Integrated Decision Support for Wellhead Protection

Teresa M. Adams, Assistant Professor
Peter J. Bosscher, Associate Professor and
Erhard F. Joeres, Professor
Department of Civil and Environmental Engineering
University of Wisconsin-Madison

Graduate Assistants:
Chen-hua Chung
Kye Kim
Nirav Majmudar, and
Agatha Tang

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Executive Summary

This report describes a Geographic Information System application named WELLHEAD. It integrates geographic data on highways, townships and hydrography on flowing and standing water and wetlands with geographic subsurface information from drilling logs and sampling of strata. To illustrate the application and utility of WELLHEAD, data from Dane County, Wisconsin has been used to allow hydrogeologists, geologists, geotechnical engineers and water chemists pursuing pollution control strategies to retrieve and view subsurface data in graphical form. Interactive options allow the users to display information in different perspectives.

The report is arranged in the following order. Chapter 1 gives the background that describes the need and benefits of WELLHEAD. It also gives an overview of its major program components. Chapter 2 describes the WELLHEAD data sets comprised of highways, township boundaries, hydrography and lithology. Chapter 3 details menu systems, interfaces, and database design. It also describes the organization of the subsurface data. Chapter 4 guides the user through spatial queries to select boring logs. The graphical information system for subsurface characterization is covered in Chapter 5. It guides the user to the generation of one, two and three-dimensional plots of the geographically based subsurface information in the database.

Chapters 2 through 5 contain the necessary detailed information to guide users through applications. This report comprises the first phase of a multi-phase research effort. Future activities, development objectives and refinements are identified in the appropriate sections.

Contents

Chapter 1

Background and Overview of WELLHEAD

Critical decisions that involve hazard mitigation, or the protection, conservation, and use of natural resources are frequently based on results of engineering or geological analysis of subsurface hydrogeological and geotechnical data. Raw data comes from a variety of sources including well cores or boring logs. These are costly to obtain. Boring log data obtained for one investigation can be reused for subsequent unrelated preliminary or final investigations, provided it is readily accessible to a wide range of practitioners. GIS technology provides a mechanism for collecting, maintaining, and making subsurface data available on demand for groundwater protection, resource studies, and engineering design.

This report describes a GIS application called WELLHEAD that enables hydrogeologists, geologists, geotechnical engineers, and water chemists to view and retrieve subsurface data interactively and graphically. Aside from serving as a composite data source, the system includes a number of utilities such as interactive screen forms for entering log data, analytical tools for data evaluation and display, and data format exchange programs for data conversion and compatibility among users and data sources. The subsurface modeling approach combines surface maps with fence diagrams. Alternative approaches such as geometric solids modeling or topological volume modeling (Youngmann 1989; Carlson 1987) will be implemented as the WELLHEAD system evolves. Future efforts will enable users to interactively to analyze subsurface conditions for tasks such as ground water contamination studies, landfill siting and others.

1.1 The WELLHEAD System

An overview of the WELLHEAD system is shown in Figure 1.1. The system comprises map data coverages of Dane County, Wisconsin obtained from three sources. A digital dataset of the state trunk highway system in Dane County was obtained from the Wisconsin Department of Transportation (Wis. DOT). The Public Land Survey System (PLSS) dataset showing townships in Dane County was obtained from the Wisconsin Geological and Natural History Survey (WGNHS). A hydrography dataset consisting of all flowing water, standing water, and wetlands was obtained from the Department of Natural Resources (DNR). All of the map datasets were made available through the Land Information and Computer Graphics Facility (LICGF) at the University of Wisconsin-Madison.

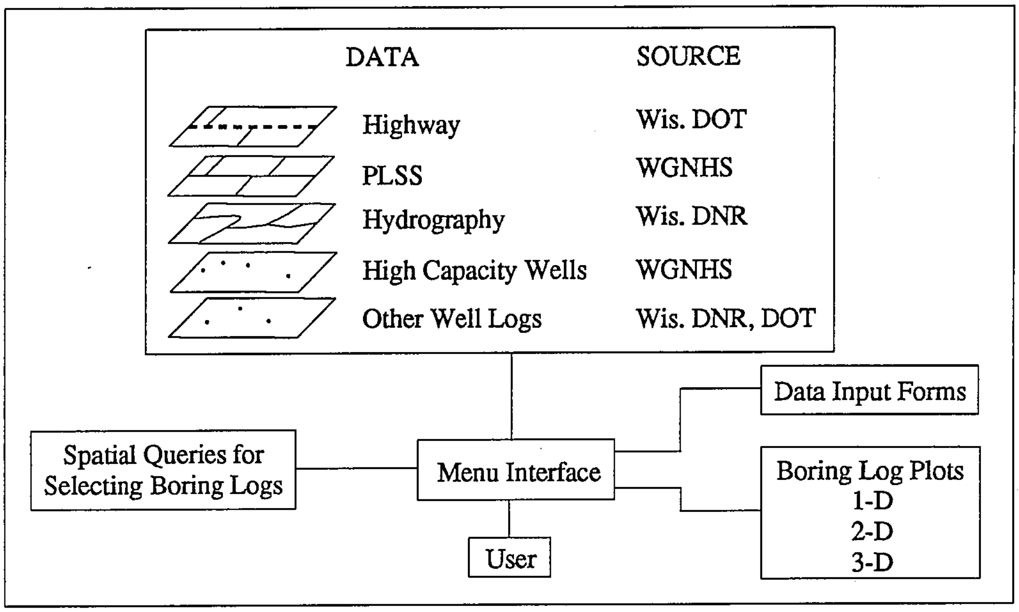


Figure 1.1: Architecture of the WELLHEAD System

The WELLHEAD system stores and manages log data collected from multiple sources. The main source of data in the current system is the WGNHS Subsurface Lab Data Base which contains a subset of the Groundwater Site Inventory (GWSI) data compiled in the 1970's by the United States Geological Survey (USGS) and the WGNHS. The database is statewide and contains logs from drilling and sampling of strata during installation of high capacity water wells. Other potential sources of log data are the Wisconsin DNR and Wisconsin DOT; however, data from these sources have not been included in the current system. Because the source agencies have different perspectives in their data collection and interpretation, regional and local, the WELLHEAD system demonstrates the usefulness of a subsurface GIS to both regional problems, such as groundwater resource management, and local problems, such as siting of a landfill.

The current version of WELLHEAD is used to store and maintain log data and to allow users to interactively generate boring logs, profiles, and 3-D fence diagrams such as shown in Figure 5.3 from a set of one or more borings selected from a map. The log data can be further analyzed to determine the location of lenses and layers of soil that are deposited below the surface. Thus a set of soil segments can be used to approximate the location of soil deposits. Efforts are underway to include into the system capabilities for building topological or solid models of subsurface strata based on output from 3-D fence diagrams.

Chapter 2

WELLHEAD Data Sets

2.1 Lineage of Datasets

As indicated above the application uses four data layers in vector format (Table 2.1). They are highways, township boundaries (PLSS), hydrography, and wells. The datasets of highways, township boundaries, and hydrography originated from the USGS in Digital Line Graph (DLG) format, and were transformed into ARC/INFO readable format. As pointed out in chapter 1, digital dataset of the state trunk highway system in Dane County was obtained from the Wisconsin Department of Transportation (Wis. DOT). The Public Land Survey System (PLSS) dataset showing townships in Dane County was obtained from the Wisconsin Geological and Natural History Survey (WGNHS).

Table 2.1: Datasets for WELLHEAD

Type	Source	Format	Scale
Highways	USGS/Wis. DOT	Vector	1:100,000
Township (PLSS)	USGS/WGNHS	Vector	1:24,000
Hydrography	USGS/Wis. DNR	Vector	1:100,000
Core Borings	USGS, WGNHS	Vector	1:24,000

A hydrography dataset consisting of all flowing water, standing water, and wetlands was obtained from the Wisconsin Department of Natural Resources (Wis. DNR). The original hydrography data layer was a mosaic of the U.S. Geological Survey 1:100,000 topographical quadrangle sheets, which also contains the quadrangle boundaries. The area covered in the hydrography dataset is larger than Dane County. Because the scope of the WELLHEAD project is Dane County, the dataset was edited to remove the quadrangle boundaries, and to clip the area outside of Dane County from the coverage.

