3A04

UNIVERSITY OF SOUTHERN CALIFORNIA

Department of Civil Engineering

Liquefaction Ground Deformation Database

by

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Disclaimer

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SUMMARY

The liquefaction ground deformation database contains information on case histories of ground deformations induced by liquefaction after worldwide earthquakes. The database is intended for usage by researchers and practitioners in geotechnical earthquake engineering. Its development was prompted to improve the probabilistic models of liquefaction-induced ground displacement used for estimating damage to lifelines after earthquakes.

The database summarizes the state-of-the-art knowledge on case histories of liquefaction-induced ground deformation originating from the 1964 Niigata, Japan, earthquake; 1971 San Fernando, California, earthquake; 1983 Nihonkai-chubu (Noshiro), Japan, earthquake; 1994 Northridge, California, earthquake; and 1995 Hyogoken Nanbu (Kobe), Japan, earthquake. The database was constructed by identifying, collecting, organizing and digitizing available data sets on liquefaction-induced ground displacements. The data originating from different sources have been combined and archived. Legacy data, including hardcopy data reports on displacement vectors and soil SPT and CPT boreholes, have been converted to digital data format and stored in ASCII and GIS formats. All data have been structured and screened using a relational database management system (RDBMS), and were published into organized files systems readily usable by researchers in geotechnical engineering, and requiring no RDBMS knowledge. Data file formats include Microsoft Excel, jpeg and gif for photos and scanned documents, ASCII digital elevation models (DEM), and GIS shape files.

ACKNOWLEDGEMENTS

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1. STRUCTURE AND USAGE OF LIQUEFACTION GROUND DEFORMATION DATABASE

This section describes the structure of the liquefaction ground deformation database, and illustrates its usage through a few examples. The database is distributed on two CDs referred to as CD-1 and CD-2.

1.1 Basic requirements

Table 1 lists the various file formats which are used in the liquefaction ground deformation database and the programs which are required to read these files. Internet Explorer 5.0 (or higher) is required to read HTML documents; it can be downloaded from www.microsoft.com. Microsoft Excel 2000 or higher is required to read Excel workbooks. The liquefaction ground deformation database CDs includes an Excel97/2000 viewer, which is freely distributed by Microsoft (www.microsoft.com). The liquefaction ground deformation database contains boreholes data files, which can be optionally edited and printed using LogPlot2001 (www.rockware.com), and Digital Elevation Models (DEM), which can be optionally edited using Surfer (www.goldensoftware.com). The liquefaction ground deformation database contains Geographic Information System (GIS) files. ArcExplorer2.0 and/or ArcGIS8.x are required to read these GIS files. The liquefaction ground deformation CDs includes ArcExplorer2.0, which is a GIS viewer freely distributed by ESRI (http://www.esri.com/software/index.html). ArcExplorer2.0 should be installed on the user's computers before attempting to read ArcExplorer2.0 project files. The project files of ArcExplorer2.0, which have *aep* as file name extension, are supported only by ArcExplorer2.0, and not by ArcExplorer3.0 and ArcExplorer4.0. ArcGIS8.x is a GIS program commercially available from ESRI, which has more advanced GIS features than ArcExplorer2.0, e.g. spatial and geostatistics analysis. The GIS files, which have for extensions *shp, sbn, sbx, shx*, and *dbf*, are called by the project files of ArcExplorer2.0 (*aep*) and ArcGIS8.x (*mxd*)..

Table 1. File formats and required software in liquefaction ground deformation database.

File Type	File Extension	Associated software
HTML Document	.htm	Microsoft Internet Explorer 5.0
Microsoft Excel Workbook	.xls	Microsoft Excel 2000
JPEG Image File	.jpg	Graphic software (e.g., PaintShop)
GIF Image File	.gif	Graphic software (e.g., PaintShop)
ASCII Text File	.txt, .dat, .cpd	ASCII file editor
Adobe Acrobat Document	.pdf	Adobe Acrobat Reader
ESRI Shapefile	.shp, .sbn, .sbx, .shx, .dbf	ArcView3.x / ArcGIS8.x / ArcExplorer2.0
ESRI Coordinate Projection File	.prj	ArcView3.x / ArcGIS8.x
USGS DEM File	.DEM	ArcView3.x / ArcGIS8.x / Surfer
ArcExplorer2.0 Project File	.AEP	ArcExplorer2.0
ArcGIS8.x Project File	.MXD	ArcGIS8.x

1.2 Organization of data

As shown in Fig. 1, the liquefaction ground deformation database is distributed on CDs as linked file systems. Files can be moved from the CDs to other media only as entire directory for preserving links between files. The main access point is the HTML file called *contents.htm*. The folder *HTML Files* contains accessory materials common to the case histories (e.g., logos). The folder *FileViewers* includes the installation files for ArcExplorer2.0 and Excel Viewer, in case these programs are needed.

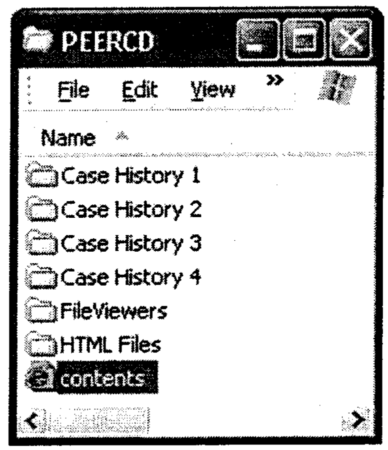

Figure 1. Directory structure of liquefaction ground deformation database.

As shown in Fig. 1, the case histories of liquefaction ground deformation are organized in different folders, which are named according to their geographic location. The case histories included in the CD-1 are listed Figure 2. There are four case histories, named as *Loma Prieta*, *Niigata*, *Noshiro* and *Van Norman Complex*, respectively.

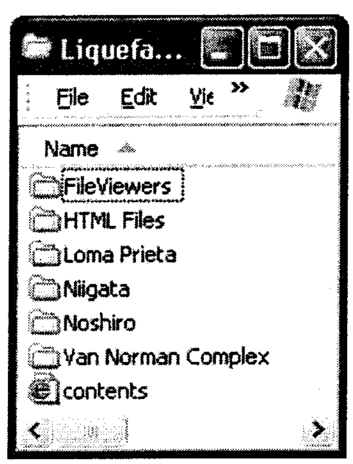

Figure 2. Four case histories included in the liquefaction ground deformation database CD-1.

As shown in Fig. 3, all the case histories are organized in four sub-directories (1) *Aerial Photos,* (2) *Boreholes,* (3) *Displacements,* and (4) *GIS Files.* These folders include original as well as processed information.

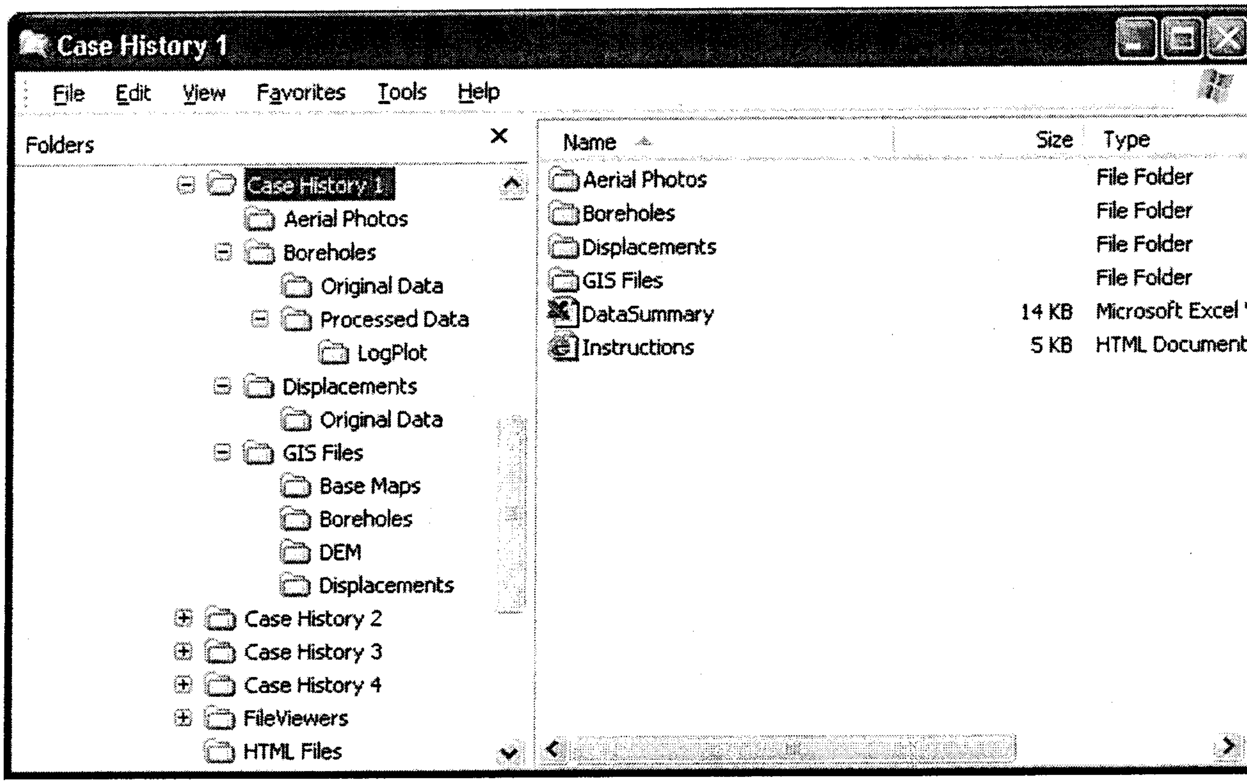

Figure 3. Subdirectory structure of case history data in liquefaction ground deformation database.

The GIS files, which include ArcExplorer2.0 and ArcGIS8.x project files, require ArcExplorer2.0 and/or ArcGIS8.x. ArcExplorer2.0 offers basic GIS functions to display and query spatial data. ArcGIS8.x offers more advanced GIS features.

The database contains some limited amount of metadata. For instance, file *DataSummary.xls* contains data on boreholes and displacements data files. There are also Excel files in the directories *Aerial Photos* and *GIS Files*, which summarize file size and type.

1.3 Displaying database contents

As shown in Fig. 4, *Contents.htm* is the main HTML page which displays the information in the liquefaction-induced ground deformation database. *Contents.htm* lists the case histories contained in this CD. Each case history data can be accessed by clicking on a case history name.

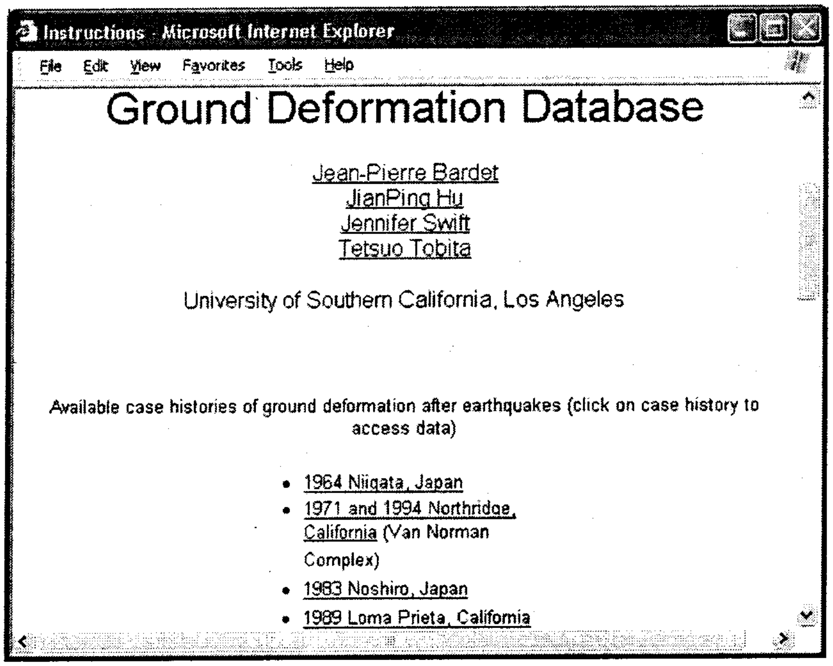

Figure 4. Case histories of liquefaction-induced ground deformation in CD 1.

As shown in Fig. 5, the complete information about a particular case history is organized using the same file structure with four subdirectories. The content of each subdirectories can be detailed as follows:

- Directory *Aerial Photos* contains the aerial photos of the areas where liquefaction ground deformations were measured. This information is useful to get a better understanding of the areas under study. Most of these aerial photos were taken after the earthquake, and have been used in the processing of displacement vectors. Aerial photos are either in JPEG or GIF formats. All the information on aerial photos is summarized in the Excel workbook *AerialPhotos.xls*. Photos can be viewed by clicking on their name.

- Directory *Boreholes* contains borehole data. It includes the original scanned borehole profiles as well as processed borehole data.

    - Subdirectory *Original Data* contains the scanned data, which were used to generate digital data for boreholes. This information is useful for verifying the transformation from hardcopy graphics (original reports) to digital data.

    - Subdirectory *Processed Data* contains borehole graphics, ASCII files of borehole profiles and LogPlot input data files. Using the LogPlot input data files, one can reproduce and edit independently the boreholes graphics provided in the liquefaction induced ground deformation database.

- Directory *Displacements* contains data files on liquefaction-induced ground deformation. Workbook *DataSummary.xls* summarizes all the information available on boreholes and displacements. It also contains information on earthquakes. Additional explanations on *Displacements* are presented in a later section.

- Directory *GIS files* contains the information related to GIS files. Workbook *GISFiles.xls* summarizes the GIS files. The GIS files are compatible with ESRI ArcExplorer2.0 and ArcGIS8.x. It is recommended to use the GIS project files, which have for extension *aep* for ArcExplorer2.0 and *mxd* for ArcGIS8.x, as those contained the various GIS layers. There are four types of GIS layers: (1) Base map, (2) DEM, (3) Boreholes and (3) Displacements. Base map is used for geo-referencing spatial data. DEM is used to create digital elevation models. Boreholes list the shape files used to represent spatial distribution of boring logs. Displacements give the spatial distribution of displacement vectors.
    - Subdirectory *Base Maps* contains the base maps that are GIS enabled.
    - Subdirectory *DEM* contains the DEM files used to generate elevation models and topography.

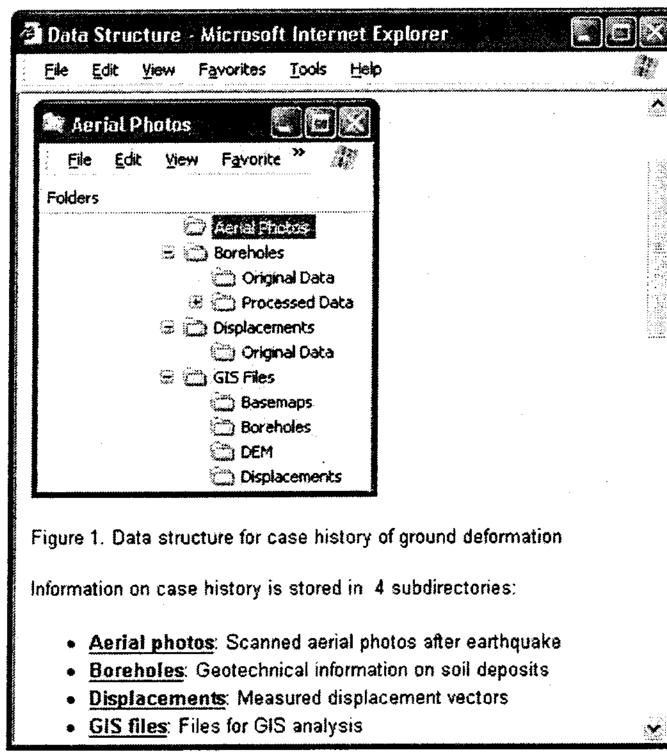

Figure 5. Sub-structure of case history data as displayed in the liquefaction ground deformation database.

