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Delineation of Faults, Fractures, Foliation, and Ground-Water-Flow Zones in Fractured-Rock, on the Southern Part of Manhattan, New York, Through Use of Advanced Borehole-Geophysical Techniques



Open-File Report 2004-1232

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Delineation of Faults, Fractures, Foliation, and Ground-Water-Flow Zones in Fractured-Rock, on the Southern Part of Manhattan, New York, Through Use of Advanced Borehole-Geophysical Techniques

By Frederick Stumm, Anthony Chu, and Jack Monti, Jr.

In cooperation with New York City Department of Environmental Protection

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U.S. Department of the Interior
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CONVERSION FACTORS, ABBREVIATIONS AND VERTICAL DATUM

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallons per minute (gal/min)	3.785	liters per minute
	Flow rate	
gallon per minute (gal/min)	0.06309	liter per second (L/s)
	Specific capacity	
gallon per minute per foot (gal/min)/ft	12.418	liter per minute per meter
	Transmissivity*	
square foot per day (ft^2/d)	0.09290	square meter per day

Other abbreviations used in this report:

greater than (>)
hour (h)
megahertz (MHz)
microsiemens per centimeter (uS/cm)
millisiemens per meter (mS/m)
minute (min)
below land surface (BLS)
proposed tunnel construction zone (PTCZ)

Northing and Easting: In this report, refers to the X and Y position for the New York State Plane Coordinate System with a Fips zone of 3101; units are in feet. The North American Datum of 1927 (NAD27) is referenced as the horizontal datum.

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD29).

Sea level: In this report, is zero feet above the National Geodetic Vertical Datum of 1929.

*Transmissivity: The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness [(ft^3/d)/ft^2]ft. In this report, the mathematically reduced form, foot squared per day (ft^2/d), is used for convenience.

Delineation of Faults, Fractures, Foliation, and Ground-Water-Flow Zones in Fractured-Rock, on the Southern Part of Manhattan, New York, Through Use of Advanced Borehole-Geophysical Techniques

By Frederick Stumm, Anthony Chu, and Jack Monti, Jr.

ABSTRACT

Advanced borehole-geophysical techniques were used to assess the geohydrology of crystalline bedrock in 20 boreholes on the southern part of Manhattan Island, N.Y., in preparation for construction of a third water tunnel for New York City. The borehole-logging techniques included natural gamma, single-point resistance, short-normal resistivity, mechanical and acoustic caliper, magnetic susceptibility, borehole-fluid temperature and resistivity, borehole-fluid specific conductance, dissolved oxygen, pH, redox, heat-pulse flowmeter (at selected boreholes), borehole deviation, acoustic and optical televiewer, and borehole radar (at selected boreholes). Hydraulic head and specific-capacity test data were collected from 29 boreholes. The boreholes penetrated gneiss, schist, and other crystalline bedrock that has an overall southwest to northwest-dipping foliation. Most of the fractures penetrated are nearly horizontal or have moderate- to high-angle northwest or eastward dip azimuths. Foliation dip within the potential tunnel-construction zone is northwestward and southeastward in the proposed North Water-Tunnel, northwestward to southwestward in the proposed Midtown Water-Tunnel, and northwestward to westward dipping in the proposed South Water-Tunnel. Fracture population dip azimuths are variable. Heat-pulse flowmeter logs obtained under pumping and nonpumping (ambient) conditions, together with other geophysical logs, indicate transmissive fracture zones in each borehole. The 60-megahertz directional borehole-radar logs delineated the location and orientation of several radar reflectors that did not intersect the projection of the borehole.

Fracture indexes range from 0.12 to 0.93 fractures per foot of borehole. Analysis of specific-capacity tests from each borehole indicated that transmissivity ranges from 2 to 459 feet squared per day; the highest transmissivity is at the Midtown Water-Tunnel borehole (E35ST-D).

INTRODUCTION

Manhattan Island is about 12.5 mi long and 2 mi wide (fig. 1) and consists of unconsolidated deposits ranging from less than 1 ft thick to more than 200 ft thick overlying metamorphic bedrock. Manhattan Island is bounded on the west by the Hudson River, on the east by the East River, and on the south by New York Harbor (fig 1).

Water is supplied to New York City through Water Tunnels number one and two constructed in 1917 and 1938, respectively. In 1970, the New York City Department of Environmental Protection (NYCDEP) began construction of a third tunnel to supply water to New York City in the event that one of the two existing water tunnels should require repair. The third water tunnel in southern Manhattan is planned in three sections; the North Water-Tunnel, the Midtown Water-Tunnel, and the South Water-Tunnel (figs. 1-3).

Twenty-nine boreholes were drilled by the NYCDEP during 1999-2004 to identify the type of rock and its degree of fracturing in the boreholes at the proposed tunnel depths. However, the cores from these boreholes are not oriented; the hydraulic characteristics of the fractures cannot be determined from the cores; and the fracture and foliation orientations, and the vertical deviation of the boreholes cannot be determined from the cores.

In 1998, the U.S. Geological Survey (USGS), in cooperation with the NYCDEP, began a study to apply advanced borehole geophysical methods to provide a comprehensive geologic and hydrologic assessment of the crystalline bedrock in southeastern New York. These techniques were applied at 20 of the 29 boreholes in southern Manhattan to identify (1) the bedrock lithology and major contacts, (2) the location and orientation (true strike and dip) of fractures, and foliation of the rock intersected by the boreholes, (3) the hydraulic characteristics of transmissive

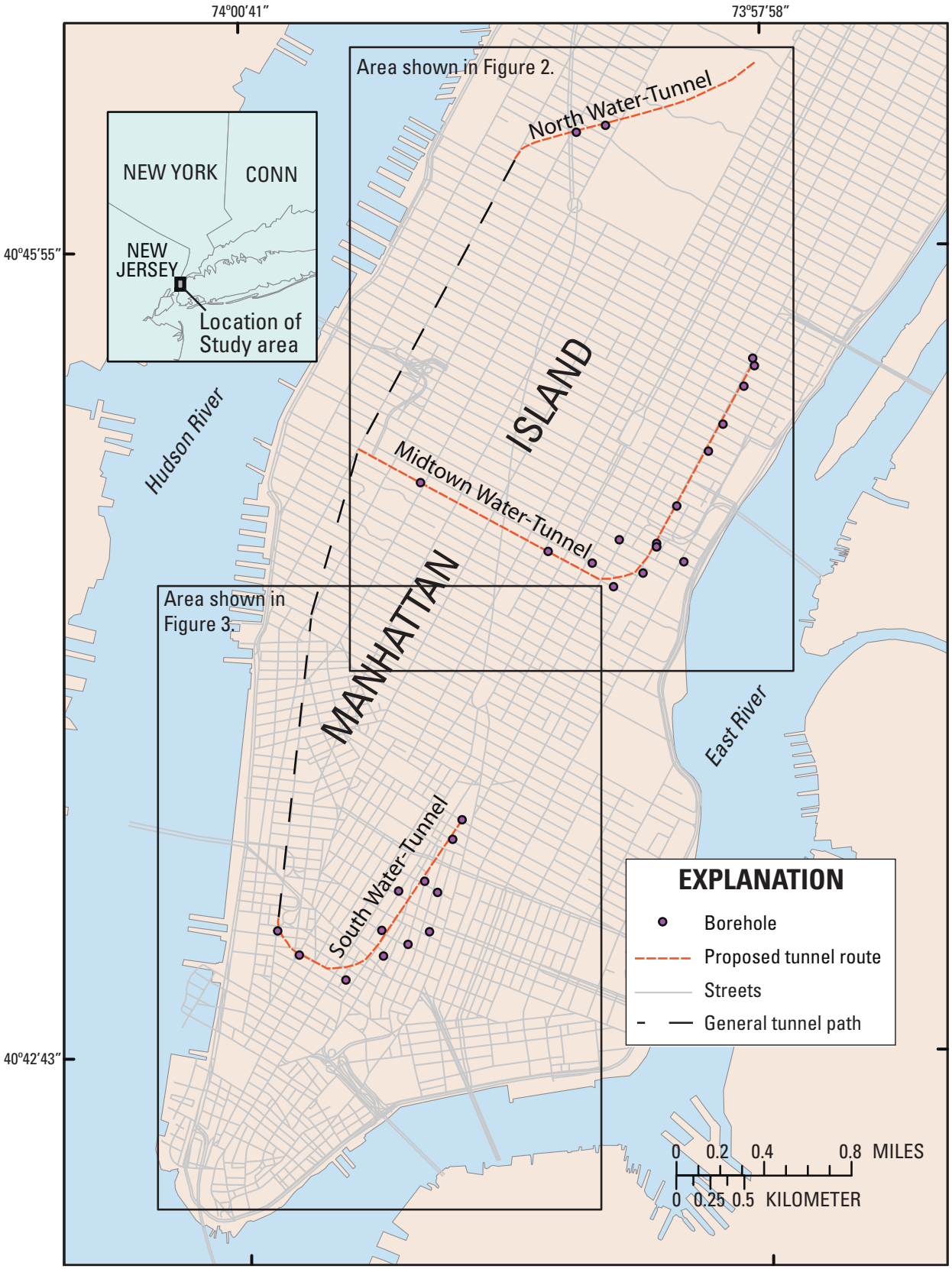


Figure 1. Locations of 29 boreholes and three sections of the proposed water tunnel (North, Midtown, and South Water-Tunnels), Manhattan Island, N.Y.

fracture zones, and (4) major fractures or faults that lie as much as 90 ft beyond the borehole (at selected boreholes). Transmissive (ground-water producing) fractures that may be intersected by the tunnel excavation could produce large quantities of ground-water flow into the tunnel.

Purpose and Scope

The purpose of this report is to present the geophysical and hydraulic data collected at the 29 boreholes. Included in this report are some preliminary analyses and interpretations.

This report (1) briefly describes the geophysical methods used; (2) presents geophysical logs, stereonet plots of fractures and foliations in each borehole and in the proposed tunnels; and summarizes the geophysical interpretations of fractures, faults, and foliation in each borehole; (3) presents ground-water levels, fluid-temperature, specific conductance, dissolved oxygen, pH, and redox logs, and specific-capacity data; and (4) summarizes the transmissivity and locations of transmissive fractures in the boreholes, and the regional directions of ground-water flow.

Borehole Network

Twenty-eight NX-sized (3-in diameter) boreholes were drilled by the wire-line diamond-core method to obtain continuous rock-core samples (table 1). A 2-in diameter borehole (E35ST-E) was installed in unconsolidated sediments in the southern part of Manhattan (figs. 1-3). All boreholes are cased with steel from land surface through the unconsolidated overburden to the top of bedrock, and are uncased or open from the bedrock surface to the bottom of the drilled depth (except E35ST-E). All boreholes were surveyed to determine their location in State Plane northing and easting, and elevation above mean sea level of their top of casing.

Hydrogeology

Southern Manhattan is underlain by high-grade metamorphic bedrock consisting of a sequence of gneiss and schistose-gneiss interlayered with granite (Baskerville, 1992). The bedrock contains many fractures, some of which are transmissive. Depth to bedrock ranges from less than 1 to 250 ft below land surface (BLS) within the southern part of Manhattan. Analysis of the water-level data from the fractured-rock boreholes indicate the highest water levels were in the north-central part of the study area, and lowest water levels were along the coastlines and in the southern part of the study area. At least two large cones of depression created by dewatering for shallow railway tunnels were detected.

METHODS

Borehole-Geophysical Logging

Borehole-geophysical logs collected in this investigation included natural gamma, single-point-resistance, short-normal resistivity, mechanical and acoustic caliper, magnetic susceptibility (collected at only one borehole), borehole-fluid temperature and resistivity, borehole specific conductance, dissolved oxygen (DO), pH, redox, heat-pulse flowmeter, borehole deviation, acoustic and optical televiewer, and directional borehole radar (table 2). The logging methods are briefly described below.

Natural-gamma (gamma) logs provide a record of the total gamma radiation detected in a borehole (Keys and MacCary, 1971; Keys, 1990) and are most commonly used for lithologic and stratigraphic correlation. Radioisotopes in bedrock minerals such as feldspar and mica are instrumental in lithologic correlation (for example, pegmatites). Clay minerals within fractures may be detected as elevated gamma responses in comparison with those of surrounding rock.

Single-point resistance (SPR) logs provide a measure of the electrical resistance of the rock or formation, in ohms, and are used to obtain qualitative lithologic information with a depth resolution approximately equal to borehole diameter (Keys and MacCary, 1971; Keys, 1990).

Short-Normal resistivity (R) logs provide a measure of the apparent resistivity in ohm-meters and are used to determine lithology and water-quality (Keys, 1990). The volume of the surrounding material to which normal resistivity probes are sensitive is about twice the electrode spacing (Serra, 1984; Keys, 1990). In this study only 16-inch short-normal resistivity logs were used.

Caliper logs provide information on lithology and the location of major fractures or faults. Mechanical calipers use spring-loaded arms to profile the surface of the borehole wall. Acoustic calipers calculate the distance from the probe to the borehole wall from the traveltime of the acoustic signal emitted from an acoustic televiewer (ATV) to provide high-resolution, compass-oriented logs (Keys, 1990).

Magnetic-susceptibility (MAG) logs provide a record of the variations in magnetic minerals within the surrounding rock. Magnetite is the most common magnetic mineral, and local variations in its abundance may indicate lithologic contacts (McNeill and others, 1996).

Specific Conductance (SpC) logs measure the specific conductance of the fluid column as a function of depth and can provide information on the movement of ground water through the borehole and the location of zones that produce or accept water.

Table 1. Data from the 29 test boreholes drilled for the proposed water tunnels on Manhattan Island, N.Y., 2003-04.

Water tunnel route	Borehole name	New York State id number	Northing	Easting	Land surface elevation, in feet	Bottom depth of borehole, in feet	Casing length, in feet	Fracture index	Water level, in feet above mean sea level	Transmissivity, in ft²/d	Potential tunnel construction zone length, in feet
North	W65ST-A	NY 225	281716.658	597283.554	79.33	585	19	0.17	57.80		200
	W67ST-A	NY 222	281878.011	597989.997	82.95	571	76	1.00	66.00	25	-
Midtown	W30ST-A	NY 227	273304.645	593466.883	31.45	600	25	0.39	9.80	37	100
	E30ST-A	NY 224	271621.095	596528.218	38.54	606	43	0.16	-3.60	31	200
	E30ST-B	NY 226	270762.567	598095.449	37.93	595	45	0.50	-42.23	131	100
	E33ST-A	NY 223	271081.467	598810.272	22.66	550	34	0.43	-22.46	2.3	100
	E31ST-A	NY 233	271333.408	597590.801	30.29	554	61	-	-23.68	4.4	-
	E34ST-B	NY 198	271892.880	598246.469	31.15	635	36	-	-14.30	4.6	-
	E35ST-A	NY 180	271348.500	599798.175	10.50	448	14	-	-6.40	247	-
	E35ST-D	NY 207	271797.021	599144.856	19.51	600	25	0.56	-2.60	459	100
	E35ST-E	NY 235	271721.744	599123.203	18.76	35	-	-	4.20	-	-
	E35ST-F	NY 234	271713.522	599140.182	18.60	531	29	-	-3.10	316	-
	E39ST-A	NY 208	272692.000	599634.359	35.98	491	35	0.67	11.40	8.8	100
	E45ST-A	NY 209	274006.568	600409.451	57.47	490	10	0.64	19.90	53	100
	E48ST-A	NY 210	274654.454	600765.986	26.89	490	105	0.73	12.10	11	100
	E52ST-A	NY 211	275566.039	601273.636	38.17	490	25	0.60	22.70	74	100
	E54ST-A	NY 212	276056.902	601533.845	38.71	490	25	0.93	14.00	61	100
	E55ST-B	NY 183	276239.782	601490.749	42.60	545	18	0.92	11.10	14	100
South	Ericsson-A	NY 213	262527.769	589945.422	18.49	525	96	0.30	-0.50	19	100
	FranklinST-B	NY 228	261940.779	590460.187	11.40	555	86	0.12	-0.50	170	100
	FranklinST-A	NY 214	261335.429	591580.273	19.88	545	120	0.28	-0.20	387	100
	HesterST-A	NY 229	261905.972	592489.200	19.08	548	100	-	1.40	219	-
	GrandST-B	NY 216	262523.477	592450.949	25.61	547	112	0.35	1.20	42	100
	ElizabethST-A	NY 178	262480.535	593600.040	37.88	600	103	-	4.30	32	-
	CrosbyST-A	NY 232	263468.598	592865.089	33.47	578	125	-	2.40	341	-
	MulberryST-A	NY 231	263697.124	593494.496	42.07	570	115	-	3.60	12	-
	PrinceST-A	NY 192	263425.879	593804.286	46.87	665	120	0.92	4.30	90	200
	BondST-A	NY 202	264704.353	594177.800	47.37	604	92	0.34	4.80	3.3	100
	31B-1	NY 185	265173.292	594408.360	44.19	654	60	0.45	6.10	32	100



Figure 2. Locations of test boreholes along the proposed routes of the North and Midtown Water-Tunnels, Manhattan Island, N.Y.



Figure 3. Locations of test boreholes along the proposed route of the South Water-Tunnel, Manhattan Island, N.Y.

Table 2. Geophysical logs and data collected at North, Midtown, and South Water-Tunnel boreholes on Manhattan Island, N.Y., 2003-04.

Water tunnel route	Borehole name	New York State id number	Caliper	Gamma	SPR	R	Temperature	Fluid resistivity	SPC	pH	Redox	DO	ATV	OTV	Borehole radar	MAG	Deviation	Heat-pulse flowmeter	Northing of borehole bottom	Easting of borehole bottom	Maximum borehole tilt angle, in degrees
North	W65ST-A	NY 225	x	x	x	x	x	-	x	x	x	x	-	x	-	-	x	-	281749.258	597323.384	13
	W67ST-A	NY 222	x	-	-	-	x	-	x	x	x	x	-	x	-	-	x	-	281882.061	597989.687	2
Midtown	W30ST-A	NY 227	x	x	x	x	x	-	x	x	x	x	-	x	-	-	x	-	273298.215	593487.483	7
	E30ST-A	NY 224	x	x	x	x	x	-	x	x	x	x	-	x	x	-	x	-	271602.065	596567.248	10
	E30ST-B	NY 226	x	x	x	x	x	-	x	x	x	x	-	x	-	-	x	-	270723.017	598133.309	9
	E33ST-A	NY 223	x	x	x	x	x	-	x	x	x	x	-	x	-	-	x	-	271053.557	598825.652	6
	E31ST-A	NY 233	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	E34ST-B	NY 198	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	E35ST-A	NY 180	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	E35ST-D	NY 207	x	x	x	x	x	-	x	x	x	x	x	x	x	-	x	-	271794.581	599150.956	2
	E35ST-E	NY 235	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	E35ST-F	NY 234	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	E39ST-A	NY 208	x	x	x	x	x	-	x	x	x	x	x	x	-	-	x	-	272662.920	599658.009	8
	E45ST-A	NY 209	x	x	x	x	x	-	x	x	x	x	x	x	-	x	x	-	273983.528	600415.341	5
	E48ST-A	NY 210	x	x	x	x	x	-	x	x	x	x	x	x	x	-	x	-	274635.904	600769.136	6
	E52ST-A	NY 211	x	x	x	x	x	-	x	x	x	x	x	x	-	-	x	-	275537.909	601275.506	6
	E54ST-A	NY 212	x	x	x	x	x	-	x	x	x	x	x	x	-	-	x	-	276048.532	601543.745	3
	E55ST-B	NY 183	x	x	x	x	x	x	-	-	-	-	x	x	x	-	x	-	276257.712	601502.249	5
South	Ericsson-A	NY 213	x	x	x	x	x	-	x	x	x	x	x	x	-	-	x	-	262513.009	589959.002	5
	FranklinST-B	NY 228	x	x	x	x	x	-	x	x	x	x	-	x	-	-	x	-	261941.059	590478.647	3
	FranklinST-A	NY 214	x	x	x	x	x	-	x	x	x	x	-	x	-	-	x	-	261305.899	591562.693	7
	HesterST-A	NY 229	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	GrandST-B	NY 216	x	x	x	x	x	-	x	x	x	x	-	x	-	-	x	-	262507.697	592455.109	3
	ElizabethST-A	NY 178	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	CrosbyST-A	NY 232	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	MulberryST-A	NY 231	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	PrinceST-A	NY 192	x	x	x	x	x	x	-	-	-	-	x	x	x	-	x	x	263393.999	593808.556	3
	BondST-A	NY 202	x	x	x	x	x	-	x	x	x	x	-	x	-	-	x	-	264672.473	594195.120	9
	31B-1	NY 185	x	x	x	x	x	x	-	-	-	-	x	x	x	-	x	x	265147.432	594418.850	7

Dissolved Oxygen (DO) logs provide a qualitative measurement of the dissolved oxygen concentration of the fluid column as a function of depth and can indicate zones within the borehole that produce or accept water.

pH logs provide a qualitative measurement of the relative changes in the pH of the fluid column as a function of depth and can identify zones that produce or accept water.

Redox logs provide a qualitative measurement of the reduction-oxidation potential of the fluid in the borehole as a function of depth and can indicate zones within the borehole that produce or accept water.

Temperature logs measure the temperature of the fluid column as a function of depth and can provide information on the movement of ground water through the borehole and the location of zones that produce or accept water (Keys and MacCary, 1971; Keys, 1990).

Borehole fluid resistivity logs provide a record of the capacity of the fluid to conduct electricity and provide an indication of salinity (Keys, 1990).

Heat-pulse flowmeter logs measure vertical flow in boreholes and can indicate which fractures are producing or accepting water in a borehole under pumping and ambient conditions (Keys, 1990). Cross-borehole flowmeter tests can be used to identify connections between fractures (Paillet, 1998).

Acoustic televiewer (ATV) uses a rotating transducer that transmits and receives high-frequency acoustic pulses to produce an image of the intensity of acoustic energy reflection. The ATV provides high-resolution information on the location and strike and dip of fractures or faults within a borehole (Keys, 1990; Williams and Johnson, 2000; 2004).

Borehole-deviation logs provide information on the borehole's angle and direction of deviation from vertical. All deep boreholes deviate from vertical; therefore, deviation logs must be obtained before three-dimensional information on fractures and faults is interpreted (Keys, 1990). After processing, the resulting log indicates the true depth of the borehole, its distance from vertical, and the direction or azimuth of deviation.

Optical televiewer (OTV) digitally records a high-resolution optical scan of the borehole wall that can be used to produce a virtual core. The virtual core is oriented to allow for visualization of major faults and fractures as they are imaged within the borehole. Faults and fractures, both opened and sealed, can be viewed in three-dimensional orientations. This system also allows measurement of true strike-and-dip orientation and fracture spacing (Stumm and others, 2000; Williams and Johnson, 2000; 2004).

Borehole radar uses a single-hole, 60-MHz directional radar unit (transmitter/receiver) that can detect fracture zones and other structural features at distances as much as 90 ft from the borehole in electrically resistive rocks. The data logs can be used to calculate the orientation of fractures (Singha and others, 2000).

Geologic-Structure Analysis

Foliation, fractures, and faults penetrated in each borehole were delineated from the analysis of OTV and ATV geophysical log analysis. Fractures were classified as small, medium, large, or very large, depending on the apparent aperture or width of the opening. Measured fracture apertures in the boreholes were considered apparent to account for alterations caused by the drilling process. Small fractures or microfractures have apparent apertures of 0.04 in. (1 mm) or less; medium fractures have apertures of greater than 0.04 to 0.39 in. (greater than 1 to 10 mm); large fractures have apertures greater than 0.39 to 9.8 in. (greater than 10 mm to 25 cm); and very large fractures have apertures greater than 9.8 in. (greater than 25 cm). Borehole-radar analysis was used to (1) verify the assumption that most fractures extend beyond the borehole, (2) detect major fractures or faults as far as 90 ft from the borehole that may not intersect any borehole in the area and would otherwise have been missed, and (3) delineate the orientation (strike and dip) of these distant fractures or faults.

Orientations of each fracture in each borehole were calculated from the ATV and OTV data through standard computer programs. Deviation from vertical and magnetic declination of each borehole is included in the final true orientation calculation from apparent orientations. The final, true-corrected orientations of fractures and foliations are listed as dip azimuth and dip angle (dip). Orientations of all fractures are listed in the appendices.

The orientations were converted through standard stereonet projections as poles to planes, where dip azimuths have 180˚ added, and dip-plunge angles were subtracted from 90˚. Computer-generated stereonet contours were used to identify fracture or foliation populations and their mean orientations. The mean fracture or foliation orientation (strike and dip) is the average for the entire cluster of features plotted.

The potential tunnel-construction zone (PTCZ) is defined as a zone 100 ft above the bottom of a borehole. In three boreholes, conditions including poor visibility, thick sediment on borehole walls, and high borehole-tilt angles, did not provide sufficient data within the PTCZ, so an additional 100 ft was added to the PTCZ at boreholes E30ST-A, Prince ST-A, and W67ST-A. A partial collapse of the W67ST-A borehole prevented probes from logging deeper than about 125 ft BLS; therefore, this borehole is undersampled. High-angle large fractures above the PTCZ at each of the boreholes, if continuous, could intersect the PTCZ at a distance and therefore are considered to be critical features. For this reason, fracture analysis of the entire borehole is useful for detecting potential intersections with the tunnel away from the borehole. Fracture and foliation data within the PTCZ are useful only at the borehole location.

The tadpole plots of foliation and fractures are included with the geophysical logs for each borehole to illustrate the

variation in dip azimuth and dip with depth. Tadpoles are circles with "tails" plotted with respect to a horizontal scale to indicate the degree of dip-plunge angle of the structures from 0 to 90°. The tail of each tadpole points to the dip azimuth of the structure.

A fracture index is calculated for each borehole. The fracture index represents the total number of fractures detected in each borehole divided by the thickness of bedrock penetrated in feet; thus, a fracture index indicates the average number of fractures per foot of bedrock.

Faults

OTV logs were carefully examined for evidence of offset or past movement along a fracture. A fracture is classified as a fault if there is evidence of offset or past movement along it. However, all faults were plotted as fractures and factored in the fracture index and stereonet analysis for a given borehole.

Fractures

Fracture analysis identifies populations with similar dip azimuths and dip angles. Analysis of the variations in fracture orientations in each borehole and within the study area included tadpole and stereonet plots. A mean fracture orientation was included for the total borehole and the PTCZ, unless multiple fracture populations were detected. Gouge-zones are defined as highly altered or weathered rock zones indicative of either mechanical or chemical weathering or weakening of the bedrock. Gouge-zones are typically found in the OTV log data and analyzed as fractures in the particular borehole's fracture index and stereonet analysis.

Foliation

Foliation analyses, grouped by depth, indicate populations with similar dip azimuths and dip angles. Foliation in each borehole was measured using OTV data. Analysis of the variations in foliation orientations in each borehole and within the study area included tadpole and stereonet plots. A mean foliation orientation was included for the total borehole and the PTCZ. The appendix lists foliation depth, dip azimuth, and dip angle of all foliation measurement stations observed by OTV within the boreholes.

Ground-Water-Flow Analysis

Ground-water levels were measured at all boreholes during field visits from April 1999 through March 2004. Fluid-temperature and fluid-specific conductance logs were collected at 20 boreholes during ambient conditions. Flowmeter logs were collected at boreholes 31B-1 and PrinceST-A during ambient and pumping conditions. Measurements of the drawdown, pumping rate, and total pumping time at 28 boreholes during test pumping were applied to a computer program (Bradbury and Rothschild, 1985) to calculate specific capacity and transmissivity of the entire borehole.

A new geophysical tool herein called the "fluid parameter log" included fluid-temperature, fluid specific conductance (SpC), DO, pH, and redox logs, which were used to help delineate transmissive fractures within the boreholes. The conventional fluid temperature and resistivity logs do not always provide information on transmissive fracture locations. Abnormal temperature gradients can be caused by ground-water flow into or out of fractures intersected by the boreholes (Keys, 1990; Williams and Conger, 1990). Changes in water quality also may occur at transmissive fractures and by expanding the measurement parameters, changes in SpC, pH, DO and redox can be detected and more transmissive fractures can be delineated.

Transmissivity

Calculated transmissivity values for the boreholes ranged from 2 to 459 ft^2/d. The transmissive fracture network is a discrete system that is not correlated specifically with the fracture index. Several fractures are highly transmissive and could produce appreciable quantities of ground-water flow into the tunnel during construction.

The flowmeter logs were analyzed through techniques of Paillet (1998, 2000), whereby differences between flow values at adjacent fracture zones within each borehole were attributed to measurement scatter and a possible net difference in borehole flow. Therefore, flow-log interpretation involves identification of the relative amounts of inflow or outflow occurring at specific depth intervals. Inflow or outflow at several depth intervals at each borehole is measured; each of these intervals coincides with a fracture, or sets of fractures. In accordance with the techniques of Molz and others (1989) and Paillet (2000), the effects of hydraulic-head differences between zones can be eliminated by analyzing flow under ambient and pumping conditions.

Ground-Water Levels

Ground-water levels were measured during borehole geophysical logging, water-level synoptics, and specific-capacity tests. Water level synoptics of all boreholes were conducted quarterly between September 2003 and April 2004.

DELINEATION OF FAULTS, FRACTURES, FOLIATION, AND GROUND-WATER-FLOW ZONES

Faults, fractures, and foliation were interpreted from OTV, ATV, borehole-radar, gamma, SPR, R, MAG and caliper logs, which are reproduced in the individual borehole summaries that follow. Typically, the gamma log response did not show many changes and is uniform throughout the boreholes. Anomalies in the gamma log correlating to fractures or lithologic changes are mentioned in the borehole geophysical log description. SPR and R log responses are variable with depth and correlated to either fracture density or slight lithologic or mineralogic changes in the bedrock. The hydraulic characteristics of the bedrock at each borehole are described in the summaries. OTV analysis (borehole depth, fracture orientation, and foliation orientation) for all fractures and faults in 20 boreholes are listed in the appendices. The remaining nine boreholes had specific capacity test and ground-water level data collected.

The ATV, OTV, and borehole-radar analysis indicate that all boreholes penetrate moderately fractured rock that contains highly fractured zones. Every borehole contains medium and (or) large open fractures that are transmissive. Structural trends of these geologic units and borehole radar logs indicate that most fractures and faults detected in each borehole may extend beyond each borehole. The gamma, SPR, R, fluid-temperature, fluid resistivity, specific conductance, DO, pH, and redox logs detected some of the fracture zones.

Total borehole-foliation dip azimuths were westward to northwestward, and dip angles range from nearly vertical (89˚ at FranklinST-B and W65ST-A) to nearly horizontal at W54ST-A and W55ST-B. The nearly vertical foliation at W65ST-A and FranklinST-B produced population clusters in stereonet plots with a southeastward dip. In general, the highest dip angles were found along the proposed route of the South Water-Tunnel. A gradual decrease in dip angles from westward to eastward and from southward to northward is detected in the Midtown Water-Tunnel area along the proposed route. In the vicinity of the proposed North Water-Tunnel foliation dip angles are about 75˚. Foliation dip azimuths along the proposed South Water-Tunnel varied from northwest to west and dip angles ranged from nearly 89˚ to 57˚.

No general correlation between fracture orientation and depth is evident in the study area. Total borehole fracture-population orientations are (1) nearly horizontal, and (2) moderate- to high-angle dip with a west-to-northwest dip azimuth. Dipole fracture populations were detected in eleven boreholes (W67ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B, PrinceST-A, BondSt-A, and 31B-1). Fractures along the proposed route of the North tunnel were dominated by sub-horizontal orientations. Mean fracture dip angles along the proposed paths of the South and Midtown Water-Tunnels have dips ranging from 4˚ to 43˚. Many fractures were detected throughout the study area with dip angles in excess of 70˚. Fracture depth, dip azimuth, and dip angle of all fractures observed by OTV within the boreholes are listed in the appendices. Analysis of the 60-MHz directional radar at six boreholes indicated strong radar reflectors that are probably fractures that, if transmissive, could produce appreciable quantities of ground-water to flow into the tunnel. Faults were detected in twelve of the twenty geophysically logged boreholes.

Water levels in the fractured bedrock are highest in the north-central part of the study area (58 and 66 ft elevation along the North Water-Tunnel route), and lowest in the southern and coastal areas. Analysis of the distribution of hydraulic head in Manhattan indicate the fractured-rock ground-water flow system is a continuum of interconnected, transmissive fractures, with areas of recharge (highest head) in the north-central part of the study area, and areas of discharge (lowest head) along the coastline and southern end. These water levels represent the transmissivity weighted average of the hydraulic heads in all transmissive fractures in each borehole. The lowest water levels (-23 ft elevation) are in boreholes along the proposed Midtown Water-Tunnel on the east side of the island. This area consists of a large cone of depression or series of depressions due to the pumping of shallow railway tunnels. In general, a ground-water divide follows the central spine of southern Manhattan Island.

The borehole summaries that follow 1) interpret results of the fault-, fracture-, and foliation-data analysis and describe the ground-water-flow zones for the North, Midtown, and South Water-Tunnel boreholes; 2) present stereonet plots of total borehole and PTCZ fractures and foliation; and 3) present gamma, SPR, EM, MAG, and caliper logs with tadpole plots of the foliation and fractures from OTV analysis for each borehole.

North Water-Tunnel

The two North Water-Tunnel boreholes are W65ST-A and W67ST-A (fig. 2, table 1). A partial collapse at 175 ft below land surface (BLS) at W67ST-A and the premature destruction of W65ST-A limited the information obtained from these boreholes. Appendix 1 lists depth, dip azimuth and dip angle of fractures and foliation (and fracture size) observed by optical televiewer in North Water-Tunnel boreholes.

W65ST-A

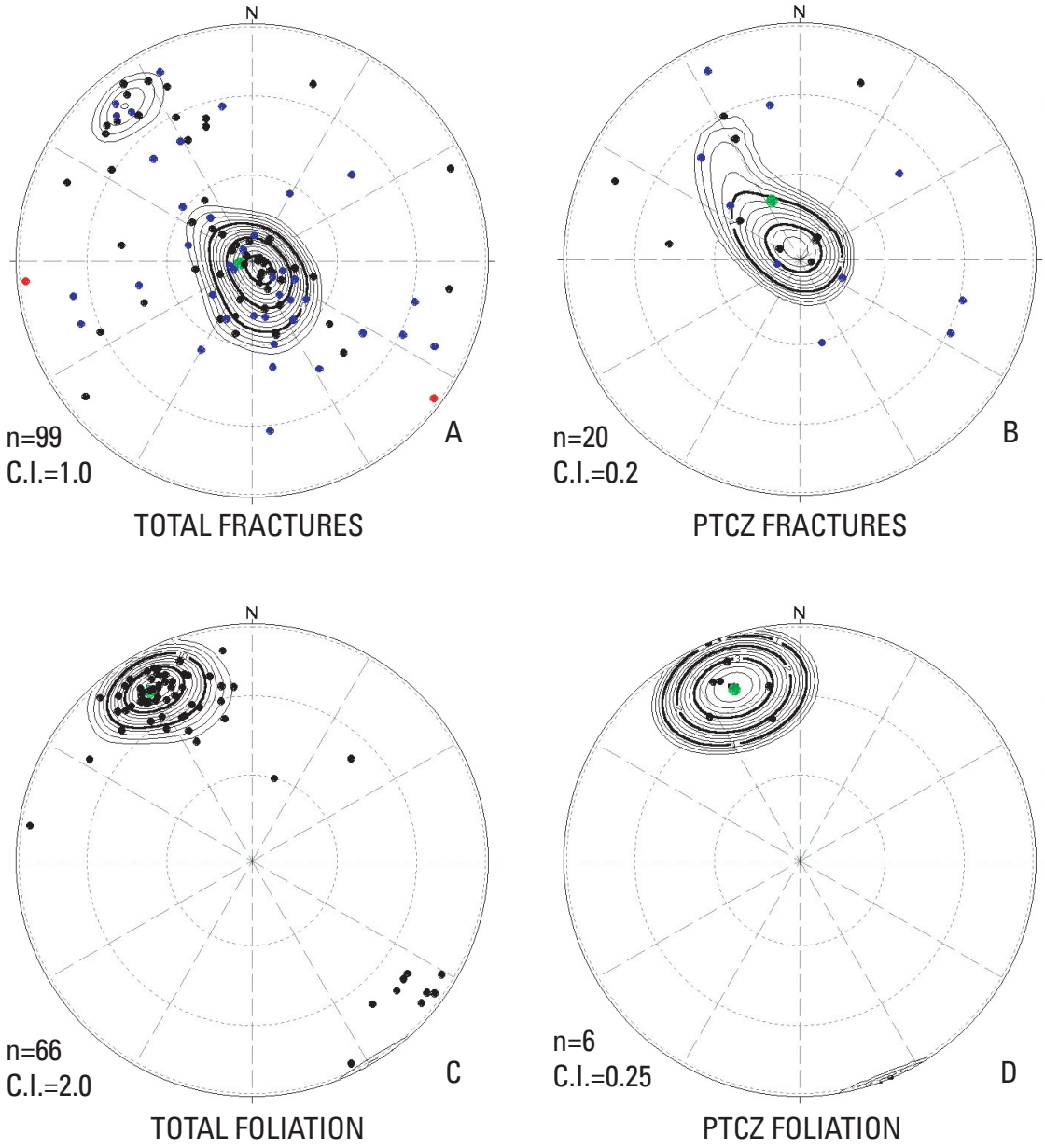
Borehole W65ST-A is the second of two boreholes drilled for the North Water-Tunnel. The borehole is drilled to a depth of 585 ft BLS (-506 ft elevation) with 18.5 ft of casing. The borehole was cemented over before a specific-capacity test could be completed.

Fractures and Foliation

OTV analysis indicated a total of 99 fractures throughout the borehole, with a fracture index of 0.17 fracture per foot of borehole. The mean orientation for the 99 fractures is N08˚E 04˚E or roughly sub-horizontal (fig. 4). Most fractures were predominantly small and medium with only two large fractures at 262 and 350 ft BLS. The proposed tunnel construction zone (PTCZ) is extended upward an additional 100 ft due to poor borehole conditions at depth. The 20 fractures in the modified PTCZ have a mean orientation of N64˚E 23˚SE. Mean foliation orientations for the total borehole and PTCZ were N59˚E 74˚SE and N69˚E 68˚SE, respectively (fig. 4). Tadpole plots of the foliation indicate the upper 175 ft has northwest-dipping foliation although the rest of the borehole is southeast-dipping (fig. 5). Poor borehole optical conditions and a high angle of borehole tilt prevented foliation from being measured below 425 ft BLS. Deviation log analysis indicated the bottom of the borehole is 52 ft from the origin, at an azimuth of 52º (table 2).

Ground-Water-Flow Zones

The hydraulic head in W65ST-A was 57.8 ft above sea level and did not appear to be tidally affected. The fluid-parameter logs had several areas of deflections or changes in slope (fig. 5). The temperature log indicated a decrease in ground-water temperature with depth, with no large changes in slope. The specific conductance, pH, and redox logs indicated changes at 350 and 430 ft BLS, which correlated to large and medium fractures. However, residual drilling fluid at depth may have caused the increases seen in the SpC log. The DO log had changes at 175-225, 260, 350, 420, and 475 ft BLS (fig. 5). No specific-capacity value was calculated due to the premature destruction of the borehole.



EXPLANATION

- SMALL FRACTURES (1 millimeter or less)
- MEDIUM FRACTURES (>1 millimeter to 10 millimeters)
- LARGE AND VERY LARGE FRACTURES (>10 millimeters)
- STATISTICAL MEAN ORIENTATION

PTCZ POTENTIAL TUNNEL CONSTRUCTION ZONE

C.I. CONTOUR INTERVAL (point density contouring)

Figure 4. Stereonet plots of borehole W65ST-A, Manhattan Island, N.Y., 2003-04: A. Total fractures. B. PTCZ fractures. C. Total foliation. D. PTCZ foliation. (Borehole location is shown in figure 2.)

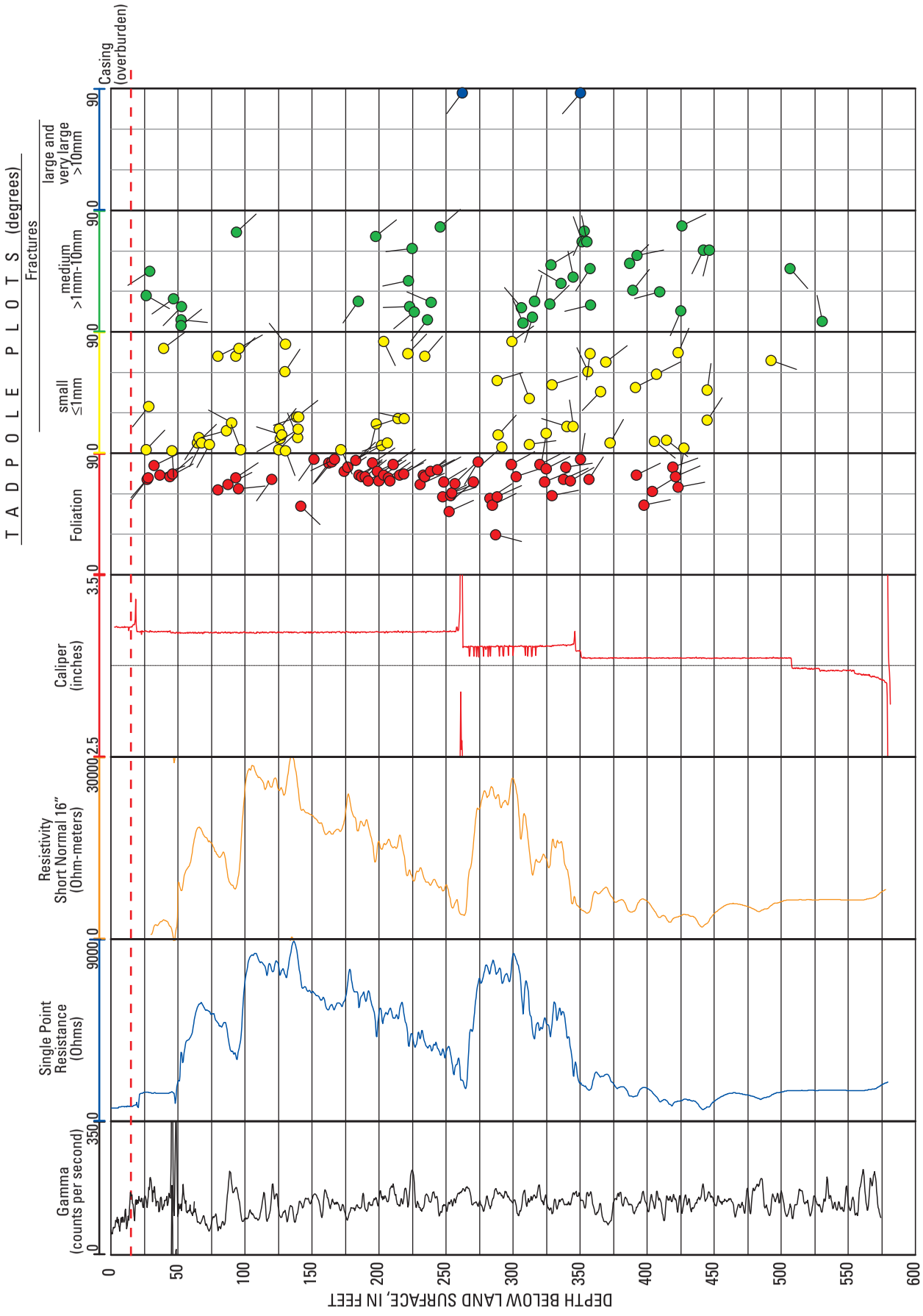


Figure 5A. Suite of borehole-geophysical logs from borehole W65ST-A, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 2.)

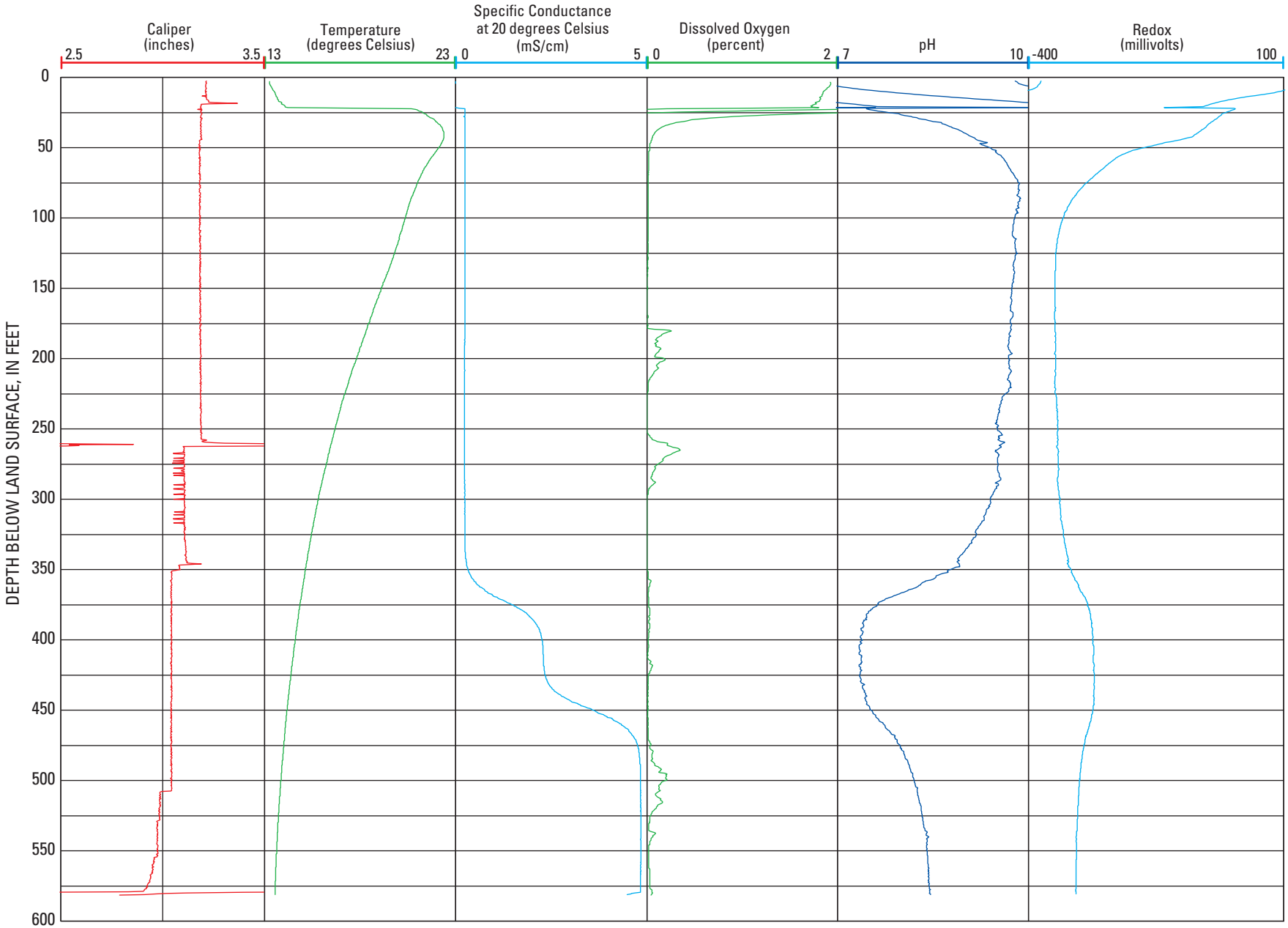


Figure 5B. Suite of borehole-geophysical logs from borehole W65ST-A, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 2.)

W67ST-A

Borehole W67ST-A, the northernmost borehole that was geophysically logged (fig. 2), is drilled to a depth of 571 ft BLS (-488 ft elevation), with steel casing extending from land surface (82.95 ft elevation) to 76 ft BLS (6.95 ft elevation) in the unconsolidated deposits to the top of bedrock.

Fractures and Foliation

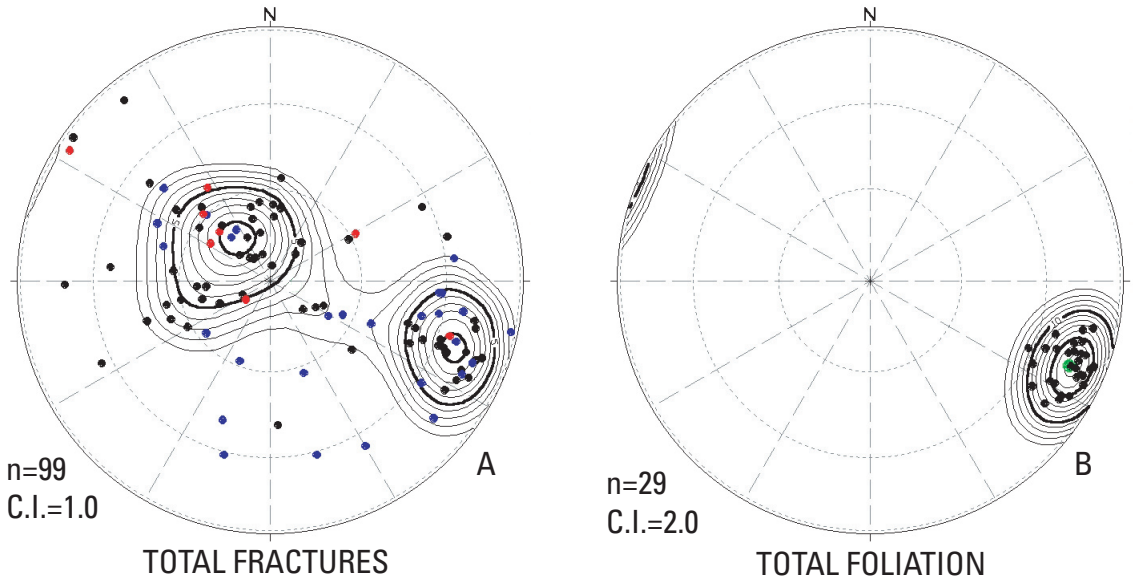
A partial collapse of the W67ST-A borehole within bedrock restricted the depth of investigation to 175 ft BLS. As a result, fracture, foliation, and fluid-parameter logs were not collected below the collapsed zone, and this borehole is therefore considered undersampled.

Analysis of the OTV data indicated 99 fractures from below the casing to the collapsed zone at 175 ft BLS. The borehole has a fracture index of 1.00 fracture per foot of borehole. Two fracture population clusters were indicated (fig. 6) —one is nearly horizontal and dipping slightly to the east (majority cluster); the second dips northwestward (minority cluster). One fault is detected at 125.4 ft BLS with an orientation of N51˚E 82˚SE. The collapsed zone below 175 ft BLS is dominated by very large open fractures. The orientation of mean foliation for the entire borehole is N23˚E 75˚NW (fig. 6). The deviation log indicated the bottom of the borehole is 4 ft from the origin, with an azimuth of 355º (table 2).

Ground-Water-Flow Zones

Hydraulic head in W67ST-A was 66 ft above sea level and is the highest water level measured at any of the boreholes. This borehole is in the central part of Manhattan Island, which is a recharge area for the fractured-rock ground-water-flow system. The partially collapsed borehole conditions hampered calculation of the transmissivity of individual fractures.

The fluid-parameter logs (temperature, specific conductance, DO, pH, and redox) indicate possible transmissive fractures at the casing-bedrock interface between 70-80 ft BLS (fig. 7). A specific-capacity test indicated a specific capacity of 0.1 (gal/min)/ft. Total borehole transmissivity is calculated to be 25 ft^2/d.



EXPLANATION

- SMALL FRACTURES (1 millimeter or less)
- MEDIUM FRACTURES (>1 millimeter to 10 millimeters)
- LARGE AND VERY LARGE FRACTURES (>10 millimeters)
- STATISTICAL MEAN ORIENTATION

C.I. CONTOUR INTERVAL (point density contouring)

Figure 6. Stereonet plots of borehole W67ST-A, Manhattan Island, N.Y., 2003-04: A. Total fractures. B. Total foliation. (Borehole location is shown in figure 2.)

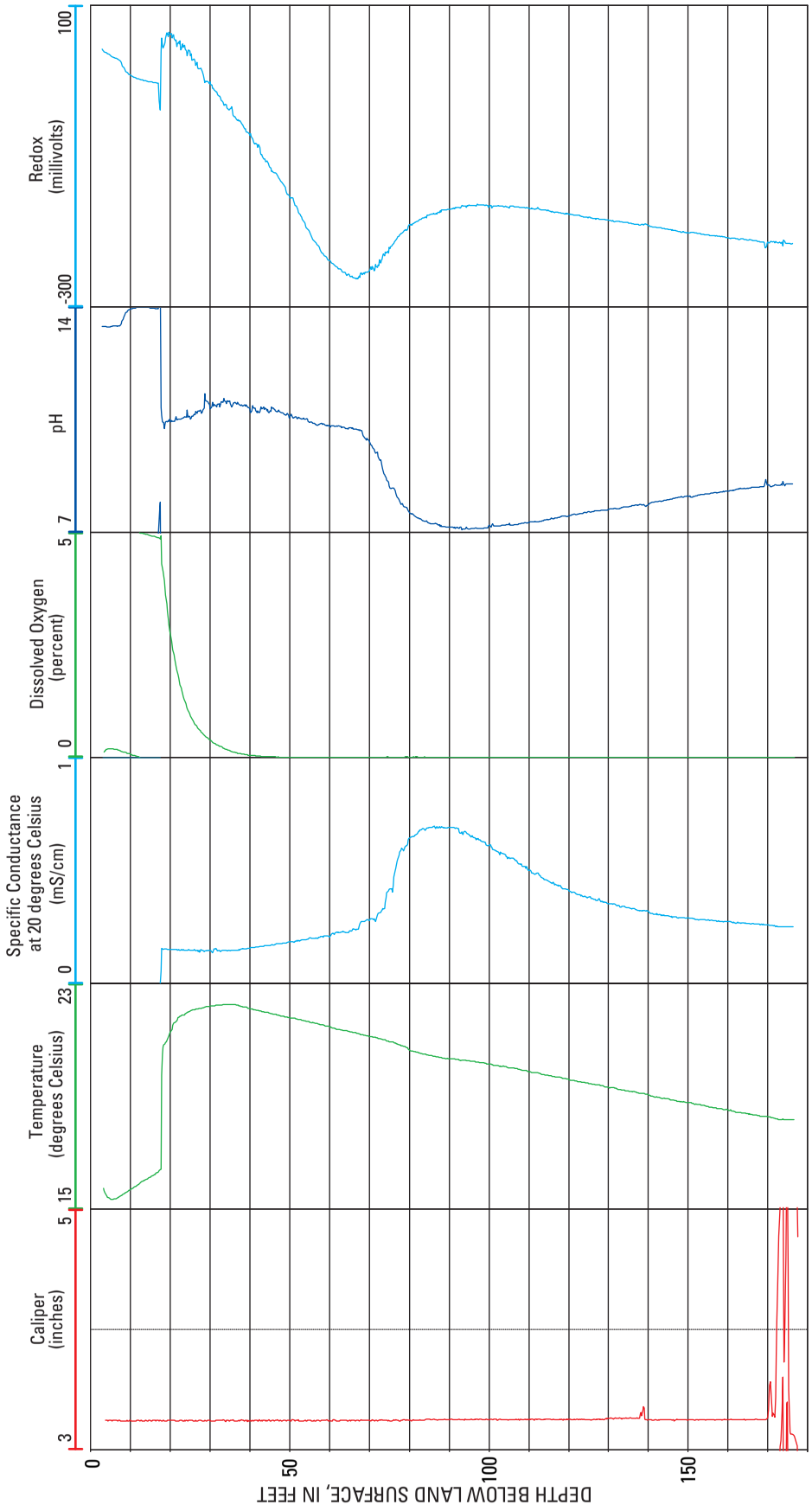


Figure 7. Suite of borehole-geophysical logs from borehole W67ST-A, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in fig. 2.)

Midtown Water-Tunnel

The Midtown Water-Tunnel boreholes included W30ST-A, E30ST-A, E30ST-B, E33ST-A, E31ST-A, E34ST-B, E35ST-A, E35ST-D, E35ST-E, E35ST-F, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, and E55ST-B (fig. 2, table 1). Appendix 2 lists depth, dip azimuth and dip angle of fractures and foliation (and fracture size) observed by optical televiewer in Midtown Water-Tunnel boreholes.

W30ST-A

The W30ST-A borehole has 25 ft of casing and extends 600 ft BLS (-569 ft elevation). The borehole is uncased in fractured bedrock.

Fractures and foliation

A total of 229 fractures were detected by analysis of the OTV. The borehole has a fracture index of 0.39 fractures per foot of borehole. The borehole is dominated by sub-horizontal fractures and westward-dipping fractures (fig. 8); one reverse fault is detected at 160.9 ft BLS with an orientation of N48ºW 68ºNE. The majority of the fractures were penetrated in the upper 200 ft of the borehole. PTCZ mean fracture orientation is N28ºE 13ºNW with sub-horizontal and northwest-dipping fracture population clusters (fig. 8). Total borehole mean foliation orientation is N07ºW 58ºW. PTCZ mean foliation orientation is N05ºE 52ºNW. The deviation log indicated the bottom of the W30ST-A borehole is 21 ft east from the origin, at an azimuth of 108º (table 2).

Ground-Water-Flow Zones

Hydraulic head in W30ST-A was 9.8 ft above sea level. Typical fluid parameter logs (temperature and specific conductance) did not indicate potentially transmissive fracture zones (fig. 9) however, the DO, pH, and redox logs indicated several zones of possible transmissive fractures at 90, 270-280, and 520-530 ft BLS (fig. 9). A specific-capacity test of the borehole indicated a specific capacity of 0.14 (gal/min)/ft and a total borehole transmissivity of 37 ft^2/d.

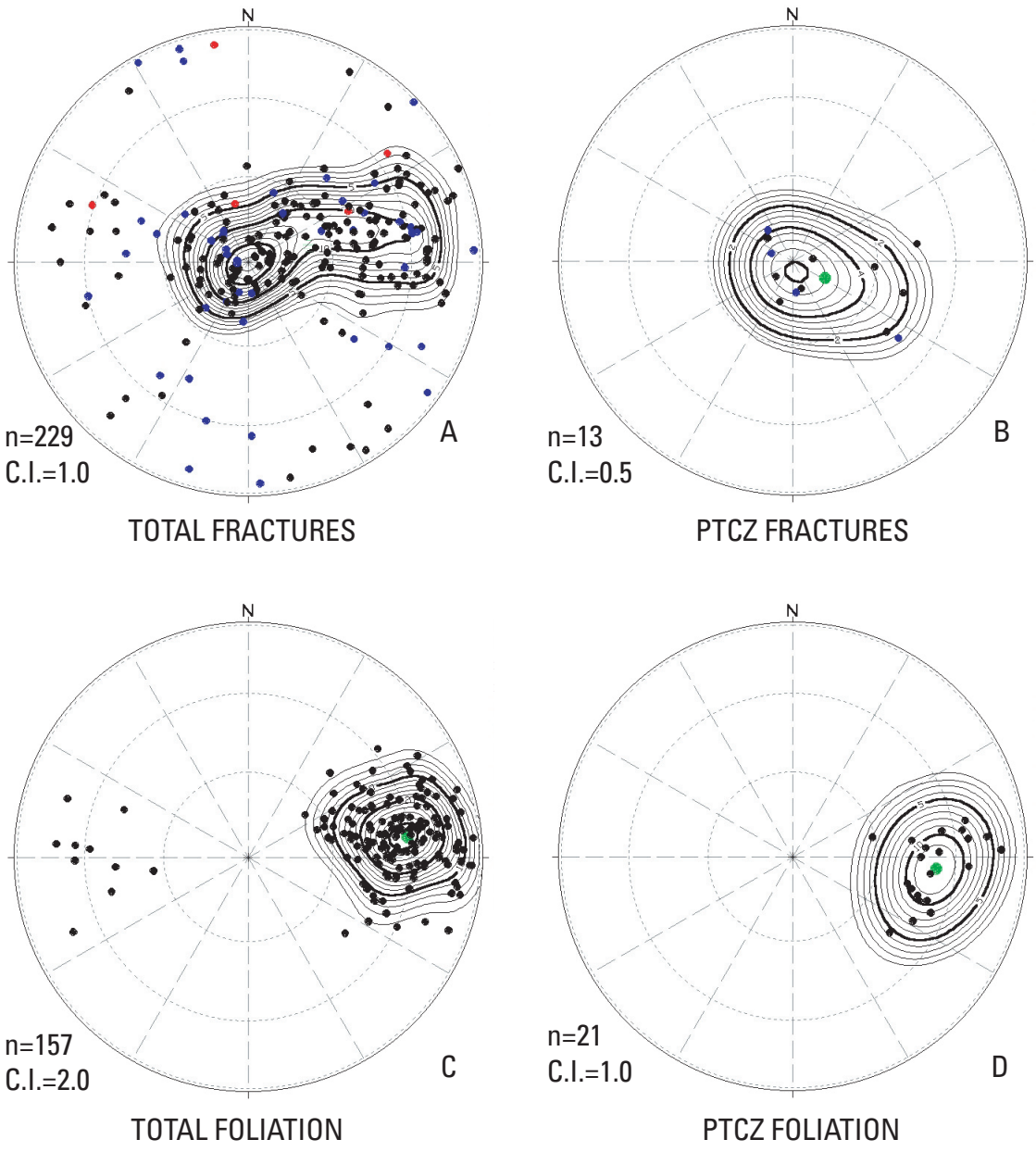


Figure 8. Stereonet plots of borehole W30ST-A, Manhattan Island, N.Y., 2003-04: A. Total fractures. B. PTCZ fractures. C. Total foliation. D. PTCZ foliation. (Borehole location is shown in figure 2.)

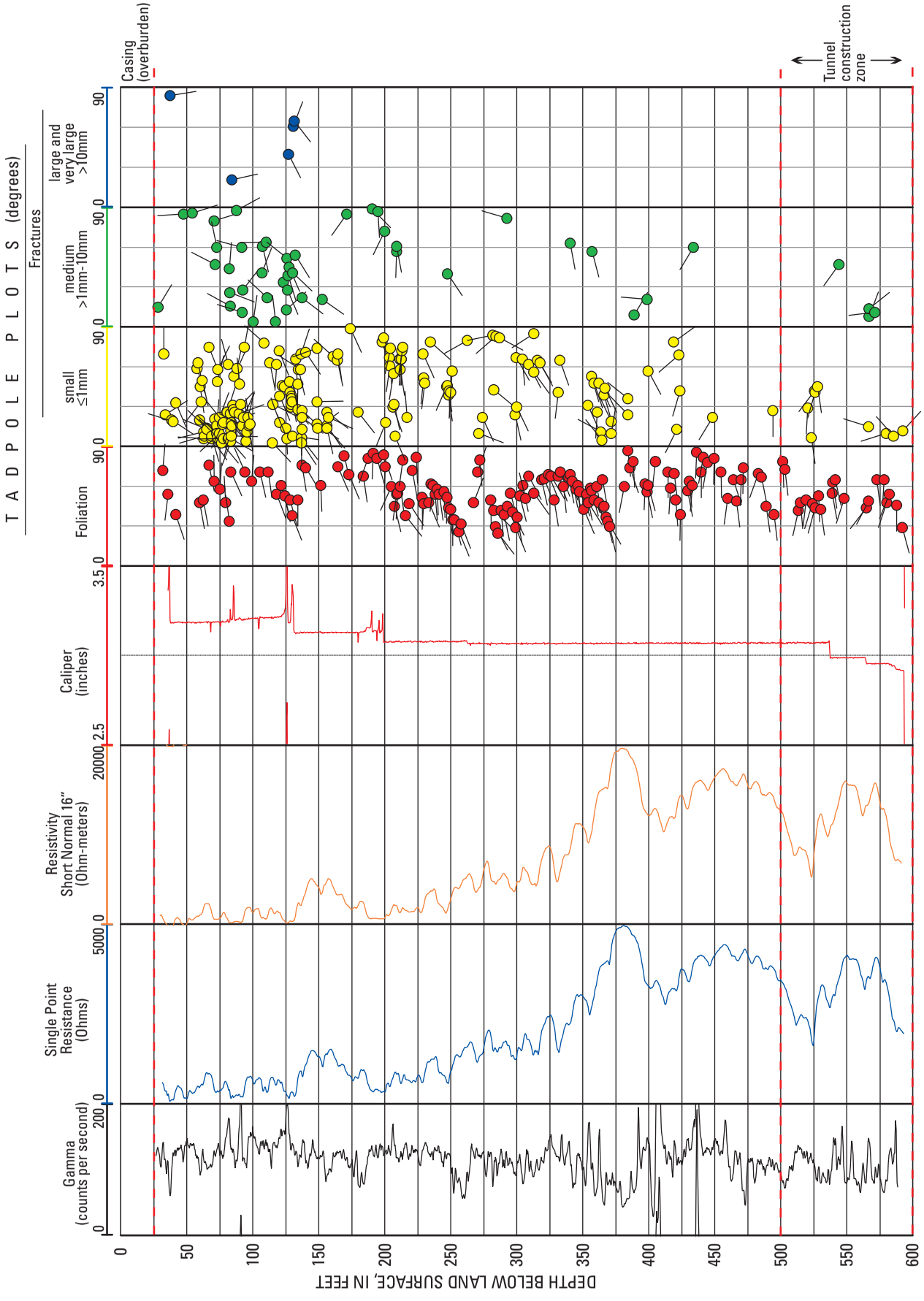


Figure 9A. Suite of borehole-geophysical logs from borehole W30ST-A, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 2.)

