PenMap Demonstration Project, Landslide Mapping System

Final Report
FHWA/CA/OR-2002/31

December 2002

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The GeoResearch Group
Caltrans
Research & Innovation

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16. ABSTRACT

This report documents the findings of a technology transfer project to demonstrate the effectiveness of a portable field mapping system to landslide field reconnaissance work. The objective of this project was to expose the latest field data collection and real-time mapping technologies to the geotechnical staff within the Department through the use of two field mapping units on existing projects. Two field mapping units were integrated by the consultant, Condor Earth Technologies, and made available for use to Caltrans staff to assist in the rapid development of topographic maps, cross-sections, and descriptions of landslides for engineering analyses and reports. Various types of positioning instrumentation were incorporated into the field mapping units to evaluate field performance and accuracies, debug the system, and develop customized packages for specialized applications for Caltrans end-users.

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INTRODUCTION

This report documents the findings of a technology transfer project to demonstrate the effectiveness of a portable field mapping system in landslide field reconnaissance work. The objective of this project was to expose the latest field data collection and real-time mapping technologies to the geotechnical staff within the Department through the use of two field mapping units on current projects. Two field mapping units were integrated by the consultant, Condor Earth Technologies, and made available for use to Caltrans staff to assist in the rapid development of topographic maps, cross-sections, and descriptions of landslides for engineering analyses and reports. Various types of positioning instruments were incorporated into the field mapping units including global positioning systems (GPS) and laser ranging devices. User feedback resulting from extensive field testing on actual projects was used to evaluate system performance and develop customized packages tailored to Caltrans end-user needs.

PROJECT BACKGROUND

Caltrans expends significant resources in dealing with landslide hazards adjacent to the State highway system. With an estimated 1200 miles of landslide prone highway corridors throughout California, approximately 200 landslides and 10 road closures occur per year at a rough cost of $10 million for clean up and mitigation. Most notably, in the Winter of 1997 the Mill Creek Landslide closed down State Route 50 and dammed the American River for several hours. The landslide caused significant damage to many homes and roadways in that area as shown in Figure 1. State Route 50 was closed for almost a month which severely impacted travel and the South Lake Tahoe region's economy.

Figure 1 – 1997 Mill Creek Landslide

Current practices in landslide mapping within the geotechnical offices of Caltrans includes relatively precise methods, such as topographic mapping from aerial photography or ground surveys, as well as approximate methods, such as sketches of slide geometry and features based upon crude tape measurements and compass bearings, or visual estimates of features and dimensions. Although conventional aerial and ground surveying techniques have provided high quality mapping products, the lengthy time and staff costs associated with these processes have limited their applicability on projects requiring rapid response. By some estimates this process can take from six to eight weeks. For example in a ground survey, a couple of weeks may be required between the time of the request for services and the time in which the survey is conducted. Another week or two may be required to process the data and deliver the survey results to the client. Considering lead time and workload, a drafting team may require an additional 2 to 3 weeks to develop a topographic map and cross-sections for use by the engineer or geologist. Only then can the cross-sections be used in a slope stability analysis program to design an effective mitigation solution. In many cases, however, the slide occurs without warning, often reducing the capacity of the highway corridor. Caltrans geotechnical staff are often tasked with rapidly responding to these incidences, developing mitigation strategies within hours to days of the event, and directing construction and maintenance crews on how to carry out the work to restore traffic. Although a proper survey is often needed in these situations, they are seldom used due to time constraints. Consequently, crude estimates of landslide geometry are often developed using tape measurements and compass bearings.

MAPPING TECHNOLOGIES

Significant improvements in Global Positioning System (GPS) and Geographic Information System (GIS) technologies, along with dropping hardware and software costs, have fueled the development and usage of small, hand-held or backpack type, single-user devices to facilitate the collection of spatial data for map making, inventory management, and similar applications. For example, a city public works department can now use GPS to identify the location of street lights, and then use GIS to display on a map their locations as well as other critical information (e.g. type, age, height, etc.) to assist in managing the street light inventory and their maintenance.

There are many products on the market that address the type of application described in the previous example and are readily available through the major GPS hardware manufacturers (e.g. Trimble, Topcon, Leica, Ashtech, etc.). These units range in price from approximately $1000 for a unit delivering 22m horizontal accuracy, to $5000 for a unit delivering 1m horizontal accuracy, to as much as $40,000 for a unit delivering 0.010m accuracy. Most of these systems utilize a small handheld computing device (e.g. Palm Pilot, PocketPC, etc.) to allow the operator to monitor GPS status, view maps, and enter descriptive information into electronic forms.

Landslide reconnaissance and mapping operations can benefit greatly from the use of these types of systems. An additional feature was identified in some of the commercially available systems that could potentially reduce the time required to develop topographic maps. This feature, referred to as real-time digital terrain modeling (DTM), allows the operator to visualize the mapping process in real-time. Three dimensional positioning data from GPS or other survey instruments are passed directly to the mapping software, which updates an evolving topographic map visually. The detail and accuracy of the topographic map is dependent upon the density of data points that the operator collects. As a result the operator can decide when a map is sufficiently complete while still in the field.

Two software applications were identified as having the real-time DTM capability: *PenMap* from Condor Earth Technologies, and *Tsunami* from Carlson Software. Both products work in conjunction with various positioning and measurement instruments such as GPS, total stations, and laser rangefinders, and allows a user to generate maps and cross-sections in real-time. The entire system integrates commercially available survey instruments to personal computers (PC) running GIS and computer aided design (CAD) software to form a complete single-user mapping operation. For this particular technology transfer project *PenMap* was used exclusively.

In a typical field mapping system the operator has a backpack or beltpack that holds the GPS unit and a ruggedized Windows PC. The interface with the computer is through a handheld pen-screen, similar to a LCD screen of a laptop PC. The GPS antenna (backpack mounted or pole mounted) provides the operator’s position, while a handheld or pole-mounted laser device allows the operator to stand in one position and acquire the relative coordinates of other points of interest. A typical field mapping system is shown in Figure 2.

Figure 2 – Field mapping system

As points are being acquired, a topographic map is generated by the software in real-time on the computer's display. From this data the user can generate cross-sections. Other data can be incorporated into maps such as field notes, digital photos, hand sketches, etc. Data from this tool can then be used for progressive landslide mapping, slope stability analysis, earthwork calculations, etc.

INITIAL DEMONSTRATION OF FIELD MAPPING SYSTEMS

On March 8, 2000, representatives from a systems integrator, Condor Earth Technologies, hosted a demonstration of field mapping technologies on an active landslide near Auburn, California, off of Highway 49. (03-ED-49-38.0). Over 16 representatives from Caltrans were in attendance, including technical staff and managers. The purpose of the field demonstration was to expose Caltrans geotechnical staff to these types of systems and gather feedback as to the applicability of these systems to practice.

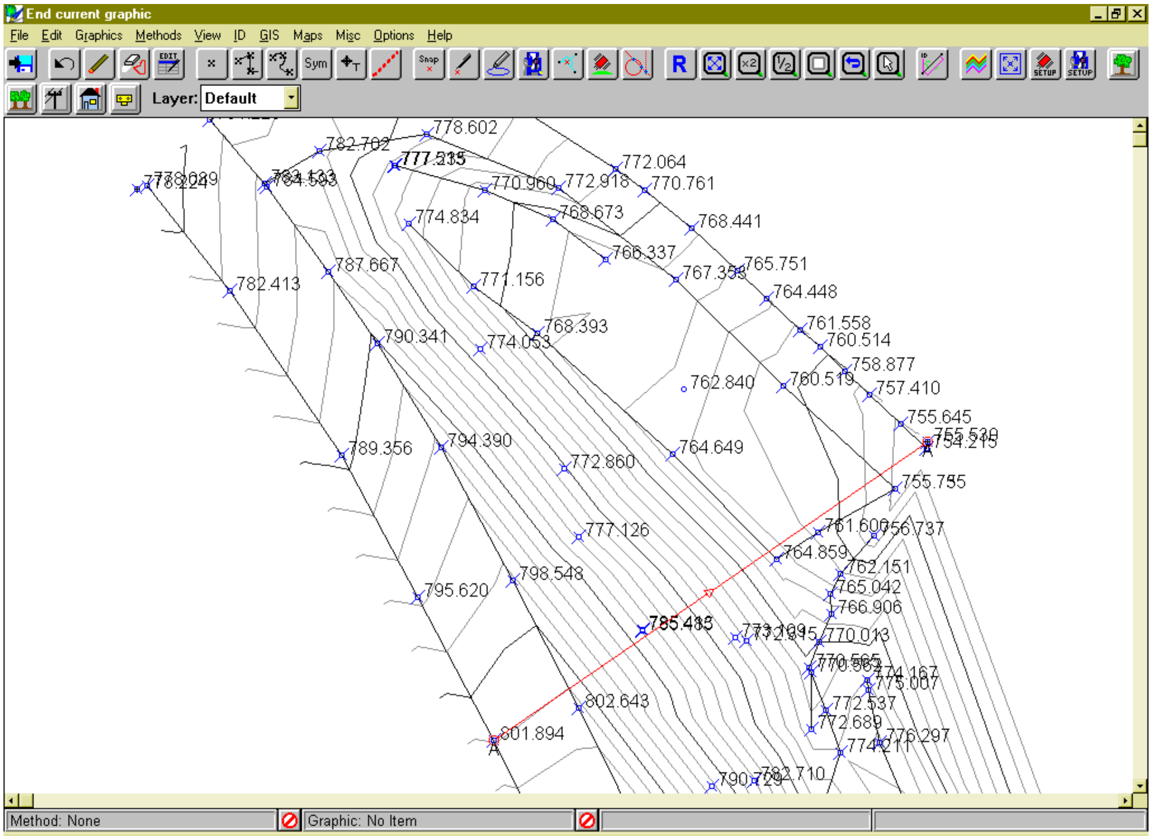
Two variations of the field mapping system were demonstrated, one incorporating a differential GPS system (DGPS) and laser rangefinder, and the other using a Real-Time-Kinematic GPS system (RTK-GPS). The demonstration of both systems was intended to show the differences in positioning accuracy for DGPS (sub-meter level, inexpensive) versus RTK-GPS (centimeter level, high cost).

Figure 3 – Field demonstration to Caltrans staff and management

In an exercise to demonstrate the mapping capabilities of these systems, Loren Turner from the Division of Research & Innovation was given a quick overview of PenMap's RTK-GPS software and hardware functions and was then permitted to map the slide area. Within a period of a half-hour, sufficient data was collected from walking the slide, shown in Figures 4 and 5, to generate topographic maps and cross-sections. The mapping results from the exercise are shown in Figures 6 and 7.

Figure 4 – Collection of data along the Southeastern scarp

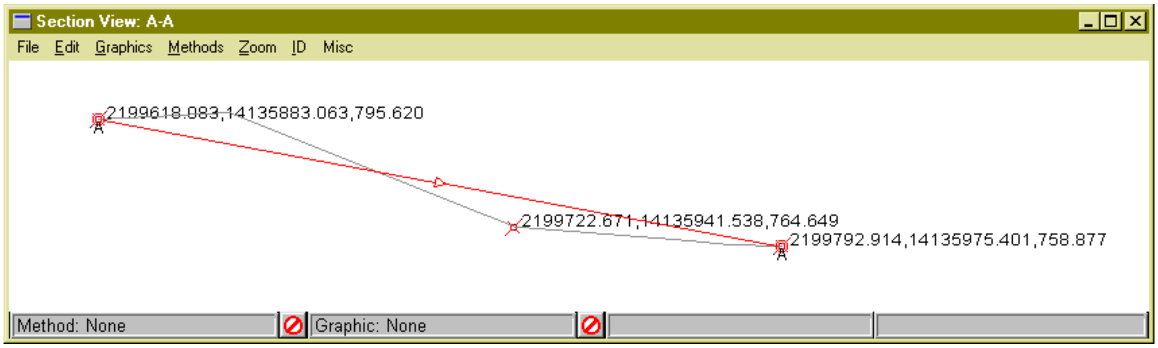
Figure 5 – Collection of data along the North end of the parking lot



Method: None

Graphic: No Item

Figure 6 – Screen shot of mapping interface. (The red line indicates the location where a cross-section is to be generated.)



Method: None

Graphic: None

Figure 7 – Cross-section of slide with X,Y,Z coordinates noted

Following the field demonstration participants were asked to complete a survey to assess the value of these systems in expediting project delivery and responding to unanticipated landslide occurrences. The results of the survey are included in Appendix A of this report. In general, most of the participants concurred that these systems would provide a significant benefit, particularly in response time following landslides. Survey responses were also used to justify the initiation of a long-term technology transfer project.

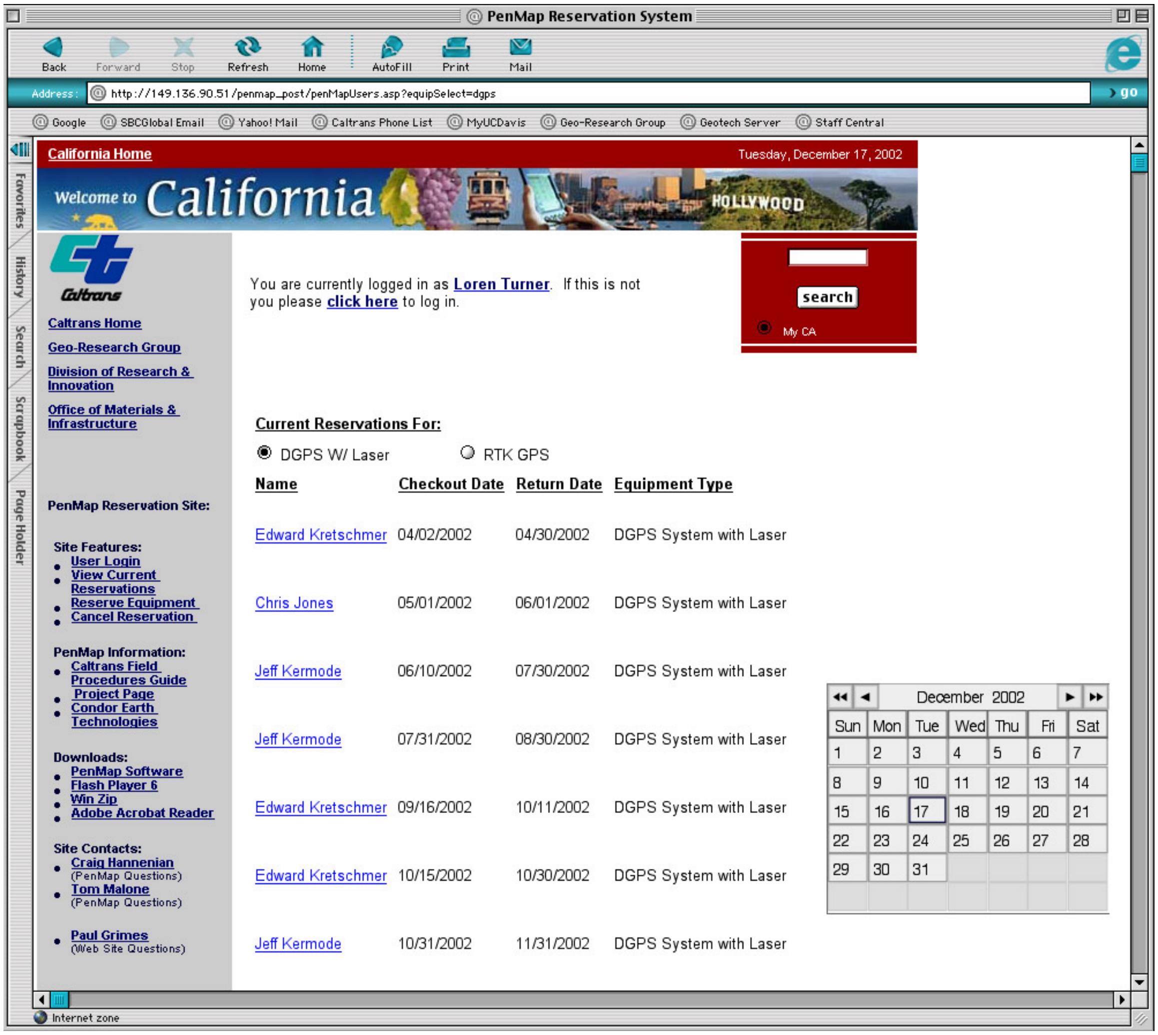
TECHNOLOGY TRANSFER PROJECT

With strong support from end-users following the field demonstration, a technology transfer project was initiated. The project was carried out in four stages: procurement, training, test deployments, and evaluation.