1.4 Data presentation using Excel Workbook

Displacement vectors and borehole information are tabulated and keyed using geographic coordinates. The database reports displacement vectors and borehole data in the Workbook *DataSummary.xls* for those who are mostly familiar with spreadsheets. Workbook *DataSummary.xls* provides users with some basic graphical display capabilities, which can be used to explore and query the database. Workbook *DataSummary.xls* contains seven worksheets:

1. Definitions: Terms used to characterize borehole data

2. GISMap: Graphic display of boreholes and displacement vectors
3. Summary: Summary results on boreholes and displacement vectors
4. Boreholes: Coordinates, types, files, and references for boreholes
5. Displacements: Coordinates and amplitude of deformation
6. Earthquake: Earthquake information
7. References: List of references about boreholes

Worksheets GISMap, Boreholes and Displacements can be used to query and visualize data graphically. Table 2 defines the headers of worksheets Borehole, Displacement, Earthquakes and References.

Table 2. Headers in worksheets Boreholes, Displacements, Earthquakes and References.

Worksheet	Header	Description
Boreholes	ID	Borehole ID
	Name	Borehole name
	Type	Borehole type (SPT, CPT, etc)
	TestDate	Test date
	Northing	Northing coordinate of borehole location (m)
	Easting	Easting coordinate of borehole location (m)
	Elevation	Elevation (m)
	GWT	Ground water depth (9999 means no measurement)
	ProcessedData	Text file containing digital version of borehole information
	OriginalScanedImage	Original scanned borehole profile used for creating Processed Data
	LogPlotData	Data file for LogPlot
	Graph	Graphic file of borehole profile generated using Processed Data
	Reference	Reference number on borehole
Displacements	No	Vector ID
	Xbefore	x-coordinate before earthquake (m)
	Ybefore	y-coordinate before earthquake (m)
	Zbefore	z-coordinate before earthquake (m)
	Xafter	x-coordinate after earthquake (m)
	Yafter	y-coordinate after earthquake (m)
	Zafter	z-coordinate after earthquake (m)
	Hdisp	Lateral displacement (cm)
	Vdisp	Vertical displacement (cm)
Earthquakes	EqID	Earthquake ID
	EqNm	Earthquake name
	Date	Date earthquake happened
	Latitude	Latitude of epicenter
	Longitude	Longitude of epicenter
	Magnitude	Magnitude of earthquake
	MagType	Magnitude type
References	RefID	Reference ID
	Authors	Authors
	Date	Publication date
	Title	Title of reference (including source)

Figure 6 displays the GISMap worksheet for the case history on the 1964 Niigata, Japan earthquake. The base map represents Niigata city boundary. The arrows represent the displacement vectors, which correspond to the displacements of actual objects tracked on aerial photographs before and after the earthquake. As shown in Fig. 6, the dots represent the borehole locations. The *Display* button is used to display interactively the result of user-defined queries. The *Clear All* button erases all of the dots and vectors.

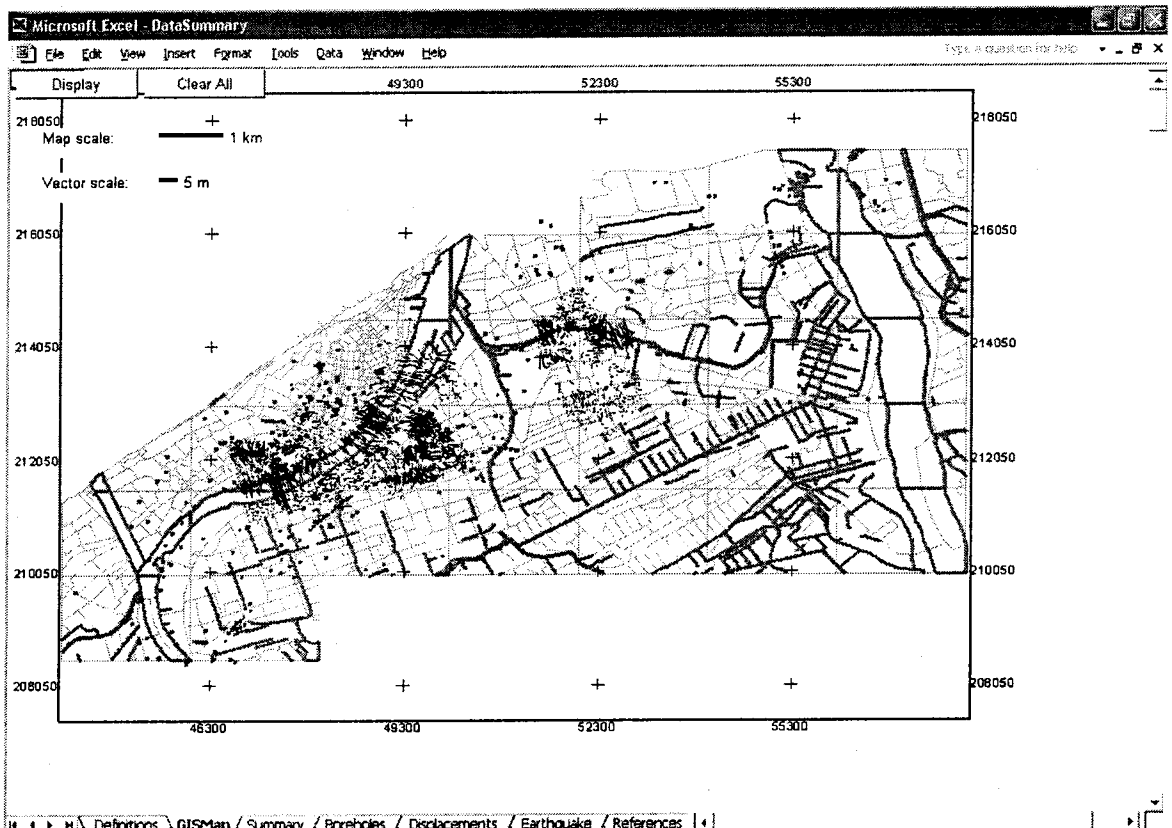

Figure 6. Graphics in Excel worksheet GISMap displaying location of boreholes and displacement vectors in Niigata, Japan.

Microsoft Excel provides users with some basic capabilities to query and extract data with desirable properties, e.g., displacements vectors over a selected region. These techniques are referred to as filtering. In the *Data* menu, the function *Filter* can be used to filter data that meet the user-defined criteria. The filtered data can be displayed in worksheet GISMap using the *Display* button. As shown in Fig. 7, data can be filtered using either *Autofilter* for basic criteria or *Advanced Filter* for more complex criteria. In most cases, *Autofilter* is versatile enough and meets most user requirements. *Advanced Filter* accepts a larger number of query parameters but is slightly more complicated to use, *Advanced Filter* performs sophisticated filtering reminiscent of those offered by SQL (Structured Query Language) in RDBMS. It is recommended to consult the Microsoft Excel Help before using *Advanced Filter.*

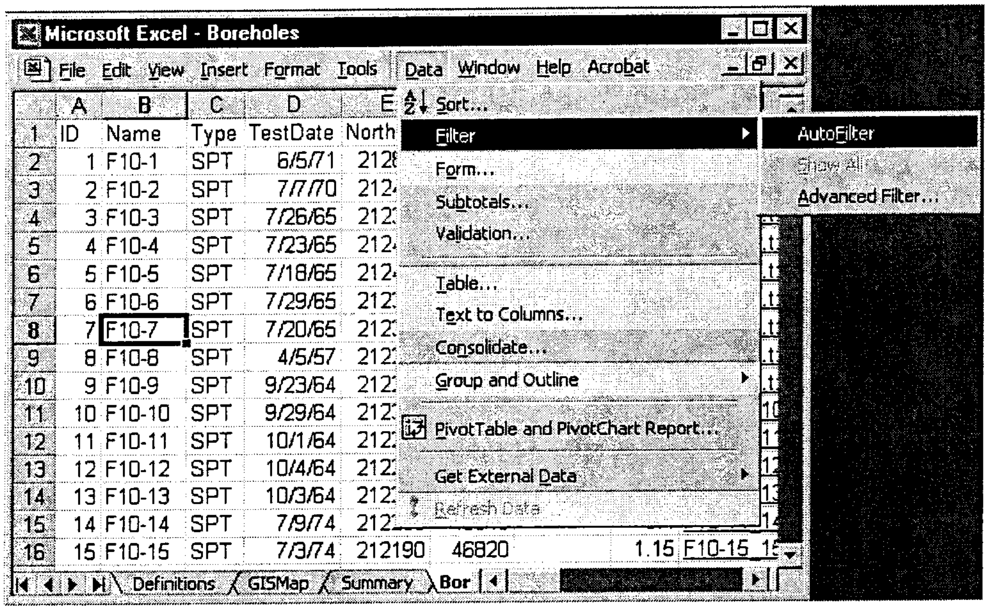

Figure 7. Data query using *AutoFilter* in Excel spreadsheet.

Two examples of user queries are given below to illustrate the application of AutoFilter to the liquefaction ground deformation database.

1.4.1 Example 1.

In this first example, we illustrate how to extract the displacement data corresponding to horizontal deformation greater than 300 cm.

1. Select Worksheet *Displacements*.
2. Using the *Data* menu, select *Filter*, and *AutoFilter*.
3. Pull the drop-down list at the header of column *Hdisp*, and select *Custom...* (Fig. 8).
4. In the Custom AutoFilter window (Fig. 9), click the drop-down menu and choose *is greater than*, enter "300", then click OK.
5. Select worksheet *GISMap*, and click the *Display* button to display the filtered data as shown in Fig. 10.

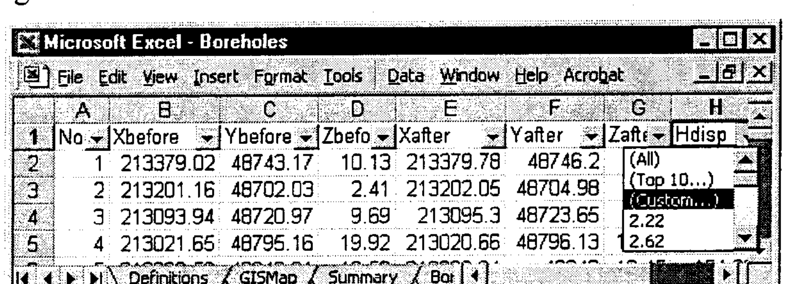

Figure 8. User-defined filter criteria using the column heading "Hdisp" in the Excel worksheet *Displacements*.

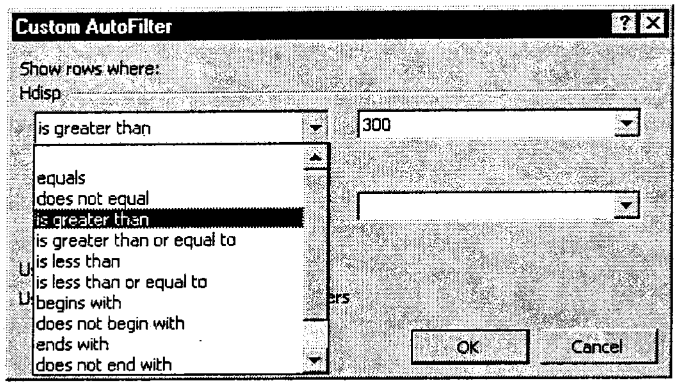

Figure 9. Custom AutoFilter dialog to input user-defined filter criteria "Hdisp >= 300cm".

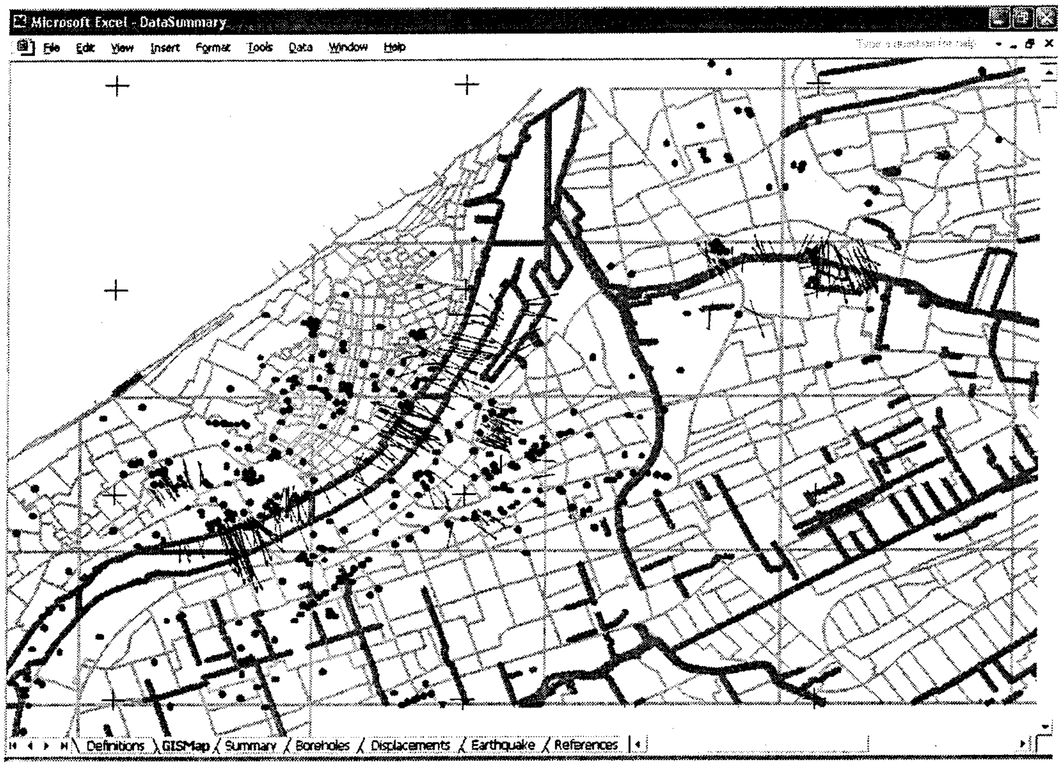

Figure 10. User-defined query result for horizontal deformation greater than 300 cm in Excel worksheet *GISMap*.

1.4.2 Example 2.

The second example illustrates how to extract boreholes and displacements data that are located between the coordinates (46500, 210800) and (50000, 213500).

1. Select worksheet *Boreholes.*
2. Using the *Data* menu, select *Filter*, and *AutoFilter*.
3. Pull the drop-down list at the header of column *Northing*, and select *Custom….*

4. In the *Custom AutoFilter* window (Fig. 11), click the drop-down list, choose *is greater than*, enter "210800", click *And*, click the second drop-down list, choose *is less than*, enter "213500", and click *OK*.
5. Pull the drop-down list at the header of column *Easting*, and select *Custom*....
6. Repeat step 4 using "46500" and "50000", respectively (See Fig. 12)
7. Select worksheet *Displacements*.
8. Repeat steps 2 to 6
9. Select worksheet *GISMap*, and click the *Display* button in order to display results similar to those of Fig. 13.