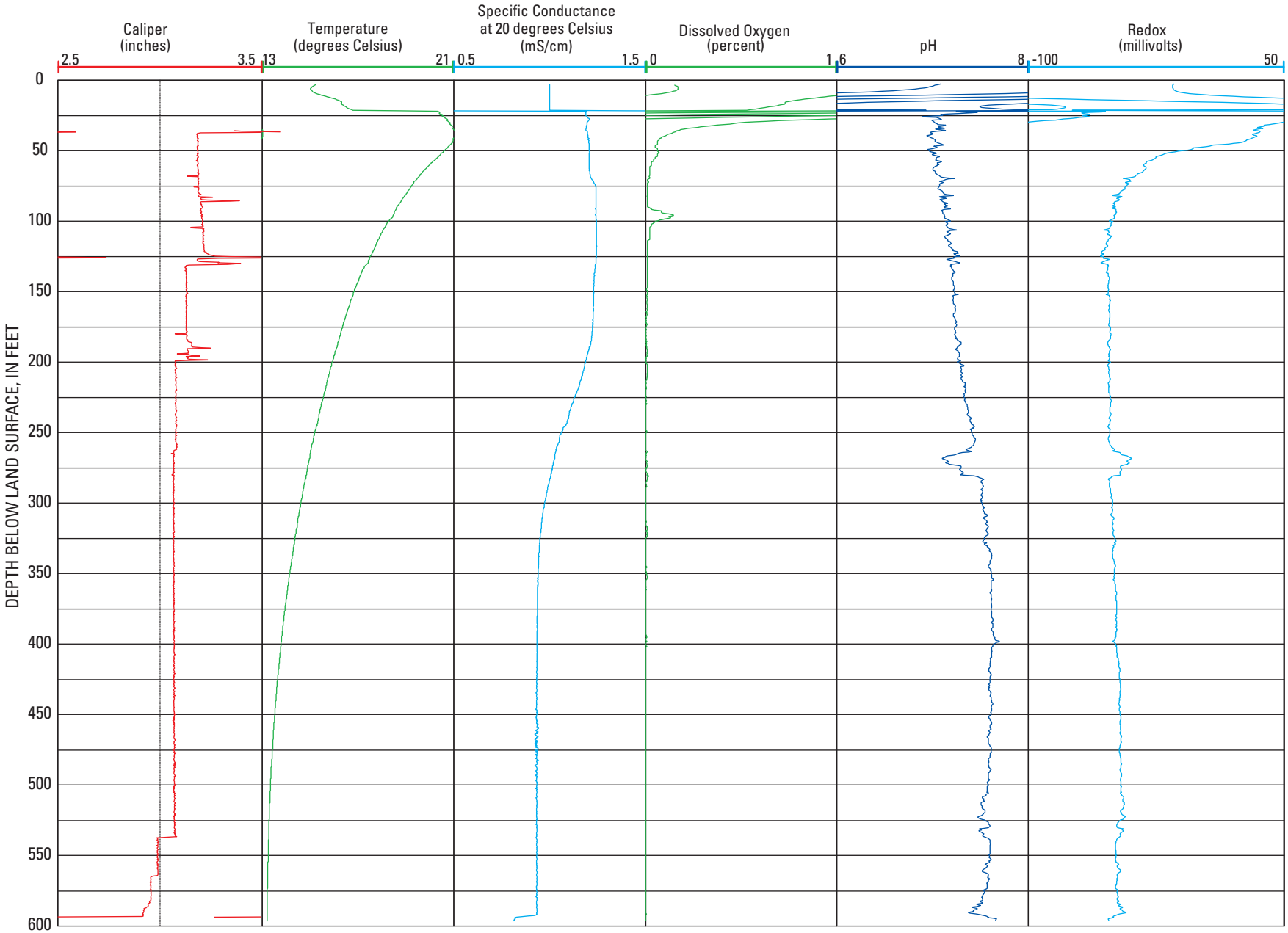


Figure 9B. Suite of borehole-geophysical logs from borehole W30ST-A, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 2.)

E30ST-A

The E30ST-A borehole has 43 ft of casing and extends 606 ft BLS (-567.5 ft elevation). The borehole is uncased in fractured bedrock.

Fractures and foliation

OTV analysis indicated a total of 90 fractures with a fracture index of 0.16. Total borehole mean fracture orientation is N01ºE 05ºW with most fractures sub-horizontal (fig. 10). The PTCZ is extended an additional 100 ft upward to provide enough fractures for analysis due to poor borehole conditions below 525 ft BLS. The PTCZ mean fracture orientation is N52ºE 43ºNW. Total borehole and PTCZ mean foliation orientation is N31ºE 70ºNW and N30ºE 73ºNW, respectively (fig. 10).

Borehole radar imaged six potentially large fractures from 528 to 605 ft BLS within the PCTZ. These reflectors had orientations of N50ºW 73ºNE, N01ºW 69ºE, N20ºW 66ºNE, N80ºE 65ºNW, N40ºE 73ºSE, and N80ºE 57ºNW, at 528, 533, 558, 592, 604, and 605 ft BLS, respectively. Two potentially large fractures were imaged by the borehole radar that would have intersected the borehole had it been drilled deeper. The reflectors had orientations of N10ºW 61ºW and N50ºW 75ºSW.

SPR and R logs detected many of the medium and large fractures as low-resistivity zones (fig. 11). No medium or large fractures were detected below 200 ft BLS. However, due to poor borehole conditions near the bottom fractures, if medium or large fractures were present, they may not have been detected by the OTV. The deviation log indicated the bottom of the E30ST-A borehole is 43 ft from the origin, at an azimuth of 180º.

Ground-Water-Flow Zones

Fluid-temperature and SpC logs detected possible transmissive fractures at 43, 60, and 100 ft BLS (fig.11). The DO, pH, and redox logs detected these zones at higher resolution and detected additional possible transmissive fractures at 175, 185, 475, 530 and 560 ft BLS (fig. 11). The hydraulic head at the borehole had a mean of -3.6 ft elevation, the borehole is within a large cone of depression due to dewatering of shallow railway tunnels. A specific-capacity test of the borehole indicated a total borehole specific capacity of 0.12 (gal/min)/ft and a transmissivity of 31 ft^2/d.

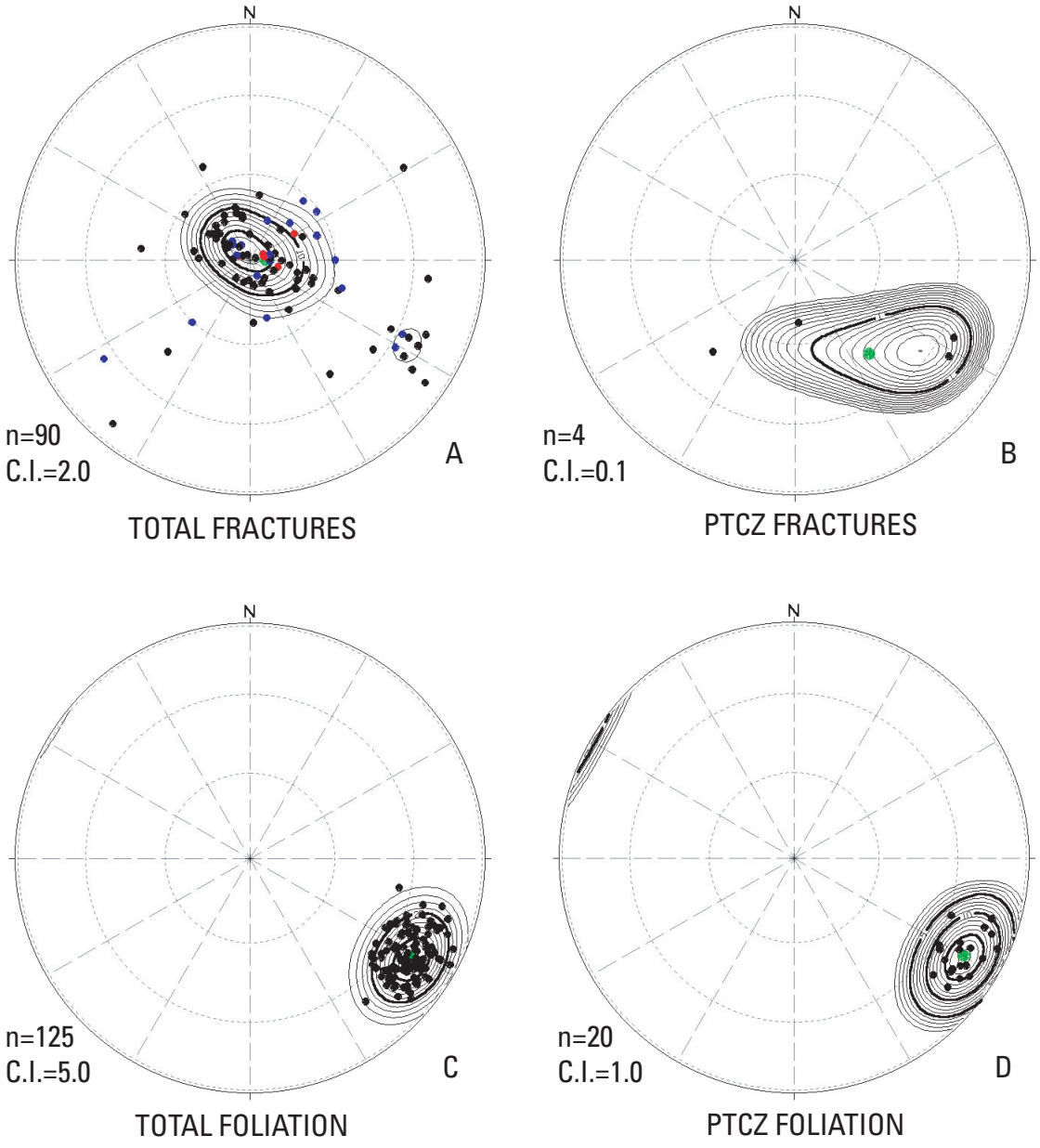


Figure 10. Stereonet plots of borehole E30ST-A, Manhattan Island, N.Y., 2003-04: A. Total fractures. B. PTCZ fractures. C. Total foliation. D. PTCZ foliation. (Borehole location is shown in figure 2.)

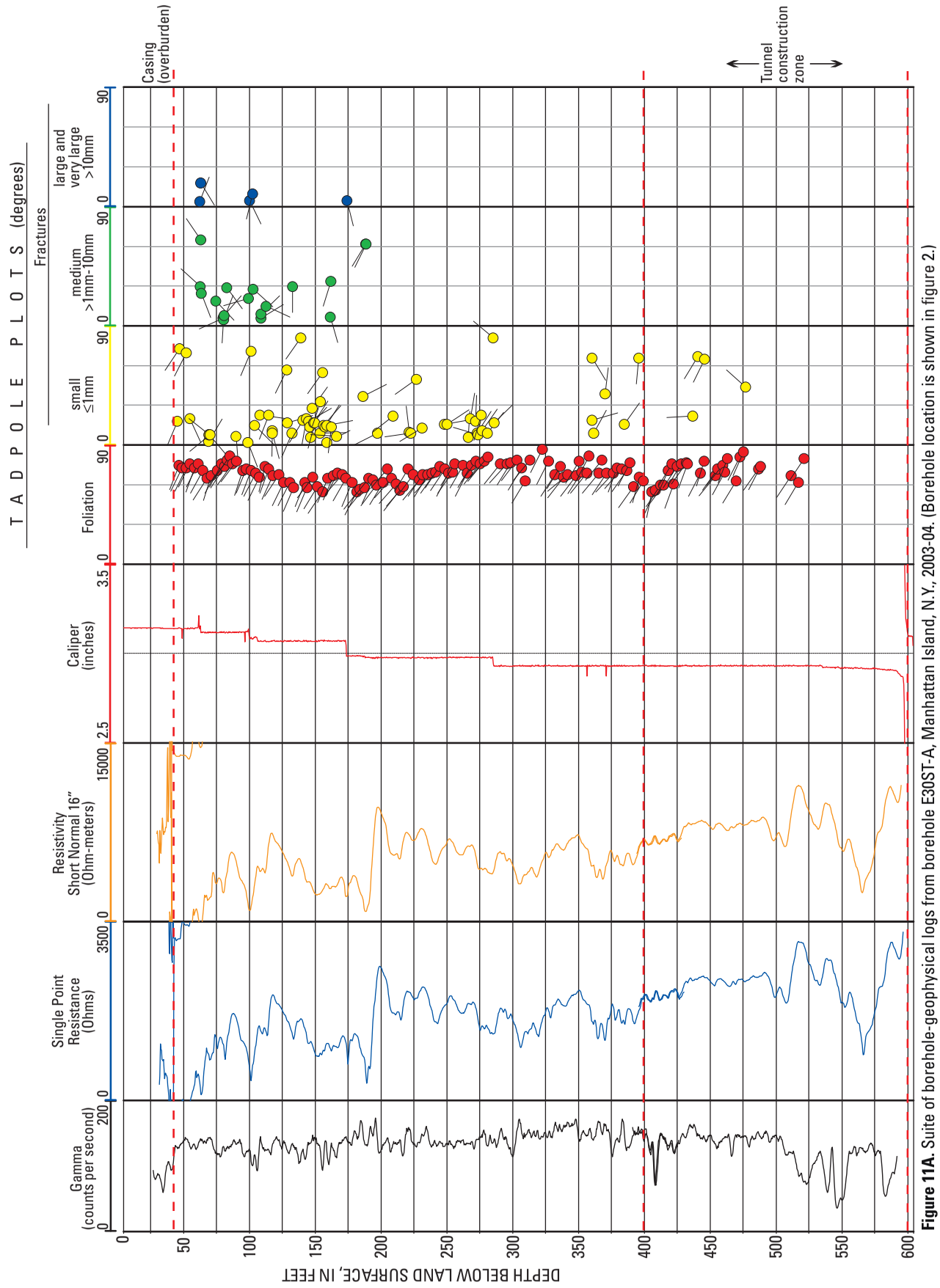


Figure 11A. Suite of borehole-geophysical logs from borehole E30ST-A, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 2.)

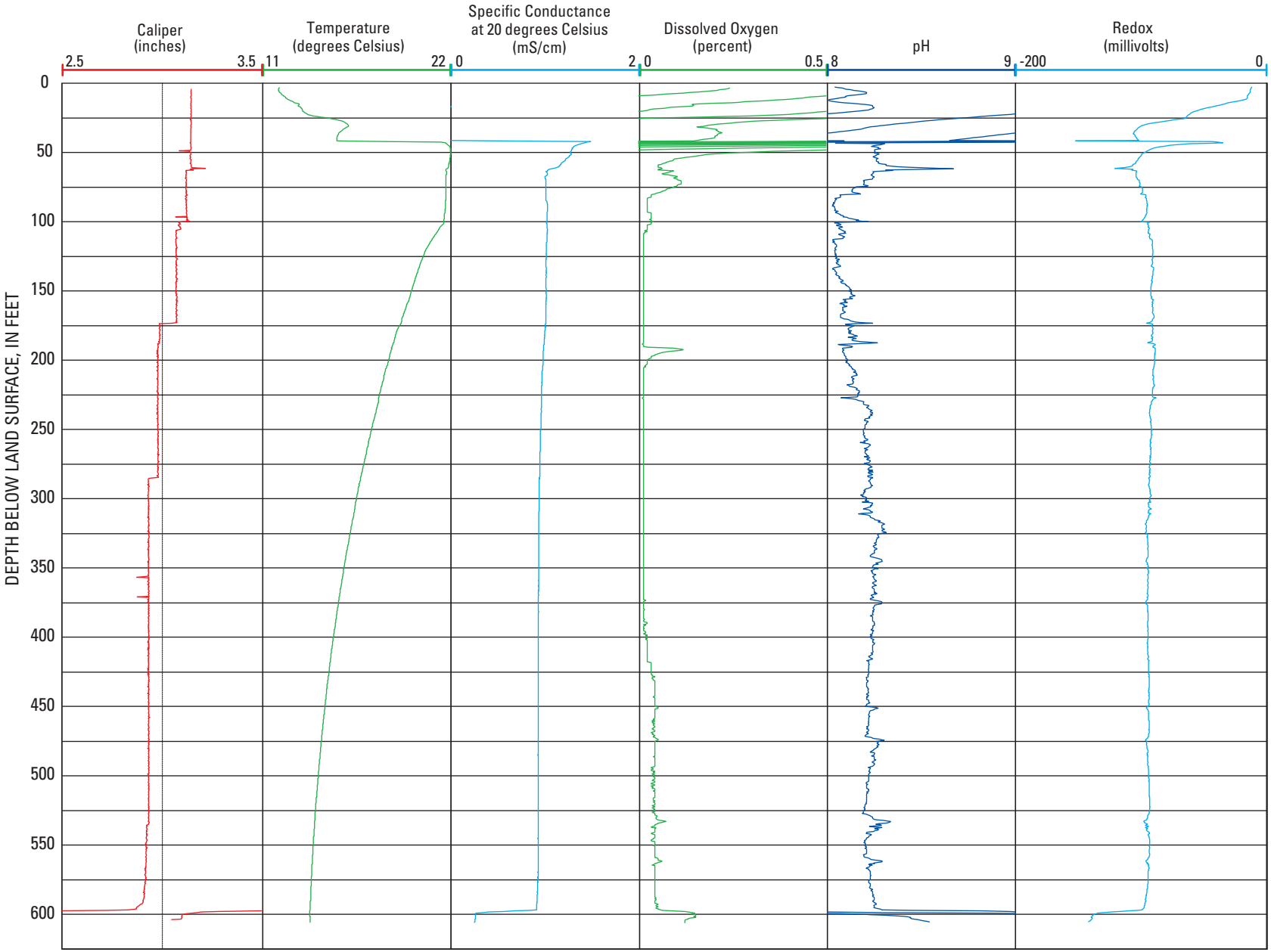


Figure 11B. Suite of borehole-geophysical logs from borehole E30ST-A, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 2.)

E30ST-B

The E30ST-B borehole extends 595 ft BLS (-557.1 ft elevation) and has 45 ft of casing. The borehole is uncased in fractured bedrock.

Fractures and foliation

The OTV log detected 280 fractures which were dominated by small and medium fractures. One very large fracture is detected at 471 ft BLS with an orientation of N25ºE 65ºNW. The borehole penetrated three faults at 86.6, 133.4, and 328.6 ft BLS. The fracture index is 0.50. Total borehole and PTCZ mean fracture orientation were N23ºE 39ºNW and N13ºE 48ºNW, respectively (fig. 12). Total borehole and PTCZ mean foliation orientation were N35ºE 41ºNW and N13ºE 37ºNW, respectively (fig. 12).

Deviation log analysis indicated the bottom of the E30ST-B borehole is 55 ft from the origin with an azimuth of 136º. SPR and R logs show variations that reflect slight lithologic changes at large and medium fractures.

Ground-Water-Flow Zones

The fluid temperature log detected possible transmissive fractures at 55, 60, 80, 115 and 120 ft BLS (fig. 13). Due to dewatering in the area three fractures (55, 60, and 80 ft BLS) above the water level were found to be transmissive with evidence of ground-water flowing from them at the time of logging, in the OTV and fluid parameter logs. The SpC, pH, and redox logs also indicated changes at higher resolution at these depths (55, 60, and 80 ft BLS) and indicated other possible transmissive fractures at 215, 235, and 310 ft BLS (fig. 13). The hydraulic head in E30ST-B was -42.23 ft elevation. This is the lowest water level of any borehole measured in southern Manhattan. This borehole is within a large cone of depression created by dewatering for shallow railway tunnels nearby. Specific-capacity test analysis indicated the borehole has a specific capacity of 0.46 (gal/min)/ft and transmissivity of 131 ft^2/d.

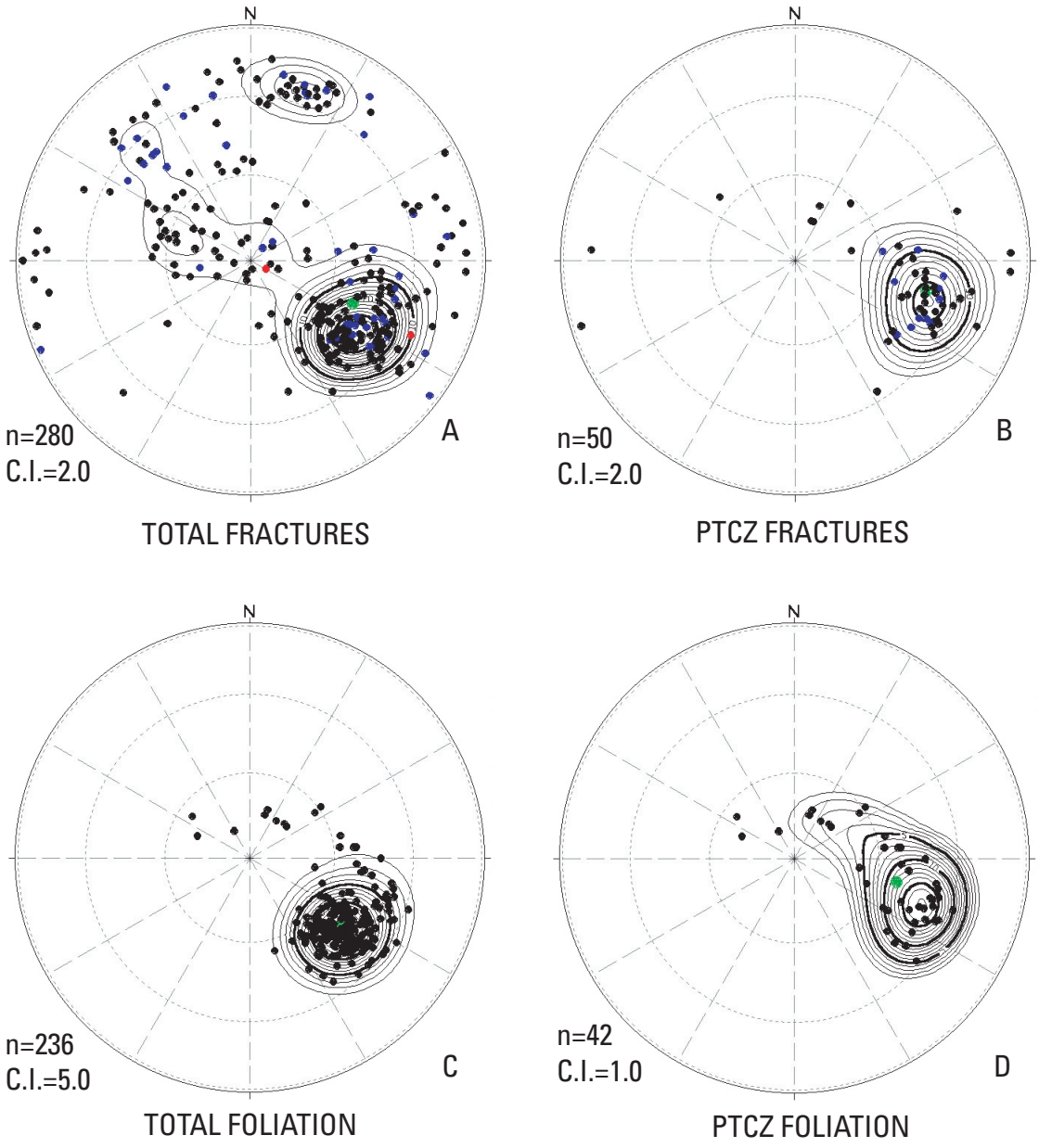


Figure 12. Stereonet plots of borehole E30ST-B, Manhattan Island, N.Y., 2003-04: A. Total fractures. B. PTCZ fractures. C. Total foliation. D. PTCZ foliation. (Borehole location is shown in figure 2.)

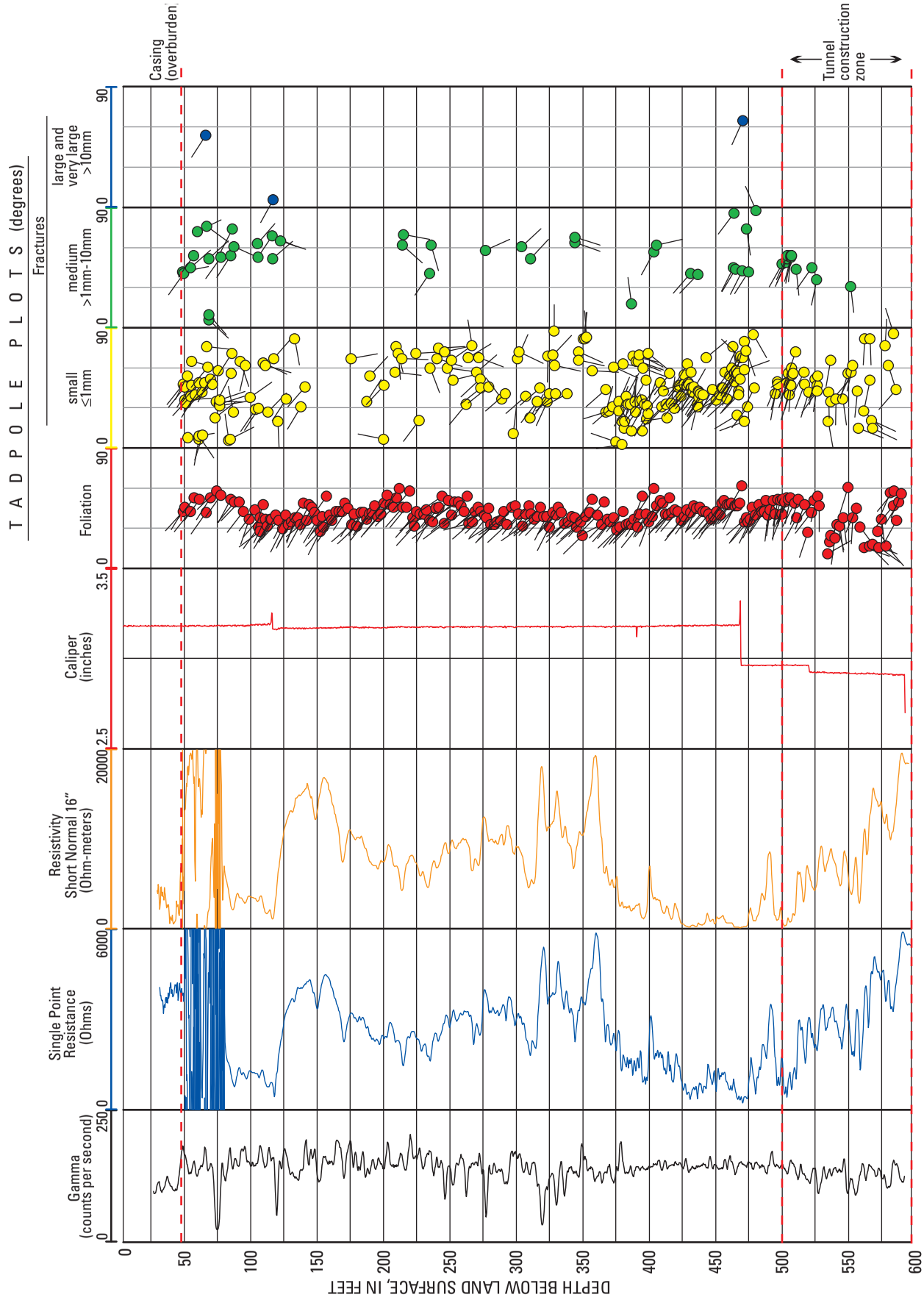


Figure 13A. Suite of borehole-geophysical logs from borehole E30ST-B, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 2.)

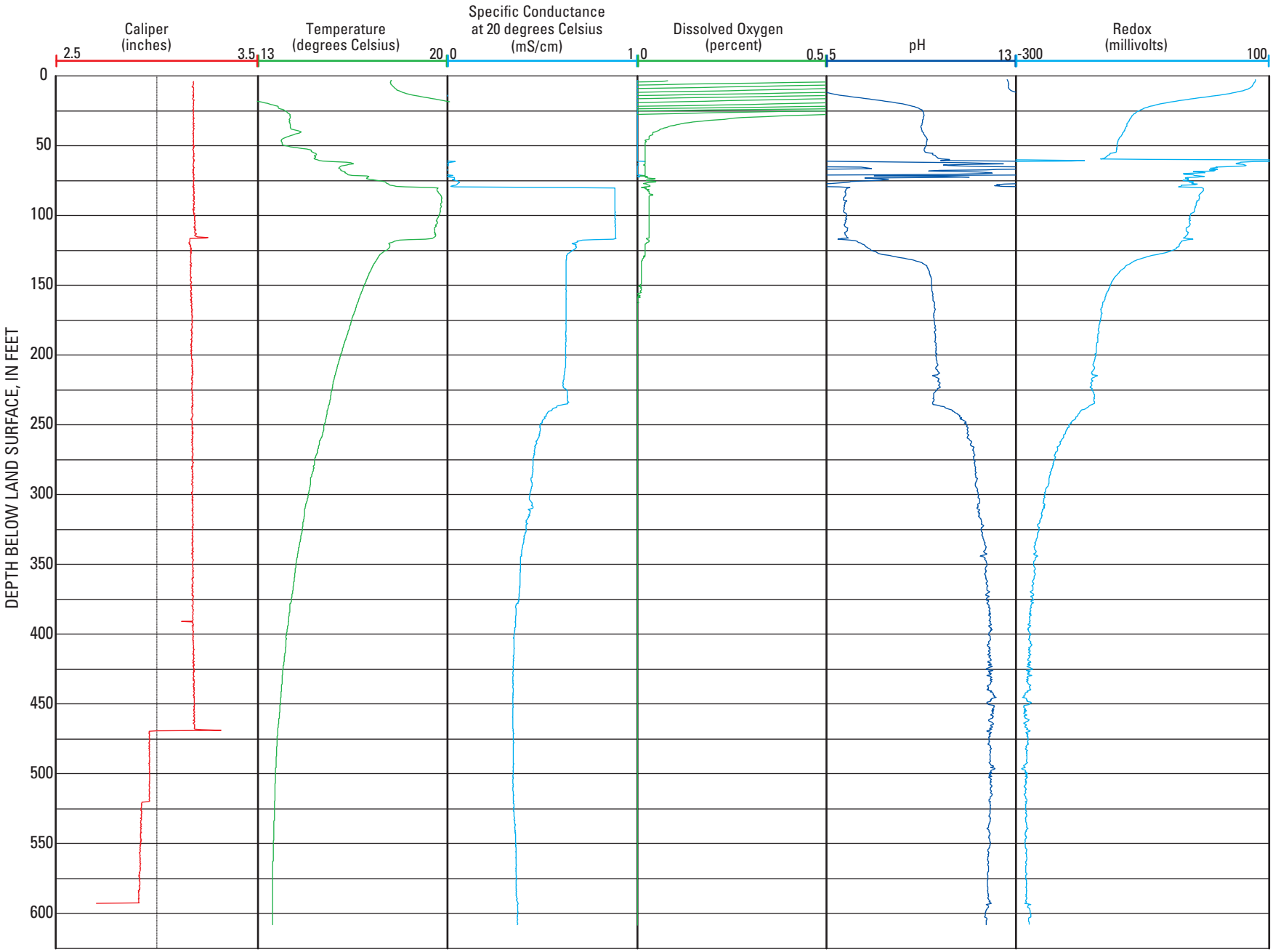


Figure 13B. Suite of borehole-geophysical logs from borehole E30ST-B, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 2.)

E33ST-A

The E33ST-A borehole has 34 ft of casing and extends 550.2 ft BLS (-527.4 ft elevation). The borehole is uncased in fractured bedrock.

Fractures and Foliation

OTV analysis indicated a total of 223 fractures. The E33ST-A borehole has a fracture index of 0.43 and most of the fractures were small and medium sized. A very large fracture is detected at 63.8 ft BLS with an orientation of N40°E 73°NW. Mean fracture orientation for the total borehole is N41°E 41°NW. The PTCZ fracture stereonet plots indicate two general clusters—one shallow cluster dipping to the northwest, and the other steeply dipping to the northeast (fig. 14). Total borehole and PTCZ mean foliation orientation were N40°E 42°NW and N39°E 37°NW, respectively (fig. 14).

The gamma log shows uniformity throughout the borehole except at 405-415 ft BLS where a sharp increase correlates to a pegmatite (fig. 15). The SPR and R logs both show variations that reflect slight lithologic changes and indicate a decrease in resistivity where some medium and large fractures were present, specifically the large fracture at 400 ft BLS (fig. 15). Deviation log analysis indicated the bottom of the E33ST-A borehole is 32 ft from the origin, with an azimuth of 152º (table 2).

Ground-Water-Flow Zones

Hydraulic head in E33ST-A was -22.46 ft BLS. The SpC log has slope changes at 70, 225, and 270 ft BLS (fig. 15). The DO log indicated an increase below 70 ft BLS with several minor and major increases that may correlate to transmissive fractures. The pH and redox logs correlated with the caliper log, indicating specific fractures that may be transmissive at 35 and 40 ft BLS (OTV and fluid parameter log evidence above the water level) and a change below 250 ft BLS (fig. 15).

Specific-capacity test analysis indicated that E33ST-A has a specific capacity of 0.01 (gal/min)/ft and a transmissivity of 2.3 ft^2/d. This borehole has the lowest transmissivity of all Midtown and South Water-Tunnel boreholes tested.

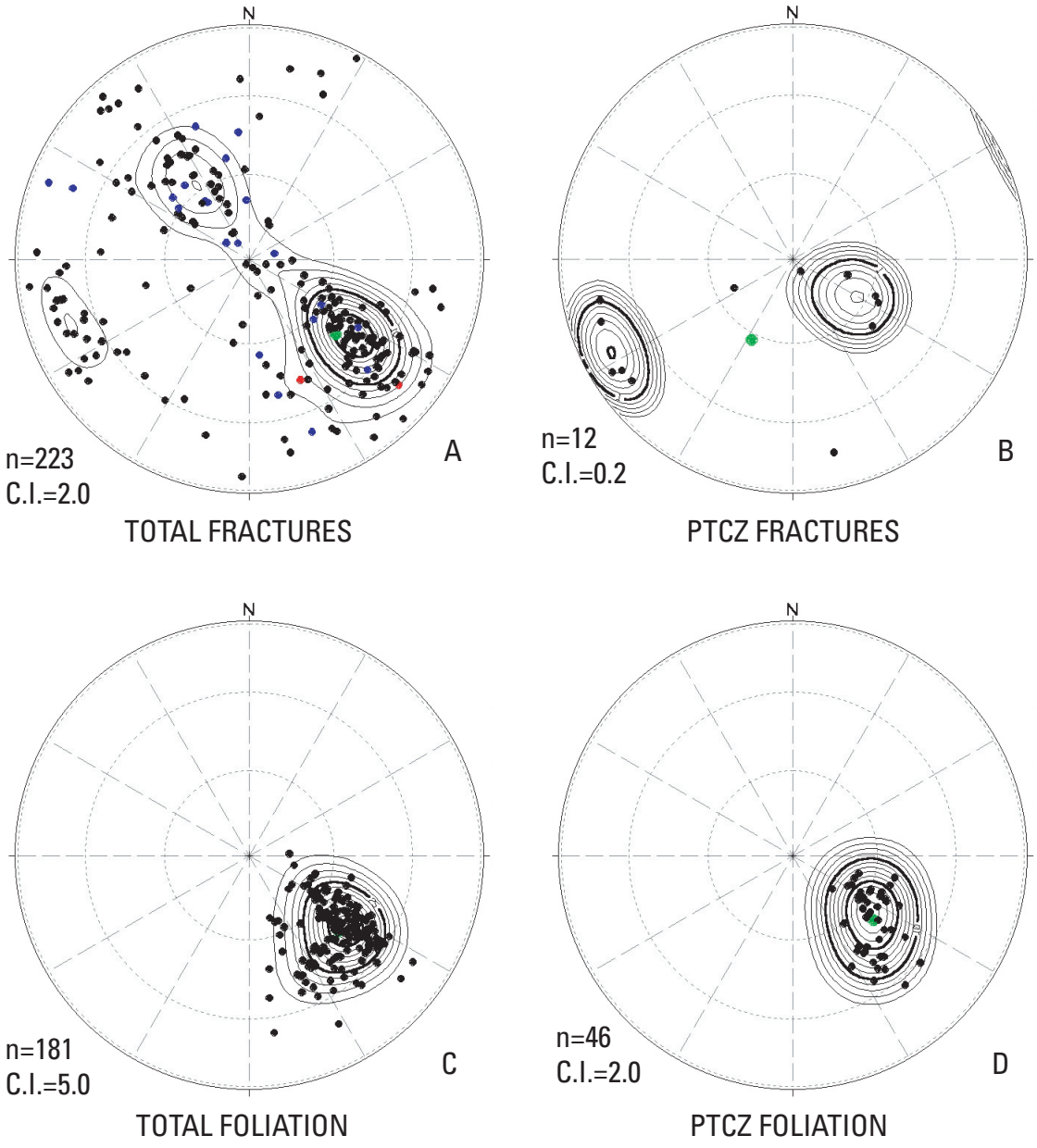


Figure 14. Stereonet plots of borehole E33ST-A, Manhattan Island, N.Y., 2003-04: A. Total fractures. B. PTCZ fractures. C. Total foliation. D. PTCZ foliation. (Borehole location is shown in figure 2.)

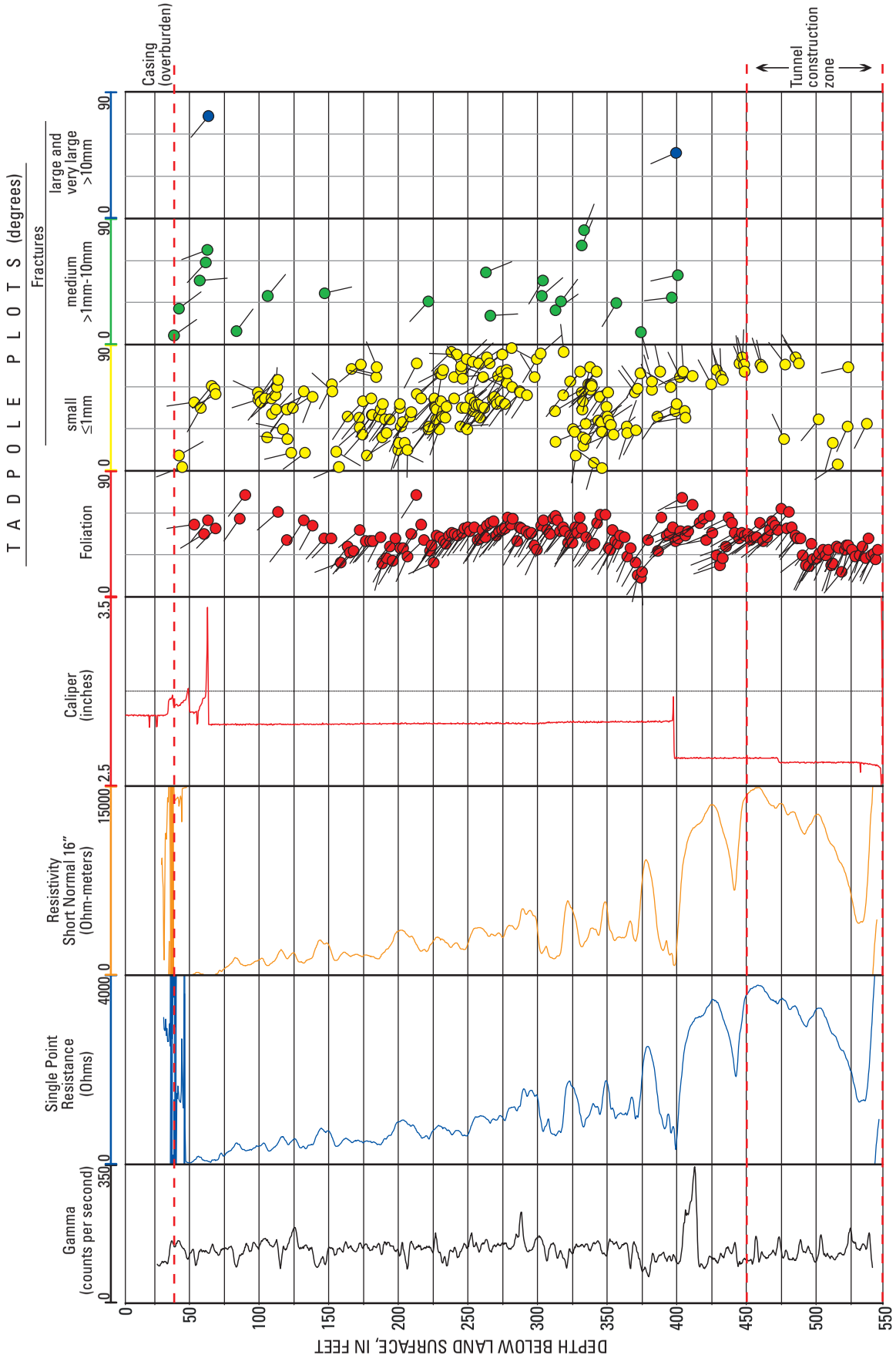


Figure 15A. Suite of borehole-geophysical logs from borehole E33ST-A, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 2.)

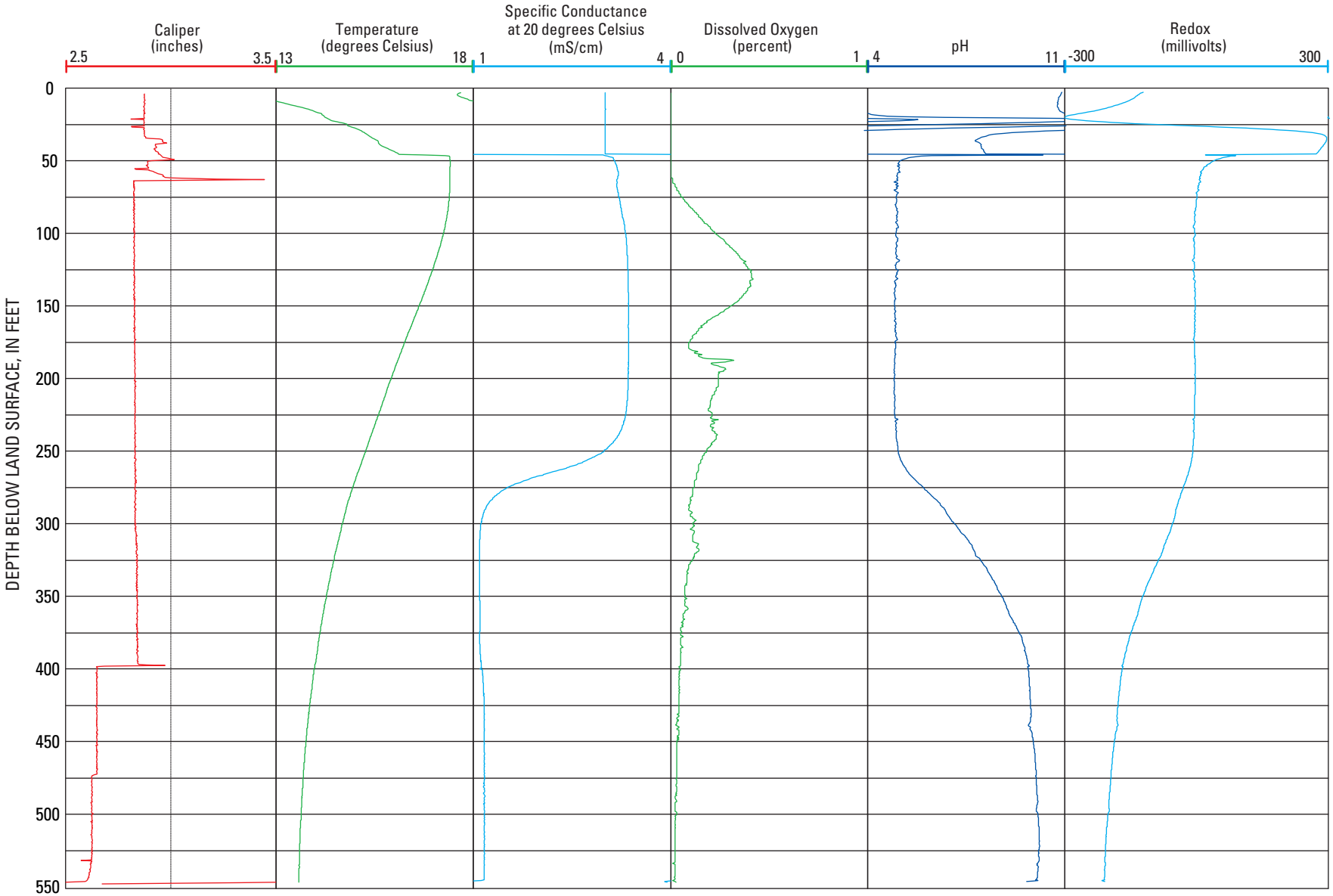


Figure 15B. Suite of borehole-geophysical logs from borehole E33ST-A, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 2.)

E31ST–A

No geophysical logs were collected at the E31ST-A borehole. The borehole is drilled to a depth of 554 ft BLS. The hydraulic head in this borehole was -23.68 ft elevation. The borehole is within a large cone of depression along the eastern side of midtown Manhattan (the east-side cone of depression) caused by the dewatering for shallow railway tunnels. Specific-capacity test analysis indicated the E31ST-A borehole has a specific capacity of 0.02 (gal/min)/ft and a transmissivity of 4.4 ft^2/d.

E34ST–B

The E34ST-B borehole is drilled to a depth of 635 ft BLS. Hydraulic head in this borehole was -14.3 ft elevation. The borehole is within the east-side midtown cone of depression. Specific-capacity test analysis of the E34ST-B borehole indicated a specific capacity of 0.02 (gal/min)/ft and a transmissivity of 4.6 ft^2/d.

E35ST–A

The E35ST-A borehole is drilled to a depth of 448 ft BLS. Hydraulic head in this borehole was -6.4 ft elevation and appeared to be tidally affected. This borehole is also within the east-side midtown cone of depression. Specific-capacity test analysis of the E35ST-A borehole indicated a specific capacity of 0.84 (gal/min)/ft and a transmissivity of 247 ft^2/d.

Geophysical logs are not available for the E31ST–A borehole.

Geophysical logs are available for the E34ST–B and E35ST–A boreholes but are not shown here because these wells are away from proposed tunnel line.

E35ST–D

Three boreholes were drilled at the same location E35ST-D, E35ST-E, and E35ST-F. E35ST-E is about 50 ft south of E35ST-D. E35ST-F is about 20 ft east of E35ST-E. Both the E35ST-D and E35ST-E boreholes are uncased in bedrock. The E35ST-F borehole is screened in unconsolidated sediments above the bedrock. The E35ST-D borehole has 25 ft of casing and extends 599.5 ft BLS (-580 ft elevation). The borehole is uncased in fractured bedrock.

Fractures and Foliation

OTV log analysis indicated 322 fractures. The borehole has a fracture index of 0.56. Two major population clusters are present— one sub-horizontal dipping to the east, and the other moderately dipping to the west (fig. 16). However, the total borehole fracture stereonet indicated a wide scatter of fracture orientations. PTCZ mean fracture orientation is N12°W 53°SW. Borehole-radar logging determined that most of the large and some medium fractures detected in the borehole by OTV extend at least 90 ft away from the borehole. Two potentially large fractures or faults were detected beyond the borehole with orientations of N60°E 67°NW and N80°W 77°NE. Four faults were detected in E35ST-D at 375, 380, 391, and 416 ft BLS from OTV analysis. Total borehole and PTCZ mean foliation orientation were N02°E 43°W and N03°W 43°W, respectively (fig. 16). SPR and R logs indicated lithologic changes and the location of medium and large fracture zones at 50, 120, 170, 190, and 415 ft BLS (fig. 17). The borehole has a fairly even distribution of small and medium fractures throughout the length of the borehole, except for large fractures which were detected in the upper 200 ft of the borehole. Foliation orientation is fairly consistent throughout the borehole. Deviation analysis indicated the bottom of the E35ST–D borehole is 7 ft southeast from the origin with an azimuth of 112º (table 2).

Ground-Water-Flow Zones

Hydraulic head in the E35ST-D borehole was -2.6 ft elevation. The borehole is within the east-side midtown cone of depression. The fluid-parameter logs indicated a series of transmissive fractures between 27 to 190 ft BLS and another zone at 325 ft BLS (fig. 17). Each of the five large fractures and several medium fractures correlated to slope changes indicated by these logs. Specific-capacity test analysis indicated the E35ST-D borehole has a specific capacity of 1.5 (gal/min)/ft and a transmissivity of 459 ft^2/d. This borehole has the highest transmissivity of any Midtown Water-Tunnel borehole and of all boreholes tested in southern Manhattan.

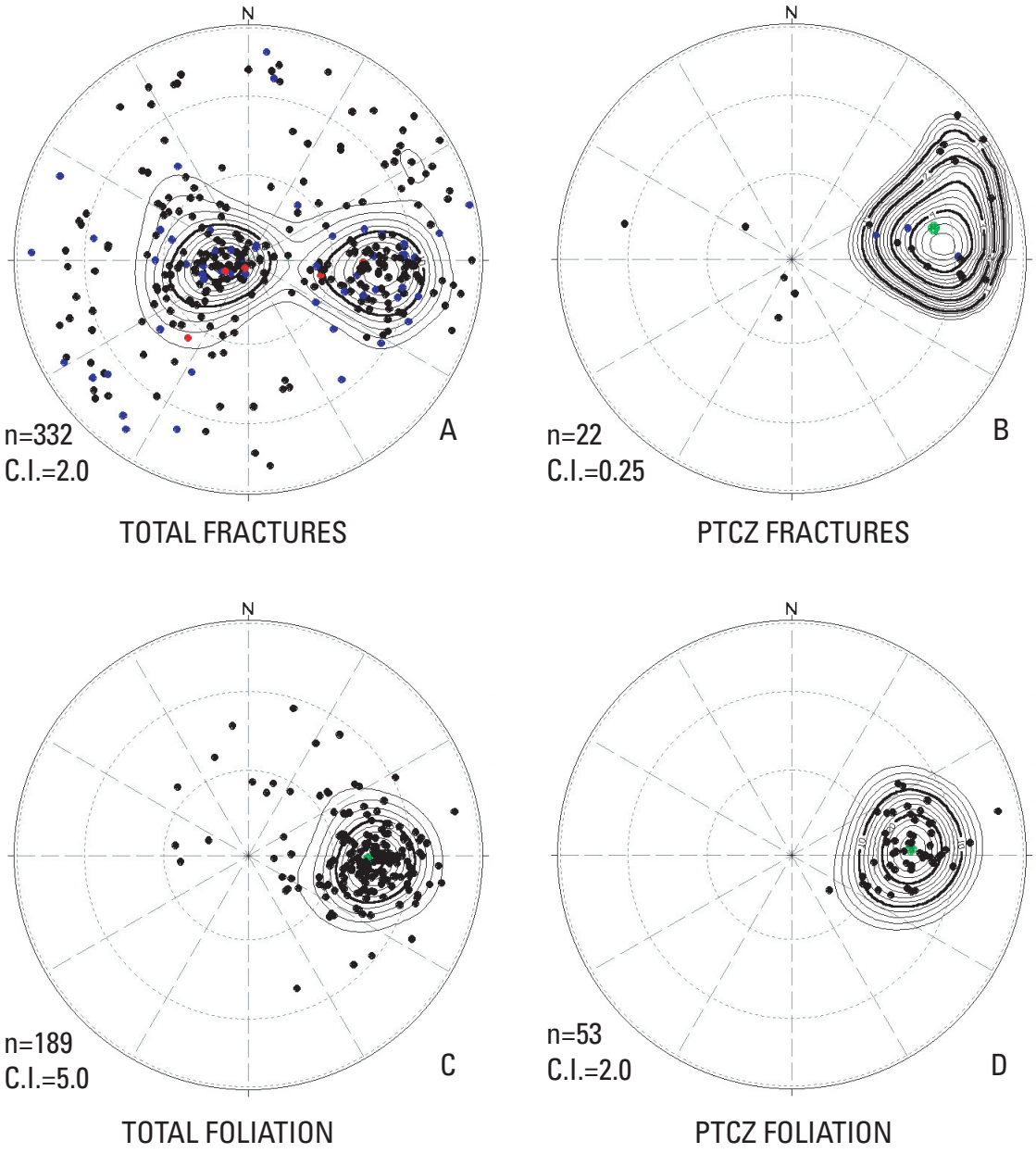


Figure 16. Stereonet plots of borehole E35ST-D, Manhattan Island, N.Y., 2003-04: A. Total fractures. B. PTCZ fractures. C. Total foliation. D. PTCZ foliation. (Borehole location is shown in figure 2.)

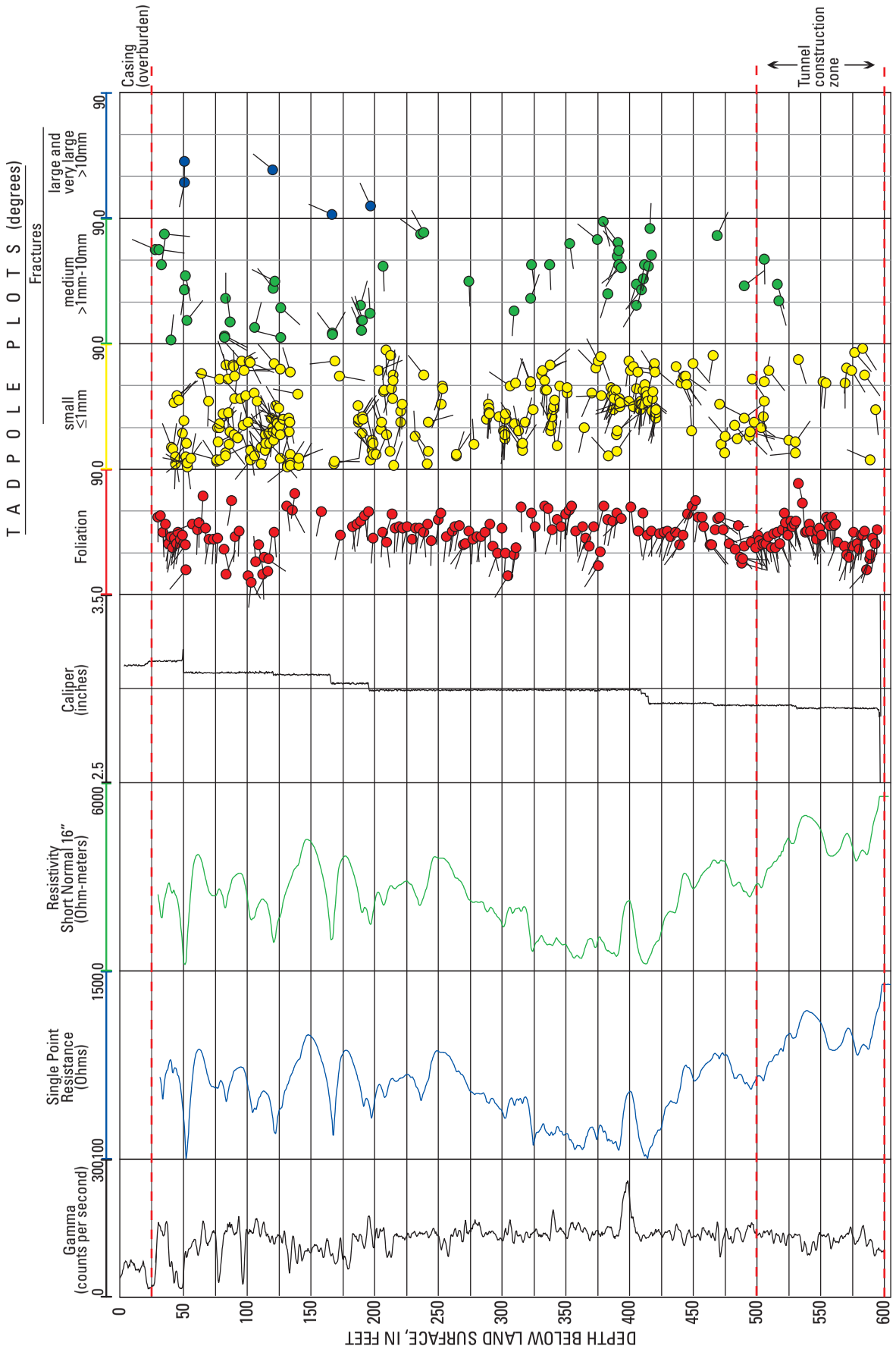


Figure 17A. Suite of borehole-geophysical logs from borehole E35ST-D, Manhattan Island, N.Y., 2004. (Borehole location is shown in figure 2.)

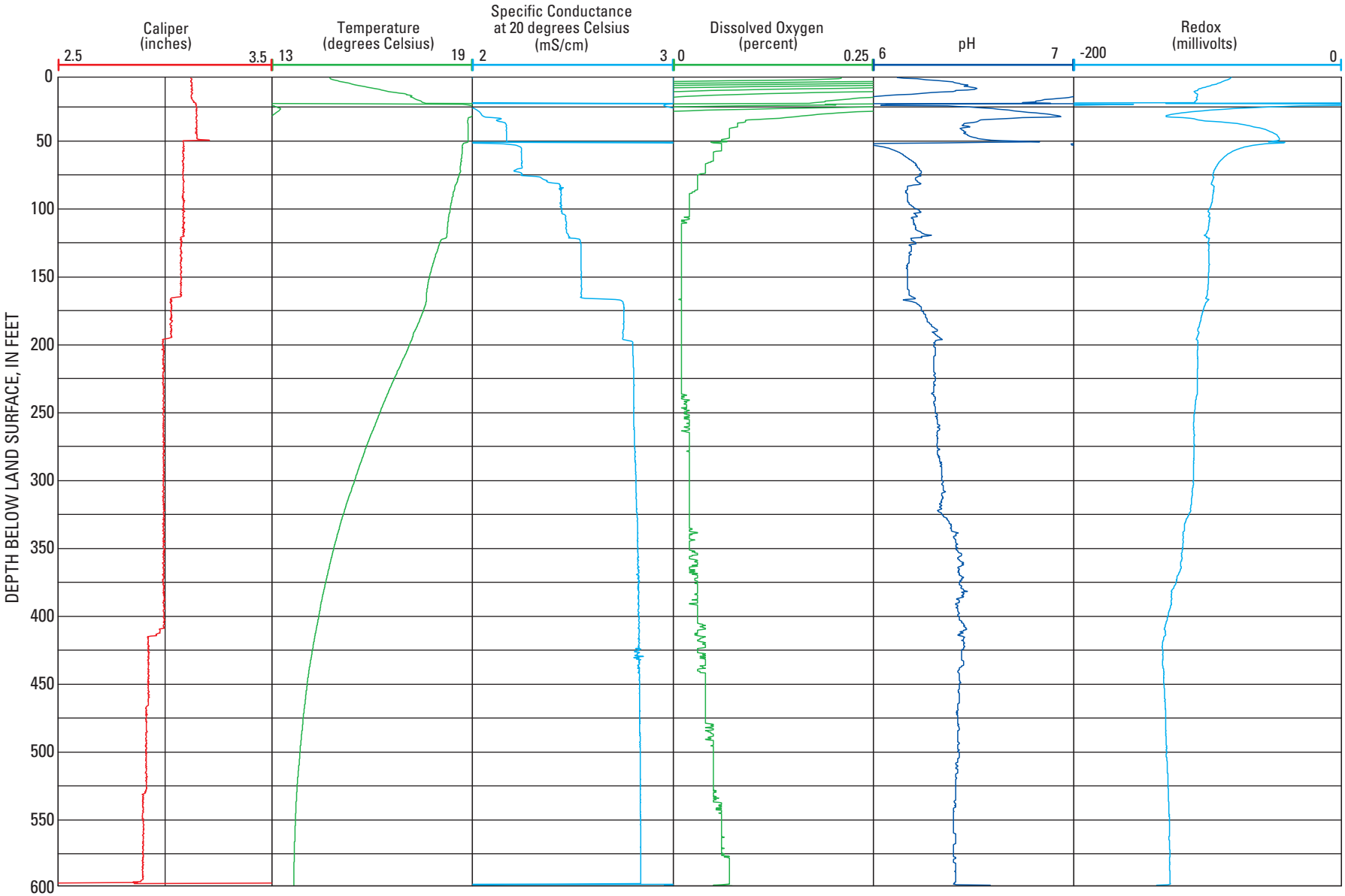


Figure 17B. Suite of borehole-geophysical logs from borehole E35ST-D, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 2.)

E35ST–E

The E35ST-E borehole is about 50 ft south of E35ST-D and is screened within unconsolidated sediments overlying the bedrock. The E35ST-E borehole had a hydraulic head of 4.2 ft above sea level. This water level represents the local unconfined water table and indicated the unconsolidated sediments were saturated 7 ft above the bedrock surface. The E35ST-E borehole was not geophysically logged.

Specific-capacity test analysis indicated the unconsolidated sediments at this location have an extremely low specific capacity and transmissivity, less than 0.01 (gal/min)/ft and less than 2 ft^2/d, respectively. The borehole is at the same location as bedrock boreholes E35ST-D and E35ST-F. Pumping of both bedrock boreholes has no effect on E35ST-E and indicated this overburden well is not hydraulically connected to the transmissive bedrock fractures at this site.

E35ST–F

The borehole E35ST-F is at the same site as the E35ST-D and E35ST-E boreholes. This borehole extends 531 ft BLS into bedrock. The E35ST-F borehole was not geophysically logged. Hydraulic head in the borehole was -3.1 ft elevation indicating this borehole is within the east-side midtown cone of depression. Water-level measurements during specific-capacity tests of all three boreholes (E35ST-D, E35ST-E, and E35ST-F) indicate transmissive fractures intersect both bedrock wells, E35ST-D and E35ST-F, which are hydraulically connected. Specific-capacity test analysis indicated the E35ST-F borehole has a specific capacity of 1.05 (gal/min)/ft and a transmissivity of 316 ft^2/d.

Geophysical logs were not collected at E35ST–E and E35ST–F boreholes.

E39ST–A

The E39ST-A borehole has 35 ft of casing and extends 491 ft BLS (-455 ft elevation). The borehole is uncased in fractured bedrock.

