# Chapter 9

# GROUNDWATER DATA ACQUISITION METHODS

## Introduction

This chapter provides information that will help select, install, and operate appropriate groundwater instrumentation and to collect, establish, maintain, and present the groundwater data. Most types of engineering geology investigations require acquisition and use of groundwater data. The data required may vary from simple monthly verification of the water level elevations along a canal-axis profile to hourly monitoring of piezometric conditions in multiple zones within a landslide or embankment. Successful implementation of a groundwater instrumen-tation program depends on knowledge of subsurface conditions, preliminary identification of all probable future uses of the data, and careful planning of an instrumentation system and data acquisition program to meet these data requirements. This chapter will provide the user with:

- A detailed description of methods employed in designing and installing groundwater monitoring systems.

- A detailed description of available manual and automated methods and techniques used in monitoring ground and surface water.

- A discussion of data base management and data presentation.

- A listing of more detailed and specific source material on groundwater data acquisition methods.

## General

The importance of fully evaluating and understanding geologic factors controlling groundwater flow—including porosity, storativity, permeability, transmissivity, velocity, recharge, and discharge—cannot be overemphasized. This evaluation needs to be made at the onset of the exploration program and continually repeated throughout the investigations. These factors will ultimately control the type of groundwater acquisition methods required.

## Geologic Controls on Groundwater

Geologic controls on groundwater flow impact the design of observation systems and must be identified in the preliminary planning of the instrumentation program. For example:

1. Permeable materials, such as clastic sediments, karstic limestone, and fractured rock, control the type and size of well point, well screen, or piezometer to be used and must be accounted for in designing instrumentation for the program.

2. Relatively impermeable materials, such as clays, silts, shales, siltstones, and massive rock present special problems which must be accounted for in selecting the type and size of piezometer to be installed. Generally these materials require use of the smallest size piezometer practical because changes in water level and volume in the hole are small and require long periods of time to react. Pore pressure measurements in this type of geologic environment should be considered, particularly if short-term periodic—daily or weekly—changes in groundwater conditions are needed.

3. Layering, attitude of layers, boundaries, weathering and alteration, and environment of deposition all influence selection of instrumentation.

## Design and Installation of Observation Wells and Piezometers

### Analysis of the Geologic Environment

The presence of variations in the geologic environment must be anticipated. Perched water tables, artesian aquifers, sources of recharge and discharge, known boundaries and barriers, and structural controls such as fractures, joints, faults, shears, slides, folds, and stratigraphic contacts should be considered when selecting instrument types and sizes. The preliminary instrumentation design should be advanced enough to allow procurement of needed equipment, but flexible enough to adapt to changes in the environment.

Different types of groundwater observation instruments provide different data types. Observation wells and piezometers are selected in accordance with the data required and the aquifer material and type. To be useful, reliable, and accurate, the well or piezometer design must be tailored to the subsurface conditions. Single or unconfined aquifer zones can be monitored by using a screened or perforated standpipe or porous tube piezometer, or by a pore-pressure transducer. Multiple zones may be monitored using multiple drill holes, multiple piezometers in a single drill hole, or multiple piezometer ports in a single standpipe.

## Design

The most important aspect in the design of a groundwater monitoring well is the purpose and use of the well; whether for taking water samples, measuring water levels, geophysical investigations, or a combination of uses.

The hydrogeologic environment and the type of down-hole instruments that may be used in the well will influence the choice of well diameter, casing type, screen to be used, and the interval to be monitored.

Components of a typical well include a screened interval surrounded by filter/gravel-pack material isolated by a bentonite and/or cement grout seal, blank casing to the surface, and a protective well cover.

PVC is the most widely used material for standpipes (casing and screens) in monitoring wells. It is relatively inexpensive and presents few chemical interferences in water quality sampling. Many other materials are available for specific uses, including galvanized and stainless steel, Teflon©, and other plastics.