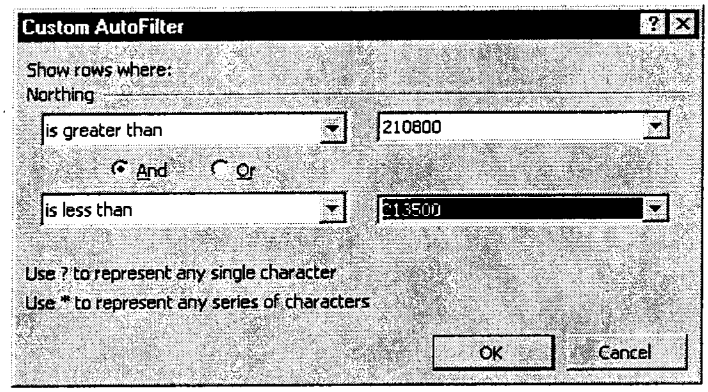

Figure 11. Custom AutoFilter dialog to input filter criteria for Northing coordinate between 210800 and 213500.

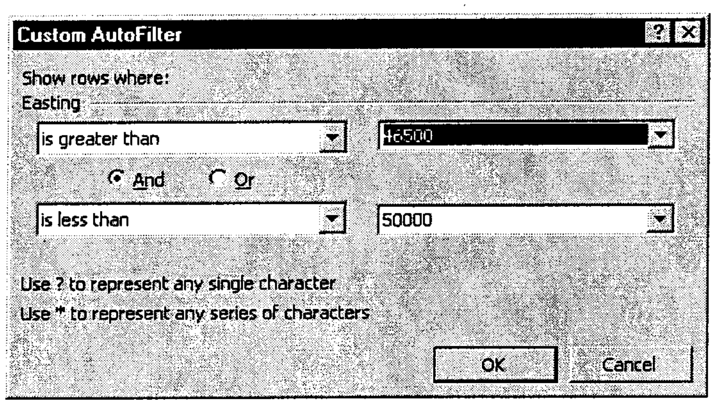

Figure 12. Custom AutoFilter dialog to input filter criteria for Easting coordinate between 46500 and 50000.

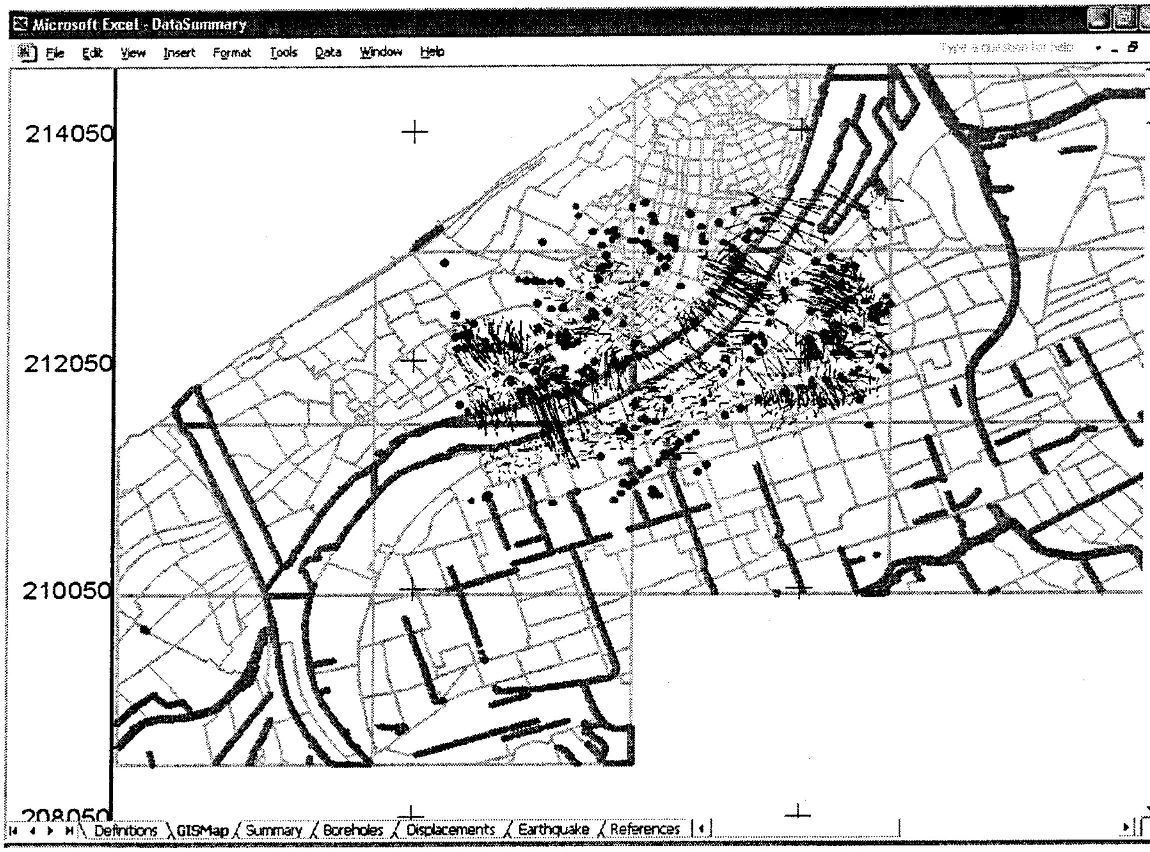

Figure 13. User-defined query result of the coordinates between (46500, 210800) and (50000, 213500) in Excel worksheet *GISMap*.

1.5 Data presentation and manipulation using GIS software

Spatial data (e.g., displacement vectors and borehole data) are best visualized using a GIS environment. GIS files such as Basemap and DEM files can be visualized through GIS software such as Surfer, ArcView and ArcGIS. GIS files in the liquefaction ground deformation database are prepared using ArcGIS8.x, which is one of the most popular commercially available GIS software (www.esri.com). DEM files are prepared according the standard format published by USGS (www.usgs.gov).

1.5.1 Data presentation

Each case history contains two GIS project files with file extension name *AEP* or *MXD*, which are included in the subdirectory *GISFiles*. ArcExplorer2.0 is required to use the *AEP* file to view the content, and for the *MXD* file, ArcGIS8.x must be used.

ArcExplorer2.0 is a lightweight GIS data viewer, which has limited data visualization or manipulation capabilities. As shown in Fig. 14, ArcExplorer2.0 can visualize *AEP* project files containing displacements, boreholes, geographic and topographic data. The menu bar and tool bars are useful to add themes to existing data sources, control theme characteristics, print the maps, zoom in/out, pan and identify map features. Users also have the capability to query geographic attribute data and perform basic statistical analysis.

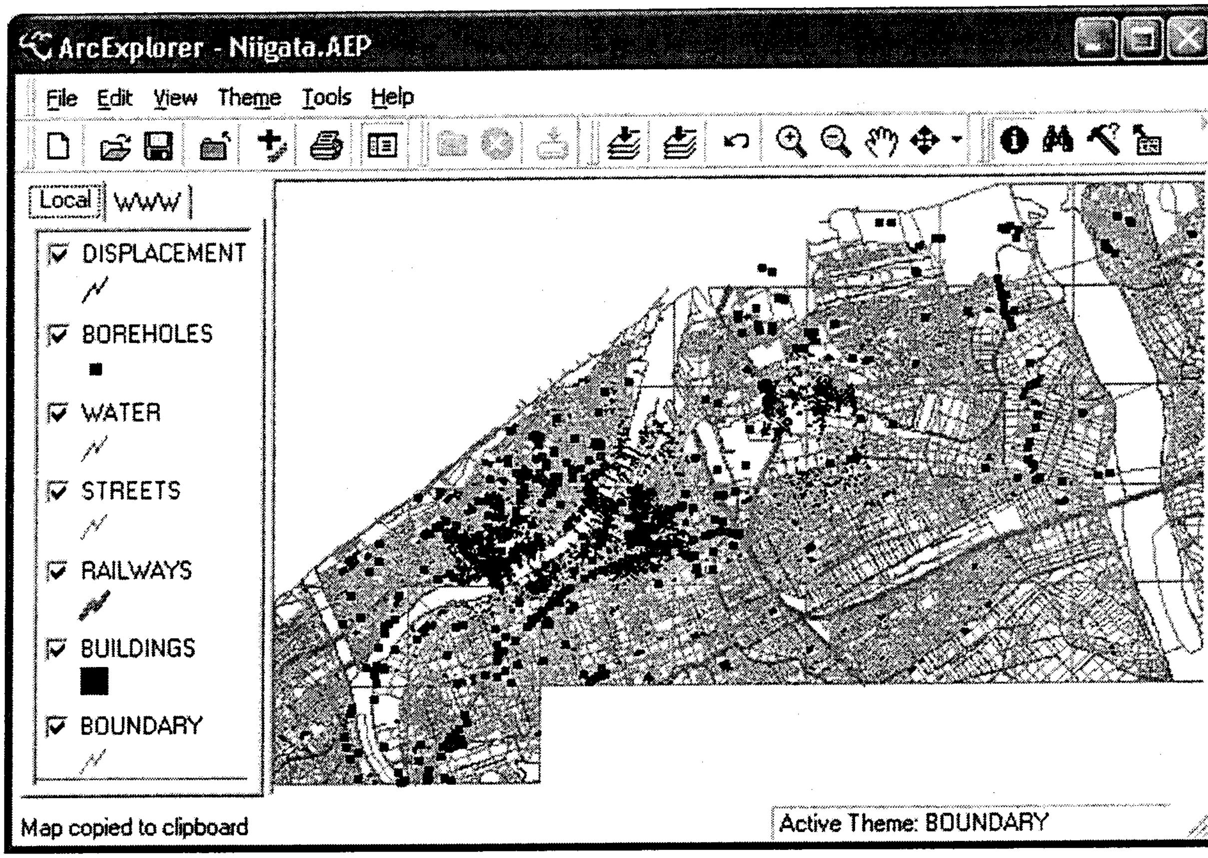

Figure 14. Example of ArcExplorer2.0 project file (data source from Niigata, Japan).

The liquefaction ground deformation database contains *MXD* project files, which require ArcView8.x but provide much more flexibility to GIS users. Figure 15 shows an example of an *MXD* project from the Niigata, Japan case history. In this project, Visual Basic functions were implemented in the MXD to extend their usability. As shown in Fig. 15, a hyperlink function displays borehole information on an HTML page. When the user moves the mouse over a given area, the name of the boreholes in this area will be displayed. By clicking on a location, boreholes will be listed in the "Hyperlinks" dialog box, and users can select a particular borehole to obtain more detailed information. For instance, Fig. 16 displays the available information on a particular borehole, including the borehole ASCII file, original scanned image of borehole profile, and LogPlot2001 data file.

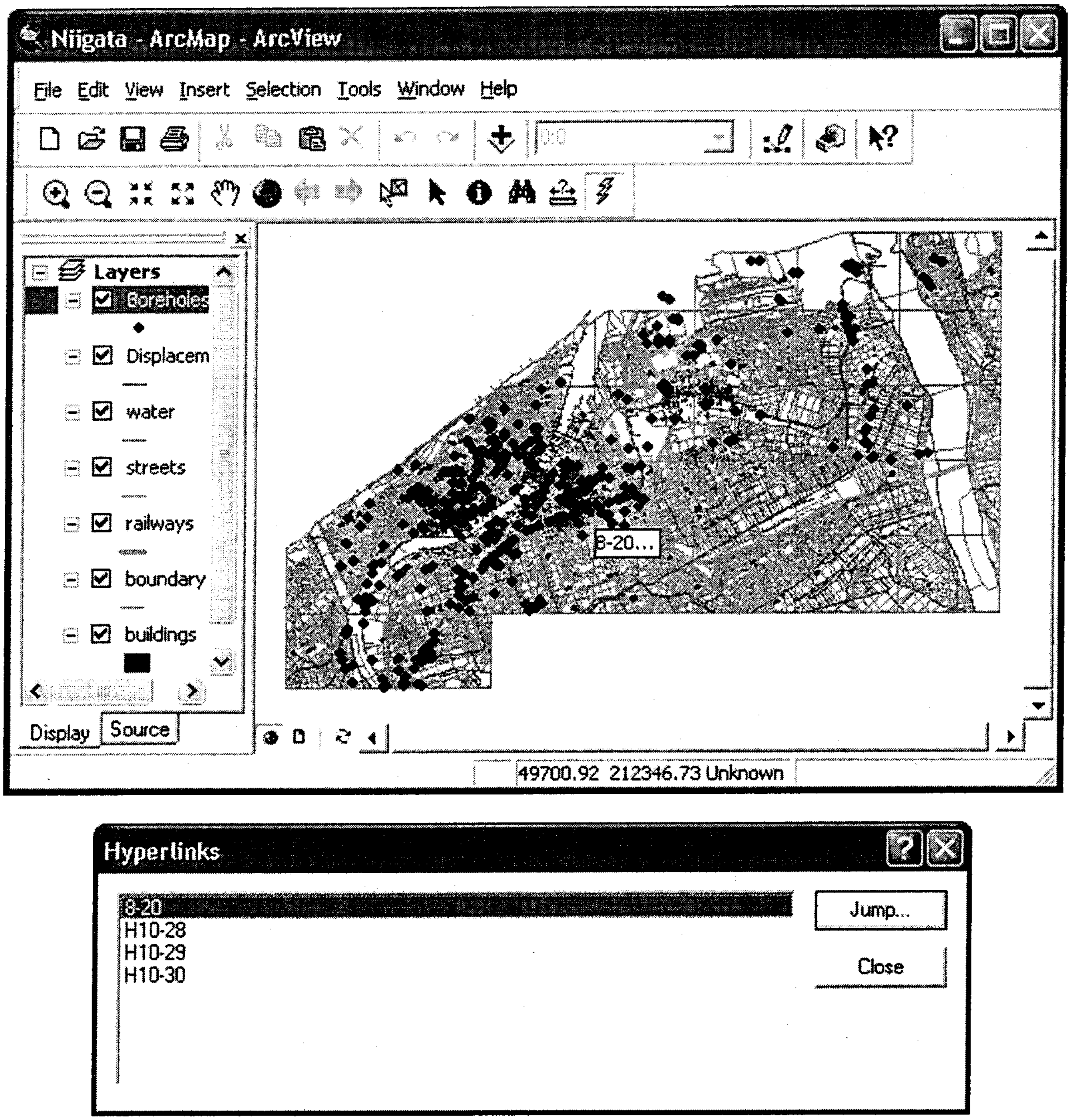

Figure 15. Example of MXD project file with Hyperlink functionality (data source from Niigata, Japan).

