ANNUAL PROJECT SUMMARY REPORT
Project period January 1, 2001 – December 31, 2001

TITLE: THE QUATERNARY GEOLOGIC FRAMEWORK FOR THE CITY OF SEATTLE AND THE SEATTLE-TACOMA URBAN CORRIDOR

Cooperative Agreement Number: 01HQAG0017

Investigators: Derek B. Booth, Kathy G. Troost, Scott A. Shimel, Michael A. O'Neal, University of Washington, Department of Earth and Space Sciences, Box 351310, Seattle, WA 98195-1310

Telephone: (206) 543-7923, FAX: (20) 685-3836 dbooth@u.washington.edu
http://www.geology.washington.edu/sea-geo

NEHRP Element: I, Pacific Northwest region **Keywords**: Geologic Mapping, Surficial Deposits, Age Dating, Tectonic Structures

INVESTIGATIONS UNDERTAKEN

Our investigations during this third year of an anticipated six-year project represent the continuation and development of a wide range of tasks that focus on the Quaternary framework of the Seattle area. This emphasis is critical for any geologic or seismic-hazard studies because most of the central Puget Lowland has a recent sedimentary cover one hundred to over one thousand meters thick.

We recognize five major components to develop this framework and to disseminate the resulting information:

1. Develop the regional stratigraphy and chronology for the central Puget Lowland;
2. Create a subsurface geologic database for the City;
3. Prepare new surficial geologic maps of the City;
4. Develop the geologic model (3-D map and database) of the City; and
5. Provide education and technical outreach.

COMPONENT 1—REGIONAL STRATIGRAPHY AND CHRONOLOGY

We have produced a chronological and lithologic composite section of glacial and nonglacial deposits in the central Puget Lowland that is being used to evaluate the distribution, correlation, and deformation of individual geologic units across the region. This component was not included in this grant, but we acknowledge it here because of its importance to the present proposal. No geologic study of a limited area, such as the City, can possibly succeed without also developing an adequate regional context.

COMPONENT 2—SUBSURFACE GEOLOGIC DATABASE FOR THE CITY OF SEATTLE

We are building a comprehensive subsurface geologic database for the City. The database had been fully designed and its population is well over half completed (Figure 1). At present, nearly 4,000 separate geotechnical reports within the City itself, which include over 17,580 individual exploration sites, have been indexed in an MS Access database and displayed on an ArcView GIS platform.

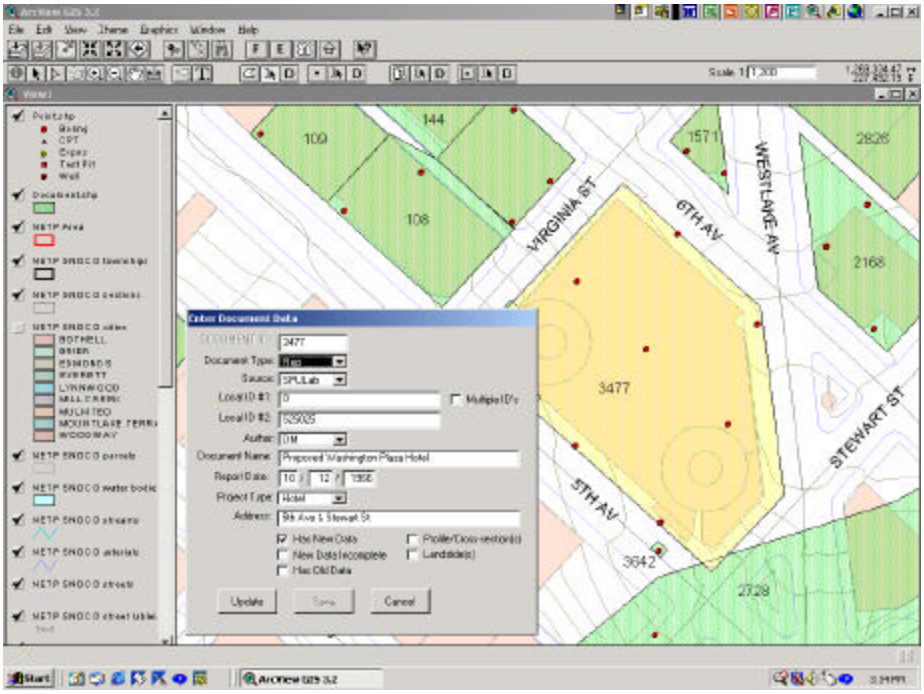

Figure 1. Data-entry screen for recording geological reports (termed **Documents**). Each point represents an individual exploration site, which have separate screens for recording information on the geologic layers.