The diameter of the well depends on the instrumentation to be installed and the intended use. If the well is to be sampled, by either pump or bailer, a 3-inch (75-mm) diameter hole is the preferred size for accuracy and for complete development of the hole, but smaller sizes can be used with small bailers and peristaltic pumps. Wells used for measuring water levels only may be smaller diameter or may have multiple small diameter standpipes within a 4-inch (100-mm) to 8-inch (200-mm) diameter hole. A standpipe designed to accommodate an M-scope water level sensor can be ¾ inch (19 mm) diameter. However, if the standpipe is to be instrumented with a pneumatic or vibrating wire piezometer or if a recorder and electric probe will be used to monitor the water level, then the diameter of the standpipe depends on the size of the instrument or transducer to be installed. Lengths of well screen and casing (PVC perforated and solid standpipe) must have uniform inner and outer casing diameters. Inconsistent inner diameters cause problems when instruments with tight clearance are lowered into the well. The pipe may need to be reamed to remove the beads and burrs. A filter pack is generally composed of washed sand and gravel and is placed within the screened interval. The interval may extend above the screen depending on the zone thickness. The pack is designed primarily to allow water to enter the standpipe while preventing the movement of fines into the pipe through the slots, and to allow water to leave the standpipe when water levels drop. If the well is to be used for sampling, the pack material should be sterilized to prevent possible contamination before placement into the well. The gravel pack should be tremied through a pipe to prevent bridging. The top of the pack may be checked using a small diameter tamping tool, or a properly weighted surveyor's tape.

A seal is installed to create an impermeable boundary between the standpipe and the casing or drill hole wall. The seal should be placed in a zone of low permeability, such as a clay bed above the zone to be monitored. This ensures that water will not travel vertically along the casing or drill hole.

Cement grout can shrink due to temperature changes during curing and may crack. This causes a poor bond between the grout and the standpipe. A 1-foot (0.3-m) bentonite seal should be placed preferably as pellets or by tremieing a bentonite slurry immediately below and above the cement grout seal. This helps ensure a reliable plug. Any seal material (optional with bentonite pellets) should be tremied into place. This prevents bridging or caking along the hole wall. The seal must be reliable so that the screened interval monitors only the desired groundwater zone.

A drill hole containing multiple standpipes, each monitoring a zone or distinct water bearing strata, may have several isolating seals. To test the integrity of the seals, a gravity head test may be performed by adding water to the shallowest standpipe and continuously measuring the water level in the next lower piezometer to detect any leakage through or around the seals. If the water leaks into the lower interval, the piezometric head will rise in the lower standpipe.

A protective cover helps prevent damage to the standpipe and reduces surface water drainage into the backfilled hole. The casing should extend 5 to 10 feet (1.5 to 3 m) below ground and be grouted into place. Upon completion of the monitoring well, standpipe should be bailed or blown dry and the water level allowed to recover to a static level. A completion log should be prepared using the drillers' records, geologic log, and measurements. The log should include the actual depths and thicknesses of each component of the well; the standpipe's total depth; the screened interval, the isolated interval; the type of filter pack; the depth, thickness, and type of isolating seals; and a reference point from which all measurements were taken, such as top of casing or ground surface. Many excellent references are available to design and install groundwater monitoring wells for various purposes. Refer to these at the end of this chapter for more detailed instructions.

## Construction Materials

Construction materials for observation wells and piezometers are dictated by the projected use of the instrument and the permeability of the aquifer. The diameter of the standpipe, the type of standpipe used (metal versus plastic), screen slot size/porous tube type, and gravel pack material are all variables dictated by aquifer characteristics.

In a relatively permeable material, the diameter of a standpipe is not critical; sand or gravel pack around the well tip may not be required, but the screen slot size may be critical to the success of the installation. Too small screen or slot size may restrict instrument reaction to changes in water levels.

In a relatively impermeable material, pipe diameter may be critical, a pack material of select sand or fabric wrap usually is required, and a well point or screen assembly usually is needed, (0.010-0.020-inch [0.0250.05 centimeter (cm)] slot size). Generally, the smallest diameter pipe practical should be used in this sort of monitoring application, keeping in mind that the standpipe diameter must be large enough to install a means of measuring water levels. If the volume of the hole is too large, too much water must move in and out of the hole to accurately reflect the water level. If rapid reaction to water level or changes is needed, a pressure transducer may be more appropriate than an open-tube piezometer or standpipe.