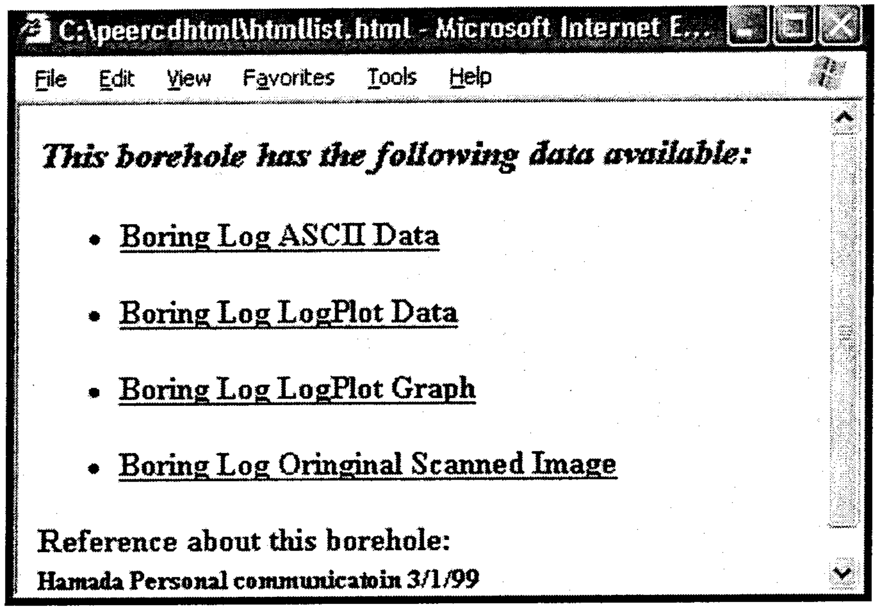

Figure 16. Available information list from selected borehole through the hyperlink.

1.5.2 Data manipulation

We will give two examples of visualization and utilization of the GIS files contained in the liquefaction deformation database, using two common GIS systems, i.e., Surfer and ArcView8.x.

Example 1

The first example shows how to visualize a basemap file.

Surfer users

1. Select *File -> Import* menu.
2. From *Import File* dialog, navigate to the directory that contains the basemap file (Fig. 17), select the file you want to visualize, and Click *Open.*
3. Customize the *Import Option* dialog or leave as default, and Click *OK.*
4. Repeat step 1 to 3 to Import all the basemaps required (See Fig. 18)

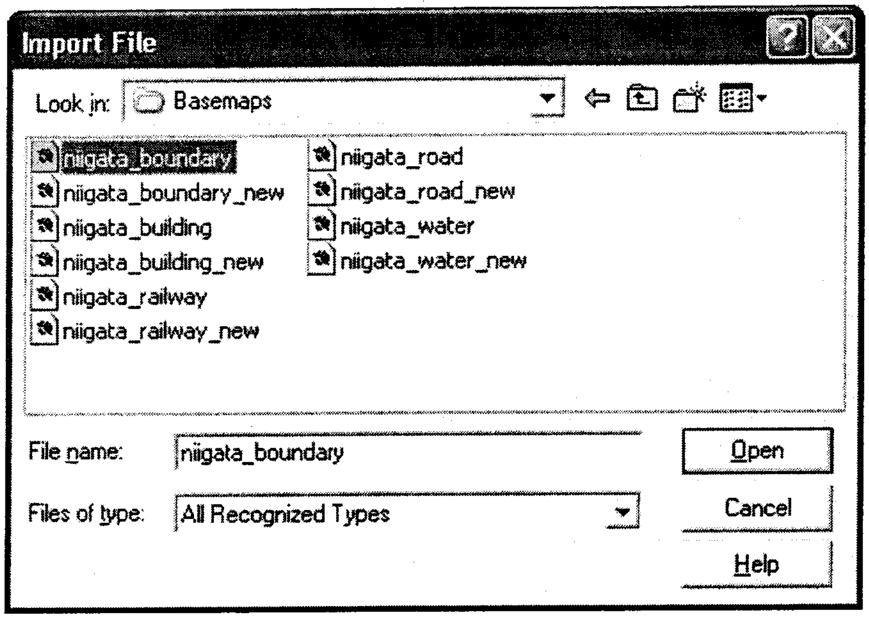

Figure 17. Open file catalog for importing basemap file of Niigata boundary in Surfer.

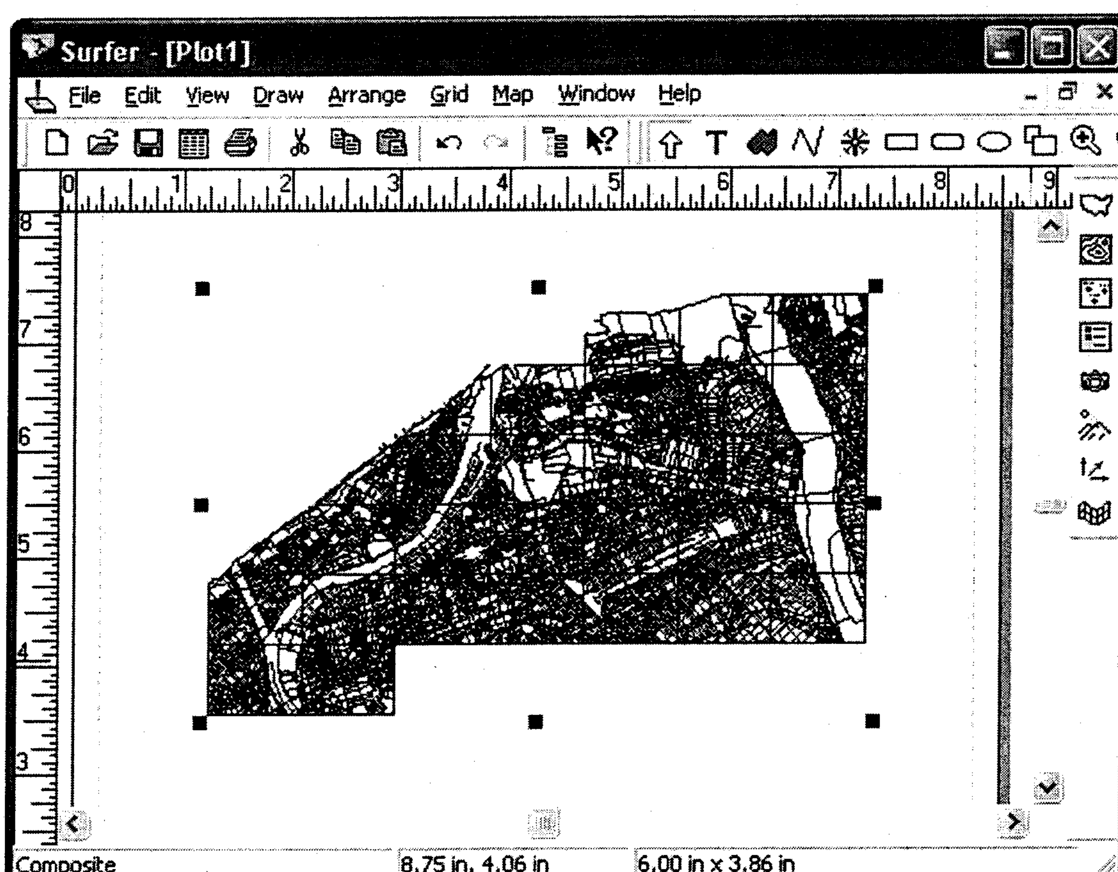

Figure 18. Imported Niigata basemap file in Surfer showing the Niigata city boundary.

ArcGIS8.x users

1. Create a new *Project* from *File* menu.
2. Click *Add data* toolbar.
3. From *Add data* dialog, navigate to the directory that contains the basemap file (Fig. 19) and select the file you want to visualize (Fig. 20). You can select multiple files pressing the *Ctrl* key, and Click *Add*.

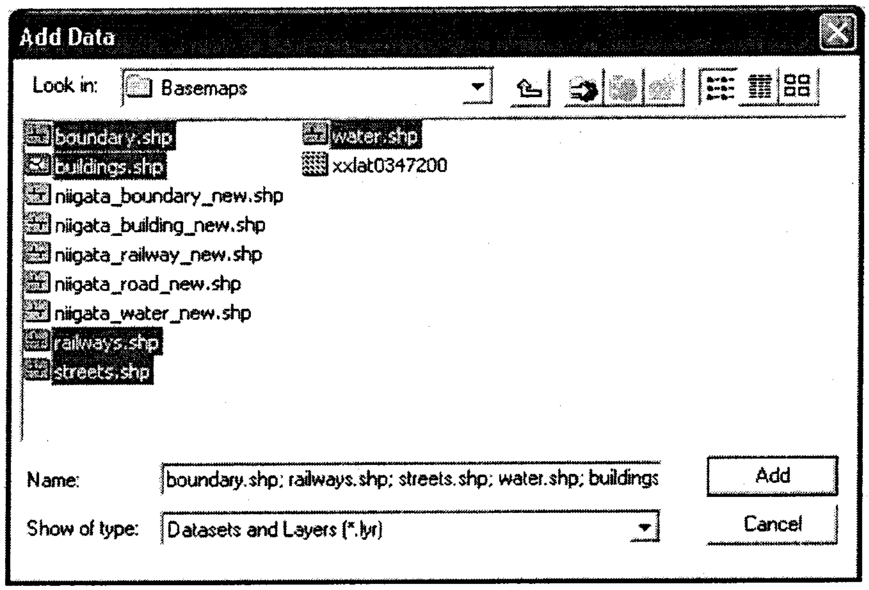

Figure 19. Import file dialog to import basemap of Niigata city in ArcGIS8.x.

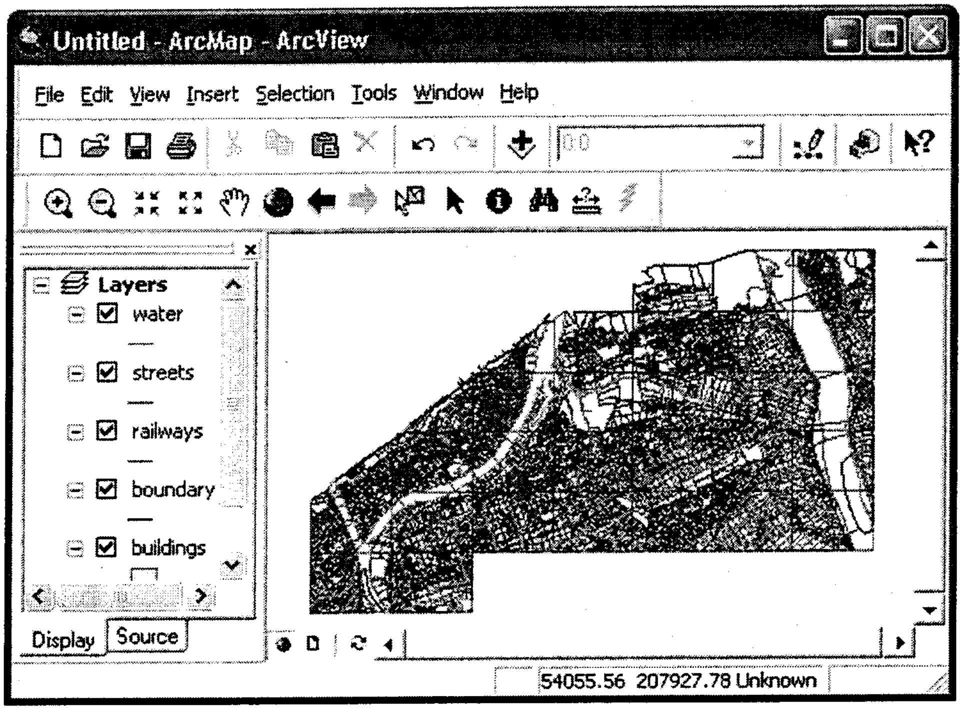

Figure 20. Imported Niigata basemap showing the water, street, railway, building and city boundary in ArcGIS8.x.

Example 2

The second example illustrates how to utilize the DEM files for deriving the slope information. DEM files are handled differently by ArcView3.x and ArcGIS8.x. Step-by-step instructions are given to import DEM files in Surfer, ArcView3.x and ArcGIS8.x. Due to a limitation of ArcView3.x or ArcGIS8.x, users should be careful not to add any spaces within the file path of DEM files.

Surfer users

1. Create a new *Plot Document* from *File -> New.*

2. Select *Grid -> Calculus....*

3. Navigate to the folder containing the DEM file in the *Open Grid* dialog (Fig. 21), select the DEM file, and then Click *Open.*

4. From *Grid Calculus* Dialog, click the drop down list for *Grid-to-Grid Operation* to choose *Terrain Modeling*, then click the drop down list for *Output Grid File* to specify the folder and file name of the new grid, then click *OK* (Fig. 22).

5. Select *Map -> Contour Map -> New Contour Map*, from *Open Grid* dialog navigate to the file you just specified to select and open it.

6. Customize the *Contour Map Properties* in the dialog or leave as default, then click *OK* (Fig. 23).

7. Slope derived from DEM is displayed as a contour map in the plot area (Fig. 24).

It is recommended to refer to the Surfer User's Manual for more information and options on Grid Calculus and Map Plotting.

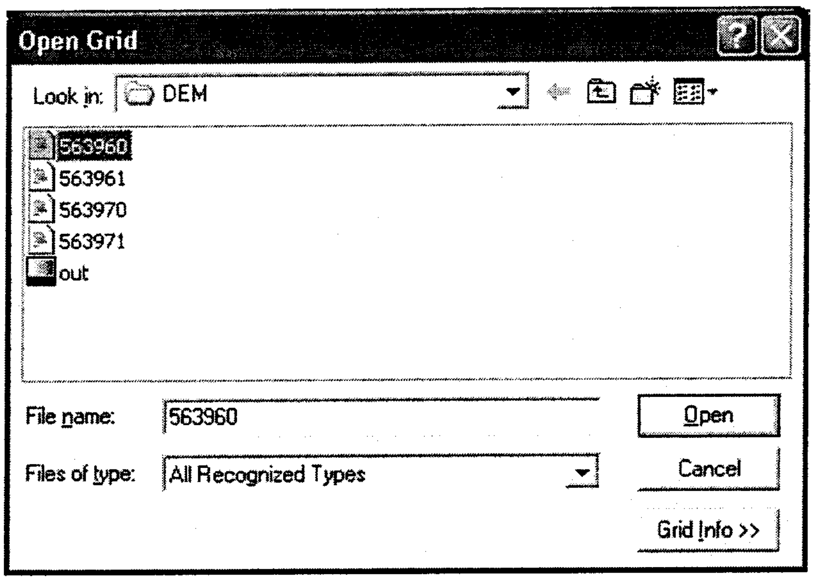

Figure 21. Open file dialog to navigate one of the DEM files in Niigata city using Surfer.

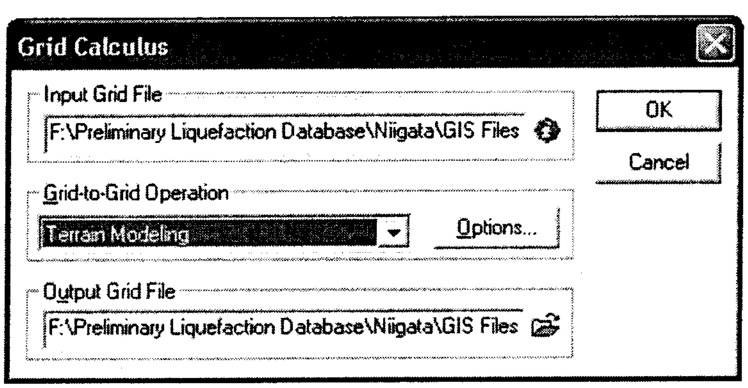

Figure 22. Option of grid calculus to derive the slope information from DEM using Surfer.