In order to plot the features in the WELLHEAD system, the three data layers, highways, townships and hydrography, were converted from ARC/INFO format to ASCII format. The ASCII data file contains line or point ID's, and X, and Y coordinates. The Dane County UTM (Universal Transverse Mercator) ground coordinates system is used to maintain a common map projection for all data layers. Thus coordinate transformation from Wisconsin Transverse Mercator (WTM) to Dane County UTM is required for the highways, township boundaries, and the hydrography data layers. The specifications of Dane County UTM and the standard UTM differ by X and Y offsets of 200,000 and 4,700,000 meters, respectively (Table 2.2)(Wisconsin State Agencies 1990; Synder 1987). The X and Y shifts allows the entire county to be represented in at most 6 digits in the Easting, and 5 digits in the Northing at one meter resolution. Thus, use of the Dane County UTM system reduces coordinate storage without sacrificing accuracy.

Table 2.2: Specifications of Dane County UTM (Zone 16)

Projection	Transverse Mercator, 6 degree longitude zones
Spheroid	Clarke 1866 in North America
Longitude of Central Meridian	-87 00 00
Latitude of Origin	0 degree (the Equator)
Scale Factor at the Central Meridian	0.9996
Unit	Meter
False Northing	0 meters
False Easting	500,000 meters
X shift	-200,000 meters
Y shift	-4,700,000 meters

Boring log data, the fourth and the major data layer, was collected from the WGNHS Subsurface Lab Data Base (WGNHS 1990). The boring log dataset contains a subset of the Groundwater Site Inventory (GWSI) data compiled in the 1970's by the United States Geological Survey (USGS) and the WGNHS. The dataset contains distributions of logs from drilling and sampling of strata during installation of high capacity water wells. The well log dataset contains surface location of each well by several methods including naming of the 7.5 minute topographic map that contains the site of the well, the use of the Public Land Survey System (PLSS), and the USGS identification number based on latitude and longitude that was assigned to each record in GWSI. Among the three, only the description in PLSS is the most complete for the whole dataset. Thus, the PLSS coordinates were converted into Dane County UTM coordinates for plotting the location of the wells on a map. A PLSS master file containing the coordinates of section corners in Dane County UTM is referenced to compute the location of each well. The master file covers Dane County and was prepared at a scale of 1:24,000. A 'C' language program with embedded SQL queries was prepared for the computation.

2.2 Database Manipulation and Schemas

The well log dataset of the WELLHEAD system is referred to as the database *WGNHS*. The *WGNHS* database is organized into four tables: *location*, *litholgy*, *formatns*, and *wellownr*. The schemas and relations of the four tables are described in Table 2.3 and 2.4. *Wellid* is the key for each table. The *location* section of Table 2.3 contains the legal location of each well and other general well data such as elevation, depth, sample numbers, and specific capacity. The *litholgy* section of Table 2.3 has detailed description of rock type, color, grain, and sample depth. The *formatns* section of Table 2.4 contains the formation code and depth of each formation in a well. The well name, owner and owner address of each well are stored in the *wellownr* section of Table 2.4.

An additional table named plss.sql was created for accessing the *dmaster.ctl*, the UTM Section Corners Control file. The *dmaster.ctl* contains the Dane County UTM X- and Y-coordinates of each section corner. The table is used for converting PLSS coordinates of each well's location to Dane County UTM coordinates.

2.3 Conversion from PLSS to Dane County UTM

The PLSS is used to describe the land in squares by Township, Range and Section (Ziegler 1981). In Wisconsin, there are 53 bands of Township running east and west in a northward direction from the southern border of the state. The Ranges run north and south from the Principal Meridian, that is a vertical line starts at the junction of the counties of Grant and Lafayette and extends north going through Outer Island of the Apostle Islands in Lake Superior. It is numbered to 20 West in the Indianhead country of Polk and Burnett Counties and 30 East on the eastern half of Washington Island in Lake Michigan. For each square, the area is about 6 square miles. The area is further subdivided into 36 sections, 640 acres each (in the state of Wisconsin, not all sections equal 640 acres). The section numbering sequence is shown in Figure 2.1. To identify an area in a finer detail, a quarter of a quarter section can be used. For example as shown in Figure 2.2, NWNE of Section 11, T7N, R6E means the north-west quarter of the north-east quarter of Section 11 in Township 7, Range number 6 East. By default, all Townships in Wisconsin are on the north because the numbering starts from the southern border of the state.

Since the PLSS identifies a location in terms of an area, rather than a point in UTM, conversion from PLSS to UTM requires prior knowledge of the UTM coordinates of the four corners of the PLSS section square. UTM coordinates reference data for each section corner in Dane County are available in the *dmaster.ctl* file. With the four corners measured in meters, the section can be partitioned into four quarter-sections (Figure 2.2). New four corner coordinates of each quarter-section are then computed. A recursive function is used to compute the quarter of a quarter. The more a quarter is divided, the more accurate is the location of a well. The centroid of the final quarter is then used as the point location of the well. The centroid coordinates are computed from the bivariate mean of n boundary vertices.

Table 2.3: Schemas and Relations for *Location, Litholgy, Formatns, and Wellownr*

Table Name (1)	Attribute (2)	Key (3)	Data Type (4)	Description (5)
Location	wellid	√	integer	a 7 digit well identification number
Location	co	√	char(2)	abbreviated county name
Location	conum	√	smallint	a well number within a given county
Location	usgsid		char(15)	USGS identification number
Location	pemno		integer	permanent well number given by Wis. DNR
Location	sampno		char(30)	range or number assigned to geologic sample
Location	ldesc		char(16)	legal description of the hole's location
Location	sect		smallint	section number (1-36) within a township in the range
Location	tn		char(2)	township number in PLSS
Location	rn		char(2)	range number in PLSS
Location	eorw		char(1)	E (east) or W (west) for range value in PLSS
Location	elev		float	elevation of the ground surface
Location	elevacc		float	accuracy of the elevation value
Location	ldepth		float	total depth of the hole
Location	wowner		char(42)	name of well owner
Location	comments		char(256)	comments for the geologic record
Location	welluse		char(20)	intended purpose or use for a well
Location	staticwl		float	static water level
Location	specap		float	specific capacity of a well (gallons per min per foot)
Location	quad		char(25)	name of the 7.5 min topographic map containing the geologic record
Litholgy	wellid	√	integer	a 7 digit well identification number
Litholgy	indvsamp		char(8)	individual sample number for a particular depth
Litholgy	lithtop		float	top depth of the sampled interval
Litholgy	lithbotm		float	bottom depth of the sampled interval
Litholgy	rocktype		char(15)	major rock type of the sample
Litholgy	color		char(19)	color of the wet sample
Litholgy	mode		char(9)	average grain size for the rock type
Litholgy	range		char(19)	grain size range for the rock type
Litholgy	ldesc2		char(256)	detailed lithologic description
Litholgy	notes		char(256)	in-house note from the studier
Litholgy	entrydte		date	the date the lithologic record was added to the computer

Table 2.4: Schemas and Relations for *Location, Litholgy, Formatns, and Wellownr (cont.)*

Table Name (1)	Attribute (2)	Key (3)	Data Type (4)	Description (5)
Formatns	wellid	√	integer	a 7 digit well identification number
Formatns	formtop		float	lower depth for the stratigraphic unit
Formatns	formbotm		float	upper depth for the stratigraphic unit
Formatns	fmcodes	√	smallint	code (500-10000) assigned to a specific stratigraphic unit
Wellownr	wellid	√	integer	a 7 digit well identification number
Wellownr	wellname		char(42)	owner of the well
Wellownr	ownrname		char(46)	full name of a well owner
Wellownr	ownraddr		char(30)	street address of this owner
Wellownr	ownrcity		char(16)	city of residence of this owner
Wellownr	ownrstate		char(2)	state of residence of this owner
Wellownr	ownrzip		char(10)	zip code for this owner
Wellownr	status		char(2)	status of a well owner relative to the well

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Figure 2.1: Public Land Survey Section Numbering Sequence

$$\overline{X} = \frac{\sum X}{n}$$

$$\overline{Y} = \frac{\sum Y}{n}$$

This algorithm gives approximate locations dependent on available data resolution. The algorithm is used owing to its simplicity and availability of the UTM Section Corners Control file. The error introduced by the algorithm may range from 2.5 acres to 160 acres.