A variety of materials can be used as the standpipe. Polyvinyl chloride (PVC) plastic pipe is economical and easy to install. Plastic pipe is fairly fragile, deformable, and can be destroyed accidentally during installation. Metal pipe is more durable for installation but generally costs more than plastic, rusts or corrodes, and is subject to iron bacterial action. Generally, if grout plugs are used to isolate zones, black pipe is preferred because the zinc in galvanized pipe can react with the plug and destroy the seal. The inside diameter (I.D.) of the pipe depends on the permeability of the aquifer material and can vary from as small as ½ inch (13 millimeters [mm]) to 2 inches (50 mm) or larger. The diameter of the riser is critical to instrumentation of the observation well or piezometer. Generally, ¾-inch (19 mm) pipe is the smallest practical size that can be used in automated applications. Reaming of the pipe prior to installation to remove burrs, weld seams, and blebs of galvanizing material is a necessary precaution to ensure that the standpipe will be usable if the pipe I.D. and measuring device outside diameter (O.D.) are close.

The screen assembly selected for an observation well or piezometer can be a well point, well screen, porous tube, or perforated pipe (commercially manufactured or field fabricated). Screen should be PVC or corrosion-resistant metal. Slot-size is determined by filter material size and aquifer material.

The gravel-pack material selected is determined by the particle sizes of the aquifer material and the size of the well screen. Concrete sand or reasonably well-graded sand to pea gravel can be used.

Plug material used to isolate the interval to be monitored can be tremied cement grout, bentonite pellets, or a combination of the two. A bentonite slurry also may be used in some instances but must be tremied in place. Bentonite pellets are preferred if only one isolation method is used.

## Methods Used to Measure Groundwater Levels

### General

Groundwater measurements (and any instrumentation readings) should be interpreted concurrently with reading. Erroneous readings and faulty equipment need to be detected as encountered, and timely interpretation is a reliable method of bad reading detection. The person(s) taking the readings must understand the equipment and gather reliable data from the instruments. If bad read-ings or faulty equipment are not detected by concurrent interpretation, months of irretrievable data can be lost, and erroneous interpretations or data impossible to inter-pret can result.

### Manual Methods Used to Measure Groundwater Levels

**Chalk and Surveyors' Chain.—**Probably the oldest and one of the most reliable methods for measuring wells is the surveyors' chain and chalk method. This method is not recommended where water level depths exceed several hundred feet (300 m+).

A lead weight may (but not necessary) be attached to a steel measuring tape (surveyors' chain). The lower 5 feet (1.5 m) of the tape is wiped dry and covered with solid carpenter's chalk if the water level is roughly known. The tape is lowered into the well, and one of the foot marks is held exactly at the top of the casing. The tape is pulled up. The line can be read to a hundredth of a foot (0.003 m) on the chalked section. This reading is sub-tracted from the mark held at the measuring point, and the difference is the depth to water.

The disadvantage to this method is that the approximate water depth must be known so that a portion of the chalked section will be submerged to produce a wetted line. Deep holes require a long surveyor's chain which can be difficult to handle.

**M-Scope (Electric Sounder).—**An M-scope is an electric sounder or electrical depth gauge consisting of an electrode suspended by a pair of insulated wires and a milliammeter that indicates a closed circuit and flow of current when the electrode touches the water surface. Usually, AA flashlight batteries supply the current. The insulated wire usually is marked off in 1-foot to 5-foot (0.3- to 1.5-m) intervals. The best devices have the measuring marks embedded directly into the line. Markers that are attached to the line slip, making it necessary to calibrate the instrument frequently.

With the reel and indicator wire in one hand and the other hand palm up with the index finger over the casing or piezometer pipe, the wire is lowered slowly over the finger into the piezometer pipe or well casing. By sliding the wire over the finger, the wire is not cut or damaged by the sharp casing or piezometer pipe. Several readings can be taken to eliminate any errors from kinks or bends in the wire. The water level depth can be measured from the top of casing using the mark-tags on the insulated wire and a tape measure marked in tenths and hundredths of a foot. The advantage of this method is that water level depths in holes several hundred feet deep can be measured fairly quickly and accurately. The disadvantage to this method is that malfunctioning or mechanical problems develop in the instrument giving er-roneous water level readings. Before going into the field, the instrument must be checked for low batteries, tears, scrapes on the insulated wires, and iron-calcium buildup on the part of the electrode touching the water surface.