COMPONENT 3—SURFICIAL GEOLOGIC MAPS OF THE CITY OF SEATTLE

We are preparing new geologic map coverage for the City, based on a combination of field investigations (coastal and river-valley bluffs, excavations, landslide scars) and near-surface borehole data. We have targeted first the areas with some of the greatest interest for seismic-hazard evaluation (*e.g.*, the trace of the Seattle fault, coastal landsliding, liquefaction-prone areas) and most readily available data.

COMPONENT 4—THREE-DIMENSIONAL GEOLOGIC MODEL OF THE CITY OF SEATTLE

This component of the project represents the integration of all previous stages. The database will be graphically supported; geologic materials will be located in space and characterized in terms of both their material properties and their stratigraphic assignment. Each stratigraphic unit will have a lateral and vertical definition. This component has been delayed by budgetary reductions in every project year to date, but we continue to explore existing and are developing new methods of cataloging and displaying subsurface geologic data.

COMPONENT 5—EDUCATION AND TECHNICAL OUTREACH

This is an ongoing effort, anticipated to continue throughout the duration of the project. Activities are listed in the next section of this report.

RESULTS

COMPONENT 1—REGIONAL STRATIGRAPHY AND CHRONOLOGY

Over the last several years, ancillary support from NCGMP (USGS) has enabled us to complete eight 7.5-minute maps at 1:24,000 in the Seattle-Tacoma area and to initiate work on two others. Although not part of our NEHRP-funded project, this effort is critical to the geologic mapping and hazard evaluation of the City of Seattle, and we intend to continue this effort. We anticipate fully remapped coverage over the next several years of the Seattle-Tacoma urban corridor and adjacent developing areas to the west.

COMPONENT 2—SUBSURFACE GEOLOGIC DATABASE FOR THE CITY OF SEATTLE

We are rapidly populating a database of existing subsurface geologic and geotechnical data that covers not only the City of Seattle but also surrounding areas to the north and east, thanks to financial support from both this agreement and a newly executed, three-year agreement with King County. This database accommodates both spatial and nonspatial data by following a GIS-based approach. The design facilitates spatial analyses, visualization, and other representations of the data, and we have developed a tool for querying individual explorations and for making cross sections directly from the database that can be displayed in ArcView (see Component 4). The basic architecture of the database is diagrammed below (Figure 2).

Our progress through 2001 in populating the main tables of the database is as follows:

	Total area—to date (10/01)	Seattle only—to date (10/01)	Total area — anticipated
DOCUMENTS	4686	3927	≈ 12,000
POINTS	21,618	17,580	≈ 75,000
LAYERS	50,958	39,473	≈ 200,000

COMPONENT 3—SURFICIAL GEOLOGIC MAPS OF THE CITY OF SEATTLE

In this third year of the project, our primary emphasis has been on the acquisition of data for preparing a geologic map of the Seattle NW quadrangle, which is in the final stages of preparation and will be submitted for USGS publications review by the end of 2001. In the summer and fall of 2001, additional financial support from King County has expanded our scope (and thus our map coverage) to the north of the City as well. In the Seattle NW quad, wave erosion and ubiquitous sand-over-silt stratigraphy have resulted in steep landslide-prone bluffs along the entire coastline. Some of the most destructive landslides, and some of the most intensive modern investigations of slope instability, have taken place in this map region. Our improved geologic data (Figure 3) is being supplied, as it becomes available, to researchers and City personnel alike to improve understanding of the geologic controls on these processes.

