Electronic Digital/Bar-Code Leveling User Manual VERSION 2

Prepared and Written by

Kevin Blake Amacker
Mechanical Engineer
Louisiana Spatial Reference Center
Louisiana State University
Baton Rouge, Louisiana

April 11, 2005

Information for the manual provided by National Geodetic Survey
Roy W. Anderson – Project Development Branch
Orland W. Murray – Geodetic Technician
Kendall Fancher – Instrumentation and Methodologies Branch
Steven Breidenbach– Instrumentation and Methodologies Branch
David B. Crockett – Geodetic Technician
Denis Riordan – Louisiana State Advisor
Curt Smith – Idaho/Montana State advisor
Brain Ward– Arkansas Technical Advisor

What is a Digital Leveling System?

Digital leveling is a relatively new system of determining height differences using near fully automatic instruments and methods. This accomplished by the use of a pattern recognition imaging system built into the level instrument and level rods graduated with a special bar code. The user points the instrument at one of the special rods, focuses as clearly as possible, and presses a button to take the measurement. An image of the bar-code rod is received at the instrument and is correlated to an internal digital image of the rod. This allows the internal software to determine where the level line of sight is intercepting the rod. The height above the footplate or zero point is then computed along with the distance to the rod. These measurements are displayed and then used to compute the difference of elevation between the backsight and foresight rods. Apart from this automation, leveling with a digital level is much the same as with an optical level. In fact most, digital levels have cross-hairs and can be used optically.

Outline of the Field Procedure

- Equipment – Instruments and Accessories
- Reconnaissance and Description/Recovery Notes
- Project Proposal to be Submitted to NGS
- Initial Instrument Settings
- Preparation for Measurements – Field Logs and Equipment Checks
- Equipment Setups and Procedures
- Digital Level Collimation
- Starting a Section – Measurements and Operations Procedures
- Ending a Section
- Important Leveling Tips
- Changing Equipment, Observer, and Conditions and Other Codes
- Data Transfer and Data Formatting for NGS Submission
- Contacts

Equipment – Instrumentation and Accessories

Digital Level

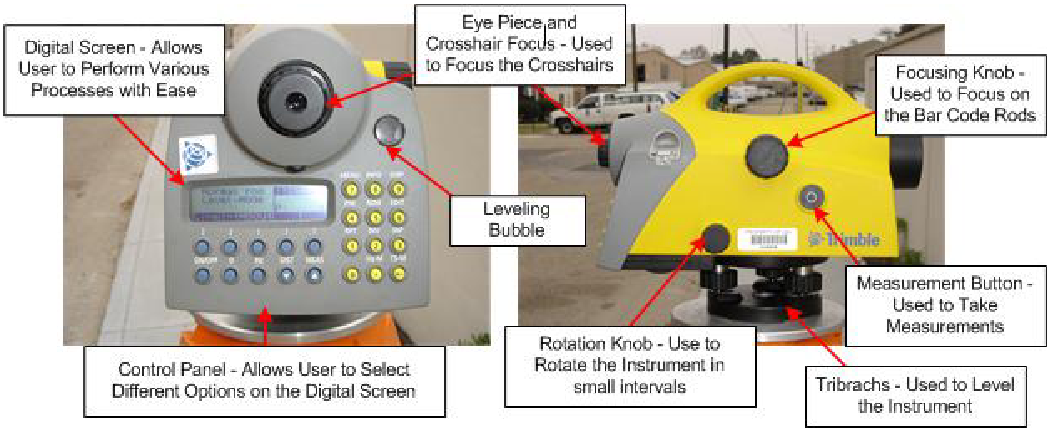


Figure 1: The Trimble DiNi 12T Precision Digital Level

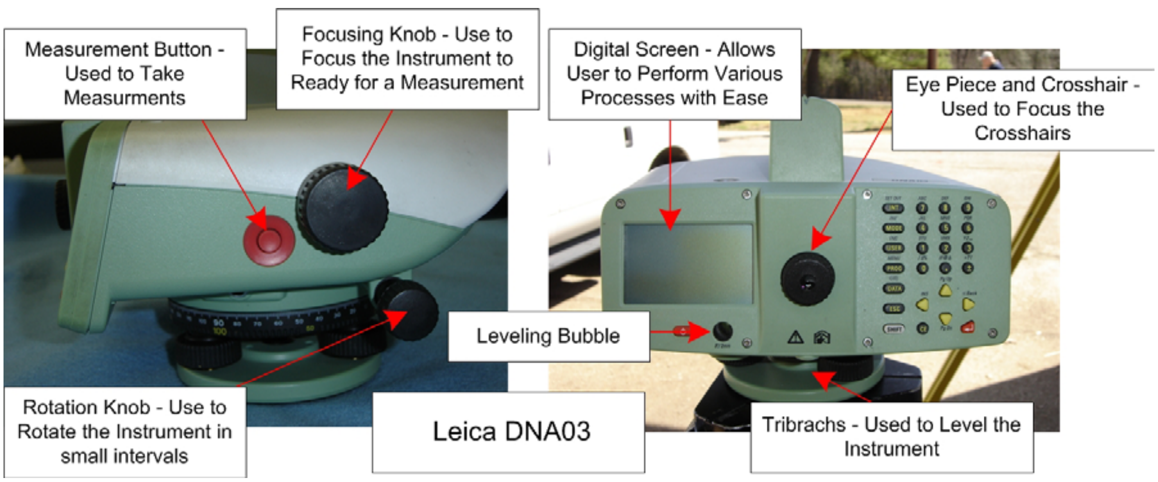


Figure 2: The Leica DNA03 Precision Digital Level

Equipment Specifications (see Appendix A)

- Minimum Repeatability of Line of Sight = 0.40”
- Instrument and Rod Resolution Combined Least Count = 0.01 mm
- Maximum Collimation Error = 0.05 mm/m = 10 arc seconds
- Programmable BF (Backsight and Foresight) Leveling Procedure
- Observer Input Options (Point Numbers, Codes/Remarks, Temperatures, etc.)
- On-board Recording Capability
- Viewable Leveling Status (setup imbalance, distance, accumulated differences, etc.)
- Compatible NGS Output Format (NGS, Maryland DOT, or Charles Whalen program)