**Airline and Gauge.—**This method uses a small diameter pipe or tube inserted into the top of the well casing down to several feet below the lowest anticipated water level. The exact length of airline is measured as the line is placed in the well. The airline must be air tight and should be checked. The airline must hang vertically and be free from twists and spirals inside the casing. Quarter-inch (6.3 mm) copper or brass tubing can be used. The upper end of the airline is fitted with suitable connections and a Schraeder valve so that an ordinary tire pump can be used to pump air into the tube. A tee is placed in the line so that air pressure can be measured on a pressure gauge.

This device works on the principle that the air pressure required to push all the water out of the submerged portion of the tube equals the water pressure of a column of water of that height. A reference point (e.g., top of casing or pipe) and the depth to the lower end of the airline must be known. Air is pumped into the airline until the pressure on the gauge increases to a maximum point where all the water has been forced out of the airline. At this point, the air pressure in the tube just balances the water pressure. The gauge reading shows the pressure necessary to support a column of water of a height equal to the distance from the water level in the well to the bottom of the tube.

If the gauge reads the direct head of water, the submerged length of airline is read directly. The total length of airline to the reference point, minus the submerged length gives the depth to water below the measuring point. If the gauge reads in pounds per square inch, multiply the reading by 2.31 to convert to feet of water. An accurate, calibrated gauge and a straight, air-tight airline are important.

**Popper.—**A simple and reliable method of measuring water levels is with a popper. A tape with a popper attached to the bottom is lowered into the well or casing until the water is reached, as indicated by a pop. The popper is raised above and lowered to the water surface several times to accurately determine the distance. A popper consists of a small cylinder closed at the top and open at the bottom. The open bottom causes a popping sound when the water surface is hit. A 1-inch (in) or 1½-in (25- or 40-mm) pipe nipple 2 to 3 in (50 to 75 mm) long with a cap on top works satisfactorily.

**Pressure Gauge for Monitoring Artesian Wells.—** Additional standpipe or casing can theoretically be extended to eventually equal the head of the water. A simple method to determine the artesian head is to attach a pressure gauge to the casing or the piezometer pipe. The gauge selected may be read directly or in feet (meters) of water. Install a tee on the standpipe or on the casing so that a pressure gauge and valve can be attached to the tee. The valve may be used to bleed the pressure gauge to see if the gauge is working and can be used to measure the flow on the artesian well. When a pressure reading is taken, a flow measurement should also be taken. During the winter months, the valve should be cracked open to allow the well to flow slightly to prevent the riser pipe from freezing and breaking. The line to the gauge should be bled of water. If the pressure gauge used is in lbs/in$^2$, multiply the gauge reading by 2.31 to obtain the head of water above the valve.

**Continuous Recorders**

**Stevens Recorder.—**The Stevens Recorder (produced by Stevens Water Resources Products) provides a reliable and economical way to obtain continuous water

level data. The recorder is a float type consisting of a 3- to 6-inch (76- to 152-mm) float connected to a pulley which turns a calibrated gear-driven drum. A power source, such as a spring clock or small motor, rotates the drum at a known rate giving a constant indication of elapsed time.
Gearing between the float pulley and the chart drum provide a changeable ratio of water movement to pen movement on the chart. A time scale is available on the chart, and continuous recordings may be maintained for up to several months. When a Stevens recorder is used in a well, the minimum diameter of the well casing is 4 inches (100 cm). An advantage of the Stevens recorder is versatility. Hydrographs can be created with scales of 1:1 to 1:20. Most recorders can be set from 4 hours to several months. Johnson-Keck has a water level sensing instrument that can continuously record water levels in ½-inch (13-mm) pipe and larger. Transistorized circuitry is used to control a battery powered motorized reel. The sensing float is attached to one end of the control wire, and the other end of the wire is connected to the reel. The instrument is connected to a Stevens type F or Stevens type A recorder. The control wire passes around the recorder pulley, and the sensing device is placed in the casing. The sensing device seeks the water surface; and once the water surface is found, the circuitry keeps the sensing device at the water surface.

Many float recorders can be attached to digital recorders for continuous records. Data from this type of instrument can be used and easily interfaced with a computer system.

**Bristol Recorders.—**Recorders for monitoring continuous artesian pressures are produced by Bristol Instrument Systems. The Bristol and Stevens recorders are similar in that pressure and time are recorded on a chart. The instrument usually contains diaphragms that can be adjusted to varying pressure conditions. The spring-driven clock usually is calibrated for 30 days. The Bristol recorder is very useful for observing pressure changes in artesian wells but is limited by freezing conditions in northern climates. A pressure gauge installed in the line between the artesian water and the pressure recorder is very useful. This gauge provides a good indication of the working condition of the instrument.