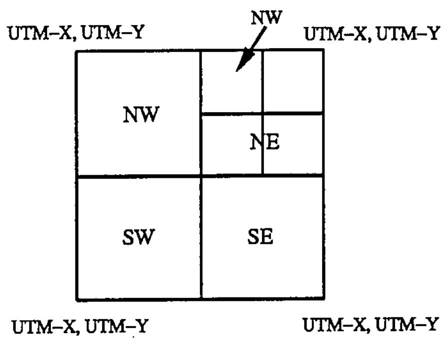


Figure 2.2: Quarter-Sections in PLSS

The subroutines listed in the appendix show how the corner coordinates of a new quarter and the centroid coordinates of a quarter are computed. The WGNHS encoded the description of quarter-quarter sections in a string combined with two-character identifiers. They include: *NE, NW, SE, SW, N2, E2, S2, W2*, and *C*,. *NE, NW, SE, SW* means North-East, North-West, South-East, South-West respectively. *N2, E2, S2, W2* stands for half on North, East, South and West respectively. And *C*, is the center. The WGNHS also described some well locations using 'Just S of Center', 'E of C', 'NW corner', and 'NE corner', etc. In order to reduce the complexity of the program while not much accuracy is sacrificed, these descriptions were edited. For example, 'Just S of Center' was edited to *S2* and 'E of C' was changed to *E2*. 'NW corner' and 'NE corner' were edited to *NW* and *NE* respectively.

2.4 WELLHEAD System Files

The *WGNHS* database is implemented in the Ingres database management system. The SQL command files, *location.sql, litholgy.sql, formatns.sql,* and *wellownr.sql,* located in the subdirectory */wgnhs* are used to load the *WGNHS* database. The data files are located in the subdirectory */wgnhs/data*. They are *location.del* for location, *nosample.del, sample1.del* and *sample2.del* for litholgy, *formatns.del* for formatns, and *wellownr.del* for wellownr. An additional SQL file, *plss.sql* is stored in */wgnhs* which can be used to read and query the Section Corners Control file *dmaster.ctl* in the subdirectory */wgnhs/data*.

2.5 Future Work

Future work of this part should focus on improving the accuracy of the ground coordinates of well locations. There are at least three possibilities to improve the accuracy.

1. To record the well location with a more detailed quarter identifier can help the computation to produce a more accurate result.

2. Since UTM coordinates are only available for the Section corners, corner coordinates of its quarters are computed from the bivariate mean. This is only an approximation. If there are UTM coordinates surveyed for the quarter or quarter-quarter corners, the accuracy of computing a well location can be improved.

3. A more direct and effective way to improve the accuracy of the well locations is to conduct a land survey and record the location of each well in a more accurate coordinate system, such as the State Plane Coordinate System or the UTM.

Chapter 3

Menu Systems, Interfaces and Database Design

3.1 Wellhead Database

The WELLHEAD database consists of table relations for storing boring log data and soil properties from field and laboratory tests. The normalized database schema is delineated in Tables 3.1, 3.2 and 3.3. The first and second columns the tables indicates relation and attribute names. There are sixteen tables in the database. The attributes are designed in such a way that redundancy in database is reduced. The attribute names are the variable names which are used to write the queries for different database functions. The third column identifies the key attribute for each table. The tables in the database are interrelated through the key attributes. The tables which store laboratory test data have jar sample num as primary key and a unique boring log number as foreign key (Date 1990). The fourth column indicates datatype for each attribute. The datatype controls the input given by the user. Datatypes are defined as supported by the INGRES database management system. The fifth column contains a short description of each attribute and the domain of possible values. The attribute names and descriptions in Tables 3.1, 3.2 and 3.3 describe the information that is stored in the database. Some of the attributes require more description, which is given below.

- *For each Boring:* a unique boring log number, name and boring log number of the user agency, date of beginning and completion of boring, initials of the personnel that worked at the site, water table level from the surface, water level at 24 hours and at completion of boring, boring termination depth, elevation and geodetic coordinates of boring log, drill rig and method.

- *For each Segment:* a unique boring log number, a segment number, depth of the segment and description of the segment.

- *For each Sample:* jar sample number, the USC and AASHTO (unified and American association of state highway and transportation officials) soil classification of the sample, the soil sample type according to basic types, sampler type such as SPT (including blow count, penetration depth and recovery), Shelby and other like piston, 3" tube sampler.

- *For each Atterberglimit:* jar sample number, a unique boring log number, name of the lab technician, date of the test, plastic limits and liquid limits, and soil description (Liu and Evett 1990).

- *For each Gradation:* jar sample number, a unique boring log number, name of the lab technician, date of the test, percentage of gravel, sand, silt and clay, coefficient of uniformity and concavity(curvature), and sample description (Liu and Evett 1990).

- *For each Watercontent:* jar sample number, a unique boring log number, name of the lab technician, date of the test and watercontent (Liu and Evett 1990).

- *For each Specific Gravity:* jar sample number, a unique boring log number, name of the lab technician, date of the test and specific gravity (Liu and Evett 1990).

- *For each Strength:* jar sample number, a unique boring log number, name of the lab technician, date of the test, shape of the specimen, sample type(eg. remoulded, undisturbed etc.), watercontent, dry density, specific gravity, degree of saturation, strain at maximum compressive stress, pore pressure, maximum compressive stress, angle of internal friction, cohesion (Liu and Evett 1990).

- *For each Consolidation:* jar sample number, a unique boring log number, name of the lab technician, date of the test, sample type, specimen height and diameter, initial water content, final water content, degree of saturation, final degree of saturation, initial void ratio, overburden pressure, preconsolidation pressure, coefficient of consolidation (Liu and Evett 1990).

3.2 Description of Wellhead Database Interface

The Wellhead menu database interface, written in the application development system Windows4GL provides easy access to the Wellhead database. Data from different source agencies with different data collection and interpretation methods may be entered using this interface. The interface allows multiple users to store and manage the log data as well as access menus to call programs to generate boring logs and perform spatial queries for selecting boring logs. Windows4GL implements the event-based, object-oriented programming language 4GL. 4GL includes a full range of control flow commands as well as all the INGRES SQL commands, providing easy access to the database (Ingres 1990). Windows4GL is a window-based application development system which simplifies the design, implementation and testing

Table 3.1: Relations and Data Dictionary for WELLHEAD

Table Name	Attribute	Key	Data Type	Description
Boring	boring#	√	smallint	WELLHEAD boring log number
Boring	agency		char(30)	name of contributing agency
Boring	agency_boring#		char(10)	agency's boring log number
Boring	date		date	date of boring
Boring	date_comp		date	completion date of boring
Boring	crew		char(30)	initials of crew members
Boring	temperature		smallint	at time of drilling in degrees Fahrenheit
Boring	precipitation		char(10)	at time of drilling: snow, rain, dry
Boring	casing_type		char(10)	casing type: steel, pvc
Boring	casing_idiam		float	casing inside diameter 2" $\leq$ and $\leq$ 36"
Boring	water_depth		float	depth from surface to water table (ft.)
Boring	water_level_comp		float	water level at completion (ft.)
Boring	water_level_hour		float	water level at 24 hours (ft.)
Boring	term_depth		float	Boring termination depth (ft.)
Boring	mud_type		char(10)	drilling mud type: bentonite
Boring	method		char(20)	hammer type
Segment	segment#	√	smallint	boring log segment number
Segment	boring#		smallint	WELLHEAD boring log number
Segment	description		char(250)	soil description
Sample	sample#	√	smallint	sample jar number
Sample	boring#		smallint	WELLHEAD boring log number
Sample	USC		char(5)	Unified soil classification
Sample	AASHTO		char(5)	AASHTO soil classification
Sample	sample_type		char(10)	soil sample type: rock, peat, mineral soil
Sample	sampler_type		char(12)	sampler type: SPT, Shelby, Piston, Auger
BoringLoc	boring#	√	smallint	WELLHEAD boring log number
BoringLoc	x		float	x geodetic coordinate
BoringLoc	y		float	y geodetic coordinate
BoringLoc	elevation		float	surface elevation
SegmentLoc	segment#	√	smallint	soil segment number
SegmentLoc	boring#		smallint	WELLHEAD boring log number
SegmentLoc	d_bottom		float	depth from surface to bottom of seg.(ft.)
SegmentLoc	up_segment#		smallint	segment number of segment on top
SampleLoc	sample#	√	smallint	sample jar number
SampleLoc	boring#		smallint	WELLHEAD boring log number
SampleLoc	depth		float	depth from surface to sample location(ft.)
SPT	sample#	√	smallint	sample jar number
SPT	boring#		smallint	WELLHEAD boring log number
SPT	blow_count		smallint	blows/ft
SPT	penetration		float	sampler penetration (inches)
SPT	begin_depth		float	depth at beginning of penetration (ft.)
SPT	recovery		float	sample recovery

Table 3.2: Relations and Data Dictionary for WELLHEAD (cont.)