Following approval and initiation of the project, two field mapping systems were purchased. The first system was based upon differential GPS (DGPS) hardware and utilized a laser positioning instrument to extend its utility. The second system was based upon Real-Time-Kinematic GPS (RTK-GPS) hardware and did not include the laser positioning system. Each system had its own significant advantage over the other in terms of accuracy, user-interaction, and cost. Equipment specifications and costs are detailed in Appendix B of this report. Condor Earth Technologies was contracted to integrate and deliver the two systems. The systems integrator provided two training sessions on the use of the software and associated equipment to a group of Caltrans staff. These staff, in turn, provided training and guidance to other Caltrans users interested in using the equipment. A short field procedures guide was developed specifically for Caltrans landslide mapping applications and is included in Appendix C.

The equipment was made available for check-out to staff in Geotechnical Services over an evaluation period of approximately one year. An online reservation and checkout system was implemented to facilitate the test deployment of the two systems on a statewide basis as shown in Figure 8.

Users were required to create individual accounts in order to log into the website. Once logged into the system, users could make reservations, find contact information for other users, download software, view training documents and tips, and contact project or training staff for further assistance. The website provided a good tool for the research project to track usage and gather feedback during the evaluation period.



http://149.136.90.51/penmap_post/penMapUsers.asp?equipSelect=dgps

Tuesday, December 17, 2002

Caltrans Home
Geo-Research Group
Division of Research & Innovation
Office of Materials & Infrastructure

PenMap Reservation Site:

Site Features:
- User Login
- View Current Reservations
- Reserve Equipment
- Cancel Reservation

PenMap Information:
- Caltrans Field Procedures Guide
- Project Page
- Condor Earth Technologies

Downloads:
- PenMap Software
- Flash Player 6
- Win Zip
- Adobe Acrobat Reader

Site Contacts:
- Craig Hannenian (PenMap Questions)
- Tom Malone (PenMap Questions)
- Paul Grimes (Web Site Questions)

You are currently logged in as Loren Turner. If this is not you please click here to log in.

Current Reservations For:

● DGPS W/ Laser ○ RTK GPS

Name	Checkout Date	Return Date	Equipment Type
Edward Kretschmer	04/02/2002	04/30/2002	DGPS System with Laser
Chris Jones	05/01/2002	06/01/2002	DGPS System with Laser
Jeff Kermode	06/10/2002	07/30/2002	DGPS System with Laser
Jeff Kermode	07/31/2002	08/30/2002	DGPS System with Laser
Edward Kretschmer	09/16/2002	10/11/2002	DGPS System with Laser
Edward Kretschmer	10/15/2002	10/30/2002	DGPS System with Laser
Jeff Kermode	10/31/2002	11/31/2002	DGPS System with Laser

December 2002

Sun	Mon	Tue	Wed	Thu	Fri	Sat
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

Figure 8 – Screenshot of online checkout system

Over the course of this period, from October 2001 to October 2002, user input was used to modify or augment the capabilities of the equipment to fit the specific needs of the end-users. Evaluations were collected as part of this project from end users to develop recommendations for further applications and improvements for these technologies.

CASE STUDY: COLUSA COUNTY, STATE ROUTE 20

Since the beginning of the project, both field mapping systems have been successfully deployed in over thirty landslide response situations at the time of writing of this report. In many cases the systems were used where conventional procedures weren't feasible due to time constraints. One of those deployments is presented here as a case study to illustrate the application of the technology.

A cut slope on State Route 20 in Colusa County (Col-20-PM2.5) had been causing maintenance problems for the past several years. In recent months the slope above and behind the face of the cut slope had begun to show signs of failure indicating the presence of a much larger landslide. A head scarp approximately 100 ft behind the top of the cut slope was evident as can be seen in Figure 9, and the toe of this slide was estimated to be about 20 feet above the base of the cut slope.

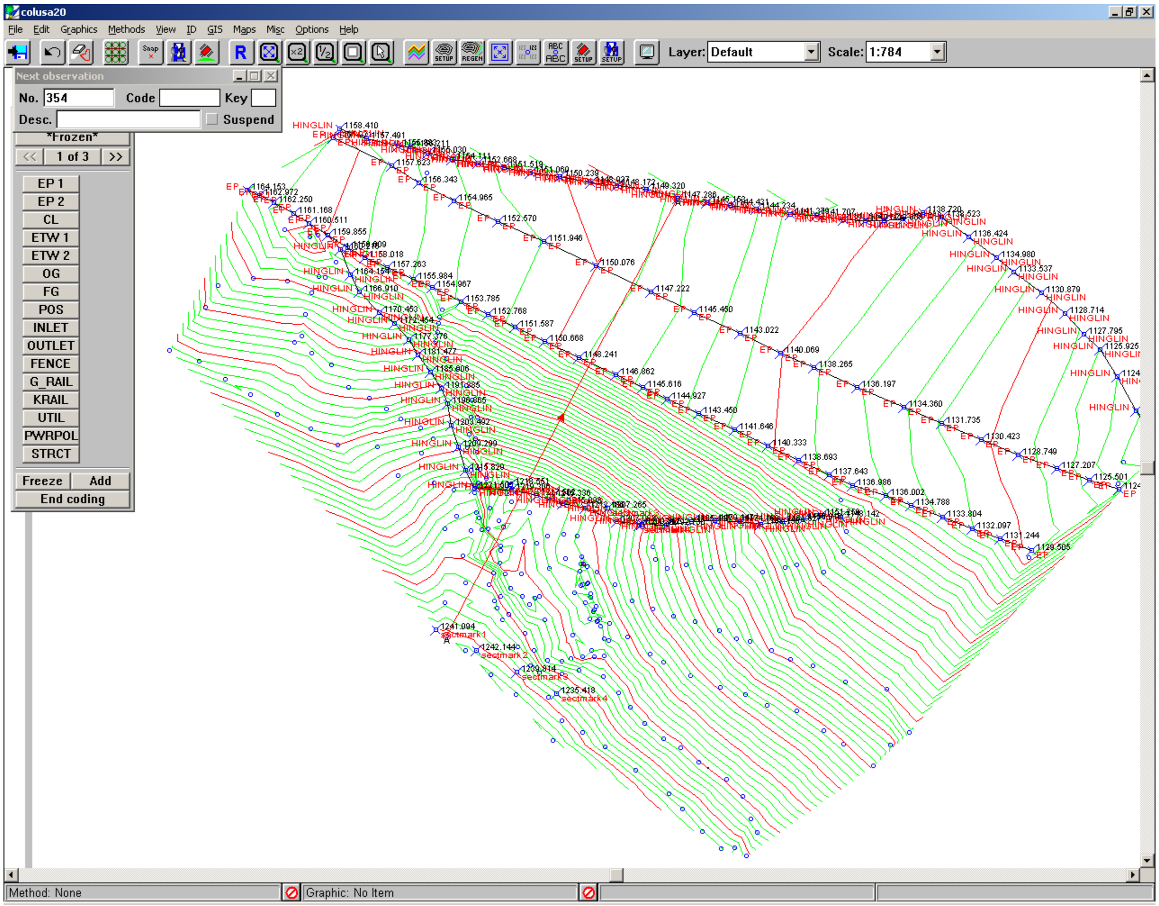
Figure 9 – Landslide on cut slope on State Route 20 in Colusa County

The slide material, which included large hard rock boulders, had on occasion rolled off the cut slope damaging the concrete barrier rail. Build up of slide material on the shoulder of the roadway and behind the barrier rail presented a risk to the public due to the potential of debris flows onto the roadway. In response this slide activity, in addition to the appearance of the relatively new head scarp, Caltrans Maintenance crews mobilized and removed between 200 to 300 cubic yards of material adjacent to the highway.

Although the removal of material addressed immediate concerns, a long term solution was still necessary. The large crack openings near the head scarp continued to provide a path for water to penetrate the slope, further weakening the underlying soil and rock, and facilitating more slide activity. Staff from Caltrans Geotechnical Services evaluated the slope and recommended that partial removal and regrading of the slide be performed before the winter rains as an initial measure. Emergency contracting procedures were initiated following the evaluation to carry out the work.

Given the limited time frame under an emergency contract to develop slope grading plans for the contractor, Caltrans Geotechnical Services staff used one of the field mapping systems to quickly survey the slope, develop cross sections, perform slope stability analyses, and provide grading recommendations.

The field work was completed by one trained staff person over the course of a day using the DGPS PenMap unit without the laser rangefinder. A topographic map was generated in real time while in the field and is shown in Figure 10. The map shown in this screen shot is the same as those displayed on the field computer while mapping on site.



No. 354 Code Key

Desc. ☐ Suspend

Layer: Default

Scale: 1:784

Method: None

Graphic: No Item

Figure 10 – Topographic map produced in the field using PenMap

Nodes, shown as blue dots in the Figure 10, represent the points where the user had collected map position data. Lines of consecutive points indicate the paths that the user walked in the collection of the data. Special nodes are noted by identifying tags, such as “HINGLIN,” indicating that the node is part of a polyline representing a hingeline. The topographic elevation lines shown in red and green are generated and updated by the PenMap software on-the-fly. These elevation lines are continually regenerated as new nodes are added to the surface.

Other views of the landslide area, including three dimensional and sectional views, are available to the user in the field. Figure 11 shows a three dimensional view generated from the same data collected for the topographic map in Figure 10, which compares well with the photo of the slide previously shown in Figure 9.

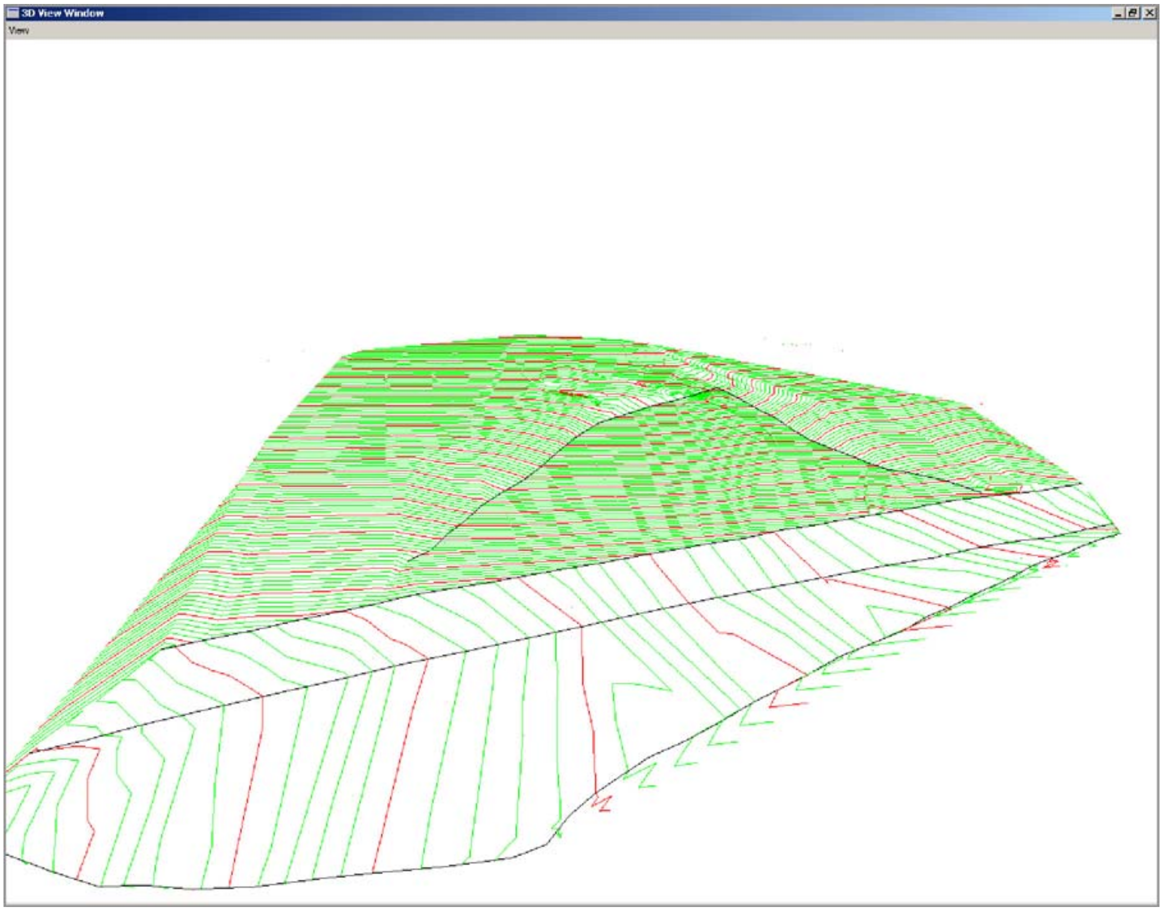


Figure 11 – View of landslide in three dimensions

In Figure 10 a red vector line is shown that is perpendicular to the roadway and crosses at about the center of the cut slope area. This vector was drawn by the user in PenMap to select the location where a cross section is to be generated. The software interpolates the data from the topo and generates the cross section along that vector as is shown in Figure 12.

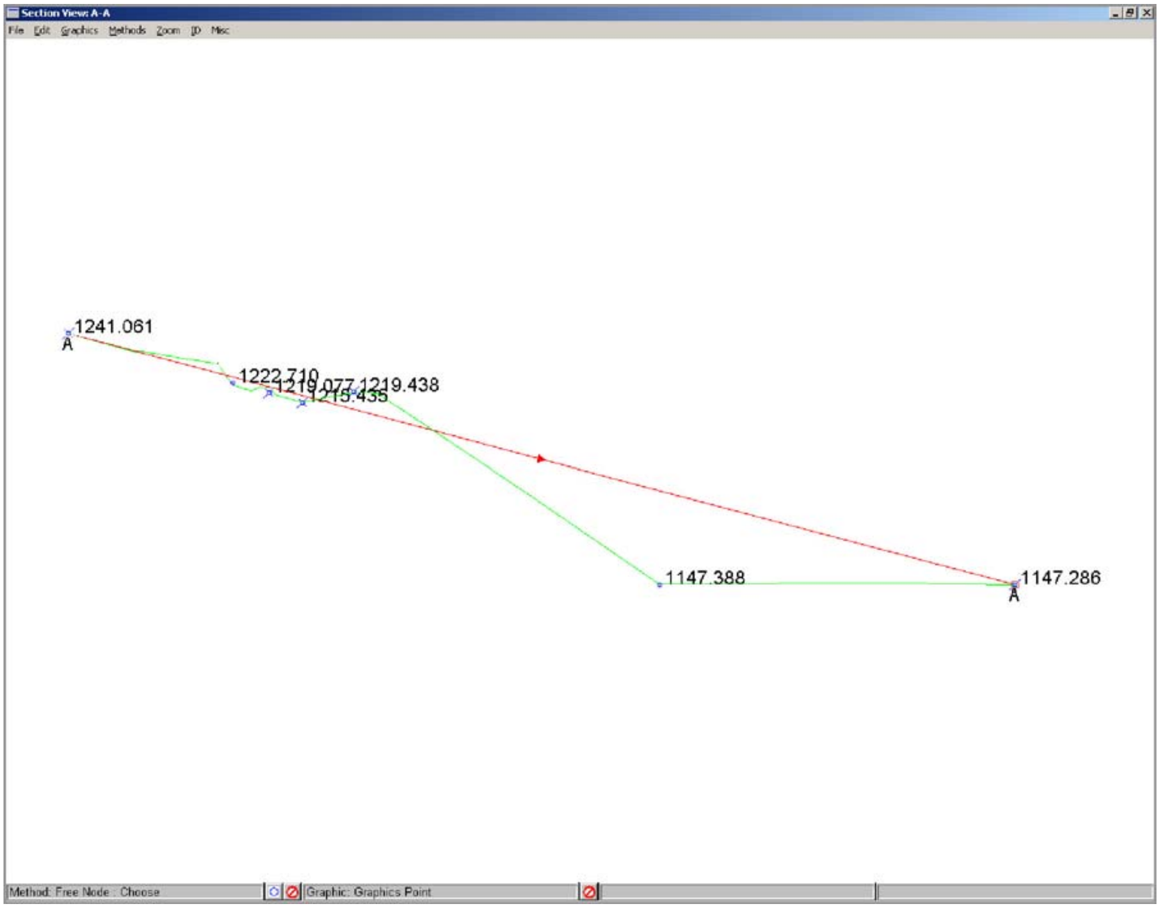
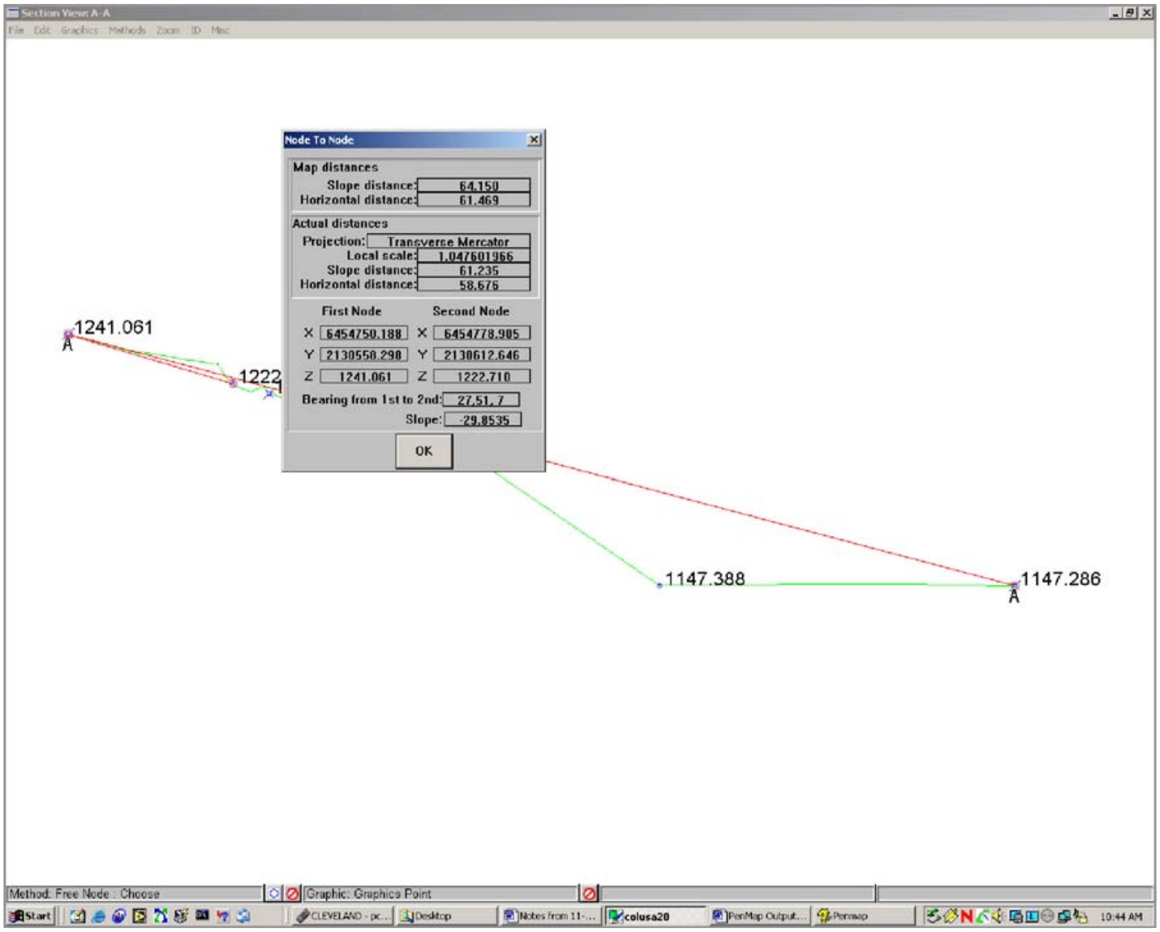