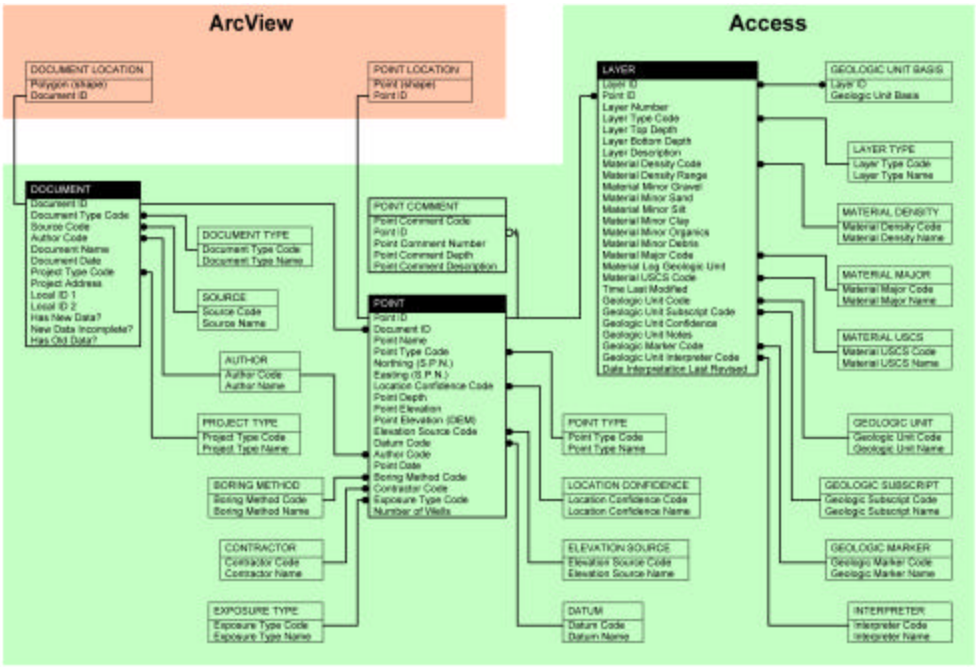

Figure 2. Database architecture. The primary elements are **DOCUMENTS** (the reports that contain the geologic and/or geotechnical information, **POINTS** (the individual exploration sites contained within a document), and **LAYERS** (the geologic strata described in an exploration).

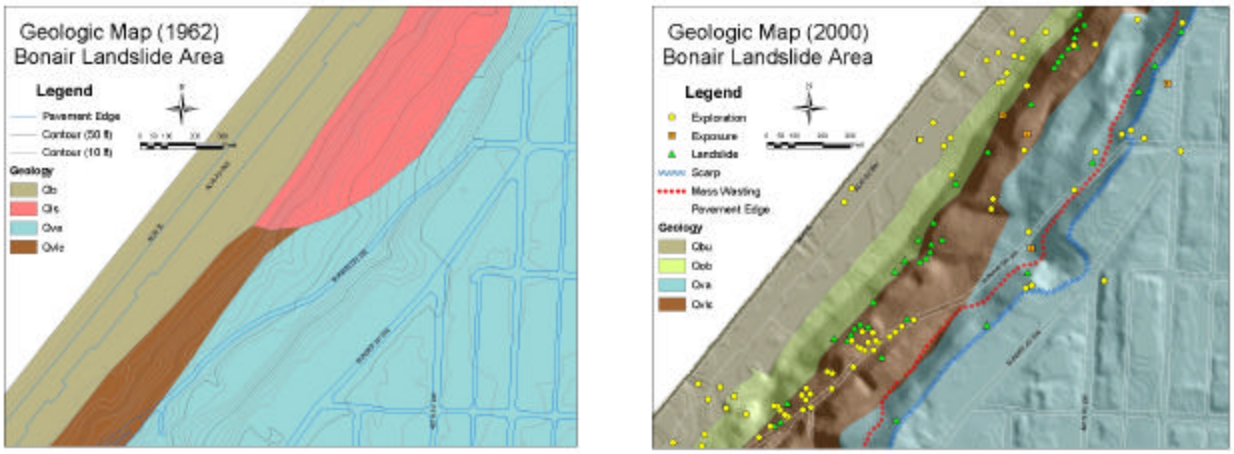

Figure 3. Example of preexisting (left) and new (right) geologic mapping. This example is from the Seattle SW quadrangle (in review). Improvements in mapping include (1) greatly increased range and quantity of data sources, particularly geotechnical explorations (yellow circles) and new field exposures (orange squares); (2) recognition of greatly expanded landslide areas (outlined by red dots) that correspond well to areas of historic landsliding (green triangles); (3) more precise delineation of geologic unit boundaries; (4) inclusion of previously unrecognized geologic units ("Qob" on the lower map); (5) more precise and intuitive rendering of topography; and (6) full digital record of all data sources, mapped contacts, and geologic interpretations.