Fractures and Foliation

A total of 307 fractures were detected by the OTV and ATV logs. The E39ST-A borehole has a fracture index of 0.67. Most fractures were small, some were medium, and only five were large. The total borehole and PTCZ mean fracture orientation were N05°E 26°W and N10°W 16°NW, respectively (fig. 18). Six faults were detected using OTV data in the borehole at 71, 138, two at 301, and an additional two faults at 320 ft BLS. Total borehole and PTCZ mean foliation orientation were N20°E 33°NW and N03°W 15°W, respectively (fig. 18).

SPR and R logs indicate changes in lithology and the location of large and medium fractures (fig. 19). A large increase in resistivity below 380 ft BLS correlates to an almost lack of fractures at this depth (fig. 19). The bottom of the E39ST-A borehole is 37 ft from the origin with an azimuth of 142º.

Ground-Water-Flow Zones

Hydraulic head in the E39ST-A borehole was 11.4 ft above sea level. The fluid parameter logs have slope changes at 45, 55, 75 and 285 ft BLS (fig. 19). These changes correlate with large and medium fractures at these depths and suggest the fractures are transmissive. Specific-capacity test analysis indicate the borehole has a specific capacity of 0.04 (gal/min)/ft and a transmissivity of 8.8 ft^2/d.

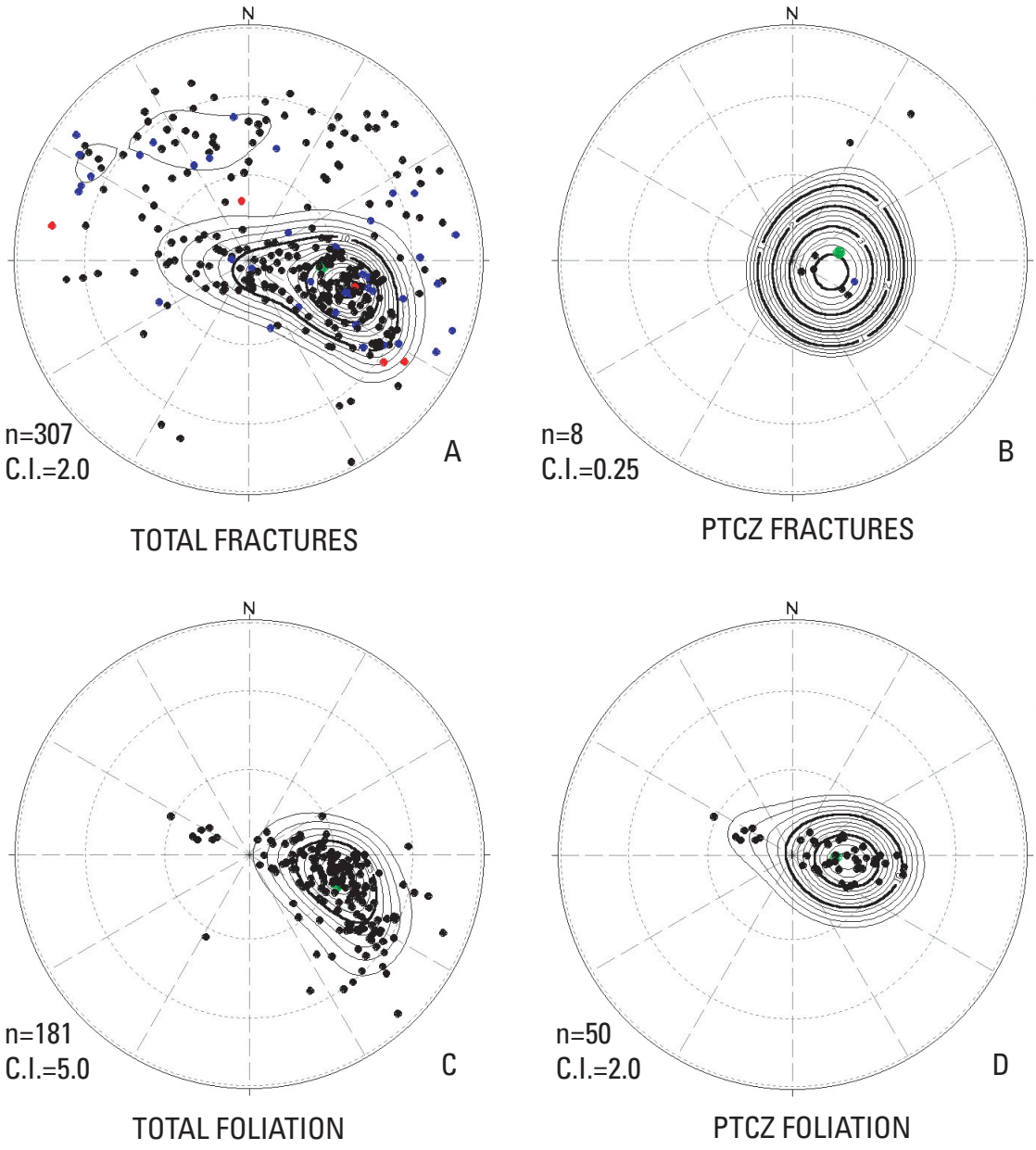


Figure 18. Stereonet plots of borehole E39ST-A, Manhattan Island, N.Y., 2003-04: A. Total fractures. B. PTCZ fractures. C. Total foliation. D. PTCZ foliation. (Borehole location is shown in figure 2.)

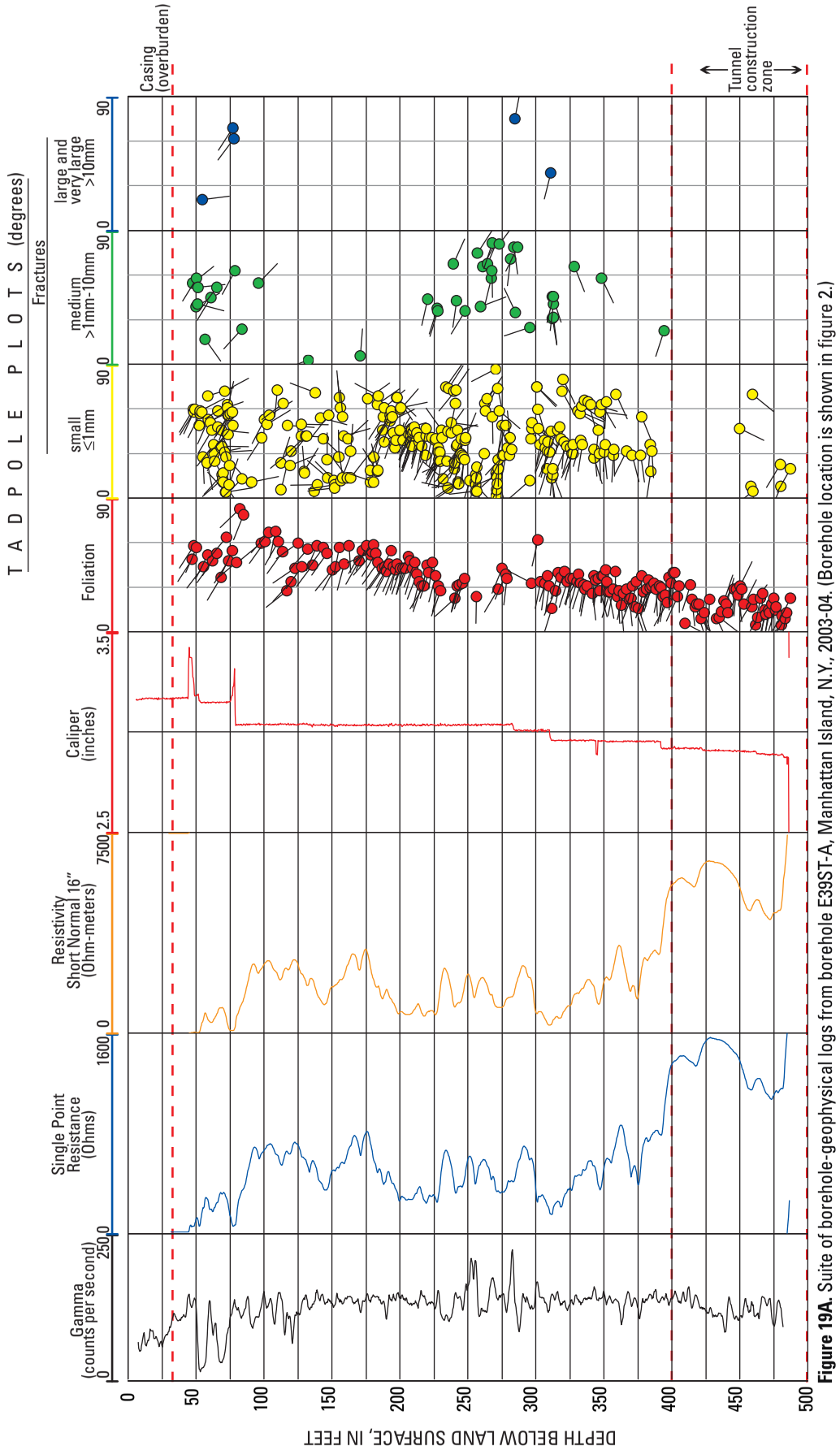


Figure 19A. Suite of borehole-geophysical logs from borehole E39ST-A, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 2.)

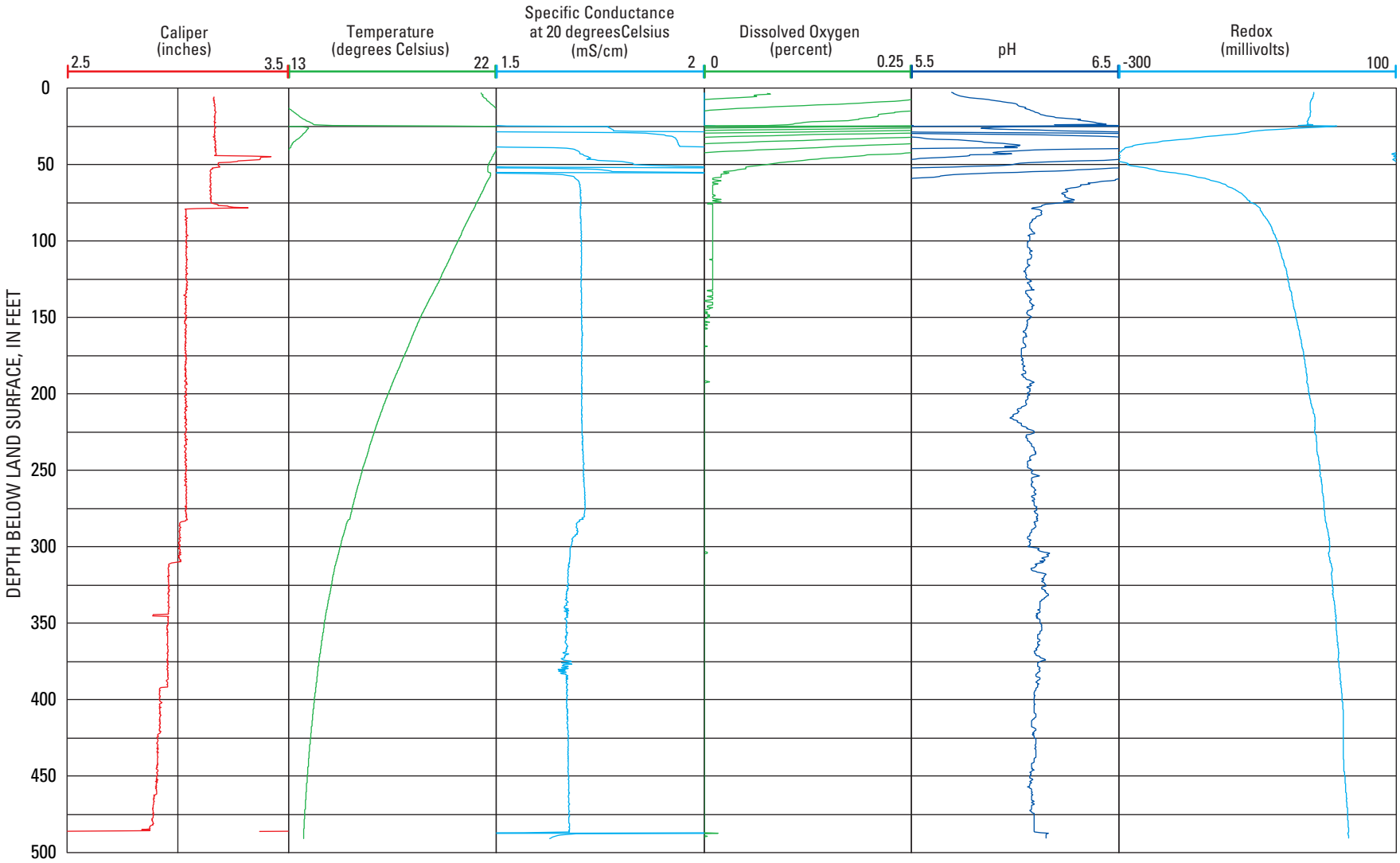


Figure 19B. Suite of borehole-geophysical logs from borehole E39ST-A, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 2.)

E45ST–A

The E45ST-A borehole has 10 ft of casing and extends 490 ft BLS (-432 ft elevation). The borehole is uncased in fractured bedrock.

Fractures and Foliation

Analysis of OTV and ATV logs detected a total of 311 fractures. The E45ST-A borehole has a fracture index of 0.64. Most fractures were small, some were medium, and only two were large. The PTCZ mean fracture orientation was N29ºE 33ºNW (fig. 20). The stereonet plot of all fractures indicated two population clusters: one east-dipping, and the other west-dipping. The mean foliation orientation for the total borehole and the PTCZ were N09ºE 30ºW and N09ºE 25ºW, respectively (fig. 20).

The SPR and R logs indicate variations in resistivity, which correlate to fracture density and lithologic changes (fig. 21). The MAG log indicated changes in lithology at a higher resolution (than the gamma log) as it relates to magnetite content (fig. 21). The bottom of the E45ST-A borehole is 24 ft from the origin with an azimuth of 165º.

Ground-Water-Flow Zones

Hydraulic head in the E45ST-A borehole was 19.9 ft above sea level. The fluid temperature, SpC, pH, and redox logs indicate possible transmissive fractures at 85, 120, 255, 295, and 325 ft BLS, where deflections or slope changes in the logs were observed (fig. 21). Specific-capacity test analysis indicated the E45ST-A borehole has a specific capacity of 0.19 (gal/min)/ft and a transmissivity of 53 ft^2/d.

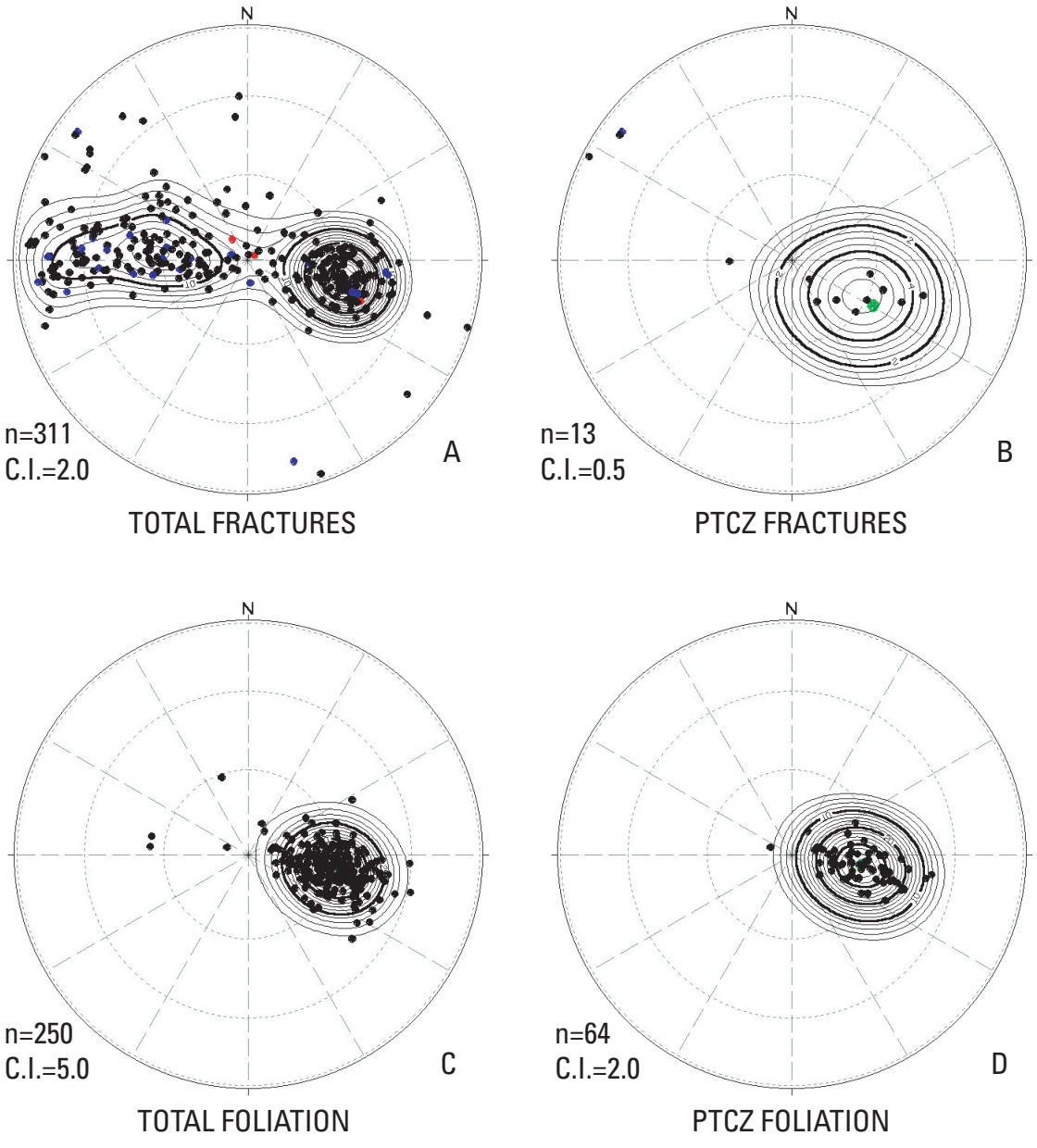


Figure 20. Stereonet plots of borehole E45ST-A, Manhattan Island, N.Y., 2003-04: A. Total fractures. B. PTCZ fractures. C. Total foliation. D. PTCZ foliation. (Borehole location is shown in figure 2.)

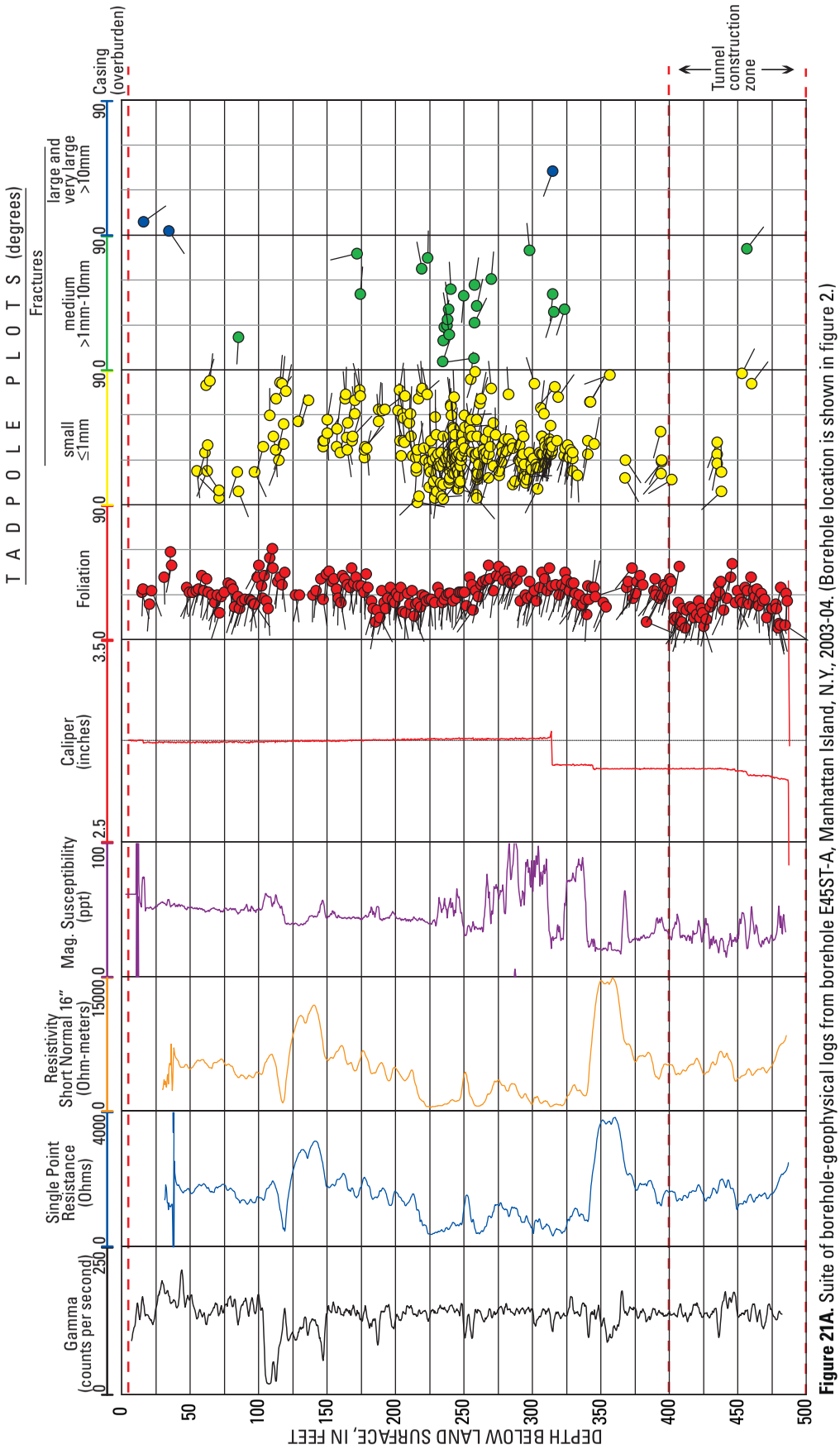


Figure 21A. Suite of borehole-geophysical logs from borehole E45ST-A, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 2.)

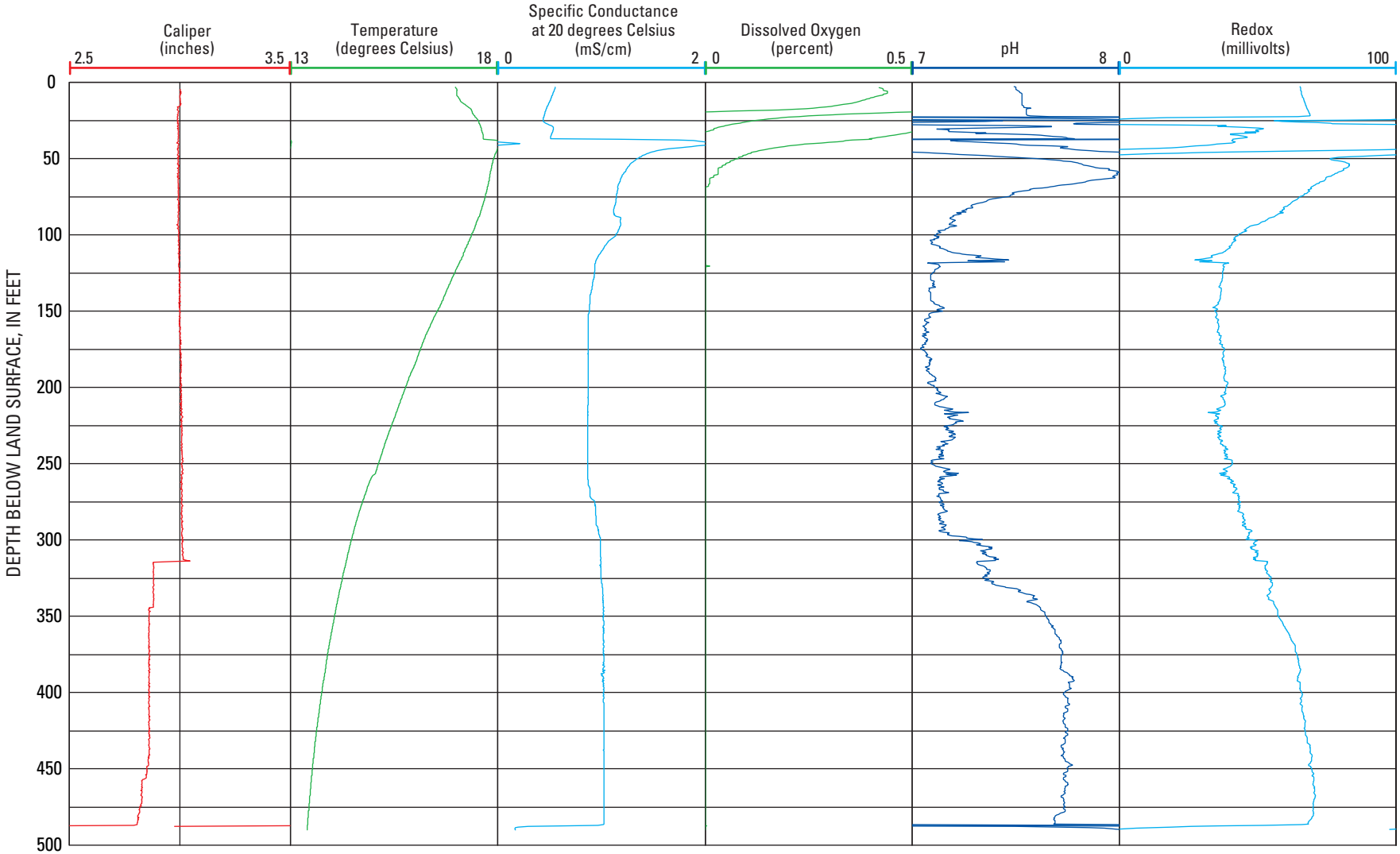


Figure 21B. Suite of borehole-geophysical logs from borehole E45ST-A, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 2.)

E48ST–A

The E48ST-A borehole has 105 ft of casing and extends 490 ft BLS (-463.1 ft elevation). The borehole is uncased in fractured bedrock.

Fractures and Foliation

OTV and ATV logs detected a total of 308 fractures. The E48ST-A borehole has a fracture index of 0.73. Most fractures were small some were medium, and one was large. One fault is detected at 157 ft BLS. Analysis of the borehole radar data indicate that most medium and large fractures extend at least 90 ft away from the borehole. The borehole radar also imaged a possible large fracture or fault that would have been intersected by the borehole had it been drilled to 553 ft BLS. This radar reflector has an orientation of N10°W 49°W. Total borehole and PTCZ mean fracture orientations were N11°E 34°NW and N61°E 49°NW, respectively (fig. 22). Total borehole and PTCZ mean foliation orientations were N13°E 03°NW and N16°E 28°NW, respectively (fig. 22).

SPR and R logs indicate a large increase in bedrock resistivity from 340 to 420 ft BLS that reflects a lithologic change from gneiss and schist to pegmatite (fig. 23). The bottom of the E48ST-A borehole is 19 ft from the origin with an azimuth of 170º.

Ground-Water-Flow Zones

Hydraulic head in E48ST-A borehole was 12.1 ft above sea level. The fluid parameter logs indicated possible transmissive fractures at 110, 160, 285, 300, and 480 ft BLS, where deflections or slope changes were observed (fig. 23). Analysis of the specific-capacity test data indicated the E48ST-A borehole has a specific capacity of 0.04 (gal/min)/ft and a transmissivity of 11 ft^2/d.

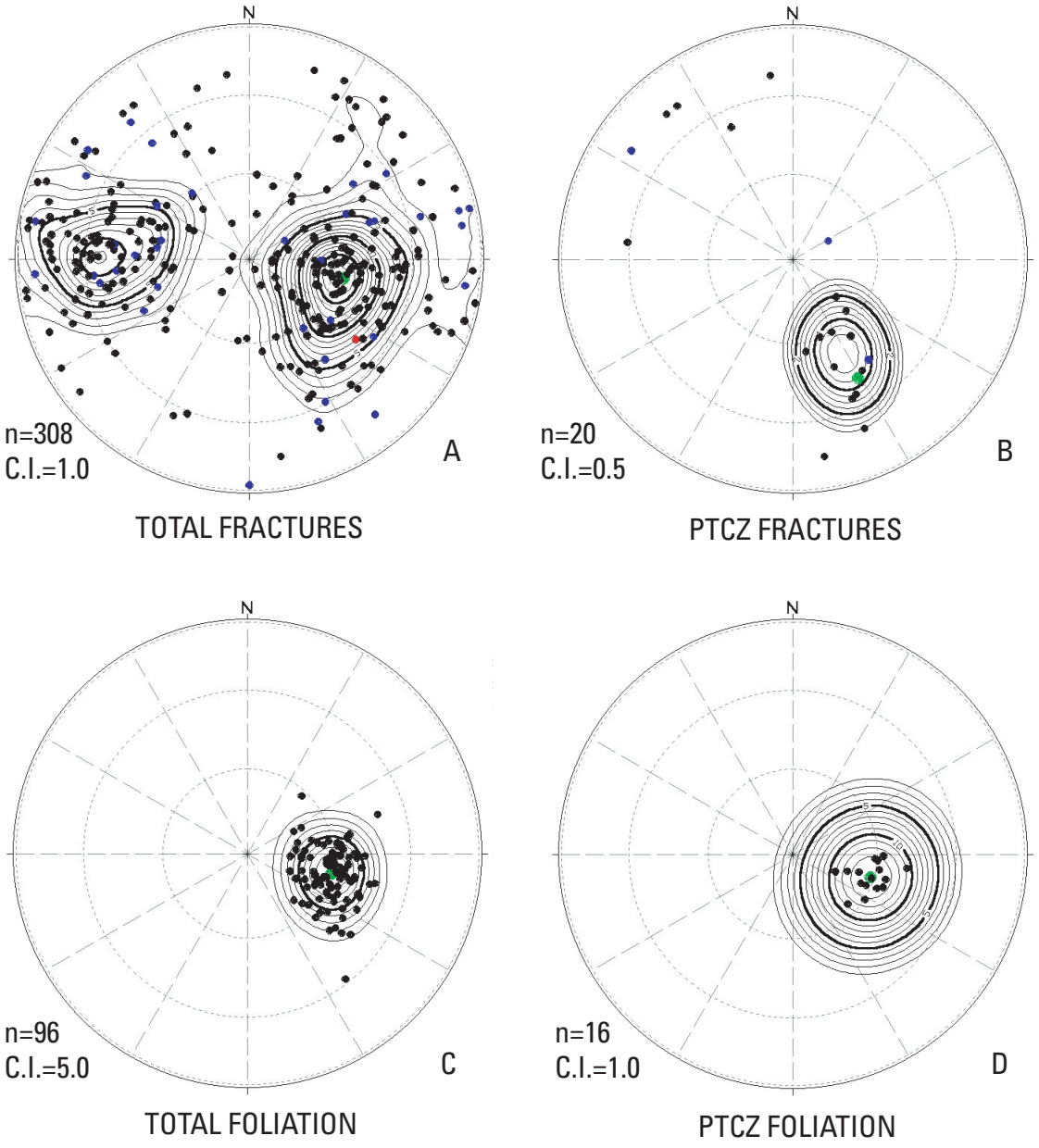


Figure 22. Stereonet plots of borehole E48ST-A, Manhattan Island, N.Y., 2003-04: A. Total fractures. B. PTCZ fractures. C. Total foliation. D. PTCZ foliation. (Borehole location is shown in figure 2.)

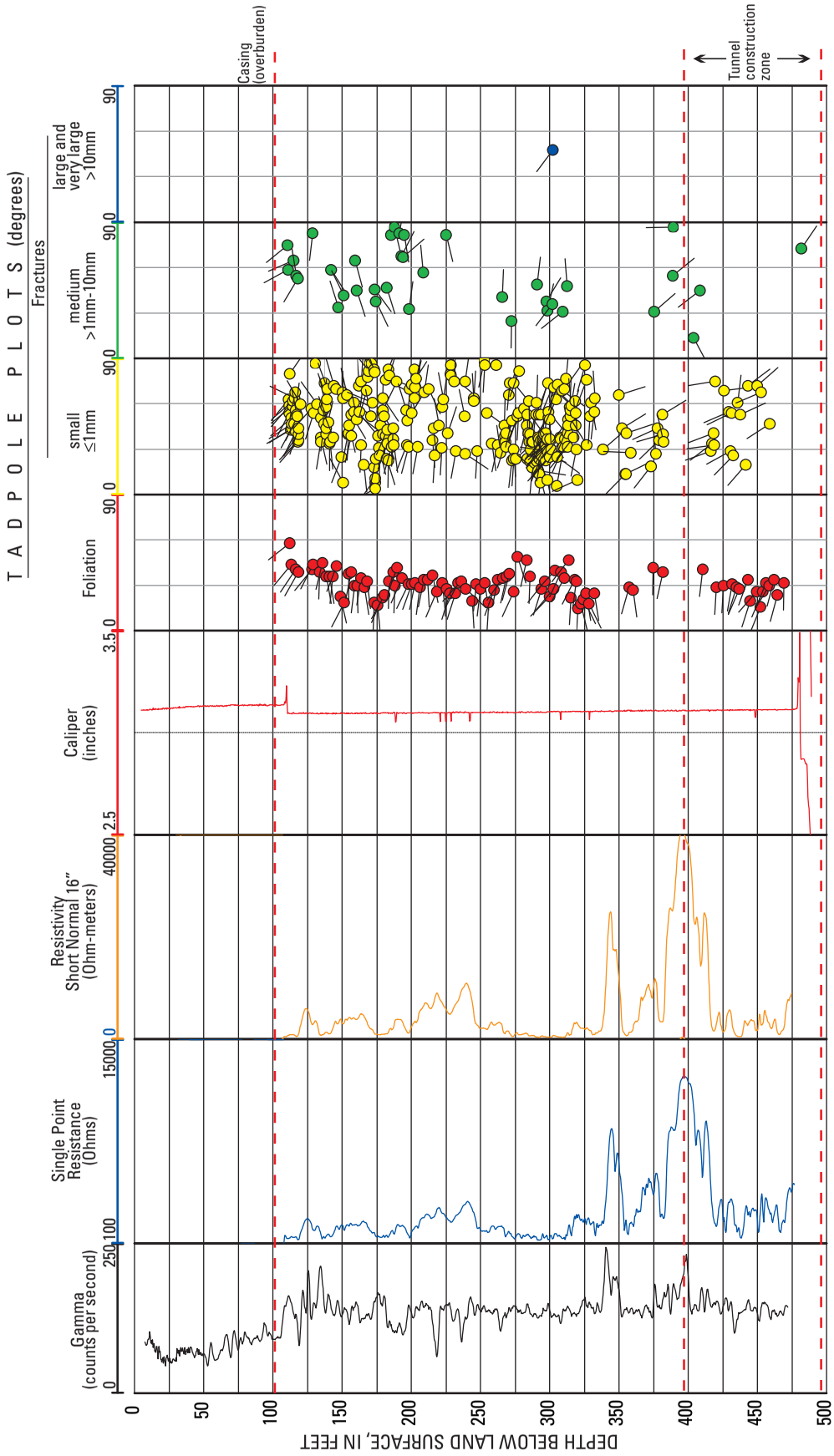


Figure 23A. Suite of borehole-geophysical logs from borehole E48ST-A, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 2.)

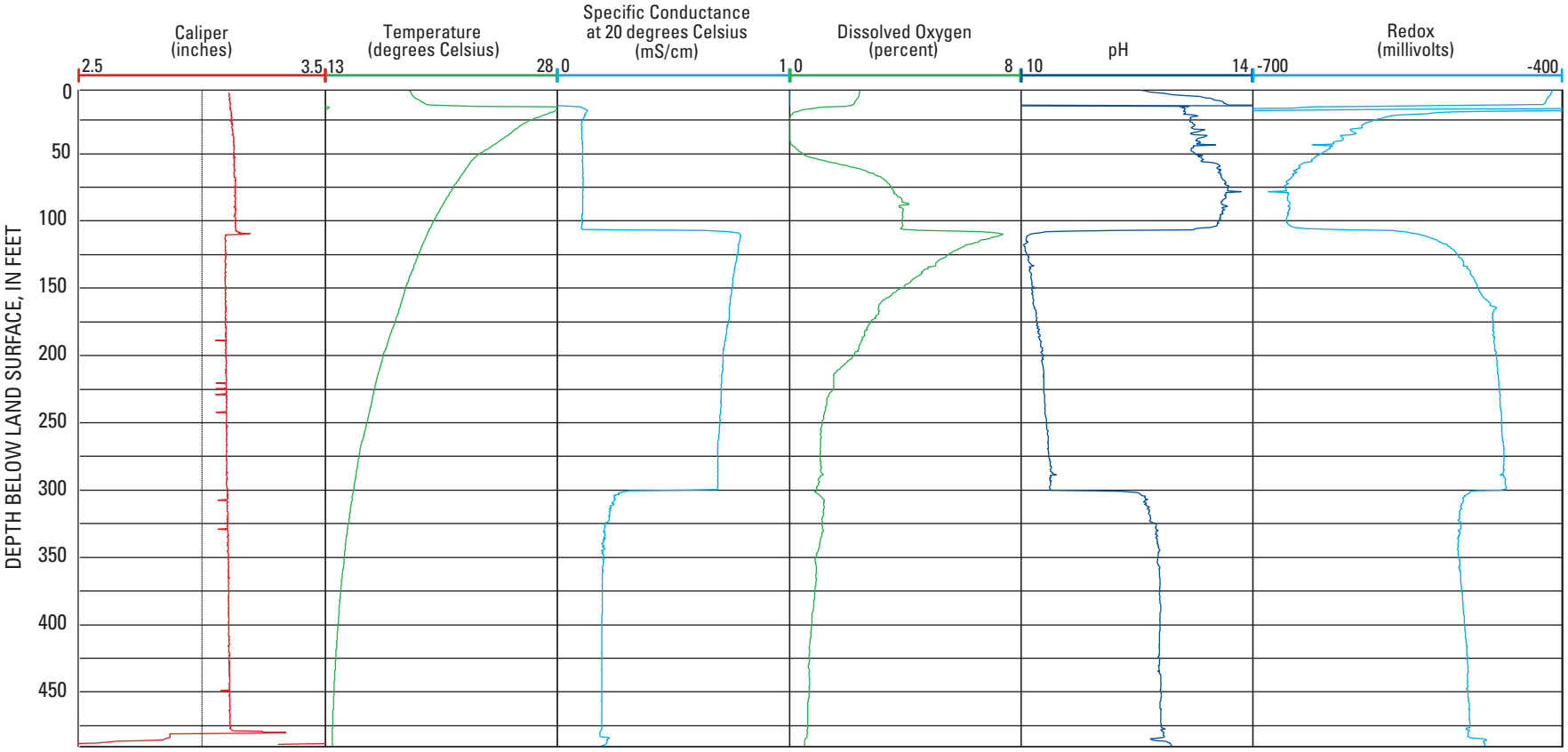


Figure 23B. Suite of borehole-geophysical logs from borehole E48ST-A, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 2.)

E52ST–A

The E52ST-A borehole has 25 ft of casing and extends 490 ft BLS (-451.8 ft elevation). The borehole is uncased in fractured bedrock.

Fractures and Foliation

A total of 279 fractures were detected by OTV and ATV logs. The borehole has a fracture index of 0.60. Most fractures were small and medium. One very large fracture is detected at 386 ft BLS. Nine faults were detected in the borehole at 114, 264, 363, 377, 386, 388, 403, 419, and 429 ft BLS. Two gouge zones were detected at 361 and 363 ft BLS using OTV data. The PTCZ stereonet plot of fractures is somewhat scattered with small population clusters dipping east and another dipping west (fig. 24). The total borehole and PTCZ mean foliation orientations were N10°E 26°NW and N13°W 21°SW, respectively (fig. 24). The gamma SPR and R logs show variations that reflect lithologic changes (fig. 25). The deviation log indicated the bottom of the E52ST-A borehole is 28 ft from the origin, at an azimuth of 177º.

Ground-Water-Flow Zones

Hydraulic head in the E52ST-A borehole was 22.7 ft above sea level. The fluid parameter logs indicate possible transmissive fractures at 70, 80, 190, 280, 385, and 480 ft BLS (fig. 25). Specific-capacity test analysis indicated the E52ST-A borehole has a specific capacity of 0.27 (gal/min)/ft and a transmissivity of 74 ft^2/d.

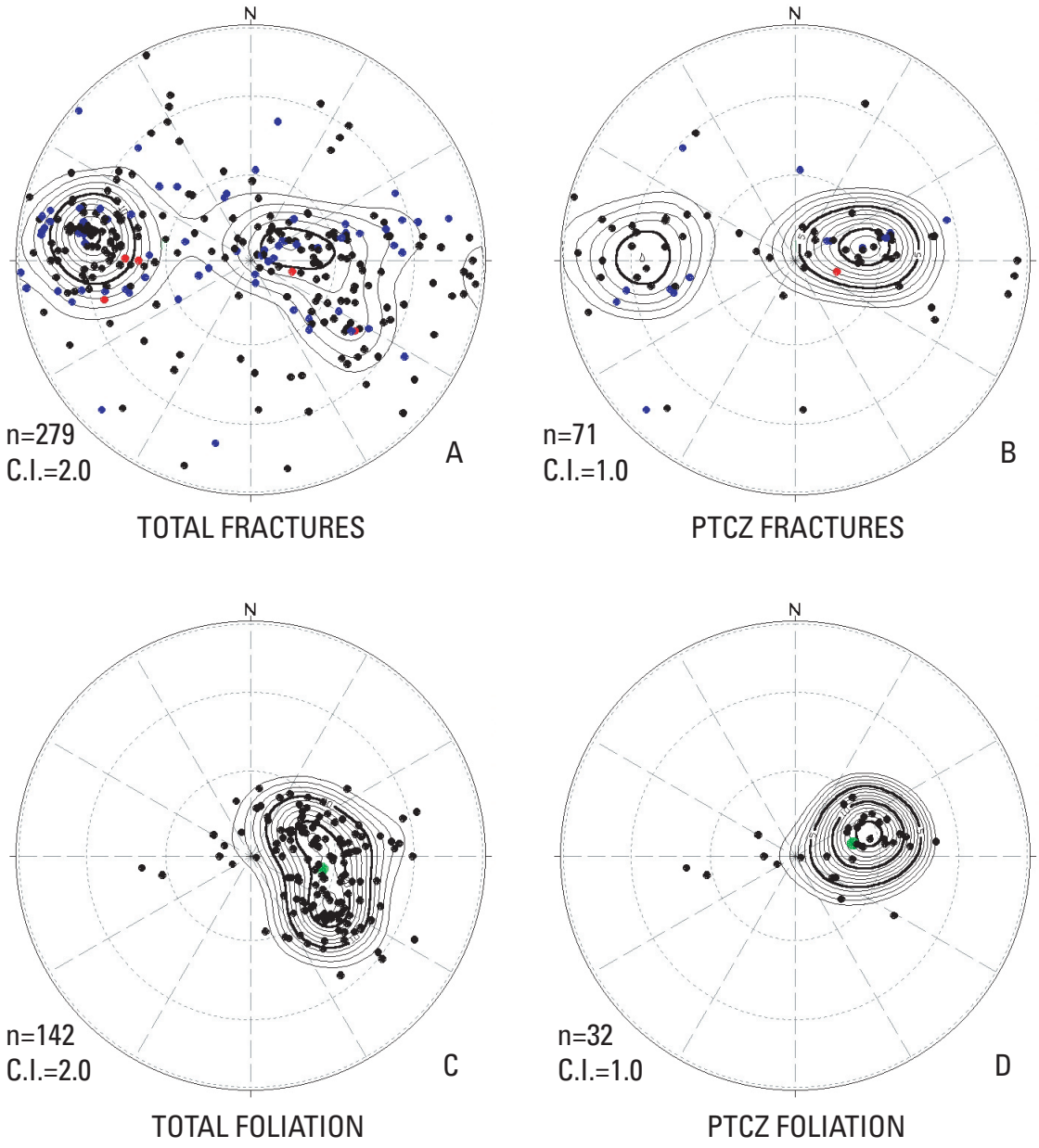


Figure 24. Stereonet plots of borehole E52ST-A, Manhattan Island, N.Y., 2003-04: A. Total fractures. B. PTCZ fractures. C. Total foliation. D. PTCZ foliation. (Borehole location is shown in figure. 2.)

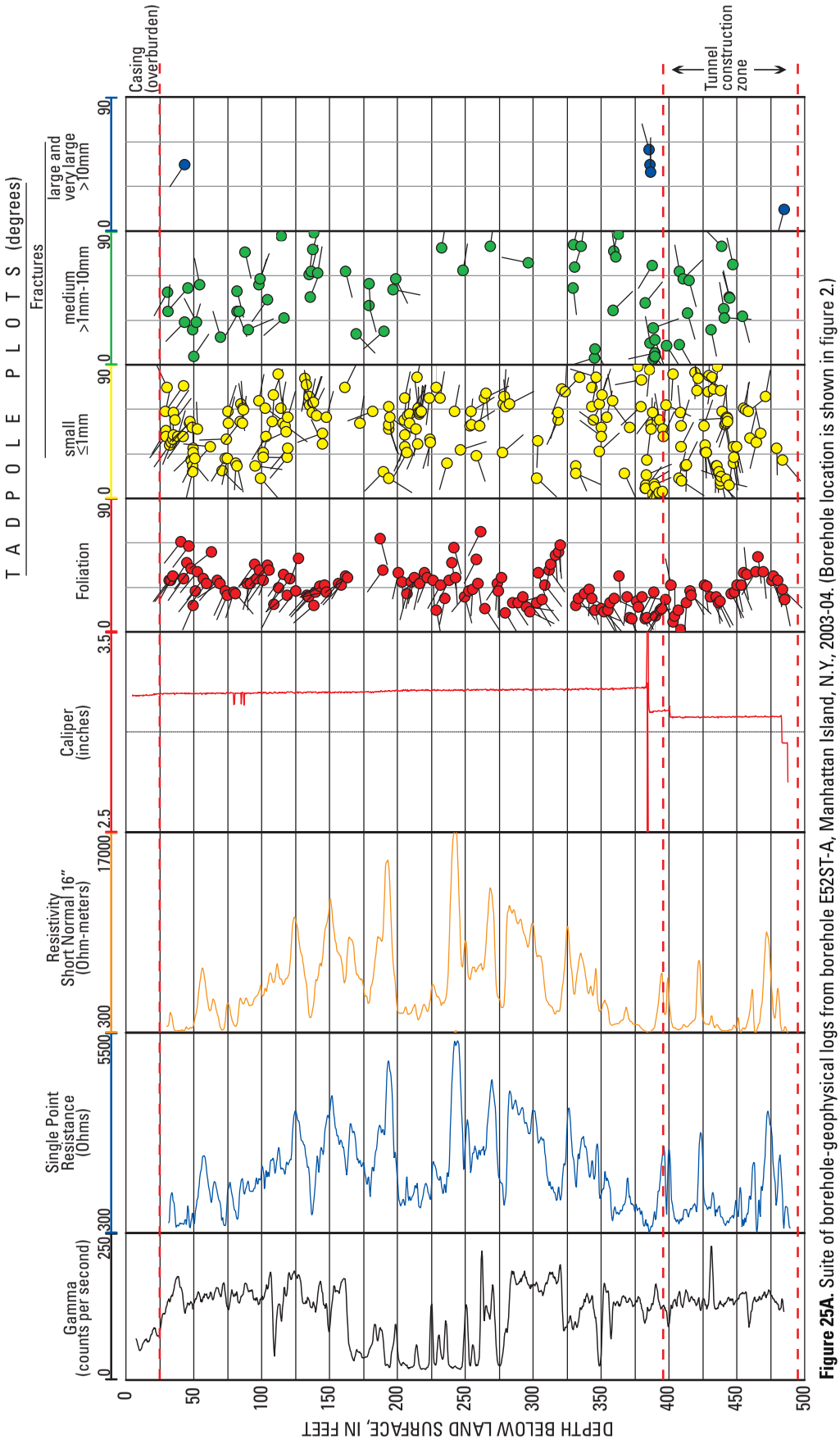


Figure 25A. Suite of borehole-geophysical logs from borehole E52ST-A, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 2.)

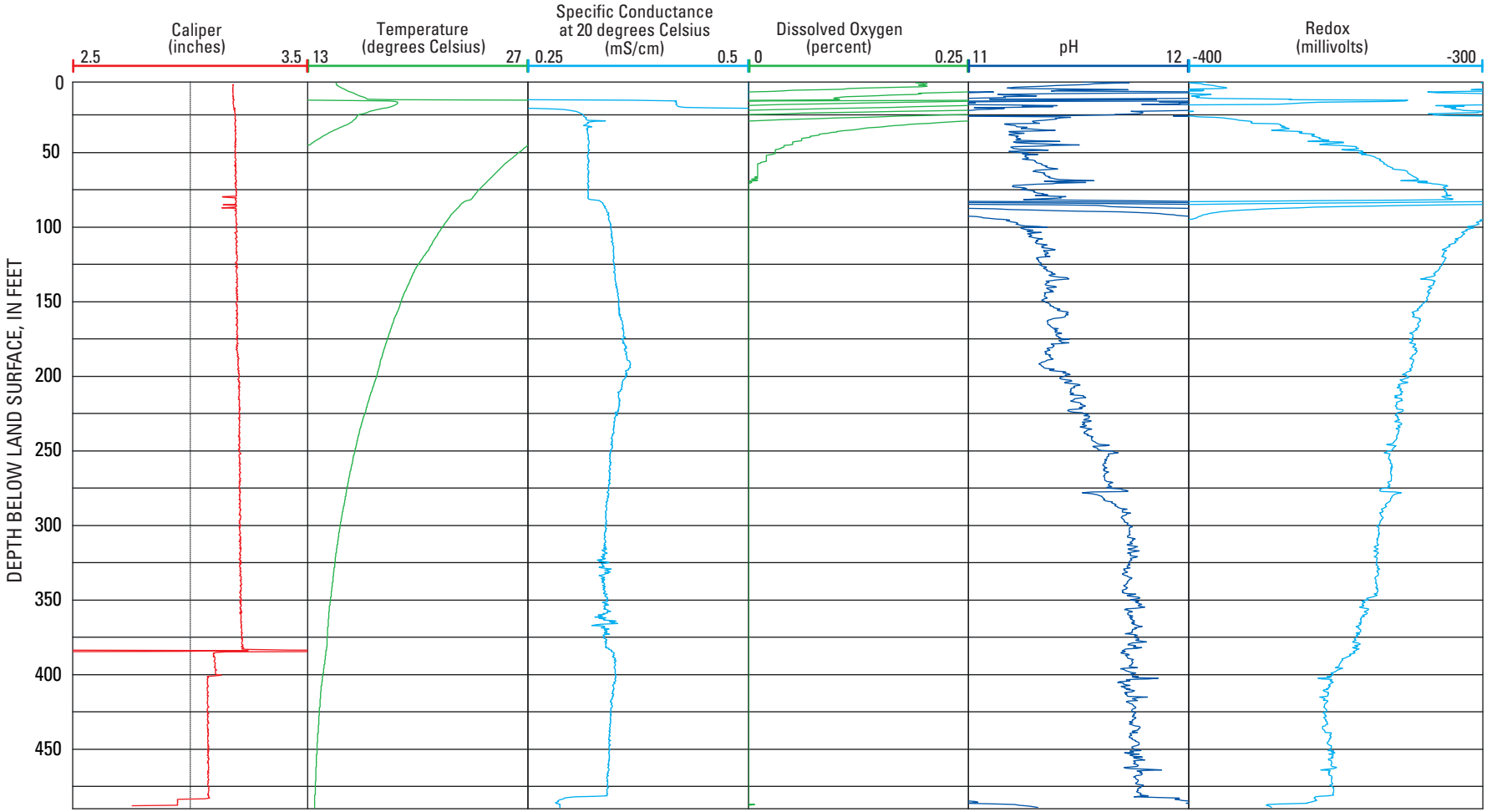


Figure 25B. Suite of borehole-geophysical logs from borehole E52ST-A, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 2.)

E54ST–A

The E54ST-A borehole has 25 ft of casing and extends 490 ft BLS (-451 ft elevation). The borehole is uncased in fractured bedrock.

Fractures and Foliation

A total of 451 fractures were detected by OTV and ATV log analysis. The borehole has a fracture index of 0.93, the largest fracture index of any Midtown Water-Tunnel borehole. Most fractures were small and medium. One very large fracture is detected at 237 ft BLS. Three faults were detected at 155, 168, and 392 ft BLS. Total borehole and PTCZ fracture orientations were highly scattered with two general populations: one is shallow-dipping to the southwest and the other is steeper and dips to the east (fig. 26). Total borehole and PTCZ mean foliation orientations were N18°W 14°SW and N17°W 14°SW, respectively (fig. 26).

The gamma log is uniform except for a low gamma-response zone from 360 to 400 ft and 445 to 460 ft BLS (fig. 27). These zones correlate with a hornblende schist. SPR and R indicate variations in lithology and in some cases, large fractures (low-resistivity zones). The deviation log indicated the bottom of the E54ST-A borehole is 13 ft from the origin, at an azimuth of 130º.

Ground-Water-Flow Zones

Hydraulic head in the E54ST-A borehole was 14.0 ft above sea level. The fluid parameter logs detected possible transmissive fractures at 35, 45, 60, 235, and 385 ft BLS, where changes in slope were observed (fig. 27). Analysis of specific-capacity test data in the E54ST-A borehole indicated it has a specific capacity of 0.22 (gal/min)/ft and a transmissivity of 61 ft^2/d.

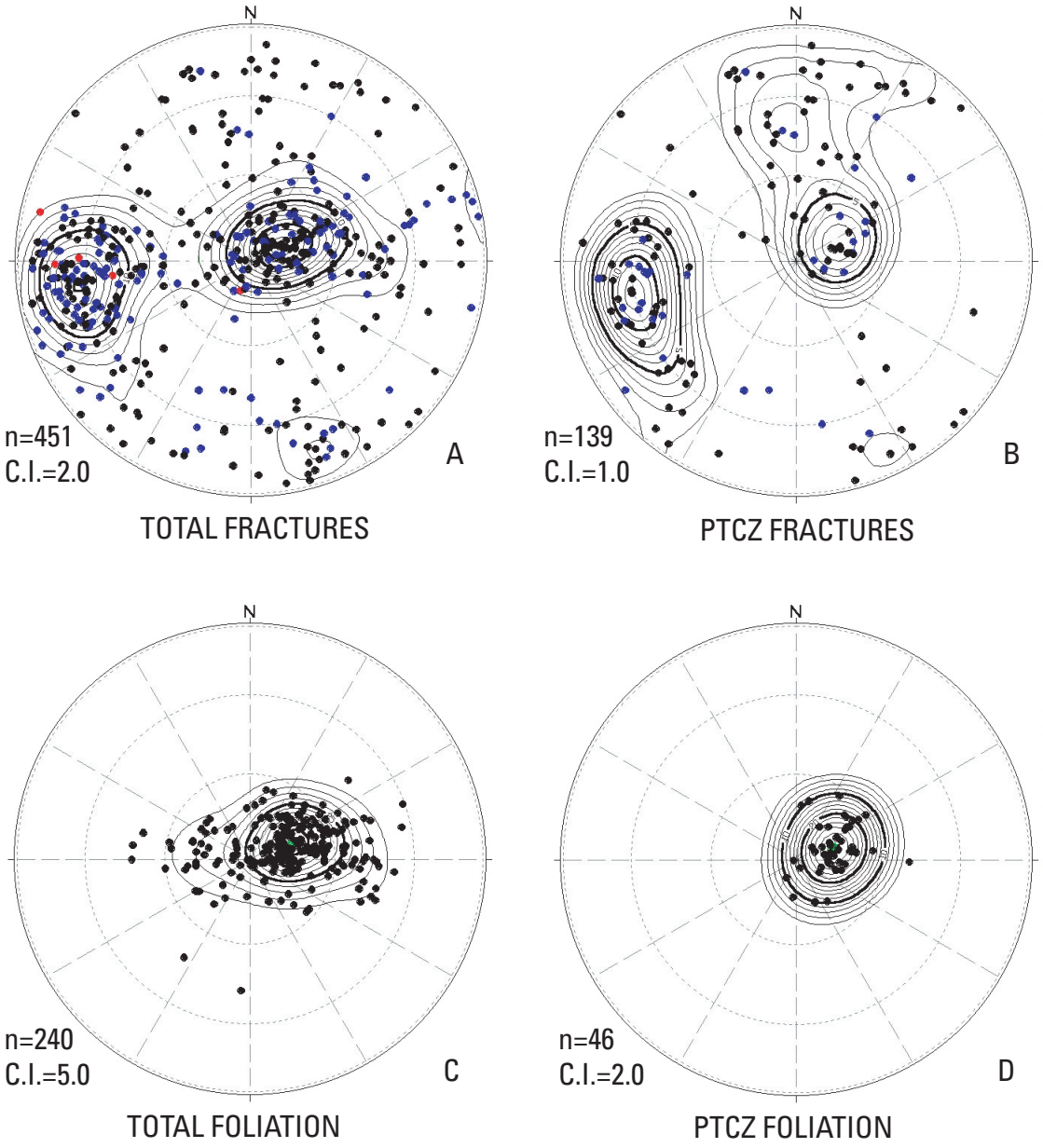


Figure 26. Stereonet plots of borehole E54ST-A, Manhattan Island, N.Y., 2003-04: A. Total fractures. B. PTCZ fractures. C. Total foliation. D. PTCZ foliation. (Borehole location is shown in figure 2.)

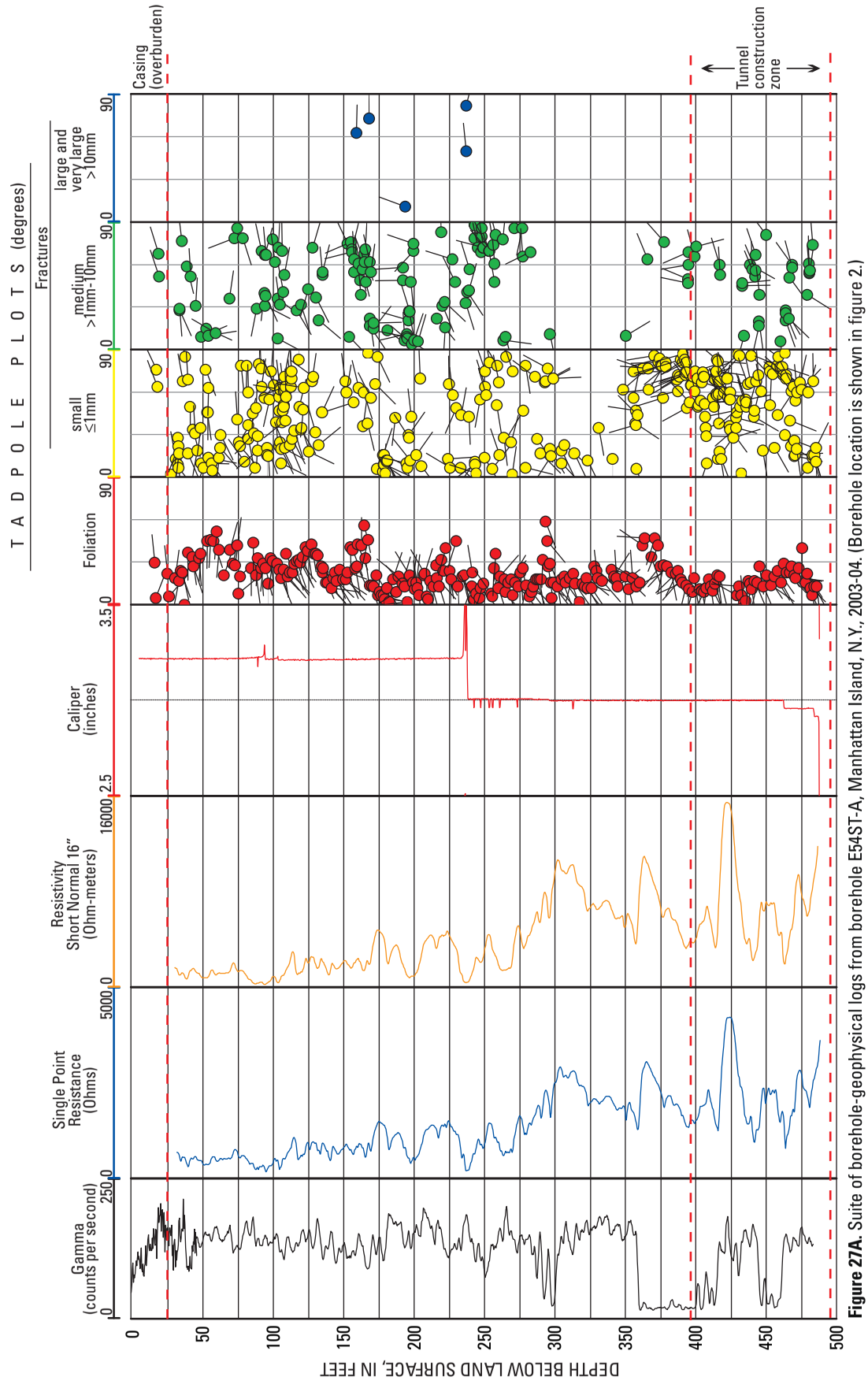


Figure 27A. Suite of borehole-geophysical logs from borehole E54ST-A, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 2.)

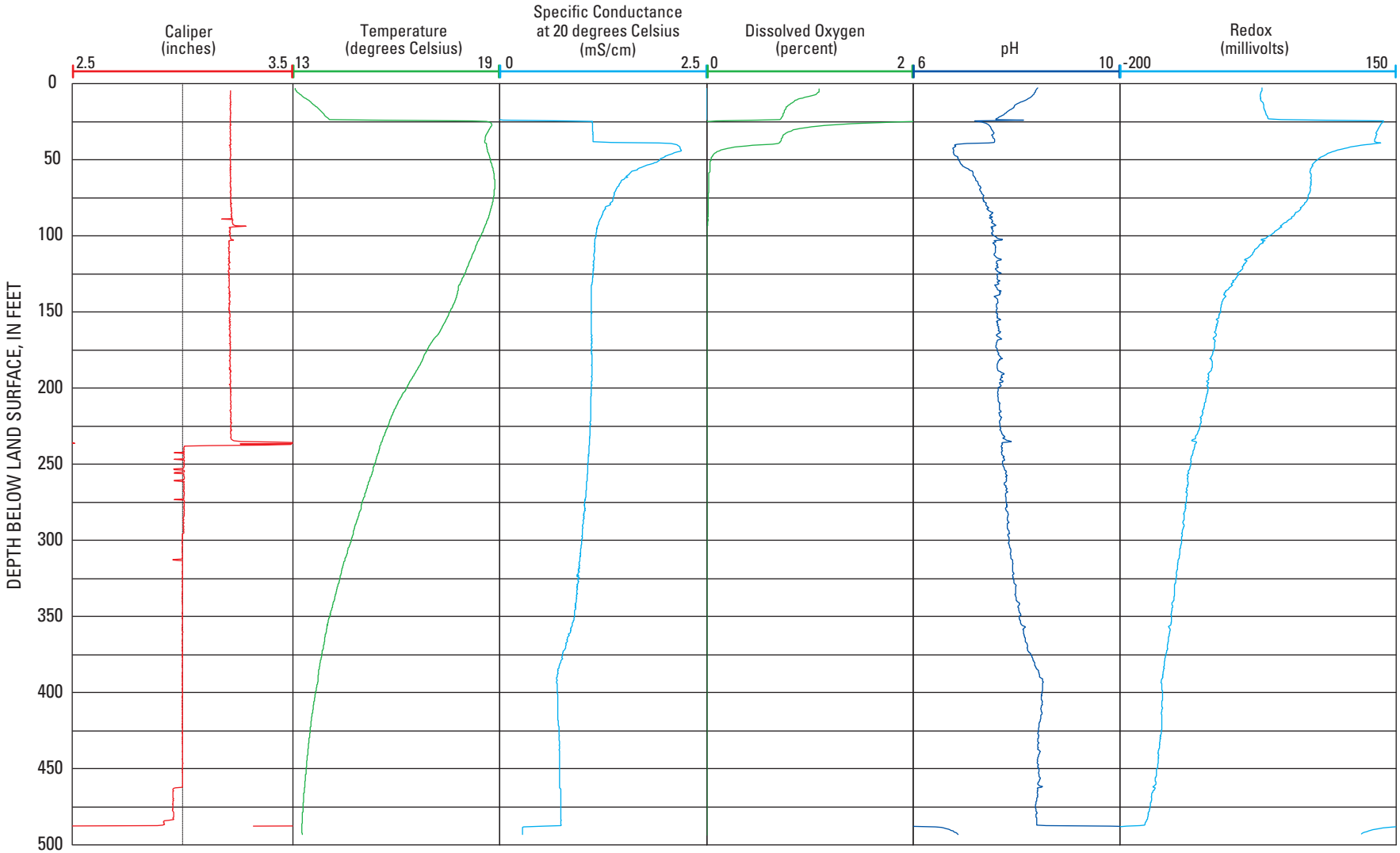


Figure 27B. Suite of borehole-geophysical logs from borehole E54ST-A, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 2.)