Figure 12 – Cross section of landslide

Figure 13 demonstrates how the software can provide detailed information on the cross section, including slope distances, angles, bearings, and other useful information.



Node To Node

Map distances
Slope distance: 64.150
Horizontal distance: 61.469

Actual distances
Projection: Transverse Mercator
Local scale: 1.047601966
Slope distance: 61.235
Horizontal distance: 58.676

	First Node		Second Node
X	6454750.188	X	6454778.905
Y	2130558.298	Y	2130612.646
Z	1241.061	Z	1222.710

Bearing from 1st to 2nd: 27.51. 7
Slope: -29.8535

OK

Figure 13 – Cross section of landslide with detailed slope data shown

Final cross sections based upon the PenMap data were generated at several locations for use in further analyses and quantity calculations. The topo map and one of the cross sections from the final geotechnical report from the project are shown in Figures 14 and 15.

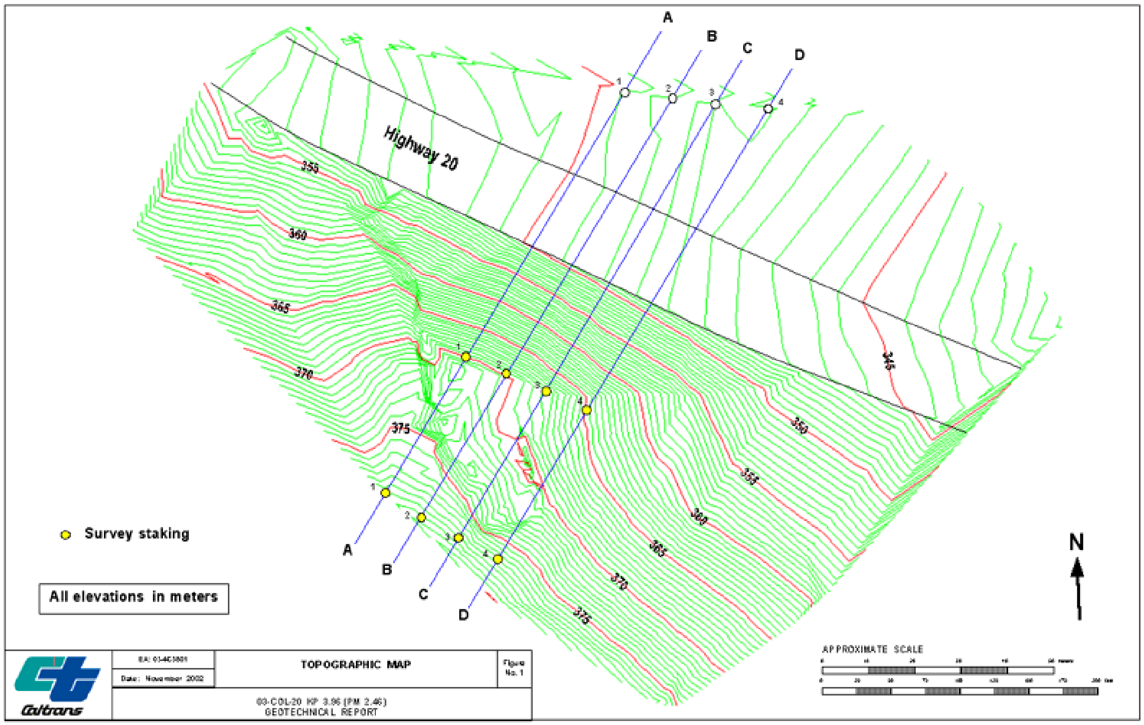


Figure 14 – Topo map from geotechnical report based upon PenMap data.

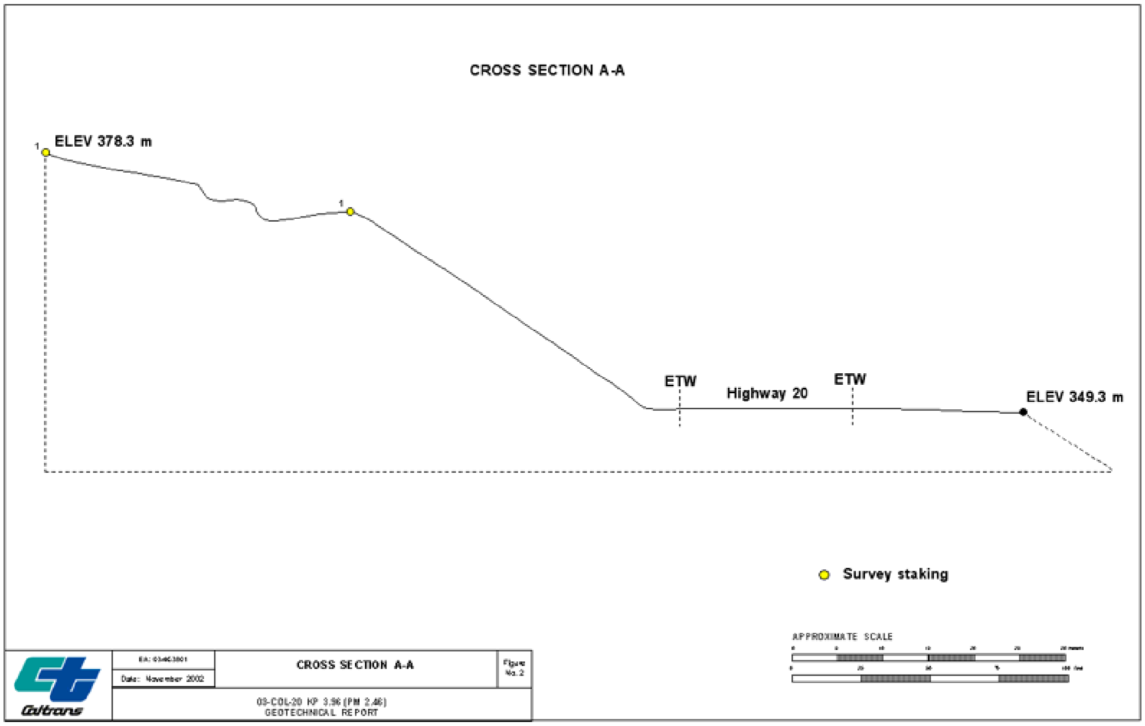


Figure 15 – Cross section from geotechnical report based upon PenMap data.

USER OBSERVATIONS & RECOMMENDATIONS

End user feedback was solicited in November 2002 following the evaluation period. A survey was distributed to everyone that had used the equipment over the course of the project. A summary of the survey responses are shown in Table 1. Numerical results are based upon the following scale:

5 = Strongly Agree
4 = Agree
3 = Neutral
2 = Disagree
1 = Strongly Disagree
0 = Not applicable to me

Survey Statement	Average Response
About the DGPS (Trimble) unit:	
• The hardware (GPS, antennas, computer, cables) was easy to set up and get running.	4.0
• The laser gun was easy to set up and connect to the computer.	4.3
• The accuracy of the DGPS was sufficient for my projects.	3.1
• The accuracy of the laser unit was sufficient for my work.	4.0
• The hardware, in general, worked reliably.	3.8
About the RTK-GPS (Leica) unit:	
• The hardware (GPS, antennas, computer, cables) was easy to set up and get running.	3.7
• Setting up the base station was easy.	4.0
• The time and complexity of setting up the base station was worth the increased accuracy.	4.7
• The accuracy of the RTK-GPS was sufficient for my projects.	4.7
• The hardware, in general, worked reliably.	3.7
About the belt worn field PC:	
• The field computer was reliable.	3.8
• The field computer was easy to use.	4.0
• I was able to figure out the pen based mouse without much assistance.	4.8
• The field computer was easier to use than a laptop.	4.4
• I'd prefer the pen-based PC to a conventional laptop for this type of application.	4.8

Table 1 – Survey results after evaluation period

Survey Statement	Average Response
About the PenMap software:	
• The software was easy to install on the Via PC.	3.0
• The software was easy to install on my desktop PC in the office.	4.0
• The software ran reliably with no errors.	3.0
• The software was easy to launch and start mapping.	3.4
• It was easy to set up the DGPS unit with the PenMap software.	4.0
• It was easy to set up the RTK-GPS units with the PenMap software.	4.0
• It was easy to set up the laser unit with the PenMap software.	3.5
• Setting up layers to do the Digital Terrain Modeling (DTM) was easy.	3.3
• Generating the topo in real time was easy.	4.0
• Generating cross-sections was easy.	4.2
• The cross-sections provided useful information for slope stability analyses.	3.8
• The software was easy to customize for Caltrans applications.	3.0
• The electronic documentation and help files within the program were useful.	3.0
About the training sessions:	
• The amount of training was adequate.	3.5
• Training materials and resources available to me were adequate.	3.6
About the systems integrator, Condor Earth Technologies:	
• The systems integrator was responsive with technical issues.	4.7
• The integrated system was packaged and configured as expected.	4.0
About the web-based checkout system:	
• Making a reservation for the system was easy.	4.8
• The procedure of transferring equipment from one user to the next worked well.	3.8

Table 1 – Survey results after evaluation period (continued)

Survey results provided useful feedback on the field mapping systems. Key observations resulting from the survey are as follows:

- The DGPS system was significantly easier to set up and use compared to the RTK-GPS system. However, users felt that the additional complexity in setting up the RTK-GPS system was worth the increased accuracy.
- The laser rangefinder was easy to set up for all users and provided sufficient accuracy.
- The accuracy of the DGPS system was not sufficient for some users, whereas the accuracy of the RTK-GPS was sufficient for all users.
- Feedback on the reliability of both systems were mixed with some users experiencing problems.

- Most users felt that the Via field computer was reliable, easy to use, and preferable over a conventional laptop for field work.
- Users found the PenMap software strong in interfacing with the GPS equipment, and for developing topos and cross sections. However, reliability and robustness of the software and documentation were a problem and need improvement.
- Training sessions and training materials were, in general, sufficient.

IMPLEMENTATION

The project was successful in accomplishing its primary goal, which was to expose the latest field data collection and real-time mapping technologies to the geotechnical staff within the Department through the use of the two field mapping units. Over the course of the evaluation period, fourteen staff persons were trained in the use of the equipment, and landslide mapping units were successfully deployed on over thirty projects.

Implementation of the technology is being carried out in two stages. As a first stage, immediate implementation has resulted from the permanent transfer of the equipment from the Division of Research & Innovation to the Division of Engineering Services, Geotechnical Services, Geotechnical Design North, Branch E. Two of the designated Caltrans trainers for the PenMap equipment are sourced to Branch E. As such, the transfer of equipment to this group has assured that the equipment is kept in good working order, and that trained personnel are always available to assist others. The equipment will continue to be made available to other geotechnical staff statewide to assist in rapid response situations, in addition to further improving mapping procedures with PenMap.

The second implementation stage will occur over the next couple of years as real time topographic mapping with systems such as PenMap becomes more routine when responding to landslide occurrences. It is anticipated that the benefits realized from the time savings, the higher quality map products, and improved designs will promote the need for other Branches to procure additional units for wider statewide availability to staff. Several of the Branch Chiefs have already expressed their intention of procuring and incorporating PenMap as one of their primary reconnaissance tools in rapid response landslide situations.

ACKNOWLEDGEMENTS

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APPENDIX A:

SURVEY RESPONSES FROM INITIAL DEMONSTRATION OF FIELD MAPPING SYSTEMS

Following the March 2000 demonstration a survey was distributed to participants. All of the responses from the survey are documented in the following pages.

How many times in a year would you utilize the PenMap system if it were readily available?

- Probably only once or twice
- 2 or 3
- I would probably use it like I would the GPS units we have. This would be approximately 3 weeks a year. Keep and mind I have not fully incorporated GPS/GIS into all of my projects, mostly due to the lack of time. PenMap would make it easier to generate maps in the field as I am taking points/lines/polygons. I believe archaeologist as well as other biologists would use as well (approximately 30+ people).
- 1 - 10 times
- At least six times a year, or, as many as possible.
- Eight times
- 5 times a year
- If coupled with digital camera for point annotation: 5-10 times/yr plus major use after EQ. If no camera capabilities: 2-4 times/yr plus EQ

Was the accuracy of the DGPS unit (+/- 1 m) sufficient for your application? Or, is the accuracy of the RTK-GPS unit needed (+/- 0.010 m)?

- The DGPS was probably good enough except in certain engineering instances 0.01 m will be of much better help (1.0 m accuracy is not enough for us). Accuracy of +/-1 acre is okay for our work. Of course, more accuracy is always better, but I do not believe we need that great of accuracy.
- RTK-GPS preferred.

- I prefer RTK-GPS system if the cost is not important.
- Either would be ok.

- I think the RTK-GPS unit would be required.
- I prefer RTK for EQ applications, but DGPS is OK for photo surveys. However, for research purposes, I believe RTK should be investigated as that is where the technology is headed.
- Regarding the 0.01 m accuracy(?), is it cumulative as you go from one station to another? For example, if you walk around and on the slide area and take measurements, is the +/- accuracy of 0.01 m is for each reading? I am wondering whether the errors add up!

What features of the system did you like? Dislike? Needs improvement?