Table Name	Attribute	Key	Data Type	Description
Shelby	sample#	√	smallint	sample jar number
Shelby	boring#		smallint	WELLHEAD boring log number
Shelby	penetration		float	sampler penetration (inches)
Shelby	begin_depth		float	depth at beginning of penetration (ft.)
Shelby	recovery		float	sample recovery
Other	sample#	√	smallint	sample jar number
Other	boring#		smallint	WELLHEAD boring log number
Other	recovery_method		char(50)	sample recovery
AtterbergLimits	sample#	√	smallint	sample jar number
AtterbergLimits	boring#		smallint	WELLHEAD boring log number
AtterbergLimits	lab_tech		char(30)	lab technician (tested by)
AtterbergLimits	test_date		date	date of test
AtterbergLimits	loc_in_sample		char(15)	location in sample
AtterbergLimits	PL		float	plastic limit
AtterbergLimits	LL		float	liquid limit
AtterbergLimits	PI		float	plasticity index
AtterbergLimits	soil_desc		char(30)	soil description
Gradation	sample#	√	smallint	sample jar number
Gradation	boring#		smallint	WELLHEAD boring log number
Gradation	lab_tech		char(30)	lab technician
Gradation	test_date		date	date of test
Gradation	loc_in_sample		char(15)	location in sample
Gradation	method		char(20)	method of analysis
Gradation	gravel_percent		float	
Gradation	sand_percent		float	
Gradation	silt_percent		float	
Gradation	clay_percent		float	
Gradation	Cu		float	coefficient of uniformity
Gradation	Cc		float	coefficient of concavity
Gradation	sample_desc		char(30)	Sample Description
WaterContent	sample#	√	smallint	sample jar number
WaterContent	boring#		smallint	WELLHEAD boring log number
WaterContent	lab_tech		char(30)	lab technician
WaterContent	test_date		date	date of test
WaterContent	loc_in_sample		char(15)	location in sample
WaterContent	w		float	water_content
Strength	sample#	√	smallint	sample jar number
Strength	boring#		smallint	WELLHEAD boring log number
Strength	lab_tech		char(30)	lab technician
Strength	test_date		date	date of test
Strength	loc_in_sample		char(15)	location in sample
Strength	spec_shape		char(15)	shape of the specimen

Table 3.3: Relations and Data Dictionary for WELLHEAD (cont.)

Table Name	Attribute	Key	Data Type	Description
Strength	test_type		char(10)	Uu, Cu, CD or Ds
Strength	sample_type		char(20)	undisturbed, remoulded etc.
Strength	wet_density		float	
Strength	dry_density		float	
Strength	deg_sat		float	degree of saturation
Strength	str_max		float	strain at maximum compressive stress
Strength	comp_stress		float	maximum compressive stress
Strength	pore_press		float	pore pressure
Strength	phi		float	angle of internal friction
Strength	c		float	cohesion
UnitWeight	sample#	√	smallint	sample jar number
UnitWeight	boring#		smallint	WELLHEAD boring log number
UnitWeight	lab_tech		char(30)	lab technician
UnitWeight	test_date		date	date of test
UnitWeight	loc_in_sample		char(15)	location in sample
UnitWeight	gama		float	unit_weight(lbs/ft^3)
SpecificGravity	sample#	√	smallint	sample jar number
SpecificGravity	boring#		smallint	WELLHEAD boring log number
SpecificGravity	lab_tech		char(30)	lab technician
SpecificGravity	test_date		date	date of test
SpecificGravity	loc_in_sample		char(15)	location in sample
SpecificGravity	Gs		float	specific_gravity
Consolidation	sample#	√	smallint	sample jar number
Consolidation	boring#		smallint	WELLHEAD boring log number
Consolidation	lab_tech		char(30)	lab technician
Consolidation	test_date		date	date of test
Consolidation	loc_in_sample		char(15)	location in sample
Consolidation	sample_type		char(20)	undisturbed, remoulded etc.
Consolidation	D		float	specimen diameter
Consolidation	H		float	specimen height
Consolidation	w_init		float	initial water content
Consolidation	w_final		float	final water content
Consolidation	in_deg_sat		float	initial degree of saturation
Consolidation	fn_deg_sat		float	final degree of daturation
Consolidation	e		float	initial void ratio
Consolidation	Po		float	overburden pressure
Consolidation	Pp		float	preconsolidation pressure
Consolidation	Cv		float	coefficient of consolidation

of an application by supplying a broad range of window-based features, including pull-down menus and mouse-based selection. It provides the information and tools necessary for the end user to examine data from or to perform operations of the database. The application is event driven, allowing the end user to direct the application by entering or changing data, selecting commands from menus, clicking buttons, moving the mouse or pressing the mouse buttons, pressing function keys and moving from one frame to the next.

Windows4GL uses frames as the building blocks of an application. A frame is a window through which the application displays information and provides control for execution operations. To the end user, a frame is divided into three basic parts;

- *window:* The window provides a boundary around the form and the menubar and contains features which allow the user to control the window. For example, the window *title bar* contains the application name, the frame name, and provides buttons to resize and close the window.

- *menubar:* The menubar contains all the pull down menus that are available in the current frame.

- *form:* The form is the portion of the frame where the user can display or modify data, view illustrations, read instructions, and select commands. Forms contain arrangements of text and images, graphic elements, and active fields. Active fields are the areas on the form where the user can view, modify, or enter data, as well as control the application. Active fields may be single-line entry fields which allow a single line of data to be entered. The data can be edited with the Windows4GL text editor. A *slide bar* on the right allows the user to scroll through the form.

During the creation of an application it is necessary to specify the contents of each frame, the data to be displayed or accepted, command buttons to be provided, and the necessary menu operations. Also, the connections between frames must be defined.

3.3 User Interaction

The WELLHEAD user interface consists of menus, screen-forms, report generator and programs. The WELLHEAD menus, forms and report generators are developed using 4GL tools provided by with the INGRES database management systems. The forms interface frees the user from applying explicit query language commands for insertion, deletion and modification of information in the database. The forms are organized in such a way that the data displayed can be perceived by user, even though it is stored in the database in a different manner (Adams 1989).

The WELLHEAD menu system layout is shown in Table 3.4. The first column in the menu system layout table indicates the internal name for each menu. The selection type indicates the type of the component as M for menu, F for form, R for report generator, and P for program. The system call indicates

Table 3.4: WELLHEAD Menu Options

Menu Name	Option No.	Selection Text	Type	System Call
main	1	Data Input	M	get_in
main	2	Spatial Queries	F	get_loc
main	3	Data Information	M	get_info
main	4	Exit		exit
get_in	1	Project Description	F	proj_des
get_in	2	Drilling Report Data	F	dril_rep
get_in	3	Laboratory Report Data	M	lab_rep
get_in	4	Close		return
lab_rep	1	Coarse Grained Soil	F	crs_soil
lab_rep	2	Fine Grained soil	F	fin_soil
lab_rep	3	Organic Soil	F	org_soil
lab_rep	4	Close		return
get_info	1	Drilling Data	F	drill_info
get_info	2	Laboratory Data	F	lab_info

the variable name for that component. The WELLHEAD menu options consists of *get_in*, *get_info* and *lab_rep* menus, which are used for data input, data information and laboratory report data, respectively.

- *get_in:* The *get_in* menu is called from the main menu. The *get_in* menu contains options for project description, drilling report data input, laboratory report data menu, and close (return to main menu).

- *lab_rep:* The *lab_rep* menu contains options for calling forms to input the laboratory test data. The options will be coarse grained, fine grained, highly organic and close.

- *get_info:* The user can get the information for different drilling data as well as laboratory test data. For those options, the user must go through these menu options.

The forms are useful components for the user interaction with the WELLHEAD database because the database is very enhanced and normalized. Without the screen forms, it is essential for the user to be knowledgable of a query language for data insertion, selection, deletion, and modification. The forms allow any user, even without the knowledge of a query language, to use the database. The forms help the user to perceive data in an easier way, regardless of their storage in the database. The forms control the data which is stored in the database and provide a means of ensuring data consistency, integrity and completeness. The function of each of the user forms in the WELLHEAD system is briefly described as follows:

- *proj_des:* This form gives the information regarding the project.