**Gas Bubbler Transducer.—**Pneumatic or gas bubble transducers are manufactured by many companies. The transducers vary from a single readout box to a complicated array of instruments that will measure several wells at once. A gas is forced through a tube at a constant rate past a diaphragm. When the pressure of the gas on the diaphragm and the water pressure on the other side of the diaphragm are equal, a constant reading is obtained. This reading equals the amount of water over the diaphragm. This number multiplied by 2.31 will give the amount of water head over the instrument. These instruments may be used as a single unit or connected into an electronic data acquisition system.

**Maintenance.—**A good maintenance program is necessary to ensure reliable performance of mechanically actuated recorders. The instruments and data collected are only as good as the preventive maintenance. A routine preventive maintenance program should be scheduled for all the instruments. In some cases, daily inspection of recorders is required; however, if the instrument is working properly, weekly inspections may be sufficient. Preventive maintenance can often be accomplished when the charts are changed.

## Methods and Techniques Used to Estimate Flows from Seeps, Springs, and Small Drainages

A thorough and detailed discussion of weirs, flumes, stilling wells, and other techniques is presented in Reclamation's *Water Measurement Manual* [1]. Small seeps, springs, and intermittent drainages are often encountered in field investigations. These features can provide key information during design and construction and may be key indicators of structure performance or environmental impacts that may affect the project. The location of drainage features, the rate of flow, and the time of year of the observation are important information. Flow can be estimated accurately using the methods described below:

Estimate the rate of flow in an open channel using $Q=VA$, where:

$Q$ = rate of flow
$V$ = velocity
$A$ = cross sectional area of channel

The cross-sectional area is determined by direct measurements where possible. Where impractical, the cross-sectional area may be estimated or scaled from a topographic map.

Velocity is determined using a float, a measuring tape, and a stop watch by timing how long a floating object takes to travel a given distance. This provides a crude but reasonably accurate estimate of flow. Other methods may include a pitot tube or flow meter.

Substitute the values obtained into the $Q=VA$ equation to obtain the volume of flow.

Measure flow from small springs and seeps directly by diverting the flow, or in some manner channel the flow to a point for collection in a container, such as a bucket. Determine the rate of flow by timing how long it takes to fill the container. Select points along a drainage where abrupt dropoffs occur and use this method. It is better to measure, however crudely; but if not possible, estimate the flow. Many more sophisticated methods can be used to obtain more accurate flow measurements, if necessary. Determination of the most appropriate method can be made if preliminary data are available.

## Computer-Based Monitoring Systems

### General

Water level monitoring may be automated. Monitoring landslides can require a great number of points and frequent readings. A variety of data types may be required, which may include measurements of not only water levels and pore pressure changes, but deformation and movement as well. Systems required to collect, store, format, and present these data are available allowing realtime analysis of a wide variety of data types.

### Components of a Computer-Based Monitoring System

1. Many types of instruments including inclinometers, pressure transducers, strain gauges, water level gauges, and flowmeters can be used in a monitoring system. Electronic instruments are available in many sizes and shapes; preliminary selection of the instrument type

should be made during the initial design of the system. The inside diameter of the well must be sized to accept the transducer.

2. Acquired data is sent from the instrument at the well to the data logger or processor. This is done by hardwire from the instrument, line-of-sight radio, satellite radio, or phone lines.

Data from the monitoring points may be preprocessed in the field prior to transmittal to the central computer. A number of microprocessor data scanners that collect and reduce data can be installed at various field locations. The central computer queries the field scanners to obtain periodic updates. The remote scanners can be interrogated as frequently as desired. This may include a continuous data scan mode.

3. Data scanners reduce the instrument output to usable data. Data scanners can be the end destination for more simple systems or can be part of a more elaborate system. Generally, two types of signals are generated by instruments used in geotechnical monitoring: (a) digital and (b) analog current or voltages. Data scanners which accept and reduce data from both types of signals are available.

Many manufacturers offer complete packages of automated instrumentation systems, including computer hardware and software. If the initial observation well program is designed for automation, most of these systems will provide the high quality data required.