COMPONENT 4—THREE-DIMENSIONAL GEOLOGIC MODEL OF THE CITY OF SEATTLE

This element of the project integrates each of the previous stages. The raw subsurface data is interpreted to make stratigraphic assignments, with not only the assignments themselves but also the date of any changes and the initials of the interpreter recorded in the database (Figure 4). This is an iterative process dependent upon the graphic display from the database (cross sections and surfaces), geologic mapping, and development of the stratigraphic sequence. This interpretive data set is being used to construct the conceptual 3-D model of subsurface geology in the Seattle area, which will be the focus of development under the second year of this Cooperative Agreement (2002).

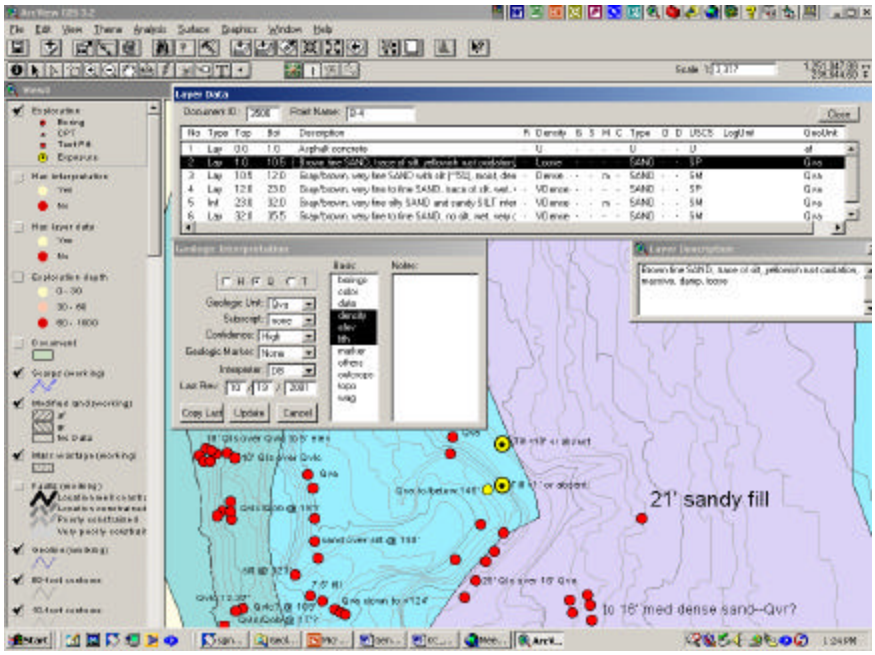

Figure 4. Screen shot of the interface for database query and interpretation. Red dots are exploration sites contained in the database. The yellow dot in the lower center part of the screen is currently selected and has its boring log displayed across the top of the screen in the "Layer Data" window. The geologist enters geologic interpretations for each layer in the left-hand window; notes also can be annotated on the screen for quick reference. The geologic contacts shown on the screen are from Waldron et al. (1962) and are being revised as part of this process.