- *drill_rep:* This form is used for entering the data regarding the field conditions and other drilling information at the time of sampling, such as method used for drilling, type of the sampler, water level, and depth of soil segment layers.

- *fin_soil:* This form is used for entering laboratory test results for the fine grained soils. Seven database tables are combined in this form for input of seven laboratory test data. The common data will be entered only once from the user. The data will be stored separately in the seven database tables according to their attributes. The seven tests are atterberglimits, strength, gradation, watercontent, specific gravity, unitweight and consolidation test.

- *crs_soil:* This form is used for entering laboratory test results for coarse grained soil. Four laboratory tests are included: unitweight, strength, gradation, specific gravity. After entering the data into form, the user presses the insert button to insert the data into the database. Error and confirmation messages will appear on the screen accordingly.

- *org_soil:* This form is used for entering data results of six laboratory tests for organic soil. The tests are strength, consolidation, watercontent, unitweight, specific gravity and atterberg limits.

- *drill_info:* This form is used to browse through the data which is stored in the database for drilling condition. The user can put any value in the appropriate column to query other data related to the given value. The data for all the columns from the database will be retrieved by clicking the select button, which will invoke the select query. The user can also query according to multiple attributes by entering values into different columns. The data can be retrieved from more than one table.

- *lab_info:* In this form, the user can retrieve the data regarding the laboratory tests from the database. The form contains button fields for different functions like data deletion, data modification(update), and data selection for interaction with the database.

Chapter 4

Spatial Queries to Select Boring Logs

This section describes the WELLHEAD graphical user interface for accessing well log data through spatial queries. The program has been developed to effectively maintain the database of high capacity well logs in Dane County, Wisconsin. The major function of this program is to display the well data in Dane County along with geographical features such as highways, streams/lakes, and township boundaries. Data is maintained with the Ingres database management system. The C programming language has been used as a source code on a Sun workstation.

The graphical interface of the WELLHEAD system has been implemented with a built-in graphical utility, called XVIEW. XVIEW is a network-based, object-oriented windowing system developed by the Massachusetts Institute of Technology in 1988. All the graphical subroutines to display the well logs and ground features have been incorporated from the XVIEW graphic library.

4.1 Input Data and Program Output

For geographical display, highway, hydrography, and township boundary data have been converted into the ASCII format using USGS (United States Geological Survey) scale DLG (Digital Line Graph) files. For easy conversion, PC-ARC/INFO, a GIS (Geographical Information System) software package developed by ESRI (Environmental System Research Institute) has been used. For global locating of the geographical features, UTM (Universal Transverse Mecator; unit: meter) has been used. The following shows individual data file names:

- *dane_hwy_utm*: ASCII format USGS highway data in UTM.
- *dane_hydro_utm*: ASCII format USGS hydrography data in UTM.
- *dane_towns_utm*: ASCII format USGS township boundaries in UTM.
- *dane_hwy_data*: converts dane_hwy_utm into screen x,y coordinate.
- *dane_hydro_data*: converts dane_hydro_utm into screen x,y coordinate.

- *dane_towns_data*: converts dane_towns_utm into screen x,y coordinate.

Program output is dependent upon user selection, geographical feature displays and the well log database contents.

- *User selection*: Users can select a specific well log or a group of well logs using the menu option. The point option can select an individual well log; the line option with buffer length can select a group of well logs along the line within the buffer length; and the area option can select group of well logs within an area.

- *Geographical feature display*: At the beginning, the user can select any geographic features as background to the well log display. This will provides more information for easy selection of well logs. The geographic overlays can be displayed or deleted using the display menu option.

- *Well log database maintenance*: According to user selection, the program will access proper well log records by interfacing with the database software Ingres. It also plots major properties of selected well logs.

4.2 Program Structure, Process Flow and Execution

For efficient user input handling, top-down structure has been used. Figure 4.1 shows the layout of the subroutines used in this program. A description of each subroutine follows.

- *canvas_repaint_proc()*: generates a canvas of a certain size and displays well log data into canvas.
- *numer_text()*: reads buffer length for line input selection option.
- *accept_point()*: opens window for point selection.
- *accept_point_coord()*: gets selected point's x,y coord (UTM coordinate).
- *point_draw()*: fills selected point with red (square shape).
- *accept_line()*: opens window for line selection.
- *accept_line_coord()*: gets the selected line coordinates (start/end points).
- *store_line_coord()*: stores x,y line coordinate for line drawing.
- *line_draw()*: draws line.
- *accept_area()*: opens window for area selection.
- *area_draw()*: draws selected area.
- *display_hwy()*: displays highways of Dane County.
- *display_town()*: displays township boundaries in Dane County.
- *display_hydro()*: displays hydrography of Dane County.
- *quit()*: quits by calling XVIEW interrupt function.

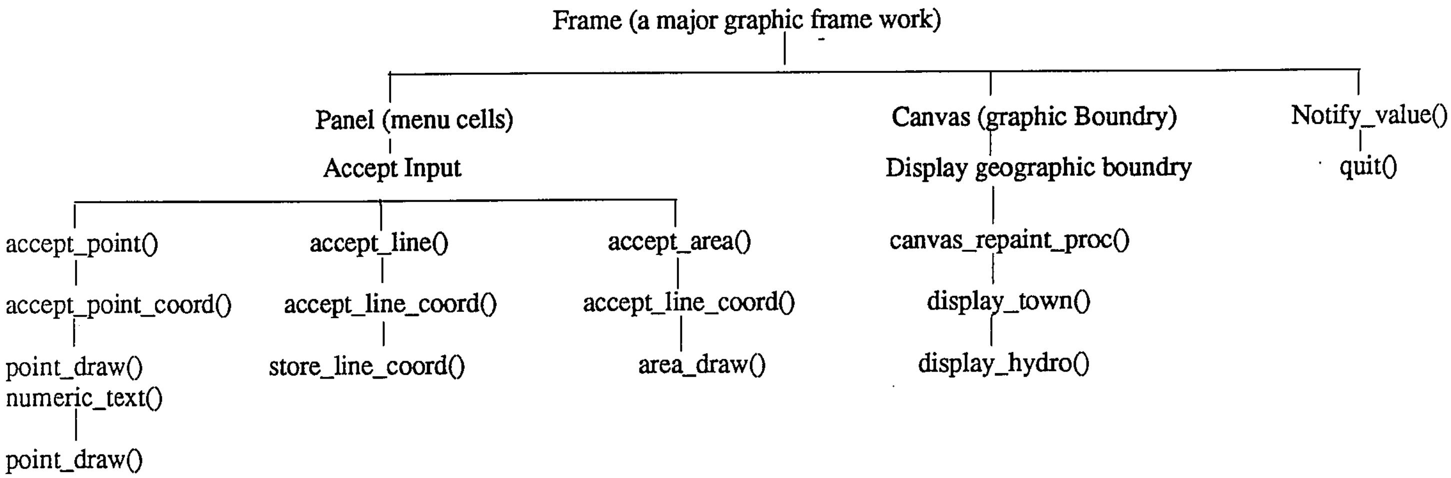


Figure 4.1: Programming Structure

The following describes the processing flow of the program.

- Define graphic framework and canvas
- Set up menu for user selection and graphic display
- Display map legends and message
- Read coverages and display (user selectable).
- User menu selection: Point, line (and line buffer), and area.
- Interface with Ingres routine so well log (individual or group) can be accessed and displayed/updated.
- Quit: calling interrupt routine

The /XVIEW directory has all of the files including the data files and the source code (wellhead.c). XVIEWRUN is a shell script that links XVIEW libraries during compilation. To compile the source code, use XVIEWRUN:

```
XVIEWRUN output wellhead.c
```

where *output* is the output file name and *wellhead.c* is the source code. To run the program, type `output`.

4.3 Future Work

1. *Interfacing with Ingres Database System.* For effective database maintenance of well logs in Dane county, more work should be done to interface the WELLHEAD system with the Ingres database

software. Once the linkage has been established, the WELLHEAD system can generate any kind of graphics and reports for the selected well logs. This will mainly depends on the generation of proper subroutines which call relevant Ingres functions based on user queries.

2. *Increasing Graphical Functionality.*

   - *Window zooming*: By,implementing multiple sub-window generation, the capability of zooming to any area of Dane County will facilitate user queries. This will also enable in-depth analysis of the area with detailed geographical features of special interest or high environmental sensitivity.