- I wasn't in direct contact with anything but the range finder so it is hard to judge, I did like the range finder.
- Needs improvement: (a) too bulky, needs to be more integrated (too many parts); (b) warranty/service duration too short (one year is not enough); (c) accuracy needs to be improved (see 1.); (d) it should be able to produce a cross-section as required for the slope stability analysis (X, Y axes, etc.); (e) I have some mixed filling about its susceptibility to the still shaky performance of the GPS satellite system/s; (f) a bit more user-friendly for the guys that are not so computer-advanced. I liked that you could actually see the map get generated before my eyes. I could see how this would help in quality control. It would let me see what I had mapped and not mapped. I liked the way you could attach other devices such as the laser rangefinder and the digital camera. The pull down menus looked to be vary detailed and flexible (permitting modification). One thing I dislike, which applies to all GPS units right now is that it does not work too well in trees or wooded areas. Of course it could also be lighter and cheaper. All we need from this system is data entry and contours generation, so that we can verify we have entered

correct information in the field. Other fancy features, such as cutting cross sections, volume calculations, may be better handled by a CAD program in the office. Therefore, probably opposite to other opinions, I prefer to see a scaled down system that is reliable and easy to use and provide backup for the data entered.

- Landslides in California mostly take place during raining season, when the system most likely to have problem to operate due to rainfall, thick cloud, and heavy vegetation.
- RTK-GPS system is real time system. You know what you get at the time when you are collecting the data. DGPS system is not a very reliable system especially for different conversion (English to metric system or etc.). It needs improvement in that regards.
- Likes: instant contouring and cross-sections. Dislikes: vegetation limitations (most of northwest CA is densely vegetated w/ rugged terrain).
- I liked the ability to generate topo, x-sections and make corrections in the field quickly. I did not see how the rangefinder worked with the system.
- Like: lightweight; nice screen; very nice interface. Dis: couple bugs crashed system; weatherproof?; needs customization & simplification .. way too many user options to easily screw up configuration.

Was the laser rangefinder useful? Given the choice, would you use the laser or just walk the slide?

- ☐ I would use the range finder for most of my work, it would be very useful
- ☐ The laser rangefinder does appear to be useful. If the slide area were dangerous to walk I would imagine that people would prefer to use the laser rangefinder. The only questionable thing that I saw was the laser gun. If it worked well, I'd be more inclined to use it, but, if it struggles to pick up the desired target then I wouldn't use it. More often than not I think we would have to walk the site because of the existing trees and shrub commonly found at landslide sites. Rangefinder is very useful as a supplement for locations that are difficult to access.

- The laser rangefinder was useful especially the slope is steep or the access is difficult. Given the choice, I would use both.
- It is depended on the project. I do not know whether DGPS system can set up other reference point and merge with the first data set.
- Yes, I would rather use the laser.
- The range finder would be very useful in areas that were difficult to access. I would use both methods.
- No opportunity to closely evaluate .. I do like the concept.
- I find laserfinder useful for certain applications, e.g., when the geologist does seismic refraction survey, he can quickly get a picture of the topography of the area where the seismic refraction survey is being conducted. For an area of say 60 m x 60 m, I think an accuracy of +/- 1 m should be OK.
- Another area where laserfinder could be useful, is to map an area where a future cut is to be made. This will give the topo, cross sections and volume of material to be excavated.

Were there any features that you would have liked to have seen on the PenMap system? Or, other survey tools integrated?

- Not at this time
- I can not think of any right now. It appears to be very inclusive as far as features that you can incorporate. Base on the contours generated, the contours generation of the system is based on TIN (triangular irregular network), a very fundamental geometry interpolation. It will be more beneficial if there are options of using Krigging to generate contours.
- Locations of faults, folds, and shear planes can be entered using these systems. However, automatic readout and entry of strikes and dips with a compass similar to the rangefinder will be very helpful.
- Positioning on USGS quads would be useful.
- Not sure, since I'm not really familiar with the software. Can it be used to estimate volumes?

- Digital camera for annotation of points.

Any other applications of this technology?

- Most of my work is with landslides or site assessment, cross-sections or topos, it seems very useful in those areas. I would work wonderfully as a tool to map important biological areas (wetlands, T&E species habitat, etc.) and archaeological sites. The incorporation of photos taken at specific sites, such as when we are documenting or monitoring, would also be very useful.
- Generate x-sections on other projects than landslides.
- I can see it used in geologic mapping and some of our legal cases.
- With camera .. all reconnaissance & field surveys would benefit. You'd have a running record of your location and where you took pictures. Could be applied to PEQIT work, vibration pre-surveys, borehole siting, .. limitless.

APPENDIX B:

EQUIPMENT & PURCHASING SPECIFICATIONS

Two complete field mapping systems, System A and System B, and on-site training shall be furnished to the State of California Department of Transportation.

Training

Delivery of the systems shall include two separate sessions of 2-day onsite trainings, 8 hours each day, with Departmental staff at the Caltrans Translab facilities at 5900 Folsom Blvd, Sacramento, CA, 95819. One additional day of training and consultation will also be provided to accommodate customization and/or modification of the package based upon user feedback. The two on-site trainings shall include an introduction to GPS and survey practices, and the proper use and maintenance of the system components and software. Trainings shall be presented in both classroom and field environments. Field training will be performed at a location within 40 miles of the Translab facilities. The first on-site training shall be provided within 3 months following the delivery of the systems. The second on-site training shall be provided within 15 months following the delivery of the systems. The additional day of training and consultation shall be provided within 18 months following the delivery of the systems. Dates and time of trainings shall be agreed upon by both the vendor and the State. The price for the training sessions shall include all labor, travel, training materials, overhead, and miscellaneous expenses incurred by the vendor. The classroom and field training facilities will be arranged by the State at no cost to the vendor.

System A

System A shall be comprised of a differential global positioning system (DGPS) receiver and antenna, laser range finder, field computer, and field data collection software. The entire system will be an integrated package of commercially available GPS, GIS, and laser-based measurement technologies that forms a complete single-user mapping operation.

The DGPS receiver shall be capable of 12-channel parallel tracking of L1 C/A code with carrier phase. The position update rate shall be at least 1 Hz. Differential speed accuracy shall be 0.1 mph or better. Differential position accuracy shall be less than 1 meter horizontal RMS given 5 satellites, PDOP<4, and receipt of RTCM SC-104 standard format correction message. The DGPS receiver shall incorporate a dual-channel medium frequency (MF) receiver as well as a L-band satellite differential correction receiver. The GPS, MF, and L-band receivers shall be integrated into one enclosure. This unit shall interface to an integrated L1 GPS, L-band satellite differential, and MF beacon antenna. The dual-channel MF receiver shall be capable of receiving correction broadcasts from government-established navigation beacon reference stations. The L-band satellite differential correction receiver shall be capable of receiving satellite correction broadcasts from the OmniStar Worldwide DGPS Service. The GPS device must be compatible with the field computer and field data collection software.

The laser-based measurement device shall be a handheld device that allows the operator to measure distance vectors in an outdoor environment. The unit shall be a Class I laser device with a wavelength of 904 to 905 mm; beam divergence 2.5 to 3.0 mrad; accuracy of +/- 6 inches or better; acquisition time of 1/3 second or better; range of at least 2,000 ft without reflectors; water resistant; and RS-232 communications support. The device shall be supplied with a tripod and vertical and horizontal encoders that provide 0.2^{o} or better accuracy. The laser-based measurement device must be compatible with the field computer and field data collection software.

The field computer shall have Microsoft Windows 98 or Windows 2000 as the operating system; a 166 MHz Pentium or Cyrix Media GXi or faster processor; 64 MB RAM or greater; 3.2 GB internal hard drive capacity or greater; two type II or one type III PC card slots; one or more USB ports; one or more RS-232 ports; at least two PS/2 ports; RGB interface; and operate in temperatures of 0^{o} to $+55^{o}$C and humidity levels of 8% to 90% non-condensing. The computer shall have a sunlight readable color display with active touch interface and stylus, interfaced by Microsoft Pen

Services. The entire computer system including CPU, display, and power systems, shall be portable (less than 5 pounds in weight) and continuously operable on battery power for up to 4 hours. Exposed components of the computer shall be water resistant. The field computer must be compatible with the field data collection software.

The field data collection software shall be the most recent version of software package *PenMap*. The PenMap software is an integrated surveying, geographic information systems (GIS), data management, and real-time visualization software package that accepts data from the GPS, laser devices, and survey total stations. PenMap is available through Condor Earth Technologies, Inc., the sole North American distributor of the software, at:

Condor Earth Technologies, Inc.
P.O. Box 3905
21663 Brian Lane
Sonora, CA 95370
(209) 532-0361
(209) 532-0773 FAX
www.condorearth.com

The software shall be configured to run on the field computer and operate with the GPS and laser devices.

The GPS receiver, field computer, and associated batteries and cables shall be mounted in a backpack with a structural frame. The backpack shall have a pole extension to accommodate the mounting of the combined L1 GPS, L-band satellite differential, and MF beacon antenna. The system shall be configured such that the operator can walk along the terrain of interest, with the backpack and field computer display and stylus in hand, and develop and view topographic maps in real-time on the display. The handheld laser-based measurement device shall be configured to operate while being held by the operator, or mounted to a tripod with encoder, or mounted to a rangepole with an encoder. When the laser-based measurement device is mounted to the encoder and rangepole, the system shall be configured such that the GPS antenna can also be mounted to the top of the rangepole.

System B

System B shall be comprised of a real time kinematic global positioning system (RTK-GPS) including two sets of receivers and antennas (base and rover units), radio modems for real time data link between base and rover, field computer, and field data collection software. The entire system will be an integrated package of commercially available GPS and GIS technologies that forms a complete single-user mapping operation.

The base and rover GPS receivers shall be dual frequency receivers capable of 12-channel parallel tracking of L1 full phase, C/A narrow code, and precision code, as well as 12-channel parallel tracking of L2 full phase and P code. The RTK-GPS units shall be capable of static, rapid static, kinematic, and on-the-fly real time kinematic, DGPS/RTCM, post processing. The basline RMS with RTK shall not exceed 10 mm + 2ppm (RMS) under moving conditions. On the fly RTK initialization shall not exceed 60 seconds. The position update rate shall be at least 5 Hz. L1/L2 antennas shall be mounted on a groundplane or choke ring. The GPS device must be compatible with the field computer and field data collection software.

The radio modems shall be ruggedized wireless RS-232 spread spectrum data transceivers operating in 902 to 928 MHz license-free frequencies. Line-of-sight range shall be a minimum of 20 miles with a unity gain antenna. Output power for transmitter shall not exceed 1 W. Throughput shall be up to 115,200 baud. The unit shall have an RS-232 1200 to 115,200 baud range and standard DB9 connector. The unit shall be capable of operation in point-to-point, point-to-multipoint, peer-to-peer, and repeater modes. The unit shall be capable of operation in temperatures of -0° to +50°C. Enclosures shall be ruggedized and water resistant. The radio modems must be compatible with the GPS units.

The field computer shall have Microsoft Windows 98 or Windows 2000 as the operating system; a 166 MHz Pentium or Cyrix Media GXi or faster processor; 64 MB RAM or greater; 3.2 GB internal hard drive capacity or greater; two type II or one type III PC card slots; one or more USB ports; one or more RS-232 ports; at least two PS/2 ports; RGB interface; and operate in temperatures of 0° to +50°C and humidity levels of 8% to 90% non-condensing. The computer shall have a sunlight readable color display with active touch interface and stylus, interfaced by Microsoft Pen Services. The entire computer system including CPU, display, and power systems, shall be portable (less than 5 pounds in weight) and continuously operable on battery power for up to 4 hours. Exposed components of the computer shall be water resistant.

The field data collection software shall be the most recent version of software package *PenMap*. The PenMap software is an integrated surveying, geographic information systems (GIS), data management, and real-time visualization software package that accepts data from the GPS, laser devices, and survey total stations. PenMap is available through Condor Earth Technologies, Inc., the sole North American distributor of the software, at:

Condor Earth Technologies, Inc.
P.O. Box 3905
21663 Brian Lane
Sonora, CA 95370
(209) 532-0361
(209) 532-0773 FAX
www.condorearth.com

The software shall be configured to run on the field computer and operate with the GPS device.

The rover GPS receiver, field computer, radio modem, and associated batteries and cables shall be mounted in a backpack with a structural frame. The backpack shall have a pole extension to accommodate the mounting of the radio modem's antenna. A rangepole shall be furnished to accommodate the mounting of the GPS L1/L2 antenna, and the field computer's display. The system shall be configured such that the operator can walk along the terrain of interest, with the backpack, rangepole in one hand, stylus pen in the other, and develop and view topographic maps in real-time on the display.

The base GPS receiver, radio modem, and associated batteries and cables shall be mounted in a field ruggedized enclose that can be placed in the interior of a stationary vehicle. A magnetic base shall be furnished to mount the GPS L1/L2 antenna and the radio modem's antenna on the roof of the vehicle.

Warranty

Individual components as well as the entire system shall be warrantied for a minimum period of one year. The system warranty shall be comprehensive and shall cover the costs associated with any software or hardware malfunctions, not resulting from missuse of equipment, requiring servicing by the vendor.

APPENDIX C:

CALTRANS FIELD PROCEDURES

BEFORE GOING TO THE JOBSITE

- DETERMINE WHICH PENMAP FIELD UNIT IS APPROPRIATE FOR YOUR MAPPING APPLICATION.
  - DGPS (TRIMBLE UNIT) WILL PRODUCE APPROXIMATELY 1 M HORIZONTAL AND 1.5 TO 2 M VERTICAL ACCURACIES.
  - RTK-GPS (LEICA UNITS) WILL PRODUCE APPROXIMATELY 1 CM HORIZONTAL AND 1.5 TO 2 CM VERTICAL ACCURACIES.
  - THE LASER RANGE FINDER WILL PRODUCE VECTOR SOLUTIONS WITHIN APPROXIMATELY 15 CM.

- CHECK TO SEE THAT YOU HAVE ALL OF THE COMPONENTS, CABLES, AND ACCESSORIES ASSOCIATED WITH THE SYSTEM (SEE EQUIPMENT CHECKLIST).

- COMPLETELY CHARGE ALL OF THE BATTERIES THE DAY BEFORE.

DO YOU NEED ADDITIONAL TRAINING?

IF YOU HAVE ANY QUESTIONS OR NEED ADDITIONAL TRAINING IN USE OF THE PENMAP SYSTEMS, THE FOLLOWING STAFF ARE AVAILABLE TO HELP:

CONTACT	UNIT	PHONE
LOREN TURNER	**NEW TECH & RESEARCH**	**(916) 227-7174**
BEN BARNES	**GEOTECH DESIGN NORTH**	**(916) 227-6979**
BRIAN GUTIERREZ	**GEOTECH DESIGN SOUTH**	**(916) 227-1984**
CHRIS JONES	**GEOTECH DESIGN NORTH**	**(805) 549-3728**

ADDITIONAL RESOURCES

PENMAP SOFTWARE, CHECK-OUT CALENDAR, AND ELECTRONIC MANUALS ARE AVAILABLE ONLINE AT:

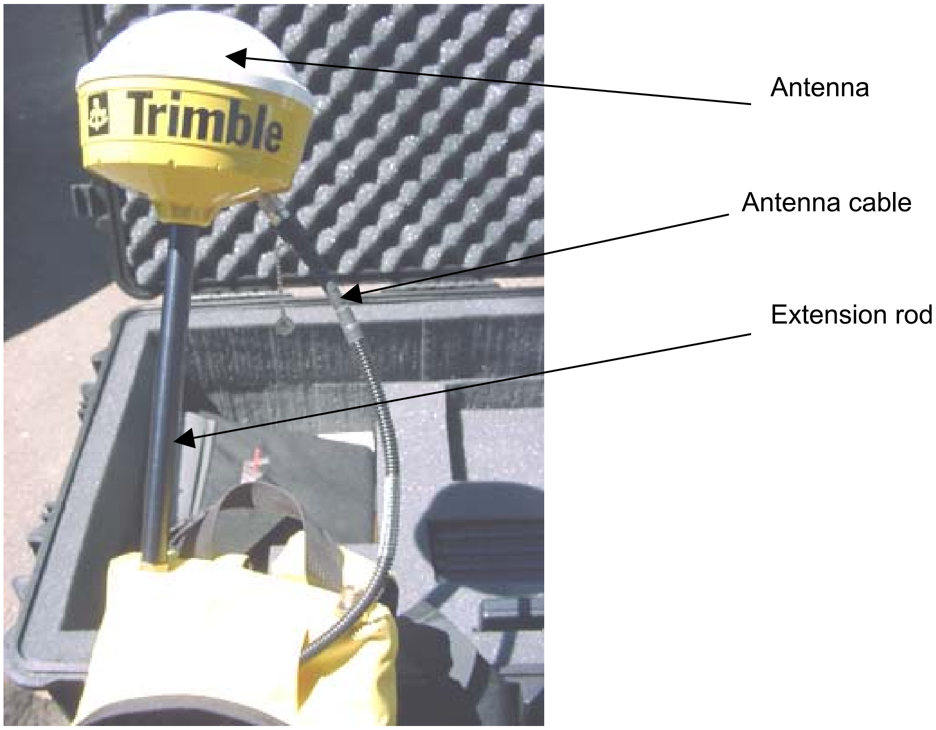
HTTP://ONRAMP.DOT.CA.GOV/NEWTECH/OFFICES/GI_BRANCH/RESEARCH_THEMES/GEO-IMPLEMENTATION/DATA-ACQ/PEN_MAP/PENMAP.HTML

ALSO, THE INCLUDED CD CONTAINS SOFTWARE AND TRAINING RESOURCES.