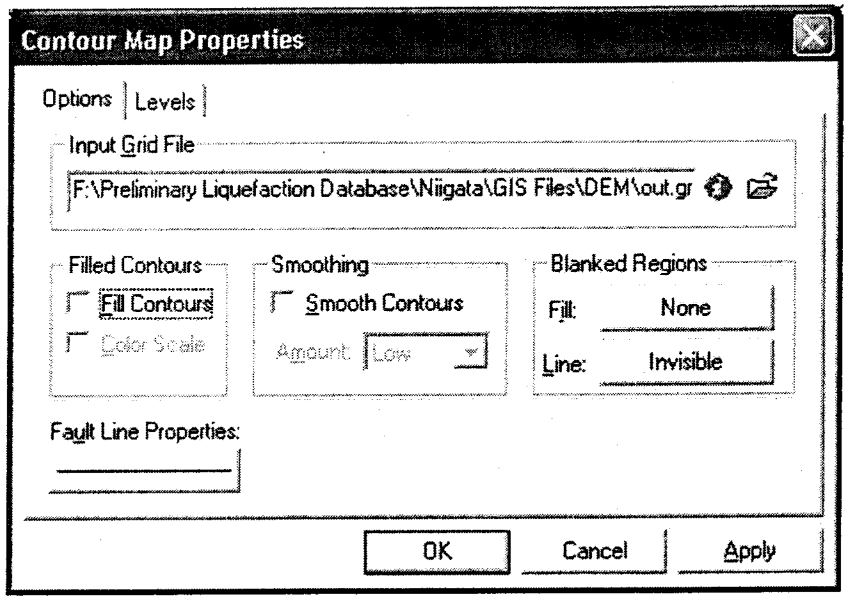

Figure 23. Contour map properties dialog to specify the contour map properties using Surfer.

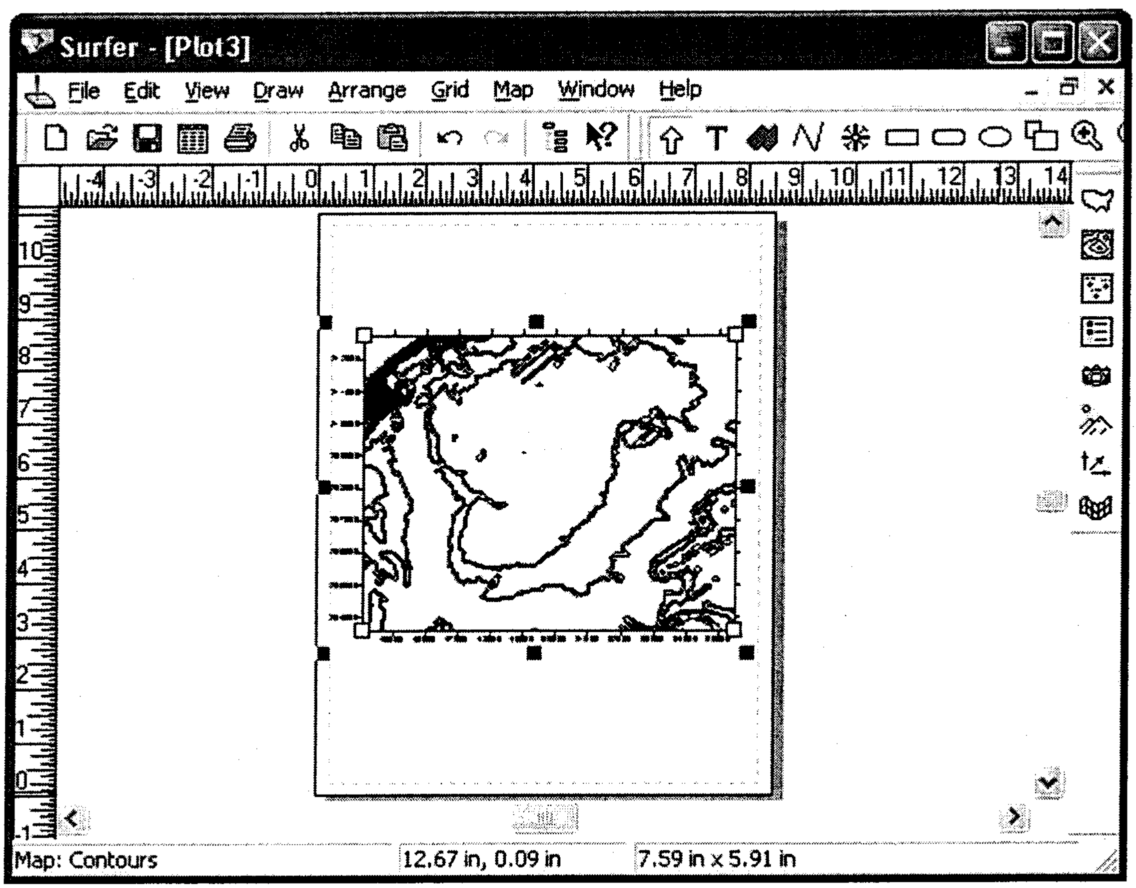

Figure 24. One of the DEM files of Niigata city represented by Surfer.

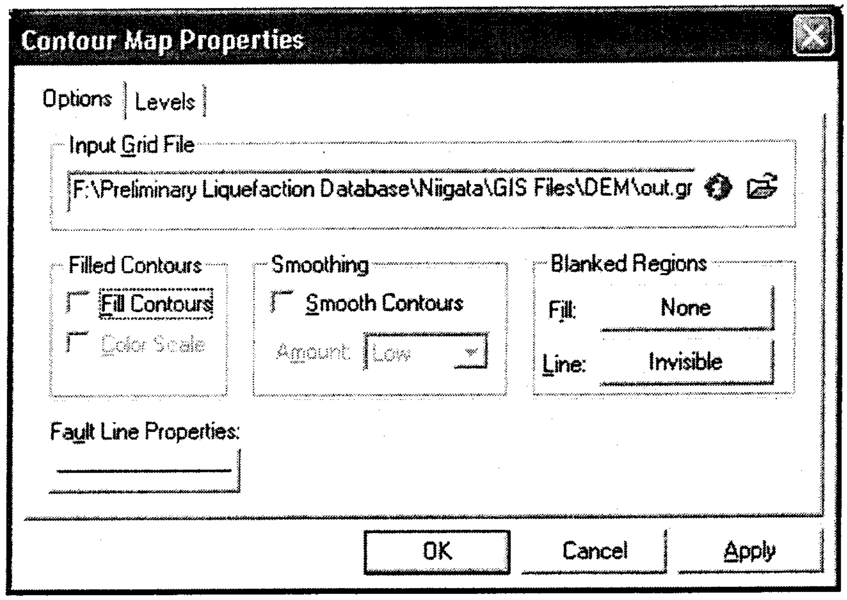

Figure 23. Contour map properties dialog to specify the contour map properties using Surfer.

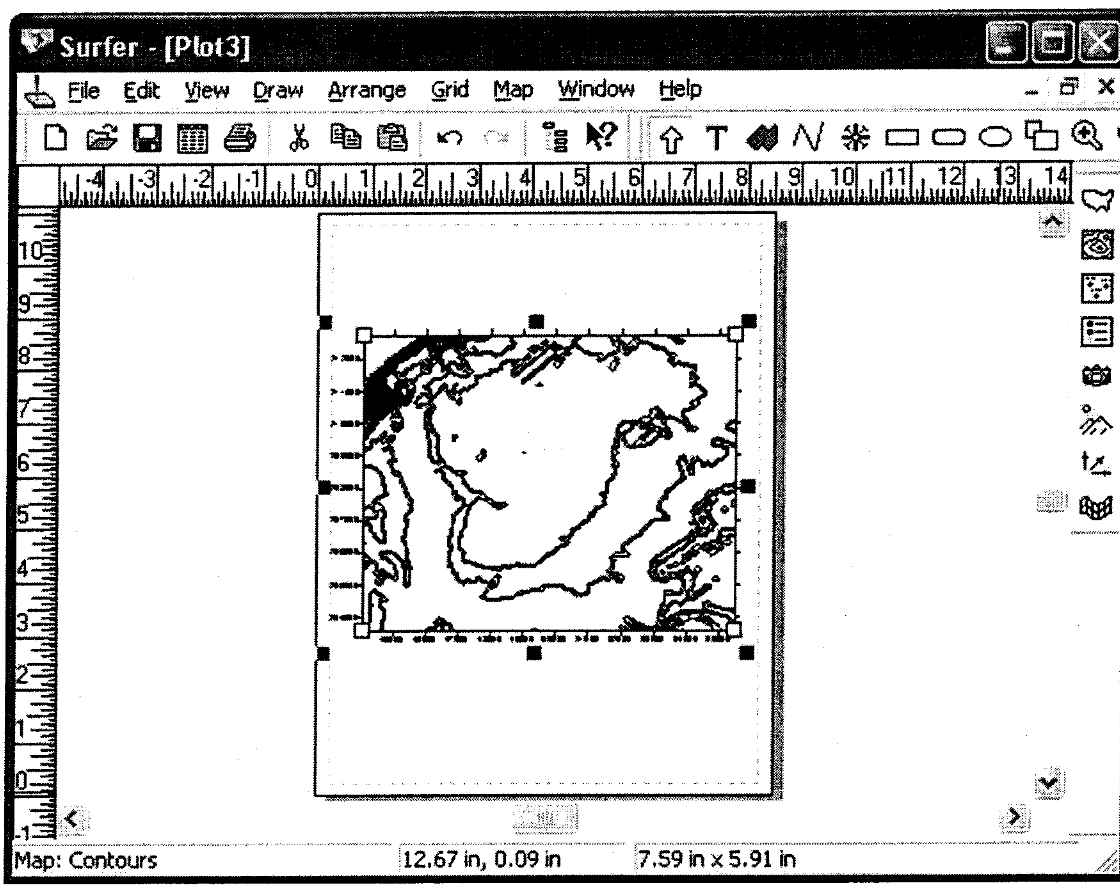

Figure 24. One of the DEM files of Niigata city represented by Surfer.

ArcView3.x users

The utilization of DEM files in ArcView3.x requires the installation of either the Spatial Analyst or the 3D Analyst extensions.

1. Create a new View from Project window.
2. Select File -> Import Data Source…
3. From Import Data Source dialog, select USGS DEM, and click OK (Fig. 25).
4. Navigate to select the DEM file from Import USGS DEM Files dialog, and click OK (Fig. 25).
5. Specify the Output grid file name and location, and click OK (Fig. 26). Ignore any error message by clicking OK.

Figure 27 gives an example of DEM files visualized in ArcView3.x.

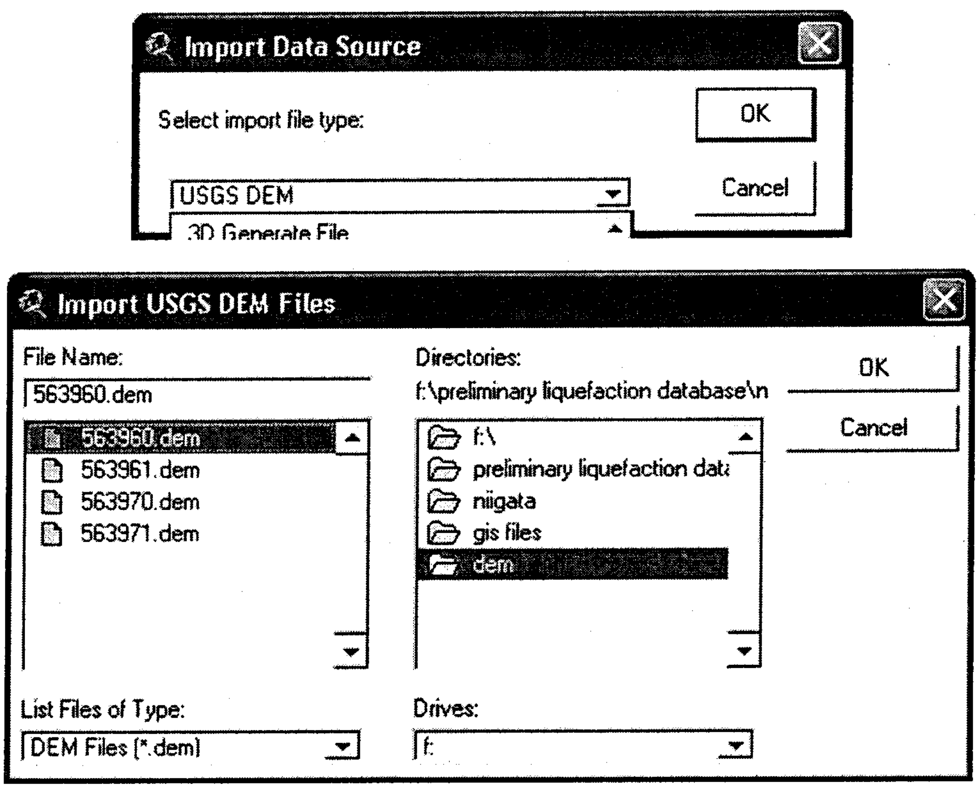

Figure 25. Import dialog to import one of the DEM file in Niigata city using ArcView3.x.

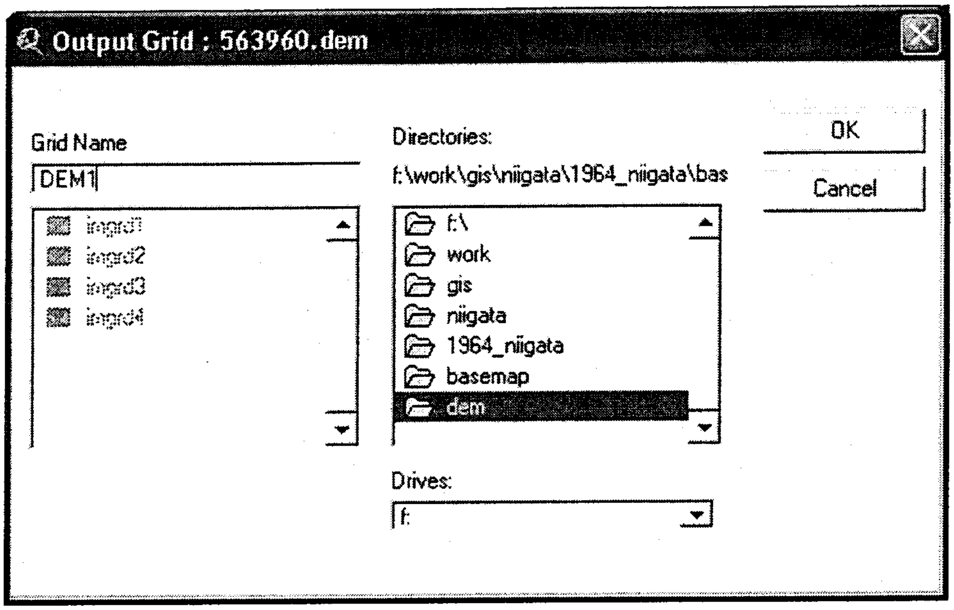

Figure 26. Output grid dialog to specify the grid obtained from DEM data imported in Figure25.