E55ST–B

The E55ST-B borehole has 18 ft of casing and extends 545 ft BLS (-502 ft elevation). The borehole is uncased in fractured bedrock.

Fractures and Foliation

The OTV and ATV logs detected a total of 496 fractures. The E55ST-B borehole has a fracture index of 0.92, the second largest fracture index of any Midtown Water-Tunnel borehole. Most fractures were small and medium, with only three large fractures detected. Six faults were detected using OTV data at 411, 413, 441, 484, and 518 ft BLS. Borehole radar logging imaged four potentially large fractures or faults that did not intersect the borehole. Their orientations were estimated to be N89ºW 83ºS, N01°E 61°E, N40°W 71°NE and N01°E 70°W, respectively.

The total borehole and the PTCZ both have two population clusters of fractures, one sub-horizontal and the other steeply dipping to the SE (fig. 28). Total borehole and PTCZ mean foliation orientation is N47°W 10°SW and N65°W 18°SW, respectively (fig. 28). A low gamma-response zone from 360 to 445 ft BLS correlates to a hornblende schist (fig. 29). The deviation log indicated the bottom of the E55ST-B borehole is 21 ft from the origin, at an azimuth of 32º.

Ground-Water-Flow Zones

Hydraulic head in the E55ST-B borehole was 11.1 ft above sea level. A standard fluid temperature and fluid resistivity log was completed. The fluid logs indicate possible transmissive fractures at 35, 165, 200, 335, 420, 425, 460, 470, and 480 ft BLS, where slope changes were observed (fig. 29). Analysis of the specific-capacity test data indicated the specific capacity for E55ST-B is 0.05 (gal/min)/ft and the transmissivity was 14 ft^2/d. Pumping at the nearby E54ST-A borehole induced a drawdown in the water levels in the E55ST-B borehole. This indicates the transmissive fractures in these boreholes extend large distances away and that both boreholes are hydraulically connected.

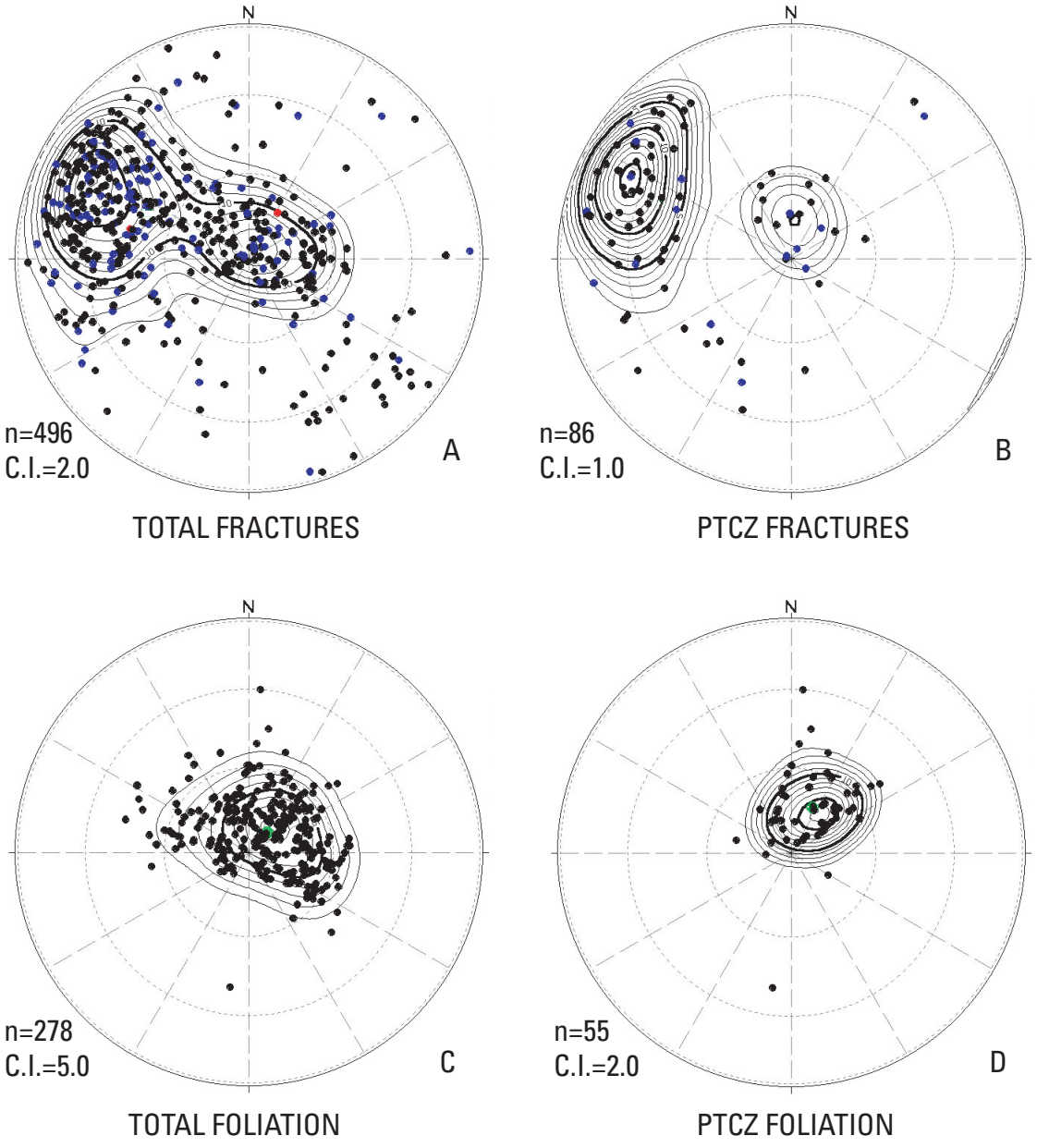


Figure 28. Stereonet plots of borehole E55ST-B, Manhattan Island, N.Y., 2003-04: A. Total fractures. B. PTCZ fractures. C. Total foliation. D. PTCZ foliation. (Borehole location is shown in figure 2.)

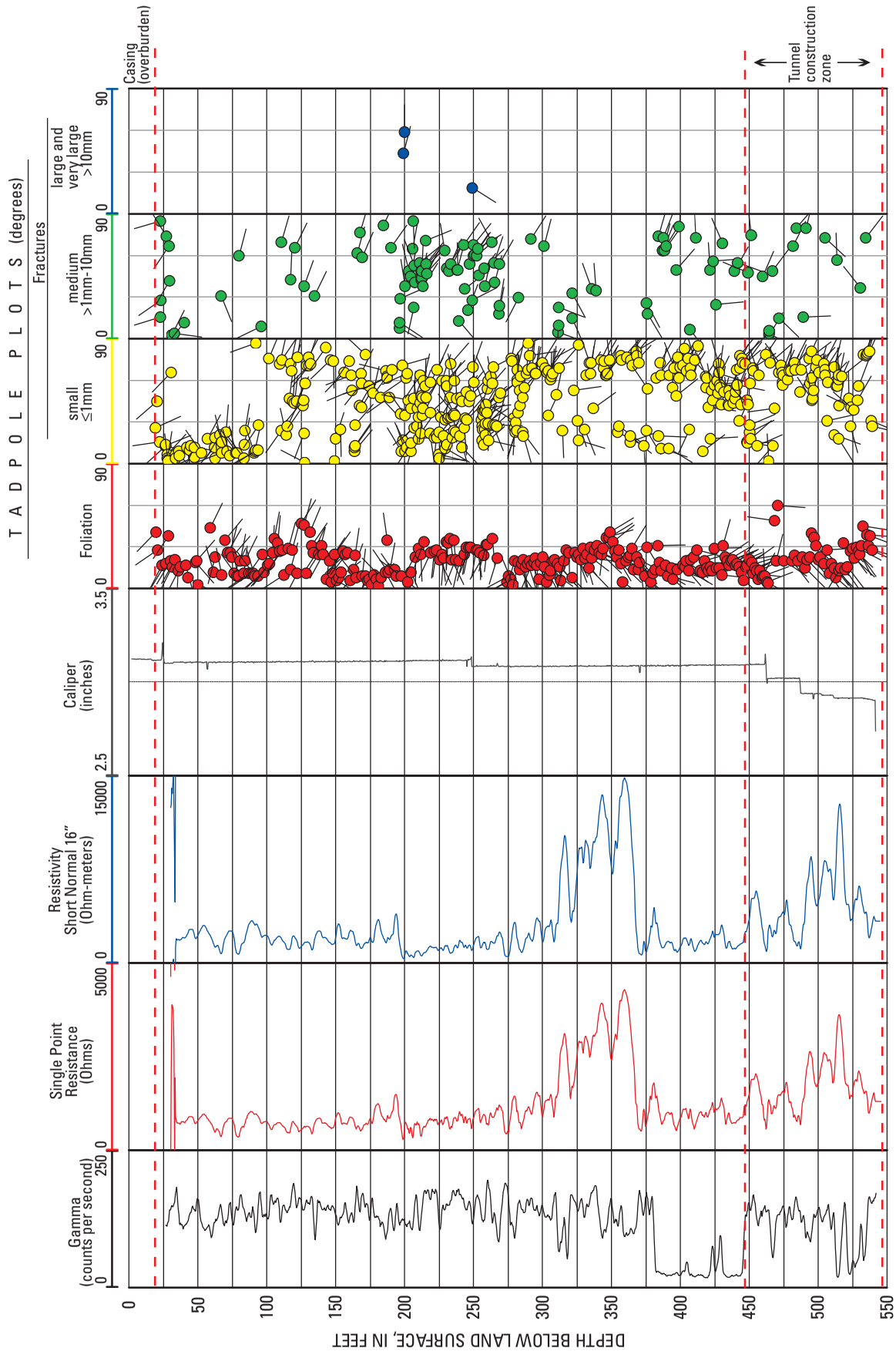


Figure 29A. Suite of borehole-geophysical logs from borehole E55ST-B, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 2.)

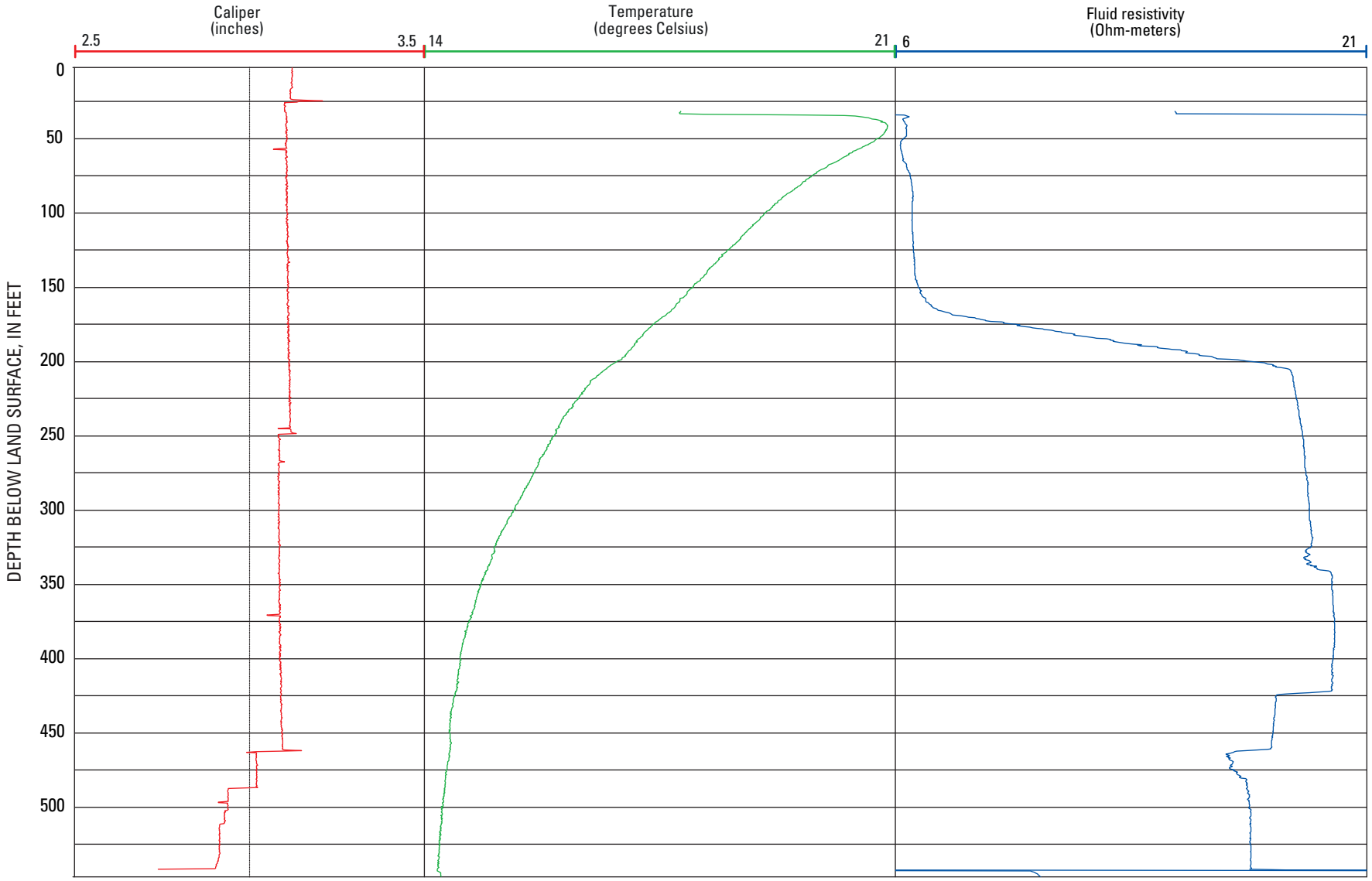


Figure 29B. Suite of borehole-geophysical logs from borehole E55ST-B, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 2.)

South Water-Tunnel

The South Water-Tunnel boreholes included Ericsson-A, FranklinST-B, FranklinST-A, HesterST-A, GrandST-B, ElizabethST-A, CrosbyST-A, MulberryST-A, PrinceST-A, BondST-A, and 31B-1 (fig. 3, table 1). Appendix 3 lists depth, dip azimuth and dip angle of fractures and foliation (and fracture size) observed by optical televiewer in South Water-Tunnel boreholes.

Ericsson-A

The Ericsson-A borehole has a 96 ft casing and extends to 525 ft BLS. The borehole is uncased in fractured bedrock.

Fractures and Foliation

OTV analysis indicated a total of 131 fractures throughout the borehole with a fracture index of 0.30. The fractures were predominantly small throughout, with medium and large fractures in the upper 175 ft BLS. Total borehole and PTCZ mean fracture orientations were N01˚W 43˚W and N13˚W 53˚SW, respectively (fig. 30). Total borehole and PTCZ foliation mean population orientations were N03˚W 60˚W and N08˚W 74˚W, respectively (fig. 30). A serpentinite zone is detected in OTV, gamma, SPR, and R logs between 225 and 340 ft BLS. The gamma log response in this zone is nearly zero and the electric logs indicated high resistivity (fig. 31). A shift in the foliation dip azimuths and dip angles was also noted within the serpentinite zone. The deviation log indicated the bottom of the borehole is 20 ft from the origin, with an azimuth of 142˚.

Ground-Water-Flow Zones

The hydraulic head in Ericsson-A was -0.5 ft elevation and did not appear to be tidally affected. The borehole is within a local cone of depression that is probably related to the dewatering of a shallow railway tunnel. The fluid parameter logs have changes in slope at 105, 130, 155, and 400 ft BLS (fig. 31). These correlate to medium and large fractures that may be transmissive. Specific-capacity test analysis indicated the Ericsson-A borehole had a specific capacity of 0.07 (gal/min)/ft and a total borehole transmissivity of 19 ft^2/d.

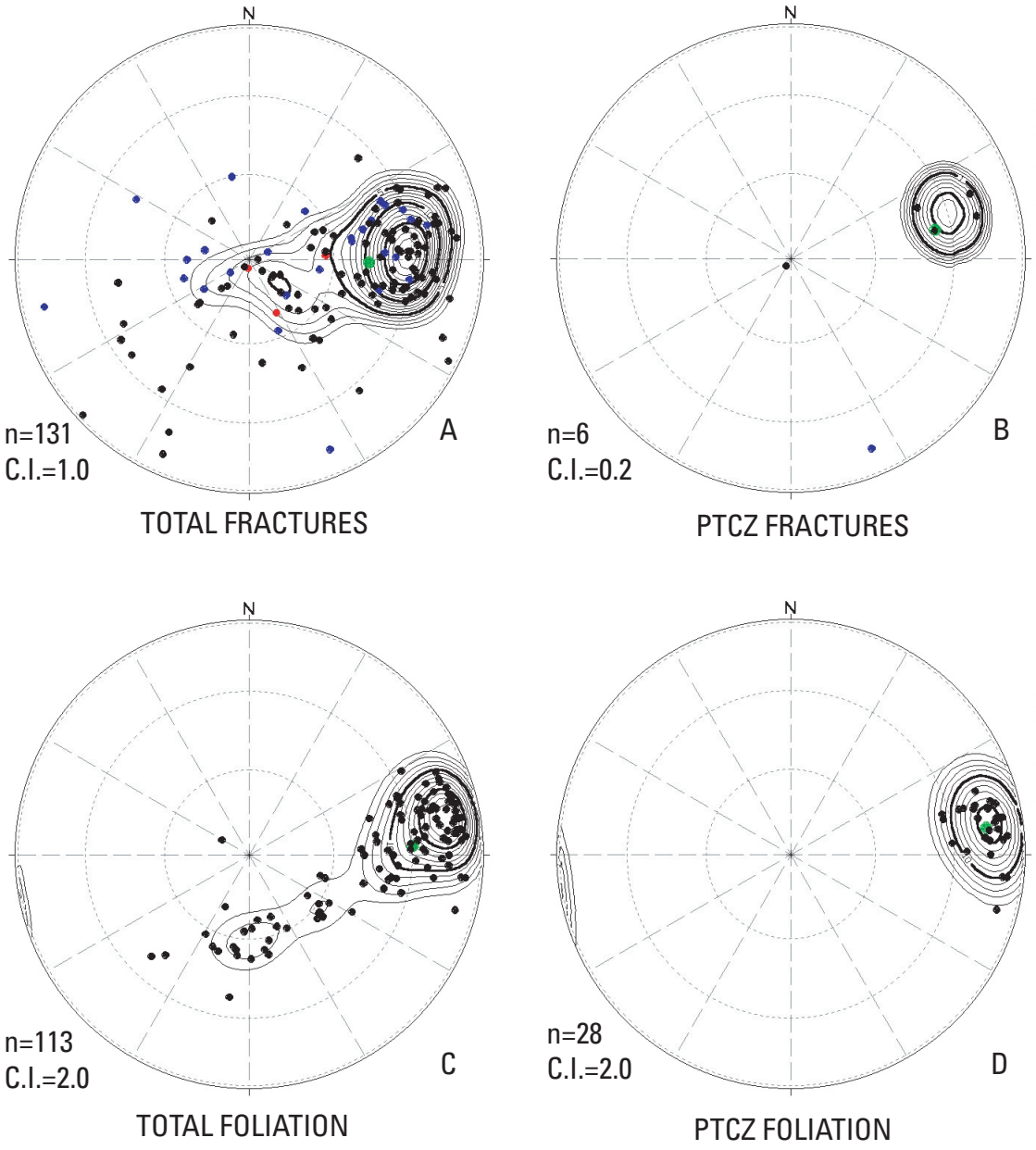


Figure 30. Stereonet plots of borehole Ericsson-A, Manhattan Island, N.Y., 2003-04: A. Total fractures. B. PTCZ fractures. C. Total foliation. D. PTCZ foliation. (Borehole location is shown in figure 3.)

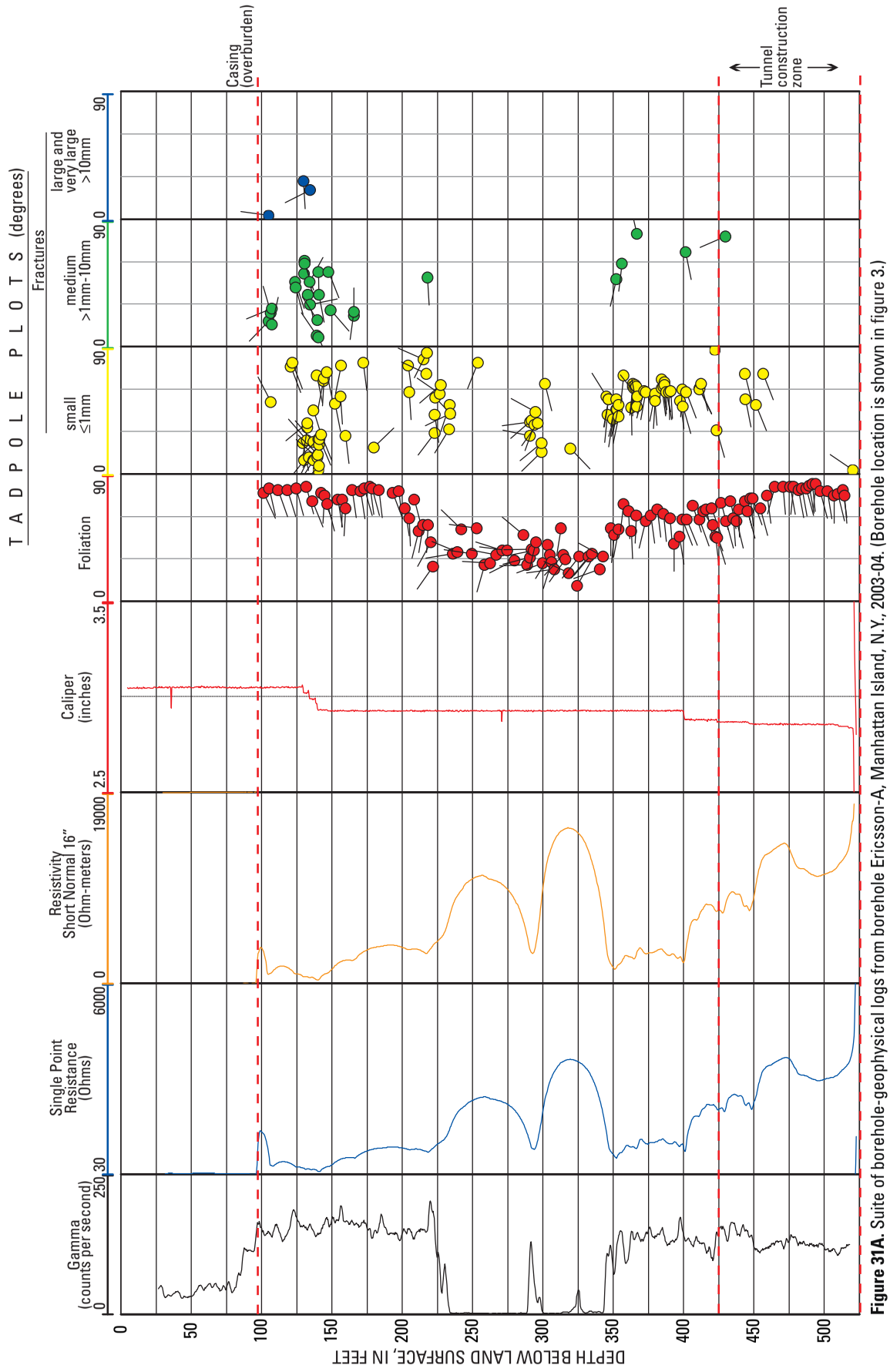


Figure 31A. Suite of borehole-geophysical logs from borehole Ericsson-A, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 3.)

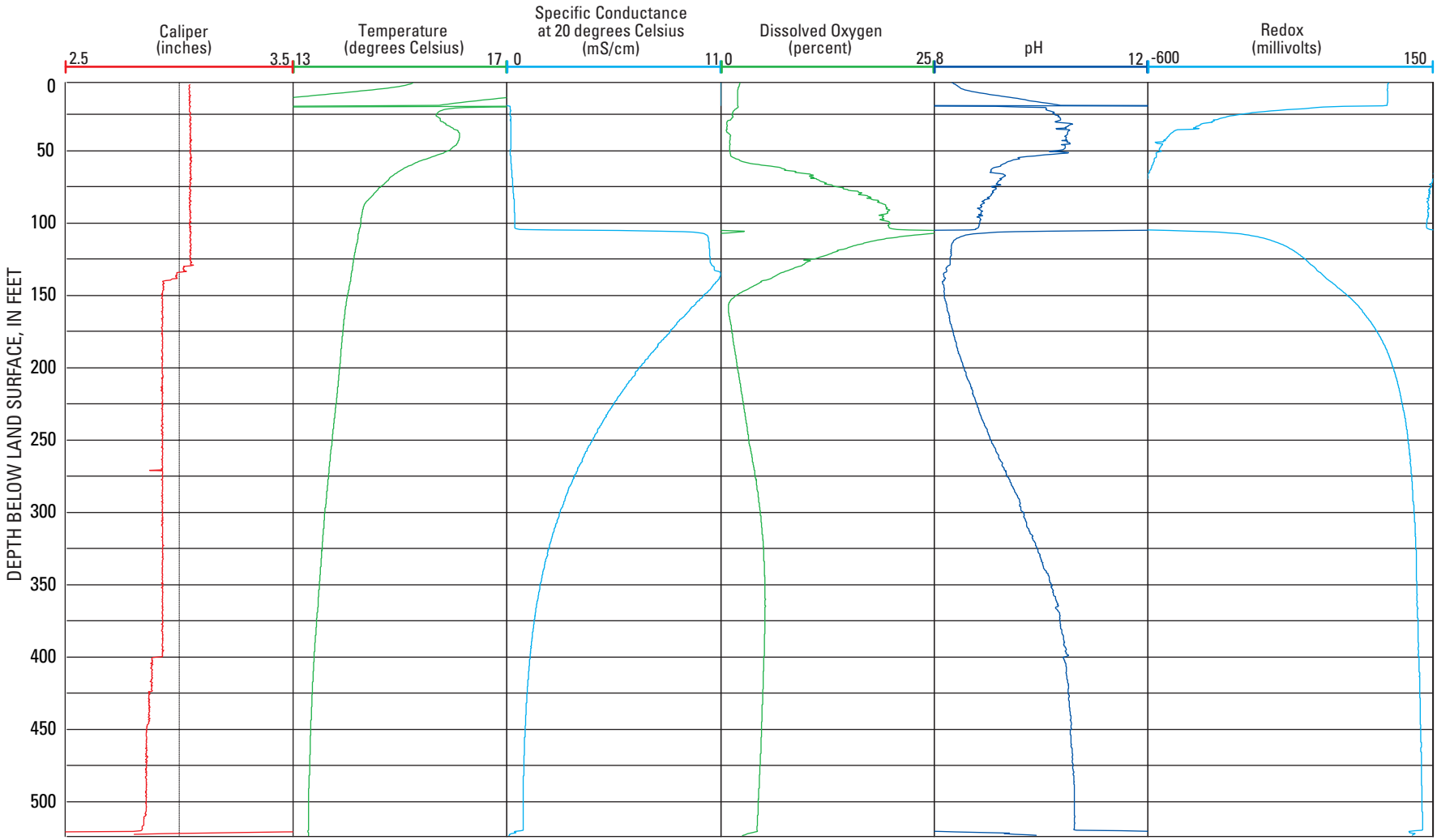


Figure 31B. Suite of borehole-geophysical logs from borehole Ericsson-A, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 3.)

FranklinST-B

The FranklinST-B borehole has 86 ft of casing and extends 555 ft BLS (-543.6 ft elevation). The borehole is uncased in fractured bedrock.

Fractures and Foliation

OTV analysis indicated a total of 58 fractures within the borehole and a fracture index of 0.12, which is the lowest of any southern Manhattan borehole analyzed. The fractures were predominantly small and medium with three large fractures detected within the PTCZ. Two of these large fractures (at 549 and 550 ft BLS) were considered gouge zones. Total borehole and PTCZ mean fracture orientations were N52˚E 08˚NW and N18˚E 41˚NW, respectively (fig. 32). The total borehole stereonet of foliation indicated two major population clusters with orientations of N15˚E 89˚SE and N16˚E 89˚NW (fig. 32). The foliation is nearly vertical in this borehole, with the highest dip angles measured of any southern Manhattan borehole. The PTCZ foliation mean population orientation is N15˚E 85˚NW, respectively.

The SPR and R logs indicated a slight increase in rock resistivity with depth and delineated all large fractures and some medium fractures as low-resistivity zones (fig. 33). The deviation log indicated the bottom of the borehole is 18 ft from the origin, with an azimuth of 90˚.

Ground-Water-Flow Zones

The hydraulic head in FranklinST-B was -0.5 ft elevation. The borehole is within a local cone of depression. The fluid parameter logs indicated changes in slope at 95, 125, and 475 ft BLS (fig. 33). The DO log indicated increases in oxygen concentrations below 150 ft BLS, possibly due to steeply dipping fractures carrying shallow sources of ground water that may have intersected the large fractures penetrated by the borehole. Specific-capacity test analysis indicate the FranklinST-B borehole has a specific capacity of 0.59 (gal/min)/ft and the total borehole transmissivity is calculated to be 170 ft^2/d.

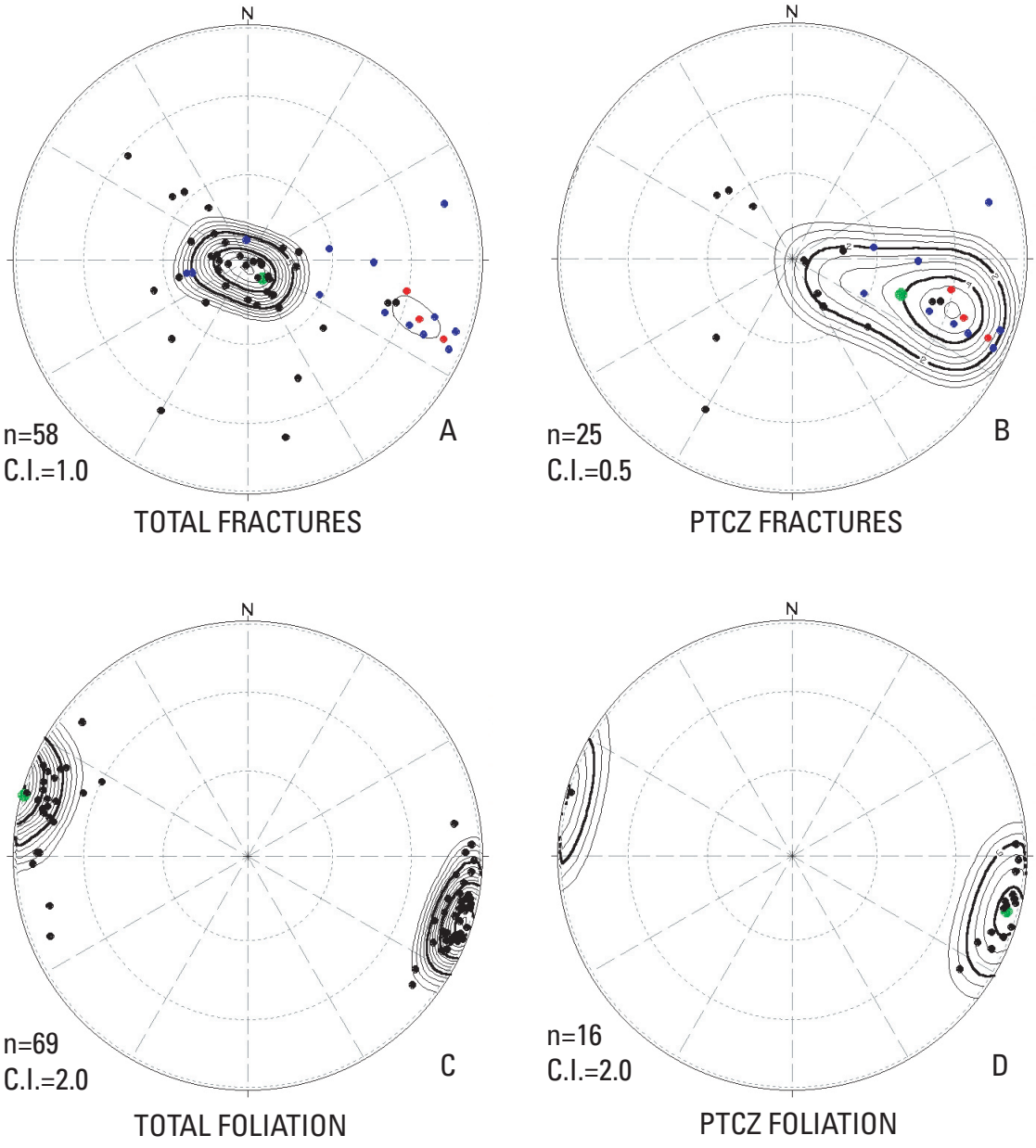


Figure 32. Stereonet plots of borehole FranklinST-B, Manhattan Island, N.Y., 2003-04: A. Total fractures. B. PTCZ fractures. C. Total foliation. D. PTCZ foliation. (Borehole location is shown in figure 3.)

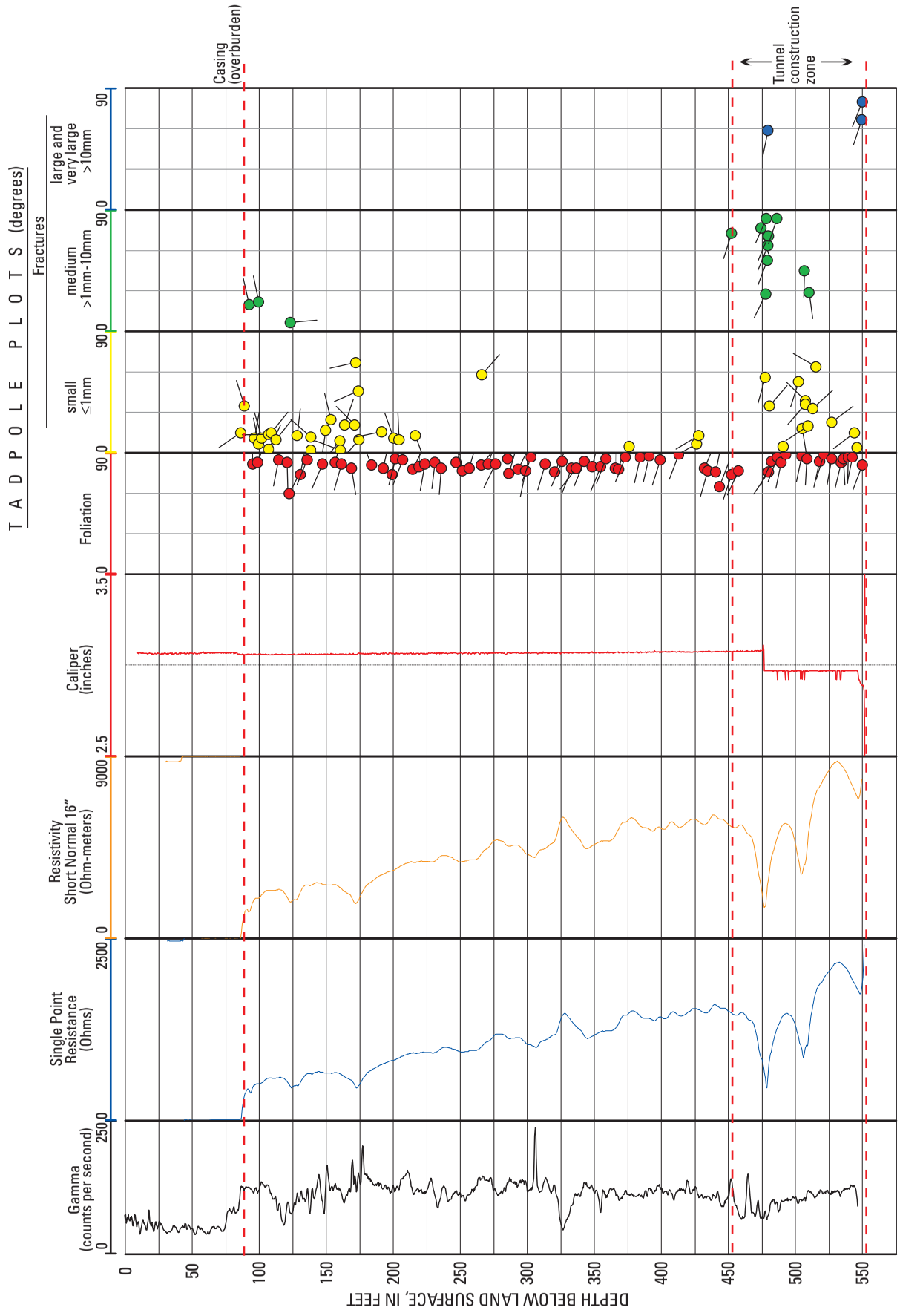


Figure 33A. Suite of borehole-geophysical logs from borehole FranklinST-B, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 3.)

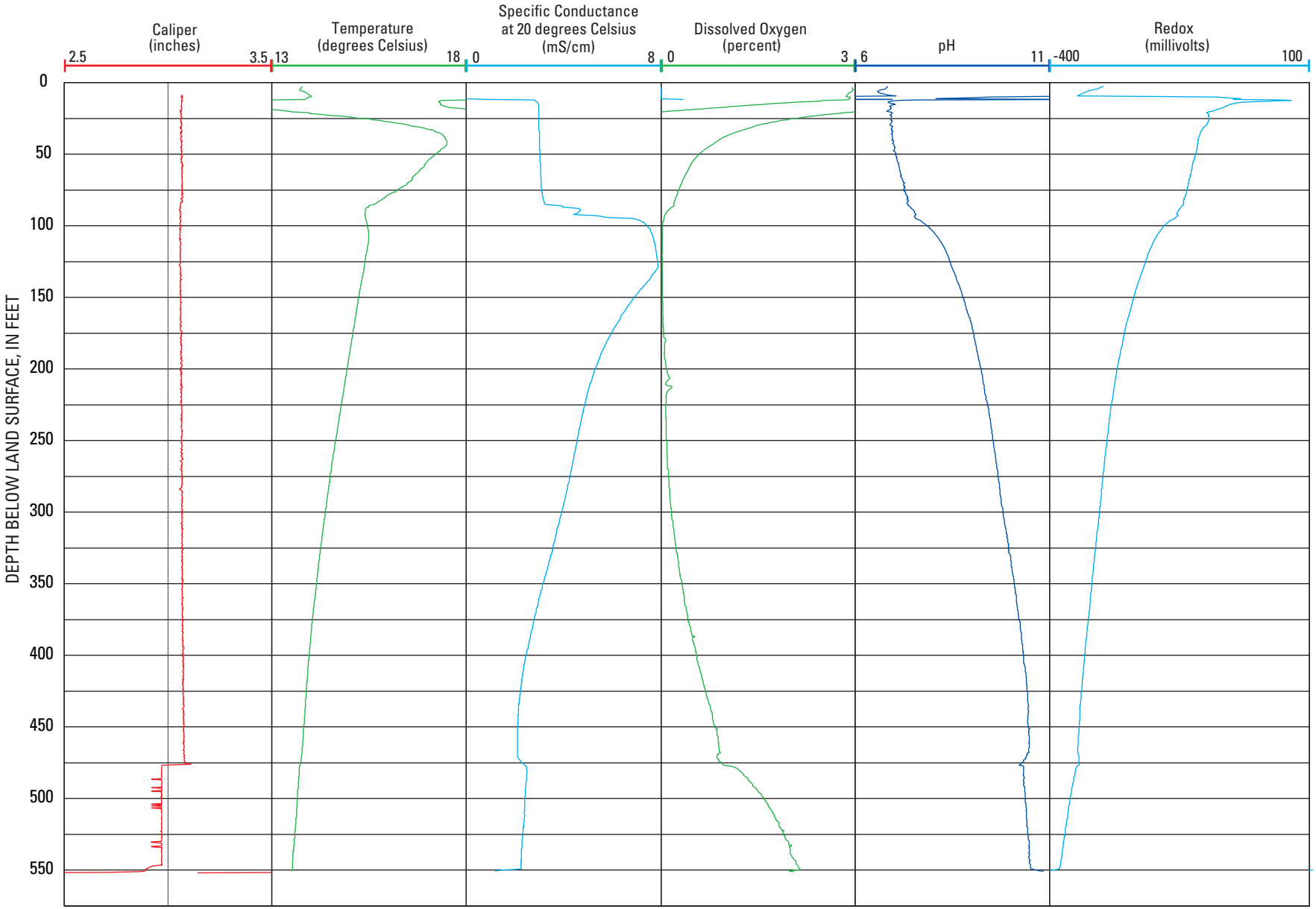


Figure 33B. Suite of borehole-geophysical logs from borehole FranklinST-B, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 3.)

FranklinST-A

The FranklinST-A borehole has 120 ft of casing and extends 545 ft BLS (-525.1 ft elevation). The borehole is uncased in fractured bedrock.

Fractures and Foliation

OTV analysis indicated a total of 120 fractures throughout the uncased borehole, with a fracture index of 0.28. The total borehole and PTCZ mean fracture orientations were N05˚E 04˚E and N20˚E 07˚SE, respectively (fig. 34). One fault is detected at 440 ft BLS. The fractures were predominantly small and medium. Total borehole and PTCZ mean foliation orientations were N12˚E 72˚NW and N20˚E 71˚NW, respectively (fig. 34).

The gamma log is fairly uniform except for the sediment (overburden), which has a lower gamma response compared to the bedrock (fig. 35). The SPR and R logs indicated a slight increase in rock resistivity with depth and delineated many of the medium and all of the large fracture zones as low-resistivity areas (fig. 35). The deviation log indicated the bottom of the borehole is 34 ft from the origin, with an azimuth of 210˚.

Ground-Water-Flow Zones

The hydraulic head in FranklinST-A was -0.2 ft elevation. The borehole is within a large local cone of depression. The fluid parameter logs indicated changes in slope at 125, 150, 190, 320, 405, and 450 ft BLS, indicating potentially transmissive fractures at these depths (fig. 35). Analysis of the specific-capacity test data indicated the FranklinST-A borehole has a specific capacity of 1.3 (gal/min)/ft, and a transmissivity of 387 ft^2/d. This borehole has the highest transmissivity of any South Water-Tunnel borehole and the second highest of all southern Manhattan boreholes tested.

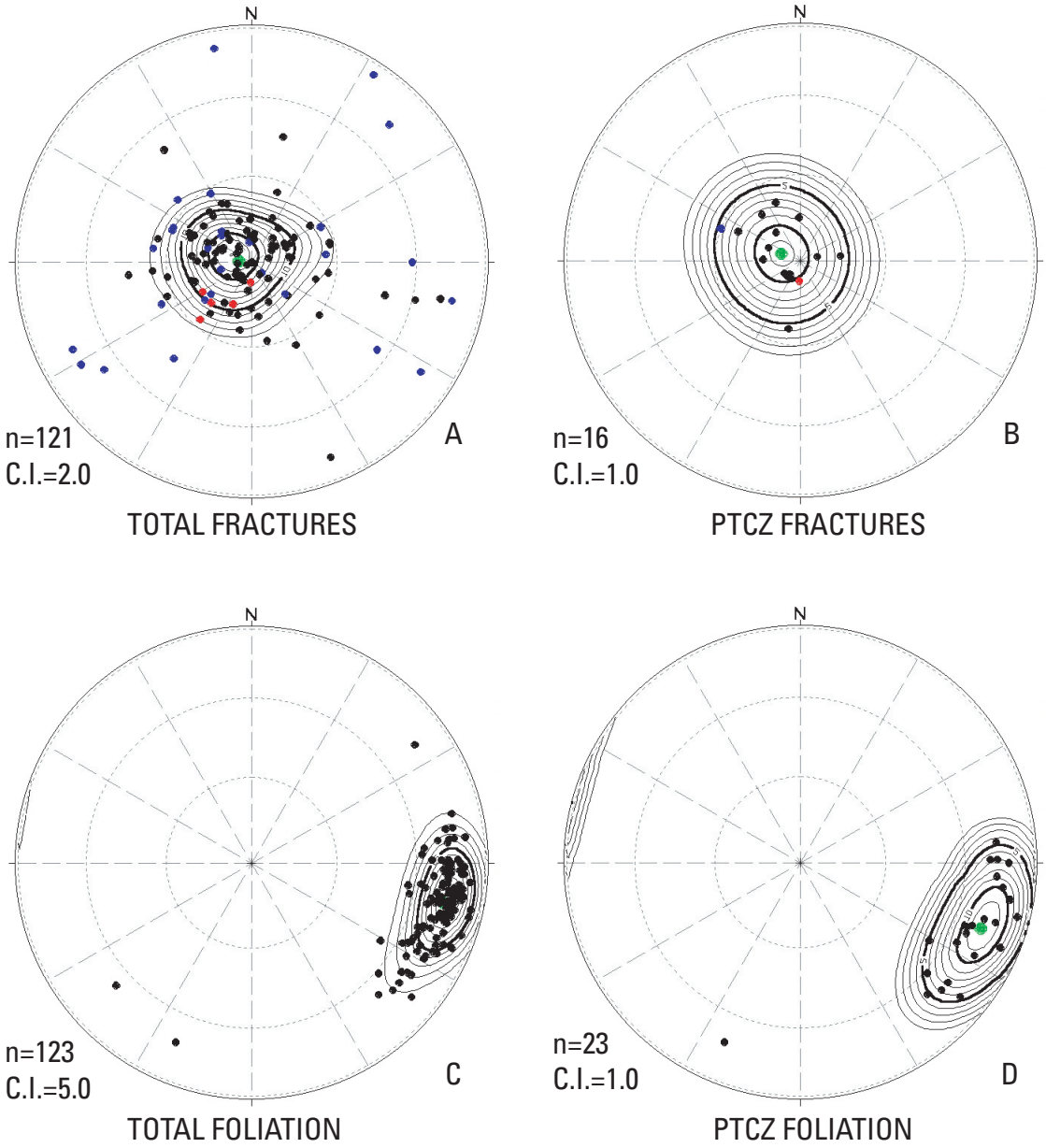


Figure 34. Stereonet plots of borehole FranklinST-A, Manhattan Island, N.Y., 2003-04: A. Total fractures. B. PTCZ fractures. C. Total foliation. D. PTCZ foliation. (Borehole location is shown in figure 3.)

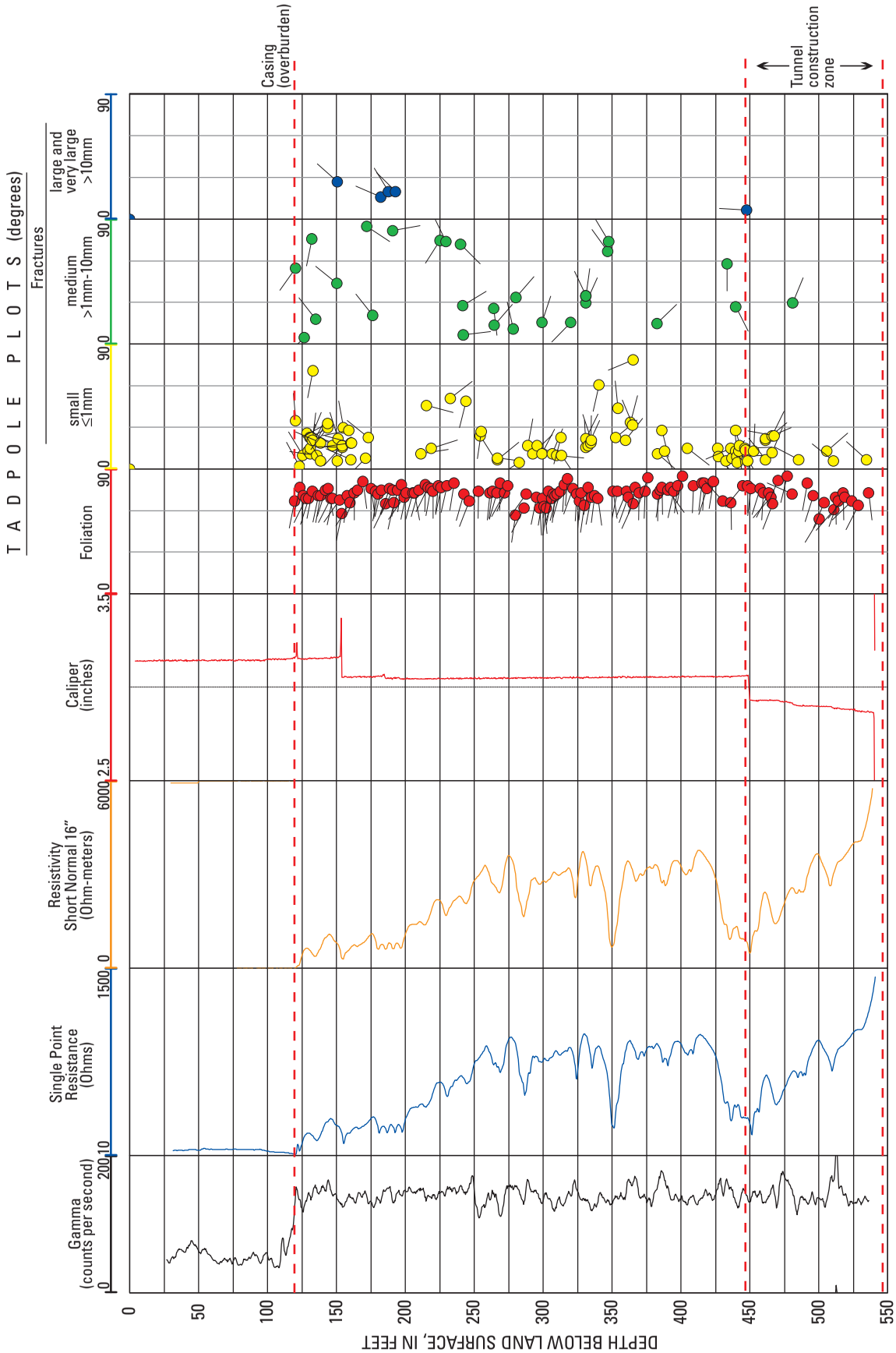


Figure 35A. Suite of borehole-geophysical logs from borehole FranklinST-A, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 3.)

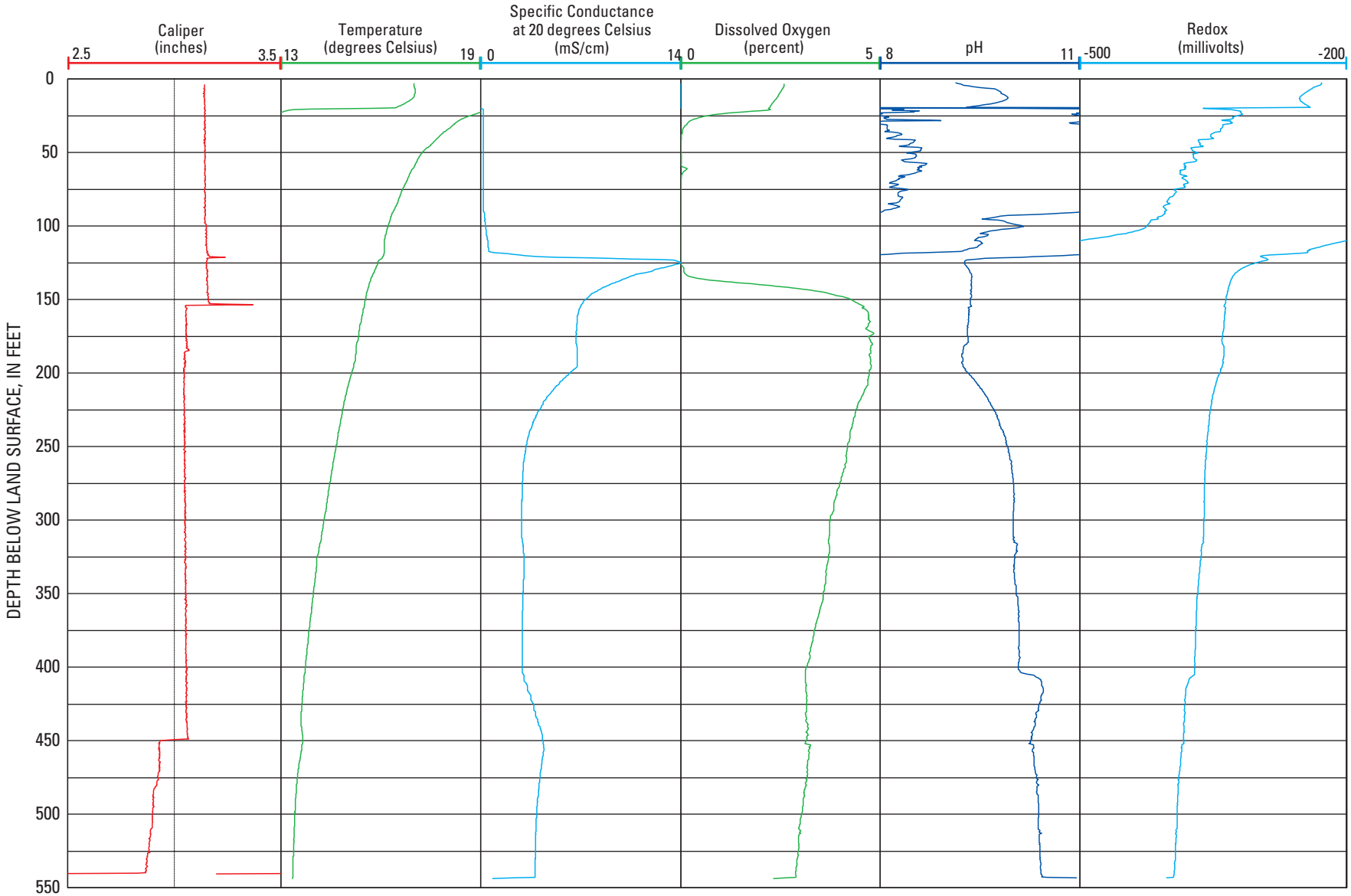


Figure 35B. Suite of borehole-geophysical logs from borehole FranklinST-A, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 3.)

HesterST-A

The HesterST-A borehole was not geophysically logged. The hydraulic head in the borehole was 1.4 ft above sea level and is within the southern ground-water discharge zone for the Manhattan Island fractured-rock ground-water-flow system. Analysis of specific-capacity test data indicated the HesterST-A borehole has a specific capacity of 0.75 (gal/min)/ft and a transmissivity of 219 ft^2/d.

Geophysical logs were not collected at the HesterST-A borehole.

GrandST-B

The GrandST-B borehole has a 112 ft casing and extends 547.4 ft BLS (-521.8 ft elevation). The borehole is uncased in fractured bedrock.

Fractures and Foliation

OTV log data analysis indicated 151 fractures were penetrated within the borehole. The GrandST-B borehole has a fracture index of 0.35. Most fractures were small and medium size. Total borehole and PTCZ mean fracture orientations were N08ºW 04ºNW and N01ºE 03ºNW, respectively (fig. 36). A secondary fracture population cluster is also indicated with a moderate dip angle toward the northwest. Total borehole and PTCZ foliation mean orientations were N16ºE 68ºNW and N17ºE 68ºNW, respectively (fig. 36).

The gamma log is fairly uniform throughout the borehole except within the upper 110 ft, which consists of overburden sediment that overlies the bedrock below (fig. 37). The gamma response in this zone is noticeably lower than for the bedrock. A transition from mica schist to schistose gneiss is delineated as a decrease in rock resistivity below 440 ft BLS (fig. 37). The deviation log indicated the bottom of the GrandST-B borehole is 16 ft from the origin, with an azimuth of 165º.

Ground-Water-Flow Zones

The hydraulic head in the GrandST-B borehole was 1.2 ft above sea level. The fluid parameter logs have slope changes at 115, 162, 165, 170, 180, 190, 212, 390, and 440 ft BLS, which indicate possible transmissive fractures at these depths (fig. 37). Analysis of the specific-capacity test data indicated the borehole has a specific capacity of 0.16 (gal/min)/ft and a transmissivity of 42 ft^2/d.

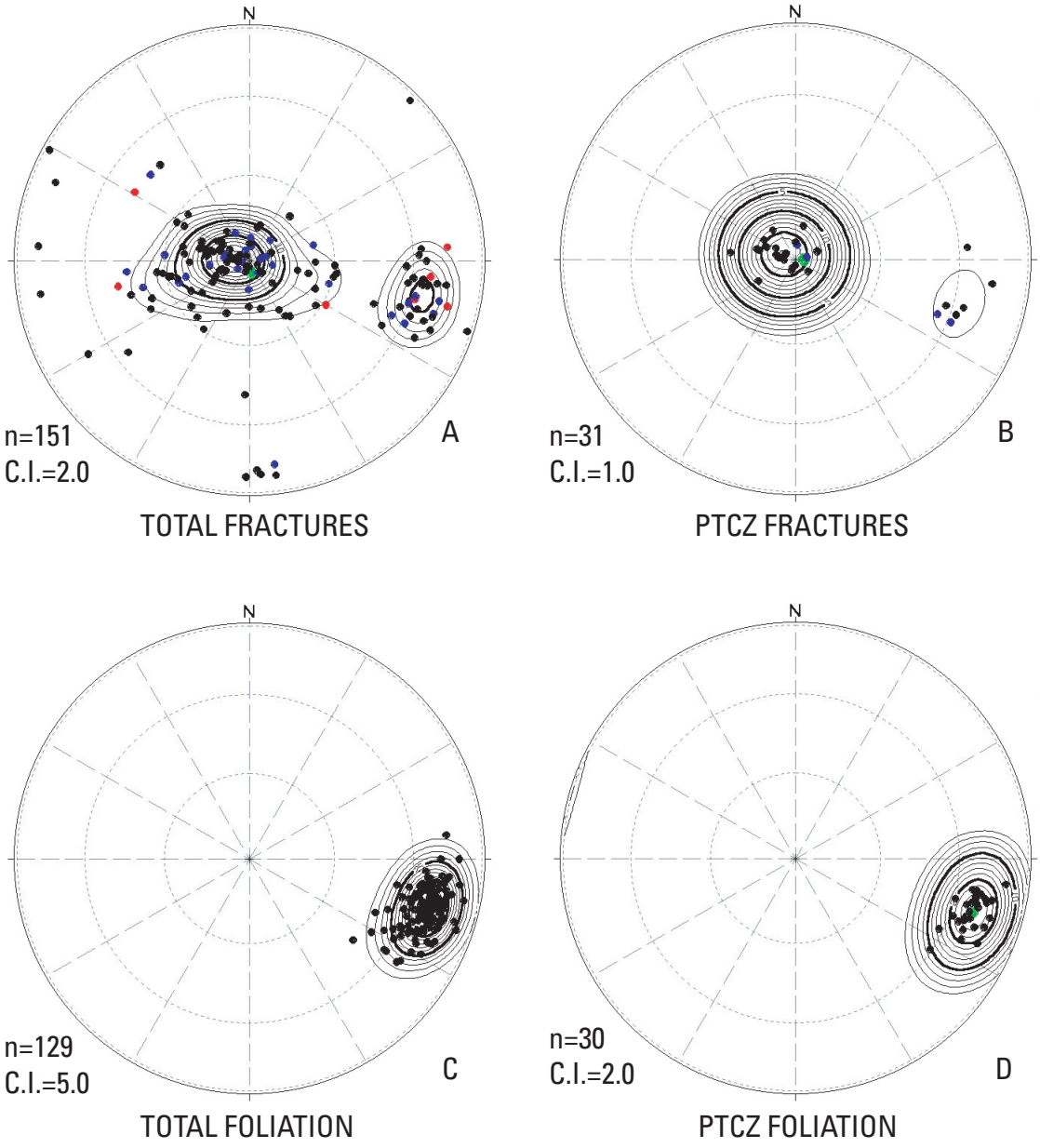


Figure 36. Stereonet plots of borehole GrandST-B, Manhattan Island, N.Y., 2003-04: A. Total fractures. B. PTCZ fractures. C. Total foliation. D. PTCZ foliation. (Borehole location is shown in figure 3.)

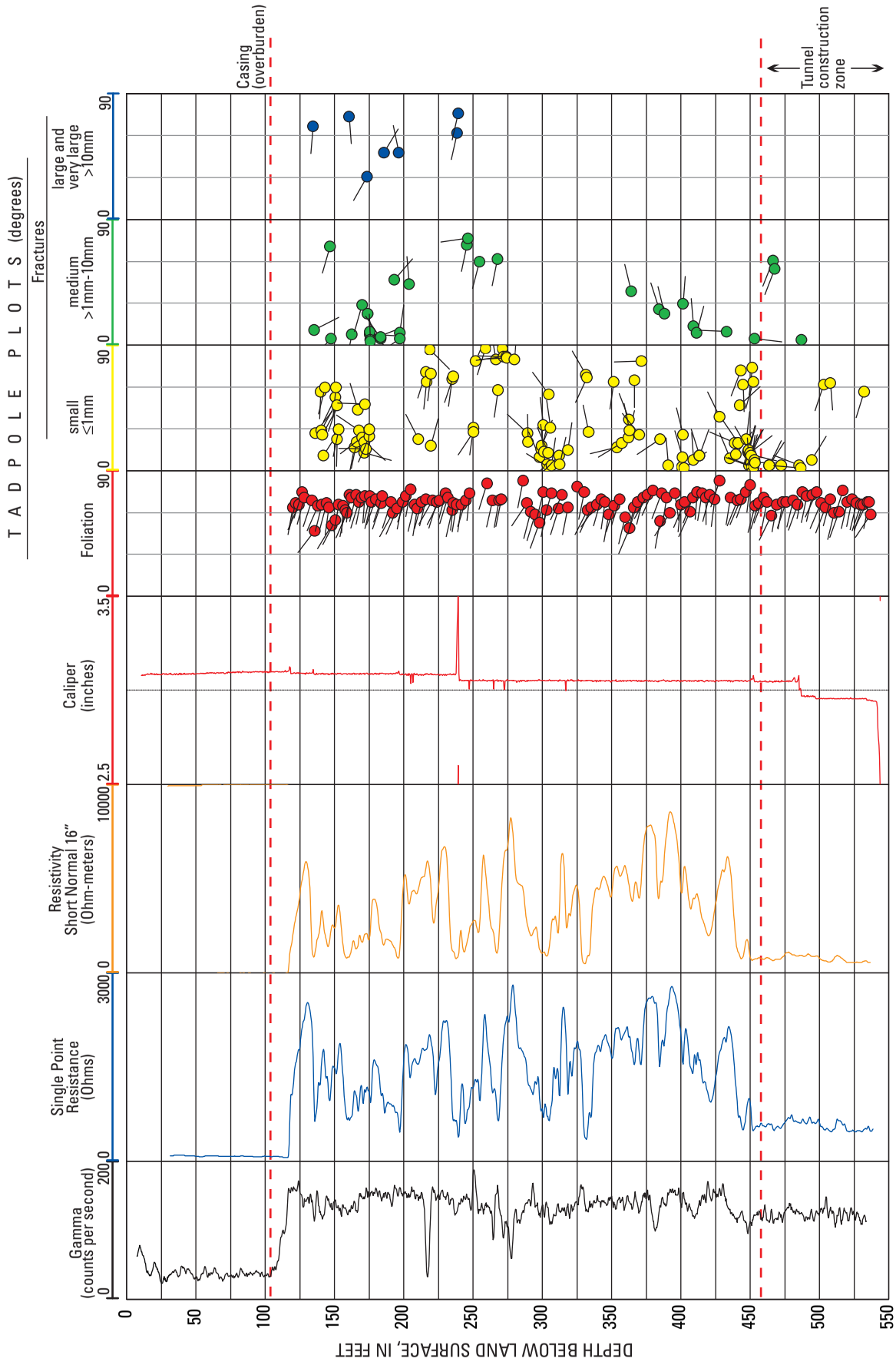


Figure 37A. Suite of borehole-geophysical logs from borehole GrandST-B, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 3.)