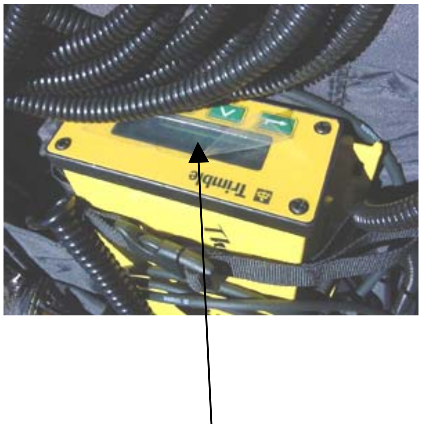
SETTING UP THE HARDWARE FOR THE DGPS FIELD MAPPING SYSTEM (TRIMBLE SYSTEM)

- UNPACK THE FIELD EQUIPMENT.

- ATTACH THE TRIMBLE ANTENNA AND EXTENSION ROD TO THE BACKPACK. CONNECT THE ANTENNA CABLE.

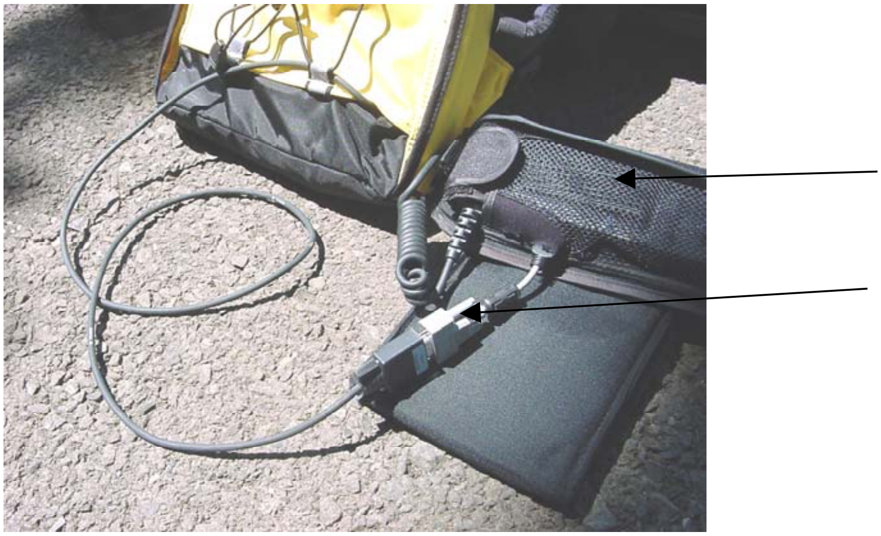


- INSERT A CHARGED MOLICEL BATTERY INTO THE BATTERY CASE IN THE BACKPACK. VERIFY THAT THE TRIMBLE GPS UNIT POWERS ON ONCE THE BATTERY IS INSERTED.



Panel should light up when powered ON

- CONNECT THE SERIAL CABLE FROM THE VIA COMPUTER TO THE SERIAL CABLE ON THE BACKPACK.



Via Computer

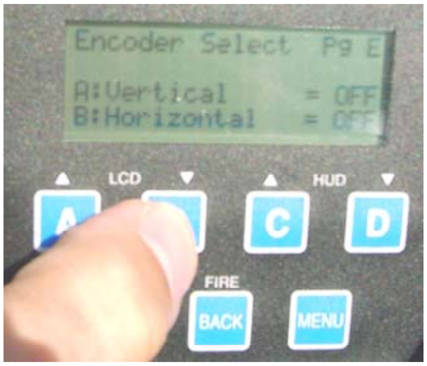
Serial cable

SETTING UP THE LASER RANGE FINDER (LASER ATLANTIC)

- UNPACK THE FIELD EQUIPMENT.

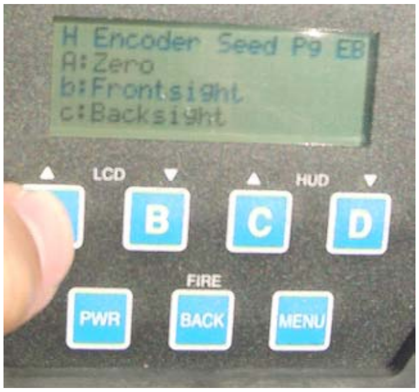
- SET UP THE TRIPOD. ATTACH LASER HANDLE (BATTERY) TO LASER UNIT. ATTACH CABLE FROM HORIZONTAL ENCODER TO THE LASER. ATTACH SERIAL CABLE TO HANDLE OF LASER UNIT.

- POWER ON THE LASER UNIT. IF SET UP PROPERLY, THE FIRST WINDOW TO APPEAR WILL BE THE “ENCODER SELECT” INTERFACE. SELECT “B” FOR HORIZONTAL.

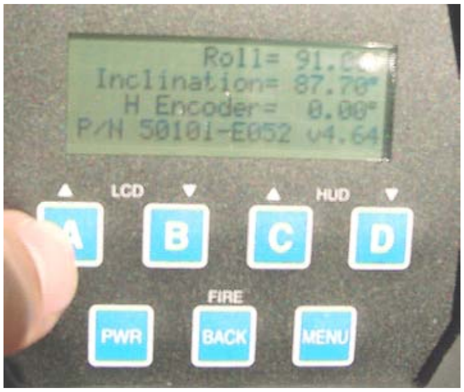


Encoder Select Pg E
A:Vertical = OFF
B:Horizontal = OFF

- NEXT, SET THE ENCODER TO “ZERO” BY PRESSING THE “A” KEY. THE SCREEN SHOULD THEN SHOW “H ENCODER = 0.00º”. THE ENCODER IS NOW PROPERLY CONFIGURED.



H Encoder Seed Pg EB
A:Zero
b:Frontsight
c:Backsight

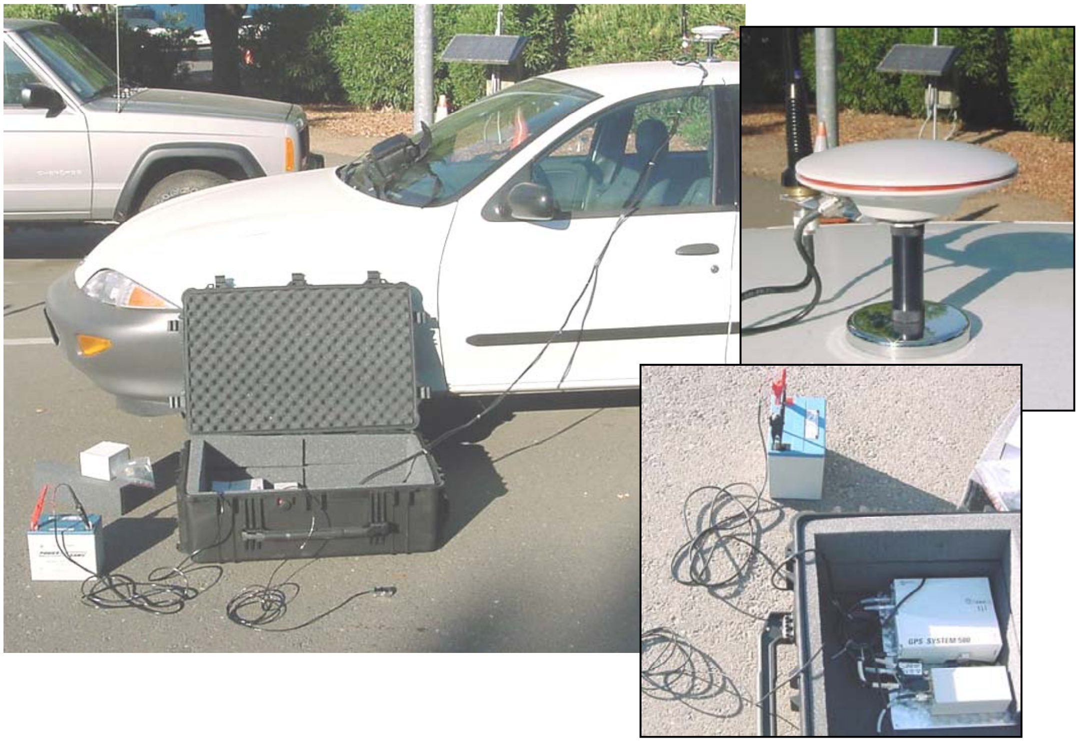


Roll= 91.
Inclination= 87.70°
H Encoder= 0.00°
P/N 50101-E052 v4.64

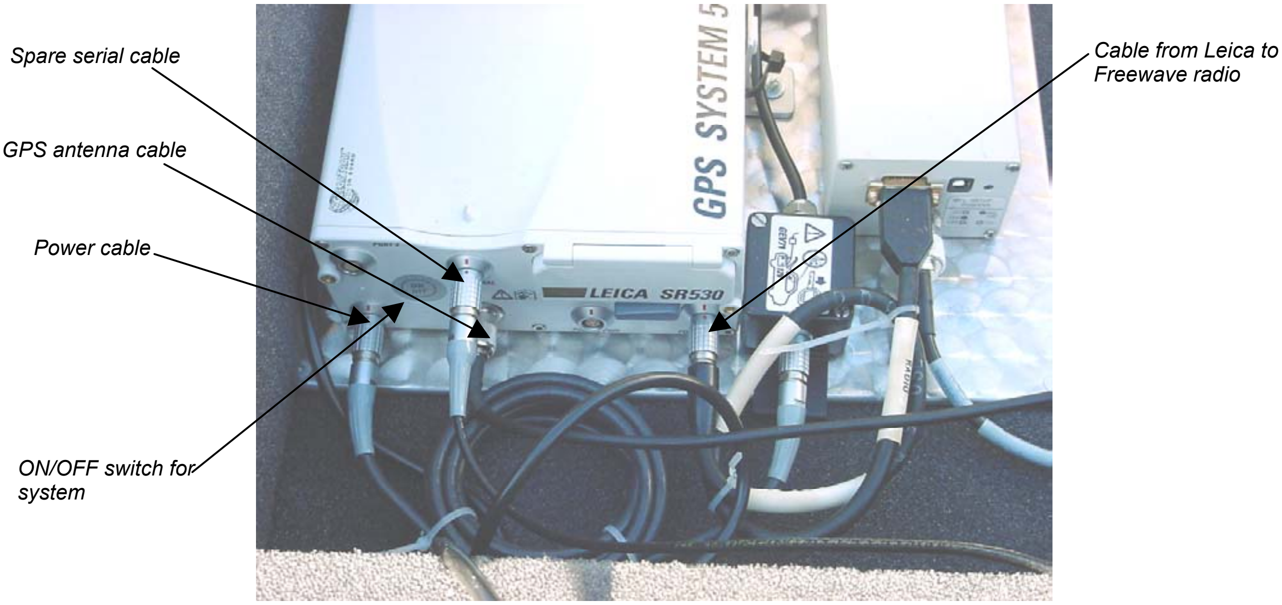
SETTING UP THE HARDWARE FOR THE RTK-GPS FIELD MAPPING SYSTEM (LEICA SYSTEM)

- UNPACK THE FIELD EQUIPMENT.

- SET UP THE RTK BASE STATION ON THE VEHICLE. MOUNT THE BASE STATION GPS ANTENNA AND RADIO WHIP ANTENNA TO THE MAG BASE AND SET ON TOP OF THE VEHICLE. CONNECT THE BATTERY CABLE TO THE BATTERY. THE ENTIRE BASE STATION PACKAGE CAN BE PLACED INSIDE THE VEHICLE FOR SECURITY.

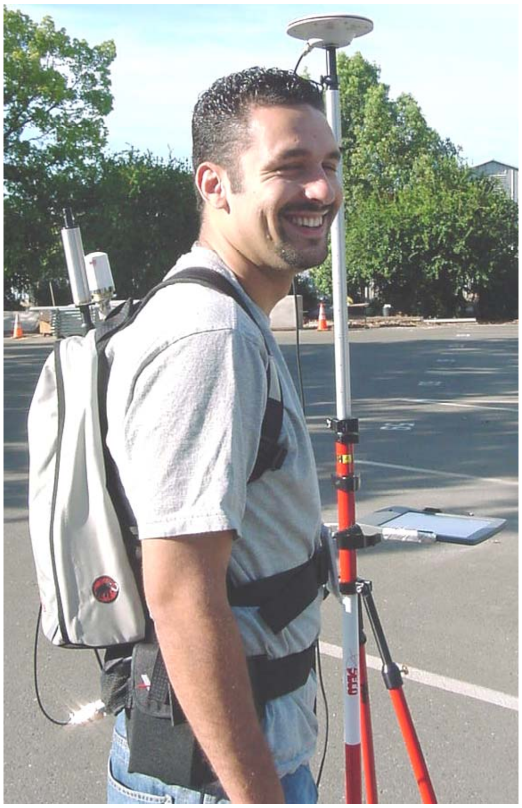


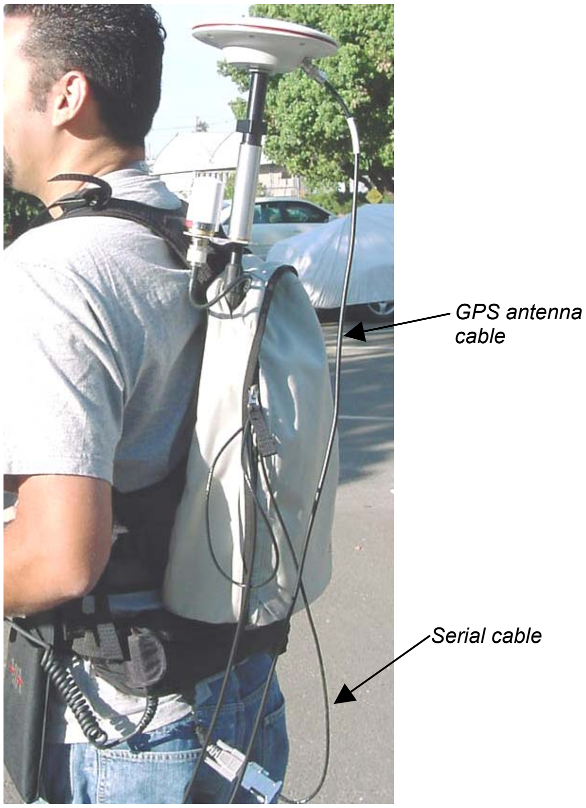
- MAKE SURE THAT THE LEICA RECEIVER IS PROPERLY CONNECTED TO THE RADIO AS SHOWN IN THE PHOTO. TURN ON THE SYSTEM BY HOLDING THE ON SWITCH ON THE LEICA FOR A FEW SECONDS. STATUS LIGHTS ON BOTH THE LEICA AND FREEWAVE SHOULD TURN ON.



- SET UP THE ROVER BACKPACK. INSERT TWO CHARGED BATTERIES INTO THE LEICA UNIT. POWER UP THE SYSTEM FOLLOWING THE SAME PROCEDURES AS THE BASE STATION SYSTEM. THERE SHOULD BE THREE CABLES EXTENDING FROM THE BACKPACK: RADIO ANTENNA CABLE, GPS ANTENNA CABLE, SERIAL CABLE. THE RADIO ANTENNA SHOULD ALREADY BE CONNECTED TO THE RADIO ANTENNA CABLE.

- THE RTK-GPS SYSTEM CAN BE CONFIGURED FOR RANGE POLE MOUNT (FOR HIGH PRECISION SURVEY WORK), OR BACKPACK MOUNT (IF HIGHEST PRECISION ISN'T WARRANTED). THE GPS ANTENNA IS MOUNTED TO A QUICK-CONNECT POST TO FACILITATE SWITCHING FROM THE BACKPACK TO THE RANGE POLE. MAKE SURE THAT THE GPS ANTENNA CABLE IS CONNECTED TO THE GPS ANTENNA. ALSO, MAKE SURE THAT THE SERIAL CABLE FROM THE BACKPACK IS CONNECTED TO THE VIA COMPUTER.