COMPONENT 5—EDUCATION AND TECHNICAL OUTREACH

Specific activities for this component through the end of 2001 are summarized in the following table:

ACTIVITY	DATE	AUDIENCE
SHORT COURSES—2001		
Puget Lowland Geologic Framework (1 day)	Oct 2001	King County and its consultants
FIELD TRIPS—2001		
Geology of Seattle	Oct 2001	Department of Earth and Space Sciences, UW alumni

TECHNICAL MEETINGS—2001		
Project Updates	Quarterly, plus more frequent as needed	City of Seattle departments; King County
Technical Advisory Group Meetings	Quarterly	TAG Members
CONFERENCES—2001		
Nisqually Earthquake symposium Seismological Society of America's Annual Meeting	April 2001	SSA attendees and general public
GSA North-Central Section Meeting Special Workshop on 3-D Mapping and Groundwater Modeling	April 2001	GSA Attendees
National Association of Geology Teachers, Western Division Meeting	June 2001	NAGT attendees and professionals
Convened symposium on the geology of glaciated regions at Geological Society of America annual meeting	November 2001	GSA attendees
PUBLIC MEETINGS AND SELECTED INVITED TALKS—2001		
Project Impact Disaster Saturdays: Display of "The Geology of Seattle" complete w/geologic samples and stratigraphic models	All, 1999, 2000, and 2001	Public
"Mapping the Geology of Seattle"	February 2001	Assoc. of Women in Science; Assoc. for Women Geoscientists
NOAA Tsunami Workshop	February 2001	Emergency. Managers
"Ground Failures from the Nisqually Earthquake" or "Geology of Seattle"	Multiple presentations	CPARM; emerg. managers; Univ. Puget Sound, K-12 classes

Local Agency and Public Outreach. Because of the potential utility of the geologic-map products, and because of the efforts being invested by this project on behalf of geologic studies by *all* scientists throughout the region, we have received unprecedented support from local governments. The value of these efforts has been directly articulated (see *Appendix)* and is more substantively demonstrated by the successful leveraging of USGS NEHRP funds (see *Financial Notes* section, below). A number of more popular articles have also appeared about this project in the past year, including "What Lies Beneath" (*Columns*, the UW Alumni Magazine for June 2001, article web site http://www.washington.edu/alumni/columns/june01/earthquake1.html), "A Geologist's Field Day—or Fortnight" (*A&S Perspectives*, the UW College of Arts and Sciences Magazine for summer 2001), and "The Toppled Chimney Mystery: Is It the Fault's Fault?" (*New York Times*, Science Tuesday section, March 27, 2001). Several national radio broadcasts interviews (National Public Radio) and local television news segments have also featured our work.

The geologic and engineering consultants of the region recognize our leadership in defining the stratigraphy, lithology, and geologic history of this area. They frequently solicit our opinions regarding various specific sites, and they utilize our database and our mapping efforts in their own investigations, which we provide in exchange for additional data.

REPORTS PUBLISHED

2001

Manuscripts:

Hagstrum, J. T., Booth, D. B., Troost, K. G., and R. J. Blakely, in press, Magnetostratigraphy, paleomagnetic correlation, and deformation of Pleistocene deposits in the south-central Puget Lowland, Washington: submitted to Journal of Geophysical Research.

Borden, R.K., and Troost, K.G., 2001, Late Pleistocene Stratigraphy in the south-central Puget Lowland, West-Central Pierce County, Washington: Olympia, Washington State Department of Natural Resources, Report of Investigations 33, 33 p .

Booth, D. B., R. A. Haugerud, and Troost, K. G., in press, Geology, Watersheds, and Puget Lowland Rivers: chapter in D. Montgomery, S. Bolton, and Booth, D. B., eds., Restoration of Puget Sound Rivers: Society for Ecological Restoration.

Booth, D. B., Troost, K. G., and Hagstrum, J. T., in review, Deformation of Quaternary strata and its relationship to crustal folds and faults, central Puget Lowland, Washington: submitted to Geology.

Abstracts:

Barnhardt, W. A., Kayen, R. E., Palmer, S., Troost, K. G., and Sherrod, B. S., 2001, Ground deformation at the Port of Seattle during the Nisqually earthquake: Seismological Research Letters, v. 72, no. 3, p. 391.

Booth, D. B., R. E. Wells, and eleven others, 2001, Chimney damage patterns in the greater Seattle area from the Nisqually Earthquake of February 28, 2001: Seismological Research Letters, v. 72, no. 3, p. 395.

Haugerud, R.A., Troost, K.G., Harp, E.L., Wegmann, K.W., Sherrod, B.L., Pratt, T.L., and Kramer, S.L., 2001, Regional map view of ground deformation associated with the Nisqually earthquake, 28 February 2001, Seismological Research Letters, v. 72, no. 3, p. 393.

