
KEFLAVIK, ICELAND

WEST END COMPLEX LOCATION MAP

drawn RAM	approved JLW	drawing no. 87040-095-AA
checked JLW	date 1-26-89	

r. e. wright associates, inc.
earth resources consultants

Groundwater flow direction at the West End Complex appears to be in a westerly direction. If groundwater quality is degraded from activities in this area groundwater transport of contaminants would potentially impair NAS Wells 1792, 1973, and 1770 to the degree observed during the PA/SI.