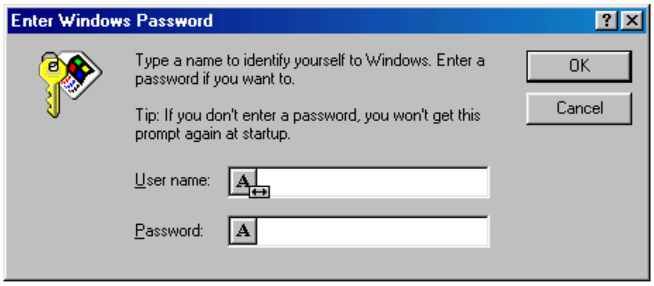
- WHEN USING THE RANGE POLE, THE SCREEN FOR THE VIA COMPUTER CAN BE MOUNTED TO THE POLE FOR CONVENIENCE.

SETTING UP THE VIA COMPUTER AND CONFIGURING PENMAP

☐ CONNECT ONE OR TWO OF THE MOLICEL BATTERIES TO THE VIA COMPUTER.

☐ START UP THE VIA COMPUTER. YOU CAN USE THE POWER BUTTON ON THE MAIN UNIT OR THE SMALL BUTTON ON THE BACK OF THE VIA'S SCREEN.

☐ WHEN WINDOWS 98 STARTS, YOU'LL BE PROMPTED FOR A USERNAME AND PASSWORD. PRESS "CANCEL"



Enter Windows Password

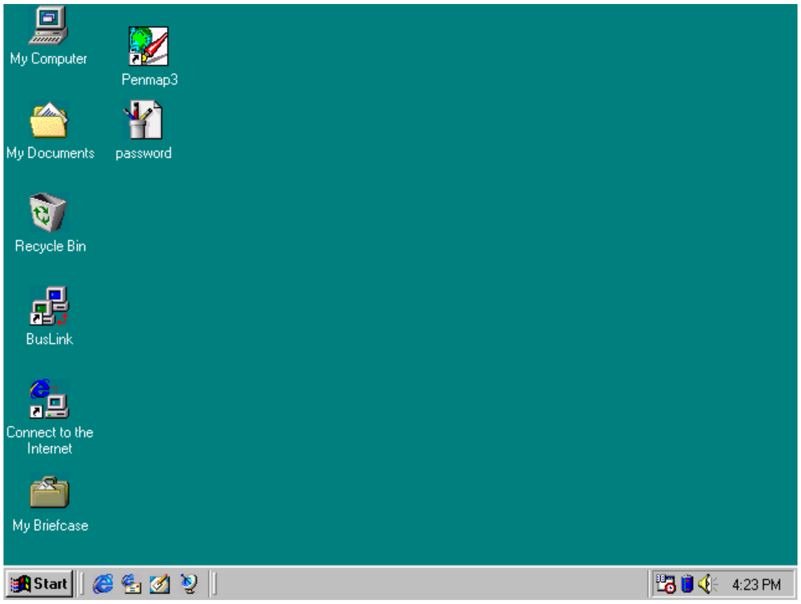
Type a name to identify yourself to Windows. Enter a password if you want to.

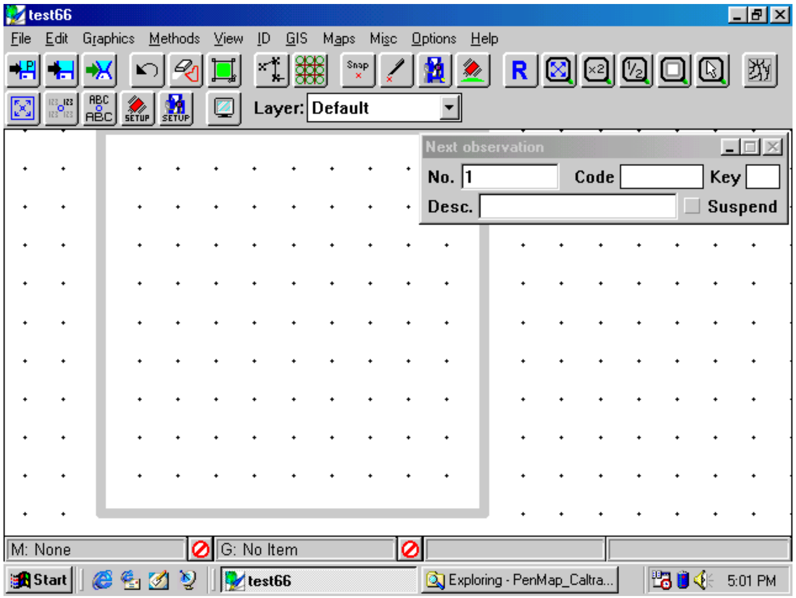
Tip: If you don't enter a password, you won't get this prompt again at startup.

User name:

Password:

- ❑ LAUNCH PENMAP FROM THE “PENMAP3” SHORTCUT ON THE DESKTOP.





Layer: Default

No. 1

Code

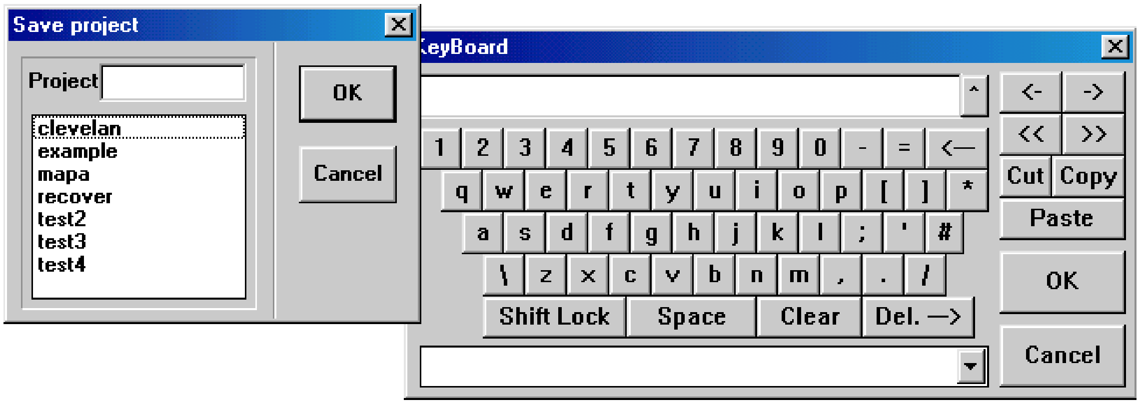
Key

Desc.

M: None

G: No Item

- PENMAP WILL FIRST PROMPT YOU FOR A PROJECT NAME. THIS IS THE NAME THAT WILL BE USED FOR ALL FILES GENERATED DURING THE MAPPING SESSION. HOLDING THE STYLUS PEN ON THE BLANK FIELD WILL BRING UP A KEYBOARD INTERFACE TO ALLOW YOU TO ENTER TEXT. PRESS OK WHEN COMPLETE.



Save project

Project

clevelan
example
mapa
recover
test2
test3
test4

- OPEN THE "CODING SYSTEM" INTERFACE BY SELECTING THE ICON IN THE MENU BAR. THESE "CODES" ALLOW YOU TO ASSIGN A DESCRIPTION OR A TAG TO THE POINTS THAT YOU COLLECT. EVERY POINT COLLECTED IN PENMAP WILL HAVE SOME CODE ASSOCIATED WITH IT *(I.E. EP1 = "EDGE OF PAVEMENT FOR LINE 1")*.

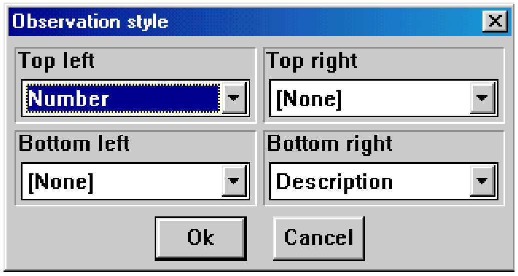
Code

Frozen

1 of 2

EP 1
EP 2
CL
ETW 1
ETW 2
SCRPT
SCRPB

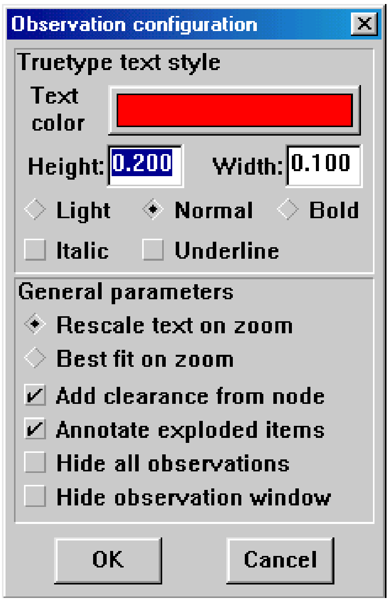
- OPEN THE "OBSERVATION STYLE" SETTINGS BY SELECTING THE ICON IN THE MENU BAR. WHEN A POINT IS COLLECTED, IT WILL APPEAR ON THE SCREEN. THESE SETTINGS WILL CONTROL WHICH LABELS APPEAR NEXT TO EACH POINT ON THE SCREEN. IN THE SCREEN BELOW, THE DATA POINT NUMBER WILL APPEAR ABOVE AND TO THE LEFT OF THE POINT, AND THE DESCRIPTION ON THE POINT WILL APPEAR BELOW AND TO THE RIGHT OF THE POINT.



Observation style

Top left: Number
Top right: [None]
Bottom left: [None]
Bottom right: Description

- OPEN THE "OBSERVATION CONFIGURATION" SETTINGS BY SELECTING THE ICON IN THE MENU BAR. THESE PREFERENCES CONTROL THE FONT SETTINGS FOR THE LABELS YOU'D LIKE TO DISPLAY NEXT TO EACH POINT.



Observation configuration

Truetype text style

Text color

Height: 0.200 Width: 0.100

○ Light ● Normal ○ Bold

☐ Italic ☐ Underline

General parameters

● Rescale text on zoom

○ Best fit on zoom

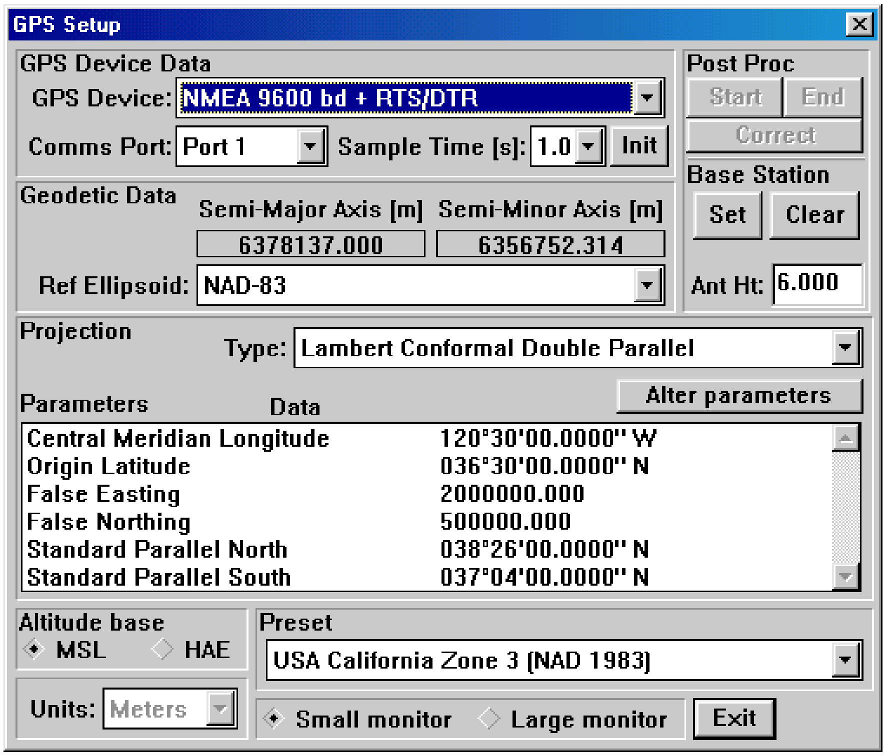
☑ Add clearance from node

☑ Annotate exploded items

☐ Hide all observations

☐ Hide observation window

- CONFIGURE THE GPS UNIT BY TAPPING THE "GPS SETUP" ICON .



GPS Setup

GPS Device Data

GPS Device: NMEA 9600 bd + RTS/DTR

Comms Port: Port 1 Sample Time [s]: 1.0

Geodetic Data

Semi-Major Axis [m]: 6378137.000

Semi-Minor Axis [m]: 6356752.314

Ref Ellipsoid: NAD-83

Post Proc

Base Station

Ant Ht: 6.000

Projection

Type: Lambert Conformal Double Parallel

Parameters	Data
Central Meridian Longitude	120°30'00.0000" W
Origin Latitude	036°30'00.0000" N
False Easting	2000000.000
False Northing	500000.000
Standard Parallel North	038°26'00.0000" N
Standard Parallel South	037°04'00.0000" N

Altitude base

● MSL ○ HAE

Preset: USA California Zone 3 (NAD 1983)

Units: Meters

● Small monitor ○ Large monitor

MAKE SURE THAT THE FOLLOWING SETTINGS ARE SELECTED:

GPS DEVICE:	**NMEA 9600 BD + RTS/DTR (IF USING THE TRIMBLE SYSTEM)** **LEICA GPS SYSTEM 500 (IF USING THE LEICA SYSTEM)**
COMMS PORT:	**PORT 1**
SAMPLE TIME:	**1.0**

IN ORDER TO COMPLY WITH CALTRANS SURVEYING STANDARDS AND DATUMS, MAKE SURE THAT THE FOLLOWING SETTINGS ARE USED:

REF ELLIPSOID:	**NAD-83**
PROJECTION:	**LAMBERT CONFORMAL DOUBLE PARALLEL**
ALTITUDE BASE:	**MSL (MEAN SEA LEVEL). THE CALTRANS STANDARD NAVD-88 IS NOT AVAILABLE IN THE SOFTWARE.**
PRESET:	**THE PRESET SHOULD BE SELECTED FOR THE SPECIFIC ZONE IN WHICH YOU ARE WORKING. FOR EXAMPLE, IN SACRAMENTO YOU WOULD USE *USA CALIFORNIA ZONE 3 (NAD 1983)* IF WORKING IN METERS, OR *USA CALIFORNIA ZONE 3 (NAD 1983) U.S. FEET* IF WORKING IN FEET. A MAP OF THE BOUNDARIES OF THE SIX ZONES IN CALIFORNIA IS SHOWN IN THE FOLLOWING PAGE.**