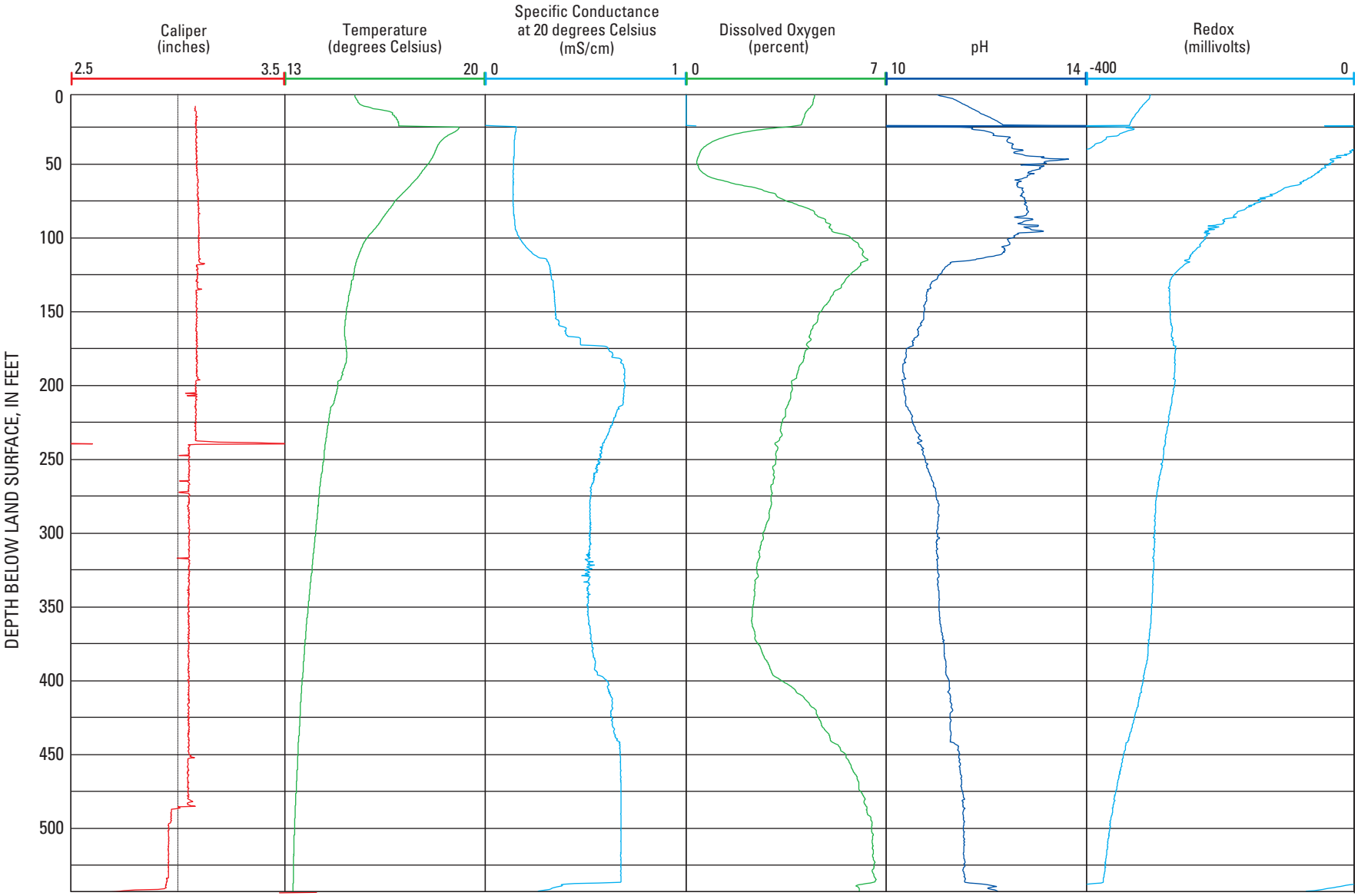


Figure 37B. Suite of borehole-geophysical logs from borehole GrandST-B, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 3.)

ElizabethST-A

The ElizabethST-A borehole was logged, but no further analysis was performed because the borehole is off the tunnel line. The hydraulic head in the borehole was 4.3 ft above sea level. Analysis of the specific-capacity test data indicated the ElizabethST-A borehole has a specific capacity of 0.12 (gal/min)/ft and a transmissivity of 32 ft^2/d.

CrosbyST-A

The CrosbyST-A borehole was not geophysically logged. The hydraulic head in the borehole was 2.4 ft above sea level. Specific-capacity test analysis indicated the borehole has a specific capacity of 1.1 (gal/min)/ft and a transmissivity of 341 ft^2/d. This is the second highest transmissivity calculated for any of the South Water-Tunnel boreholes.

MulberryST-A

The MulberryST-A borehole was not geophysically logged. The hydraulic head in the borehole was 3.6 ft above sea level. Specific-capacity test analysis indicated the borehole has a specific capacity of 0.05 (gal/min)/ft and a transmissivity of 12 ft^2/d.

Geophysical data is available for the ElizabethST-A borehole, however, it is not shown because the borehole is off the tunnel line.

Geophysical logs were not collected at the CrosbyST-A and MulberryST-A boreholes.

PrinceST-A

The PrinceST-A borehole has 120 ft of casing and extends 665 ft BLS (-618 ft elevation). The borehole is uncased in fractured bedrock.

Fractures and Foliation

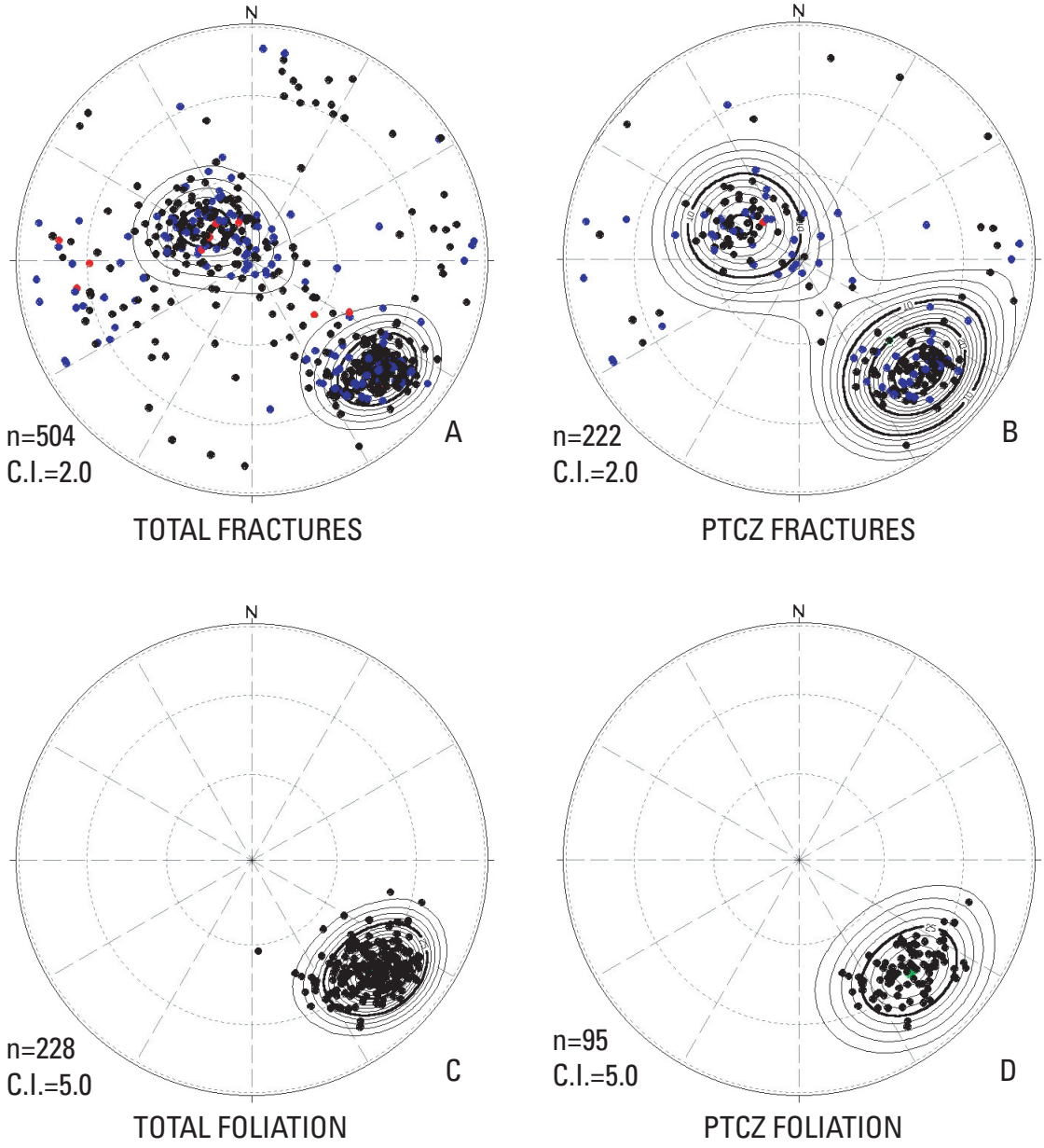
Analysis of the OTV and ATV log data indicated 504 fractures were penetrated within the borehole. The PrinceST-A borehole has a fracture index of 0.92. This borehole has the largest fracture index of any South Water-Tunnel borehole. The majority of the fractures were small and medium in size. A large fracture and gouge zone is detected at 235 ft BLS, with an orientation of N28ºE 39ºNW. Two faults were detected at 452 and 479 ft BLS, with orientations of N05ºW 82ºE and N04ºE 84ºW, respectively. Both the total borehole and PTCZ fracture stereonet plots indicate two major population clusters: one shallow dipping toward the southeast and the other moderately dipping toward the northwest (fig. 38).

Borehole radar logging imaged five potentially large fractures or faults away from the borehole. One feature is nearly vertical adjacent to the borehole with an estimated orientation of N10ºE 85ºSW. The other four features did not intersect the borehole and have orientations of N60ºW 58ºSW, N70ºW 63ºSW, N20ºW 67ºSW, and N20ºE 53ºSE. The total borehole and PTCZ mean foliation orientations were N42ºE 60ºNW and N45ºE 57ºNW, respectively (fig. 38).

The overburden sediment has lower gamma response than that of the bedrock below (fig. 39). The deviation log indicated the bottom of the borehole is 31 ft from the origin at an azimuth of 172º.

Ground-Water-Flow Zones

The hydraulic head in the PrinceST-A borehole was 4.3 ft above sea level. Fluid temperature and fluid resistivity logs have slope changes indicating a possible leaky casing at 100 ft BLS and potentially transmissive fractures at 120, 162, 407, 507, 615, 640, and 650 ft BLS (fig. 39). Specific-capacity test analysis indicated the PrinceST-A borehole has a specific capacity of 0.32 (gal/min)/ft and a transmissivity of 90 ft^2/d. Heat-pulse flowmeter logging within the borehole under ambient and pumping conditions indicated slight ambient upflow from 615 to 162 ft BLS (fig. 39). Transmissive fractures were delineated with the flowmeter at 162, 230, 407, 507, and 615 ft BLS. Analysis of the ambient and pumping flowmeter data indicate the fractures at 162, 230, 407, and 507 ft BLS have estimated transmissivities of 83, 2, 3, and 2 ft^2/d, respectively. The transmissivity of the zone at 615 ft BLS was not determined and is probably below the detection limit of the flowmeter.



EXPLANATION

- SMALL FRACTURES (1 millimeter or less)
- MEDIUM FRACTURES (>1 millimeter to 10 millimeters)
- LARGE AND VERY LARGE FRACTURES (>10 millimeters)
- STATISTICAL MEAN ORIENTATION

PTCZ POTENTIAL TUNNEL CONSTRUCTION ZONE

C.I. CONTOUR INTERVAL (point density contouring)

Figure 38. Stereonet plots of borehole PrinceST-A, Manhattan Island, N.Y., 2003-04: A. Total fractures. B. PTCZ fractures. C. Total foliation. D. PTCZ foliation. (Borehole location is shown in figure 3.)

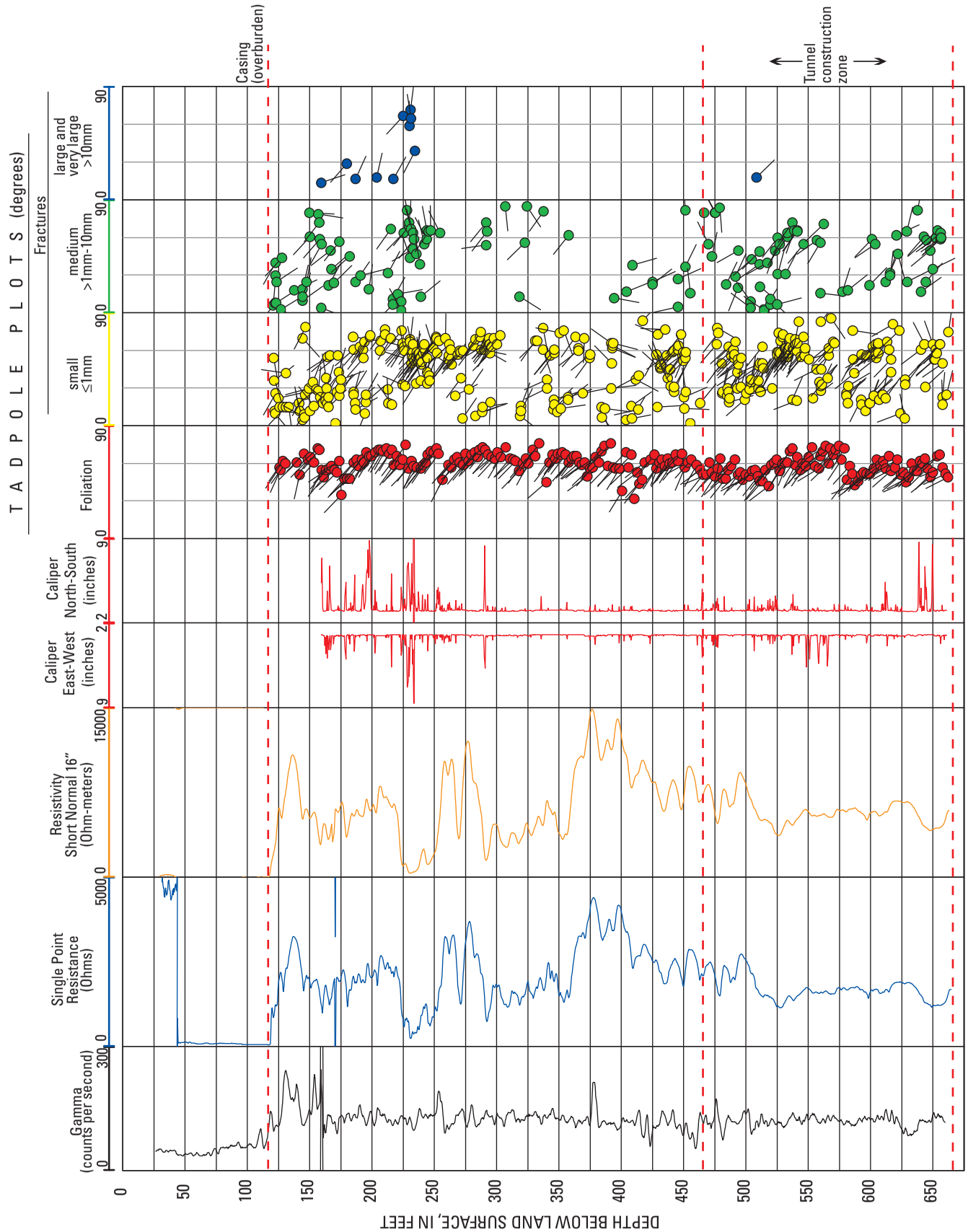


Figure 39A. Suite of borehole-geophysical logs from borehole PrinceST-A, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 3.)

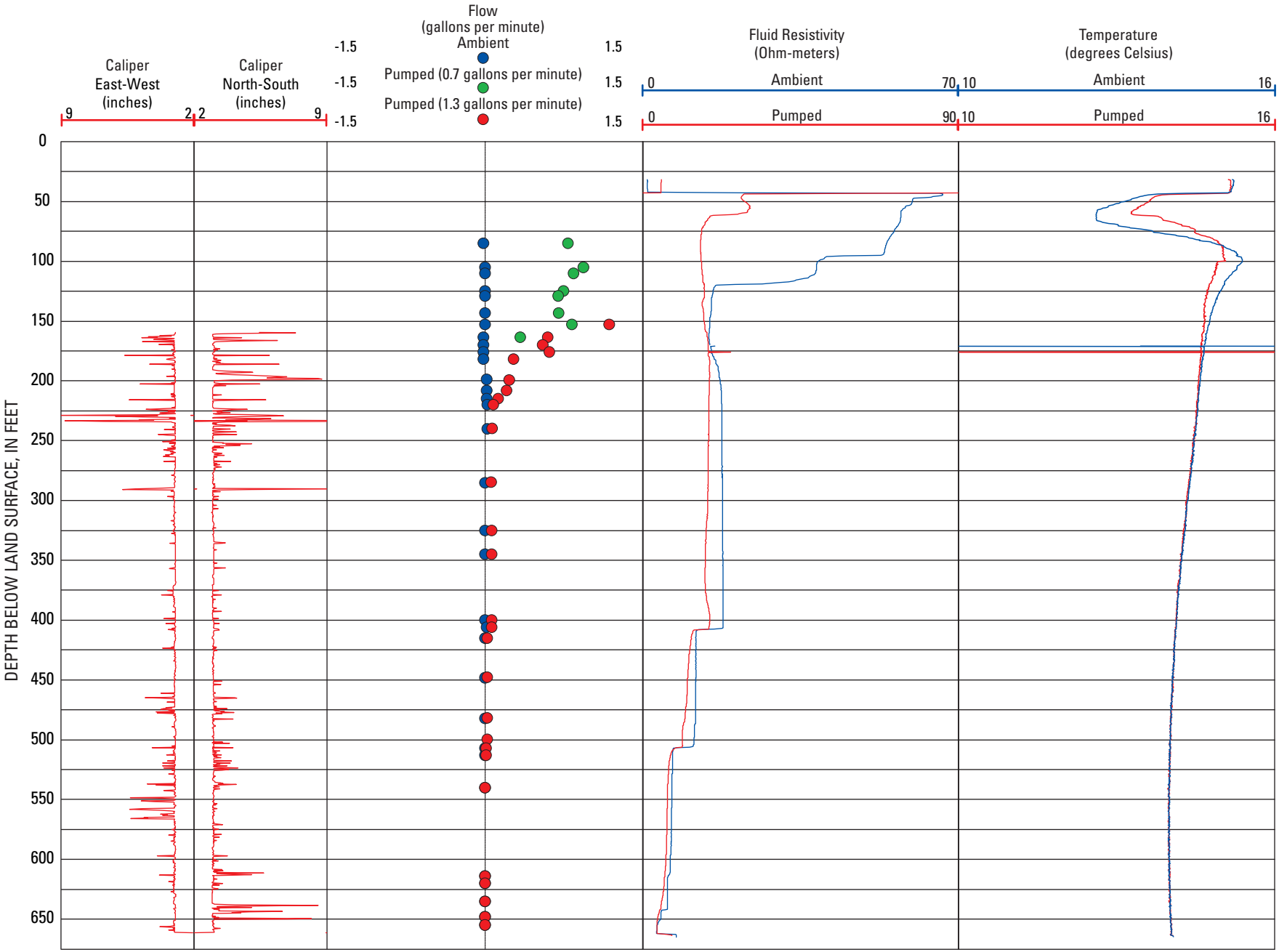


Figure 39B. Suite of borehole-geophysical logs from borehole PrinceST-A, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 3.)

BondST-A

The BondST-A borehole has a casing of 92 ft and extends 604 ft BLS (-556.6 ft elevation). The borehole is uncased in fractured bedrock.

Fractures and Foliation

A total of 177 fractures were detected within the BondST-A borehole using the OTV log. The borehole has a fracture index of 0.34. Most fractures were small in this borehole. Several fracture populations were observed in the borehole (fig. 40). The PTCZ mean fracture orientation was N56ºW17ºNE (fig. 40). Total borehole and PTCZ mean foliation orientations were N12ºE57ºNW and N11ºE59ºNW, respectively (fig. 40).

The SPR and R logs indicate variations that reflect lithologic changes and some large and some medium fractures (fig. 41). The deviation log indicated the bottom of the borehole is 36 ft from the origin, at an azimuth of 152º.

Ground-Water-Flow Zones

The hydraulic head in the BondST-A borehole was 4.8 ft above sea level. Fluid parameter logs have slope changes at 95, 200, 260, 305, and 480 ft BLS, indicating possible transmissive fractures at these depths (fig. 41). Specific-capacity test analysis indicated the borehole has a specific capacity of 0.02 (gal/min)/ft and a transmissivity of 3 ft^2/d. The BondST-A borehole has the lowest transmissivity of any South Water-Tunnel borehole tested.

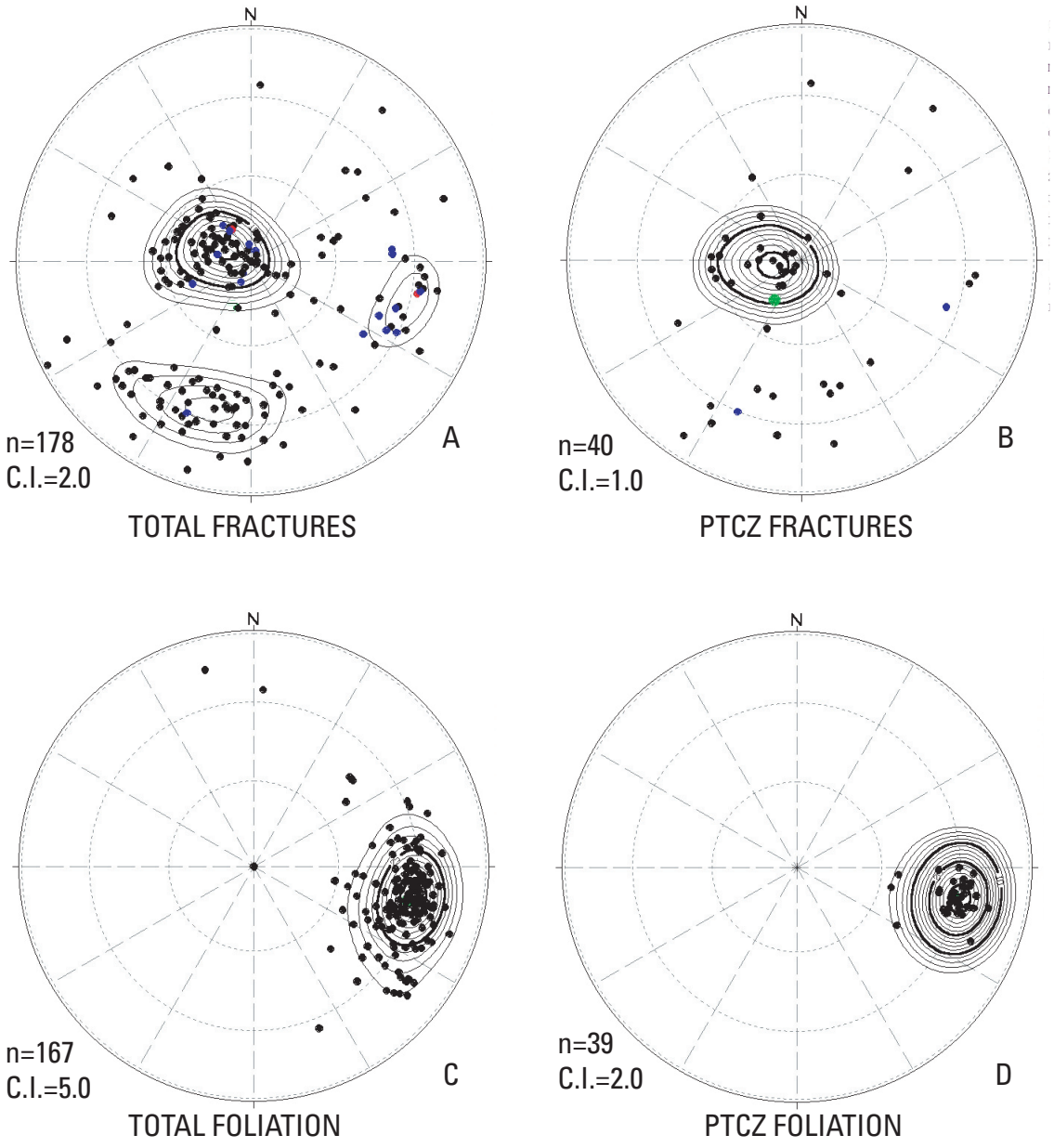


Figure 40. Stereonet plots of borehole BondST-A, Manhattan Island, N.Y., 2003-04: A. Total fractures. B. PTCZ fractures. C. Total foliation. D. PTCZ foliation. (Borehole location is shown in figure 3.)

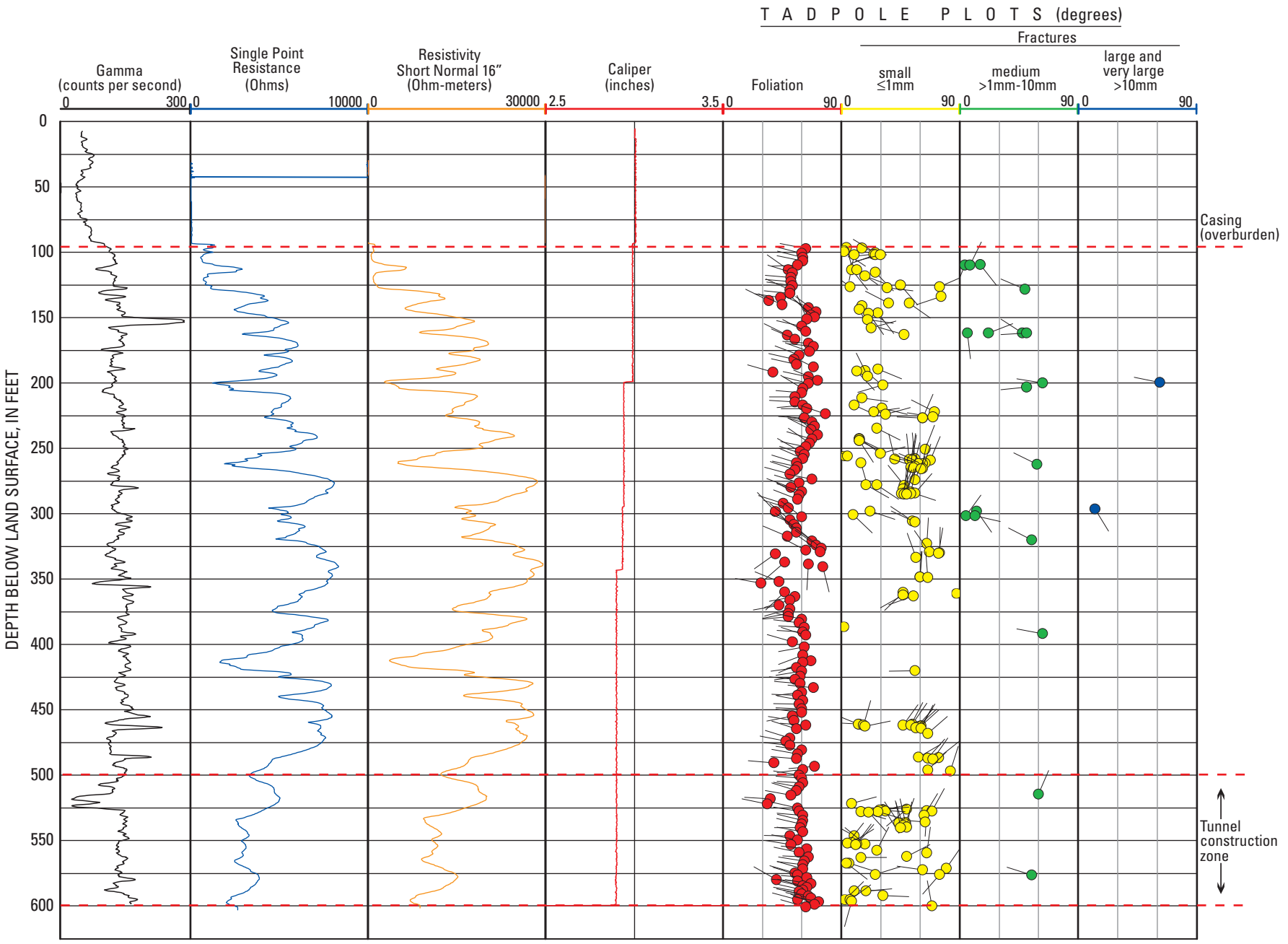


Figure 41A. Suite of borehole-geophysical logs from borehole BondST-A, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 3.)

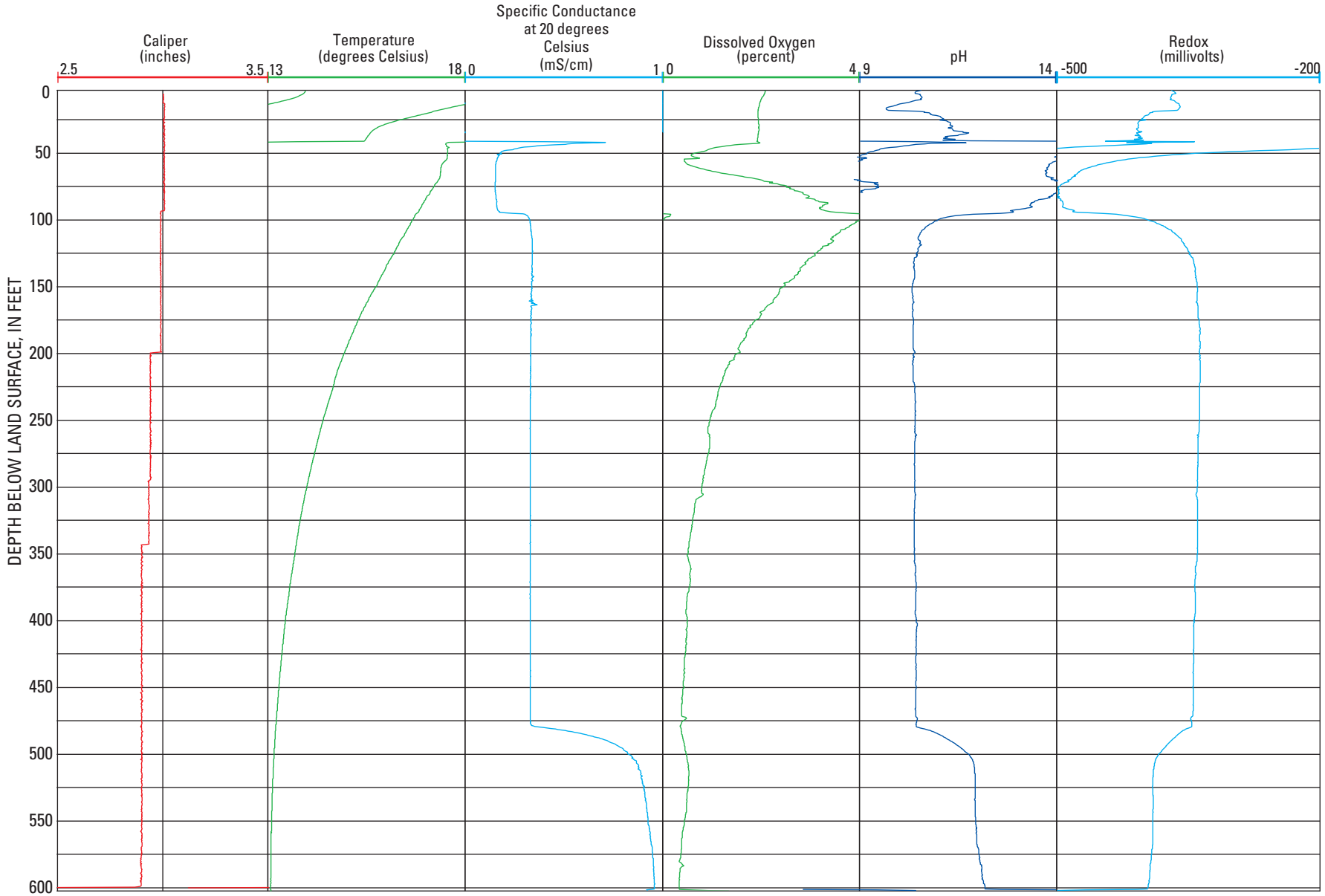


Figure 41B. Suite of borehole-geophysical logs from borehole BondST-A, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 3.)

31B-1

The 31B-1 borehole has 60 ft of casing and extends 653.7 ft BLS (-609.5 ft elevation). The borehole is uncased in fractured bedrock.

Fractures and Foliation

A total of 267 fractures were detected based upon the analyses of the OTV and ATV logs. The 31B-1 borehole has a fracture index of 0.45. The majority of fractures were small and medium in size. Two main fracture populations were observed in the borehole (fig. 42). The primary population cluster is shallow dipping to the southeast, and the secondary population cluster that dips steeply toward the northwest (fig. 42). PTCZ fractures were evenly distributed between two population clusters, one moderately dipping toward the southeast and the other is steeply dipping toward the west (fig. 42).

Directional borehole radar logging imaged four potentially large fractures or faults that did not intersect the borehole below, with orientations of N60ºW 61ºSW, N30ºW 67ºSW, N50ºE 79ºSE, and N40ºE 61ºNW. One radar point reflector imaged at 423 ft BLS and about 45 ft away from the borehole, could be interpreted as a tunnel (fig. 43).

The overburden sediment caused a reduction in the gamma response above 60 ft BLS as compared to the bedrock response below (fig. 44). The deviation log indicated the bottom of the borehole is 28 ft from the origin, at an azimuth of 158º.

Ground-Water-Flow Zones

The hydraulic head at the 31B-1 borehole was 6.1 ft above sea level. The fluid temperature and fluid resistivity logs have slope changes at 60, 65, 75, 90, 160, and 213 ft BLS, indicating possible transmissive fractures at these depths (fig. 44). Specific-capacity test analysis indicated this borehole had a specific capacity of 0.12 (gal/min)/ft and a transmissivity of 32 ft^2/d. Heat-pulse flowmeter logging measured no ambient flow and large upflow during pumping conditions from 213 ft BLS. Analysis of the heat-pulse flowmeter data indicated the following eight different transmissive fracture zones at: 72-77, 89-90, 90-97, 120-140, 160-171, 171-176, 213, and 604-610 ft BLS, had calculated transmissivities of 1.8, 1.8, 1.8, 1.3, 2.3, 1.5, 20.8, and 0.5 ft^2/d, respectively.

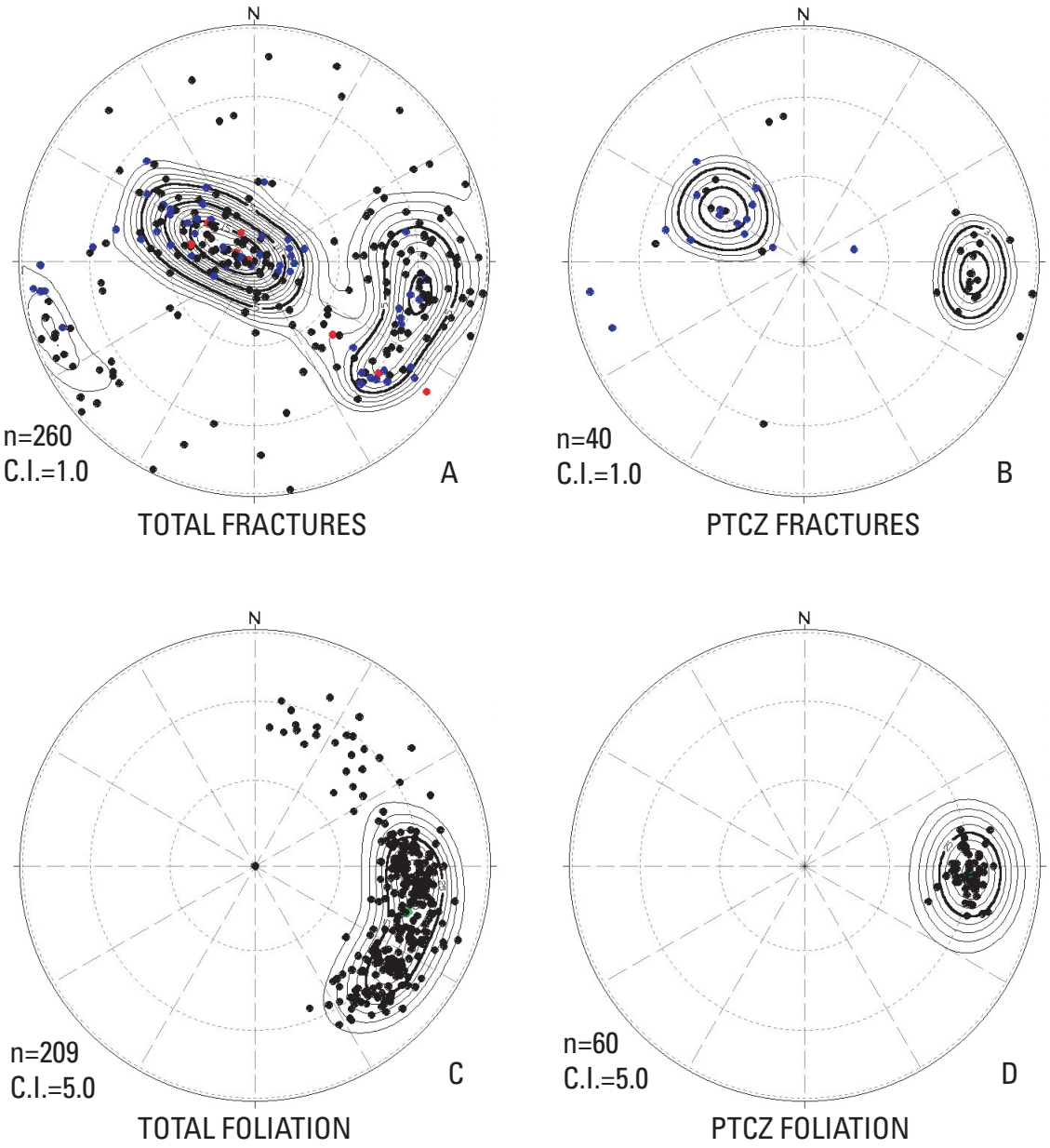


Figure 42. Stereonet plots of borehole 31B-1, Manhattan Island, N.Y., 2003-04: A. Total fractures. B. PTCZ fractures. C. Total foliation. D. PTCZ foliation. (Borehole location is shown in figure 3.)

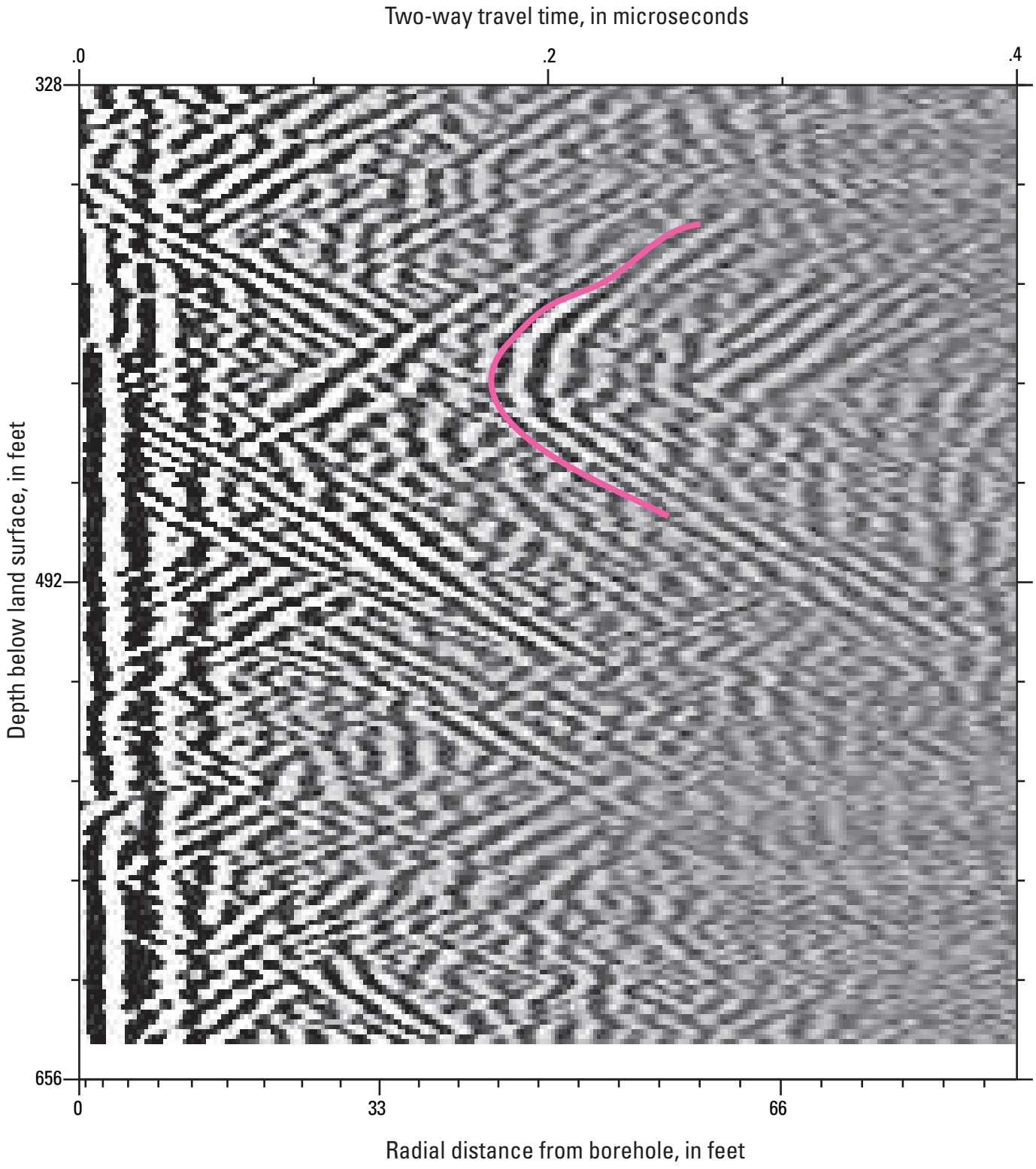


Figure 43. Dipole image of borehole-radar data from borehole 31B-1, Manhattan Island, N.Y. (Borehole location is shown in figure 3.)

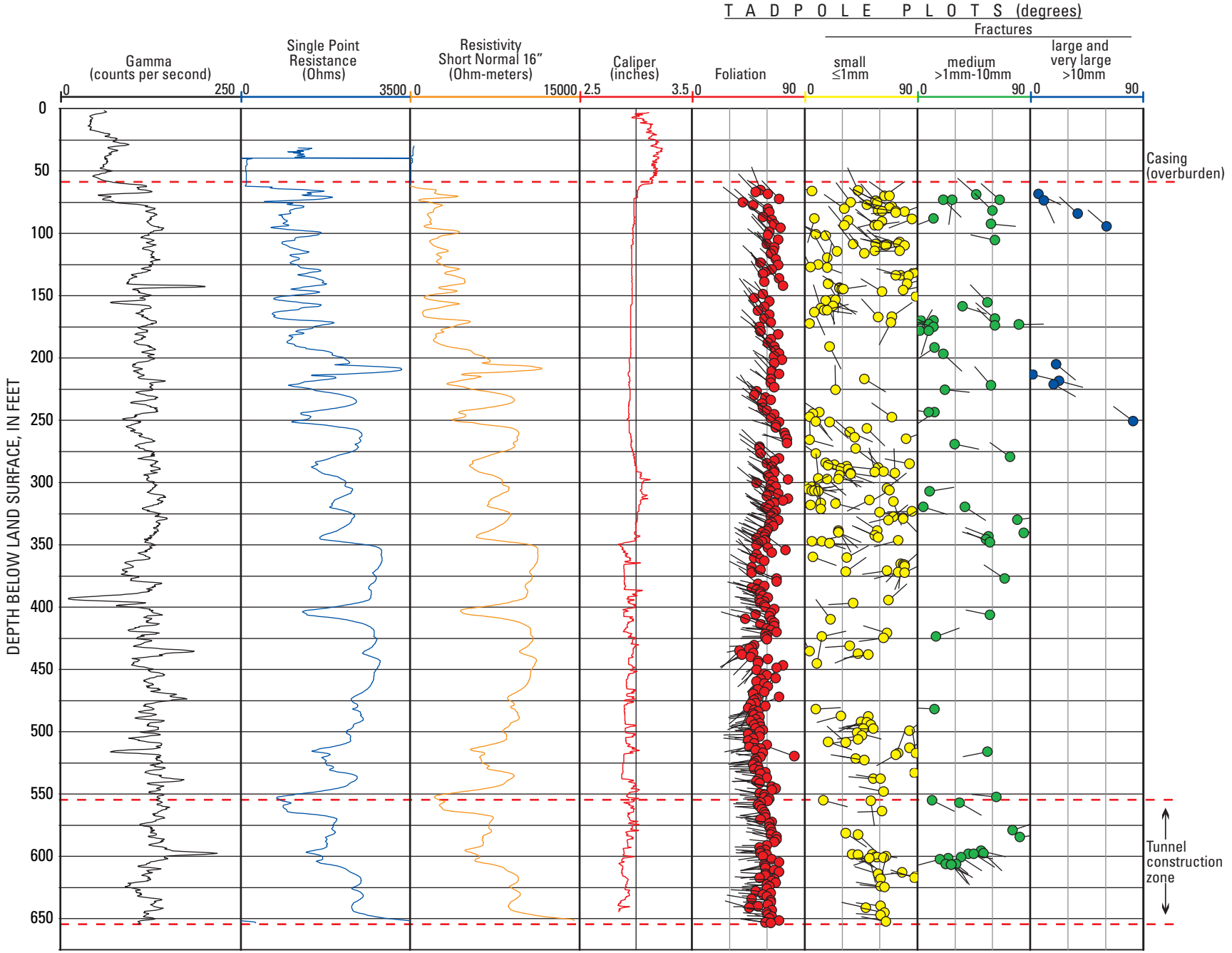


Figure 44A. Suite of borehole-geophysical logs from borehole 31B-1, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 3.)

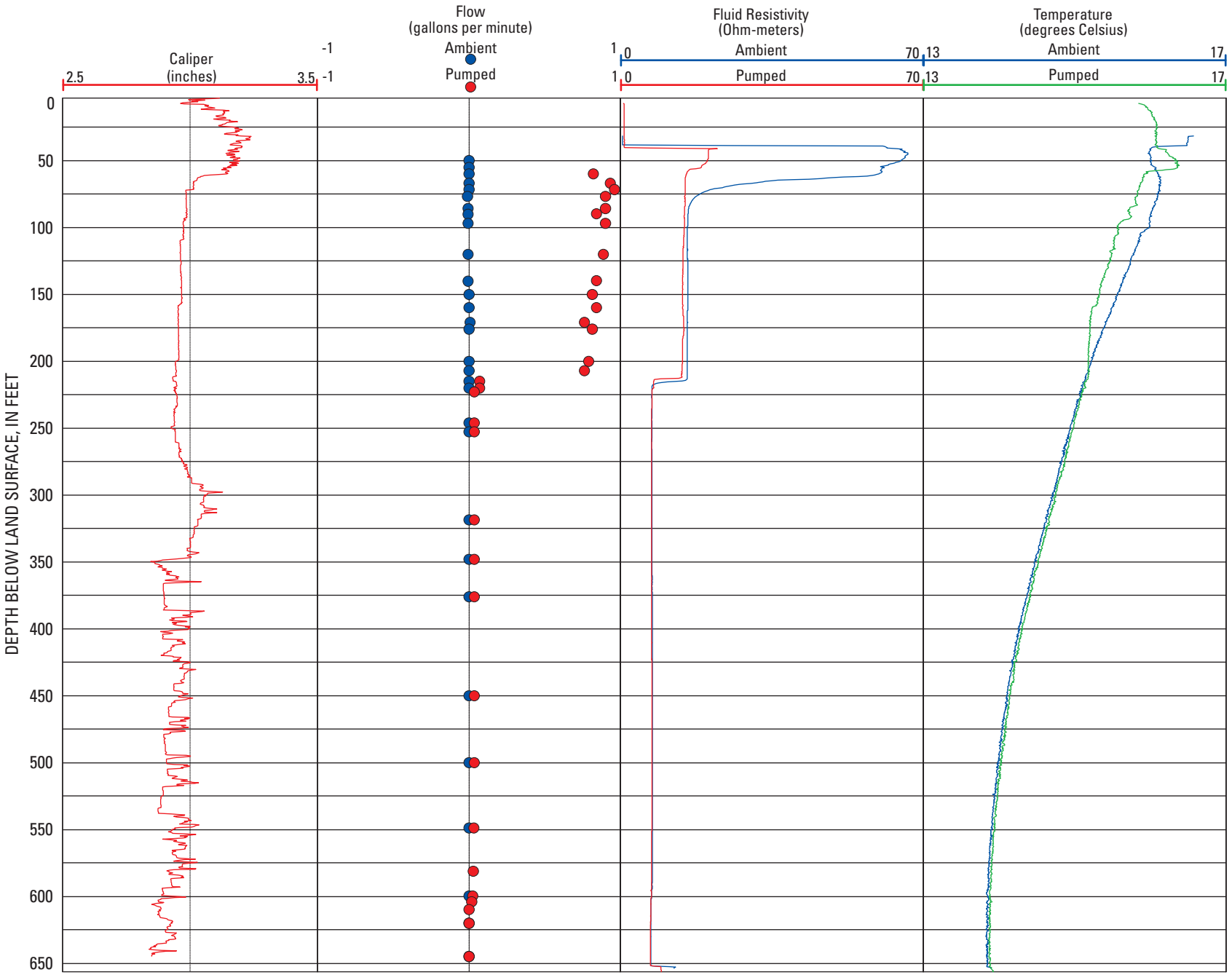


Figure 44B. Suite of borehole-geophysical logs from borehole 31B-1, Manhattan Island, N.Y., 2003-04. (Borehole location is shown in figure 3.)

SUMMARY AND CONCLUSIONS

In 1970, the New York City Department of Environmental Protection (NYCDEP) began construction of a third tunnel to supply water to New York City in case one of the two existing tunnels should require repair. Twenty-nine boreholes on the southern part of Manhattan Island were drilled by the NYCDEP to provide cores, geophysical logs, and geotechnical information for the design and construction of City Water Tunnel 3. This proposed water tunnel has been segmented into three separate units, which include the North Water-Tunnel, the Midtown Water-Tunnel, and the South Water-Tunnel. In 1998, the U.S. Geological Survey (USGS), in cooperation with the NYCDEP, began a study to apply advanced borehole-geophysical methods to assess the hydrogeology of the crystalline bedrock in southeastern New York including Manhattan Island.

The geophysical logs provided data on the deviation of the boreholes from vertical, the location and orientation (dip azimuth and dip angle) of fractures (optical and acoustic televiewers), the orientation (dip azimuth and dip angle) of rock foliation (optical televiewer), locations of contacts between rock units of differing lithology, and locations of possible transmissive (water-producing) fractures. The geophysical logs also provided information on the magnetic susceptibility, electrical resistivity and resistance of the bedrock, the direction and quantity of ground-water flow within the borehole (at PrinceST-A and 31B-1), resistivity, temperature, specific conductance, dissolved oxygen, pH, and redox of ground water, a profile of the borehole diameter, and the extent of fractures or geologic features up to 90 ft beyond the borehole with directional radar.

The bedrock beneath the southern part of Manhattan contains numerous fractures. Depth to bedrock ranges from less than 1 to 250 ft below land surface. Unconsolidated sediments overlie the bedrock. The twenty-nine boreholes are cased off with steel to the bedrock surface. Small fractures have apertures of 0.04 in. (1 mm) or less, medium fractures have apertures of greater than 0.04 to 0.39 in. (greater than 1 to 10 mm), large fractures have apertures greater than 0.39 in. (greater than 10 mm) and very large fractures have apertures greater than 9.8 in. (greater than 25 cm). The potential tunnel construction zone (PTCZ) is defined as a horizon from 100 ft above the bottom of each borehole to the bottom; this represents the major area of proposed construction. Stereonet and tadpole analyses were used to identify foliation and fracture relations.

Some of the boreholes have large transmissive fractures that may produce appreciable quantities of ground-water flow into the proposed tunnel and could thereby affect construction. Fracture indices range from 0.12 to 0.93 fractures per foot of bedrock. No correlation is indicated between fracture orientation and depth. Total-borehole fracture population dip azimuths are somewhat variable throughout the study area, with east or northwest azimuths for the North Water-Tunnel; northwest, southwest, and west for the Midtown Water-Tunnel; and southwest, northwest, west, and northeast for the South Water-Tunnel.

In general, the average foliation of the bedrock ranges from southwest to northwest dip azimuth. Foliation along the North Water-Tunnel have common strikes with dip angles of about 75˚ dipping toward the northwest at W67ST-A and southeast at W65ST-A. Foliation along the Midtown Water-Tunnel dips toward the northwest to west. Foliation dip angles ranged from 70˚ along the southwestern part of the Midtown Water-Tunnel to less than 15˚ and sub-horizontal along the northeastern-most part. South Water-Tunnel foliation dip azimuths are northwest to westward. Foliation dip angles ranged from nearly vertical (89˚ at FranklinST-B) to 57˚ at 31B-1.

Analysis of the 60-MHz directional radar indicated strong radar reflectors, which probably are fractures that extend beyond the boreholes and would intersect the boreholes if the boreholes were deeper. Radar analysis indicated that some of these fractures, if water bearing, could produce appreciable quantities of ground-water flow into the tunnel and could thereby affect construction. A point reflector is imaged at 423 ft BLS in the 31B1-1 borehole. This point reflector could be a nearby tunnel, which is estimated to be only 45 feet away from the borehole.

Water levels measured quarterly from September 2003 to April 2004 in the fractured bedrock ranged from 66 ft above sea level in the northern part of the study area (W67ST-A) to -42 ft elevation in the southern part (E30ST-B). This indicated a recharge zone in the central-northern part of the study area and discharge zones along the coastlines and southern parts. Two large cones of depression were detected, one in the eastern midtown area, and the other in the southwestern part of the island. Transmissivity values for most of the transmissive fracture zones in two boreholes were estimated (PrinceST-A and 31B-1). Transmissive fracture zones were delineated by correlating inflow zones interpreted from heat-pulse flowmeter logs with major fracture zones indicated by other geophysical logs. Each of the twenty boreholes that were geophysically logged had several transmissive fracture zones. Some of these fractures have high transmissivity, especially at those boreholes with moderate to high total borehole transmissivity.

Acknowledgments

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Appendices

Appendix 1. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in North Water-Tunnel boreholes (W65ST-A, W67ST-A), Manhattan Island, N.Y., 2003-04.

[W65ST-A, borehole id. Borehole location is shown in fig. 2. Depth in feet below land surface. S, small fracture (0.04 inch or less); M, medium fracture (greater than 0.04 to 0.39 inch); L, large fracture (greater than 0.39 inch to 9.8 inches); VL, very large fracture (greater than 9.8 inches); GW, ground water; FLT, fault; LWR, lower; CNT, contact; ZN, zone; GEO, geologic; NM, normal; RV, reverse]

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
W65ST-A			
Fractures			
26.4	133	3	S
26.5	209	27	M
28.2	309	35	S
29.2	328	45	M
39.2	143	78	S
45.7	267	2	S
46.9	325	25	M
52.4	185	9	M
52.4	141	5	M
52.6	315	19	M
64.7	136	8	S
65.8	303	12	S
67.5	298	8	S
73.5	299	7	S
80.0	154	72	S
86.3	345	17	S
90.1	29	23	S
93.2	136	72	S
93.5	137	74	M
95.5	150	78	S
96.7	69	3	S
125.4	136	3	S
125.5	129	18	S
126.4	331	11	S
127.4	18	14	S
130.0	123	61	S
130.3	51	81	S
130.3	250	2	S
138.7	142	27	S
139.5	68	12	S
139.8	328	18	S
140.0	342	27	S
171.7	246	3	S
184.7	305	23	M
197.6	141	71	M
198.0	284	22	S
202.2	332	6	S
203.7	245	83	S
206.1	342	8	S
214.2	342	26	S
218.8	13	26	S
221.6	133	74	S
222.0	349	38	M
222.9	358	19	M
224.9	354	62	M
226.6	321	15	M
234.4	131	72	S
236.3	308	9	M
239.0	24	22	M
245.8	139	78	M
262.4	307	87	L
288.0	162	54	S
288.8	132	14	S
291.6	319	5	S
299.3	144	83	S
306.1	50	18	M
307.4	66	7	M
312.0	172	7	S
312.3	69	41	S
314.4	287	11	M
316.0	104	23	M
324.8	279	15	S
327.5	136	21	M
328.2	149	50	M
329.1	161	51	S
335.8	30	36	M
340.2	17	20	S
344.8	82	20	S
345.1	78	41	M
350.2	85	87	L
351.4	70	67	M

Appendix 1. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in North Water-Tunnel boreholes (W65ST-A, W67ST-A), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
353.3	295	75	M
355.0	79	67	M
356.0	65	61	S
357.5	303	47	M
357.5	278	74	S
358.0	347	20	M
365.4	315	46	S
369.3	142	68	S
372.4	119	8	S
386.9	136	51	M
389.3	128	31	M
391.5	152	49	S
392.5	169	57	M
405.3	219	9	S
407.2	152	59	S
409.5	345	30	M
414.5	218	10	S
423.2	113	75	S
425.3	293	16	M
426.1	154	79	M
427.5	279	4	S
442.2	296	61	M
444.9	97	47	S
445.1	123	25	S
446.6	284	61	M
492.4	199	69	S
506.7	229	47	M
530.6	79	8	M
W65ST-A			
Foliation			
27.2	308	71	
28.0	312	72	
32.4	154	81	
36.8	160	74	
44.1	151	73	
46.1	138	75	
79.8	144	63	
87.4	152	67	
93.3	146	72	
95.4	174	64	
119.9	306	71	
141.7	224	51	
151.5	306	86	
162.5	307	83	
165.1	310	84	
167.1	334	86	
174.1	147	77	
176.7	141	80	
182.5	137	85	
185.0	150	74	
187.2	140	73	
189.6	142	73	
192.2	147	70	
195.4	146	83	
198.8	155	77	
200.2	167	70	
203.6	146	74	
206.9	145	72	
208.2	146	70	
210.5	144	82	
215.2	152	74	
218.5	147	75	
230.7	155	67	
232.9	149	74	
234.4	140	73	
238.4	154	77	
243.7	151	78	
247.7	154	58	
248.4	149	69	
252.4	155	47	
253.5	161	59	
254.3	159	61	
256.5	135	68	
270.6	320	69	
274.2	301	84	
282.5	147	57	
284.7	154	52	
287.0	195	30	

Appendix 1. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in North Water-Tunnel boreholes (W65ST-A, W67ST-A), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
288.1	155	58	
298.8	151	82	
302.2	161	73	
319.9	153	82	
323.6	158	69	
325.0	153	79	
329.2	169	59	
338.0	155	71	
339.5	172	80	
343.1	150	70	
350.3	99	86	
356.6	122	71	
392.1	154	74	
397.8	169	52	
403.8	148	62	
419.4	160	80	
421.3	156	73	
423.3	170	65	
W67ST-A			
Fractures			
79.2	256	62	S
79.4	127	39	S
79.9	146	37	L
80.2	295	73	S
80.7	291	63	S
80.9	289	61	S
82.1	242	29	S
82.4	219	16	S
83.0	126	87	S
84.3	282	88	M
84.8	134	23	L
85.4	127	29	S
86.8	295	19	S
87.1	300	17	S
87.4	291	55	S
87.7	288	67	M
87.9	143	9	S
88.0	301	22	M
91.3	152	16	S
91.8	146	20	M
92.5	279	67	M
93.3	122	23	L
94.8	293	36	M
95.7	298	73	S
97.3	274	57	M GW
100.5	294	51	S
101.8	223	12	S
103.4	64	64	S
105.4	131	47	M
105.9	281	58	M
106.7	96	32	S
111.1	292	65	S
111.3	302	71	S
112.0	182	25	S
113.2	148	9	S
113.2	130	13	S
113.2	139	24	S
114.4	129	52	S
116.2	164	9	S
116.2	165	25	S
117.0	164	21	S
117.3	172	26	S
119.4	283	73	S
121.9	168	16	S
122.2	138	10	S
123.4	183	21	S
123.8	137	33	S
124.4	288	51	S
124.5	64	10	S
125.4	141	82	SFLT
125.7	287	48	S
129.2	244	57	S
131.1	77	35	S
133.0	188	24	S
138.6	138	19	M
138.8	117	42	M

Appendix 1. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in North Water-Tunnel boreholes (W65ST-A, W67ST-A), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
138.9	95	54	S
139.1	296	74	M
139.1	136	30	M
139.6	135	31	L
139.7	310	74	M
140.4	296	77	S
142.3	86	24	S
143.0	69	35	S
143.1	61	31	S
147.8	108	37	M
148.7	290	79	S
149.2	290	72	S
149.3	281	72	S
150.0	283	52	M
150.7	263	63	M
150.9	311	14	S
151.1	295	26	M
151.4	291	77	S
151.6	357	48	S
151.7	72	43	S
157.3	186	34	S
157.5	310	35	S
159.6	66	18	S
163.5	274	58	M
165.7	291	61	S
167.5	75	23	S
167.7	78	30	S
167.8	186	5	S
168.3	85	21	S
169.3	89	71	S
170.6	292	76	M
170.9	304	62	M
171.1	287	64	L
171.4	19	49	M
171.7	340	32	M
171.7	51	27	M
171.7	330	65	M
172.0	21	28	M
172.4	345	61	M
173.3	15	61	M
173.3	123	85	VL CAVITY
173.9	53	10	VL
174.4	241	32	VL
W67ST-A Foliation			
87.6	291	85	
99.2	303	66	
102.4	302	78	
107.8	299	71	
109.1	305	74	
115.0	290	73	
116.8	287	74	
122.0	297	62	
122.9	293	58	
128.5	290	68	
138.7	286	66	
140.3	301	78	
142.1	292	84	
144.1	300	81	
146.3	296	84	
149.5	289	80	
151.5	293	78	
153.2	291	64	
154.9	299	73	
156.2	295	80	
157.9	282	80	
159.9	289	78	
160.7	283	76	
162.7	294	82	
163.8	294	81	
165.4	291	78	
167.3	293	76	
168.8	286	77	
170.3	289	75	

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B) Manhattan Island, N.Y., 2003-04.