Note: It is very important that the level is carried vertically (slightly slanted on shoulder for comfort) during the leveling process (see Figure 3). DO NOT lay tripod with instrument horizontally over shoulder

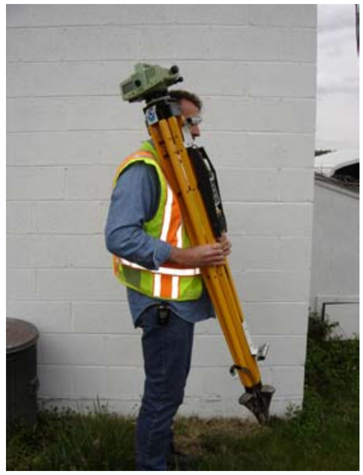


Figure 3: Proper way to carry the Digital Level

Tripod and Weather Equipment

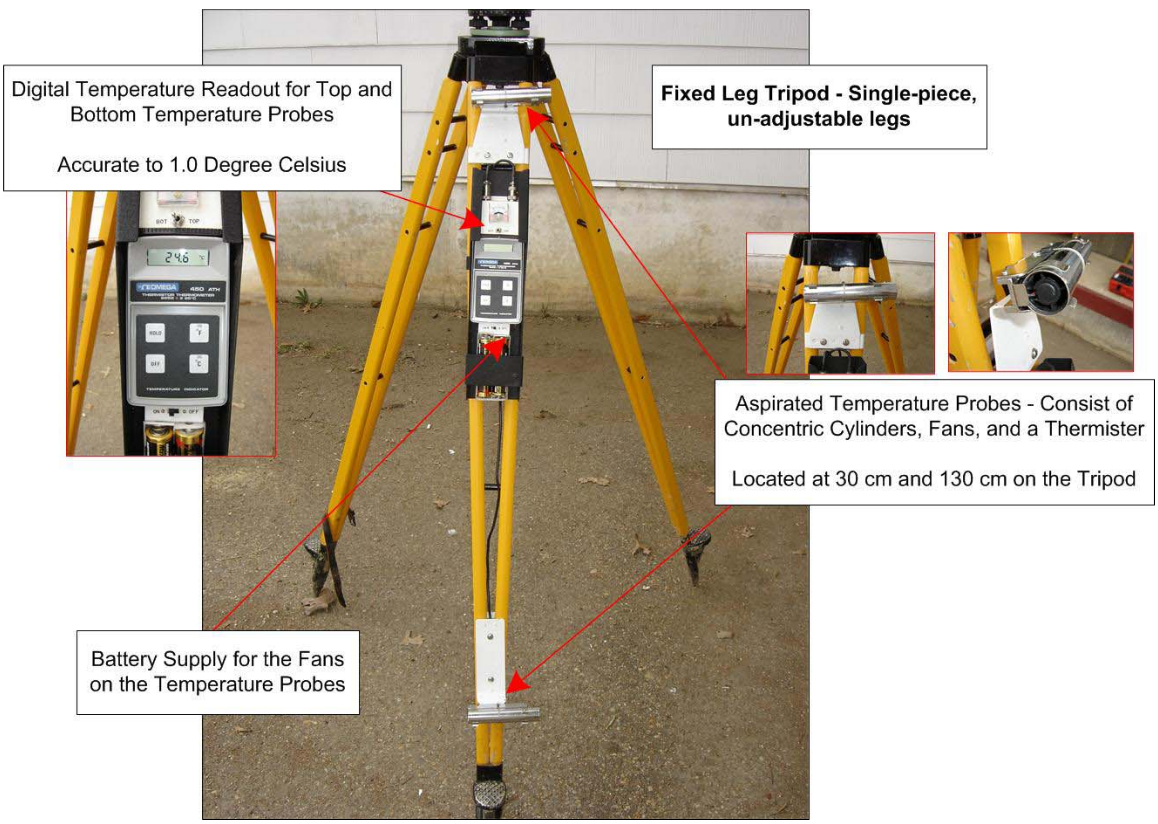


Figure 4: Fixed-Leg Tripod with Aspirated Temperature Probes and Digital Readout

<u>Note</u>: It is very important to make sure the tripod is as stable as possible during the measurement process. This is done by pushing the feet of the tripod firmly into the ground (see Figure 5). DO NOT setup on asphalt or other surface that could settle during the observing procedure.