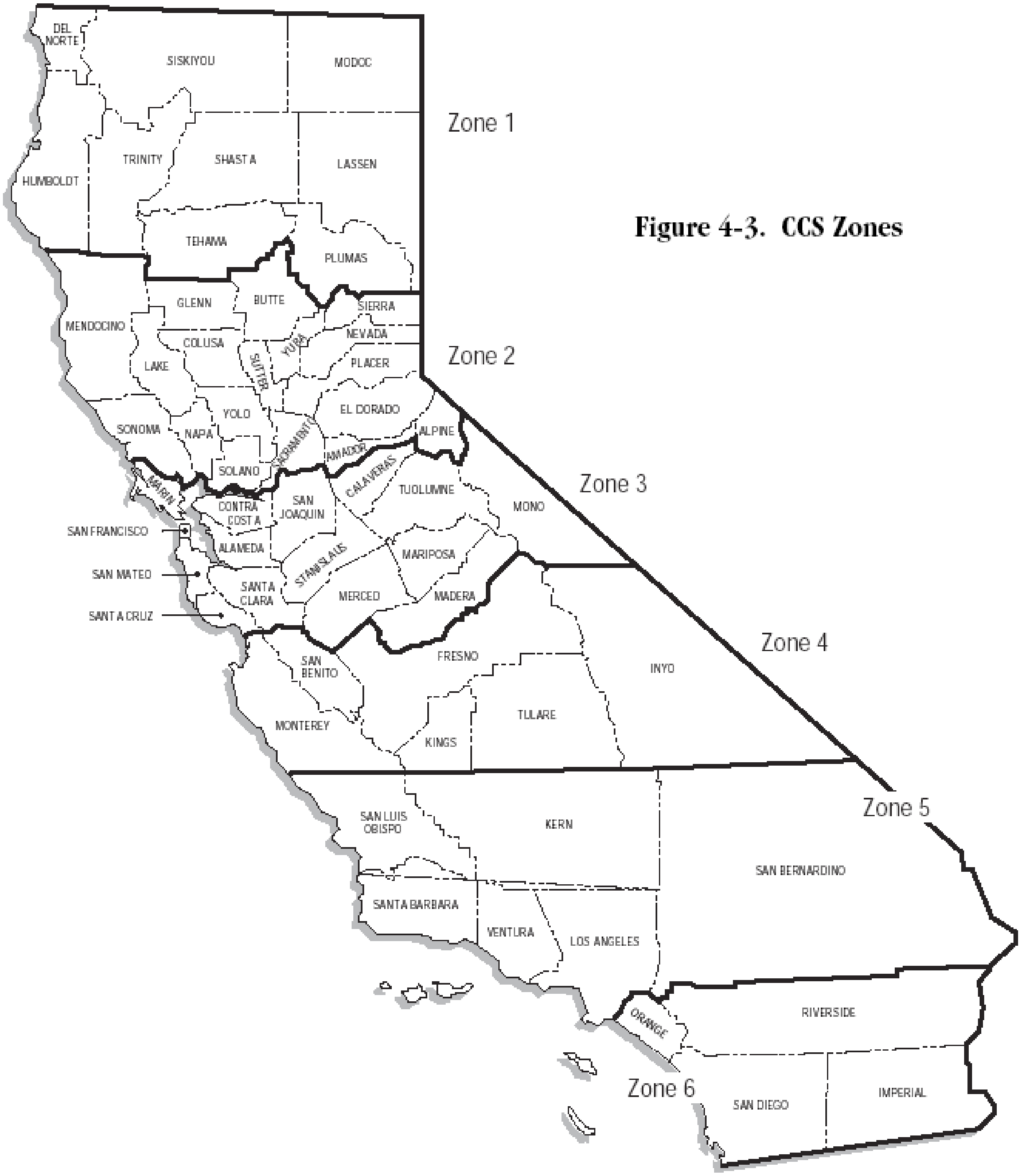


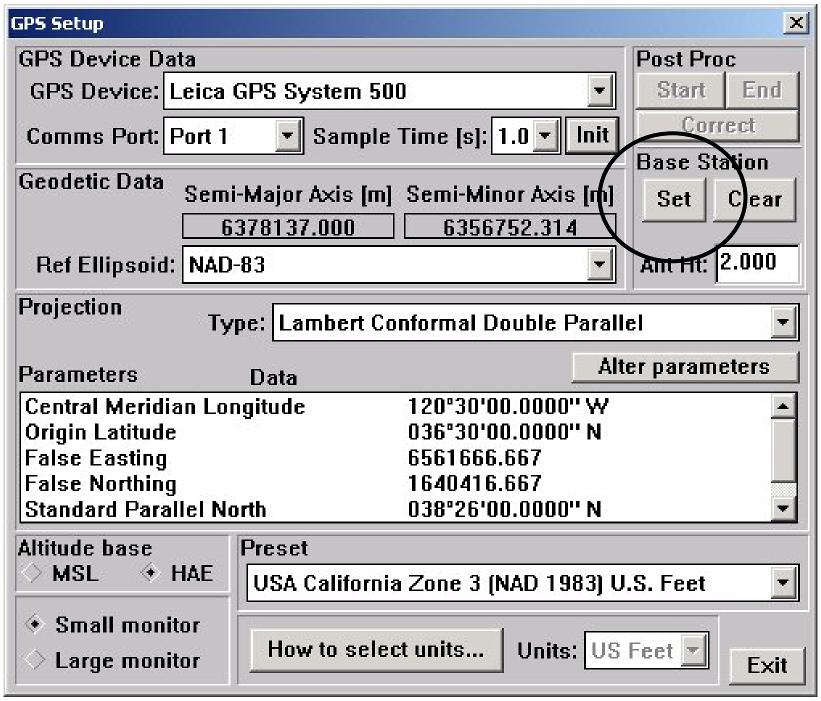
Figure 4-3. CCS Zones

IF USING THE RTK-GPS LEICA SYSTEM, THE FOLLOWING ADDITIONAL STEPS ARE REQUIRED TO SET UP THE SYSTEM.

DISCONNECT THE SERIAL CABLE FROM THE BACKPACK TO THE VIA. CONNECT THE VIA TO THE BASE STATION'S SERIAL CABLE. THIS CAN BE DONE WITHOUT SHUTTING DOWN THE VIA COMPUTER.

Base station serial cable

SELECT THE BASE STATION "SET" BUTTON.



GPS Device Data

GPS Device: Leica GPS System 500

Comms Port: Port 1

Sample Time [s]: 1.0

Geodetic Data

Semi-Major Axis [m]	Semi-Minor Axis [m]
6378137.000	6356752.314

Ref Ellipsoid: NAD-83

Ant Ht: 2.000

Projection

Type: Lambert Conformal Double Parallel

Parameters	Data
Central Meridian Longitude	120°30'00.0000" W
Origin Latitude	036°30'00.0000" N
False Easting	6561666.667
False Northing	1640416.667
Standard Parallel North	038°26'00.0000" N

Altitude base

○ MSL ● HAE

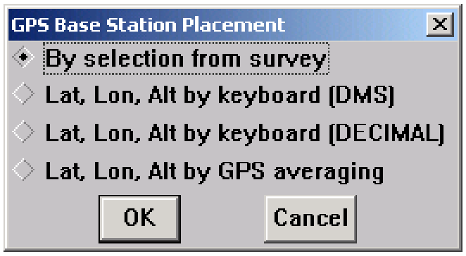
Preset: USA California Zone 3 (NAD 1983) U.S. Feet

● Small monitor

○ Large monitor

Units: US Feet

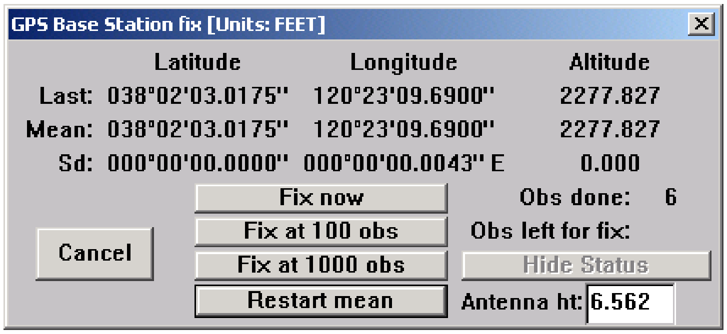
THE FOLLOWING WINDOW WILL APPEAR. CHECK THE BOX NEXT TO “LAT, LON, ALT, BY GPS AVERAGING.” CHECK THE OK BUTTON.



GPS Base Station Placement

● By selection from survey
○ Lat, Lon, Alt by keyboard (DMS)
○ Lat, Lon, Alt by keyboard (DECIMAL)
○ Lat, Lon, Alt by GPS averaging

A WINDOW WILL THEN APPEAR SHOWING CURRENT GPS STATUS. SELECT “FIX AT 100 OBS” AND WAIT UNTIL THE BASE POSITION IS ESTABLISHED.



GPS Base Station fix [Units: FEET]

	Latitude	Longitude	Altitude
Last:	038°02'03.0175"	120°23'09.6900"	2277.827
Mean:	038°02'03.0175"	120°23'09.6900"	2277.827
Sd:	000°00'00.0000"	000°00'00.0043" E	0.000

Obs done: 6
Obs left for fix:
Antenna ht: 6.562

A WINDOW WILL APPEAR CONFIRMING THE ESTABLISHMENT OF THE BASE STATION POSITION. CLOSE THE GPS SETUP WINDOW.

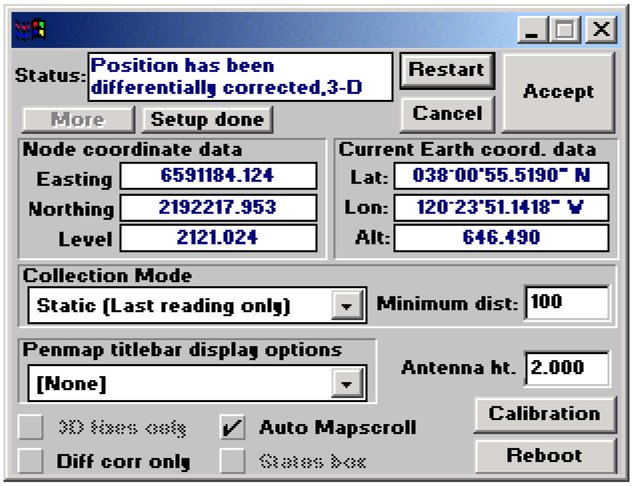
- OPEN THE GPS INTERFACE WINDOW BY TAPPING THE "GPS" ICON . IF THE GPS EQUIPMENT IS CONNECTED PROPERLY, THE SOFTWARE CONFIGURED PROPERLY, AND REAL-TIME DIFFERENTIAL CORRECTIONS AVAILABLE, THE STATUS WINDOW SHOULD BE SHOWING "GPS DIFFERENTIAL FIX AVAILABLE" WHEN USING THE TRIMBLE SYSTEM, OR "PHASE SOLUTION" WHEN USING THE LEICA SYSTEM.

IIIIIII Obs:104 GPS differential fix av...

Status: GPS differential fix available

NOTE: WHEN USING THE LEICA SYSTEM, A "DIFFERENTIAL" SOLUTION INDICATES <u>METER</u> ACCUARACY, WHEREAS A "PHASE" SOLUTION INDICATES <u>CENTIMETER</u> ACCURACY. THE USER SHOULD ALWAYS CHECK THE TYPE OF SOLUTION AVAILABLE PRIOR TO ACCEPTING POINTS.

- SELECTING "SETUP" WILL EXPAND THE WINDOW TO SHOW COMPLETE POSITIONING DATA.



Status: Position has been differentially corrected,3-D

Node coordinate data

Easting 6591184.124

Northing 2192217.953

Level 2121.024

Current Earth coord. data

Lat: 038°00'55.5190" N

Lon: 120°23'51.1418" W

Alt: 646.490

Collection Mode: Static (Last reading only)

Minimum dist: 100

Penmap titlebar display options: [None]

Antenna ht. 2.000

☐ 3D fixes only ☑ Auto Mapscroll

☐ Diff corr only ☐ Status box

- MAKE SURE THAT THE "COLLECTION MODE" IS SET TO "STATIC (LAST READING ONLY)." FOR "ANTENA HT" ENTER THE HEIGHT OF THE ANTENNA ABOVE THE GROUND SURFACE. USE METERS OR FEET DEPENDING UPON THE GPS SETTING USED IN THE GPS SETUP DIALOGUE. CHECK THE "DIFF CORR ONLY" SO THAT ONLY DIFFERENTIALLY CORRECTED MEASUREMENTS ARE ALLOWED TO BE SAVED. THIS WILL INSURE SUB-METER ACCURACIES.

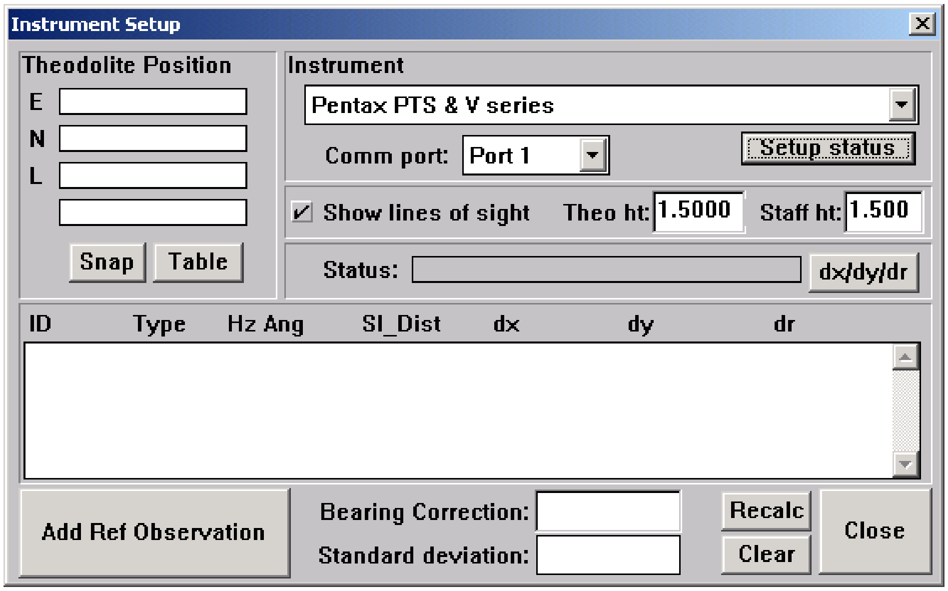
- THE LASER RANGE FINDER CAN BE USED IN LIEU OF THE GPS TO COLLECT FIELD DATA. IN ORDER TO USE THE LASER, YOU FIRST NEED TO COLLECT TWO REFERENCE POINTS. USING THE GPS, ESTABLISH TWO REFERENCE POINTS IN THE FIELD. THESE TWO POINTS DO NOY NEED TO BE SIGNIFICANT MAP DATA, BUT SHOULD BE SEPARATED BY AT LEAST 100 FT. THE TWO POINTS WILL ALLOW YOU TO ESTABLISH THE BEARING OF LASER.

- “CANCEL” THE GPS INTERFACE, AND DISCONNECT THE SERIAL CABLE FROM THE GPS TO THE VIA COMPUTER.

Status: GPS differential fix available

- PLUG IN THE SERIAL CABLE FROM THE LASER RANGE FINDER TO THE VIA COMPUTER. SET UP THE LASER AND TRIPOD ON TOP OF ONE OF THE TWO POSITIONS AS DESCRIBED EARLIER IN THE DOCUMENT. POWER ON THE SYSTEM. TARGET THE LASER AT THE OTHER REFERENCE POSITION. RESET THE HORIZONTAL ENCODER TO ZERO.

- SELECT THE INSTRUMENT SETUP BUTTON . THE FOLLOWING WINDOW SHOULD APPEAR.



Instrument: Pentax PTS & V series

Comm port: Port 1

☑ Show lines of sight

Theo ht: 1.5000

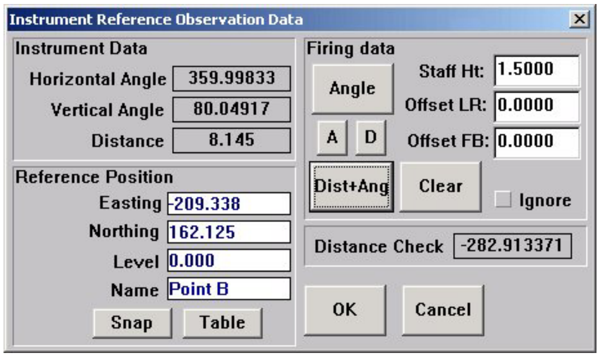
Staff ht: 1.500

- THE FOLLOWING SETTINGS SHOULD BE USED:

INSTRUMENT: LASER ATLANTA
COMM PORT: PORT 1
THEO HT: (USE HEIGHT OF LASER INSTRUMENT;
USE SAME UNITS AS WITH GPS)
STAFF HT: (USE HEIGHT OF TARGET ABOVE GROUND SURFACE)

- SPECIFY THE LOCATION OF THE LASER AND TRIPOD. USE THE “SNAP” BUTTON TO SELECT THE POSITION OF THE LASER.

- SPECIFY THE LOCATION OF THE TARGET REFERENCE POSITION. SELECT "ADD REF OBSERVATION." THE FOLLOWING WINDOW SHOULD APPEAR.



Instrument Data
Horizontal Angle: 359.99833
Vertical Angle: 80.04917
Distance: 8.145

Reference Position
Easting: -209.338
Northing: 162.125
Level: 0.000
Name: Point B

Firing data
Staff Ht: 1.5000
Offset LR: 0.0000
Offset FB: 0.0000

Distance Check: -282.913371

- USE THE "SNAP" BUTTON TO SELECT THE POSITION OF THE REFERENCE TARGET.

- CAREFULLY AIM THE LASER AT THE REFERENCE TARGET AND FIRE THE LASER.

- SELECT "DIST + ANG" BUTTON. FIRE THE LASER A SECOND TIME. DATA SHOULD NOW APPEAR IN THE "INSTRUMENT DATA" BOXES. THESE NUMBERS SHOULD BE IDENTICAL TO THOSE SHOWN ON THE LASER UNIT. HIT "OK."

- CLOSE THE "INSTRUMENT SETUP" WINDOW.