[W30ST-A, borehole id. Borehole location is shown in fig. 2. Depth in feet below land surface. S, small fracture (0.04 inch or less); M, medium fracture (greater than 0.04 to 0.39 inch); L, large fracture (greater than 0.39 inch to 9.8 inches); VL, very large fracture (greater than 9.8 inches); GW, ground water; FLT, fault; LWR, lower; CNT, contact; ZN, zone; GEO, geologic; NM, normal; RV, reverse]

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
W30ST-A			
Fractures			
28.2	120	15	M
32.5	90	70	S
33.8	147	24	S
37.3	171	84	L
38.7	214	20	S
39.7	18	19	S
41.8	247	33	S
47.7	357	85	M
54.3	162	86	M
57.9	253	59	S
58.7	259	63	S
59.7	219	20	S
60.4	263	45	S
61.1	308	34	S
61.8	258	50	S
63.1	3	6	S
63.2	347	11	S
63.2	344	8	S
65.3	43	14	S
65.4	22	13	S
66.8	249	75	S
68.9	235	6	S
69.0	254	8	S
70.8	162	80	M
71.4	150	21	S
71.8	27	47	M
72.6	94	16	S
72.8	43	10	S
73.0	78	60	M GW
73.3	103	49	S
73.4	45	7	S
73.6	115	58	S
74.6	317	10	S
74.6	111	22	S
76.3	231	3	S
77.1	295	17	S
77.8	0	6	S
78.0	51	18	S
80.9	107	26	S
81.3	75	62	S
81.6	229	6	S
81.7	209	7	S
82.3	94	44	M
82.6	200	26	M
82.9	211	25	S
83.1	29	16	M
83.4	290	4	S
83.6	285	12	S
83.9	234	18	S
84.0	181	8	S
84.1	151	16	S
84.4	167	21	L
84.9	228	31	S
85.3	263	28	S
85.9	114	53	S
86.4	133	26	S
87.9	151	88	M
88.1	101	59	S
89.9	160	25	S
90.3	84	47	S
91.1	261	32	S
91.7	15	60	M
92.1	28	16	S
92.2	17	11	M
92.5	127	28	M
93.1	114	22	S
93.6	100	75	S
94.8	57	4	S
95.5	87	11	S
96.4	103	22	S

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
97.3	263	16	S
98.2	81	17	S
100.4	98	4	M
106.9	111	41	M
107.5	258	61	M
108.6	42	78	S
110.1	359	64	M
110.9	43	22	M
112.8	259	63	S
115.4	207	32	S
117.5	83	4	M
118.0	274	62	S
120.1	249	72	S
120.6	248	38	S
120.6	70	18	S
122.5	251	46	S
123.3	107	34	M
124.2	257	45	S
125.2	267	14	S
125.5	137	13	M
125.9	68	6	S
126.2	38	52	M
126.3	247	28	M
126.9	253	39	M
127.0	243	40	L
127.5	247	45	M
128.0	251	49	S
128.2	241	41	S
128.9	238	30	S
129.1	229	32	S
129.6	260	38	S
129.7	229	36	S
130.0	251	34	S
130.2	188	8	S
130.4	223	41	M
130.9	110	61	L
131.3	232	65	L
132.3	238	54	M
132.8	267	66	S
134.3	79	28	S
134.4	271	47	S
134.7	257	58	S
136.2	33	58	S
136.7	108	70	S
136.8	232	6	S
136.9	270	7	S
136.9	236	3	S
137.3	223	27	S
137.4	218	22	M
137.4	218	22	S
137.4	271	13	S
140.0	236	71	S
148.6	179	34	S
148.7	341	74	S
148.9	215	17	S
149.3	143	14	S
152.9	215	21	M
156.3	218	26	S
156.4	236	16	S
156.5	228	14	S
156.5	258	14	S
157.4	205	22	S
160.9	42	68	S RVFLT
164.0	259	65	S
164.8	263	70	S
171.1	306	85	M
174.0	246	89	S
180.0	232	26	S
190.5	226	89	M
195.1	267	87	M
198.1	253	79	S
199.1	252	82	S
200.1	296	72	M
200.8	292	18	S
203.6	266	67	S

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
204.1	278	61	S
204.1	282	74	S
206.2	251	30	S
206.8	279	55	S
207.3	258	32	S
208.0	248	8	S
209.2	272	57	M
209.2	260	61	M
211.6	269	66	S
211.8	261	58	S
212.4	270	66	S
212.8	275	66	S
213.0	276	72	S
213.7	279	75	S
216.9	85	22	S
229.2	246	70	S
229.7	276	52	S
230.2	277	48	S
234.6	222	79	S
246.9	294	45	S
247.4	237	40	M
247.7	261	46	S
248.3	263	39	S
248.7	269	42	S
250.2	273	41	S
251.0	275	57	S
262.6	331	80	S
271.1	201	10	S
274.1	246	22	S
281.8	349	84	S
282.5	219	43	S
284.1	320	83	S
286.9	208	82	S
292.5	16	82	M
298.9	258	24	S
299.4	241	67	S
299.8	245	30	S
304.4	266	66	S
308.9	243	62	S
313.1	235	56	S
313.1	328	85	S
315.7	238	65	S
317.6	242	63	S
331.4	277	41	S
332.7	251	65	S
340.4	260	63	M
354.0	246	31	S
356.8	254	53	S
356.9	255	57	M
358.7	252	48	S
360.9	274	26	S
362.3	245	48	S
363.8	29	11	S
364.5	51	5	S
366.0	254	39	S
366.9	245	44	S
371.7	65	19	S
371.8	99	10	S
384.2	46	24	S
384.3	38	36	S
389.1	120	9	M
398.7	5	21	M
399.6	242	57	S
418.9	145	79	S
421.1	296	13	S
422.8	320	69	S
423.8	286	42	S
434.0	301	60	M
448.3	302	22	S
494.3	270	27	S
520.7	274	29	S
523.1	263	7	S
525.7	307	42	S
525.8	286	41	S
527.8	262	45	S

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
544.0	306	47	M
566.7	18	15	S
567.0	110	8	M
567.0	141	14	M
571.2	354	11	M
579.8	343	10	S
585.6	48	8	S
592.7	132	12	S
W30ST-A			
Foliation			
31.7	94	72	
35.7	277	54	
41.7	252	39	
59.9	260	48	
62.4	260	50	
67.0	259	76	
70.9	89	64	
75.2	93	58	
79.5	86	48	
82.1	82	34	
83.6	246	71	
93.9	67	71	
99.3	94	64	
105.6	258	71	
111.9	263	71	
118.1	249	54	
121.5	256	61	
124.3	259	53	
128.2	255	50	
129.9	249	38	
134.4	270	50	
137.5	261	76	
140.3	239	74	
151.5	268	61	
164.4	247	75	
169.4	258	83	
172.8	247	69	
184.0	262	68	
187.5	290	81	
191.5	272	85	
194.0	254	81	
199.3	252	84	
200.4	272	75	
205.0	295	60	
207.4	257	45	
209.1	278	54	
209.9	274	55	
211.8	262	60	
213.9	278	80	
215.9	233	38	
218.5	236	47	
220.7	260	72	
224.0	268	82	
228.5	269	52	
229.7	273	47	
233.4	247	48	
235.0	230	62	
236.5	277	61	
238.2	266	54	
239.7	268	58	
241.2	262	54	
244.9	268	56	
247.3	271	52	
248.3	263	44	
250.1	265	43	
251.5	270	35	
252.6	256	35	
256.5	248	26	
257.8	250	32	
267.3	111	48	
270.4	108	71	
272.1	266	80	
280.3	269	50	
282.5	224	42	
283.9	243	30	
286.0	233	25	

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
288.2	266	42	
290.4	259	39	
292.8	248	45	
295.5	255	55	
296.9	244	41	
299.1	248	29	
300.5	260	37	
302.5	257	53	
304.6	259	61	
306.9	76	51	
309.0	242	68	
313.1	235	55	
318.8	258	65	
320.8	250	66	
324.1	248	69	
326.1	240	68	
328.2	261	50	
331.5	251	68	
333.2	250	71	
335.6	265	60	
339.2	259	67	
340.7	254	69	
342.0	259	64	
344.8	255	58	
346.4	266	61	
347.8	247	56	
350.8	247	43	
353.2	259	54	
354.3	239	48	
355.9	249	59	
356.9	256	57	
358.6	242	50	
360.6	260	60	
362.2	248	48	
364.8	260	65	
366.1	255	45	
367.6	257	37	
369.0	241	34	
370.5	258	30	
381.6	281	60	
384.4	265	87	
386.0	252	74	
388.2	267	79	
397.1	272	62	
398.8	259	56	
399.7	256	61	
405.0	277	79	
414.6	270	71	
416.7	273	59	
419.5	264	70	
420.5	266	50	
424.0	271	39	
429.7	260	57	
430.6	265	64	
433.2	275	61	
436.4	272	86	
439.6	270	71	
441.4	280	82	
444.4	280	78	
449.8	271	81	
454.6	269	71	
460.0	278	51	
464.2	253	65	
466.7	264	49	
470.0	272	65	
471.6	271	74	
483.0	290	70	
485.4	259	67	
489.1	263	45	
494.8	264	39	
501.4	268	79	
503.0	264	73	
513.4	283	42	
514.8	266	48	
519.2	277	50	
523.8	287	47	

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
525.8	285	44	
528.7	268	53	
530.4	262	43	
538.9	260	55	
539.5	261	63	
541.2	258	65	
548.2	288	51	
564.9	308	44	
566.4	298	49	
572.7	264	65	
578.5	273	65	
580.4	289	48	
582.4	292	54	
587.7	270	46	
592.2	256	29	
E30ST-A			
Fractures			
45.3	293	18	S
47.0	304	73	S
52.1	297	70	S
54.8	246	20	S
62.2	111	4	L
63.0	56	65	M
62.6	43	30	M
63.3	239	18	L
63.5	250	25	M
68.8	120	3	S
69.6	38	8	S
69.6	230	8	S
70.1	321	8	S
74.7	227	19	M
80.2	336	6	M
80.3	273	7	M
80.6	131	8	M
80.6	110	5	M
83.0	234	29	M
89.7	266	7	S
98.8	250	2	S
99.2	344	21	M
100.2	244	5	L
101.2	293	71	S
102.3	284	10	L
102.8	222	28	M
104.2	225	15	S
107.8	188	23	S
108.8	136	9	M
108.8	149	6	M
112.8	204	15	M
114.6	291	23	S
117.4	271	11	S
117.4	255	9	S
128.4	296	57	S
128.8	164	17	S
132.6	294	9	S
132.9	270	30	M
139.0	305	81	S
140.6	302	19	S
143.4	280	20	S
144.9	150	18	S
145.6	131	14	S
146.7	141	6	S
147.9	125	28	S
148.8	122	17	S
149.9	285	17	S
153.7	179	9	S
154.0	289	33	S
155.7	306	55	S
156.4	131	15	S
157.6	122	14	S
158.6	170	15	S
158.6	153	2	S
161.8	287	34	M
161.6	254	7	M
162.5	277	14	S
166.3	3	7	S
174.1	257	5	L

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
186.3	153	37	S
188.5	301	62	M
188.7	296	62	M
197.2	333	9	S
209.0	322	22	S
221.3	83	10	S
222.7	352	9	S
226.9	325	50	S
231.1	329	13	S
248.0	170	16	S
250.1	146	16	S
266.1	93	6	S
267.9	99	20	S
271.8	92	18	S GW
272.9	122	9	S
273.9	16	8	S
276.2	286	23	S
277.0	125	11	S
280.8	127	9	S
285.0	40	81	S
286.0	135	17	S
360.3	164	19	S
360.5	239	66	S
361.5	118	9	S
370.3	96	39	S
384.9	125	16	S
395.9	276	66	S
436.8	357	22	S
440.8	302	67	S
445.7	296	65	S
476.9	42	44	S
E30ST-A			
Foliation			
46.7	291	75	
49.0	296	73	
52.2	296	73	
55.0	296	76	
58.4	290	73	
61.3	298	76	
64.6	299	71	
67.8	303	65	
70.8	288	67	
75.7	299	71	
78.8	298	76	
81.1	303	74	
83.0	307	79	
85.3	304	82	
87.3	306	76	
90.2	307	78	
95.0	289	71	
97.9	293	72	
101.2	291	71	
104.7	297	69	
107.6	296	66	
111.9	284	74	
114.8	290	72	
117.7	295	67	
122.5	304	68	
125.9	296	62	
130.9	297	62	
133.4	294	58	
142.2	292	62	
144.0	293	58	
148.1	307	66	
151.9	301	59	
155.6	304	55	
159.7	293	65	
164.1	293	67	
167.2	297	69	
170.5	311	68	
173.3	300	65	
178.1	293	62	
181.5	297	55	
183.8	309	57	
187.5	309	58	
190.5	309	65	

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
193.8	295	64	
196.7	307	60	
201.6	302	62	
204.7	311	72	
208.1	312	65	
211.6	311	61	
214.3	308	56	
217.0	311	59	
220.6	301	72	
224.4	307	68	
229.2	310	64	
231.7	304	68	
235.4	301	68	
238.6	311	69	
241.6	306	70	
244.4	304	74	
248.4	304	72	
251.2	298	69	
254.5	306	70	
256.1	303	76	
262.3	300	75	
265.4	298	69	
268.7	301	75	
272.0	306	78	
275.3	309	76	
278.5	310	78	
281.3	311	81	
290.8	309	76	
295.8	313	76	
298.4	302	77	
303.4	307	79	
306.7	302	73	
309.6	301	63	
313.1	310	79	
322.7	298	87	
327.1	297	78	
331.8	303	68	
336.3	301	74	
338.6	308	66	
341.8	321	68	
348.1	307	67	
350.6	302	78	
352.6	303	70	
356.5	310	69	
357.9	298	82	
365.5	310	69	
367.8	310	79	
371.3	304	69	
376.4	313	69	
379.3	290	73	
382.7	312	72	
386.8	306	71	
389.0	298	77	
391.9	306	59	
396.0	285	66	
399.2	301	63	
405.5	281	55	
408.6	295	56	
412.2	304	60	
414.5	307	60	
418.3	295	71	
420.8	302	76	
422.1	290	61	
425.1	303	74	
427.9	302	76	
432.1	306	77	
432.9	290	76	
442.7	297	69	
445.2	287	78	
454.0	310	67	
455.7	305	72	
459.4	310	75	
461.3	299	70	
463.1	291	80	
469.8	302	63	
472.7	298	81	

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
475.1	294	85	
486.8	306	72	
488.3	297	74	
511.4	304	67	
516.9	301	62	
521.5	304	80	
E30ST-B			
Fractures			
48.8	168	42	M
49.5	309	48	S
49.8	305	41	M
50.5	176	36	S
50.7	309	46	S
51.4	135	34	S
52.4	298	54	S
53.1	171	8	S
54.7	313	39	S
55.1	138	45	M
55.6	304	47	S
55.5	195	65	S
57.1	305	54	M
58.4	301	40	S
60.2	154	72	M
61.1	236	9	S
61.0	280	7	S
61.1	311	49	S
63.7	314	42	S
64.0	287	10	S
65.4	306	49	S
67.0	186	76	S
66.4	303	54	L
67.2	216	76	M
67.9	310	61	S
68.7	223	6	M
68.7	229	10	M
68.6	137	52	M
69.9	299	52	S
71.4	319	48	S
73.3	142	23	S
74.4	181	35	S
75.8	309	58	S
76.7	162	33	S
77.1	161	36	S
77.1	171	32	S
77.9	306	53	M
83.8	82	6	S
84.7	152	7	S
85.0	303	54	M
85.7	298	56	S
85.9	303	71	S
86.6	298	74	M FLT?
87.2	79	27	S
87.5	204	61	M
92.3	252	65	S
96.1	283	62	S
99.8	145	38	S
103.7	304	29	S
105.3	131	63	M
105.8	123	53	M GW
106.2	303	30	S
109.8	206	64	S
111.1	196	62	S
113.3	134	27	S
116.4	204	69	M
116.7	139	52	M
116.9	299	6	L
117.3	131	67	S
120.8	268	20	S
122.6	198	65	M
127.0	303	37	S
133.4	260	82	S FLT
137.9	302	31	S
141.2	312	46	S
175.9	170	67	S
187.6	122	35	S
189.9	132	54	S

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
200.3	12	7	S
200.5	313	47	S
208.8	186	57	S
209.7	255	76	S
211.4	266	71	S
214.0	182	67	S
214.4	222	62	M
215.1	190	70	M
224.7	177	71	S
227.0	307	21	S
234.9	304	41	M
235.1	250	60	S
236.1	254	62	M
240.2	197	67	S
241.6	176	75	S
246.3	167	72	S
248.4	187	60	S
251.3	144	66	S
252.5	166	51	S
262.2	310	33	S
264.1	149	68	S
266.8	81	77	S
270.2	138	57	S
271.7	201	68	S
273.2	318	52	S
273.6	322	45	S
276.8	155	58	M
279.4	322	46	S
289.2	53	37	S
291.8	320	41	S
297.9	96	11	S
300.9	113	67	S
302.2	205	72	S
304.2	137	61	M
307.3	320	39	S
310.3	119	23	S
310.9	132	52	M
316.0	308	35	S
317.9	319	45	S
323.4	295	35	S
323.9	271	69	S
325.1	306	41	S
327.8	133	70	S
328.5	90	88	S FLT
328.7	192	62	S
329.6	319	41	S
338.6	332	41	S
344.3	199	64	M
344.4	197	68	M
347.0	204	72	S
347.1	192	66	S
350.8	98	82	S
351.6	92	82	S
353.0	85	83	S
357.2	183	58	S
367.4	104	27	S
367.6	320	44	S
369.9	343	28	S
372.7	319	31	S
373.3	204	61	S
375.0	19	5	S
377.3	113	35	S
377.4	109	28	S
379.6	351	3	S
379.8	121	20	S
380.4	190	63	S
381.2	126	15	S
381.6	102	20	S
382.8	118	39	S
384.4	303	33	S
385.9	105	33	S
386.8	65	13	S
386.9	82	18	M
387.9	193	69	S
389.5	92	35	S
389.8	87	27	S

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
390.4	202	65	S
392.1	199	65	S
392.8	207	70	S
394.7	308	36	S
395.1	105	13	S
395.5	200	60	S
396.8	300	33	S
397.6	302	51	S
398.3	75	22	S
398.6	109	32	S
399.3	219	71	S
399.4	302	26	S
403.7	299	57	M
405.8	167	62	M
408.4	310	49	S
409.5	313	31	S
411.0	311	43	S
413.0	313	33	S
413.6	353	23	S
415.6	305	56	S
416.8	98	34	S
419.0	105	30	S
421.7	309	46	S
422.6	310	47	S
424.3	312	39	S
426.5	309	48	S
426.7	308	55	S
428.7	309	47	S
429.0	301	63	S
429.5	344	49	S
430.0	304	48	S
431.3	312	41	M
431.5	314	45	S
431.8	303	57	S
432.0	308	45	S
432.6	119	42	S
433.4	307	42	S
433.7	299	46	S
436.5	284	33	S
436.6	315	40	M
436.8	309	31	S
437.3	309	43	S
437.4	302	42	S
437.7	298	38	S
438.6	300	41	S
440.8	308	40	S
443.1	140	68	S
447.8	299	44	S
450.5	332	36	S
453.3	311	40	S
454.7	317	45	S
455.8	309	45	S
457.1	116	57	S
458.7	318	37	S
460.7	303	54	S
462.4	307	60	S
463.1	263	76	S
463.7	298	45	M
464.0	307	86	M
464.2	302	56	S
464.5	297	50	S
465.2	302	44	M
465.7	301	54	S
465.9	298	56	S
466.0	305	58	S
466.3	329	25	S
466.8	309	56	S
467.3	310	43	S
467.4	314	40	S
468.8	293	52	S
468.8	44	68	S
469.2	307	69	S
470.2	298	43	M
470.5	306	68	S
470.7	295	65	VL
471.7	285	80	S

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
471.7	160	59	S
471.7	339	20	S
473.0	251	73	S
473.5	263	74	M
474.1	307	31	S
474.8	303	42	M
478.6	241	85	S
479.5	298	45	S
480.3	67	88	M
495.0	280	41	S
496.5	292	50	S
496.9	285	48	S
500.2	300	48	M
503.2	295	49	M
503.6	288	49	S
504.1	294	52	M
504.2	295	54	M
504.8	293	56	S
505.5	289	40	S
505.9	282	48	S
506.7	281	53	M
506.9	276	54	M
507.0	275	47	S
507.2	285	54	M
507.3	286	60	S
507.8	296	55	S
508.6	328	56	S
510.2	290	72	S
510.6	265	44	M
516.9	298	57	S
517.1	291	48	S
520.4	287	42	S
522.5	306	45	M
525.0	283	52	S
526.3	282	36	M
526.4	278	47	S
526.6	306	43	S
526.8	290	54	S
534.8	260	20	S
535.0	269	42	S
536.7	130	35	S
536.8	280	66	S
540.7	271	37	S
545.9	262	37	S
549.9	287	56	S
551.9	264	31	M
552.3	294	57	S
553.4	283	62	S
556.8	276	43	S
557.8	202	15	S
561.6	224	28	S
562.4	273	82	S
566.3	281	51	S
566.3	268	82	S
567.7	204	21	S
568.5	205	15	S
577.9	93	77	S
580.1	253	62	S
584.0	73	86	S
586.1	311	44	S
E30ST-B			
Foliation			
49.5	313	43	
50.6	301	46	
54.7	309	43	
57.6	308	53	
61.7	306	52	
66.7	305	42	
70.0	303	53	
74.6	317	58	
77.9	306	55	
85.1	299	52	
87.8	310	50	
91.3	314	50	
94.6	308	43	
98.9	289	37	

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
103.2	307	44	
107.1	324	28	
106.3	305	31	
107.4	311	38	
109.5	289	48	
111.3	296	37	
112.7	302	32	
115.2	300	37	
115.8	299	37	
119.2	300	40	
121.4	313	36	
124.1	297	30	
126.4	298	40	
128.4	298	33	
131.0	301	35	
133.6	289	38	
135.4	296	38	
137.6	299	33	
139.8	307	49	
142.1	322	36	
144.4	298	48	
146.2	298	46	
148.4	303	42	
150.0	302	36	
152.4	298	28	
154.2	303	39	
154.8	313	31	
157.3	306	54	
159.7	314	40	
161.4	304	36	
164.4	309	43	
166.8	312	43	
169.0	311	43	
171.2	305	49	
173.3	304	45	
176.1	319	33	
178.1	302	41	
180.1	318	32	
183.3	297	42	
185.2	306	42	
187.7	308	37	
189.4	308	41	
191.5	311	42	
193.5	308	47	
195.9	310	39	
198.2	312	41	
200.5	313	49	
202.8	306	55	
205.5	315	48	
207.5	314	46	
209.9	316	53	
212.2	306	60	
214.9	311	46	
217.7	310	46	
219.9	312	58	
222.3	311	38	
223.6	313	32	
225.1	308	43	
227.8	321	41	
230.3	313	41	
232.5	309	44	
235.0	302	36	
237.3	321	35	
239.6	310	45	
242.0	310	46	
244.2	326	54	
245.7	324	34	
249.1	308	51	
251.5	321	40	
253.7	321	50	
256.3	328	50	
258.4	314	47	
261.0	325	43	
263.1	303	54	
264.2	345	34	
267.0	319	35	

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
269.2	322	43	
271.6	320	46	
273.6	316	43	
276.1	317	40	
277.6	312	38	
279.4	332	45	
281.0	327	33	
283.6	316	33	
285.7	317	35	
288.2	327	36	
290.6	314	43	
293.0	318	33	
296.8	305	46	
299.6	315	47	
301.8	309	41	
304.9	326	32	
307.3	310	41	
309.7	313	47	
311.4	311	41	
313.4	321	37	
315.8	315	39	
318.3	313	46	
320.7	314	39	
322.8	297	39	
325.1	297	31	
327.7	306	42	
330.2	314	40	
331.5	301	46	
333.9	306	42	
336.4	314	34	
339.3	326	35	
342.1	318	39	
344.1	315	38	
345.6	319	31	
348.4	319	35	
350.0	316	25	
352.6	312	39	
355.2	325	42	
357.1	307	52	
361.2	314	40	
364.3	333	33	
366.3	313	50	
368.5	315	37	
370.8	312	35	
373.5	308	38	
375.8	316	29	
378.2	310	31	
380.3	310	43	
382.9	312	33	
385.0	314	34	
386.6	314	33	
388.9	314	37	
391.4	309	31	
392.8	301	41	
395.2	291	54	
397.6	299	41	
400.0	291	35	
402.7	312	39	
403.6	304	60	
405.8	310	47	
408.4	302	51	
410.3	304	49	
412.3	310	41	
414.2	316	40	
415.6	310	53	
417.2	309	42	
419.6	316	44	
421.8	312	43	
424.1	309	36	
426.7	311	39	
428.7	304	44	
431.2	306	42	
433.7	300	47	
435.8	295	45	
438.2	311	46	
440.7	312	43	

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
442.5	314	43	
444.9	310	41	
446.5	311	37	
448.8	304	39	
451.1	311	43	
453.5	316	40	
454.8	307	49	
456.4	301	51	
458.8	309	48	
460.5	308	48	
462.1	306	49	
464.7	297	47	
466.9	318	47	
468.4	311	49	
469.8	300	62	
471.9	305	35	
473.5	319	38	
474.6	311	35	
476.3	295	37	
477.9	283	46	
480.2	299	40	
482.9	300	48	
484.8	301	43	
486.9	304	43	
488.0	307	51	
489.6	277	40	
491.3	278	44	
493.7	285	51	
495.0	276	41	
496.9	280	52	
498.8	286	51	
500.3	292	41	
500.8	280	52	
502.1	291	50	
503.6	289	53	
504.8	295	52	
506.5	282	53	
509.6	298	49	
511.1	299	38	
512.3	287	52	
517.1	291	48	
519.7	289	27	
522.4	308	42	
524.1	308	51	
526.9	285	54	
528.1	270	47	
534.4	150	11	
536.1	113	20	
536.8	126	25	
540.1	278	23	
541.7	256	33	
543.6	263	32	
546.2	264	38	
550.0	288	61	
553.3	273	38	
556.0	294	45	
558.7	234	31	
561.8	199	16	
565.8	225	17	
568.3	200	18	
572.3	235	28	
573.0	215	16	
575.2	264	37	
578.7	229	17	
581.7	293	57	
584.0	310	47	
584.6	310	58	
586.3	299	36	
587.9	302	50	
590.0	294	56	
E33ST-A			
Fractures			
39.1	145	7	M
44.7	339	3	S
42.6	150	11	S
42.5	143	26	M

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
53.6	353	49	S
57.6	175	46	M
58.3	300	45	S
61.9	313	59	M
62.8	340	68	M
66.2	310	61	S
63.8	310	73	VL
68.0	308	59	S
68.9	329	55	S
83.9	126	10	M
99.3	25	56	S
99.5	343	51	S
100.2	124	53	S
101.3	120	49	S
104.4	308	52	S
106.0	124	24	S
106.3	129	35	M
108.9	318	52	S
109.4	133	41	S
111.9	93	54	S
112.2	154	44	S
113.2	307	60	S
113.8	320	65	S
117.2	11	30	S
120.1	307	44	S
120.6	6	23	S
123.4	347	13	S
124.4	147	45	S
132.3	301	57	S
133.0	324	13	S
138.7	291	53	S
147.4	167	37	M
152.3	297	62	S
152.9	42	57	S
155.4	210	14	S
157.6	337	3	S
163.8	304	39	S
166.4	192	73	S
172.2	310	38	S
172.3	319	31	S
173.2	321	76	S
174.4	311	26	S
174.9	315	50	S
177.4	147	11	S
180.8	303	52	S
181.2	306	40	S
181.5	307	40	S
184.2	14	67	S
184.6	68	74	S
186.1	303	39	S
187.4	304	44	S
188.6	307	24	S
189.2	299	48	S
190.7	305	37	S
191.7	153	27	S
194.0	310	37	S
200.6	286	20	S
200.1	206	15	S
201.0	311	45	S
201.2	307	48	S
202.1	295	32	S
203.1	294	35	S
204.6	295	20	S
206.9	271	15	S
208.7	309	39	S
209.4	301	42	S
213.2	298	77	S
213.5	142	55	S
216.5	184	52	S
221.7	308	30	S
221.8	313	31	M
221.9	305	32	S
225.8	313	51	S
226.0	316	52	S
226.3	302	46	S
226.8	309	45	S

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
227.0	330	37	S
227.7	293	44	S
229.4	290	30	S
229.9	313	70	S
230.5	289	50	S
231.5	299	39	S
231.2	279	69	S
232.3	333	72	S
233.8	311	38	S
234.5	313	46	S
238.2	316	85	S
240.3	177	67	S
240.1	150	52	S
242.3	2	83	S
244.7	177	32	S
245.2	201	75	S
245.2	59	72	S
245.0	160	32	S
245.8	141	45	S
246.6	123	66	S
248.5	139	45	S
249.4	123	30	S
249.0	135	80	S
252.1	107	52	S
253.4	137	78	S
253.9	150	43	S
254.6	302	46	S
255.1	304	49	S
256.3	141	47	S
258.6	76	38	S
257.9	306	47	S
257.9	147	77	S
261.1	204	67	S
261.8	308	45	S
263.9	306	81	S
263.2	158	52	M
265.8	140	77	S
266.1	177	21	M
268.3	304	52	S
269.2	302	53	S
271.0	305	48	S
271.8	314	68	S
273.6	311	50	S
274.0	299	71	S
274.7	325	83	S
276.6	305	48	S
277.8	313	63	S
278.0	333	72	S
278.5	299	70	S
281.4	208	88	S
282.1	306	60	S
287.5	302	57	S
287.8	316	56	S
292.6	304	54	S
297.9	58	67	S
299.6	302	80	S
302.2	138	84	S
303.3	139	35	M
304.1	302	46	M
312.7	149	43	S
313.0	158	21	S
313.1	144	25	M
317.0	126	31	M
318.6	309	54	S
319.0	83	85	S
323.8	140	64	S
325.8	153	30	S
326.9	157	28	S
327.5	279	11	S
330.6	307	71	S
331.7	120	56	S
332.0	112	71	M
332.4	127	44	S
332.6	151	50	S
332.6	154	24	S
333.0	156	18	S

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
333.6	111	82	M
334.7	158	34	S
334.7	123	23	S
336.5	281	62	S
337.8	284	74	S
338.0	321	58	S
337.8	310	62	S
338.6	316	62	S
338.8	332	62	S
339.0	304	61	S
340.4	286	6	S
342.3	310	71	S
343.9	147	36	S
344.9	304	53	S
345.8	304	35	S
346.4	35	2	S
346.6	122	28	S
349.5	306	46	S
350.6	135	39	S
350.7	304	56	S
351.0	146	36	S
352.6	301	33	S
354.9	140	26	S
356.5	302	30	M
364.1	109	32	S
364.6	287	27	S
370.0	53	56	S
370.8	298	29	S
372.1	55	59	S
373.9	300	70	S
374.4	256	9	M
382.4	72	64	S
382.3	67	58	S
386.3	304	39	S
388.0	78	71	S
395.8	31	60	S
396.3	354	34	M
399.2	330	43	S
400.0	334	48	S
399.6	337	47	L
400.8	348	50	M
402.4	64	67	S
404.6	334	70	S
404.8	86	71	S
405.8	345	43	S
406.3	351	38	S
411.3	349	68	S
424.8	61	62	S
428.6	78	72	S
432.0	88	68	S
432.9	70	65	S
445.1	82	77	S
447.1	92	81	S
448.8	67	71	S
448.2	76	76	S
460.2	72	76	S
461.2	78	74	S
477.1	64	23	S
477.8	53	76	S
485.3	58	81	S
487.8	57	77	S
502.1	310	37	S
512.2	286	20	S
515.6	327	5	S
522.8	294	32	S
523.2	348	74	S
536.6	297	34	S
E33ST-A Foliation			
53.7	352	52	
60.6	329	45	
63.5	309	55	
69.0	314	49	
86.3	306	56	
90.1	309	73	
113.9	320	61	

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
120.1	308	41	
132.3	303	55	
138.7	299	51	
146.9	311	42	
152.1	315	42	
158.6	339	25	
163.8	308	36	
165.3	309	32	
168.2	312	33	
172.6	321	48	
176.7	306	40	
179.7	308	40	
182.1	311	40	
187.4	298	43	
188.6	286	24	
191.8	300	28	
194.0	303	36	
196.2	301	26	
198.1	310	42	
201.6	296	35	
203.5	307	35	
206.5	295	29	
209.4	300	45	
212.9	303	73	
216.4	305	52	
218.4	317	41	
222.8	308	33	
224.0	303	37	
225.7	336	25	
227.7	301	44	
229.8	309	43	
232.6	311	40	
234.3	306	38	
236.4	306	44	
238.6	309	46	
240.7	305	45	
243.0	306	44	
246.2	303	46	
247.5	314	49	
249.9	306	50	
251.7	308	47	
254.6	302	50	
257.0	301	41	
259.0	303	42	
260.7	305	48	
262.5	296	43	
263.6	301	51	
266.1	305	53	
268.7	307	54	
270.3	309	44	
272.4	306	47	
274.6	320	48	
276.6	308	49	
278.6	318	57	
281.0	310	52	
282.4	313	56	
285.3	300	40	
287.2	305	50	
288.5	296	49	
292.1	311	47	
293.9	303	45	
295.6	299	46	
297.6	309	37	
299.5	295	34	
302.6	303	51	
304.5	308	55	
307.2	297	48	
309.2	303	45	
311.5	305	56	
313.2	306	58	
314.6	310	55	
316.2	306	47	
318.5	305	50	
319.7	311	47	
322.2	300	39	
323.6	299	44	

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
325.3	310	39	
327.2	302	50	
328.7	305	46	
330.3	303	57	
331.9	307	49	
334.9	299	43	
339.1	308	37	
340.7	306	38	
342.9	301	53	
345.1	303	59	
348.8	300	59	
351.0	309	35	
352.4	297	34	
354.0	299	48	
355.9	296	40	
357.8	293	38	
359.4	302	44	
362.6	295	43	
364.6	292	29	
366.9	301	35	
370.4	300	25	
372.2	282	16	
374.5	267	14	
375.3	304	18	
379.6	306	41	
386.7	312	33	
389.1	304	57	
392.7	308	44	
395.1	313	46	
397.2	336	50	
399.2	325	40	
401.1	333	42	
402.7	337	47	
403.8	332	71	
406.4	331	44	
408.3	336	47	
411.3	352	66	
416.3	334	53	
419.2	322	56	
421.4	350	41	
423.7	328	58	
425.6	338	46	
428.9	339	30	
431.2	342	23	
433.2	334	28	
435.5	341	36	
437.5	334	57	
439.8	339	53	
441.9	331	46	
444.9	324	42	
446.9	329	46	
449.0	321	44	
451.1	332	45	
453.3	326	41	
455.6	323	43	
457.6	324	43	
459.9	321	53	
462.0	324	40	
464.9	314	43	
467.0	323	48	
468.4	327	54	
470.9	323	51	
473.0	319	48	
475.1	319	63	
479.0	318	49	
480.6	310	61	
482.8	306	50	
485.3	307	44	
486.6	309	42	
488.9	321	42	
490.6	323	30	
492.8	296	23	
494.9	299	22	
496.9	307	38	
498.2	302	27	
500.6	304	28	

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
502.5	307	31	
505.0	310	34	
507.1	295	30	
508.9	308	34	
511.0	290	23	
512.2	285	24	
514.8	295	36	
516.6	301	35	
518.5	310	18	
520.7	292	34	
521.9	296	37	
523.4	282	37	
526.0	295	34	
528.4	301	29	
531.4	294	30	
533.6	287	36	
535.7	300	28	
537.8	295	42	
539.7	293	30	
541.6	302	31	
543.1	298	27	
544.7	306	34	
E35ST-D			
Fractures			
27.9	23	68	M
30.6	188	68	M
32.6	98	57	M
35.1	185	79	M
40.3	95	3	M
40.6	69	16	S
41.8	98	15	S
42.7	131	48	S
43.8	272	4	S
43.8	262	9	S
45.0	145	53	S
46.5	130	50	S
49.2	278	26	S
50.4	285	35	S
50.7	282	26	L
50.8	278	39	M
51.0	271	41	L
51.7	259	49	M
52.1	322	9	S
52.6	307	19	S
52.7	125	5	S
52.7	128	17	M
52.7	263	4	S
53.0	30	2	S
53.0	12	5	S
55.9	100	8	S
64.3	259	69	S
69.7	272	49	S
75.8	57	6	S
75.8	15	7	S
76.7	137	30	S
77.0	157	20	S
78.2	125	30	S
78.3	14	65	S
78.5	121	33	S
78.7	121	7	S
81.2	241	40	S
82.4	207	6	M
82.4	210	5	M
82.9	106	12	S
83.0	155	10	S
83.2	90	33	M
83.4	71	75	S
84.9	78	65	S
85.6	272	41	S
86.0	233	18	S
86.5	30	27	S
86.6	83	16	M
88.8	150	75	S
89.5	160	74	S
89.6	84	25	S
90.0	95	51	S

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
90.1	88	67	S
92.4	97	23	S
94.9	48	51	S
95.5	48	78	S
96.9	143	32	S
97.7	180	71	S
99.0	269	53	S
100.7	74	34	S
101.5	243	78	S
102.4	71	8	S
102.4	203	77	S
102.9	309	7	S
102.9	263	14	S
105.6	265	55	S
105.9	104	12	M
106.0	78	10	S
107.7	260	49	S
111.0	63	4	S
111.1	89	16	S
114.3	50	14	S
114.3	56	25	S
114.4	53	19	S
117.1	40	26	S
117.9	64	19	S
118.9	65	37	S
120.0	80	30	S
120.2	38	35	L
120.5	277	27	S
120.5	52	40	M
121.0	291	21	S
121.3	50	76	S
121.6	27	45	M
122.4	243	46	S
122.8	11	26	S
123.0	19	28	S
123.1	50	35	S
123.8	46	33	S
124.7	60	44	S
125.5	71	31	S
125.8	230	8	S
125.8	358	72	S
126.1	52	25	S
126.5	14	5	M
126.5	222	26	M
128.2	21	36	S
131.4	154	3	S
131.4	322	2	S
132.8	259	37	S
133.2	286	27	S
133.6	15	34	S
133.7	76	11	S
134.0	122	5	S
134.0	46	3	S
134.1	72	70	S
139.8	11	54	S
140.4	119	3	S
140.5	159	8	S
166.7	23	3	L
166.8	53	8	M
166.9	119	7	M
168.3	167	4	S
168.5	181	6	S
169.0	354	78	S
172.6	190	67	S
187.0	264	46	S
187.5	118	34	S
187.5	122	36	S
189.2	105	28	M
190.0	67	17	M
190.0	66	10	M
190.1	277	26	S
190.6	73	17	M
190.7	122	38	S
190.9	128	36	S
196.4	86	22	M
196.8	77	7	S

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
196.9	65	9	L
198.0	45	14	S
198.0	47	21	S
198.7	77	19	S
198.7	56	11	S
201.3	82	11	S
203.2	157	71	S
204.8	71	29	S
205.7	72	34	S
206.6	268	56	M
206.9	86	56	S
207.6	265	57	S
209.2	270	86	
209.6	292	25	S
212.1	80	13	S
212.7	289	82	S
213.5	289	58	S
214.3	96	51	S
214.4	93	68	S
214.7	103	64	S
215.1	109	3	S
220.3	285	34	S
220.4	272	42	S
221.7	271	47	S
231.9	87	24	S
236.3	36	79	M
238.5	52	68	S
238.7	61	80	M
241.5	67	4	S
242.1	164	34	S
242.3	54	13	S
252.5	292	47	S
253.3	289	60	S
253.7	282	58	S
264.0	107	10	S
264.1	123	11	S
273.9	268	45	M
278.1	87	18	S
287.7	93	36	S
289.5	268	47	S
289.7	267	44	S
289.8	275	41	S
290.0	274	40	S
297.7	266	38	S
301.0	273	28	S
302.1	277	27	S
302.3	279	22	S
302.3	272	25	S
302.4	273	25	S
302.7	266	36	S
302.9	276	40	S
306.4	34	60	S
309.5	275	24	M
309.7	57	33	S
310.8	106	62	S
312.9	79	28	S
315.7	123	17	S
315.7	54	18	S
316.0	56	14	S
316.1	81	19	S
318.2	105	34	S
322.5	109	33	M
322.6	72	60	S
322.6	66	63	S
323.4	264	57	M
324.5	287	43	S
331.3	148	68	S
331.9	158	71	S
333.4	277	64	S
334.1	275	57	S
335.0	270	57	S
337.3	268	57	M
337.9	140	75	S
338.2	80	28	S
338.6	65	32	S
339.5	265	38	S

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
340.2	294	43	S
340.4	288	45	S
341.4	266	50	S
343.5	98	17	S
345.2	272	60	S
351.0	269	55	S
351.4	271	59	S
353.0	262	72	M
364.6	283	30	S
370.4	293	55	S
373.6	46	73	S
374.8	39	75	M FLT
375.7	62	78	S
377.6	251	81	S
377.8	358	53	S
379.6	256	88	M FLT
383.0	288	36	M
383.4	48	10	S
385.5	289	59	S
386.3	287	53	S
386.8	297	57	S
387.2	290	43	S
387.7	289	54	S
387.9	284	51	S
389.3	273	57	S
389.8	128	25	S
390.3	123	13	S
390.4	291	63	M
390.4	142	28	S
391.0	53	73	M FLT
391.6	51	67	M
391.7	302	57	M
392.3	303	51	S
392.6	343	45	S
392.8	342	48	S
393.6	322	55	M
399.5	277	78	S
399.7	199	49	S
400.8	187	71	S
403.2	189	74	S
403.3	36	45	S
405.4	287	43	M
405.6	302	28	M
405.6	276	58	S
406.7	280	70	S
407.8	345	48	S
408.6	274	43	S
408.9	269	49	S
409.2	275	47	S
409.3	309	39	M
409.7	276	47	S
409.8	288	47	S
410.7	281	57	S
411.1	283	47	M
411.6	280	57	M
412.3	272	61	S
412.6	260	53	S
412.9	299	56	S
413.4	220	52	S
413.8	219	53	S
414.6	282	49	S
414.9	284	56	M
416.0	92	83	M FLT
417.4	282	64	M
417.6	266	42	S
418.3	277	51	S
418.4	277	56	S
419.3	220	73	S
419.6	283	76	S
419.9	57	70	S
420.8	287	38	S
420.8	281	37	S
420.9	282	41	S
421.0	283	43	S
436.7	244	74	S
440.5	245	62	S

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
442.0	252	66	S
443.5	244	67	S
444.0	215	67	S
444.9	235	61	S
448.7	86	28	S
449.8	230	76	S
465.8	279	82	S
469.1	114	78	M
471.0	207	47	S
472.2	148	18	S
475.0	95	12	S
475.1	49	24	S
482.9	231	32	S
484.7	153	22	S
490.1	143	37	S
490.2	143	42	M
493.9	226	24	S
494.7	197	27	S
496.5	236	65	S
498.1	215	34	S
503.6	246	30	S
505.1	261	38	S
505.8	273	49	S
505.9	269	61	M
506.0	102	63	S
509.6	233	71	S
516.0	255	43	M
517.4	254	31	M
525.2	13	21	S
530.2	125	20	S
530.3	355	12	S
532.7	253	79	S
552.1	276	63	S
554.3	275	62	S
569.2	270	62	S
570.6	276	73	S
574.6	239	71	S
576.9	229	84	S
583.2	238	87	S
584.5	234	68	S
589.1	23	7	S
593.1	265	43	S
E35ST-D Foliation			
29.9	270	56	
31.7	263	57	
33.7	268	45	
35.9	269	51	
38.2	273	37	
40.0	282	42	
41.4	282	34	
42.9	277	41	
44.5	277	37	
45.5	280	45	
47.7	280	40	
49.3	296	43	
51.4	305	36	
52.0	310	18	
57.2	340	51	
61.0	272	47	
62.1	270	52	
65.3	273	71	
67.2	269	48	
70.2	279	40	
73.5	274	40	
76.6	274	41	
81.8	258	33	
83.5	111	15	
87.8	279	68	
90.7	273	42	
93.6	272	46	
100.6	242	14	
103.3	276	9	
106.6	85	24	
109.1	261	36	
112.3	268	15	

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
113.5	213	27	
116.2	298	17	
117.0	98	26	
121.3	266	45	
131.1	264	64	
135.6	242	61	
137.4	278	73	
158.3	282	60	
173.2	283	43	
182.6	265	49	
186.3	280	51	
188.8	278	53	
192.3	264	57	
195.2	275	60	
198.9	275	41	
206.4	273	45	
209.3	264	38	
213.8	288	58	
216.3	272	48	
219.4	277	49	
222.1	271	48	
225.5	282	49	
229.5	276	40	
232.3	269	48	
235.1	277	48	
238.6	266	45	
241.7	287	51	
244.5	271	39	
249.9	273	54	
251.9	280	59	
256.3	276	42	
261.1	278	46	
263.0	280	49	
266.7	280	50	
269.5	289	36	
271.4	305	37	
274.0	267	46	
277.2	273	40	
280.3	266	42	
283.4	279	42	
286.8	269	45	
290.5	269	51	
293.1	258	35	
296.3	290	30	
299.9	270	48	
302.7	273	30	
304.7	302	14	
309.4	277	29	
310.8	278	34	
315.1	269	63	
323.4	266	59	
326.1	269	49	
333.4	270	64	
336.1	262	62	
339.4	286	47	
343.3	271	54	
346.4	272	49	
350.1	272	58	
352.6	276	61	
354.7	283	64	
357.8	266	46	
363.2	278	49	
365.6	289	41	
368.5	286	35	
371.9	296	49	
375.4	303	21	
377.2	298	31	
379.9	284	64	
383.1	278	54	
387.0	282	53	
390.3	277	59	
393.6	316	55	
401.3	265	63	
407.1	262	46	
410.5	267	59	
414.2	280	43	

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
417.5	270	46	
423.4	296	44	
427.0	280	45	
429.8	297	46	
432.4	288	42	
436.1	290	45	
439.2	307	36	
442.1	296	43	
445.7	309	58	
449.2	286	64	
451.9	297	68	
454.1	278	56	
457.0	259	56	
458.2	259	49	
463.3	232	36	
464.5	231	36	
467.4	211	47	
469.4	217	55	
471.0	197	56	
473.6	173	47	
478.5	161	37	
483.0	230	33	
485.3	261	50	
487.0	199	27	
488.1	196	23	
489.1	183	26	
490.1	134	35	
495.7	247	38	
499.1	243	34	
500.6	260	43	
502.0	247	39	
503.4	269	36	
505.1	262	37	
507.1	268	37	
508.9	264	42	
511.3	257	34	
513.5	261	44	
514.6	262	34	
516.0	251	45	
518.1	246	37	
520.1	238	47	
521.6	274	59	
522.6	257	52	
524.4	264	43	
526.8	248	53	
527.8	251	49	
529.7	257	51	
530.7	271	53	
532.7	258	80	
535.9	266	66	
538.1	247	45	
539.4	254	46	
541.4	261	51	
542.3	236	46	
546.7	268	40	
547.7	269	46	
549.1	270	48	
550.9	286	43	
554.5	268	56	
555.8	270	54	
556.9	266	50	
558.6	268	56	
560.7	271	50	
561.8	273	51	
563.3	292	38	
568.8	283	35	
570.4	275	29	
572.5	292	27	
575.1	276	35	
576.0	287	45	
578.9	278	37	
580.1	292	33	
582.0	277	43	
583.1	275	43	
584.7	286	46	
586.4	313	18	

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
588.5	287	26	
589.2	292	29	
591.1	274	41	
592.9	278	37	
594.7	271	47	
E39ST-A			
Fractures			
47.7	141	55	M
48.1	301	60	S
48.4	302	58	S
49.4	295	60	S
49.9	150	39	M GW
50.6	302	58	M
51.3	194	41	M
51.5	174	52	M
52.3	157	49	S
53.1	298	57	S
53.2	152	59	S GW
54.5	217	58	S
54.8	173	21	L
55.2	268	28	S
56.5	235	17	M GW
58.4	259	24	S GW
58.5	162	69	S
58.9	294	53	S
60.6	142	51	S
61.1	301	45	M GW
61.8	302	46	S
63.1	308	36	S
63.2	168	30	S
63.8	243	25	S
65.3	307	52	M GW
66.0	245	48	S GW
66.3	160	59	S
68.3	302	34	S
68.7	185	46	S
68.9	180	35	S
69.4	313	16	S
69.7	320	13	S
69.9	265	17	S
69.9	236	11	S
71.1	151	72	S RVFLT
71.3	177	31	S
71.5	171	4	S
71.9	228	28	S
72.1	47	4	S
73.2	328	63	S
73.3	102	61	S
73.6	316	43	S
73.8	302	56	S
74.0	291	56	S
74.4	108	9	S
74.7	73	22	S
75.0	303	57	S
76.7	296	58	S
77.2	310	49	S
77.2	303	69	L
77.9	307	62	L
78.9	299	63	M
83.9	316	13	S
83.9	313	24	M
90.7	169	11	S
96.0	134	55	M
98.6	303	41	S
100.3	297	53	S
102.4	148	50	S
103.8	148	56	S
109.9	276	73	S
112.6	103	6	S
112.6	108	24	S
114.1	324	64	S
117.2	184	49	S
119.2	158	22	S
120.0	321	32	S
127.4	180	50	S

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
127.6	182	42	S
129.4	120	18	S
129.9	85	17	S
130.8	317	42	S
131.6	310	42	S
132.8	339	3	M
136.9	274	5	S
137.8	21	71	S
			NMFLT
139.4	359	9	S
141.5	194	54	S
143.5	224	40	S
146.5	90	26	S
146.7	40	14	S
147.7	308	56	S
151.4	45	12	S
151.9	351	9	S
151.9	354	7	S
155.1	89	28	S
155.5	84	68	S
156.3	84	61	S
156.5	110	12	S
157.7	82	14	S
157.9	85	55	S
158.8	164	42	S
161.5	53	14	S
161.9	137	40	S
163.6	127	14	S
163.6	94	32	S
170.8	94	6	M
176.4	145	67	S
178.2	113	19	S
178.2	109	11	S
180.8	103	28	S
180.8	19	11	S
183.4	57	18	S
183.4	144	63	S
183.7	76	19	S
184.3	28	69	S
187.2	298	46	S
187.8	303	55	S
188.4	138	61	S
188.6	145	38	S
192.9	154	52	S
192.9	304	56	S
193.3	304	54	S
193.6	298	59	S
194.3	290	55	S
195.3	289	44	S
196.6	109	34	S
197.3	120	39	S
197.6	224	68	S
198.0	237	68	S
200.0	164	46	S
200.3	130	60	S
200.9	168	61	S
202.2	278	39	S
206.6	292	43	S
207.7	287	38	S
207.8	289	38	S
208.2	278	44	S
208.4	296	42	S
208.5	292	47	S
208.6	302	46	S
209.0	291	35	S
209.1	293	35	S
209.5	287	44	S
210.4	288	45	S
210.5	294	48	S
212.7	280	44	S
214.0	286	38	S
214.3	286	41	S
216.2	280	35	S
218.9	295	29	S
219.3	283	42	S
219.4	280	47	S

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
220.4	283	44	M
223.4	283	41	S
226.1	283	39	S
226.3	273	40	S
227.6	288	38	M
227.9	288	36	M
228.4	279	34	S
228.5	294	31	S
228.6	300	26	S
229.1	295	25	S
229.4	300	29	S
229.5	302	31	S
230.0	275	25	S
230.7	55	46	S
231.2	160	41	S
231.9	40	13	S
233.7	125	75	S
234.6	336	25	S
235.2	125	45	S
235.4	11	7	S
235.9	122	74	S
237.6	187	51	S
237.9	163	44	S
239.2	114	68	M
239.6	124	72	S
240.1	314	20	S
240.6	317	24	S
241.1	281	64	S
241.1	310	73	S
241.6	279	35	S
241.8	278	43	M
242.2	284	36	S
242.6	259	46	S
242.8	326	10	S
243.1	328	11	S
243.2	352	10	S
245.1	295	30	S
245.2	287	27	S
245.4	293	40	S
245.9	288	29	S
246.9	273	28	S
247.5	281	26	S
248.0	301	36	M
248.0	308	39	S
248.3	112	41	S
251.6	287	12	S
255.5	255	11	S
255.8	354	5	S
255.9	228	9	S
256.1	283	16	S
256.2	265	14	S
256.5	276	21	S
256.6	137	5	S
257.1	122	75	M
259.5	159	39	M
261.0	118	66	M
262.2	289	30	S
262.7	122	64	S
262.8	116	59	S
264.1	124	67	S
264.7	112	68	M
267.5	284	58	M
267.8	269	63	M
268.0	269	55	S
268.2	289	82	M
270.3	333	87	S
270.8	265	2	S
271.0	254	17	S
271.2	294	6	S
271.3	337	15	S
271.5	275	10	S
272.2	259	74	S
272.4	285	20	S
272.6	270	26	S
273.3	221	59	S
273.3	126	81	M

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
275.3	278	49	S
275.7	297	29	S
276.5	313	29	S
277.9	286	49	S
279.1	281	34	S
280.7	87	29	S
281.1	84	41	S
281.5	277	71	M
282.3	61	33	S
283.8	263	79	M
284.6	100	75	L
285.1	65	35	M
286.6	296	79	M
295.7	320	12	S
295.8	342	25	M
296.4	222	40	S
297.2	223	47	S
297.4	215	51	S
300.8	223	75	S FLT
301.0	227	75	S FLT
301.6	254	60	S
301.9	224	47	S
303.3	280	36	S
306.2	287	39	S
307.0	292	34	S
308.2	288	20	S
308.5	284	32	S
309.0	278	38	S
310.0	294	31	S
311.1	284	39	L
311.2	278	45	S
311.9	263	14	S
312.0	265	14	S
312.0	261	31	M
312.1	252	46	M
312.5	250	16	S
312.7	276	20	S
312.9	264	32	M
312.9	277	41	M
313.0	284	46	M
316.1	295	46	S
317.7	279	48	S
318.3	294	40	S
319.5	242	72	S FLT
320.1	245	80	S FLT
320.8	275	38	S
322.9	294	35	S
325.6	287	34	S
326.7	285	30	S
327.5	296	30	S
327.7	281	36	S
328.4	248	66	M
330.9	203	59	S
332.8	212	57	S
333.0	286	39	S
334.0	212	62	S
334.1	279	36	S
335.9	222	66	S
338.4	256	65	S
340.7	194	63	S
342.8	253	27	S
342.9	265	33	S
346.2	276	46	S
346.9	268	30	S
347.3	186	58	S
348.4	245	58	M
348.6	240	63	S
350.3	265	31	S
351.1	275	36	S
352.1	273	65	S
357.1	273	29	S
357.4	269	33	S
359.1	246	70	S
366.9	297	32	S
370.7	255	29	S
377.2	262	29	S

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
378.1	248	55	S
384.3	275	36	S
384.7	279	18	S
385.5	267	32	S
394.6	289	23	M
449.9	206	47	S
458.1	258	8	S
459.3	219	70	S
460.0	322	5	S
479.7	302	23	S
480.1	293	8	S
487.4	300	20	S
E39ST-A			
Foliation			
316.4	286	40	
318.6	282	37	
321.1	290	41	
323.3	288	34	
325.6	280	36	
327.7	289	36	
330.2	286	34	
331.4	295	39	
333.0	287	33	
335.2	279	32	
336.3	279	29	
337.8	283	31	
341.7	264	26	
343.0	272	38	
344.1	273	35	
345.9	280	36	
347.4	255	28	
348.8	272	38	
349.7	275	38	
351.6	274	42	
352.2	276	34	
353.4	259	27	
354.8	287	27	
357.1	281	29	
358.7	270	41	
360.1	266	24	
361.4	270	28	
362.9	266	18	
364.5	284	26	
366.8	242	29	
368.7	265	22	
369.9	291	23	
371.1	287	31	
372.6	252	17	
374.1	281	34	
375.5	252	16	
377.9	271	38	
379.1	286	27	
381.7	282	29	
383.1	277	35	
384.2	296	30	
385.5	288	31	
387.1	294	33	
388.7	268	29	
390.8	281	31	
392.2	272	30	
393.9	281	24	
395.3	281	25	
396.9	300	20	
397.9	270	37	
399.4	275	33	
401.0	280	40	
402.4	276	40	
404.4	295	24	
405.4	270	31	
409.7	208	6	
413.7	287	32	
414.9	265	22	
417.4	252	17	
418.6	248	19	
420.2	251	19	
421.8	236	9	

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
423.9	253	13	
427.8	273	22	
433.0	245	9	
434.9	217	10	
436.7	112	14	
438.5	108	21	
440.3	106	19	
441.5	118	13	
446.0	275	29	
447.5	276	29	
448.9	263	25	
450.4	116	31	
451.5	273	29	
453.3	117	19	
459.1	124	17	
460.4	301	22	
461.6	272	5	
463.3	300	10	
465.3	282	23	
467.1	272	26	
468.4	278	15	
469.4	286	12	
471.4	278	15	
471.9	283	13	
473.7	270	19	
475.2	276	23	
476.3	270	15	
476.9	287	17	
480.8	315	5	
481.2	303	11	
483.4	302	9	
484.5	281	13	
487.4	298	23	
E45ST-A			
Fractures			
16.1	144	9	L GW
34.5	236	3	L
55.3	265	23	S
61.0	285	35	S
61.6	106	80	S
62.7	292	23	S
63.1	272	40	S
64.5	95	83	S
71.2	45	5	S
71.3	56	10	S
84.4	287	22	S
85.5	249	9	S
85.5	274	22	M GW
97.2	246	22	S
103.5	285	39	S
108.2	90	60	S
111.1	262	46	S
112.8	267	37	RVFLT
112.8	124	71	S
114.8	291	30	S
115.9	94	82	S
117.3	95	81	S
118.3	291	41	S
118.6	283	54	S
120.1	101	76	S
136.4	287	70	GEOCNT
129.0	103	56	S
147.3	126	39	S
147.4	106	43	S
147.9	122	43	S
150.2	99	57	S
150.2	268	48	S
157.2	92	39	S
157.5	96	51	S
159.9	100	35	S
163.2	85	71	S
163.7	91	74	S
164.5	259	45	S
165.1	263	37	S
165.5	101	55	S
168.4	106	43	S

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
168.9	133	46	S
170.3	84	61	S
170.5	89	70	S
172.0	347	78	M
174.3	85	73	S
173.9	76	77	S
174.6	94	51	M
177.4	103	32	S
177.5	123	37	S
177.9	132	39	S
179.2	266	38	S
187.9	86	56	S
187.7	94	64	S
190.5	89	63	S
192.6	143	64	S
201.8	92	63	S
203.0	97	77	S
203.6	87	43	S
204.4	263	33	S
205.3	89	61	S
205.8	73	43	S
206.0	81	58	S
206.6	85	42	S
207.0	88	73	S
210.2	91	55	S
210.8	92	61	S
211.6	92	46	S
212.7	82	33	S
214.9	83	32	S
215.3	274	23	S
215.5	75	25	S
216.0	101	37	S
216.3	190	2	S
216.8	139	71	S
217.5	316	6	S
219.2	80	68	M
219.5	81	76	S
219.7	86	78	S
221.0	84	38	S
222.1	135	30	S
222.1	277	30	S
223.3	80	74	S
223.6	91	75	M
224.6	267	12	S
224.7	265	24	S
224.8	269	29	S
224.8	255	25	S
225.6	76	22	S
226.1	87	43	S
227.1	277	30	S
227.6	262	35	S
228.1	86	16	S
228.7	175	5	S
229.2	90	59	S
229.3	92	32	S
230.0	88	47	S
230.2	277	9	S
231.2	266	34	S
231.8	262	28	S
232.5	164	26	S
233.2	100	15	S
233.4	126	35	S
233.8	61	6	S
234.5	108	6	M
234.9	109	46	S
235.0	92	20	M
235.1	103	4	S
235.2	71	14	S
235.6	88	29	S
235.7	99	29	M
236.5	268	31	S
237.7	91	30	M
238.2	81	34	M
239.1	83	41	M
239.2	82	24	M
239.4	88	34	S

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
239.4	71	15	S
239.7	84	17	S
239.8	83	23	S
239.9	72	18	S
240.5	87	54	M
240.6	83	67	S
240.7	86	66	S
240.9	89	60	S
241.1	88	30	S
241.2	85	27	S
241.7	71	31	S
242.0	86	52	S
242.0	78	21	S
242.5	86	51	S
242.8	88	72	S
243.1	88	31	S
243.4	90	35	S
243.2	86	21	S
243.5	94	47	S
243.6	108	30	S
243.5	118	39	S
244.1	264	33	S
244.1	272	28	S
244.7	265	26	S
244.7	91	32	S
244.9	268	35	S
245.2	72	11	S
245.4	269	33	S
245.6	107	24	S
246.0	198	11	S
246.3	308	17	S
246.6	94	21	S
246.6	273	34	S
246.9	80	15	S
247.0	272	27	S
247.5	276	26	S
247.7	233	16	S
248.0	263	30	S
248.3	319	33	S
249.1	108	47	S
249.4	96	42	S
249.8	275	50	M
250.2	177	60	S
250.3	95	36	S
250.4	104	38	S
250.7	175	52	S
254.9	94	84	S
254.4	246	53	S
254.5	253	46	S
254.8	82	50	S
255.5	101	57	S
255.7	281	35	S
255.9	293	46	S
258.4	287	89	S
257.4	353	8	M
258.0	98	57	M
257.8	116	32	M
258.4	298	34	S
258.6	281	31	S
259.1	117	34	S
259.2	90	7	S
259.3	280	22	S
259.4	102	43	M
259.4	230	5	S
259.6	99	57	S
259.8	53	17	S
260.0	291	19	S
260.0	106	46	S
260.2	270	21	S
260.2	291	23	S
260.4	118	21	S
260.7	96	35	S
261.1	280	28	S
261.1	98	27	S
261.8	106	68	S
262.7	100	71	S

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
264.3	285	37	S
264.5	285	34	S
265.0	275	32	S
265.3	284	33	S
265.6	277	44	S
266.4	280	35	S
266.8	125	31	S
267.1	288	31	S
268.2	288	18	S
268.0	279	49	S
268.5	104	34	S
269.4	281	39	S
270.0	84	78	S
270.1	94	61	M
271.7	103	26	S
271.7	271	55	S
273.2	89	47	S
276.0	106	20	S
276.1	152	23	S
277.4	311	29	S
277.8	281	39	S
278.4	98	35	S
279.9	286	44	S
281.0	298	36	S
282.8	87	74	S
282.8	298	44	S
285.5	296	41	S
285.7	292	38	S
285.9	101	14	S
287.2	122	16	S
290.0	96	30	S
290.7	283	40	S
291.4	284	29	S
291.8	284	53	S
292.3	294	50	S
293.0	199	24	S
293.3	155	18	S
293.3	280	34	S
293.6	292	46	S
294.0	282	27	S
294.3	178	19	S
295.4	69	15	S
296.1	90	17	S
298.2	281	35	S
298.0	84	80	M
299.2	278	27	S
299.6	95	24	S
300.6	280	31	S
301.5	72	81	S
302.9	286	27	S
303.3	284	25	S
303.8	298	11	S
304.2	129	25	S
305.7	288	35	S
306.2	96	65	S
306.7	281	34	S
307.1	270	46	S
307.2	277	46	S
307.8	281	34	S
308.0	271	34	S
308.5	101	61	S
309.1	279	42	S
309.3	288	39	S
309.9	287	28	S
310.9	272	34	S
311.7	279	39	S
311.9	283	35	S
312.3	91	35	S
312.6	287	43	S
312.7	286	44	S
312.9	289	39	S
313.0	287	42	S
313.3	279	53	S
313.7	278	34	S
313.9	292	34	S
314.1	277	40	S