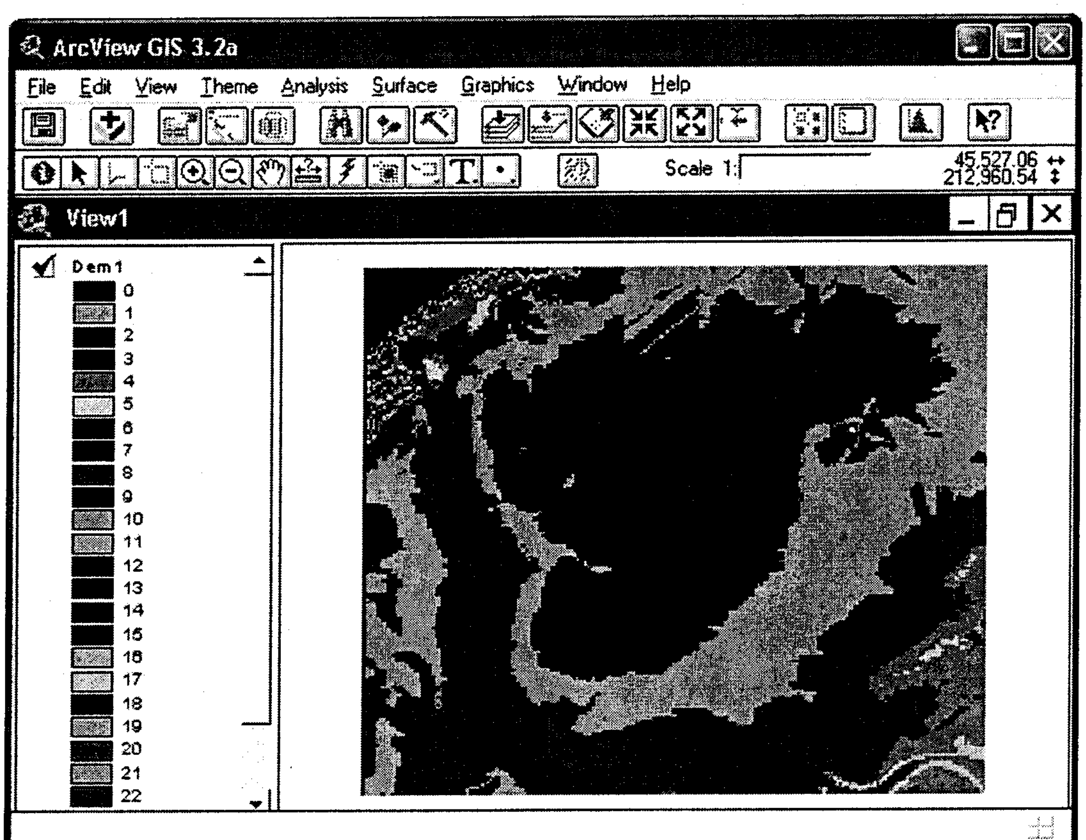

Figure 27. A DEM files in Niigata city represented in ArcView3.x.

Spatial Analyst or 3D Analyst extensions can be used to derive slope, after a DEM file has been imported to ArcView3.x as grid file. Refer to the Online Help of ArcView3.x for advanced GIS operations.

ArcGIS8.x users

ArcGIS8.x handles DEM files differently from ArcView3.x. The ArcToolBox, which is bundled with ArcView8.x, must be launched to utilize DEM files.

1. Select Conversion tools -> Import to Raster -> DEM to Grid (Fig. 28).
2. Specify data source (path) of DEM file and provide a output grid file name in the DEM to Grid dialog (Fig. 29).

When finished, the process generates a GRID file, which can be directly imported into ArcView3.x or ArcView8.x. The same approach can be used to handle the grid file to get slope or other spatial information.

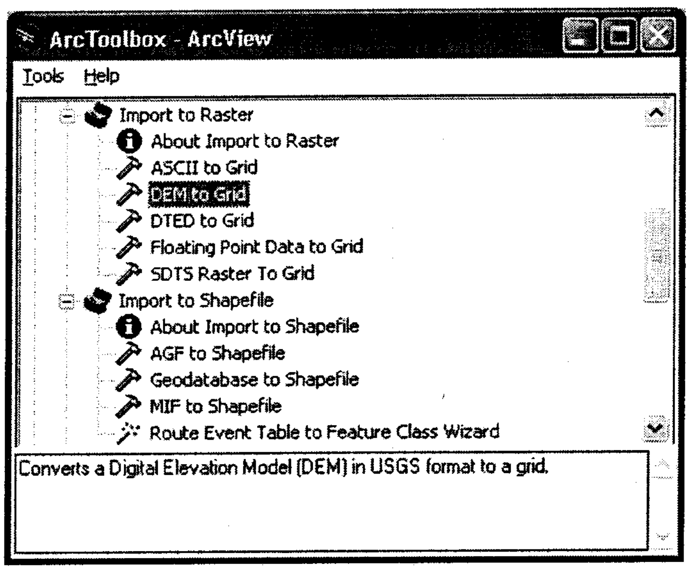

Figure 28. ArcToolbox DEM to grid utility in ArcView8.x.

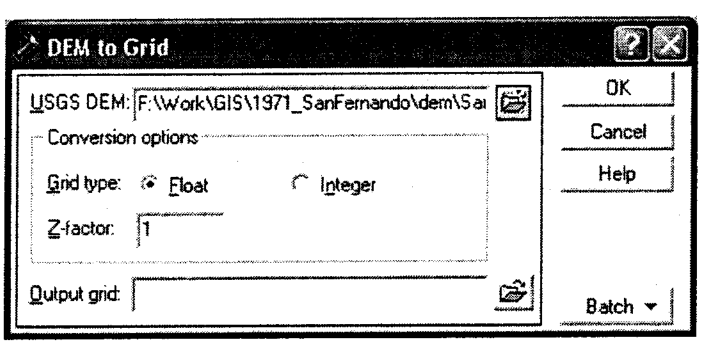

Figure 29. Import one of the DEM files in ArcView8.x.

2. CONTENTS OF LIQUEFACTION GROUND DEFORMATION DATABASE

The liquefaction ground deformation database (Version 1.0) is made of two CDs. As listed in Table 3, CD-1 contains the case histories of liquefaction-induced ground deformation from the 1964 Niigata, Japan earthquake; the 1971 San Fernando, California earthquake; the 1983 Noshiro, Japan earthquake; the 1989 Loma Prieta, California earthquake; and the 1994 Northridge California earthquake. CD-2 contains data from the 1995 Hyogoken-Nanbu, Japan earthquake.

Table 3. Case histories included in the liquefaction ground deformation database CDs

CD	Case history
1	Niigata, Japan
	Noshiro, Nihonkai-chubu, Japan
	Van Norman Complex, California
	Loma Prieta, California
2	Kobe, Hyogoken Nanbu, Japan

As detailed in the breakdown of SPT and CPT data in Table 4, the database contains a total of 5,204 boreholes, consisting of 4,975 SPT and 162 CPT soundings. Table 5 summarizes the actual contents of the database in terms of displacement vectors. There are 16,191 vectors originating from seven earthquakes and six regions in California and Japan. Table 6 summarizes the number of displacement vectors. Most displacements are between 1 and 200 cm. Tables 7-10 summarize all other information in the database, including aerial photos and original documents. The contents of the GIS and DEM files in Tables 7-8 are displayed in Figs. 30-35.

Boreholes in each case history have been processed and plotted using LogPlot2001. The data files for Logplot2001, which can be used to reproduce the graphic borehole profile, are included in the CDs. Appendix A lists the soil lithology legend used in LogPlot2001 to illustrate the different soil type in borehole test.

The coordinate of spatial data such displacement and borehole has been identified in the DataSummary.xls for each case history. The data from Japan uses the unique Japanese coordinate system, which is documented in the Appendix B.

Table 4. Summary of SPT and CPT soundings in the database.

Location	SPT	CPT
Niigata, Japan	645	-
Noshiro, Nihonkai-chubu, Japan	71	-
Kobe, Hyogoken Nanbu, Japan	4002	-
Van Norman Complex, USA	257	153
Loma Prieta, USA	-	9

Table 5. Summary of displacement vector data in the database.

Earthquake	Year	Area Name	Number
Niigata	1964	Niigata, Japan	2498
San Fernando	1971	Jensen Filtration Plant	864
Nihonkai-Chubu,Japan	1983	Noshiro,Japan	2954
Loma Prieta	1989	San Francisco, USA	-
Northridge	1994	Van Norman Complex	1011
Hyogoken Nanbu Earthquake	1995	Kobe, Japan	8894

Table 6. Summary of aerial photos in the database.

Location	Number of aerial photos
Kobe	59
Loma Prieta	1 (Marina district in California).
Niigata	20
Van Norman Complex	67
Noshiro	4

Table 7. Summary of basemaps in the database.

Location	Description
Kobe	Includes several ESRI shapefiles* covering Kobe City, Japan. The shape files are converted from "Digital Map 50m Grid (elevation) Nippon-III," published by the Japan Geographical Survey Institute. Also contains railway, roads, water, building, and city boundary shape files of Kobe City.
Loma Prieta	One image file covering the Marina district in California.
Niigata	Includes several ESRI shape files covering Niigata City, Japan. The shape files are converted from "Digital Map 50m Grid (elevation) Nippon-III," published by Japan Geographical Survey Institute. Also contains railway, roads, water, building, and city boundary shapefiles of Niigata City.
Van Norman Complex	Image files scanned from original paper maps of the Van Norman Complex in California.
Noshiro	Includes several ESRI shapefiles covering Noshiro City, Japan. The shapefiles are converted from "Digital Map 50m Grid (elevation) Nippon-III," published by Japan Geographical Survey Institute. Also contains railway, roads, water, building, and city boundary shapefiles of Noshiro City.

Table 8. Summary of DEMs in the database.

Location	Description
Kobe	8 DEM files covering Kobe City, Japan. The DEM files are converted to USGS DEM format from "Digital Map 50m Grid (elevation) Nippon-III," published by the Japan Geographical Survey Institute.
Loma Prieta	2 USGS DEM zip files downloaded from http://edc.usgs.gov/geodata. The DEM files cover the east and west region of San Francisco Bay, California.
Niigata	4 DEM files covering Niigata City, Japan. The DEM files are converted to USGS DEM format from "Digital Map 50m Grid (elevation) Nippon-III," published by the Japan Geographical Survey Institute.
Northridge	2 USGS DEM zip files downloaded from http://edc.usgs.gov/geodata. The DEM files cover the San Fernando Valley and Oat Mountain, California.
Noshiro	4 DEM files covering Noshiro City, Japan. The DEM files are converted to USGS DEM format from "Digital Map 50m Grid (elevation) Nippon-III," published by the Japan Geographical Survey Institute.
San Fernando	1 text file, which provides elevation points in San Fernando valley. This file can be used to generate a DEM using GIS software such ESRI ArcView.

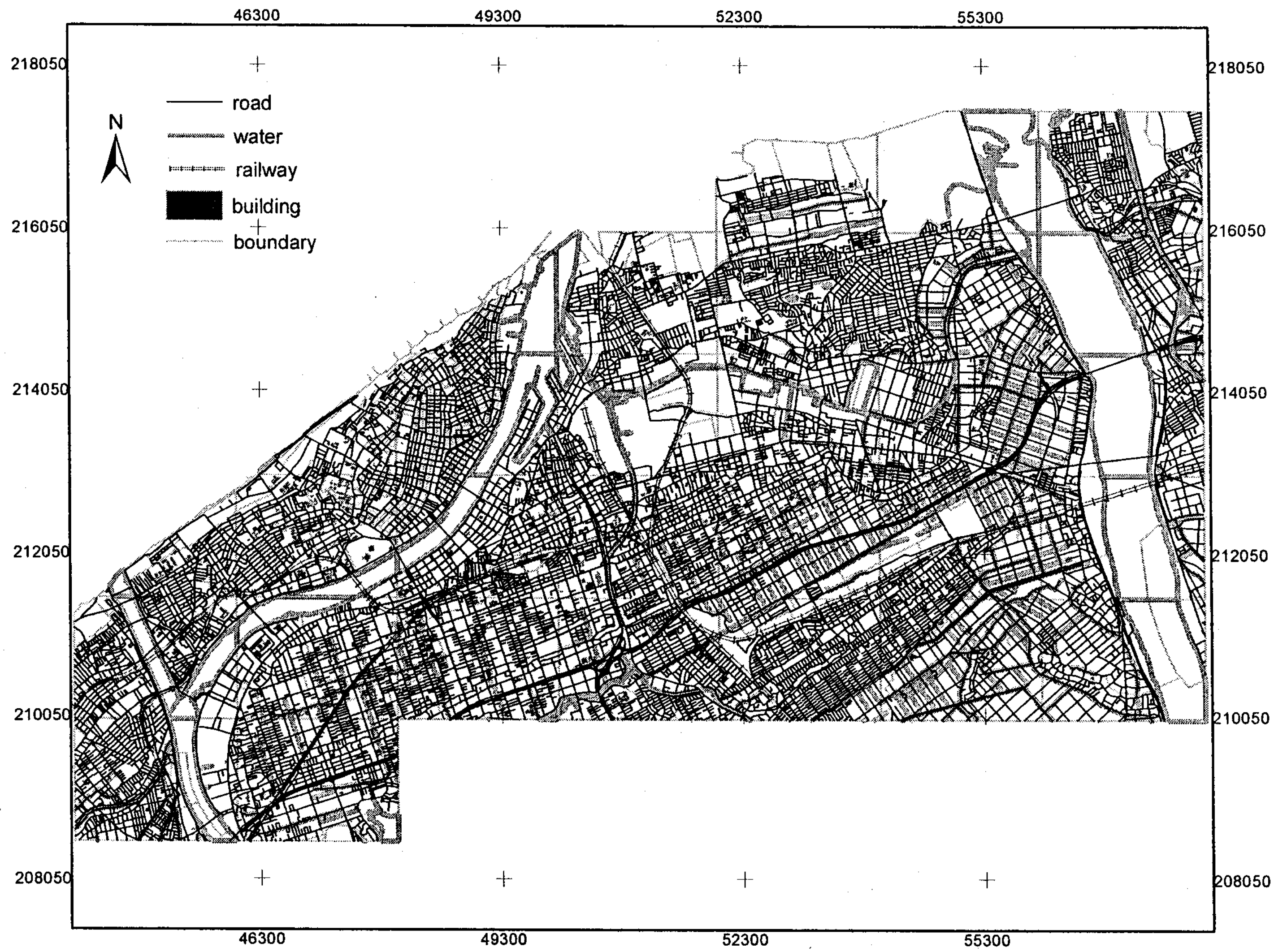

Figure 30. Display of contents of GIS files on Niigata case history in the database.