Figure 5: Pushing the feet of the tripod into the ground

Bar Code Rods

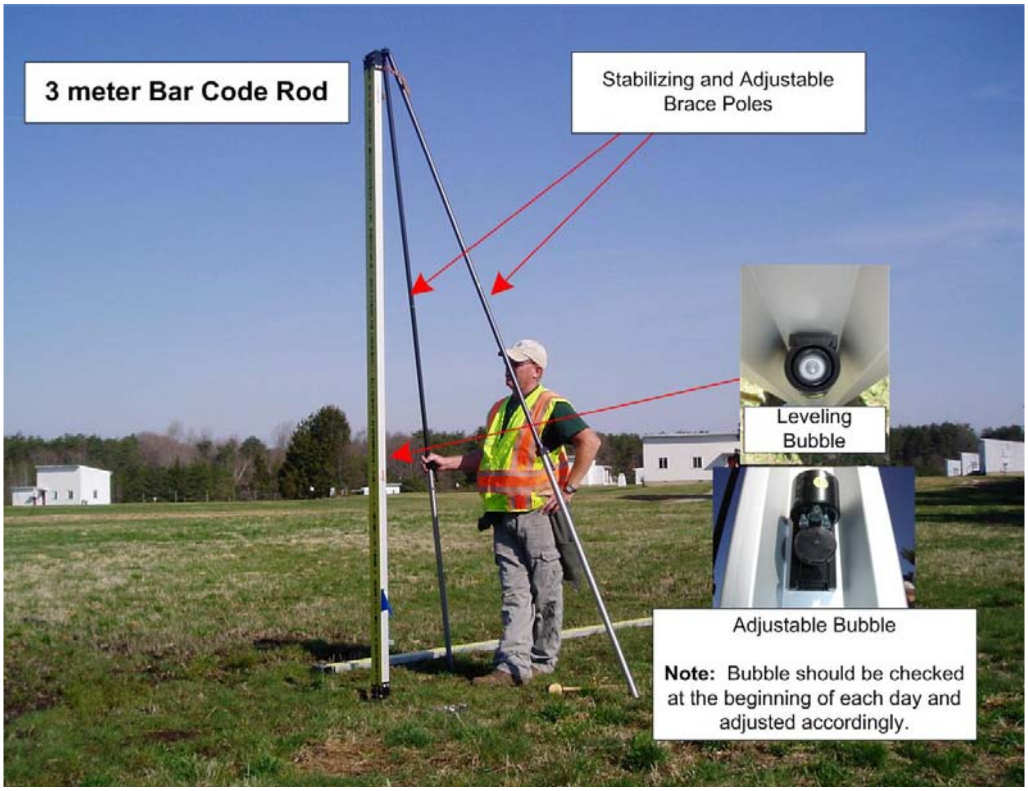


Figure 6: 3 meter Bar Code Rod with Adjustable Brace Poles

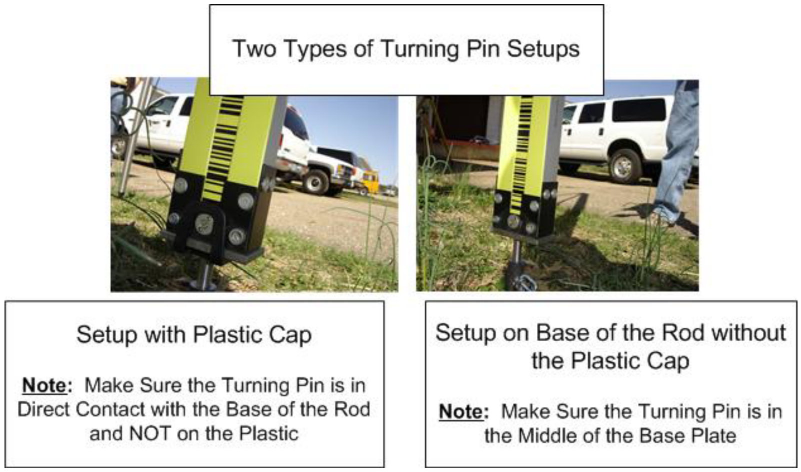


Figure 7: Types of Turning Pin Setups

<u>Note</u>: Invar Bar Code Scale Calibrations (see Appendix B) should be provided in Digital Format and Paper Copy. This Invar Bar Code Scale Calibrations must be submitted to NGS Observation and Analysis Division in digital format in order to submit leveling data to NGS for first order, class I and II and second order, class I levels. Scale Calibrations must be performed every 3 years.

<u>Note</u>: It is very important to protect the Base of the Rod at all times when holding and moving the Rod (see Figure 8). Never place the base of the rod on the ground or other surfaces that could damage or cause unnecessary wear to the base of the rod. The base of the rod, if damaged, can affect the measurements taken in the field.

Figure 8: Protect the Base by using your shoe instead of placing it on the ground

Turning Points

Figure 9: Steel Turning Pin and Driving Cap with Mallet with Plastic Heads
For Specifications see Appendix C

Figure 10: Turning Plate ("Turtle") Top View and Side View

<u>Note</u>: Leveling rods must be one piece. A turning point consisting of a steel turning pin with a driving cap should be utilized. If a steel pin cannot be driven, then a turning plate ("turtle") weighing at least 7 kg (15 lbs.) should be substituted. In situations allowing neither turning pins nor turning plates (sandy or marshy soils), a long wooden stake with a double-headed nail should be driven to a firm depth (Appendix A).

Accessories

Spacer ("Plug")

If a bench mark is recessed, to the point where the base plate of the rod cannot come in direct contact with the bench mark, use a spacer. In order to deduct the use of the initial spacer's height from the total height measurement, it must also be used on a foresight, i.e., add 2 cm from the height of a 2 cm spacer on the bench mark and then subtract 2 cm using the same spacer on a foresight.

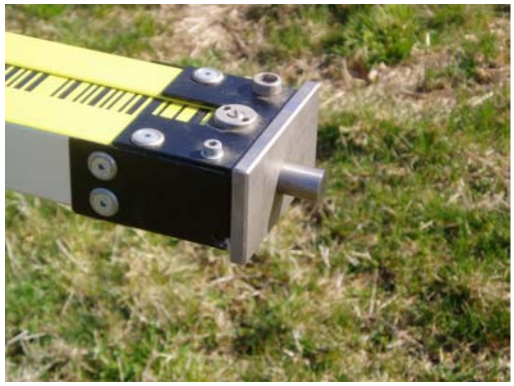


Figure 11: 2 centimeter Magnetic Spacer ("Plug") on the base of the 3 meter rod

Figure 12: 2 centimeter Spacer used on a recessed bench mark

Invar Strip

The Invar Strip is needed to establish elevations on points or marks that can not be accessed using a standard leveling rod, such as, bench marks set vertically in foundations, bridge abutments, etc., or special elevation points required by a given survey (see Appendix D).

Figure 13: 0.5 meter Invar Strip

Hand Level

Figure 14: Hand Level and Protective Case

Used by the pacer during setups to determine that the instrument will not be observing over the rod or below 0.5 meters on the rod. (See NOAA MANUAL NOS NGS 3 – Geodetic Leveling page 3-49)

Umbrella (if required to cover level)

<u>Note</u>: Direct sunlight can cause differential heating within the instrument, which causes significant errors. Umbrella will reduce the heating within the instrument. Refer to manufacturer's specifications for umbrella requirements.

Yellow Crayon to Mark Setup ("Lumber Crayon")

Assists in marking paced setups when a pacer is available and is often used in double runs to identify setups.

<u>Reconnaissance and Description/Recovery</u>

Reconnaissance

Reconnaissance is performed prior to any leveling activity. Existing bench marks should be recovered and description/recovery notes prepared. New bench marks along the level line are established and must meet spacing requirements according to NGS standards (see NOAA Manual NOS NGS 1 – Geodetic Bench Marks and NOAA Manual NOS NGS 3 – Geodetic Leveling, Chapter 2).

Reconnaissance Tips:

- The ground over which the leveling progresses should be free of characteristics that will introduce anomalous measurements.
- Ground that radiates high refraction or that is soft or uneven should be bypassed if possible (e.g. concrete, blacktop, etc.).