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
314.2	280	42	S
314.3	287	36	S
314.5	286	36	S
314.4	287	37	S
314.6	278	39	S
314.8	290	43	L
315.1	276	51	M
315.9	287	39	M
316.6	310	79	S
318.1	286	43	S
319.0	125	72	S
323.1	283	33	S
323.7	287	41	M
324.1	280	38	S
326.1	293	40	S
328.0	283	37	S
327.0	280	32	S
329.6	281	35	S
329.5	273	31	S
329.4	274	23	S
333.1	268	20	S
340.4	282	34	S
340.6	279	43	S
342.4	119	69	S
342.1	120	69	S
345.2	100	41	S
356.6	341	87	SNMFLT
367.8	241	18	S
368.0	236	30	S
393.5	285	49	S
394.1	312	21	S
394.3	309	29	S
394.4	298	30	S
402.0	329	17	S
434.8	291	42	S
435.0	288	34	S
435.1	280	28	S
438.2	89	22	S
438.3	318	9	S
453.2	117	88	S
456.6	127	81	M
460.2	126	81	S
E45ST-A			
Foliation			
15.1	256	32	
15.6	272	34	
20.6	275	24	
22.2	250	33	
31.3	269	42	
35.8	273	59	
36.7	281	50	
47.5	269	35	
49.6	283	32	
52.0	296	32	
54.8	287	33	
56.4	283	34	
58.5	281	43	
60.3	277	33	
62.0	284	41	
63.4	274	32	
66.2	291	30	
68.1	281	25	
70.0	276	30	
71.6	288	18	
72.8	298	29	
75.2	298	32	
77.8	259	38	
80.1	263	37	
81.6	278	34	
82.5	287	22	
84.9	285	29	
86.4	287	21	
88.3	286	26	
90.1	286	27	
93.7	281	27	
94.9	260	26	

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
96.5	276	24	
97.3	237	24	
99.1	295	42	
100.5	299	50	
102.2	291	36	
103.0	299	28	
104.3	282	43	
105.9	274	26	
107.1	267	21	
108.3	285	55	
110.1	283	61	
110.8	279	48	
114.1	275	39	
115.9	281	42	
117.3	264	37	
119.4	276	45	
127.1	264	30	
130.1	283	30	
139.9	271	30	
142.1	275	33	
145.5	282	41	
147.3	263	27	
149.7	275	44	
151.5	277	46	
153.9	268	39	
155.3	267	41	
157.1	277	34	
158.5	271	28	
160.2	261	25	
161.5	276	43	
163.1	278	41	
164.9	281	37	
166.8	264	35	
168.1	272	48	
169.7	279	38	
171.3	269	42	
172.8	280	36	
175.2	272	36	
177.1	268	32	
178.7	274	44	
179.8	277	35	
182.5	271	26	
183.8	286	21	
185.4	280	12	
186.7	282	20	
188.5	243	15	
190.0	264	33	
191.6	271	25	
193.0	287	21	
194.5	266	28	
196.3	271	35	
197.9	253	27	
199.4	255	25	
200.8	276	31	
202.3	277	29	
203.9	277	35	
205.6	259	19	
207.6	272	18	
208.9	275	31	
210.7	265	24	
212.2	265	33	
213.7	250	16	
214.9	277	24	
216.6	269	25	
218.3	271	22	
219.7	273	30	
221.5	291	29	
222.9	283	26	
224.7	264	27	
226.5	276	27	
228.8	269	25	
231.3	266	35	
232.5	272	31	
234.4	271	25	
236.0	278	27	
237.4	263	30	

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
239.0	275	31	
240.3	270	31	
242.0	272	26	
244.4	271	28	
246.3	264	32	
247.7	259	32	
249.3	273	32	
250.5	285	32	
252.1	300	23	
254.4	242	42	
255.7	282	37	
256.7	306	20	
258.8	292	33	
260.5	283	29	
262.8	281	37	
263.8	269	39	
266.1	284	40	
268.0	289	50	
269.4	291	41	
271.8	277	33	
274.1	297	43	
275.5	294	49	
278.6	291	40	
280.0	273	46	
281.8	283	42	
282.8	292	40	
284.3	284	38	
285.9	283	38	
287.7	296	42	
289.0	287	40	
291.4	276	26	
292.2	302	46	
294.9	288	30	
296.4	279	28	
298.0	272	39	
299.2	281	29	
301.7	295	33	
303.3	292	26	
305.6	271	35	
307.1	281	45	
309.1	281	41	
311.1	284	33	
312.7	278	48	
314.3	282	36	
317.3	276	37	
319.8	293	30	
321.7	278	37	
323.9	289	45	
325.2	284	40	
327.1	286	33	
328.6	282	38	
330.1	286	38	
331.6	286	31	
332.4	308	25	
334.2	279	30	
335.9	289	23	
337.1	291	24	
339.0	277	27	
339.7	274	17	
340.6	275	36	
341.4	291	27	
343.8	95	35	
345.4	101	35	
345.9	161	29	
352.1	291	25	
353.9	295	22	
368.9	279	35	
369.9	274	39	
372.7	309	48	
373.7	308	28	
375.5	307	31	
376.2	287	39	
378.7	293	43	
380.6	284	37	
383.3	203	12	
388.8	295	33	

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
389.6	287	41	
390.3	310	30	
392.7	299	28	
394.4	297	30	
396.0	296	37	
397.4	285	36	
398.9	282	34	
400.3	288	41	
401.6	285	39	
403.6	281	15	
404.5	269	13	
406.1	283	15	
406.8	280	25	
407.4	280	49	
408.3	286	10	
408.9	306	12	
409.9	293	21	
411.7	110	8	
412.4	271	20	
415.3	289	22	
416.9	277	21	
418.1	292	15	
420.0	283	17	
421.8	277	26	
422.4	275	15	
423.5	267	21	
424.3	280	18	
425.1	253	9	
427.2	281	14	
429.8	285	22	
431.3	289	25	
434.3	281	29	
436.1	284	37	
436.6	278	32	
437.7	272	39	
439.7	295	20	
442.1	280	28	
444.7	287	42	
445.9	278	51	
448.4	243	25	
450.0	270	33	
452.1	269	27	
453.4	282	25	
455.4	280	35	
457.0	278	33	
458.3	290	24	
459.9	277	42	
461.8	281	33	
462.7	266	29	
464.1	287	34	
465.3	269	23	
467.4	286	31	
468.6	259	26	
469.7	274	27	
471.3	264	15	
474.9	260	21	
475.2	278	21	
478.0	278	24	
478.5	249	21	
479.4	258	8	
480.2	260	11	
480.9	255	10	
481.5	281	35	
484.8	214	10	
485.6	270	31	
486.3	275	26	
E48ST-A			
Fractures			
110.5	321	75	M
111.0	332	59	M
111.3	310	63	S
111.6	311	59	S
111.8	297	54	S
112.3	124	80	S
112.9	331	43	S
113.2	319	51	S

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
113.6	328	44	S
113.9	328	47	S
114.3	321	59	S
114.5	320	62	S
114.8	337	65	M
115.4	299	47	S
115.7	26	64	S
116.2	282	68	S
116.6	96	56	S
116.7	296	42	S
116.9	81	55	M
117.2	79	53	S
117.7	296	52	S
117.9	302	53	M
118.2	312	35	S
118.3	315	36	S
118.5	306	40	S
119.9	60	60	S
128.6	277	83	M
129.6	288	54	S
130.8	110	87	S
131.8	55	60	S
134.6	258	38	S
134.7	279	35	S
134.8	254	51	S
136.7	274	56	S
136.8	277	47	S
137.4	90	74	S
137.9	78	60	S
138.4	91	40	S
138.6	103	44	S
138.7	90	58	S
138.9	71	63	S
139.3	70	70	S
140.3	69	48	S
140.8	270	34	S
141.3	265	35	S
142.0	238	59	M
143.5	68	38	S
144.0	74	72	S
145.5	212	70	S
147.2	73	34	M
149.4	291	25	S
150.4	208	68	S
150.6	61	8	S
150.8	89	64	S
151.1	64	42	M
153.4	77	66	S
154.5	281	40	S
154.6	273	41	S
155.0	258	46	S
156.7	240	53	SFLT
156.9	283	39	S
158.7	218	61	S
158.7	217	55	S
159.5	256	65	M
160.5	253	45	M
160.8	80	50	S
162.1	87	72	S
162.7	97	55	S
163.8	272	33	S
163.9	94	75	S
165.7	265	20	S
167.8	286	69	S
168.4	82	78	S
169.4	52	82	S
169.9	80	87	S
171.0	78	52	S
171.1	82	87	S
172.1	22	61	S
173.1	60	83	S
173.2	272	18	S
173.7	70	81	S
173.8	234	46	M
174.0	272	8	S
174.1	305	11	S

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
174.1	332	4	S
174.2	245	38	M
174.4	282	24	S
175.8	50	39	S
176.9	257	31	S
177.2	271	26	S
177.9	242	46	S
179.0	91	55	S
179.5	116	56	S
179.5	236	64	S
179.7	246	40	S
180.3	239	52	S
181.6	208	76	S
181.6	274	39	S
182.2	253	47	M
182.3	253	24	S
182.6	290	34	S
182.8	294	43	S
183.4	111	83	S
183.5	271	23	S
184.2	106	79	S
185.5	86	82	M
185.8	286	32	S
186.9	274	37	S
187.1	274	44	S
187.3	263	33	S
187.7	257	87	M
189.2	199	75	S
191.5	100	83	M
193.0	117	68	M
193.9	139	67	M
195.1	261	82	M
196.3	73	56	S
196.9	292	33	S
197.2	94	49	S
198.2	285	32	S
198.4	97	33	M
199.0	257	70	S
200.3	122	73	S
200.6	120	54	S
202.3	97	64	S
202.5	251	83	S
202.8	102	71	S
203.4	102	77	S
204.5	280	32	S
208.8	84	57	M
209.4	98	68	S
212.5	246	70	S
215.5	266	36	S
216.0	265	44	S
216.9	273	26	S
220.0	80	46	S
221.9	273	31	S
222.2	98	58	S
223.4	80	63	S
225.3	257	82	M
226.3	108	41	S
228.4	100	80	S
228.9	98	86	S
228.9	220	79	S
231.2	92	75	S
232.3	280	29	S
238.6	78	52	S
238.8	97	75	S
239.0	214	27	S
245.1	93	64	S
245.4	87	62	S
247.6	274	29	S
252.8	281	89	S
253.1	273	86	S
254.8	216	54	S
258.2	263	34	S
261.5	100	86	S
262.5	283	33	S
264.5	82	28	S
265.8	92	41	M

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
267.4	91	46	S
267.7	121	39	S
268.1	288	35	S
268.3	110	41	S
268.4	111	32	S
270.4	105	66	S
271.4	276	74	S
272.6	271	25	M
272.6	277	23	S
272.7	284	49	S
273.9	267	30	S
274.0	231	74	S
274.1	274	24	S
275.4	137	24	S
276.6	289	52	S
277.6	273	54	S
278.0	290	82	S
281.5	272	57	S
283.6	284	46	S
283.7	269	53	S
283.9	117	24	S
284.8	272	41	S
285.1	269	62	S
285.4	101	35	S
285.7	277	40	S
286.0	241	22	S
286.3	248	30	S
286.8	123	35	S
287.5	275	18	S
287.9	95	35	S
290.2	110	53	S
290.5	92	61	S
290.8	117	22	S
291.0	96	49	M
291.3	40	15	S
291.8	189	16	S
291.9	111	38	S
292.1	228	37	S
292.2	105	53	S
292.4	210	34	S
292.6	251	24	S
292.7	256	14	S
292.8	198	27	S
292.9	185	30	S
293.2	278	8	S
293.5	112	53	S
293.6	276	36	S
294.1	280	27	S
294.2	291	26	S
295.2	312	37	S
295.4	91	35	S
295.5	109	34	S
296.0	99	40	S
296.3	313	31	S
296.5	311	33	S
297.1	311	23	S
297.1	101	33	S
297.2	304	41	S
297.6	120	38	M
298.3	314	36	S
298.3	260	10	S
298.3	8	29	S
298.4	102	32	M
298.5	54	37	S
298.9	224	74	S
299.0	96	51	S
299.0	231	55	S
299.8	309	26	S
299.9	96	50	S
300.1	311	25	S
300.5	301	37	S
301.0	86	30	S
302.0	307	36	M
302.4	307	48	L
303.0	224	71	S
304.8	295	63	S

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
305.1	100	6	S
305.4	216	25	S
306.1	290	73	S
307.5	311	38	S
307.8	299	37	S
308.9	215	69	S
309.6	322	31	M
309.8	293	32	S
310.8	125	70	S
310.9	111	37	S
311.6	95	77	S
312.5	85	48	M
312.9	310	32	S
312.9	85	41	S
313.3	305	50	S
313.5	292	46	S
314.6	92	58	S
314.9	107	52	S
315.0	99	56	S
315.8	84	59	S
317.1	309	38	S
318.3	267	62	S
318.8	85	46	S
318.9	267	54	S
319.1	282	30	S
320.0	336	10	S
325.4	286	86	S
326.7	291	76	S
326.8	58	33	S
329.2	274	52	S
329.8	260	61	S
332.2	277	55	S
332.8	86	64	S
338.5	138	30	S
350.0	163	66	S
352.3	149	44	S
354.9	315	14	S
355.1	154	14	S
355.4	161	41	S
358.8	2	28	S
373.1	308	19	S
375.5	139	31	M
376.9	84	27	S
378.1	336	44	S
379.3	316	36	S
381.4	149	53	S
381.8	344	40	S
382.4	77	35	S
388.8	140	55	M
389.5	0	87	M
404.1	242	14	M
408.7	323	45	M
416.6	341	29	S
417.3	323	34	S
418.5	339	41	S
418.8	352	33	S
419.6	351	75	S
425.9	173	69	S
429.6	337	55	S
430.6	332	29	S
431.3	335	54	S
432.5	314	26	S
435.9	96	61	S
437.8	155	53	S
441.7	311	20	S
443.3	143	72	S
449.8	139	72	S
452.8	337	68	S
459.0	328	47	S
482.0	124	73	M
E48ST-A Foliation			
112.2	322	58	
113.4	310	44	
116.4	304	41	
118.4	300	39	

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
128.2	310	41	
129.3	297	44	
133.8	272	39	
135.8	284	45	
138.6	260	36	
141.0	261	36	
143.1	276	36	
145.9	291	43	
148.8	258	23	
151.5	297	19	
154.7	270	38	
156.8	282	39	
159.0	277	30	
161.1	269	30	
163.8	279	35	
166.3	261	29	
168.1	264	33	
173.2	272	19	
175.5	265	17	
179.1	294	22	
180.7	299	24	
184.0	271	33	
186.8	283	39	
188.3	272	30	
189.7	290	42	
193.4	294	35	
197.9	296	31	
200.3	290	31	
202.9	282	32	
206.1	278	29	
209.2	281	34	
211.6	267	34	
215.4	259	37	
218.6	293	26	
222.3	265	32	
225.4	274	28	
227.9	287	25	
231.8	288	25	
233.7	297	32	
236.1	313	33	
239.3	223	28	
244.3	267	20	
246.8	276	31	
249.9	277	28	
253.2	263	32	
255.8	274	19	
259.8	290	27	
262.5	282	34	
266.0	306	35	
268.8	283	36	
270.8	285	38	
274.1	295	26	
276.7	253	49	
283.5	283	47	
285.7	272	36	
294.2	287	28	
296.5	309	33	
300.0	315	23	
302.9	310	28	
304.0	313	40	
308.3	295	39	
310.6	299	35	
313.6	308	47	
315.4	273	22	
318.0	297	34	
319.2	278	33	
320.3	273	15	
322.5	257	18	
324.4	244	21	
326.2	261	25	
328.4	244	18	
332.4	261	25	
357.6	286	29	
360.3	263	27	
374.9	271	42	
381.9	283	39	

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
410.8	277	41	
420.6	273	29	
425.6	274	30	
431.8	280	31	
435.0	287	29	
437.1	293	28	
443.4	290	34	
445.0	287	20	
449.5	312	26	
452.5	292	16	
454.1	293	26	
456.1	292	32	
458.7	302	30	
462.1	285	34	
464.6	285	24	
469.2	271	32	
E52ST-A			
Fractures			
29.0	101	59	S
29.3	302	46	S
29.5	307	42	S
30.3	65	75	S
30.6	300	49	M
30.9	93	36	M
32.4	305	36	S
33.6	87	38	S
34.6	292	40	S
34.8	88	43	S
35.1	124	58	S
36.2	126	53	S
38.0	106	42	S
42.1	305	42	S
42.5	306	76	S
43.2	304	45	L
43.4	315	29	M
45.7	312	52	M
46.9	317	51	S
47.3	312	52	S
48.0	231	26	S
48.8	317	48	S
49.2	106	24	M
49.2	132	22	S
49.3	284	18	S
49.4	89	34	S
49.8	316	31	S
49.9	124	6	M
50.9	298	27	S
51.8	62	29	M
52.7	88	47	S
54.5	78	54	M
62.0	6	35	S
69.8	74	19	M
71.0	225	19	S
73.2	302	27	S
73.9	358	40	S
74.8	282	27	S
75.1	107	59	S
75.5	102	51	S
81.2	273	24	S
81.8	249	36	M
81.9	257	50	M
81.9	258	22	S
83.5	300	36	M
84.4	308	52	S
84.5	262	64	S
85.9	98	51	S
86.4	87	61	S
86.5	80	60	S
88.0	258	76	M
90.0	157	24	M
95.3	187	22	S
97.9	100	66	S
98.2	106	54	M
98.7	109	58	M
99.1	229	14	S
101.1	104	31	S

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
101.3	181	28	S
102.6	216	61	S
103.0	302	42	S
104.5	305	44	M
108.0	93	52	S
108.6	109	70	S
112.1	264	84	S
114.0	100	61	S FLT
114.6	83	87	M
115.8	90	51	S
116.3	320	32	M
117.5	216	49	S
118.1	336	45	S
118.8	310	28	S
119.1	106	55	S
119.4	310	34	S
132.0	273	81	S
133.0	280	77	S
134.8	96	61	M
135.1	80	69	S
135.4	101	63	S
135.9	111	46	M
136.7	103	63	M
137.4	116	58	S
137.7	104	78	M
138.0	107	65	S
138.1	108	65	S
138.6	87	89	M
140.6	66	56	S
141.3	99	62	M
144.7	65	37	S
144.8	341	44	S
147.8	105	55	S
161.3	116	75	S
161.9	257	63	M
169.6	226	21	M
172.6	97	51	S
179.3	256	40	M GW
179.3	267	55	M GW
182.1	339	59	S
189.9	315	18	S
190.0	319	23	M GW
193.5	250	47	S
193.6	254	50	S
193.8	265	62	S
193.9	212	14	S
194.4	216	55	S
196.9	191	51	M
198.8	245	58	M
205.0	94	53	S
205.4	282	43	S
205.5	101	68	S
205.6	294	35	S
207.0	299	31	S
207.6	95	56	S
209.1	121	57	S
209.2	109	51	S
213.9	275	47	S
214.6	101	82	S
214.9	293	37	S
215.5	83	61	S
215.7	100	58	S
216.3	88	57	S
216.4	95	58	S
217.3	99	59	S
217.5	99	59	S
223.6	277	68	S
224.0	275	40	S
224.3	286	38	S
228.9	90	75	S
231.4	99	68	S
232.8	99	79	M
236.5	286	24	S
242.2	100	59	S
246.4	163	33	S
248.3	99	64	M

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
253.4	95	49	S
254.4	149	59	S
254.6	149	50	S
258.4	252	29	S
260.5	100	49	S
264.2	154	68	SFLT
265.4	266	71	S
268.4	97	80	M
277.5	138	31	S
278.0	101	64	S
278.5	93	69	S
279.7	85	62	S
282.5	152	64	S
296.5	11	69	M
302.7	223	14	S
303.4	272	39	S
318.3	295	53	S
318.5	286	58	S
321.1	292	74	S
323.6	93	72	S
329.6	264	52	M
329.8	102	81	M
330.6	107	66	M
331.4	247	22	S
331.5	204	17	S
334.4	315	82	S
335.2	98	80	M
343.2	95	75	S
343.5	100	62	S
344.7	114	53	S
345.4	343	5	M
345.5	242	11	M
346.3	18	82	S
348.8	137	32	S
348.8	106	64	S
350.3	35	48	S
350.4	37	42	S
350.9	108	70	S
354.4	101	55	S
358.6	80	66	S
359.2	135	37	M
359.5	101	77	M
361.1	81	73	M GOUGE
362.9	131	88	MFLTGOUGE
367.5	246	17	S
371.4	53	48	S
377.0	153	89	S NMFLT
379.4	317	62	S
380.1	350	80	S
382.5	129	42	M
382.6	126	7	S
382.9	149	9	S
383.1	157	7	S
383.4	157	16	S
384.0	96	26	S
385.5	75	55	L
385.7	276	87	SFLT
386.1	91	45	VL
386.3	80	15	M
386.7	90	40	L
386.8	92	50	S
387.1	97	47	S
387.6	302	67	M
388.0	307	58	S FLT
388.3	226	3	S
388.5	160	25	M
388.7	246	4	M
389.3	273	6	M
389.5	282	10	S
389.6	298	8	S
389.7	348	8	M
389.7	264	8	M
389.8	251	17	M
389.9	233	6	M

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
392.8	310	4	S
393.5	80	53	S
395.3	244	5	S
395.8	96	47	S
396.2	113	42	S
397.9	204	63	S
398.5	238	13	M
403.3	274	84	S
			RVFLT
407.6	103	14	S
407.7	80	63	M
407.8	241	14	M
408.7	84	58	S
409.0	117	35	S
409.2	107	49	S
409.4	213	12	S
410.8	135	58	M
412.0	116	22	S
412.8	271	23	S
413.9	254	35	M
414.8	255	57	M
419.3	270	85	S FLT
420.8	85	73	S
421.8	76	81	S
426.1	108	49	S
426.6	268	32	S
426.8	267	36	S
427.4	255	31	S
427.7	251	31	S
429.1	90	72	S
			NMFLT
429.5	92	83	S
431.1	259	24	M
431.7	279	82	S
433.1	102	74	S
434.8	272	22	S
435.6	267	22	S
435.9	106	89	S
437.0	258	18	S
438.1	41	73	S
438.3	224	10	S
438.4	192	12	S
438.5	242	15	S
438.8	45	80	M
439.4	100	59	S
440.5	81	38	M
440.8	183	32	M
441.1	260	50	S
441.9	260	51	S
442.1	357	54	S
442.5	19	13	S
442.8	293	55	S
443.2	87	54	S
443.3	289	52	S
444.3	96	9	S
444.6	77	46	M
444.7	75	45	M
447.2	77	68	M
447.6	261	24	S
447.8	255	35	S
447.9	260	28	S
450.1	258	35	S
454.1	256	33	M
455.2	102	61	S
456.9	95	60	S
458.8	142	59	S
459.8	102	41	S
464.5	284	38	S
467.7	78	44	S
471.3	100	69	S
479.4	269	34	S
483.7	230	26	S
484.9	285	15	L
E52ST-A			
Foliation			
31.9	307	35	

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
33.0	307	35	
34.7	299	38	
40.7	308	61	
42.7	306	36	
44.7	303	47	
46.3	307	58	
48.0	309	43	
49.5	294	18	
51.0	309	28	
52.6	310	41	
57.3	308	36	
59.3	308	33	
62.8	323	54	
67.2	311	35	
69.4	328	33	
73.2	295	28	
74.9	294	25	
79.4	287	27	
80.7	229	26	
89.2	269	33	
91.6	286	33	
94.9	306	46	
96.5	297	36	
98.6	322	42	
101.3	306	35	
104.4	312	45	
105.5	292	42	
109.1	297	19	
112.7	297	30	
116.1	306	39	
118.9	323	25	
120.8	308	36	
125.2	308	28	
127.0	291	50	
133.3	311	25	
134.5	311	24	
138.6	320	18	
139.7	315	27	
143.0	337	31	
146.5	335	32	
147.8	349	27	
156.5	311	33	
158.8	313	32	
161.7	302	38	
163.4	327	37	
187.3	255	63	
189.4	305	42	
200.7	283	40	
203.4	268	34	
207.3	285	26	
210.2	281	34	
212.8	284	37	
216.3	283	33	
219.9	319	40	
222.0	291	37	
226.3	268	35	
228.8	260	15	
231.8	299	32	
234.9	282	23	
238.1	298	35	
240.3	261	47	
241.8	256	57	
242.9	267	37	
249.7	255	24	
252.8	310	28	
255.5	273	29	
258.1	298	49	
259.5	262	33	
261.6	297	68	
264.6	236	16	
273.5	274	33	
274.2	270	28	
276.9	304	37	
279.6	240	13	
285.0	237	20	
289.1	165	20	

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
292.5	229	24	
295.4	187	17	
297.7	206	14	
302.7	240	20	
303.9	254	40	
306.6	233	22	
308.7	233	32	
311.6	235	42	
312.9	281	46	
316.6	267	52	
318.9	265	54	
320.1	270	59	
331.5	191	18	
333.6	232	23	
337.9	212	26	
341.5	271	29	
343.1	257	23	
345.7	203	15	
350.5	240	16	
352.3	229	14	
355.2	248	15	
356.7	239	20	
359.9	206	23	
363.4	267	38	
369.4	277	24	
371.4	244	10	
372.7	256	9	
376.3	247	21	
377.4	237	17	
380.4	187	24	
382.8	159	9	
383.7	112	10	
388.9	300	27	
390.1	270	11	
393.6	300	15	
394.7	298	16	
397.8	313	22	
401.6	78	32	
403.1	67	7	
404.4	90	11	
407.1	120	15	
408.8	281	2	
413.2	273	20	
415.8	240	28	
416.7	223	25	
426.2	262	32	
428.1	241	31	
430.8	245	24	
434.8	262	24	
436.7	245	20	
437.9	242	21	
445.9	243	26	
448.5	257	27	
450.5	259	32	
453.4	248	32	
455.2	260	40	
457.4	84	39	
464.3	301	41	
465.7	264	51	
469.8	265	41	
475.9	248	35	
477.0	258	38	
480.2	262	35	
483.7	224	29	
485.4	259	22	
E54ST-A			
Fractures			
17.1	65	76	S
17.5	69	64	S
18.4	73	68	M
18.8	71	52	M
27.0	300	2	S
30.7	80	13	S
32.2	263	9	S
32.4	277	28	S
32.7	291	22	S

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
32.8	233	7	S
32.9	277	17	S
33.3	246	28	M
33.4	266	29	M
34.8	83	77	M
35.7	80	68	S
37.5	79	85	S
38.6	257	59	M
39.5	87	69	S
39.5	247	17	S
40.9	270	50	S
41.3	87	52	M
43.0	255	34	S
44.5	87	31	S
44.8	93	31	M
46.0	280	19	S
48.5	277	35	S
48.8	181	10	S
48.9	156	9	M
50.2	290	7	S
52.1	249	76	S
52.3	204	15	M
53.1	263	46	S
53.3	270	46	S
53.7	191	14	S
53.7	271	63	S
54.1	171	10	M
56.2	236	10	S
56.7	233	5	S
59.0	30	12	M
61.6	276	14	S
62.2	229	21	S
62.5	244	30	S
69.0	98	36	M
72.6	339	79	M
74.2	86	41	S
74.4	72	86	M
75.7	122	25	S
76.5	230	22	S
76.9	265	79	S
78.4	253	79	M
79.5	54	11	S
81.1	271	79	S
82.2	89	60	S
82.3	105	37	S
82.4	259	27	S
85.5	273	45	S
86.2	313	31	S
87.2	304	7	S
87.8	92	49	S
88.2	281	29	M
88.8	272	29	S
88.9	319	19	S
89.9	92	80	S
91.1	88	77	S
91.5	97	64	S
91.8	77	70	M
93.5	127	56	S
93.6	277	40	M
94.0	105	67	M
94.1	207	31	M
94.4	246	38	M
95.0	84	67	M
95.7	249	21	S
95.8	270	16	S
96.4	267	15	S
97.3	283	55	S
98.5	94	75	S
99.4	92	78	M
100.4	68	65	S
101.1	82	62	M
101.8	266	39	S
103.0	208	8	M
103.1	218	36	M
103.5	93	72	M
104.1	122	47	S

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
104.3	67	57	S
104.4	208	22	S
104.6	82	32	M
104.8	245	25	S
104.8	83	63	S
105.2	9	62	S
105.4	206	10	S
105.6	244	20	S
106.3	89	70	M
106.4	87	39	S
106.7	85	47	S
107.1	80	41	M
107.3	91	51	S
107.4	83	61	S
107.6	75	50	S
107.9	100	53	M
107.9	100	71	S
108.4	68	21	S
108.5	322	40	S
108.7	341	64	S
108.9	88	57	S
111.8	247	23	S
112.6	83	64	S
112.8	88	70	S
113.0	85	75	S
113.4	243	27	S
115.0	253	33	S
116.3	240	28	M
117.9	90	83	S
118.4	103	50	S
119.5	253	32	M
119.8	240	34	S
120.2	252	35	S
121.2	276	48	S
121.6	9	63	S
124.9	286	43	M
125.1	206	18	S
127.6	98	68	S
128.0	106	72	M
128.5	36	71	S
129.7	74	32	S
130.3	243	37	M
132.2	140	23	S
132.4	220	21	M
134.6	114	46	S
135.0	84	53	M
135.0	103	55	M
151.3	82	68	S
152.0	99	60	S
152.6	65	75	M
153.8	226	9	M
155.2	337	76	M RVFLT
155.8	103	71	M
156.0	347	69	M
157.1	342	53	S
157.3	93	55	M
157.5	87	64	M
158.9	91	63	L
160.6	256	61	M
160.7	76	63	S
161.7	90	49	M
162.4	84	39	M
163.5	257	57	M
163.8	97	36	S
164.3	253	60	S
164.6	252	68	M
164.9	69	62	M
165.4	93	71	M
165.6	95	48	M
166.7	257	38	S
167.4	48	88	S
168.0	89	73	LFLT
168.5	77	62	M
168.5	262	22	M
168.7	237	17	M

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
169.3	97	55	M
169.3	63	56	S
171.4	127	15	M
171.4	179	19	M
172.6	225	66	S
173.7	232	6	S
174.0	245	85	S
178.1	108	16	S
178.1	95	4	S
178.4	213	9	S
178.5	204	9	S
178.7	207	16	S
179.7	257	3	S
180.2	241	12	S
180.8	242	11	S
180.9	249	12	S
181.3	217	14	M
186.6	277	42	S
192.2	0	49	M
192.3	357	58	M
193.1	87	7	M
193.8	20	11	L
194.5	13	10	S
194.8	348	11	M
195.0	10	9	M
195.1	261	7	S
195.2	213	8	M
195.9	16	21	M
196.1	125	30	S
196.3	260	27	M
196.5	57	28	S
196.9	73	27	M
197.1	52	12	S
197.7	265	48	M
198.2	83	43	S
198.5	41	4	M
199.4	313	70	M
199.5	19	75	M
200.0	108	7	M
201.7	125	16	S
202.6	106	6	M
204.4	88	70	S
205.0	234	8	S
216.2	231	22	M
219.4	88	83	M
220.2	247	31	M
221.8	223	34	M
222.2	273	16	M
224.2	177	13	S
224.7	89	66	S
225.6	31	7	S
227.0	18	64	M
227.6	83	58	S
229.2	64	48	M
230.1	294	49	S
232.9	224	7	S
233.3	100	44	S
236.6	253	33	M
237.0	103	82	VL
237.1	84	50	L
237.8	236	41	M
238.8	105	42	M
238.9	268	43	S
239.2	73	57	M
242.6	259	89	M
242.8	74	79	M
243.2	305	11	S
243.2	255	88	M
243.2	325	9	S
244.2	17	3	S
245.1	79	72	M
247.0	280	55	S
247.8	85	69	M
247.9	64	80	M
248.0	253	86	M
248.8	15	72	M

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
249.3	81	72	M
250.1	240	14	S
250.2	72	64	S
250.4	71	75	S
251.0	74	58	S
253.1	48	70	M
253.3	63	70	M
253.5	80	81	S
255.5	127	6	S
256.3	81	74	M
257.0	80	48	M
257.2	85	61	M
257.8	76	81	M
258.5	261	51	S
259.1	59	79	S
260.1	78	67	S
260.6	71	16	S
263.0	95	78	M
263.2	188	7	M
263.8	264	28	S
265.1	256	9	M
265.3	79	85	S
269.0	104	25	S
269.5	97	2	S
270.2	71	75	S
271.3	68	86	M
276.8	282	86	M
277.3	85	66	M
277.5	301	47	S
278.9	261	79	S
279.0	193	7	S
282.6	334	69	M
285.7	36	71	S
287.2	236	27	S
289.6	225	17	S
292.7	152	67	S
293.5	151	68	S
294.8	29	77	S
296.5	259	11	M
296.5	240	20	S
297.3	303	15	S
298.6	178	70	S
304.6	245	19	S
304.8	227	10	S
306.6	221	23	S
313.8	245	17	S
323.1	244	12	S
330.9	260	35	S
340.9	270	13	S
348.4	139	62	S
350.3	149	10	M
355.9	101	56	S
356.0	180	75	S
357.2	214	38	S
357.3	344	37	S
357.5	8	47	S
357.9	252	6	S
358.8	45	44	S
362.6	19	77	S
365.7	68	64	M
365.9	5	77	S
366.6	354	62	S
370.4	351	86	S
373.8	358	81	S
374.5	345	84	S
375.0	344	79	S
376.0	341	79	S
376.5	343	56	S
377.5	48	76	M
378.6	301	81	S
378.8	321	78	S
386.5	331	69	S
387.2	343	72	S
387.6	348	61	S
388.7	338	71	S
389.2	343	83	S

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
390.8	95	81	S
390.9	345	87	S
392.1	328	83	S FLT
392.6	328	74	S
392.8	343	72	S
393.2	334	81	S
393.2	341	74	S
393.8	332	49	S
394.3	22	50	M
394.5	12	47	M
394.7	351	60	M
394.9	337	69	M
395.6	46	53	S
396.4	69	65	S
396.8	51	65	S
398.4	75	71	S
399.0	79	61	S
399.1	75	66	M
399.7	162	75	S
400.4	165	73	M
401.3	169	70	S
401.7	168	50	S
401.9	156	51	S
403.5	183	54	S
404.2	197	67	S
405.1	160	74	S
405.3	162	71	S
405.7	182	71	S
406.3	156	52	S
406.6	169	43	S
407.2	165	35	S
407.4	181	29	S
408.0	289	10	S
412.4	105	56	S
412.9	96	50	S
413.8	187	69	S
414.5	187	75	S
414.7	184	59	S
414.8	40	83	S
414.9	75	58	S
415.6	125	13	S
415.8	184	82	S
415.9	186	59	S
416.6	87	38	S
416.8	84	68	S
416.9	261	18	S
417.0	73	60	M
417.2	86	53	M
420.2	101	60	S
422.5	70	70	S
422.7	66	57	S
423.8	194	36	S
424.0	42	55	S
424.2	234	34	S
424.2	42	60	S
424.5	49	55	S
426.7	162	28	S
428.6	194	42	S
429.2	171	46	S
429.7	316	87	S
430.9	312	86	S
431.6	320	50	S
432.1	209	3	S
432.9	169	54	S
433.0	179	45	M
433.2	174	47	M
434.2	285	10	M
435.5	70	55	S
435.7	73	50	S
435.9	72	53	S
437.0	70	66	S
438.4	209	60	M
439.0	78	67	S
439.3	227	86	S
440.3	88	57	M
441.1	210	43	S

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
441.7	103	47	S
442.1	68	52	M
442.4	68	56	M
442.4	71	67	M
443.1	286	68	S
444.6	85	72	S
444.9	262	20	M
445.0	283	17	M
445.1	83	39	M
446.6	80	61	S
447.6	261	19	S
449.9	53	81	M
452.3	211	78	S
452.6	92	51	S
452.6	213	75	S
454.8	207	73	S
455.7	241	21	S
457.7	220	79	S
458.4	123	44	S
458.6	35	85	S
460.1	22	78	S
460.4	267	6	M
461.2	198	78	S
462.2	205	72	S
463.3	130	88	S
463.6	243	30	S
463.7	251	21	M
463.7	240	28	M
463.8	248	26	M
464.2	41	72	S
464.3	37	70	S
466.2	224	22	M
466.4	234	51	M
466.7	202	40	S
467.8	211	22	S
468.2	50	61	S
468.4	54	60	M
468.4	75	58	M
469.2	62	64	S
470.1	201	26	S
470.2	191	15	S
470.3	177	16	S
470.8	99	54	S
471.7	263	20	S
472.2	84	60	S
473.8	102	67	S
475.3	132	62	S
479.1	212	39	M
479.6	309	7	S
480.0	104	60	S
480.4	89	61	M
480.8	85	54	M
480.8	86	55	M
480.9	98	56	M
483.2	253	14	S
483.2	85	74	M
483.2	251	16	S
483.3	89	68	S
484.0	254	16	S
485.4	116	21	S
485.5	269	11	S
E54ST-A			
Foliation			
15.6	84	30	
16.5	111	5	
24.8	84	22	
26.1	130	6	
30.3	98	19	
32.9	281	17	
34.2	251	24	
35.6	258	23	
37.0	180	0	
39.3	270	37	
42.7	262	34	
43.1	252	27	
47.3	266	33	

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
48.5	273	36	
53.1	271	45	
55.3	273	46	
57.3	252	45	
59.7	275	52	
61.2	275	39	
64.9	108	21	
69.1	104	39	
71.3	102	29	
72.9	98	28	
74.3	97	42	
75.1	140	8	
76.2	135	20	
84.3	270	26	
85.6	270	44	
87.6	262	21	
89.0	274	33	
91.2	266	26	
92.9	276	29	
94.5	257	26	
96.5	270	15	
98.1	264	33	
99.6	278	31	
102.9	251	29	
104.5	227	25	
105.6	248	19	
107.4	261	25	
109.0	248	36	
110.1	230	20	
111.7	227	23	
113.6	235	23	
115.0	252	29	
116.6	251	31	
117.9	233	32	
119.4	242	30	
120.9	252	34	
122.8	281	41	
124.2	261	38	
127.3	261	43	
128.9	248	36	
130.2	250	36	
131.5	242	35	
134.3	247	27	
134.9	247	23	
135.5	241	26	
137.4	227	16	
138.6	230	16	
141.4	188	12	
142.6	223	19	
143.7	248	23	
144.8	238	17	
147.3	199	25	
149.7	213	18	
151.5	228	18	
152.9	248	23	
154.5	269	41	
156.4	250	39	
158.1	260	26	
159.3	245	27	
159.9	250	43	
162.4	90	42	
164.4	258	56	
165.3	262	33	
167.4	283	46	
168.6	232	14	
169.9	254	14	
171.2	237	13	
173.0	239	21	
174.5	233	7	
175.5	272	9	
176.9	241	7	
178.4	198	7	
179.3	185	4	
180.8	239	12	
182.1	325	2	
184.8	108	18	

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
187.3	327	9	
189.0	39	20	
191.7	106	15	
193.4	47	13	
195.3	354	2	
196.8	58	21	
199.0	96	16	
200.5	88	11	
201.4	96	16	
202.5	82	12	
203.5	265	7	
207.2	107	21	
207.4	60	22	
209.1	89	6	
209.9	285	4	
211.4	254	17	
213.8	272	13	
215.6	260	28	
216.2	228	19	
217.6	253	13	
219.3	253	32	
221.0	241	24	
222.4	285	40	
225.3	263	24	
226.4	272	18	
230.1	287	45	
231.1	268	13	
234.2	257	20	
235.3	259	21	
240.9	290	13	
241.4	81	23	
242.5	60	4	
244.2	281	8	
246.5	283	5	
247.1	230	12	
249.3	288	15	
254.6	55	8	
255.6	103	6	
256.8	272	26	
257.8	273	36	
259.6	252	12	
260.8	130	20	
264.0	252	18	
265.1	234	9	
266.9	129	16	
268.9	121	18	
269.9	137	7	
271.6	205	16	
273.9	230	13	
275.4	266	23	
277.1	261	26	
279.3	280	14	
281.8	270	6	
283.3	232	9	
284.5	227	13	
286.5	252	18	
287.6	176	18	
288.9	261	18	
290.0	216	18	
291.3	272	32	
293.1	250	59	
294.4	231	45	
295.3	263	27	
296.3	248	29	
297.1	232	16	
297.8	245	5	
298.8	229	16	
301.7	261	13	
304.6	249	18	
306.6	220	20	
307.4	235	16	
310.7	251	19	
313.0	285	22	
314.0	236	15	
317.4	303	2	
319.7	195	15	

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
321.2	233	13	
322.6	217	19	
323.1	240	12	
326.0	237	12	
327.9	225	27	
329.7	217	24	
330.5	83	19	
333.4	229	17	
340.1	193	25	
342.1	122	20	
343.7	87	19	
344.6	143	13	
350.1	225	20	
352.5	255	11	
355.0	85	19	
358.0	152	13	
360.2	33	16	
362.3	34	42	
363.9	4	47	
368.5	252	34	
370.8	288	47	
373.3	291	42	
375.0	310	27	
377.1	282	28	
379.4	313	27	
382.5	260	23	
385.9	316	22	
387.4	296	24	
389.3	312	18	
390.5	336	16	
393.1	284	14	
395.3	274	11	
397.5	286	9	
399.0	261	19	
402.6	269	11	
404.3	259	10	
405.9	298	9	
407.6	277	12	
409.4	323	18	
410.7	262	13	
412.1	243	10	
413.9	256	15	
415.3	263	21	
416.9	257	20	
429.2	29	7	
430.7	5	13	
432.1	231	7	
434.0	84	1	
435.5	335	3	
437.2	275	17	
438.7	273	15	
439.7	263	11	
441.7	247	17	
443.7	283	16	
445.4	263	27	
448.0	247	13	
450.2	237	21	
453.3	215	14	
455.7	238	20	
458.2	235	24	
460.7	241	16	
462.7	237	29	
464.5	227	23	
467.1	229	23	
468.1	214	27	
470.2	192	21	
470.9	185	19	
473.3	237	26	
475.5	271	40	
477.9	224	16	
479.1	238	22	
481.3	258	12	
482.5	246	7	
484.4	242	13	
485.7	264	13	

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
E55ST-B			
Fractures			
19.2	155	26	S
20.3	319	45	S
22.5	352	16	S
22.7	344	85	M
22.8	343	16	M GW
23.4	326	28	M GW
26.4	158	13	S
26.8	318	13	S
26.9	204	14	S
27.3	58	74	M
27.9	132	7	S
28.0	99	4	S
28.4	220	3	S
28.4	83	2	S
29.2	304	67	M
29.4	300	42	M
30.6	315	66	S
31.1	117	3	M GW
32.9	188	4	M GW
33.9	272	7	S GW
33.9	259	4	S GW
36.2	279	9	S
36.5	226	6	S
40.2	309	12	M GW
42.3	261	12	S
44.1	274	10	S
45.0	192	13	S
47.8	337	5	S
47.8	297	12	S
52.9	55	8	S
57.1	118	18	S
62.4	311	12	S
62.5	265	19	S
62.7	258	4	S
66.3	302	21	S
66.8	248	31	M
67.2	76	16	S
67.2	339	8	S
70.4	94	23	S
71.1	66	9	S
73.1	75	6	S
77.5	76	8	S
78.2	55	8	S
79.8	104	60	M
83.6	53	4	S
83.7	100	14	S
84.3	99	24	S
91.0	71	8	S
91.4	102	9	S
92.1	341	87	S
92.3	327	10	S
93.6	332	10	S
94.0	304	28	S
95.9	335	9	M
101.6	112	76	S
109.4	102	72	S
110.5	106	70	M
110.6	305	24	S
111.0	123	75	S
114.2	77	21	S
115.1	116	27	S
116.6	96	47	S
117.3	92	43	M
117.4	102	72	S
118.3	108	67	S
119.1	94	45	S
120.2	96	44	S
120.6	116	66	M
121.6	115	45	S
122.4	97	77	S
126.4	304	42	S
126.7	310	46	S
127.1	109	38	M
127.3	291	22	S

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
127.6	28	1	S
128.0	292	58	S
129.0	108	71	S
130.3	117	77	S
130.8	308	71	S
131.9	316	72	S
134.8	115	31	M
142.8	305	84	S
146.3	317	75	S
148.5	269	74	S
149.3	281	2	S
149.8	107	18	S
153.4	269	25	S
156.5	314	66	S
159.7	305	74	S
161.5	340	64	S
161.8	338	53	S
163.7	129	9	S
163.8	125	12	S
164.0	124	13	S
164.1	131	28	S
165.6	105	62	M
167.3	119	42	S
167.9	106	77	M
168.4	116	65	S
168.7	120	41	S
168.7	308	58	S
169.3	113	59	M
171.8	43	79	S
174.3	343	56	S
177.2	102	51	S
182.9	227	48	S
184.6	116	82	M
186.7	14	67	S
187.4	332	63	S
187.5	337	62	S
188.9	325	48	S
190.0	125	66	M
190.8	307	68	S
196.5	209	8	M
196.6	214	12	M
197.0	156	29	M
197.3	143	36	S
197.8	59	9	S
198.2	164	71	S
198.8	125	17	S
199.4	104	44	L
199.8	90	59	L
200.3	81	38	M
200.5	71	9	S
200.5	55	35	S
201.3	326	62	S
201.7	64	12	S
201.8	337	65	S
202.6	11	46	S
203.2	76	49	M
204.2	101	45	M
204.5	109	40	S
204.8	286	9	S
204.9	303	15	S
206.0	100	65	M
206.3	268	85	M
206.6	93	47	S
206.7	283	23	M
206.9	321	26	S
207.0	69	53	M
207.3	117	41	M
208.9	117	27	S
209.3	82	40	S
210.2	174	18	S
210.4	274	34	S
211.1	140	55	M
211.4	95	44	S
211.5	304	64	S
211.8	124	22	S
212.0	109	49	S

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
212.1	101	43	M
212.2	131	49	M
212.3	133	48	M
212.5	132	44	M
212.7	92	49	M
213.0	97	48	S
213.1	277	35	S
213.2	122	38	M
213.3	118	40	S
213.9	102	60	S
214.9	91	56	S
215.4	158	71	M
215.8	126	48	S
215.8	128	54	M
216.1	117	47	M
218.4	262	22	S
218.9	117	59	S
219.0	137	37	S
221.8	149	19	S
223.3	276	21	S
223.4	114	68	S
223.7	128	19	S
224.6	193	7	S
225.1	184	4	S
225.3	261	23	S
226.4	121	34	S
227.3	108	60	S
228.4	276	20	S
229.2	81	64	M
229.4	97	32	S
229.5	209	11	S
230.1	138	56	S
230.5	132	60	S
230.6	120	56	S
230.7	122	51	M
230.8	115	14	S
231.4	125	33	S
232.1	117	49	M
233.2	88	48	S
233.3	130	72	S
233.5	113	54	M
234.0	118	34	S
234.8	270	19	S
235.6	264	35	S
235.7	52	24	S
235.8	65	36	S
236.3	76	60	S
236.6	52	35	S
237.1	295	23	S
237.6	88	47	S
238.3	105	50	M
238.5	89	50	M
239.3	230	13	M
240.0	255	20	S
240.8	126	48	S
241.6	227	12	S
241.8	113	45	S
243.0	125	68	M
243.4	266	26	S
243.8	142	36	M
243.9	131	33	S
244.8	129	52	S
245.2	134	32	S
246.0	110	21	M
246.8	148	45	S
247.3	127	54	M
248.2	133	49	S
249.1	153	28	M
249.4	212	19	L
249.4	109	70	S
249.8	124	60	M
250.0	129	68	M
250.4	90	59	S
250.6	125	61	M
252.4	139	60	M
253.0	149	65	M

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
253.8	127	46	M
256.0	146	32	S
256.2	143	17	S
256.4	120	27	S
256.5	133	25	S
256.6	121	39	S
257.1	119	35	S
257.3	173	40	S
257.5	139	14	S
257.7	135	51	M
258.0	127	38	S
258.2	102	38	M
258.3	115	25	S
258.5	137	21	S
258.6	146	29	S
258.9	147	39	S
259.1	138	43	S
259.8	69	37	S
260.2	131	54	S
260.6	270	29	S
260.6	64	60	S
260.9	192	17	S
262.6	288	63	S
263.2	61	70	M
263.6	80	58	S
264.3	248	28	S
264.7	153	70	S
265.1	108	55	M
265.3	104	41	M
265.7	181	28	S
267.1	104	27	S
268.4	100	18	M
268.6	139	48	S
268.9	99	24	M
269.1	119	54	M
269.5	147	51	S
277.5	101	76	S
277.9	126	74	S
279.1	112	33	S
280.0	273	26	S
280.4	286	23	S
280.7	33	30	S
281.5	290	24	S
281.8	102	68	S
281.9	91	61	S
282.0	93	59	S
282.5	112	37	S
282.6	298	30	M
283.6	109	53	S
284.0	100	42	S
284.2	139	63	S
285.7	120	48	S
286.0	234	23	S
286.3	254	20	S
286.9	130	55	S
288.6	93	65	S
289.6	159	87	S
289.6	101	68	S
290.9	171	78	S
291.6	122	72	M
292.6	95	69	S
295.0	97	65	S
295.4	100	65	S
299.9	120	73	S
301.1	104	67	M
302.1	166	69	S
303.6	119	66	S
304.2	126	67	S
304.4	114	35	S
305.9	92	61	S
306.7	95	63	S
307.3	96	65	S
310.1	101	50	S
311.6	199	5	M
311.6	274	10	M
311.7	201	23	M

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
312.2	130	69	S
314.7	268	24	S
321.7	247	15	M
321.8	242	33	M
322.9	172	53	S
325.6	252	31	S
326.2	332	86	S
326.3	197	17	S
330.8	248	25	S
331.9	121	64	S
334.3	71	73	S
334.9	96	65	S
335.4	100	73	S
335.9	70	36	M
336.9	145	40	S
339.1	85	35	M
342.5	115	75	S
344.3	122	69	S
345.1	119	74	S
346.2	122	64	S
346.5	119	64	S
347.2	109	65	S
349.0	83	75	S
354.8	208	23	S
355.5	216	27	S
357.1	308	78	S
357.6	131	75	S
361.3	128	77	S
363.7	160	16	S
363.8	219	20	S
364.2	129	75	S
365.3	132	71	S
368.1	148	81	S
368.4	87	78	S
370.1	85	73	S
373.5	267	13	S
375.5	240	24	S
375.6	242	26	M
376.3	56	54	S
376.4	240	18	M
382.6	129	62	S
384.3	182	20	S
384.4	106	74	M
385.5	119	73	S
386.0	100	64	S
386.3	198	11	S
387.3	112	64	M
387.4	104	64	M
388.0	111	73	M
388.6	125	64	M
389.8	121	67	M
391.7	211	11	S
392.3	107	64	S
394.4	91	55	S
395.6	69	69	S
397.1	141	49	S
397.2	131	50	M
398.3	112	77	S
399.0	99	62	S
399.4	94	81	M
400.1	119	70	S
402.1	123	71	S
403.1	230	83	S
404.7	126	67	S
405.7	124	76	S
406.9	295	25	S
407.0	232	7	M
407.3	107	69	S
407.8	121	64	S
410.5	73	75	S FLT
411.4	86	73	M
413.0	89	85	S RV FLT
416.4	143	9	S
418.4	123	63	S
419.1	126	55	S

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
419.2	68	62	S
420.6	187	41	S
421.8	86	50	M
422.2	177	18	S
422.8	81	53	S
423.7	91	46	S
423.9	175	56	M
424.7	174	57	S
426.1	174	25	M
426.8	116	60	S
427.7	104	51	S
427.8	74	72	S
428.3	97	66	S
428.7	86	57	S
429.2	81	55	S
429.8	104	43	S
430.5	67	69	M
432.1	71	52	S
435.0	82	43	S
435.4	114	53	S
435.5	112	42	S
436.1	106	49	S
438.7	96	44	S
439.2	119	49	M
439.9	113	47	S
440.2	114	52	S
441.1	114	68	S FLT
441.5	191	57	S
441.7	199	55	M
442.8	114	31	S
443.2	128	78	S
443.3	138	69	S
444.2	83	43	S
444.9	137	76	S
445.1	126	73	S
447.4	126	72	S
448.3	94	46	S
448.4	190	16	S
449.0	179	15	S
449.1	45	43	S
449.3	22	48	M
450.4	154	23	S
450.5	157	28	S
450.8	18	58	S
451.0	139	18	S
451.8	83	75	M
452.7	147	69	S
453.3	118	67	S
455.8	156	13	S
457.0	71	64	S
459.8	113	45	M
462.4	123	79	S
464.3	87	2	S
464.4	120	2	M
464.4	209	4	M
464.6	304	6	M
465.3	138	73	S
467.0	126	49	M
467.3	312	13	S
468.6	353	40	S
471.7	224	15	M
471.8	70	66	S
473.3	54	71	S FLT
474.1	111	66	S
474.3	120	59	S
474.5	104	57	S
474.9	113	64	S
478.0	114	61	S
479.3	95	67	S
480.3	129	67	S
481.7	117	67	M
483.1	117	73	S
483.5	113	68	S
484.4	130	80	M FLT
486.9	115	52	S
488.0	144	68	S

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
489.5	178	16	M
491.5	103	80	M
493.6	143	76	S
494.1	107	58	S
495.1	121	62	S
495.1	114	81	S
495.7	57	46	S
495.9	77	47	S
496.9	102	53	S
498.5	134	70	S
499.4	218	75	S
500.7	105	66	S
504.3	117	72	S
505.2	122	68	S
505.2	223	73	M
505.3	126	64	S
506.6	167	31	S
506.9	133	59	S
511.7	199	21	S
512.0	103	70	S
513.6	90	56	S
513.9	88	57	M
514.2	114	56	S
514.9	101	61	S
515.0	88	64	S
515.0	238	18	S
515.4	100	42	S
517.5	141	63	S FLT
522.5	89	47	S
523.6	255	27	S
524.0	26	41	S
526.2	41	39	S
528.8	119	46	S
529.7	111	56	S
530.7	51	37	M
533.0	117	79	S
534.5	127	73	M
534.9	102	78	S
535.4	102	79	S
536.2	107	80	S
537.3	114	81	S
538.7	203	31	S
539.5	193	27	S
E55ST-B			
Foliation			
19.5	314	41	
20.7	326	28	
23.9	297	17	
26.8	302	18	
28.7	304	38	
30.2	302	20	
31.5	297	16	
33.4	300	21	
35.8	273	13	
37.5	298	16	
41.3	255	17	
43.1	210	8	
48.6	229	19	
49.1	130	20	
49.9	231	3	
59.2	116	44	
61.2	74	12	
62.5	285	23	
67.4	79	10	
69.7	129	35	
71.6	119	26	
73.7	103	26	
74.9	130	23	
76.6	114	11	
78.2	54	9	
79.4	76	9	
80.8	101	20	
83.3	96	11	
84.3	116	20	
86.9	325	11	
89.0	327	11	

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
90.1	53	11	
91.4	72	9	
93.6	315	9	
97.0	305	25	
98.1	321	12	
100.8	309	17	
102.2	307	18	
104.2	93	26	
105.7	100	36	
107.8	95	33	
109.4	299	27	
111.5	306	28	
112.6	328	10	
115.7	105	29	
117.4	104	14	
118.6	104	28	
122.2	298	11	
125.1	121	47	
127.3	105	46	
128.9	122	11	
131.4	112	41	
132.8	124	31	
133.8	114	26	
137.7	103	25	
139.9	304	31	
141.0	299	25	
143.4	98	7	
145.6	123	20	
146.7	251	5	
148.0	104	11	
149.4	125	25	
151.0	211	6	
152.4	143	8	
154.0	298	12	
155.4	303	27	
157.3	317	25	
158.5	308	26	
160.8	313	6	
162.9	109	14	
164.1	97	24	
165.0	52	8	
169.4	96	9	
171.6	285	9	
173.1	305	6	
174.5	280	7	
175.9	129	3	
178.1	274	10	
179.5	273	7	
181.0	124	2	
183.0	46	8	
186.1	242	12	
187.4	82	35	
188.1	56	12	
189.2	100	14	
192.8	230	14	
193.9	56	9	
197.6	36	9	
202.2	219	5	
204.7	247	12	
208.1	270	23	
210.4	297	29	
211.8	268	25	
214.3	291	34	
218.8	295	26	
221.5	276	27	
223.3	278	28	
225.6	246	21	
227.3	264	25	
228.4	275	22	
230.2	270	34	
231.5	274	33	
233.1	262	36	
234.4	245	21	
235.7	266	35	
237.1	292	21	
239.7	283	20	

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
243.1	285	25	
245.0	278	30	
246.8	282	30	
248.0	293	30	
252.0	279	28	
253.3	263	28	
254.7	269	26	
257.6	300	24	
259.4	286	32	
260.4	277	32	
263.9	266	36	
267.5	287	22	
274.2	332	5	
275.6	332	9	
277.2	331	7	
278.8	68	3	
280.1	288	20	
282.1	282	19	
283.6	236	14	
285.0	257	18	
286.3	266	21	
288.0	267	16	
289.3	252	18	
291.0	244	20	
292.1	293	17	
293.9	265	19	
294.8	244	22	
296.2	268	17	
297.8	227	7	
298.9	230	19	
300.3	230	23	
301.7	227	16	
303.3	272	5	
304.9	243	10	
306.0	215	13	
307.7	261	20	
309.2	251	21	
311.0	230	18	
312.6	228	16	
313.5	263	6	
315.9	284	20	
317.3	281	28	
319.1	269	26	
321.5	227	8	
323.6	243	26	
325.0	249	23	
326.2	230	25	
328.1	270	21	
329.6	259	29	
331.2	254	22	
332.4	217	25	
334.0	226	15	
335.2	183	30	
335.9	188	22	
337.7	206	28	
339.7	187	31	
341.4	199	26	
342.8	223	25	
344.3	277	29	
346.4	164	37	
348.3	148	37	
349.3	148	41	
351.1	141	34	
352.8	222	27	
353.9	240	23	
355.4	214	28	
356.9	223	18	
358.2	215	5	
360.6	206	20	
362.5	148	23	
363.9	207	24	
365.1	120	29	
366.3	211	14	
368.5	228	23	
369.8	226	14	
370.6	262	19	

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
374.5	222	9	
376.0	239	30	
378.9	65	5	
380.5	171	11	
381.9	201	14	
383.8	179	31	
385.2	185	19	
386.3	210	13	
389.5	182	17	
391.0	195	9	
393.8	192	15	
395.1	222	7	
397.9	199	14	
402.1	229	17	
403.4	214	16	
404.4	218	20	
406.3	211	13	
407.4	167	21	
409.9	207	23	
412.3	195	28	
414.5	181	13	
416.3	153	12	
417.9	164	20	
419.3	163	15	
420.4	176	13	
422.2	176	16	
423.4	175	13	
424.8	179	29	
426.2	175	15	
428.4	176	15	
430.2	186	10	
431.2	105	31	
432.8	146	23	
434.3	148	20	
435.5	152	17	
437.1	158	20	
438.3	158	21	
440.1	131	17	
441.2	156	18	
442.8	153	16	
444.5	162	12	
445.9	220	6	
447.5	163	16	
448.6	208	17	
450.3	171	21	
451.8	144	19	
452.8	186	11	
454.5	160	15	
455.5	147	13	
456.6	220	7	
458.0	154	13	
459.4	117	8	
460.2	160	9	
461.5	87	9	
463.1	159	5	
463.9	208	4	
468.5	8	49	
469.6	103	20	
470.9	184	60	
475.3	213	20	
481.0	232	20	
483.2	195	24	
485.4	174	20	
488.5	172	23	
490.6	225	15	
492.1	226	21	
494.1	227	23	
495.3	232	40	
497.2	230	37	
498.6	227	31	
500.2	214	21	
501.4	226	23	
504.2	205	18	
506.6	177	28	
508.2	236	11	
509.9	232	18	

Appendix 2. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in Midtown Water-Tunnel boreholes (W30ST-A, E30ST-A, E30ST-B, E33ST-A, E35ST-D, E39ST-A, E45ST-A, E48ST-A, E52ST-A, E54ST-A, E55ST-B), Manhattan Island, N.Y., 2003-04.—Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
511.6	226	15	
513.1	221	8	
515.4	235	13	
516.4	301	15	
518.5	224	33	
519.7	235	14	
521.1	232	16	
523.8	234	27	
525.1	223	29	
526.5	223	22	
528.0	208	30	
529.3	243	27	
530.3	234	25	
531.4	204	31	
532.8	189	45	
535.4	184	39	
536.8	180	31	
537.9	200	38	
539.5	196	28	

Appendix 3. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in South Water-Tunnel boreholes (Ericsson-A, FranklinST-B, FranklinST-A, GrandST-B, PrinceST-A, BondST-A, 31B-1), Manhattan Island, N.Y., 2003-04.