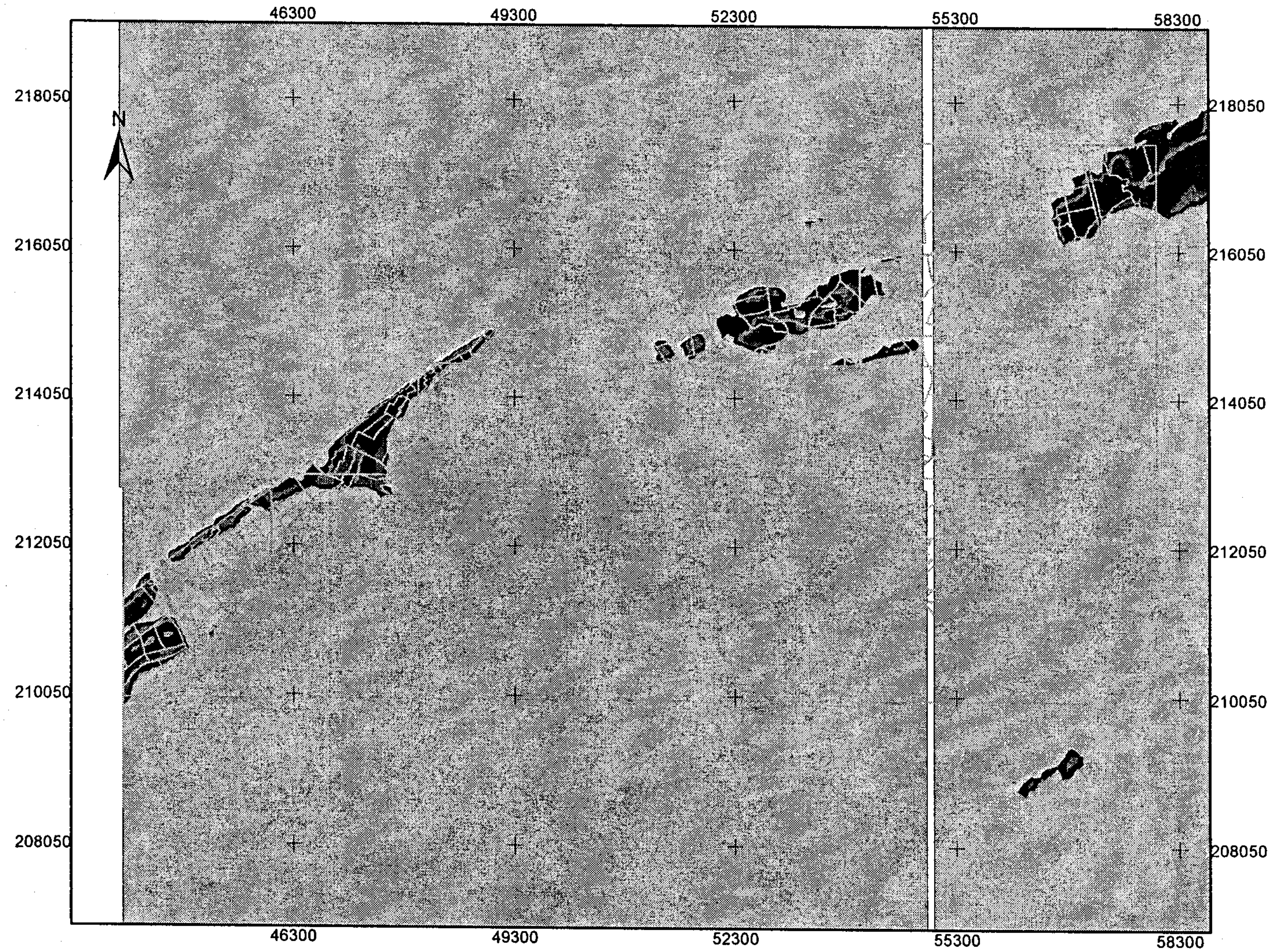

Figure 31. Display of DEM file contents on Niigata case history in the database.

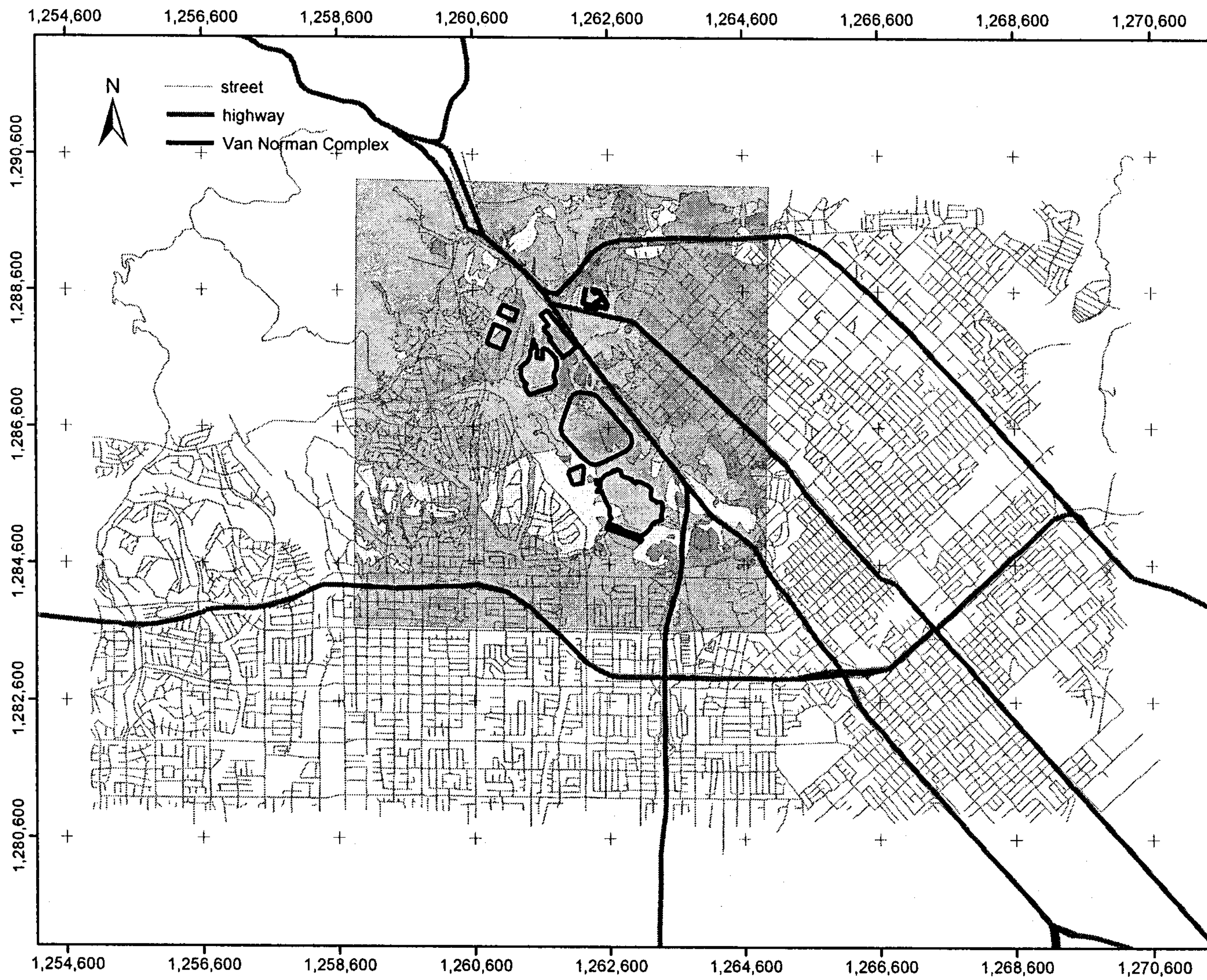

Figure 32. Display of contents of GIS files on Van Norman Complex case histories in the database.

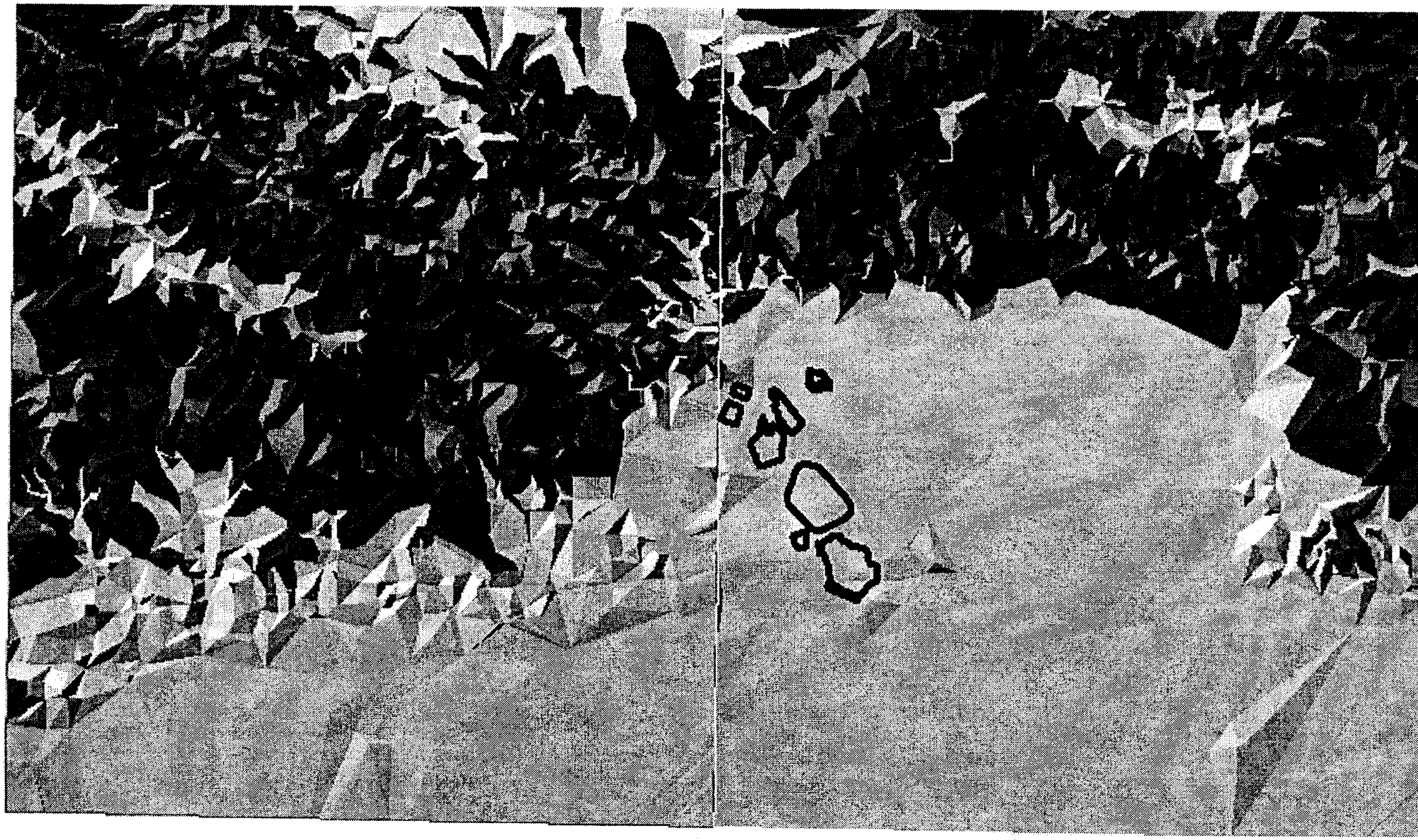

Figure 33. Display of contents of DEM files on Van Norman Complex case history in the database.

Figure 34. Display of contents of DEM files on Loma Prieta case history in the database.

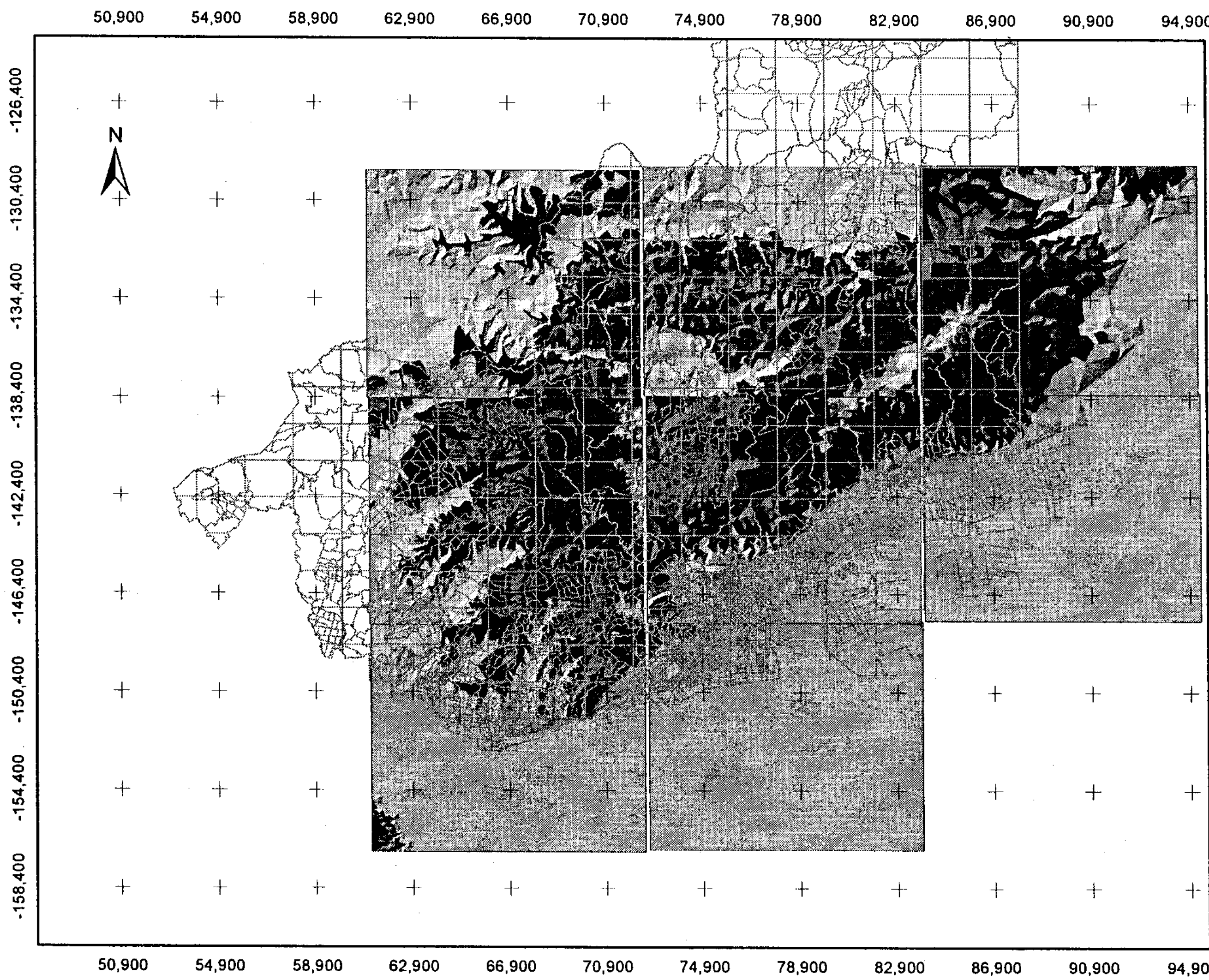

Figure 35. Display of contents of DEM files on Kobe case history in the database.