   - *User defined graphical layers*: Rather than drawing pre-defined graphical layers, it will be more useful to generate graphical layers based on specific attribute values of the well log database. For example, the user could generate graphical layers which represent the spatial distribution of any well log attribute (e.g. well capacity, or depth) for the county. The linkage between the WELLHEAD system and Ingres as described above will be the pre-requirement of this functionality.

   - *Generation of graphical layers with environmental indexes*: Currently the WELLHEAD system displays only major physical surface features such as highways, townships, and hydrography. It will be essential in the future to have qualitative graphical layers which represent environmental indexes(e.g. VOCs, BOD, PH, etc.). This will facilitate the site suitability to locate environmental treatment facilities (e.g. landfill sites, sewage treatment facility, etc.). Since many local/governmental agencies (e.g. USEPA, USGS, Wisconsin DNR) already have these databases, no major problems should be encountered in data procurement. It may however require some data conversion.

3. *Spatial Modeling Capability*: Since the initial version of WELLHEAD has the capability of displaying the selected area of well logs, it will be possible to have area-limited spatial modeling capability. Any kind of spatial modeling technique (e.g. kriging, or moving average approaches, etc.) can be implemented. Although the algorithm and logical complexity will require highly skilled programmers and considerable effort, this will provide baseline information especially useful for environmental impact analysis.

Chapter 5

Generation of One, Two, and Three Dimensional Plots

This chapter describes the WELLHEAD system graphics demonstration programs for 1, 2 and 3-D subsurface boring log plots. With the graphic demonstration programs, users are able to view the subsurface data of a single boring, several borings along a line, or a group of borings within a rectangular area. The boring data graphs may be viewed on the screen and printed. These graphic demonstration programs are written in FORTRAN with embedded GKS subroutines. The programs are compiled with SUN/GKS libraries. Input data for the graphic demonstration programs is obtained from the WELLHEAD database through the spatial query function of the system. The data format required by the boring log plotting programs is described in this chapter.

5.1 Description of the Programs

There are 6 FORTRAN programs: *borlog01.f*, *borlogps.f*, *prof2d01.f*, *prof2dps.f*, *fenced01.f*, and *fencedps.f*. They are described as follows.

1. Programs for displaying single boring log information: *borlog01.f* is used to graph a single boring log profile including information such as soil description, water content, dry density, liquid limit, water table, and ground elevation. The *borlogps.f* program is used to produced a postscript file of the graph shown by *borlog01.f*. The postscript output can be printed and embedded in report documents. An example of the output from *borlogps* is shown in Figure 5.1.

2. Programs for plotting 2-D profiles of boring logs along a specified cross section: The *prof2d01.f* program displays the profile of boring logs along a specified cross section on the screen. The cross section is defined by 2 points on the map. The profile includes all boring logs within a user defined

buffer zone, such as 20 feet from the cross section. The *prof2dps.f* program is used to produce a postscript file of the 2-D profile graph shown by *prof2d01.f*. An example of the output from *prof2dps* is shown in Figure 5.2.

3. Programs for plotting 3-D fence diagrams of boring logs within a specified area: The *fenced01.f* displays the fence diagram of boring logs within a specified rectangular area on the map in a 3-D "dynamic" style. The user can change the viewing angle of the diagram by using the mouse device. If we pick up 2 points on the map, a rectangular area will be defined, then a 3-D fence diagram of boring logs within the area will be shown on the monitor with default viewing angles. The user can also change viewing angles by using mouse device simultaneously. The *fencedps.f* program is used to produce a postscript file of the 3-D fence diagram generated by the *fenced01.f* program. An example of the output from *fencedps* is shown in Figure 5.3.

5.2 Compiling the Programs

Two shell scripts were written to simplify the compilation process. For systems using GKS with Sunview libraries, the "g77" script should be used to compile FORTRAN programs. For systems using GKS with XVIEW libraries, the "ng77" script should be used to compile the programs. The ways to compile are :

- For Sunview's SUNGKS

```
g77  <name of source program>  <name of executive file>
```

For example: `g77 borlog01.f borlog01`

- For Xview's SUNGKS

```
g77  <name of source program>  <name of executive file>
```

For example: `ng77 fencedps.f fencedps`

The shell scripts are as follows:

- g77 :

```
f77 \$1 -o \$2 -lgks77 -lgks -lsuntool -lsunwindow -lpixrect -lm
```

- ng77 :

```
f77 -I\$GKSDIR/../../include \
 -I\$OPENWINHOME/include \$1 -o \$2 -L\$OPENWINHOME/lib \
 -L\$GKSDIR/.. -lgks77 -lgks -lxview -lolgx -lX11 -lm
```

5.3 The Data Files

Execution of the programs requires that the data files have been produced by the "query" function of the system and are located in the current directory along with with the executable programs. The data files

Figure 5.1: Postscript Output From *borlogps*

PROJECT : IPDS Geotechnical Demo I
LOCATION: UW Madison
CLIENT : Sam

BORING: B-3

DATE : 03/02/88
DRILLERS: Richard Bore

BUILDING: A
LOCATION: Civil Engineering Department

WATER TABLE: 10.00

COORDINATES: E 380,N 180

GROUND ELEVATION: 202.00

SOIL DESCRIPTION	N b/ft	Water Content %	Dry Density	Liquid Limit %	Plastic Limit %	Fines %
Fine sand, medium dense.	2	25	110			20
Silty clay, gray to rusty, very moist, stiff.		18	118	36	15	68
	8	15	110	40	15	58
						67
		23	118			
Clayey sand (SC), fine, light grey firm to stiff with pockets of shell fragments, moderate plasticity, wet to saturated.		32	108			
	15			34	14	68
Gravelly lean clay (CL), moderate plasticity.		28	118			
	15	32	119	45	17	62
Lean Clay (CL), moderate plasticity.		23	117	43	17	
	17					
Limestone, buff, unweathered, weak, foliated.	40					