[Ericsson-A, borehole id. Borehole location is shown in fig. 3. Depth in feet below land surface. S, small fracture (0.04 inch or less); M, medium fracture (greater than 0.04 to 0.39 inch); L, large fracture (greater than 0.39 inch to 9.8 inches); VL, very large fracture (greater than 9.8 inches); GW, ground water; FLT, fault; LWR, lower; CNT, contact; ZN, zone; GEO, geologic; NM, normal; RV, reverse]

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
Ericsson-A Fractures			
105.1	8	3	L
105.3	314	18	M
106.8	74	24	M
106.9	63	51	S
107.5	338	27	M
107.6	102	16	M
120.9	249	76	S
121.9	250	79	S
124.0	252	46	M
124.4	255	42	M
129.6	259	22	S
130.1	267	27	L
130.3	308	10	S
130.4	246	52	M
130.6	256	61	M
130.8	252	59	M
132.1	49	24	S
132.5	279	33	S
132.6	321	36	S
132.9	258	37	M
134.0	296	12	S
134.4	118	46	M
134.5	333	21	L
134.5	168	30	M
137.1	253	45	S
137.1	303	10	S
137.2	49	23	S
139.2	259	70	S
139.3	56	8	M
139.6	57	19	M
139.9	40	12	S
140.1	44	14	S
140.4	316	25	S
140.6	269	53	M
140.6	267	3	S
140.7	247	7	M
140.9	311	6	S
140.9	260	37	M
141.0	306	21	S
141.5	247	25	S
142.6	248	28	S
144.2	281	66	S
144.6	274	68	S
146.6	259	72	S
147.5	248	53	M
149.3	229	26	M
152.4	259	50	S
156.3	267	55	S
156.8	281	77	S
159.8	264	27	S
165.6	90	22	M
165.6	278	25	M
172.6	264	79	S
180.0	136	19	S
204.3	262	77	S
204.9	267	58	S
215.5	24	81	S
217.4	25	71	S
217.6	297	86	S
218.2	267	49	M
223.1	307	29	S
223.3	262	42	S
223.7	227	54	GEOCNT
226.6	34	57	GEOCNT
227.6	320	63	GEOCNT
233.6	302	32	S
233.8	289	49	S
234.4	334	43	S
254.0	292	79	S
290.8	12	27	S

Appendix 3. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in South Water-Tunnel boreholes (Ericsson-A, FranklinST-B, FranklinST-A, GrandST-B, PrinceST-A, BondST-A, 31B-1), Manhattan Island, N.Y., 2003-04. —Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
290.9	353	37	S
292.1	319	38	S
293.9	290	35	S
294.8	29	44	S
296.5	306	36	S
299.2	316	16	S
299.3	321	22	S
301.4	257	64	S
319.8	227	18	S
345.3	58	55	S
346.1	276	42	GEOCNT
346.7	280	53	S
346.8	279	53	S
349.8	279	39	S
352.3	282	53	S
352.4	283	48	M
352.5	286	46	S
352.7	282	46	S
353.8	282	41	S
354.0	281	49	S
356.2	277	59	M
357.4	276	70	S
363.1	269	47	S
364.1	276	64	S
364.3	276	62	S
365.1	274	61	S
365.7	281	63	S
366.0	283	61	S
366.6	268	62	S
366.8	77	80	M
367.1	80	48	S
367.5	51	55	S
372.1	285	59	S
373.2	280	58	S
379.6	266	54	S
380.0	281	57	S
380.1	274	52	S
384.5	262	67	S
384.8	262	61	S
385.7	265	62	S
386.5	266	65	S
386.5	258	63	S
387.6	259	58	S
389.7	269	58	S
390.9	267	59	S
397.5	262	52	S
399.1	273	60	S
399.5	254	48	S
401.5	259	67	M
401.9	249	58	S
411.4	245	61	S
411.5	244	60	S
412.4	257	64	S
422.3	47	88	S
423.5	254	31	S
429.7	337	78	M
443.6	257	71	S
444.3	259	53	S
451.6	248	49	S
456.6	250	71	S
520.6	34	3	S
Ericsson-A Foliation			
101.5	246	77	
105.5	258	80	
111.6	251	79	
118.6	253	79	
124.7	256	80	
132.0	256	81	
136.2	248	71	
142.6	248	77	
144.9	273	75	
146.7	256	69	
154.1	261	72	
157.5	271	72	
159.7	274	66	

Appendix 3. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in South Water-Tunnel boreholes (Ericsson-A, FranklinST-B, FranklinST-A, GrandST-B, PrinceST-A, BondST-A, 31B-1), Manhattan Island, N.Y., 2003-04. —Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
164.7	263	79	
170.4	261	78	
173.3	254	80	
177.2	263	81	
178.7	256	80	
183.5	264	79	
193.2	249	77	
197.6	264	78	
202.0	261	66	
204.9	268	59	
208.8	256	72	
211.9	284	50	
215.0	279	54	
218.5	274	54	
220.3	299	42	
222.0	305	25	
236.1	351	34	
239.2	22	35	
242.2	44	51	
249.5	8	34	
253.1	8	52	
258.6	286	26	
262.5	4	27	
267.1	10	33	
271.1	18	36	
274.8	7	36	
280.0	333	29	
286.0	40	47	
288.9	358	26	
290.9	347	31	
292.1	359	37	
293.8	349	36	
295.2	284	42	
300.1	339	27	
303.5	267	40	
305.2	301	33	
306.4	287	28	
308.2	353	23	
312.8	279	52	
314.7	313	33	
316.0	305	30	
318.6	25	20	
324.4	119	11	
326.0	309	32	
332.8	310	32	
335.1	310	34	
340.4	341	23	
342.8	29	32	
348.3	270	52	
350.8	276	47	
354.0	280	51	
357.4	277	69	
360.8	268	64	
363.1	268	50	
366.7	272	61	
373.2	284	57	
376.7	262	61	
381.6	264	65	
385.7	265	62	
390.4	266	59	
393.1	270	41	
397.2	261	46	
399.1	249	58	
402.5	248	58	
406.8	253	68	
411.4	251	58	
414.0	241	64	
416.0	257	65	
420.0	251	66	
420.7	250	54	
422.8	264	46	
423.9	253	45	
426.9	256	70	
430.4	255	57	
433.5	259	71	
435.3	266	59	

Appendix 3. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in South Water-Tunnel boreholes (Ericsson-A, FranklinST-B, FranklinST-A, GrandST-B, PrinceST-A, BondST-A, 31B-1), Manhattan Island, N.Y., 2003-04. —Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
437.9	257	57	
439.5	269	65	
443.6	255	71	
445.6	255	64	
447.5	265	73	
449.4	251	73	
454.6	255	66	
459.6	263	75	
464.8	285	81	
471.0	266	81	
476.0	260	81	
478.3	276	81	
481.9	260	79	
484.3	260	80	
487.2	256	80	
489.4	260	82	
491.7	265	83	
494.1	276	83	
497.1	255	78	
502.2	261	78	
507.2	270	75	
509.8	257	76	
513.3	263	79	
514.5	266	75	
FranklinST-B Fractures			
86.1	326	15	S
89.0	72	35	S
92.7	77	20	M
96.4	100	11	S
99.5	79	7	S
99.6	78	22	M
102.0	74	11	S
106.9	116	3	S
107.1	0	14	S
109.2	128	15	S
112.7	128	10	S
123.2	175	7	M
128.5	96	13	S
138.7	41	12	S
138.8	286	2	S
149.6	278	17	S
153.7	76	25	S
160.1	309	9	S
160.5	20	2	S
163.8	108	21	S
171.4	45	21	S
172.0	348	67	S
173.9	337	46	S
174.2	312	10	S
191.3	349	16	S
200.3	70	11	S
204.4	88	10	S
216.4	251	13	S
266.0	131	58	S
375.9	290	5	S
426.5	331	7	S
427.8	329	13	S
452.5	287	73	M
474.6	254	77	M
477.6	286	56	S
478.0	296	28	M
478.5	294	84	M
479.3	291	53	M
479.4	281	59	L
479.6	292	64	M
479.7	293	71	M
480.6	130	35	S
486.1	289	84	M
490.9	286	5	S
502.5	287	53	S
505.2	261	18	S
506.8	271	45	M
507.4	44	39	S
507.6	312	36	S
509.6	327	20	S

Appendix 3. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in South Water-Tunnel boreholes (Ericsson-A, FranklinST-B, FranklinST-A, GrandST-B, PrinceST-A, BondST-A, 31B-1), Manhattan Island, N.Y., 2003-04. —Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
510.3	262	29	M
513.1	137	33	S
515.3	30	64	S
527.4	143	23	S
544.0	324	15	S
545.9	277	4	S
549.4	289	67	L GOUGE ZN
550.0	292	80	L GOUGE ZN
FranklinST-B Foliation			
95.3	88	82	
98.8	110	83	
114.5	281	85	
120.7	269	83	
122.6	117	60	
130.7	100	74	
135.7	292	85	
147.1	293	82	
156.6	105	83	
161.6	286	82	
169.0	261	79	
183.8	68	81	
192.6	102	79	
199.4	100	74	
201.6	284	86	
207.2	291	85	
214.4	115	78	
219.2	91	80	
223.8	280	82	
231.2	277	83	
235.9	275	79	
246.7	113	83	
251.7	76	77	
256.7	106	79	
265.9	129	81	
271.0	108	82	
276.4	296	82	
285.3	114	86	
286.1	106	75	
293.3	115	78	
299.0	282	77	
302.7	290	87	
313.4	286	82	
320.4	116	76	
326.1	293	84	
333.2	291	79	
336.4	308	79	
342.3	292	84	
348.5	103	80	
354.9	292	80	
358.7	291	86	
365.8	91	79	
368.3	104	78	
373.2	292	87	
384.1	283	87	
390.9	283	88	
399.0	287	85	
413.1	291	89	
432.1	112	79	
434.6	286	77	
440.7	101	76	
443.5	111	65	
452.5	289	74	
457.6	295	77	
480.1	304	76	
482.4	295	84	
486.6	291	87	
489.2	282	83	
492.9	106	89	
504.8	282	88	
508.6	274	86	
518.2	283	84	
521.3	288	89	

Appendix 3. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in South Water-Tunnel boreholes (Ericsson-A, FranklinST-B, FranklinST-A, GrandST-B, PrinceST-A, BondST-A, 31B-1), Manhattan Island, N.Y., 2003-04. —Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
527.2	280	86	
534.2	284	83	
536.0	267	86	
539.3	271	87	
542.4	281	87	
550.0	291	81	
FranklinST-A Fractures			
120.3	305	55	M
120.4	85	35	S
123.1	61	2	S
125.7	59	10	S
126.6	317	5	M
128.7	200	26	S
129.5	104	13	S
130.7	153	23	S
131.0	115	11	S
131.2	117	15	S
131.5	112	23	S
132.2	281	76	M
132.7	96	21	S
132.9	281	71	S
135.0	52	18	M
135.7	8	10	S
138.7	60	6	S
138.7	24	19	S
143.7	308	30	S
143.8	332	33	S
147.4	34	17	S
150.3	39	44	M
150.6	42	27	L
150.7	119	6	S
151.0	73	22	S
154.3	1	16	S
154.4	313	17	S
155.2	80	30	S
159.0	349	28	S
160.5	15	19	S
160.8	24	7	S
160.9	353	19	S
171.4	315	8	S
171.9	213	85	M
173.2	39	23	S
176.2	51	21	M
182.2	24	16	L
187.7	59	20	L
190.9	170	82	M
193.0	45	20	L
211.6	171	11	S
215.5	194	46	S
218.8	163	15	S
225.3	303	75	M
229.5	64	74	M
232.6	142	51	S
240.2	225	72	M
241.9	149	28	M
242.1	173	7	M
244.3	284	49	S
254.5	238	24	S
255.2	278	27	S
264.3	264	26	M
264.5	131	14	M
266.8	140	7	S
266.9	186	8	S
278.2	77	11	M
280.2	130	34	M
282.6	328	5	S
289.0	100	17	S
292.7	135	11	S
295.7	205	17	S
299.1	117	11	S
299.2	108	16	M
306.6	112	11	S
310.0	185	10	S
313.1	285	23	S
313.2	236	10	S

Appendix 3. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in South Water-Tunnel boreholes (Ericsson-A, FranklinST-B, FranklinST-A, GrandST-B, PrinceST-A, BondST-A, 31B-1), Manhattan Island, N.Y., 2003-04. —Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
319.9	314	16	M
330.9	87	16	S
331.1	115	22	S
331.1	114	30	M
331.1	65	35	M
331.1	98	35	M
332.8	114	17	S
334.7	91	19	S
335.1	71	21	S
340.4	283	61	S
346.8	54	67	M
347.5	59	74	M
352.7	140	23	S
354.3	84	44	S
359.7	127	21	S
363.4	104	34	S
364.8	68	32	S
365.3	338	79	S
382.7	136	15	M
383.0	221	11	S
386.2	257	28	S
388.2	247	13	S
404.9	218	15	S
426.8	244	15	S
427.3	230	9	S
432.9	132	6	S
433.3	270	58	M
436.1	337	15	S
436.9	239	8	S
439.6	240	13	S
439.7	256	28	S
439.7	243	27	M FLT
440.4	178	9	S
441.1	85	5	S
442.1	262	13	S
442.6	240	17	S
446.6	178	15	S
446.7	263	14	S
447.5	3	7	L
448.5	256	6	S
452.9	92	13	S
461.3	140	21	S
461.3	157	22	S
461.3	52	7	S
466.0	115	24	S
466.1	112	12	S
467.6	10	24	S
481.0	112	30	M
485.4	28	7	S
506.0	139	13	S
510.7	38	6	S
534.6	42	7	S
FranklinST-A Foliation			
119.8	281	67	
123.5	283	77	
125.9	272	71	
127.9	296	69	
129.8	287	69	
132.8	281	74	
137.0	282	71	
138.6	280	71	
142.2	287	75	
144.2	260	76	
145.9	298	69	
147.2	282	69	
152.3	306	68	
154.0	281	58	
158.0	277	71	
159.8	301	66	
163.1	270	73	
165.3	294	75	
169.4	263	81	
175.2	263	76	
178.4	273	74	
180.5	281	72	

Appendix 3. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in South Water-Tunnel boreholes (Ericsson-A, FranklinST-B, FranklinST-A, GrandST-B, PrinceST-A, BondST-A, 31B-1), Manhattan Island, N.Y., 2003-04. —Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
182.7	284	75	
185.6	296	65	
188.7	290	76	
190.9	296	75	
191.6	283	66	
194.4	283	75	
197.1	278	79	
199.1	305	70	
200.8	282	73	
205.4	285	73	
206.8	260	73	
209.9	286	75	
214.4	271	79	
216.5	296	77	
218.7	280	76	
220.0	270	74	
224.0	276	78	
225.8	281	77	
230.2	283	78	
235.3	279	80	
242.7	286	72	
246.5	291	67	
253.1	271	74	
261.5	276	73	
263.4	278	74	
266.6	286	73	
268.7	271	80	
272.1	299	73	
274.5	293	78	
279.8	278	57	
286.2	298	62	
287.9	305	72	
295.2	281	70	
297.5	267	62	
299.6	279	69	
300.7	265	63	
302.4	277	62	
304.1	282	74	
306.2	282	69	
307.4	285	72	
308.8	276	71	
310.2	285	72	
312.7	286	74	
315.2	273	79	
317.7	275	83	
321.8	290	76	
324.6	273	72	
326.5	274	67	
327.7	275	73	
329.8	278	64	
332.8	279	77	
335.2	281	70	
337.4	277	71	
339.9	263	69	
350.8	263	74	
353.9	281	74	
360.6	292	74	
361.8	290	70	
365.3	295	65	
366.8	285	77	
369.6	271	73	
374.0	272	74	
376.1	289	84	
383.0	270	72	
384.9	279	75	
386.3	269	77	
390.6	234	75	
392.5	256	77	
394.9	283	74	
397.5	277	78	
401.1	282	85	
409.0	272	78	
415.4	277	80	
416.9	273	80	
419.0	287	76	
423.8	279	81	

Appendix 3. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in South Water-Tunnel boreholes (Ericsson-A, FranklinST-B, FranklinST-A, GrandST-B, PrinceST-A, BondST-A, 31B-1), Manhattan Island, N.Y., 2003-04. —Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
430.5	48	67	
436.3	269	66	
445.0	310	78	
448.2	270	78	
450.8	277	76	
457.6	287	76	
459.7	274	73	
463.8	298	73	
465.2	312	70	
466.5	291	65	
470.6	293	82	
477.0	284	85	
480.7	23	72	
491.6	280	80	
496.0	287	71	
500.5	301	54	
504.0	293	66	
511.2	311	61	
512.2	269	70	
514.1	290	67	
517.6	269	73	
519.0	309	70	
524.0	316	67	
528.6	297	64	
536.2	264	73	
GrandST-B Fractures			
134.8	275	67	L
135.4	153	11	M
136.0	127	27	S
140.0	272	57	S
140.7	118	29	S
141.1	118	26	S
142.2	122	11	S
143.3	284	60	S
146.7	286	71	M
147.8	314	5	M
150.9	296	53	S
151.2	276	60	S
152.0	271	23	S
152.1	289	47	S
153.2	281	30	S
160.6	266	74	L
162.5	281	8	M
164.6	281	17	S
166.1	282	21	S
167.1	74	44	S
167.5	34	29	S
170.3	324	24	S
170.2	286	29	M
171.5	222	21	S
171.5	196	13	S
171.9	2	48	S
172.8	1	16	S
173.5	300	31	L
174.2	256	23	M
175.0	293	25	S
175.2	273	30	S
175.5	183	8	M
175.5	225	10	M
175.8	159	4	M
175.9	88	3	M
183.3	256	6	M
183.3	56	5	M
185.8	121	48	L
193.3	131	47	M
196.5	79	48	L
197.3	325	5	M
197.3	98	9	M
204.0	85	44	M
210.6	63	23	S
216.1	287	71	S
216.5	276	64	GEOUPCNT
219.7	277	70	GEOLWCNT
219.5	104	18	S
218.9	225	87	S

Appendix 3. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in South Water-Tunnel boreholes (Ericsson-A, FranklinST-B, FranklinST-A, GrandST-B, PrinceST-A, BondST-A, 31B-1), Manhattan Island, N.Y., 2003-04. —Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
234.9	278	66	S
235.7	289	68	S
238.8	283	62	L
239.4	283	76	VL
245.8	282	72	M
246.6	353	77	M
250.3	278	31	S
250.5	304	28	S
252.1	112	79	S
259.2	288	88	S
254.8	285	60	M
266.6	81	80	S
268.2	278	58	S
267.9	282	62	M
272.1	353	82	S
274.5	357	81	S
273.9	1	82	S
271.4	119	88	S
279.9	94	80	S
289.2	43	27	S
289.8	89	21	S
298.2	67	10	S
299.2	105	16	S
299.6	112	18	S
300.7	83	33	S
301.2	83	14	S
303.6	317	5	S
304.4	66	13	S
304.6	53	55	S
305.3	32	2	S
306.1	82	31	S
306.8	98	4	S
312.0	314	11	S
312.5	102	5	S
318.5	97	15	S
331.3	60	69	S
332.4	295	67	S
333.3	79	28	S
351.6	278	64	S
354.1	347	17	S
357.4	329	20	S
362.2	102	24	S
362.5	69	37	S
363.2	79	29	S
364.1	76	39	M
366.5	270	65	S
370.0	52	26	S
371.5	358	79	S
384.4	73	26	M
385.0	327	23	S
388.2	76	23	M
390.9	85	4	S
400.9	296	3	S
401.2	74	10	S
401.6	76	26	S
401.7	94	30	M
402.5	145	2	S
409.0	87	8	S
409.1	85	14	M
411.4	105	9	M
413.5	109	11	S
413.4	72	11	S
428.1	64	39	S
433.0	2	10	M
435.5	68	9	S
439.0	24	20	S
439.8	125	12	S
441.5	56	20	S
442.4	137	47	S
443.1	291	72	S
445.1	268	62	S
447.1	96	23	S
448.6	105	14	S
448.7	122	13	S
448.8	104	13	S
449.0	60	15	S

Appendix 3. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in South Water-Tunnel boreholes (Ericsson-A, FranklinST-B, FranklinST-A, GrandST-B, PrinceST-A, BondST-A, 31B-1), Manhattan Island, N.Y., 2003-04. —Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
449.4	87	4	S
449.8	193	12	S
450.0	142	13	S
450.1	104	7	S
451.4	20	3	S
452.5	286	64	S
452.9	314	6	S
452.9	20	3	S
453.0	249	8	S
453.1	186	5	M
463.7	115	4	S
463.6	122	4	S
472.2	256	4	S
485.5	21	4	S
486.6	5	2	S
487.2	259	4	M
453.5	180	6	S
450.7	97	6	S
450.9	113	11	S
451.4	277	74	S
466.5	292	61	M
467.9	291	55	M
494.5	120	8	S
503.1	289	62	S
507.8	266	63	S
532.4	287	57	S
GrandST-B Foliation			
120.2	280	64	
121.9	284	67	
124.3	294	66	
126.8	288	75	
128.4	285	71	
134.0	289	69	
135.7	308	47	
138.0	294	65	
141.1	284	66	
144.6	285	67	
146.1	278	64	
148.0	301	51	
151.0	298	55	
153.1	280	66	
156.4	274	65	
157.7	282	62	
159.1	294	60	
161.0	277	73	
162.3	289	71	
165.7	284	73	
167.6	287	68	
169.6	282	71	
172.2	275	72	
175.7	283	72	
176.7	284	68	
180.0	290	70	
183.8	289	67	
184.8	289	72	
190.9	289	68	
192.1	299	60	
195.2	293	63	
199.4	281	68	
201.4	288	72	
205.0	280	77	
207.7	284	66	
210.0	279	63	
213.0	285	68	
216.1	284	70	
220.7	300	69	
224.1	287	68	
226.1	297	69	
230.4	285	74	
231.9	288	71	
234.9	283	62	
235.9	276	67	
238.3	279	66	
241.9	278	66	
244.8	287	69	

Appendix 3. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in South Water-Tunnel boreholes (Ericsson-A, FranklinST-B, FranklinST-A, GrandST-B, PrinceST-A, BondST-A, 31B-1), Manhattan Island, N.Y., 2003-04. —Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
247.5	276	74	
260.3	287	81	
264.0	283	69	
268.9	280	69	
270.6	281	70	
286.0	281	83	
288.9	304	67	
291.5	285	61	
294.8	288	59	
298.0	290	53	
300.8	284	75	
303.1	282	62	
306.7	286	74	
311.8	287	63	
314.4	295	73	
318.5	281	64	
325.3	270	79	
330.3	281	75	
332.5	297	62	
335.6	295	64	
339.2	305	66	
342.3	286	70	
345.3	278	68	
348.0	280	59	
351.9	287	65	
356.0	287	70	
359.9	284	57	
362.9	293	49	
366.0	283	64	
368.8	288	68	
372.7	284	71	
376.1	299	73	
380.0	294	76	
385.2	280	54	
386.4	291	74	
389.8	279	71	
392.1	304	60	
395.9	263	74	
400.0	276	66	
402.8	293	68	
406.8	295	61	
408.8	291	71	
411.7	275	75	
415.2	279	74	
418.2	270	71	
420.9	285	73	
424.4	277	70	
428.1	289	83	
435.9	279	71	
440.8	292	69	
443.4	293	70	
446.8	290	75	
449.9	277	80	
453.5	285	65	
456.5	287	67	
459.7	291	71	
462.3	281	68	
465.5	296	58	
469.2	280	66	
473.6	280	68	
476.2	289	68	
481.0	284	69	
484.2	290	66	
487.8	282	75	
490.8	282	72	
494.9	283	73	
498.2	295	75	
501.2	293	67	
504.2	291	64	
507.8	285	70	
510.4	284	60	
514.1	290	61	
517.0	287	76	
519.9	283	68	
523.8	281	70	
526.8	284	67	

Appendix 3. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in South Water-Tunnel boreholes (Ericsson-A, FranklinST-B, FranklinST-A, GrandST-B, PrinceST-A, BondST-A, 31B-1), Manhattan Island, N.Y., 2003-04. —Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
529.9	289	66	
531.6	289	66	
534.8	296	68	
535.9	282	68	
536.9	304	59	
PrinceST-A Fractures			
120.9	307	6	M
121.4	260	54	S
121.7	143	36	S
121.9	184	12	S
122.5	231	10	S
122.5	221	8	M
122.7	300	26	S
122.7	275	30	M
122.9	300	40	M
123.4	147	8	M
123.5	146	25	M
125.0	167	22	S
126.1	164	15	S
127.1	148	3	M
128.0	313	44	M
128.7	73	15	S
131.0	8	42	S
131.0	314	15	S
133.5	264	15	S
137.6	155	18	M
141.8	119	18	S
142.1	78	12	S
144.4	102	19	M
144.4	228	70	S
144.5	75	5	S
144.6	145	10	M
144.6	108	13	M
145.8	304	9	S
146.0	29	7	S
146.4	301	25	S
146.7	298	79	S
147.8	100	25	M
149.6	345	30	S
149.9	183	80	M
150.5	313	61	M
150.5	127	12	S
152.7	110	35	S
153.4	51	16	S
155.7	322	29	S
157.1	189	79	M
157.2	95	28	S
157.8	309	72	M
158.2	312	59	M
158.9	128	23	S
159.4	200	4	M
159.5	161	14	L
160.0	300	55	M
161.0	118	19	S
161.1	130	18	S
162.9	87	23	S
163.1	39	20	S
163.5	81	38	S
163.7	106	30	S
164.3	125	18	S
164.4	328	55	S
165.2	135	23	S
165.2	118	22	M
165.3	135	15	S
166.5	320	56	S
166.9	323	50	M
167.7	138	35	M
169.6	136	24	M
170.9	204	2	S
171.9	136	27	S
172.9	322	56	S
173.6	104	43	S
173.8	120	24	S
174.1	309	57	MS
175.0	95	30	S

Appendix 3. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in South Water-Tunnel boreholes (Ericsson-A, FranklinST-B, FranklinST-A, GrandST-B, PrinceST-A, BondST-A, 31B-1), Manhattan Island, N.Y., 2003-04. —Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
175.4	160	37	S
179.9	311	29	L
182.4	319	45	M
185.2	189	71	S
185.4	120	27	S
185.5	319	61	S
185.5	105	25	S
186.5	140	18	S
186.8	151	13	S
187.0	124	25	M
187.2	114	17	L
190.4	312	63	S
190.9	166	30	M
193.1	308	61	S
193.4	311	54	S
193.9	303	67	S
194.3	292	10	S
195.3	139	19	S
195.4	118	25	S
197.6	97	19	M
198.3	304	71	S
198.6	297	72	S
204.0	102	18	L
206.8	197	60	S
207.1	193	68	S
210.7	307	77	S
210.8	203	73	S
213.1	118	32	M
213.1	124	29	S
213.2	87	18	S
215.2	302	70	S
215.2	305	67	M
216.0	55	17	S
217.1	118	11	M
217.1	314	7	M
217.2	119	17	L
220.9	170	15	M
223.5	263	9	M
223.6	61	2	M
223.9	310	76	S
224.4	313	64	S
224.8	308	63	S
224.9	123	33	S
225.0	314	66	S
225.4	313	67	L
225.6	314	64	M
225.9	303	63	S
225.9	78	60	S
226.9	24	32	S
228.5	79	82	M
230.0	310	69	M
230.1	94	72	M
230.1	89	59	L
230.5	71	44	M
230.7	307	69	S
230.7	96	67	S
231.2	96	72	L
231.4	81	65	L
231.6	75	67	M
231.9	305	50	S
232.2	109	55	S
232.6	79	60	S
233.0	75	64	M
233.1	330	51	M
233.2	306	65	S
233.7	308	54	S
233.8	309	59	M
234.4	303	52	S
234.6	298	39	L GOUGE ZN
235.4	312	55	S
235.6	303	34	S
235.9	89	47	M
236.0	316	59	S
237.2	294	57	S

Appendix 3. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in South Water-Tunnel boreholes (Ericsson-A, FranklinST-B, FranklinST-A, GrandST-B, PrinceST-A, BondST-A, 31B-1), Manhattan Island, N.Y., 2003-04. —Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
237.2	93	56	S
237.3	87	51	S
237.8	307	57	S
238.1	306	58	S
238.6	81	39	M
239.3	74	36	S
239.5	305	54	S
239.5	140	13	M
239.6	305	49	S
240.1	306	51	S
241.2	308	58	S
241.9	213	62	S
242.1	76	55	M
242.1	307	65	S
244.2	80	66	M
244.2	61	59	M
244.3	312	54	S
244.4	94	34	S
244.5	71	43	S
245.8	304	65	M
246.2	109	40	S
246.3	125	36	S
247.2	89	66	M
249.2	73	62	S
251.1	309	69	S
251.6	307	71	S
251.9	309	70	S
252.5	305	58	S
254.0	315	68	S
254.5	62	64	M
258.9	91	70	S
261.6	310	53	S
261.8	304	56	S
262.0	317	65	S
263.5	299	61	S
264.3	123	49	S
266.9	153	24	S
268.9	310	57	S
270.4	313	60	S
271.1	315	59	S
271.6	307	38	S
272.7	124	6	S
273.2	311	60	S
277.9	124	29	S
281.5	307	64	S
283.2	305	69	S
283.3	158	8	S
286.9	311	71	S
287.5	305	75	S
288.0	191	61	S
288.5	161	11	S
289.0	172	15	S
290.1	209	61	S
291.5	310	72	M
291.9	353	54	M
292.1	330	65	S
292.4	308	65	M
292.9	306	67	S
293.7	313	68	S
294.2	309	70	S
294.5	297	65	S
294.7	310	65	S
294.9	315	58	S
295.3	273	19	S
296.0	305	63	S
298.2	311	70	S
300.3	313	65	S
303.1	311	72	S
307.2	265	85	M
318.5	212	13	M
318.9	217	8	S
319.6	110	16	S
319.6	117	12	S
323.0	316	56	M
324.3	237	85	M
331.0	305	68	S

Appendix 3. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in South Water-Tunnel boreholes (Ericsson-A, FranklinST-B, FranklinST-A, GrandST-B, PrinceST-A, BondST-A, 31B-1), Manhattan Island, N.Y., 2003-04. —Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
332.7	316	68	S
337.2	253	61	S
337.6	260	78	S
337.9	305	81	M
340.5	336	37	S
340.5	334	30	S
343.1	310	56	S
343.3	311	56	S
345.5	135	13	S
346.2	162	21	S
346.3	137	17	S
346.4	306	58	S
346.6	310	61	S
348.9	122	11	S
350.7	12	74	S
351.7	172	14	S
354.0	251	76	S
357.6	161	23	S
357.7	142	21	S
358.0	309	62	M
363.2	305	71	S
365.6	311	62	S
365.7	323	60	S
369.4	169	26	S
370.5	272	70	S
374.8	305	54	S
375.1	321	57	S
384.1	252	15	S
384.8	230	7	S
386.9	187	14	S
392.1	173	30	S
392.3	35	66	S
392.5	46	50	S
393.0	202	62	S
393.1	207	64	S
393.7	195	66	S
394.5	190	12	M
403.9	169	5	S
404.3	158	17	M
408.4	144	16	S
408.6	120	6	S
409.2	164	38	M
411.9	208	37	S
413.9	348	13	S
414.2	332	40	S
417.3	132	84	S
425.1	155	25	M
425.1	141	23	M
428.5	299	57	S
429.2	176	15	S
429.6	24	73	S
431.3	42	46	S
431.6	61	47	S
431.7	70	49	S
435.5	2	77	S
436.7	326	56	S
437.3	64	38	S
439.6	50	45	S
439.6	63	32	S
441.4	313	59	S
442.0	321	60	S
442.4	113	27	S
442.5	119	31	S
445.7	348	5	M
445.7	155	27	M
445.9	313	61	S
446.0	312	64	S
448.1	308	73	S
449.4	308	56	S
449.8	315	52	S
450.0	307	59	S
450.5	157	23	S
450.8	182	14	S
451.1	293	57	S
451.5	69	54	S
451.6	115	37	M

Appendix 3. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in South Water-Tunnel boreholes (Ericsson-A, FranklinST-B, FranklinST-A, GrandST-B, PrinceST-A, BondST-A, 31B-1), Manhattan Island, N.Y., 2003-04. —Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
451.7	85	82	M FLT
451.8	81	27	S
452.0	324	59	GEOCNT
455.5	244	2	S
455.6	83	16	M
463.5	129	18	S
466.5	270	80	M
470.1	64	55	M
472.7	101	45	M
475.1	62	80	M
475.6	61	80	M
476.9	312	65	GEOCNT
477.3	209	78	S
477.9	308	74	S
479.0	266	84	M FLT
480.6	307	50	S
481.3	104	26	S
481.4	100	27	S
484.4	115	23	M
484.9	115	24	S
485.5	135	30	S
486.2	117	27	S
486.3	317	63	S
486.5	165	19	S
487.0	111	22	S
488.2	314	56	S
490.1	321	61	S
490.6	315	54	S
491.1	315	57	S
491.6	317	67	S
491.7	114	29	M
493.2	327	43	S
493.2	98	30	S
493.7	318	53	S
493.9	292	20	M
494.0	327	49	S
494.2	331	50	M
496.2	105	31	S
496.6	318	54	S
499.4	320	21	S
500.5	106	26	S
503.1	116	29	S
503.8	54	9	M
503.8	37	4	M
504.4	104	35	S
504.4	100	37	S
504.7	320	43	M
508.6	136	18	L
510.1	106	30	S
510.2	118	36	S
510.5	326	48	S
511.0	325	39	M
511.1	315	49	M
511.3	220	21	M
511.4	336	50	S
511.8	119	28	S
511.9	114	27	S
513.3	306	50	S
513.4	309	63	S
514.0	306	46	S
514.6	122	3	M
514.6	34	2	M
517.4	331	40	M
519.5	281	7	M
519.6	223	11	M
521.3	345	30	S
523.8	290	50	M
525.0	308	59	S
525.1	308	57	S
525.2	165	7	M
525.4	308	60	M
525.6	105	31	M
526.3	304	59	S
526.4	266	74	S
527.0	306	55	S
527.3	299	55	M

Appendix 3. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in South Water-Tunnel boreholes (Ericsson-A, FranklinST-B, FranklinST-A, GrandST-B, PrinceST-A, BondST-A, 31B-1), Manhattan Island, N.Y., 2003-04. —Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
527.6	304	58	S
528.0	260	68	S
529.4	274	71	S
530.0	261	73	S
531.4	304	62	S
531.7	117	31	M
532.0	306	62	S
532.3	304	62	S
533.3	308	61	S
533.4	306	61	M
533.6	306	64	M
533.9	305	55	S
534.1	305	59	S
534.4	307	58	S
534.7	307	61	S
535.0	305	63	S
535.6	302	70	S
537.3	113	21	S
537.4	305	72	M
537.8	300	62	S
538.6	283	61	S
538.8	290	66	M
539.6	305	65	S
539.8	305	69	S
540.1	304	65	S
540.9	339	20	S
540.9	311	61	S
541.1	305	60	S
541.2	304	66	M
541.4	309	66	S
541.5	307	65	M
542.5	281	83	S
544.0	306	55	S
546.4	311	71	S
546.6	310	55	M
547.1	312	60	S
547.4	314	56	S
547.5	311	62	S
550.9	162	53	S
553.9	142	22	S
556.8	333	45	S
557.0	325	58	M
559.2	136	35	S
559.6	186	16	M
559.7	302	56	M
560.2	128	83	S
560.3	121	28	S
560.4	115	32	S
560.7	116	45	S
560.8	128	33	S
562.6	317	71	M
565.8	313	38	S
566.4	316	56	S
566.6	315	62	S
568.5	237	86	S
569.9	321	67	S
571.1	312	66	S
577.5	107	17	M
580.5	142	26	S
580.6	138	24	S
581.7	141	18	M
582.1	119	18	S
582.4	149	32	S
585.6	189	76	S
586.2	299	53	S
586.9	321	42	S
592.4	298	21	S
592.9	165	17	S
593.1	312	57	S
596.1	142	12	S
596.7	330	56	S
599.2	111	18	S
599.3	134	22	M
599.6	111	18	S
601.2	315	59	M
601.9	308	63	S

Appendix 3. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in South Water-Tunnel boreholes (Ericsson-A, FranklinST-B, FranklinST-A, GrandST-B, PrinceST-A, BondST-A, 31B-1), Manhattan Island, N.Y., 2003-04. —Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
602.9	138	24	S
602.9	136	24	S
603.9	327	55	M
604.2	323	65	S
604.5	328	58	S
604.9	322	54	S
606.0	322	65	S
606.1	305	66	S
606.4	329	58	S
607.1	136	21	S
609.7	101	25	S
612.1	125	22	S
612.1	113	25	M
613.4	305	67	S
615.1	330	61	S
615.7	106	32	M
615.7	96	30	M
616.5	314	53	S
616.7	312	43	S
618.2	330	81	S
620.8	155	62	M
622.2	255	47	M
623.1	317	76	GEOCNT
623.9	340	10	S
627.6	79	6	S
627.9	134	37	S
628.0	127	33	S
629.3	103	65	M
629.3	152	25	M
637.7	100	82	M
640.5	145	17	M
640.6	324	61	GEOCNT
642.9	311	61	M
643.4	62	65	S
644.2	137	31	S
644.5	131	25	M
644.8	320	58	M
648.1	321	50	M
649.8	70	65	S
650.0	154	35	M
651.2	318	53	S
651.9	321	53	S
652.2	318	61	S
652.6	325	60	M
653.0	324	58	S
654.0	320	66	M
655.7	310	65	S
655.9	315	65	S
656.2	321	64	M
656.4	320	59	M
656.5	325	60	M
656.7	318	60	M
657.8	94	23	S
657.9	88	17	S
658.0	326	50	S
660.9	103	25	S
662.5	97	75	S
PrinceST-A Foliation			
125.9	304	57	
126.6	295	55	
128.6	305	62	
130.6	306	60	
139.8	316	61	
142.2	283	51	
145.5	315	68	
148.7	315	63	
150.7	305	65	
153.5	312	61	
156.5	318	72	
157.9	310	71	
159.8	296	55	
161.3	310	49	
163.4	310	55	
165.9	327	56	
167.8	317	58	

Appendix 3. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in South Water-Tunnel boreholes (Ericsson-A, FranklinST-B, FranklinST-A, GrandST-B, PrinceST-A, BondST-A, 31B-1), Manhattan Island, N.Y., 2003-04. —Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
170.1	317	55	
172.2	316	53	
173.9	330	62	
175.5	314	35	
177.8	312	48	
180.2	316	48	
182.4	321	48	
185.5	313	61	
187.6	310	63	
189.4	310	58	
191.9	312	63	
193.9	299	61	
195.7	308	69	
198.0	305	66	
199.4	301	66	
202.7	308	69	
205.4	307	71	
207.1	300	71	
209.0	302	70	
211.7	300	72	
214.0	306	68	
216.1	301	71	
217.9	305	59	
220.2	308	66	
222.5	314	59	
224.9	312	63	
227.1	306	75	
229.4	314	56	
232.0	305	62	
233.5	293	58	
236.1	304	57	
239.5	308	56	
241.4	309	59	
243.4	304	61	
245.0	307	67	
247.3	304	70	
249.8	313	69	
251.9	305	72	
253.6	305	68	
256.6	297	47	
261.3	311	59	
263.7	303	57	
266.1	311	63	
268.4	311	65	
270.3	317	61	
273.4	310	59	
275.0	308	68	
277.6	310	62	
280.1	300	67	
282.7	311	69	
285.1	315	65	
286.1	312	71	
288.8	314	73	
290.8	310	71	
293.4	309	67	
295.9	320	65	
298.7	313	64	
300.9	314	69	
303.5	301	65	
307.6	302	73	
311.1	312	64	
313.5	317	63	
315.5	315	62	
318.0	315	54	
321.1	307	60	
323.7	310	64	
325.6	299	60	
329.2	301	71	
331.2	306	66	
334.3	306	76	
340.3	320	45	
342.6	309	61	
344.8	305	67	
347.1	304	64	
349.1	304	68	
351.9	312	67	

Appendix 3. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in South Water-Tunnel boreholes (Ericsson-A, FranklinST-B, FranklinST-A, GrandST-B, PrinceST-A, BondST-A, 31B-1), Manhattan Island, N.Y., 2003-04. —Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
352.8	306	69	
355.4	307	67	
358.0	311	61	
360.1	308	64	
362.3	307	66	
364.3	308	66	
366.4	319	61	
368.6	325	59	
370.8	321	61	
373.0	324	50	
375.0	317	56	
377.2	312	57	
379.4	327	65	
382.5	318	61	
384.2	310	70	
386.4	311	74	
389.3	314	58	
391.9	313	76	
393.7	310	57	
395.7	317	56	
398.6	302	56	
400.9	301	38	
403.8	314	69	
405.8	317	57	
408.1	314	67	
410.6	356	32	
413.0	323	53	
414.5	307	44	
416.8	313	47	
418.9	323	61	
423.5	314	63	
426.6	308	67	
428.4	303	56	
430.7	291	61	
432.7	305	63	
435.1	303	58	
437.3	296	64	
439.1	309	60	
441.3	303	61	
443.5	308	67	
445.9	309	62	
448.7	317	68	
451.1	293	57	
453.6	332	61	
456.3	311	63	
460.8	300	59	
463.6	324	55	
465.7	309	51	
468.6	338	51	
470.9	324	61	
472.9	310	53	
475.1	303	50	
477.5	313	56	
479.6	284	64	
481.6	320	48	
483.9	309	48	
485.7	315	55	
488.1	313	58	
491.3	316	63	
493.6	306	51	
495.7	320	53	
497.8	333	47	
500.1	319	51	
502.9	333	50	
505.0	309	54	
507.6	323	55	
509.9	308	50	
511.1	308	46	
513.3	311	46	
515.7	308	55	
518.5	324	42	
520.4	310	59	
522.8	310	61	
525.0	304	63	
527.3	303	54	
529.5	299	60	

Appendix 3. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in South Water-Tunnel boreholes (Ericsson-A, FranklinST-B, FranklinST-A, GrandST-B, PrinceST-A, BondST-A, 31B-1), Manhattan Island, N.Y., 2003-04. —Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
531.4	304	61	
533.3	292	61	
535.3	305	70	
537.5	307	72	
539.9	297	59	
541.5	305	65	
543.8	313	55	
545.7	305	60	
547.9	306	58	
550.5	313	65	
553.2	307	73	
555.5	328	58	
558.5	329	56	
559.8	322	66	
561.9	319	70	
564.2	327	74	
566.4	316	60	
567.9	326	72	
569.9	315	67	
572.2	317	71	
574.7	303	74	
576.9	304	63	
579.2	302	72	
581.2	308	47	
583.7	313	58	
585.5	306	52	
587.6	339	43	
590.1	323	46	
592.7	314	51	
594.5	309	53	
597.0	321	52	
599.5	326	52	
602.7	316	56	
605.1	308	63	
607.9	322	59	
610.2	307	62	
612.4	330	56	
614.9	325	66	
616.6	319	54	
619.7	332	57	
621.8	329	63	
624.3	319	51	
626.3	323	53	
628.4	337	45	
630.9	332	49	
632.9	319	60	
635.1	321	54	
637.3	320	54	
639.6	301	62	
641.6	319	60	
643.7	315	64	
645.7	316	56	
647.9	322	49	
650.1	316	53	
653.7	322	66	
655.6	317	67	
658.0	338	57	
660.1	334	52	
662.3	333	49	
BondST-A Fractures			
96.5	164	4	S
96.7	105	16	S
98.8	300	2	S
99.5	123	2	S
100.3	302	26	S
101.7	265	25	S
101.8	251	26	S
101.9	256	30	S
102.1	191	10	S
109.6	142	16	M
109.7	202	4	M
109.7	26	8	M
113.3	141	8	S
113.3	125	12	S

Appendix 3. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in South Water-Tunnel boreholes (Ericsson-A, FranklinST-B, FranklinST-A, GrandST-B, PrinceST-A, BondST-A, 31B-1), Manhattan Island, N.Y., 2003-04. —Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
115.5	135	26	S
118.0	110	18	S
125.2	139	45	S
126.4	305	7	S
126.5	67	75	S
127.3	96	35	S
128.3	293	50	M
133.9	252	76	S
139.0	125	52	S
139.2	298	36	S
140.8	124	16	S
143.7	154	14	S
146.4	142	28	S
146.8	144	21	S
151.6	98	20	S
157.8	75	23	S
161.7	303	48	M
161.9	69	22	M
162.0	173	6	M
162.0	267	51	M
162.9	286	48	S
189.3	112	28	S
190.4	130	18	S
191.1	137	12	S
194.9	335	20	S
199.8	281	62	L
199.9	279	63	M
201.6	254	32	S
203.3	265	51	M
211.4	97	16	S
217.1	114	10	S
219.5	103	31	S
221.9	82	25	S
222.1	298	71	S
224.0	75	34	S
226.2	279	70	S
226.7	24	62	S
226.8	272	62	S
234.7	117	27	S
242.6	125	14	S
242.8	115	14	S
244.2	115	14	S
244.3	147	14	S
250.8	21	64	S
254.0	75	30	S
255.8	219	3	S
255.8	293	5	S
257.9	355	56	S
258.3	347	41	S
258.3	7	54	S
258.7	355	52	S
258.9	9	54	S
259.0	22	68	S
260.9	164	15	S
261.6	279	64	S
261.8	294	62	S
261.9	290	59	S
262.1	296	59	M
263.9	287	56	S
264.8	6	53	S
265.0	14	55	S
265.5	19	62	S
265.9	13	61	S
274.1	24	56	S
278.1	119	19	S
278.1	123	27	S
278.5	322	48	S
281.3	15	47	S
283.4	108	53	S
284.2	41	56	S
284.4	26	48	S
284.5	24	46	S

Appendix 3. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in South Water-Tunnel boreholes (Ericsson-A, FranklinST-B, FranklinST-A, GrandST-B, PrinceST-A, BondST-A, 31B-1), Manhattan Island, N.Y., 2003-04. —Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
284.6	16	50	S
284.8	10	53	S
284.9	6	48	S
285.1	2	50	S
296.3	149	13	L
297.9	108	22	S
297.8	145	13	M
300.9	133	9	S
301.4	36	5	M
301.5	102	12	M
305.3	304	54	S
306.2	295	56	S
320.1	297	55	M
323.0	3	65	S
329.2	325	67	S
330.0	1	75	S
330.2	9	74	S
333.5	341	57	S
348.3	2	60	S
348.5	5	60	S
348.8	356	66	S
360.2	226	47	S
362.2	241	47	S
362.8	251	55	S
361.0	63	88	S
386.5	266	2	S
391.6	280	63	M
420.2	269	56	S
461.0	292	13	S
461.0	274	14	S
461.2	34	54	S
461.7	36	47	S
461.9	16	17	S
462.0	28	53	S
462.4	33	61	S
462.8	78	18	S
462.9	47	58	S
463.0	48	60	S
463.8	42	57	S
464.2	27	61	S
467.9	49	66	S
486.1	60	59	S
486.7	51	74	S
487.1	42	66	S
487.9	35	70	S
496.0	46	66	S
496.8	17	83	S
514.6	23	60	M
521.6	75	8	S
526.0	230	50	S
526.5	84	32	S
526.6	78	31	S
526.7	93	29	S
527.1	183	65	S
527.5	149	34	S
527.5	29	69	S
527.8	106	28	S
528.1	106	15	S
528.2	137	21	S
530.6	32	63	S
535.8	275	64	S
536.4	19	49	S
536.8	326	44	S
537.5	348	49	S
538.7	343	47	S
539.6	12	50	S
540.3	350	45	S
546.5	299	10	S
551.7	59	8	S
552.2	38	5	S
552.8	310	18	S
552.8	41	12	S

Appendix 3. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in South Water-Tunnel boreholes (Ericsson-A, FranklinST-B, FranklinST-A, GrandST-B, PrinceST-A, BondST-A, 31B-1), Manhattan Island, N.Y., 2003-04. —Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
553.1	37	11	S
557.3	27	27	S
559.3	8	65	S
562.2	63	50	S
562.9	90	15	S
567.2	107	6	S
567.3	127	4	S
571.3	34	80	S
572.4	278	62	S
576.1	221	75	S
576.1	72	26	S
576.2	288	55	M
588.4	89	10	S
588.5	85	19	S
592.1	92	32	S
595.2	46	3	S
595.3	54	7	S
596.3	196	8	S
599.9	350	69	S
BondST-A Foliation			
97.4	281	63	
100.7	284	60	
103.8	284	61	
106.9	281	61	
109.9	268	57	
113.6	305	50	
115.7	288	53	
119.1	275	52	
122.5	275	52	
125.6	278	53	
128.7	295	51	
131.5	276	51	
134.6	278	44	
137.0	296	35	
140.1	295	45	
142.5	296	65	
145.6	307	71	
148.1	313	67	
149.5	312	70	
151.1	338	64	
156.8	283	60	
160.8	298	63	
163.5	296	49	
166.6	294	55	
169.8	275	65	
172.1	276	69	
175.9	290	66	
178.8	291	58	
182.0	283	54	
185.9	283	56	
187.9	296	69	
191.5	286	38	
195.1	282	65	
198.1	293	72	
200.5	285	65	
204.1	302	61	
207.6	275	60	
210.8	270	55	
214.5	273	55	
216.9	265	61	
219.8	270	64	
223.4	289	78	
226.8	273	62	
230.0	283	68	
233.0	288	70	
235.7	297	67	
239.6	311	72	
242.8	286	68	
245.9	306	66	
248.8	282	63	
252.2	300	59	
254.5	289	62	
257.7	294	61	
261.1	287	56	

Appendix 3. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in South Water-Tunnel boreholes (Ericsson-A, FranklinST-B, FranklinST-A, GrandST-B, PrinceST-A, BondST-A, 31B-1), Manhattan Island, N.Y., 2003-04. —Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
264.2	283	57	
266.6	289	55	
269.9	285	51	
273.7	282	68	
276.3	287	58	
279.9	290	52	
283.0	287	60	
285.8	299	58	
289.1	291	57	
292.1	288	46	
295.6	288	50	
298.4	317	40	
302.2	307	60	
304.8	310	51	
308.1	295	54	
311.0	306	56	
314.0	318	56	
317.1	293	49	
320.7	307	68	
323.8	306	71	
326.5	310	75	
328.0	298	63	
329.2	306	74	
330.5	235	40	
337.0	229	47	
338.4	183	65	
340.4	166	76	
352.1	292	43	
353.2	280	29	
359.9	227	47	
363.2	260	55	
366.2	254	51	
369.9	260	43	
372.6	254	51	
376.3	260	50	
378.7	265	50	
380.9	283	60	
383.5	277	58	
386.9	274	62	
390.6	274	61	
392.9	288	63	
398.1	286	53	
401.8	260	62	
408.3	249	61	
412.5	253	67	
413.9	247	61	
417.8	263	56	
420.6	261	60	
424.2	262	59	
426.7	276	55	
430.0	275	59	
433.1	276	69	
436.5	264	60	
439.1	272	57	
443.1	280	61	
445.7	271	58	
449.3	272	60	
451.8	277	60	
454.7	259	53	
458.1	279	54	
461.8	275	63	
464.4	287	56	
471.5	287	51	
473.9	281	48	
477.2	276	51	
480.7	278	60	
483.9	280	57	
487.2	275	56	
490.6	275	39	
493.4	266	70	
495.8	264	61	
500.0	279	58	
502.4	275	60	
506.0	274	61	
509.0	280	58	
511.9	287	56	

Appendix 3. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in South Water-Tunnel boreholes (Ericsson-A, FranklinST-B, FranklinST-A, GrandST-B, PrinceST-A, BondST-A, 31B-1), Manhattan Island, N.Y., 2003-04. —Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
515.3	280	52	
518.1	274	36	
522.0	282	34	
525.1	283	57	
527.7	279	58	
530.8	275	61	
534.7	284	61	
537.3	283	60	
540.2	270	59	
543.3	280	61	
546.3	271	51	
549.7	281	57	
553.1	279	52	
556.2	276	64	
559.0	282	58	
562.7	272	65	
565.6	279	62	
568.5	277	61	
571.5	286	61	
574.7	286	55	
576.3	287	57	
578.2	275	64	
579.8	300	41	
581.1	275	57	
583.1	279	67	
584.5	285	61	
585.8	283	64	
587.6	283	61	
588.9	279	58	
590.8	282	60	
592.5	283	65	
593.9	283	67	
595.2	285	57	
596.9	282	73	
598.7	293	70	
600.9	286	63	

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
31B-1			
Fracture			
65.7	336	43	S
66.1	285	6	S
68.5	116	7	L
68.9	311	47	M
69.9	55	64	S
70.1	306	68	S
73.1	312	66	M
73.1	134	21	M
73.1	187	28	M
73.4	155	11	L
74.1	297	57	S
74.1	297	57	S
75.3	324	37	S
75.8	319	58	S
77.3	314	50	S
78.7	294	70	S
79.6	282	68	S
80.5	306	32	S
81.8	315	60	M
82.0	305	59	S
82.2	295	62	S
82.4	278	73	S
82.5	70	80	S
83.3	268	73	S
84.2	313	38	L
88.0	196	8	S
88.0	250	13	M
88.7	250	86	S
89.8	130	35	S
90.5	257	62	S
92.3	95	59	M
93.1	310	56	S
93.5	321	32	S
93.5	82	56	S
93.8	302	59	S
94.4	312	61	L

Appendix 3. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in South Water-Tunnel boreholes (Ericsson-A, FranklinST-B, FranklinST-A, GrandST-B, PrinceST-A, BondST-A, 31B-1), Manhattan Island, N.Y., 2003-04. —Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
100.7	305	9	S
102.0	295	17	S
105.5	283	62	M
107.3	271	76	S
108.3	289	75	S
108.5	322	39	S
108.8	315	57	S
109.2	283	66	S
109.5	285	64	S
109.7	310	65	S
109.9	280	80	S
114.0	79	56	S
114.3	269	76	S
114.5	329	26	S
116.1	322	48	S
119.6	331	18	S
125.1	109	11	S
127.0	334	5	S
127.4	10	18	S
132.0	70	87	S
133.7	286	77	S
133.9	70	73	S
134.4	278	83	S
140.6	75	82	S
140.7	148	19	S
143.9	193	28	S
143.9	183	28	S
144.7	82	30	S
144.9	303	31	S
145.7	79	79	S
146.7	301	62	S
150.7	26	89	S
153.5	175	22	S
153.6	125	25	S
153.7	159	17	S
155.3	316	56	M
158.2	103	23	S
158.6	107	36	M
160.3	343	13	S
161.7	76	16	S
161.7	97	18	S
163.4	155	8	S
166.7	55	70	S
167.4	318	59	S
168.5	310	62	M
170.0	221	3	M
170.1	262	13	M
171.5	208	69	S
172.4	276	4	S
172.7	293	9	M
173.3	89	81	M
174.0	314	62	M
175.1	286	13	M
178.2	30	2	M
178.2	197	9	M
190.9	152	20	S
191.7	237	14	M
196.9	133	21	M
205.0	129	21	L
213.5	103	2	L
217.1	121	48	S
218.5	105	23	L
221.2	119	19	L
222.2	319	59	M
225.7	359	25	S
225.7	95	22	M
243.6	304	12	S
243.8	237	14	M
243.9	279	9	M
244.9	145	7	S
247.2	179	4	S
247.5	305	70	S
250.6	307	82	L
251.3	139	9	S
251.5	130	20	S
256.6	134	50	S

Appendix 3. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in South Water-Tunnel boreholes (Ericsson-A, FranklinST-B, FranklinST-A, GrandST-B, PrinceST-A, BondST-A, 31B-1), Manhattan Island, N.Y., 2003-04. —Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
259.4	113	36	S
263.9	311	40	S
265.1	69	81	S
265.8	105	4	S
269.1	101	30	M
272.9	126	41	S
276.6	305	9	S
279.5	306	74	M
284.1	118	17	S
285.1	281	84	S
285.8	122	24	S
286.1	120	19	S
287.1	95	34	S
288.1	124	59	S
288.5	138	29	S
289.4	287	35	S
291.3	323	63	S
291.9	348	56	S
292.5	358	72	S
292.7	97	37	S
293.4	111	37	S
294.0	118	28	S
296.8	355	11	S
297.2	95	27	S
297.3	130	18	S
303.5	62	2	S
303.5	102	6	S
304.9	52	66	S
305.4	84	3	S
305.5	114	10	S
306.1	240	68	S
306.7	78	6	S
306.8	157	8	S
306.9	81	10	M
307.2	85	11	S
314.0	244	52	S
315.2	161	71	S
316.7	343	13	S
316.9	103	25	S
318.0	242	5	S
319.7	122	38	M
319.8	107	5	M
321.4	357	13	S
323.2	269	86	S
324.1	93	60	S
327.4	257	71	S
328.5	136	79	S
329.1	60	79	S
330.0	82	80	M
330.3	51	67	S
338.4	150	27	S
338.5	304	58	S
339.8	129	27	S
340.0	113	27	S
340.6	83	85	M
342.5	294	56	S
343.1	291	57	M
344.0	295	59	S
345.7	288	55	M
346.6	256	75	S
347.2	81	6	S
347.3	107	14	S
348.0	293	58	M
349.0	93	20	S
360.0	109	7	S
360.2	61	34	S
365.2	184	77	S
365.9	224	79	S
366.1	48	80	S
367.4	203	80	S
371.0	263	66	S
371.7	55	33	S
372.0	255	75	S
372.4	64	80	S
377.0	304	70	M
394.6	48	67	S

Appendix 3. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in South Water-Tunnel boreholes (Ericsson-A, FranklinST-B, FranklinST-A, GrandST-B, PrinceST-A, BondST-A, 31B-1), Manhattan Island, N.Y., 2003-04. —Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
396.9	267	39	S
406.5	282	58	M
409.9	324	21	S
420.7	288	66	S
423.7	77	14	S
423.7	70	15	M
424.8	262	63	S
430.9	267	36	S
435.3	335	4	S
437.4	248	43	S
438.0	263	51	S
445.1	10	10	S
481.8	87	9	S
482.1	273	14	M
487.6	256	29	S
487.8	240	51	S
491.9	247	45	S
492.5	259	50	S
494.5	267	53	S
497.5	271	47	S
497.6	270	55	S
499.4	52	84	S
500.7	104	42	S
503.1	263	46	
506.3	263	43	S
508.1	108	19	S
508.5	312	33	S
513.0	64	84	
516.3	259	56	M
517.3	241	75	S
517.5	351	89	S
518.6	21	73	S
521.7	279	41	S
522.8	279	48	S
533.1	49	88	S
537.7	275	55	S
537.8	279	61	S
548.1	281	63	S
552.4	276	63	M
555.2	115	12	M
555.3	104	15	S
555.4	172	53	S
557.1	119	34	M
563.9	268	62	S
579.0	71	76	M
581.3	123	33	S
582.5	133	43	S
584.7	82	82	M
595.7	103	51	M
597.5	133	53	M
598.0	101	41	M
598.0	122	45	M
598.4	120	38	S
598.4	97	54	S
598.9	126	43	S
600.2	264	65	S
600.4	266	57	S
600.6	252	58	S
600.9	122	35	M
601.1	261	63	S
601.7	166	52	S
601.7	127	25	M
602.3	256	18	M
606.2	115	23	M
606.5	147	31	M
606.6	138	27	M
606.7	120	27	M
613.1	264	78	S
614.1	288	59	S
616.3	278	89	S
617.4	289	88	S
618.2	14	61	S
624.1	279	61	S
624.9	276	64	S
639.9	277	61	S
641.3	283	49	S

Appendix 3. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in South Water-Tunnel boreholes (Ericsson-A, FranklinST-B, FranklinST-A, GrandST-B, PrinceST-A, BondST-A, 31B-1), Manhattan Island, N.Y., 2003-04. —Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
645.2	282	64	S
647.4	274	61	S
652.2	281	65	S
31B-1			
Foliation			
65.5	339	55	
66.9	317	51	
68.7	304	61	
72.3	317	70	
75.2	308	41	
77.4	311	49	
80.2	307	61	
83.2	308	62	
86.9	308	57	
89.2	303	64	
92.8	306	66	
95.8	315	71	
98.7	316	62	
101.6	319	61	
105.0	316	69	
108.8	309	60	
111.4	308	66	
114.3	321	65	
116.7	326	63	
120.7	328	67	
123.5	314	55	
125.5	313	69	
129.2	306	64	
131.0	324	59	
132.6	332	57	
136.4	322	70	
139.1	328	58	
142.2	318	73	
148.6	307	57	
151.9	324	50	
154.6	324	62	
158.9	321	58	
162.2	325	53	
165.2	324	62	
168.4	320	58	
171.5	322	63	
175.2	314	54	
178.7	307	55	
181.2	314	69	
184.9	314	63	
187.7	318	61	
190.8	308	66	
194.0	305	67	
196.5	314	70	
198.8	332	66	
201.6	308	72	
204.5	301	66	
210.7	317	64	
213.0	318	70	
217.1	319	63	
219.9	304	63	
223.5	312	66	
226.7	306	52	
230.0	326	50	
231.9	312	59	
233.9	306	63	
236.7	309	56	
240.1	302	57	
242.1	305	60	
245.2	306	66	
248.6	296	63	
251.4	306	70	
253.9	307	67	
255.9	287	67	
260.3	295	74	
262.4	304	75	
265.2	280	76	
268.4	292	76	
271.3	315	54	
272.6	305	54	

Appendix 3. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in South Water-Tunnel boreholes (Ericsson-A, FranklinST-B, FranklinST-A, GrandST-B, PrinceST-A, BondST-A, 31B-1), Manhattan Island, N.Y., 2003-04. —Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
276.6	306	55	
280.9	309	70	
282.7	315	66	
284.8	307	60	
287.6	295	64	
290.5	317	66	
292.0	328	66	
294.5	306	61	
296.2	304	62	
297.6	314	77	
298.9	304	65	
300.2	310	52	
302.0	296	63	
303.7	294	67	
306.1	294	62	
307.2	308	63	
309.0	293	69	
311.0	322	60	
313.0	293	77	
314.5	287	73	
316.6	306	66	
318.1	292	62	
320.0	305	59	
321.3	301	61	
322.8	291	67	
324.8	296	65	
326.2	304	63	
327.7	305	63	
329.1	285	67	
330.3	299	69	
332.3	292	64	
333.6	295	62	
335.0	298	65	
337.2	292	61	
338.8	304	60	
340.1	293	56	
341.8	297	59	
343.5	294	58	
344.9	296	52	
346.1	292	59	
347.7	303	56	
349.3	306	53	
350.5	302	52	
352.4	289	61	
354.2	307	75	
356.2	305	64	
358.0	304	52	
360.5	321	50	
361.5	295	55	
363.1	293	58	
368.2	301	48	
370.0	289	55	
372.3	298	48	
377.0	291	68	
379.7	295	68	
381.6	310	53	
383.2	283	58	
384.6	284	48	
386.1	289	52	
387.7	291	55	
389.2	286	55	
390.8	287	57	
392.4	280	61	
394.2	277	54	
395.6	296	58	
396.8	285	55	
398.3	284	58	
399.8	280	59	
401.4	281	66	
404.7	280	63	
406.0	281	51	
407.5	293	62	
409.4	286	43	
411.1	296	64	
412.5	282	66	
413.7	291	55	

Appendix 3. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in South Water-Tunnel boreholes (Ericsson-A, FranklinST-B, FranklinST-A, GrandST-B, PrinceST-A, BondST-A, 31B-1), Manhattan Island, N.Y., 2003-04. —Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
415.3	289	66	
417.1	272	60	
418.6	274	63	
420.0	285	68	
421.7	281	59	
423.2	269	60	
424.3	269	59	
426.0	258	60	
430.8	268	50	
432.3	259	48	
433.5	237	46	
434.9	227	38	
437.0	252	49	
438.2	241	40	
440.0	224	47	
441.9	240	61	
443.4	221	53	
445.0	213	53	
446.9	233	73	
448.8	204	68	
450.4	228	52	
453.4	223	58	
454.8	229	60	
457.3	215	67	
457.9	204	55	
459.7	205	52	
461.4	215	58	
463.7	189	61	
466.2	196	53	
468.3	193	58	
469.5	192	49	
472.1	248	70	
473.8	228	52	
474.9	186	50	
477.0	197	51	
478.1	202	47	
479.6	217	59	
481.0	231	45	
482.5	257	50	
483.8	262	53	
485.5	261	49	
486.7	261	50	
488.2	257	54	
490.0	257	51	
491.4	250	47	
493.1	265	54	
494.4	267	50	
495.9	261	55	
497.4	272	51	
498.9	274	57	
500.2	273	54	
502.1	268	45	
504.0	267	54	
505.4	275	49	
506.9	276	45	
509.4	247	50	
510.7	277	60	
512.2	259	46	
513.4	263	55	
515.0	267	51	
516.8	265	57	
519.5	290	82	
520.4	278	55	
522.2	260	51	
523.8	267	52	
525.4	262	50	
526.6	271	49	
528.2	271	53	
529.7	270	50	
531.2	268	54	
532.8	276	59	
533.9	275	55	
537.0	278	60	
538.2	265	53	
539.9	270	52	
541.2	281	54	

Appendix 3. Depth, dip azimuth, and dip angle of fractures and foliation observed by optical televiewer in South Water-Tunnel boreholes (Ericsson-A, FranklinST-B, FranklinST-A, GrandST-B, PrinceST-A, BondST-A, 31B-1), Manhattan Island, N.Y., 2003-04. —Continued

Depth, in feet	Dip azimuth, in degrees	Dip angle, in degrees	Fracture size
544.0	280	64	
545.7	282	67	
547.0	275	64	
549.5	280	54	
551.0	280	58	
552.6	276	58	
554.1	273	62	
555.4	275	61	
556.8	269	55	
558.6	272	53	
560.0	269	54	
562.3	276	56	
564.4	262	58	
566.5	263	59	
568.8	275	59	
570.5	276	55	
572.3	271	64	
573.6	283	62	
576.5	287	62	
577.9	283	63	
580.8	280	64	
582.6	277	63	
584.2	285	68	
586.5	285	68	
588.7	276	66	
591.3	270	60	
592.8	271	54	
594.7	265	59	
596.1	274	55	
597.5	271	55	
598.8	280	60	
600.0	263	57	
602.2	267	64	
604.6	270	70	
606.5	257	58	
608.1	260	59	
609.4	265	59	
611.0	272	66	
612.5	259	70	
614.1	273	59	
615.5	264	59	
617.1	272	54	
618.4	270	66	
619.8	266	64	
621.4	263	67	
622.8	266	60	
624.1	276	62	
625.9	269	60	
627.8	274	51	
629.6	278	63	
630.7	274	57	
632.2	271	60	
634.1	279	48	
635.2	275	63	
637.1	273	63	
638.9	277	61	
640.1	269	53	
641.3	286	46	
643.2	276	64	
645.2	283	60	
646.7	275	61	
648.5	272	64	
650.2	269	62	
651.6	284	70	
653.0	278	59	
653.7	278	63	