Network Connections:

- First Order requires a minimum of a three mark tie at the beginning and end of the level line.
- Second Order requires a minimum of a two mark tie at the beginning and the end of the level line.

Note: For specific information on network connections refer to NOAA Manual NOS NGS 3 – Geodetic Leveling Chapter 2 "Mark Setting"

Station Designation

Station Designations should be what is stamped on the bench mark without including the date or precast information. A project unique survey-point serial number (SPSN) will be assigned to each bench mark to correlate that mark with its description and used to identify the station in the leveling data.

Project – Survey-Point Serial Numbers (SPSN)

- SPSN numbers should be assigned in a sequential order (NOT RANDOMLY!!)
- SPSN numbers are Project specific
- SPSN numbers can not be changed or duplicated in a Project
- SPSN numbers for common points in multiple lines (junction points) must maintain their single unique SPSN numbers throughout that project

Safety Tips:

- Leveling route should be chosen to provide the safest route for the survey party.
- High-traffic areas should be avoided, and if this is not possible, the leveling party should maintain high visibility and utilize safety signage at all times.
- Road-guard vests and additional personnel (flag persons, traffic controllers, etc.) may be necessary to ensure the leveling party's safety.

Bench Mark Recovery Procedure and Submission

National Geodetic Survey Station Description/Recovery Form

A station is required for all stations observed in the project. A digital Station Description/Recovery form is available at www.ngs.noaa.gov/PROJECTS/FBN listed under forms and in Appendix E

Tips for filling out Form:

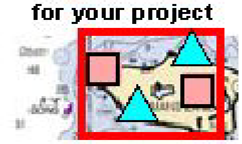
- 4-char ID – Does Not Apply (GPS only)

- Designation – Stamping on the Bench Mark without stamped date. Should be exactly the same as that listed on the NGS Data Sheet for existing stations in the NGS Database.
- PID – Permanent Identifier found on NGS Data Sheets located at www.ngs.noaa.gov (**Note:** PIDs are only for existing stations in NGS Database.)
- Latitude and Longitude – NAD 83 (Coordinates determined by GPS, scaled from USGS topographic maps, or from NGS Data Sheets located at www.ngs.noaa.gov)
- New Marks – Require a complete descriptions
- Existing Marks Not in NGS Database – Require a complete description
- Existing Marks in the NGS Database – Require a recovery note
- For Recovered Marks Not included in the Project – Submit recovery information through the NGS Submit Recovery link available online at http://www.ngs.noaa.gov/FORMS_PROCESSING-cgi-bin/recvy_entry_www.prl.

Project Proposal to be Submitted to NGS

Note: It is very important that the proposed Project is submitted to NGS for approval prior to any Leveling!!

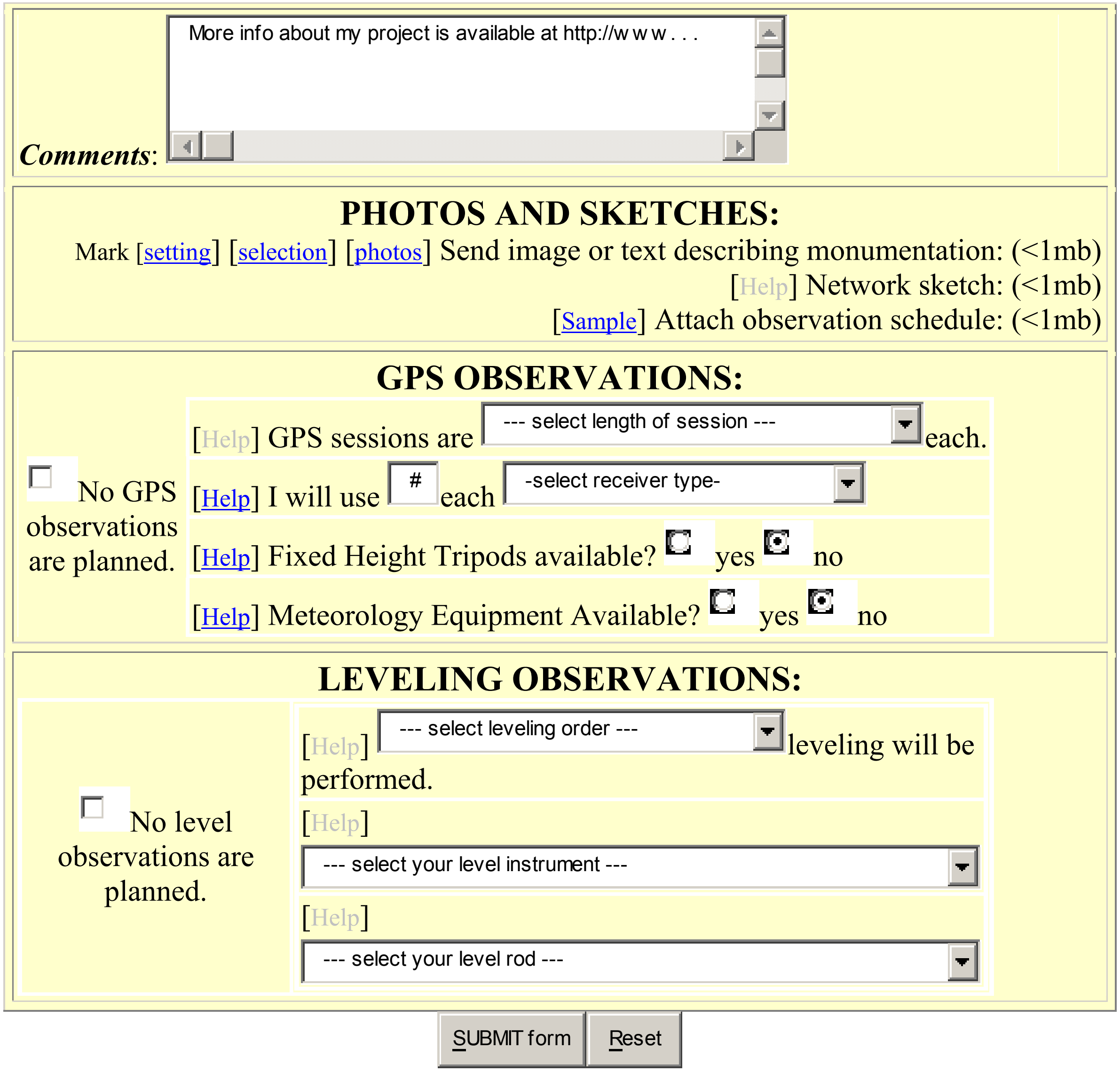
Project Submission is located at **www.ngs.noaa.gov/Projects/proposals/project1.shtml** or on **www.ngs.noaa.gov** under Products & Services under Data Contribution – Project Proposal Form.