Table 9. Summary of original displacement vectors data files

Earthquake	Data	Description
1964 Niigata	vector.xls	Original data supplied by Prof. Hamada. This data has been imported to Excel file format. Displacement vectors are represented by pre and post earthquake coordinates.
1971 SanFernando	vncno1.dat vncno2.dat vncno3.dat vncno4.dat vncno5.dat vncno6.dat	Original displacement vectors are digitized from displacement maps supplied by LADWP. The pre and post earthquake coordinates, horizontal displacement sand vertical settlements are provided.
1983 Nihonkaichubu	noshiro_pre.txt noshiro_post.txt	Original data supplied by Prof. Hamada. Displacement vectors are represented by pre and post earthquake coordinates and settlements.
1994 Northridge	Vct_NR1994.dat	Displacement vectors are represented by pre and post earthquake coordinates and settlements.
1995 Kobe	hanshin_pre.txt hanshin_post.txt	Original data extracted from KOBE JIBANKUN database from Japan. Displacement vectors are represented by pre and post earthquake coordinate and settlement.

Table 10. Summary of scanned documents on boreholes.

Location	Description
Niigata	Original borehole data are scanned and stored as image files.
Noshiro	Original borehole data are stored in the database. No image files are available.
Van Norman Complex	Original SPT profiles are as image files. Original CPT data files are stored as collected.
Kobe	SPT information is stored in the database. Data was extracted and translated from KOBE JIBANKUN database.
Loma Prieta	CPT profiles are scanned as image files.

APPENDIX A: BOREHOLE LEGENDS

Fill	Alt. of Sand and Clay	Loam with clay
Fill and sandy silty clay	Silty Sand	Loam with silt
Fill and sandy silt	Coarse sand with gravel	Loam with sand
Fill with sand	Sand with Pebbles	Loam and humus (organic)
Clay	Alt of Humus and Sand	Sandstone
Clay with fill	Sand with Shells	Clayey sandstone
Alt of Clayey Silt and Sand	Sand with loam	Silty sandstone and clayey sandstone
Clay with Sand	Coarse Sand with Rounded Stones~Clay with Rounded	Sandstone and gravel
Clay with gravel	Gravel	Sandstone and cobbles
Clay with Pebbles	Gravel with Clay	Sandstone and silty siltstone
Clay with Humus	Gravel with Silt	Clayey siltstone
Clay with Shells	Gravel with sand	Sandy siltstone
Clay with loam	Gravel and cobbles	Clayey siltstone and gravel
Silt	Humus with Gravel	Mud
Sandy silt with fill	Cobbles	Silty claystone
Alt of Silt and Clay with Sandy Gravel	Clayey Pebbles with Clay with Sandy Gravel	Silty claystone and gravel and sand
Silt with gravel	Embankment(Fine Sand with Gravel)	Silty claystone and sandy claystone and gravel
Silt with Humus	Embankment(Fine Sand with Silt)	Conglomerate
Silt with Shells	Humus	Conglomerate layered with sandstone layered with clay
Silt with loam	Clayey humus (organic)	Asphalt
Sand	Sandy humus (organic)	Bedrock(Granite)
sand with fill	Loam	Coals

APPENDIX B: COORDINATE SYSTEMS IN LIQUEFACTION-INDUCED GROUND DEFORMATION DATABASE

There are several coordinate systems available for characterizing the position of a point on the earth surface. Geographic coordinate system is one set of coordinate system used around the world. Coordinate position on the spherical surface is uniquely defined by means of two vectorial angles: latitude and longitude. This is one unique coordinate system extensively used for all kinds of purpose including global positioning system (GPS) and map projection. There are also other set of coordinate systems called plane cartesian coordinates which are used in surveying and mapping. These coordinates systems use two orthogonal axes: the y-axis in ordinate, and the x-axis in abscissa. Sometimes the abscissa is called Easting and the ordinate Northing. Different regions of the world use different coordinate systems to maintain accurate maps. The liquefaction-induced ground deformation database utilizes three different types of coordinate systems:

1. Globe geographic coordinate system, using longitude and latitude.
2. Japan cartesian coordinate.
3. US cartesian coordinate (Universal Transverse Mercator system).

The *Japan Cartesian coordinate* is designed by the Japan Tertian Geographic Institution. It divides Japan into 19 zones, each of which covers 600 km (N-S) by 320 km (E-W) area. Each zone has its own coordinate origin and supplies one globe geographic coordinate system. Every zone is also divided into several 30 km (N-S) x 40 km (E-W) regions.

The *Universal Transverse Mercator (UTM)* system was devised in the late 1940s by the US Army, and has been widely used around the world since. It intends to provide world coverage between the latitudes 84°N and 80°S. The world has been divided into 60 zones. Each zone is 6° longitude in width and extends from 80°S to 80°N. The origin of each zone is the point on the equator where it is intersected by the central meridian of the zone. The Eastings of the origin of each zone are assigned the value of 500,000 m. For the northern hemisphere, the Northing coordinate of equator is zero, but for the southern hemisphere, the equator is assigned a Northing value of 1,000,000 m. The transformation of coordinates between Japan Cartesian coordinates, UTM coordinates and geographic coordinates are given in this Appendix.

Transformation from UDL to UTM and Japanese cartesian coordinate systems

Provided that the drawings and photographs are free of distortions and warping, these local cartesian systems can be related to the more general cartesian systems (e.g., UTM) by basic transformation of coordinates including translation of axes origin, change in scale, and rotation of axes. As shown in Fig. B1, the final global horizontal position *(X,Y)* of point M is related to the local user-defined horizontal position *(x, y)* through:

$$\begin{pmatrix} X \\ Y \end{pmatrix} = \begin{pmatrix} X_0 \\ Y_0 \end{pmatrix} + f \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{pmatrix} x \\ y \end{pmatrix} \quad (1)$$

where f is the scale ratio between local and global coordinates, θ is the rotation of axis-coordinates (generally set to zero), and (X_0, Y_0) is the global coordinates of point O.

Within a specific global coordinate system, there are many ways of defining ground elevation, related to the choice of datum, e.g., mean sea level. Therefore, the following transformation may be necessary to have elevations expressed with the same datum:

$$Z = z - Z_0 \quad (2)$$

where Z_0 is the difference between the local and global datum. In other words, the coordinates of a point are specified by using three variables: x, y, z, and a transformation type I to a global coordinate system, which is characterized by 6 variables: I, θ, f, X_0, Y_0, and Z_0. All the points digitized from the same maps or drawings have the same transformation type I. The selection of user-defined coordinates and transformation type is general enough to adapt to all situations. When the global coordinates are selected as user-defined coordinates, then the transformation type is trivial, i.e., $\theta=0, f=1, X_0 = Y_0 = Z_0 = 0$.

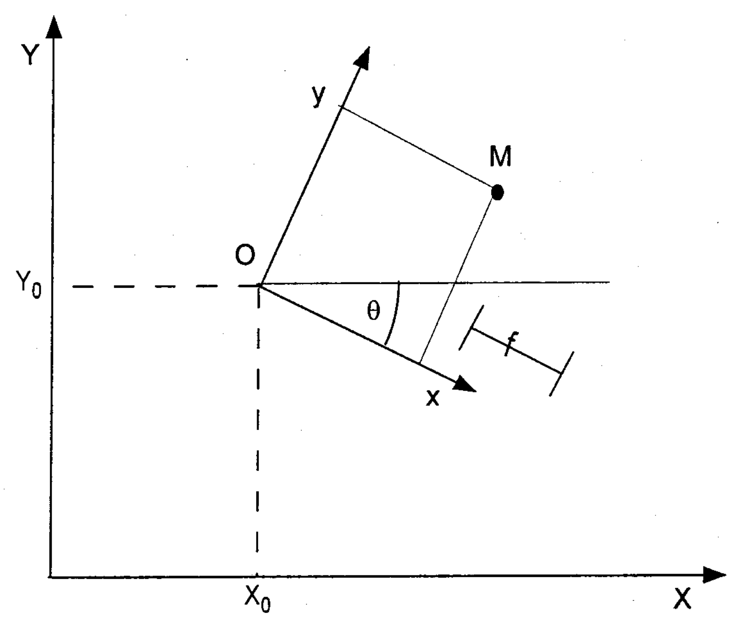

Figure B1. Transformation of user-defined coordinates into a global coordinate system.

Coordinate transformation from geographic to Japanese systems

The following section is an excerpt from Japan Association for Surveying, 1999, Regulations for surveying of control points, http://vldb.gsi-mc.go.jp/sokuchi/surveycalc/xy2bl/xy2bl.html (in Japanese).

Latitude

$$\varphi = \varphi_1 - \left(\frac{\tan\varphi_1}{2M_1N_1}\right)\left(\frac{y}{m_0}\right)^2 \rho$$
$$+\left(\frac{\tan\varphi_1}{24M_1N_1^3}\right)\left(5+3\tan^2\varphi_1+\eta_1^2-9\eta_1^2\tan^2\varphi_1-4\eta_1^2\right)\left(\frac{y}{m_0}\right)^4 \rho$$
$$-\left(\frac{\tan\varphi_1}{720M_1N_1^5}\right)\left(61+90\tan^2\varphi_1+45\tan^4\varphi_1\right)\left(\frac{y}{m_0}\right)^6 \rho$$

Longitude

$$\lambda = \lambda_0 + \Delta\lambda$$

$$\Delta\lambda = \left(\frac{1}{N_1\cos\varphi_1}\right)\left(\frac{y}{m_0}\right)\rho - \left(\frac{1+2\tan^2\varphi_1+\eta_1^2}{6N_1^3\cos\varphi_1}\right)\left(\frac{y}{m_0}\right)^3 \rho$$
$$+\left(\frac{5+28\tan^2\varphi_1+24\tan^4\varphi_1}{120N_1^5\cos\varphi_1}\right)\left(\frac{y}{m_0}\right)^5 \rho$$

Meridian aberration angle

$$\gamma = \left(\frac{\tan\varphi_1}{N_1}\right)\left(\frac{y}{m_0}\right)\rho + \left(\frac{\tan\varphi_1}{3N_1^3}\right)\left(1+\tan^2\varphi_1-\eta_1^2\right)\left(\frac{y}{m_0}\right)^3 \rho$$
$$-\left(\frac{\tan\varphi_1}{15N_1^5}\right)\left(1+\tan^2\varphi_1\right)\left(2+3\tan^2\varphi_1\right)\left(\frac{y}{m_0}\right)^5 \rho$$

Scale factor

$$m = m_0\left(1+\frac{y^2}{2M_1N_1m_0^2}+\frac{y^4}{24M_1^2N_1^2m_0^4}\right)$$

where,

φ : Latitude of point of interest

λ_0 : Longitude of reference point

λ : Longitude of point of interest

γ : meridian aberration angle of point of interest

sign of γ is negative when the point of interest is located in the east of Cartesian coordinate, and positive in the west.

m : scale factor of point of interest

$m_0 = 0.9999$

$\eta_1^2 = e^2 \cos^2 \varphi_1$

y : y coordinate of point of interest

a : major axis length of ellipse (bessel 6377397.155m)

f : flattening (bessel 1/299.152813)

$$M_1 = \frac{c}{\sqrt{\left(1+\eta_1^2\right)^3}} \qquad N_1 = \frac{c}{\sqrt{\left(1+\eta_1^2\right)}} \qquad c = a\sqrt{1+e^2} \quad e = \frac{\sqrt{2/f-1}}{1/f-1}$$

Latitude of intersection between standard meridian and a perpendicular line from the point of interest

$$\varphi_1 = \begin{pmatrix} A_1\theta + A_2 \sin 2\theta + A_3 \sin 4\theta + A_4\theta \cos 2\theta + A_5 \sin 6\theta + A_6\theta \cos 4\theta \\ + A_7\theta^2 \sin 2\theta + A_8 \sin 2\theta \cos 4\theta + A_9 \sin 8\theta + A_{10}\theta \cos 6\theta + A_{11}\theta \sin 2\theta \sin 4\theta \\ + A_{12}\theta^2 \sin 4\theta + A_{13}\theta^3 \cos 2\theta + A_{14} \sin 6\theta \cos 2\theta \end{pmatrix} \rho$$

where,

$$\theta = \frac{M}{a}$$

$$M = S_0 + \frac{x}{m_0} + \frac{\text{x coordinate of point of interest}}{\text{m}_0}$$

$$A_1 = 1 + \frac{1}{4}e^2 + \frac{7}{64}e^4 + \frac{15}{256}e^6 + \frac{579}{16384}e^8$$

$$A_2 = \frac{3}{8}e^2 + \frac{3}{16}e^4 + \frac{93}{1024}e^6 + \frac{87}{2048}e^8 \qquad A_3 = \frac{21}{256}e^4 + \frac{21}{256}e^6 + \frac{261}{4096}e^8$$

$$A_4 = \frac{3}{16}e^4 + \frac{45}{256}e^6 + \frac{285}{2048}e^8 \qquad A_5 = \frac{29}{768}e^6 + \frac{231}{4096}e^8$$

$$A_6 = \frac{21}{256}e^6 + \frac{483}{4096}e^8 \qquad A_7 = -\frac{3}{64}e^6 - \frac{33}{512}e^8$$

$$A_8 = -\frac{27}{1024}e^6 - \frac{81}{2048}e^8 \qquad A_9 = \frac{921}{131072}e^8$$

$$A_{10} = \frac{71}{2048}e^8 \qquad A_{11} = -\frac{27}{1024}e^8$$

$$A_{12} = -\frac{21}{512}e^8 \qquad A_{13} = -\frac{1}{128}e^8$$

$$A_{14} = \frac{11}{1024}e^8$$

Arc length of meridian from the equator to the origin of Cartesian Coordinate

S_0 : Arc length of median from the equator to the origin of Cartesian Coordinate φ_0

$$S_0 = a(1-e^2)\left(A\varphi_0 - \frac{B}{2}\sin 2\varphi_0 + \frac{C}{4}\sin 4\varphi_0 - \frac{D}{6}\sin 6\varphi_0 + \frac{E}{8}\sin 8\varphi_0 - \frac{F}{10}\sin 10\varphi_0\right)$$

where, $e = \sqrt{2f - f^2}$

$$A = 1 + \frac{3}{4}e^2 + \frac{45}{64}e^4 + \frac{175}{256}e^6 + \frac{11025}{16384}e^8 + \frac{43659}{65536}e^{10} + \frac{693693}{1048576}e^{12} + \frac{19324305}{29360128}e^{14} + \frac{4927697775}{7516192768}e^{16}$$

$$B = \frac{3}{4}e^2 + \frac{15}{16}e^4 + \frac{525}{512}e^6 + \frac{2205}{2048}e^8 + \frac{72765}{65536}e^{10} + \frac{297297}{262144}e^{12} + \frac{135270135}{117440512}e^{14} + \frac{547521975}{469762048}e^{16}$$

$$C = \frac{15}{16}e^4 + \frac{105}{256}e^6 + \frac{2205}{4096}e^8 + \frac{10395}{16384}e^{10} + \frac{1486485}{2097152}e^{12} + \frac{45090045}{5870256}e^{14} + \frac{766530765}{939524096}e^{16}$$

$$D = \frac{35}{512}e^6 + \frac{315}{2048}e^8 + \frac{31185}{131072}e^{10} + \frac{165165}{524288}e^{12} + \frac{45090045}{117440512}e^{14} + \frac{209053845}{46972048}e^{16}$$

$$E = \frac{315}{16384}e^8 + \frac{3465}{65536}e^{10} + \frac{99099}{1048576}e^{12} + \frac{4099095}{29360128}e^{14} + \frac{348423075}{1879048192}e^{16}$$

$$F = \frac{693}{131072}e^{10} + \frac{9009}{524288}e^{12} + \frac{4099095}{117440512}e^{14} + \frac{26801775}{469762048}e^{16}$$