**Special Applications**

Many types of instrumentation can be used in a single drill hole. A multiple use casing collects groundwater data from a large number of horizons within a single drill hole. Casing is available specifically for pore-pressure observations, or grooved casing can be used so that the well can be completed for both pressure and inclinometer measurements. Isolation between horizons can be accom-plished either by installing a bentonite seal or by using a packer assembly designed as an integral part of a monitoring system. Use of a monitoring system greatly reduces drilling costs, provides detailed monitoring of critical drill holes, and provides a greater flexibility than systems previously available. Small diameter drill holes can be used to obtain a large number of isolated water level intervals and, depending on the application, can be very cost effective.

## Data Base Management and Data Presentation

Standard forms are available to record field data, although standard data sheets often must be modified for specific applications. Data sheets must include remarks and information that include the monitoring well num-ber, location, elevation reference points, type and size of well, dates and times the well was read, depth to water, and the elevation of the water surface. Periodic readings of these observation wells over long periods of time generate numerous data sheets. Computerization of the data base very rapidly can become a necessity if data are to be readily available and easily analyzed.

Data entry and storage in digital format allows electronic transfer of data and greater flexibility in developing, analyzing, and presenting data. Data may be tabulated or presented as time-depth/elevation plots and interpre-tive drawings such as contours and other three dimensional plots. Tremendous volumes of data can be reduced quickly to a usable format. Use of a commer-cially available data base allows data use and manipu-lation without specialized software or training.

## Definitions

**Aquifer**—A body of soil or rock that is sufficiently permeable to conduct groundwater and to yield economically significant quantities of water to wells and springs.

- **Confined aquifer—**An aquifer bounded above by impermeable beds, or beds of distinctly lower permeability than that of the aquifer itself. An aquifer containing confined groundwater.

- **Unconfined aquifer—**An aquifer having a water table. An aquifer containing unconfined ground-water.

**Artesian**—An adjective referring to groundwater confined under hydrostatic pressure.

**Artesian aquifer—**An aquifer containing water under artesian pressure.

**Aquitard—**A confining bed that retards but does not prevent the flow of water to or from an adjacent aquifer; a leaky confining bed. An aquitard does not readily yield water to wells or springs but may serve as a storage unit for groundwater.

**Aquiclude—**A body of relatively impermeable rock or soil that is capable of absorbing water slowly but functions as an upper or lower boundary of an aquifer and does not transmit significant groundwater.

**Water table or water level—**The surface between the zone of saturation and the zone of aeration; the surface of a body of unconfined groundwater at which the pressure is equal to atmospheric pressure.

**Zone of aeration or Vadose zone—**Subsurface zone containing water under pressure less than atmospheric, including water held by capillarity, and containing air or gases generally under atmospheric pressure. This zone is limited above by the land surface and below by the surface of the zone of saturation or water table.

**Saturation—**The maximum possible content of water in the pore space of rock or soil.

**Zone of saturation—**A subsurface zone in which all of the interstices are filled with groundwater under pressure greater than atmospheric. The zone is still considered saturated even though the zone may contain gas-filled interstices or interstices filled with fluid other than water. This zone is separated from the zone of aeration by the water table.

## References

American Geological Institute, *Glossary of Geology,* 4th edition, Alexandria, VI, 1997.

Bureau of Reclamation, *Embankment Dam Instrumentation Manual*, U.S. Department of the Interior, United States Government Printing Office, Washington, DC, 1987.

Bureau of Reclamation, *Ground Water Manual,* 2nd edition, A Water Resources Technical Publication, U.S. Department of the Interior, United States Government Printing Office, Washington, DC, 1995.

Driscoll, Fletcher G., *Groundwater and Wells*, 2nd edition, published by Johnson Division, St. Paul, MN 55112, 1987.

Leupold and Stevens Inc., *Stevens Water Resources Data Book,* 3rd edition, P.O. Box 688, Beaverton, OR 97005.

Morrison, Robert D., "Equipment, and Application," *Ground Water Monitoring Technology Procedures,* Timco Manufacturing Inc., Prairie du Sac, WI, 1983.

## BIBLIOGRAPHY

[1] Bureau of Reclamation, *Water Measurement Manual*, 3rd edition, A Water Resources Technical Publication, U.S. Department of the Interior, United States Government Printing Office, Washing-ton, DC, 1997.