PROJECT TITLE:	PROJECT EXTENTS:
Enter proposed project title here Choose your intended local accuracies: [[Help]] horizontal ▾ ellip. ht. ▾ ortho. ht. ▾ &/OR type: No special project type. ▾ begining on or about : 12/25/2003 & ending on or about: 12/31/2003	Max Latitude N33224 (Nddmmss) W089224 Max Longitude (Wdddmmss) — Enter approximate geographic bounds for your project  — W089221 Min Longitude (Wdddmmss) Min Latitude N33221 (Nddmmss)

NSRS STATIONS	NON-NSRS STATIONS
List all existing NSRS network control stations in your project: [Search for NSRS control] List PIDs below.	List all new (non-NSRS) stations in your project: 4-char-ID, approx latitude, longitude, comma delimited. 4-ID, NDDMMSS, WDDDMMSS STA1, N332211, W0892211 STA2, N332222,

PROJECT LEADER CONTACT INFO:

Name: First	***Last***	***Title***		Select your preferred contact method:
Organization		***E-mail***	name@isp.com	◉
Postal Address		***Work_Phone***		○
City		***FAX***		○
State	***Zip***	***Cell Phone***		○



Comments: More info about my project is available at http://w w w . . .

PHOTOS AND SKETCHES:

Mark [setting] [selection] [photos] Send image or text describing monumentation: (<1mb)

[Help] Network sketch: (<1mb)

[Sample] Attach observation schedule: (<1mb)

GPS OBSERVATIONS:

No GPS observations are planned.

[Help] GPS sessions are --- select length of session --- each.

[Help] I will use # each -select receiver type-

[Help] Fixed Height Tripods available? yes no

[Help] Meteorology Equipment Available? yes no

LEVELING OBSERVATIONS:

No level observations are planned.

[Help] --- select leveling order --- leveling will be performed.

[Help] --- select your level instrument ---

[Help] --- select your level rod ---

SUBMIT form Reset

Figure 15: Project Proposal Form

Initial Instrument Settings

Digital Level Settings

- Units are set to meters
- 5 Decimal Places recorded (e.g. 0.00001)
- Record Data to Instrument
- Earth Curvature Turned OFF
- Apply Daily Collimation to Measurements (also note in digital data files that this correction has been applied to all measurements)
- Measurement Type is Mean with Standard Deviation
- Set Maximum Standard Deviation = 0.1 mm at 60 meters
- Minimum Number of Measurements = 3

- Maximum Sight Distance = 60 meters
- Minimum Sight Distance = Instrument Specific (See Manufacturer’s Manual)
- Individual Setup Imbalance = 5 meters
- Accumulated Imbalance per Section = 10 meters
- Set Instrument to BF Measurement Mode (Backsight and Foresight)

Preparation for Measurements – Field Log and Equipment Checks

DIGITAL GEODETIC LEVELING – BACKUP RECORDING SHEET (see Appendix F)

LINE	PROJECT	FILENAME	PAGE
L-			Of

SURVEY ORDER	SURVEY CLASS	TIME ZONE CODE	TEMP PROBE TOP HGT	TEMP PROBE BOTTOM HGT
			1.3m	0.3 m

CODE 1 – BEGINNING OF DAY OR CHANGE IN OBSERVER / EQUIPMENT

INFO 1 DATE(MMDDYY)	**INFO 2** OBSERVER #	OBSERVER INITIALS	**INFO 3** INST TYPE	**INFO 4** TEMP CODE

CODE 2 – EQUIPMENT USED

INFO 1 INST SERIAL #	**INFO 2** COLLIMATION "	ROD CODE	**INFO 3** ROD 1 S/N	**INFO 4** ROD 2 S/N

CODE 11 – BEGINNING SECTION INFORMATION

SPSN #	BENCH MARK STAMPING	**INFO 1** TIME (HHMM)	**INFO 2** ROD / MK	**INFO 3** TEMP	DIR F / B

CODE 99 – ENDING SECTION INFORMATION

SPSN #	BENCH MARK STAMPING	**INFO 1** TIME (HHMM)	**INFO 2** ROD/ MK	**INFO 3** TEMP	**INFO 4** W / S

SECTION OBSERVATION INFORMATION

TOTAL SETUPS	TOTAL DISTANCE KM	ACCUMULATED M	ELEV DIFFERENCE M

CLOSURE

REMARKS

F		
B		
DIF		
ALW'D		

TIME ZONE CODES

Q = UTC-4 HOURS =EDT
R = UTC-5 HOURS =EST, CDT
S = UTC-6 HOURS =CST, MDT
T = UTC-7 HOURS =MST, PDT
U = UTC-8 HOURS =PST

TEMPERATUR
0 = CELCIUS; 1 = FARENHEIGHT

OTHER INFORMATION CODES

E CODE
CODE 33 – GRADIENT TEMPERATURE
INFO 1 = BOTTOM PROBE TEMP;
INFO 2 = TOP PROBE TEMP
(NO DECIMAL PLACE; 288 FOR 28.8 C)

CODE 9999 – END OF DAY, CHANGE OF OBSERVER OR EQUIPMENT
ALL BLANK – NO INFO ENTRIES

MAX SECTION MISCLOSURE (MM)

1,1 = $3\sqrt{D}$; 1,2 = $4\sqrt{D}$; 2,1 = $6\sqrt{D}$;
2,2 = $8\sqrt{D}$; 3 = $12\sqrt{D}$
(D = KM DISTANCE)

WIND AND SUN INFORMATION

WIND – (0) CALM (1) BREEZY (2) WINDY
SUN – (0) OVERCAST (1) PARTLY SUNNY (2) SUNNY

NOTES: IDENTIFY POSITIVE OR NEGATIVE (+ OR -) FOR ACCUMULATED IMBALANCES AND ELEVATION DIFFERENCES

PERSONNEL

OBSERVER: ______________________

ROD 1: ______________________

ROD 2: ______________________

Note: A separate Backup Recording Sheet, completely filled in, is required for each section. Certain items can be typed on each Backup Recording Sheet then copies made to minimize standard information input.