Depth (feet): 5, 10, 15, 20, 25, 30

IPDS - Geotechnical

Figure 5.2: Example Output From *prof2dps*

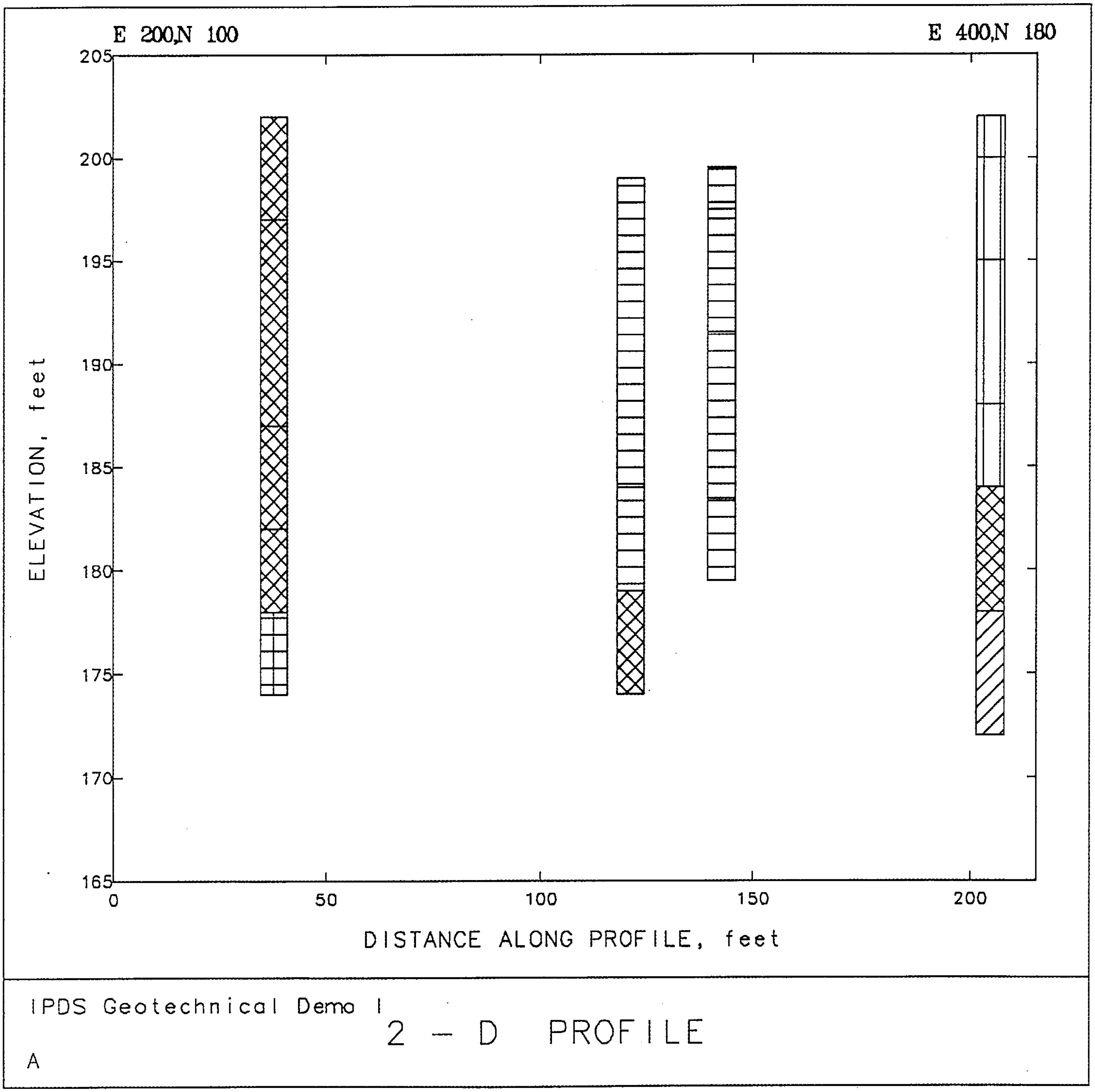
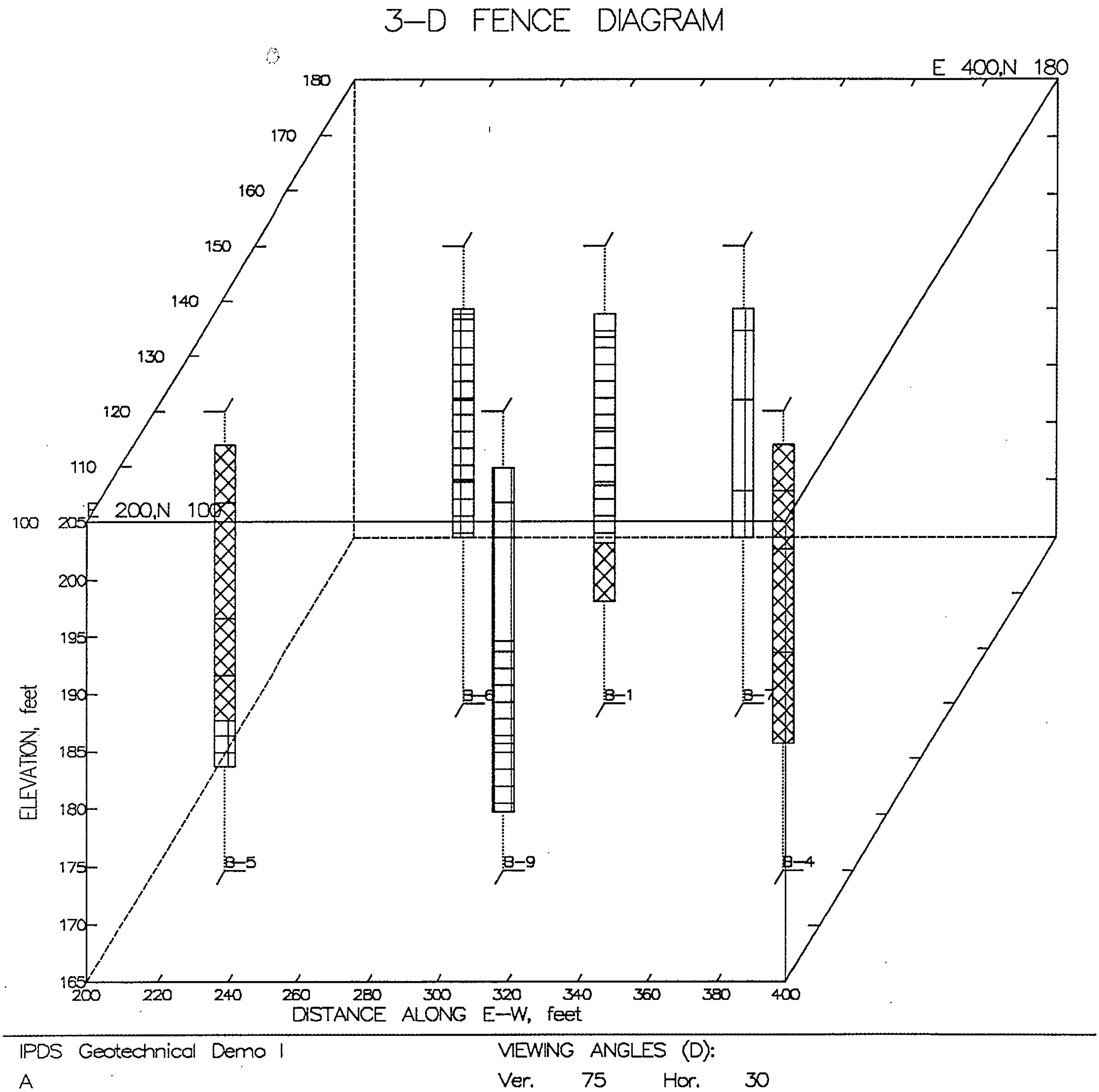


Figure 5.3: Sample 3-D Fence Diagram Output from *fencedps*



required for each program were listed in Table 5.1.

Table 5.1: Data Files for the Plot Programs

borlog01 *borlogps*	*prof2d01* *prof2dps*	*fenced01* *fencedps*
gdborl.inp	gd2dp.inp	gd2dp.inp
pjinfo.dat	bdata1.dat	bdata1.dat
bdinfo.dat	bdata2.dat	bdata2.dat
brinfo.dat	bdata3.dat	bdata3.dat
ldesc.dat	bdata4.dat	bdata4.dat
dmax.dat		
sample.dat		
dd.dat		
wc.dat		
ll.dat		
pl.dat		
fn.dat		

The data files contain necessary information to graph boring log plots such as shown in Figures 5.1, 5.2 and 5.3. The content and formats of the data files list above are as follows. (Many of the data items can be identified from Figures 5.1, 5.2 and 5.3. Where additional information is needed, comments following the "%" symbol have been added for clarity. The comments should not be included in actual data files.)

gdborl.inp : graphics descriptor for the boring log chosen(Sengara 1988) (appendix B, pp.71-73).

```
'PAGE'
 1.750000E+00 1.250000E+00 1.000000E+00 7.500000E-01 % Margins
 % top          bottom       left          right      (in inches)

'LAYOUT'
    'DESC'  60          % Width (in %) of Soil Description
    'DEPTH' 10          % Width (in %) of Depth
    'SPT'    5          % Width (in %) of SPT
    'WC'     5          % Width (in %) of Water Content
    'DD'     5          % Width (in %) of Dry Density
    'LL'     5          % Width (in %) of Liquid Limit
    'PL'     5          % Width (in %) of Plastic Limit
    'FN'     5          % Width (in %) of Fines
    'HATCH'  3          % Width (in %) of Soil profile
    'SPTH'   1          % Width (in %) of Sample profile
```

pjinfo.dat : project information (Sengara 1988) (appendix D, pp.78, appendix A, pp.55).

```
'IPDS Geotechnical Demo I','UW Madison','Sam'
```

bdinfo.dat : building & location information (Sengara 1988) (appendix D, pp.79, appendix A, pp.55).

```
'A','Civil Engineering Department'
```

brinfo.dat : boring information (Sengara 1988) (appendix D, pp.79, appendix A, pp.55).

```
'B-3','E 380,N 180','  202.00','03/02/88','Richard Bore','10.00'
```

ldesc.dat : layer descriptor; The layer descriptor file contains 3 fields. The first field contains the boring name, the second field contains layer depth, the third field contains the soil description (Sengara 1988) (appendix D, pp.80, appendix A, pp.56).

```
'B-3',2.00,'Fine sand, medium dense.'
'B-3',7.00,'Silty clay, gray to rusty, very moist, stiff.'
'B-3',18.00,'Gravelly lean clay (CL), moderate plasticity.'
'B-3',24.00,'Lean Clay (CL), moderate plasticity.'
'B-3',30.00,'Limestone, buff, unweathered, weak, foliated.'
```