Sherrod, B.L., Haeussler, P.J., Wells, R., Troost, K., and Haugerud, R., , 2001, Surface rupture in the Seattle fault zone near Bellevue, Washington, Seismological Research Letters, v. 72, no. 2, p. 253.

Shimel, S. A., Blouke, K., O'Neal, M. A., Troost, K. G., and Booth, D. B., 2001, Spatial database for enhanced geologic mapping in Seattle, WA: Geological Society of America, Annual Meeting, Boston, MA, November 4-7, 2001.

Troost, K.G., Booth, D.B., Shimel, S.A., Haugerud, R.A., Kramer, S.L., Kayen, R.E., and Barnhardt, W.A., 2001, Geologic controls on ground failures in Seattle and vicinity during the 2001 Nisqually earthquake, Seismological Research Letters, v. 72, no. 3, p. 393.

Troost, K.G., Haugerud, R.A., Walsh, T.J., Harp, E.L., Booth, D.B., Steele, W.P., Wegmann, K.W., Pratt, T.L., Sherrod, B.S., and Kramer, S.L., 2001, Ground failures produced by the Nisqually earthquake, Seismological Research Letters, v. 72, no. 3, p. 396.

Geologic Maps:

Booth, D. B. and H. H. Waldron, in press, Geologic map of the Des Moines 7.5-minute quadrangle, Washington: U.S. Geological Survey Miscellaneous Field Investigation, scale 1:24,000.

Troost, K. G., Booth, D. B., and S. Shimel, in review, Geologic map of the Seattle SW quadrangle: U.S. Geological Survey Miscellaneous Investigations Map, scale 1:12,000.

Booth, D. B., H. H. Waldron, and Troost, K. G., in review, Geologic map of the Poverty Bay 7.5-minute quadrangle, Washington: U.S. Geological Survey Miscellaneous Field Investigation, scale 1:24,000.

Booth, D. B., R. A. Haugerud, and J. Sacket, in review, Geologic map of King County, Washington: U.S. Geological Survey Open-File Report, scale 1:100,000.

Troost, K. G. and Booth, D. B., in review, Geologic map of the Steilacoom 7.5-minute quadrangle, Washington: U.S. Geological Survey Open-File Report, scale 1:24,000.

Troost, K. G., Booth, D. B., and R. Borden, in review, Geologic map of the Tacoma North 7.5-minute quadrangle, Washington: U.S. Geological Survey Open-File Report, scale 1:24,000.

Troost, K. G., in review, Geologic map of the Tacoma South 7.5-minute quadrangle, Washington: U.S. Geological Survey Open-File Report, scale 1:24,000.

Troost, K. G., in review, Geologic map of the Puyallup 7.5-minute quadrangle, Washington: U.S. Geological Survey Open-File Report, scale 1:24,000.

NON-TECHNICAL SUMMARY
Project period January 1, 2001 – December 31, 2001

TITLE: THE QUATERNARY GEOLOGIC FRAMEWORK FOR THE CITY OF SEATTLE AND THE SEATTLE-TACOMA URBAN CORRIDOR

Cooperative Agreement Number: 01HQAG0017

Investigators: Derek B. Booth, Kathy G. Troost, Scott A. Shimel, Michael A. O'Neal, University of Washington, Department of Earth and Space Sciences, Box 351310, Seattle, WA 98195-1310

Telephone: (206) 543-7923, FAX: (20) 685-3836 dbooth@u.washington.edu
http://www.geology.washington.edu/sea-geo

NEHRP Element: I, Pacific Northwest region **Keywords**: Geologic Mapping, Surficial Deposits, Age Dating, Tectonic Structures

Many engineering applications in urban and urbanizing areas depend on the spatial distribution of geologic materials and the sequence and history of their deposition. This project is mid-way through developing a detailed understanding and representation of the three-dimensional distribution of geologic materials beneath Seattle. To date, we have acquired and organized nearly 40,000 items of geologic information, representing a substantial start on of the vast amount of existing data; in combination with our ongoing field investigations, we have begun preparing and publishing the geologic maps that will display this information for scientists, agencies, and the public.