Examples

- Line Number
- Project Name
- Survey Order and Class
- Time Zone
- Temperature Probe Heights
- Temperature Code

Certain information can be modified for a specific crew on each Backup Recording Sheet then copies made to minimize standard information input per observing crew.

Examples

- Instrument Type and Serial Number
- Rod Type and Serial Numbers

Equipment Checks

Note: Required at beginning of EVERY Project and ANY time there is a question or concern about the equipment.

- Check and Adjust the Circular Level for Digital Level Instrument
- Check and Adjust the Circular Levels for the Bar Code Rods
- Check Temperature Probes to ensure that they are functioning properly (Compare against a Standard to ensure the probes are reading accurately)

Refer to Manufacturer's Manuals, Appendix G of this manual, and NOAA Manual NOS NGS 3 – Geodetic Leveling, Chapter 3 for proper adjustment procedures.

Note: Check DAILY that the Circular Levels for all the equipment are in Adjustment and the Top and Bottom Temperature Probes are functioning properly (Compared against each other to ensure the probes are reading the same).

Equipment Setups and Procedures

Note: Detailed instructions describing setup procedures are listed in NOAA Manual NOS NGS 3 – Geodetic Leveling, Chapter 3 and specific instrument issues are addressed in the Manufacturer's User Manuals.

Digital Level

- Attach the Instrument to the Tripod
- Setting the Tripod
- Leveling the Instrument
- Pointing the Instrument
- Removing Parallax and Focusing Instrument
- Taking the Measurement

Rods

- Rod Setup
- Leveling Rod

Turning Points

- Turning Point Selection
- Turning Point Setup (Steel Pin/Turtle)

FGCS Specifications (Appendix A)- A turning point consisting of a steel turning pin with a driving cap should be utilized. If a steel pin cannot be driven, then a turning plate ("turtle") weighing at least 7 kg (15 lbs.) should be substituted. In situations allowing neither turning pins nor turning plates (sandy or marshy soils), a long wooden stake with a double-headed nail should be driven to a firm depth.

Weather Equipment

- Aspirated Temperature Probes
- Umbrella

Digital Level Collimation ("Peg Test" or "C-check")

Collimation Tips:

- Allow the instrument and rods to acclimate prior to performing the collimation and/or leveling (allow the equipment to adjust to the working environment for 10 minutes or more).
- Perform Collimation check on level ground at the work site in the work environment.
- Perform a Collimation check at the beginning of every day that geodetic leveling is performed or when the level is jarred or any time there is a question about instrument.

- Perform a Collimation check whenever the ambient temperature changes more than 10 degrees Celsius during the course of leveling during the day.
- It is critical to remove parallax and sharply focus the instrument.
- Ensure instrument and rods circular levels are in adjustment.
- Apply collimation to all future measurements (also note in digital data files that this correction has been applied to all measurements).
- Record collimation (arc-seconds) on Backup Recording Sheet

Types of Collimation:

A x B x - Kukkamaki Method

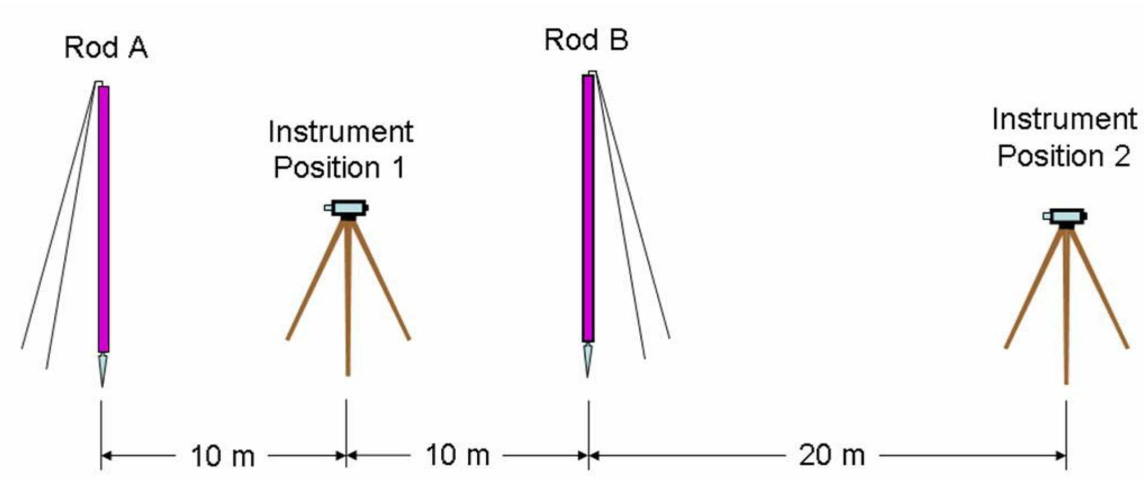


Figure 16: Kukkamaki Method – Instrument Positions

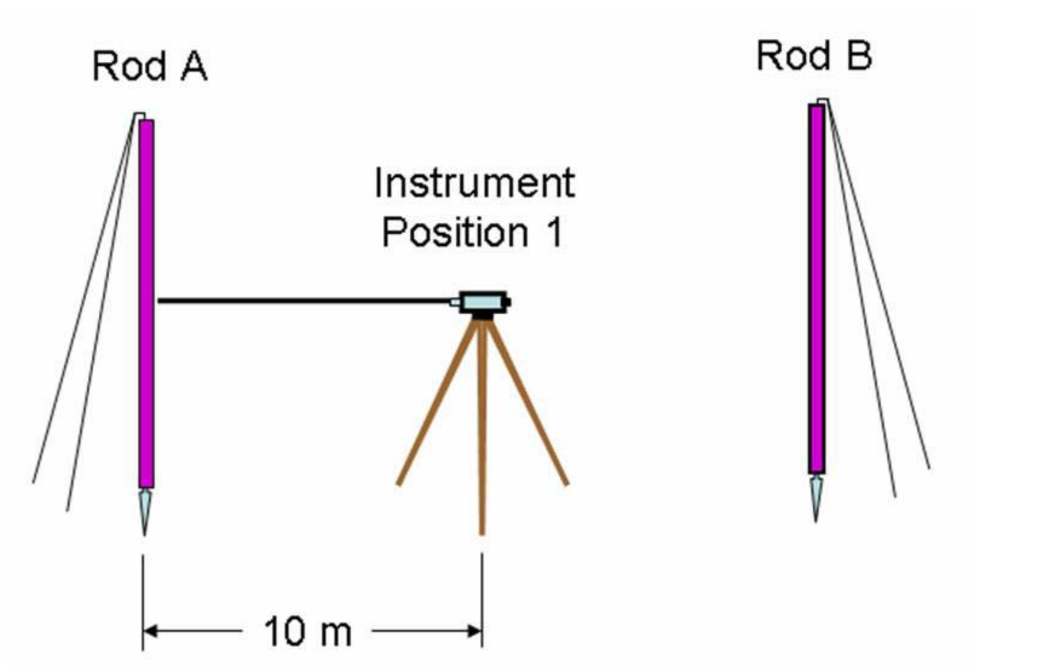


Figure 17: Kukkamaki Method – First Setup – First Measurement

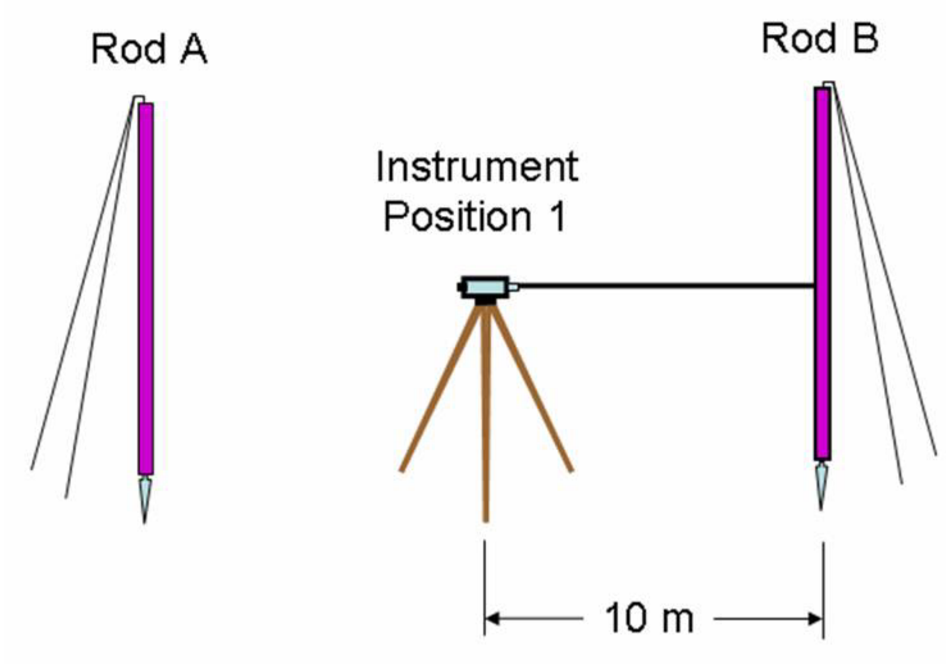


Figure 18: Kukkamaki Method – First Setup – Second Measurement

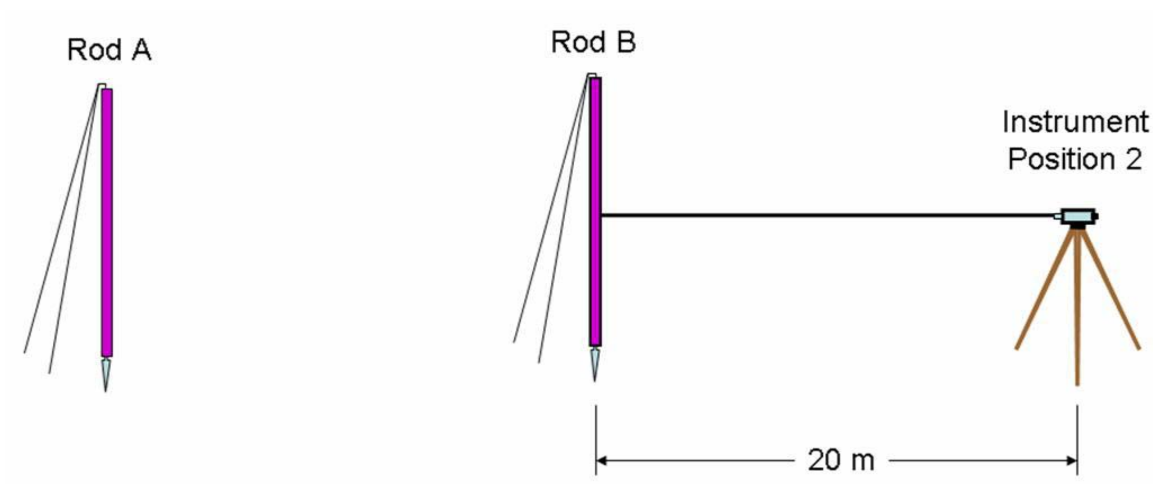


Figure 19: Kukkamaki Method – Second Setup – First Measurement