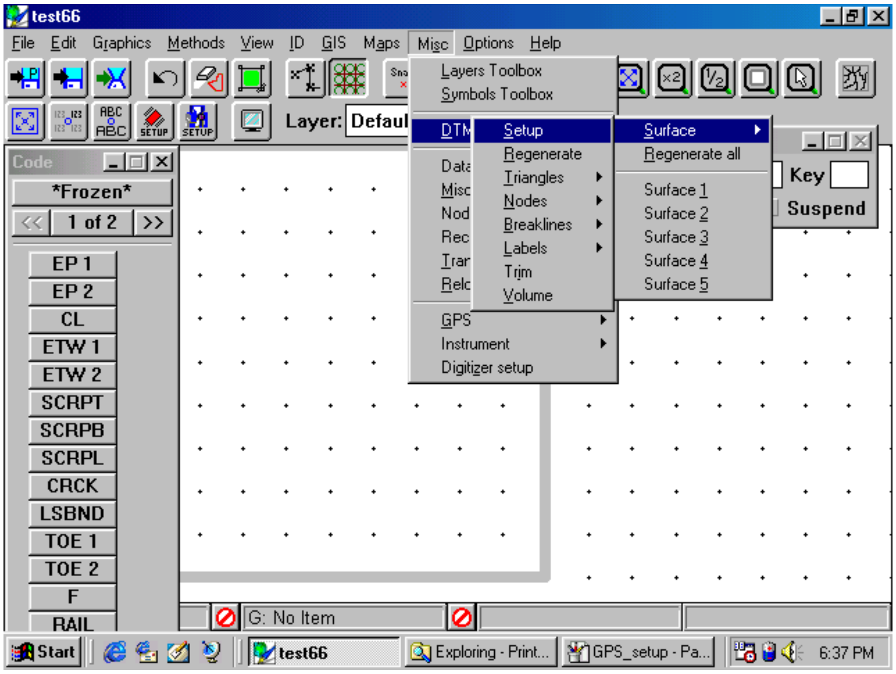
- SELECT THE "TOTAL STATION" ICON . THE FOLLOWING WINDOW SHOULD APPEAR.

- YOU ARE NOW READY TO COLLECT DATA USING THE LASER RANGE FINDER. DEPRESSING THE TRIGGER ON THE LASER WILL COLLECT THE POINT AND DISPLAY IT ON THE SCREEN.

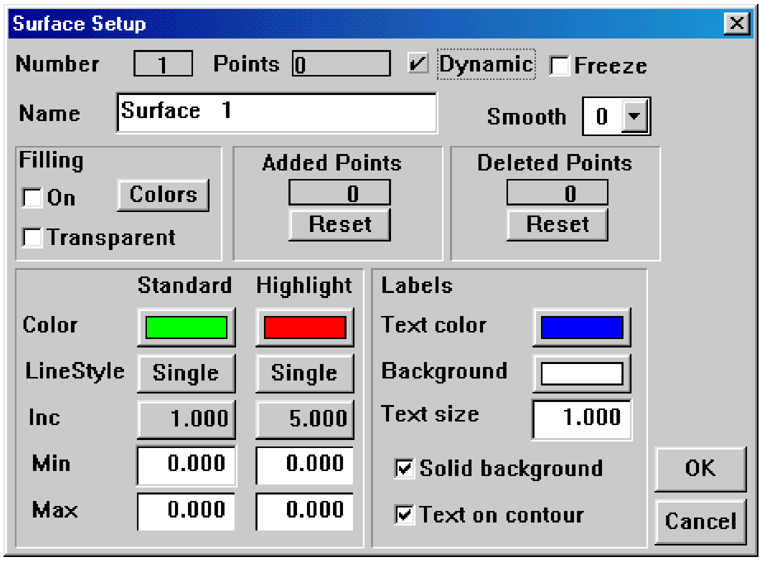
- TO RETURN TO USING THE GPS, UNPLUG THE LASER UNIT FROM THE VIA AND RECONNECT THE GPS UNITS. GO THROUGH THE GPS SETUP AS DESCRIBED PREVIOUSLY IN THIS DOCUMENT.

GENERATING TOPOGRAPHIC MAPS IN REAL-TIME

- TO GENERATE A TOPOGRAPHIC MAP IN THE FIELD WHILE COLLECTING DATA, SET UP THE DIGITAL TERRAIN MODELLING (DTM) PARAMETERS.



- SET THE INTERVALS, COLORS, AND LINE STYLES FOR THE "STANDARD" AND THE "HIGHLIGHT" TOPO ELEVATION LINES.



Surface Setup

Number 1 Points 0 ☑ Dynamic ☐ Freeze

Name Surface 1 Smooth 0

Filling ☐ On Colors ☐ Transparent

Added Points 0 Reset

Deleted Points 0 Reset

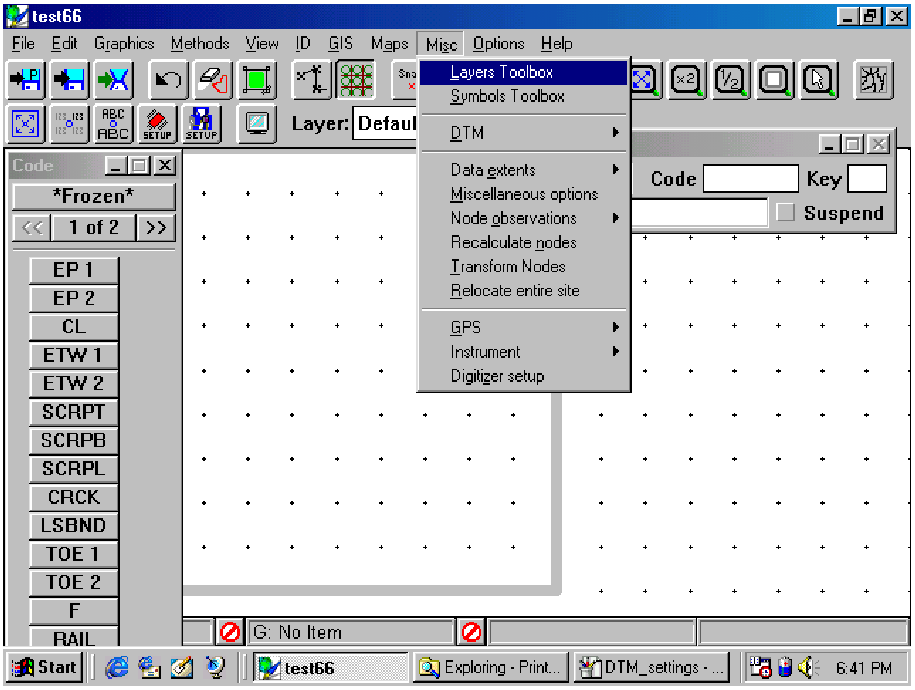
	Standard	Highlight
Color	🟩	🟥
LineStyle	Single	Single
Inc	1.000	5.000
Min	0.000	0.000
Max	0.000	0.000

Labels
Text color 🟦
Background ⬜
Text size 1.000
☑ Solid background
☑ Text on contour

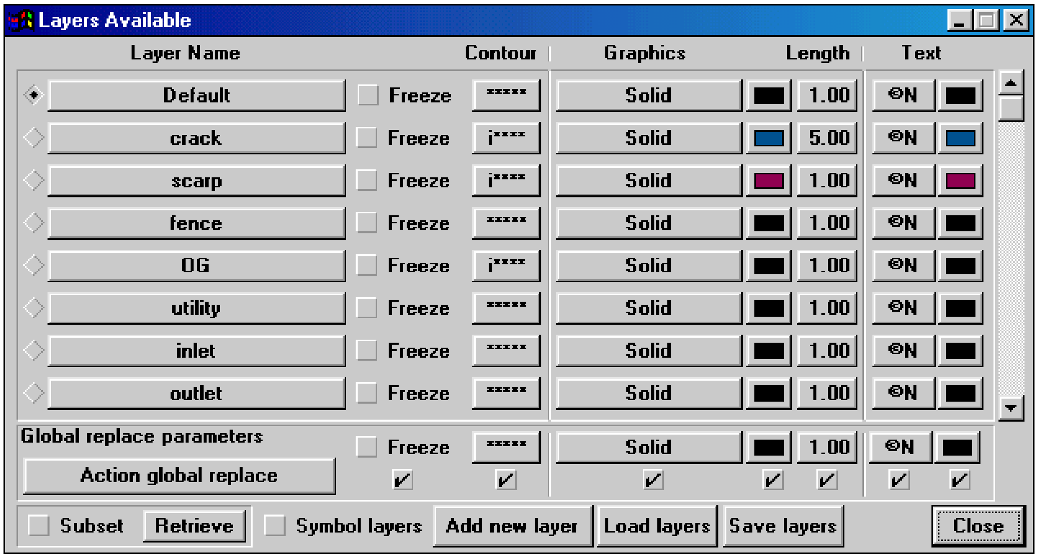
OK Cancel

- CHECKING THE "DYNAMIC" BOX WILL ENABLE THE REAL-TIME TOPO GENERATION FEATURE. CHECKING THE "FREEZE" BOX WILL DISABLE THE REAL-TIME TOPO GENERATION FEATURE.

- ❑ SET UP THE LAYERING PARAMETERS. OPEN THE “LAYERS TOOLBOX.”

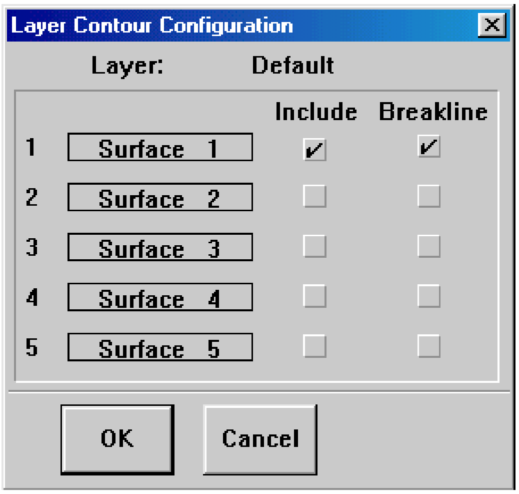


- ❑ THIS WINDOW DISPLAYS ALL OF THE LAYERS FOR THE PROJECT. THE DTM IS GENERATED FROM POINTS IN ONE OR MORE LAYERS SPECIFIED BY THE USER.


Layers Available

	Layer Name	Contour		Graphics		Length	Text	
●	Default	☐ Freeze	*****	Solid	■	1.00	ON	■
○	crack	☐ Freeze	i****	Solid	🟦	5.00	ON	🟦
○	scarp	☐ Freeze	i****	Solid	🟪	1.00	ON	🟪
○	fence	☐ Freeze	*****	Solid	■	1.00	ON	■
○	OG	☐ Freeze	i****	Solid	■	1.00	ON	■
○	utility	☐ Freeze	*****	Solid	■	1.00	ON	■
○	inlet	☐ Freeze	*****	Solid	■	1.00	ON	■
○	outlet	☐ Freeze	*****	Solid	■	1.00	ON	■
	Global replace parameters	☐ Freeze	*****	Solid	■	1.00	ON	■
	Action global replace	☑	☑	☑	☑	☑	☑	☑

- TO SPECIFY A LAYER TO BE USED IN THE DTM, TAP THE BUTTON BELOW THE “CONTOUR” COLUMN ASSOCIATED WITH THE LAYER. CHECK THE “INCLUDE” AND “BREAKLINE” BOXES NEXT TO “SURFACE 1.” CHECK “OK” AND THEN “CLOSE” TO CLOSE OUT THE LAYER SETTINGS WINDOWS. YOU ARE NOW CONFIGURED TO GENERATE A TOPOGRAPHIC MAP IN REAL-TIME WHICH WILL INCLUDE ALL DATA POINTS IN ALL LAYERS SELECTED.

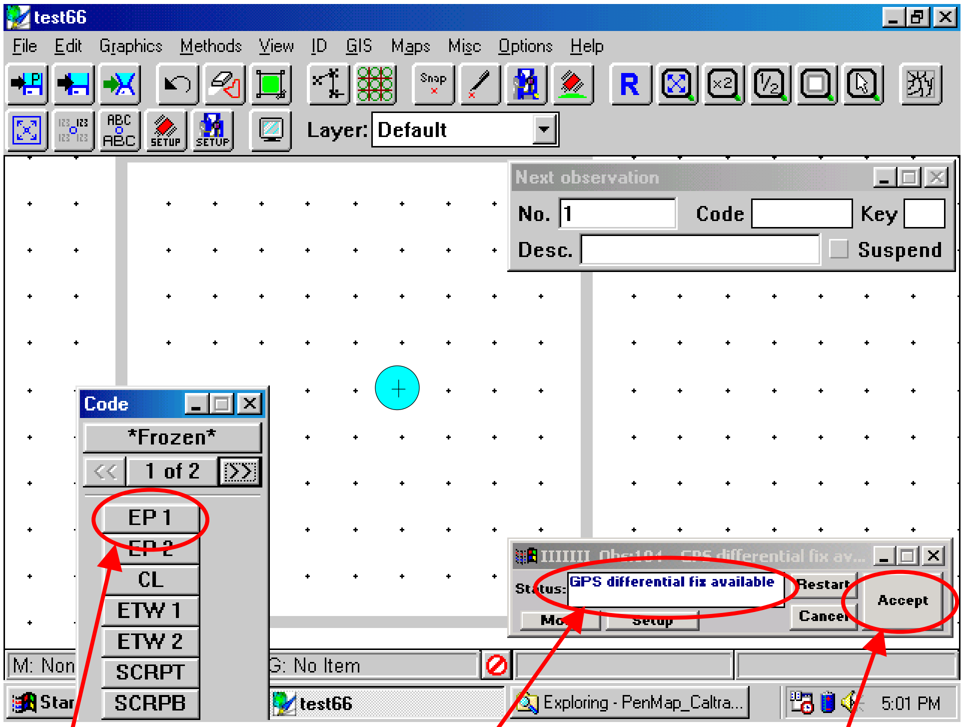


Layer Contour Configuration

Layer: Default

		Include	Breakline
1	Surface 1	☑	☑
2	Surface 2	☐	☐
3	Surface 3	☐	☐
4	Surface 4	☐	☐
5	Surface 5	☐	☐

COLLECTING AND DISPLAYING DATA



Layer: Default

No. 1

Status: GPS differential fix available

STEP 1:
Select point type to collect.

STEP 2:
Check that the GPS solution is "differential" for the Trimble or "phase" for the Leica.

STEP 3:
Accept the point.

CONDOR PENMAP DGPS FIELD MAPPING SYSTEM EQUIPMENT LIST
(TRIMBLE DGPS SYSTEM)

QTY.	DESCRIPTION
1	ROVER BACKPACK CONTAINING: • TRIMBLE AGGPS 132 GPS RECEIVER • DGPS/GPS/L-BAND ANTENNA ON POLE EXTENSION • SERIAL CABLE • ANTENNA CABLE • BATTERY ENCLOSURE • MAG BASE
1	VIA II COMPUTER
2	MOLICEL BATTERY CHARGER
4	MOLICEL RECHARGEABLE BATTERY
1	IOMEGA 100MB ZIP DRIVE USB
1	LASER RANGE FINDER W/ 2 BATTERIES & CHARGER
1	HORIZONTAL ENCODER FOR LASER
1	TRIPOD
1	PELICAN SHIPPING CASE
1	SKB SHIPPING CASE

CONDOR PENMAP RTK-GPS FIELD MAPPING SYSTEM EQUIPMENT LIST
(LEICA RTK-GPS SYSTEM)

QTY.	DESCRIPTION
1	BASE STATION PACKAGE CONTAINING: • LEICA SR530 DUAL FREQUENCY GPS RECEIVER • FREEWAVE DATA TRANCEIVER • AT502 GPS ANTENNA AND FREEWAVE ANTENNA ON MAG BASE • GPS AND RADIO ANTENNA CABLES • DATA CABLE FROM FREEWAVE TO LEICA • SPARE DATA CABLE TO LEICA • BATTERY CABLE
1	ROVER BACKPACK CONTAINING: • LEICA SR530 DUAL FREQUENCY GPS RECEIVER • AT502 GPS ANTENNA • FREEWAVE DATA TRANCEIVER • ANTENNEX ANTENNA ON POLE EXTENSION W/QUICK DISCONNECT • SERIAL CABLE • ANTENNA CABLE

1	SECO RANGE POLE W/TRIPOD
1	VIA SCREEN BRACKET FOR RANGE POLE
1	VIA II COMPUTER
1	MOLICEL BATTERY CHARGER
2	MOLICEL RECHARGEABLE BATTERY
3	LEICA BATTERY CHARGER
6	LEICA RECHARGEABLE BATTERY
1	POWERSONIC 12V 33AH BATTERY
1	12V 6A BATTERY CHARGER
1	IOMEGA 250MB ZIP DRIVE USB
1	PELICAN SHIPPING CASE
1	SKB SHIPPING CASE