dmax.dat : maximum depth of the boring log (Sengara 1988) (appendix D, pp.80, appendix A, pp.56).

```
30.00
```

sample.dat : samples for experiment; The sample.dat file contains 4 fields. The first field contains the sampler name, the second field contains the sample depth, the third field contains the blow count, the fourth field contains the sample recovery (Sengara 1988) (appendix D, pp.79, appendix A, pp.56).

```
'SPT',2.00,2,1.00
'Shelby Tube',4.00,0,1.00
'SPT',5.50,8,1.00
'Shelby Tube',7.00,0,1.50
'SPT',10.50,15,1.50
'Shelby Tube',15.00,0,0.50
'SPT',17.50,15,1.00
'Shelby Tube',20.00,0,1.00
'SPT',23.00,17,1.50
```

dd.dat : dry density of the samples; The dd.dat file contains 4 fields. The first field contains the sample depth, the second field contains the location in sample, the third field contains the sample recovery, the fourth field contains the run or test result (Sengara 1988) (appendix D, pp.79, appendix A, pp.57).

```
2.00,'Middle',1.00,110
4.00,'Top',1.00,118
5.50,'Top',1.00,110
7.00,'Middle',1.50,118
10.50,'Top',1.50,108
15.00,'Top',0.50,118
17.50,'Middle',1.00,119
20.00,'Top',1.00,117
```

wc.dat : water content of the samples;The wc.dat file contains 4 fields. The first field contains the sample depth, the second field contains the location in sample, the third field contains the sample recovery, the fourth field contains the run or test result (Sengara 1988) (appendix D, pp.79, appendix A, pp.57).

```
2.00,'Middle',1.00,25
4.00,'Top',1.00,18
5.50,'Top',1.00,15
7.00,'Middle',1.50,23
10.50,'Top',1.50,32
15.00,'Top',0.50,28
17.50,'Middle',1.00,32
20.00,'Top',1.00,23
```

ll.dat : liquid limit of the samples; The ll.dat file contains 4 fields. The first field contains the sample depth, the second field contains the location in sample, the third field contains the sample recovery, the fourth field contains the run or test result (Sengara 1988) (appendix D, pp.79, appendix A, pp.57).

```
4.00,'Middle',1.00,36
5.50,'Middle',1.00,40
10.50,'Middle',1.50,34
17.50,'Middle',1.00,45
20.00,'Top',1.00,43
```

pl.dat : plastic limit of the samples; The pl.dat file contains 4 fields. The first field contains the sample depth, the second field contains the location in sample, the third field contains the sample recovery, the fourth field contains the run or test result (Sengara 1988) (appendix D, pp.80, appendix A, pp.57).

```
4.00,'Middle',1.00,15
5.50,'Middle',1.00,15
10.50,'Middle',1.50,14
17.50,'Middle',1.00,17
20.00,'Top',1.00,17
```

fn.dat : fines of the samples; The fn.dat file contains 4 fields. The first field contains the sample depth, the second field contains the location in sample, the third field contains the sample recovery, the fourth field contains the run or test result (Sengara 1988) (appendix D, pp.80, appendix A, pp.57).

```
2.00,'Middle',1.00,20
4.00,'Bottom',1.00,68
5.50,'Middle',1.00,58
7.00,'Top',1.50,67
10.50,'Middle',1.50,68
17.50,'Middle',1.00,62
20.00,'Top',1.00,71
```

gd2dp.inp : graphics descriptor for the two points chosen (Sengara 1988) (appendix C, pp.75-76).

```
'PAGE'
 1.750000E+00 1.250000E+00 1.000000E+00 7.500000E-01 % Margins
'COORDINATES'                                       %(in inches)
200 100 'E 200,N 100'        % Coordinates of the first picked point
400 180 'E 400,N 180'        % Coordinates of the second picked point
```

bdata1.dat : descriptor of boring logs included; The bdata1.dat file contains 3 fields. The first field contains the boring name, the second field contains the soil description, the third field contains the layer depth (Sengara 1988) (appendix E, pp.82, appendix A, pp.56).

```
'B-1','Sandy Clay, medium stiff.',2.00
'B-1','Silty Clay, medium stiff, low plasticity, moist, shrinkage.',10.00
'B-1','Clay with some gravel (CL), low plasticity.',20.00
'B-1','Lean Clay (CL), stiff, low plasticity.',25.00
'B-3','Fine sand, medium dense.',2.00
'B-3','Silty clay, gray to rusty, very moist, stiff.',7.00
'B-3','Gravelly lean clay (CL), moderate plasticity.',18.00
'B-3','Lean Clay (CL), moderate plasticity.',24.00
```

```
'B-3','Limestone, buff, unweathered, weak, foliated.',30.00
'B-4','Sandy Clay (CH), medium plasticity, fine, dry to moist.',4.00
'B-4','Silt (ML), stiff, low plasticity, grey, saturated.',26.00
'B-5','SANDY CLAY (CL), very stiff, blue-green.',5.00
'B-5','Elastic Silt (MH), high plasticity, brown, wet.',28.00
'B-6','Sandy Clay (CH), high plasticity.',1.00
'B-6','Silty clay, gray brown, medium plasticity, medium stiff.',8.00
'B-6','Gravelly lean clay (CL), very stiff, moderate plasticity.',20.00
'B-7','Sand, fine grained, dry.',2.00
'B-7','Silty Clay, greyish brown, moist, stiff, shrinkage.',8.00
'B-7','Gravelly Lean Clay (CL), very stiff, moderate plasticity.',20.00
'B-8','Siltstone, moderately hard, unweathered.',25.00
'B-9','Silty Clay , gray brown, medium plasticity, medium stiff.',6.00
'B-9','Clay with stiff Silt, non plastic, grey, moist.',30.00
```

bdata2.dat : surface elevations and depths of boring logs chosen; The bdata2.dat file contains 3 fields. The first field contains the boring name, the second field contains the ground elevation, the third field contains the maximum depth (Sengara 1988) (appendix E, pp.85, appendix A, pp.55).

```
'B-1',199.00,25.00
'B-3',202.00,30.00
'B-4',202.00,26.00
'B-5',202.00,28.00
'B-6',199.50,20.00
'B-7',199.50,20.00
'B-8',200.00,25.00
'B-9',200.00,30.00
```

bdata3.dat : surface elevations and coordinates of boring logs chosen; The bdata3.dat file contains 4 fields. The first field contains the boring name, the second field contains the ground elevation, the third field contains the x-coordinate of the boring, the fourth field contains the y-coordinate of the boring (Sengara 1988) (appendix E, pp.85, appendix A, pp.55).

```
'B-1',199.00,300.00,150.00
'B-3',202.00,380.00,180.00
'B-4',202.00,380.00,120.00
'B-5',202.00,220.00,120.00
'B-6',199.50,260.00,150.00
'B-7',199.50,340.00,150.00
```

```
'B-8',200.00,300.00,180.00
'B-9',200.00,300.00,120.00
```

bdata4.dat : project information; The bdata4.dat file contains the project name and building name (Sengara 1988) (appendix E, pp.82, appendix A, pp.55).

```
'IPDS Geotechnical Demo I','A'
```

5.4 Running the Programs

The binary programs can be executed to display the graphs required or to create related postscript files for printing the graphs. For running *borlog01* or *prof2d01*, enter the program's name and the graph will be shown on the screen. Pushing the "Return" key again will quit the program immediately. For running *borlogps* or *prof2dps*, enter the program's name. Postscript files *borlog.ps* and *prof2d.ps* will be produced which, respectively, can then be printed on a postscript printer respectively.

For running *fenced01*, after entering the file name, a 3-D fence diagram with viewing angle (45,45) degrees will appear on the screen. There will be a small circle labeled "Rotate" shown on the bottom of the diagram. The arrow cursor can now be moved (by mouse) to "Rotate" and clicking and holding the right hand side button of the mouse will produce the choice menu. Moving the arrow to the chosen menu item, i.e., "v+5","v-5","h+5","h-5" or "exit", and releasing the button while either turn the fence diagram through an angle of 5 degrees either vertically or horizontally to avoid overlaying of the boring logs to one another, or just quit the program.

For running *fencedps*, after entering the file name, the program will ask the user to input viewing angles, and then it will produce a postscript file called *fenced.ps* with viewing angles as previously input.

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