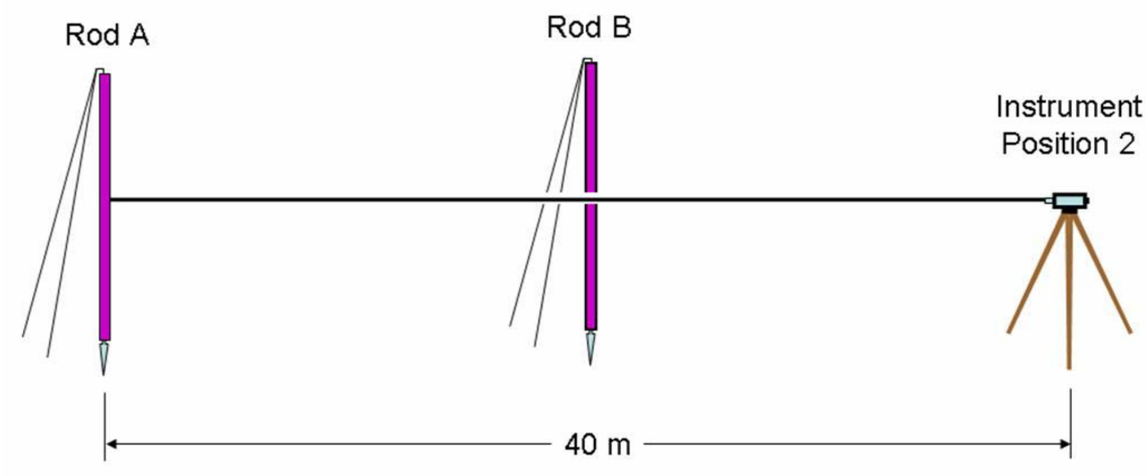


Figure 20: Kukkamaki Method – Second Setup – Second Measurement

A x x B – Förstner Method

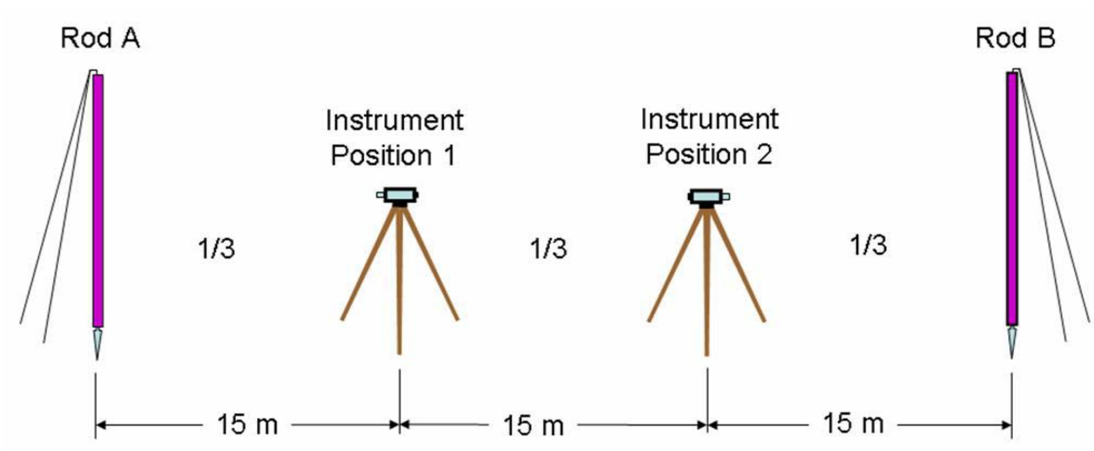


Figure 21: Förstner Method – Instrument Positions

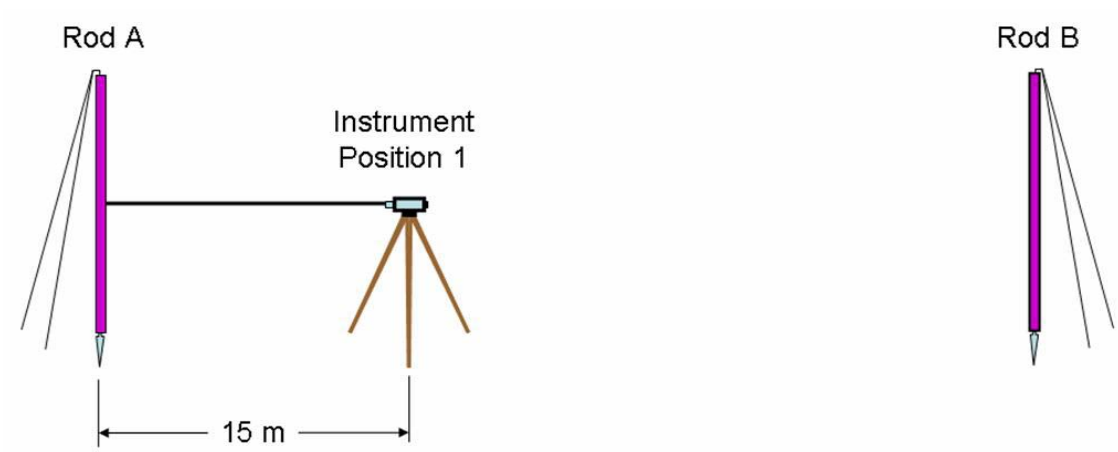


Figure 22: Förstner Method – First Setup – First Measurement

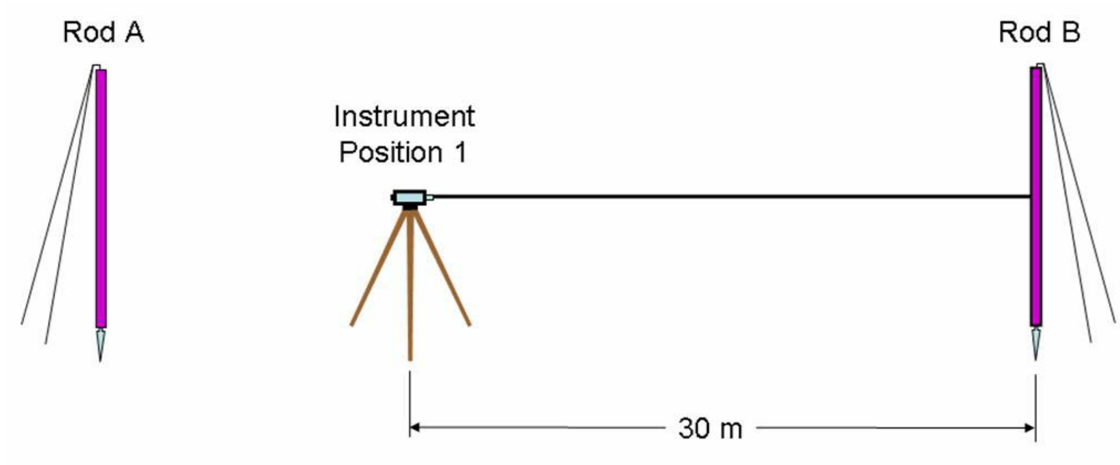


Figure 23: Förstner Method – First Setup – Second Measurement

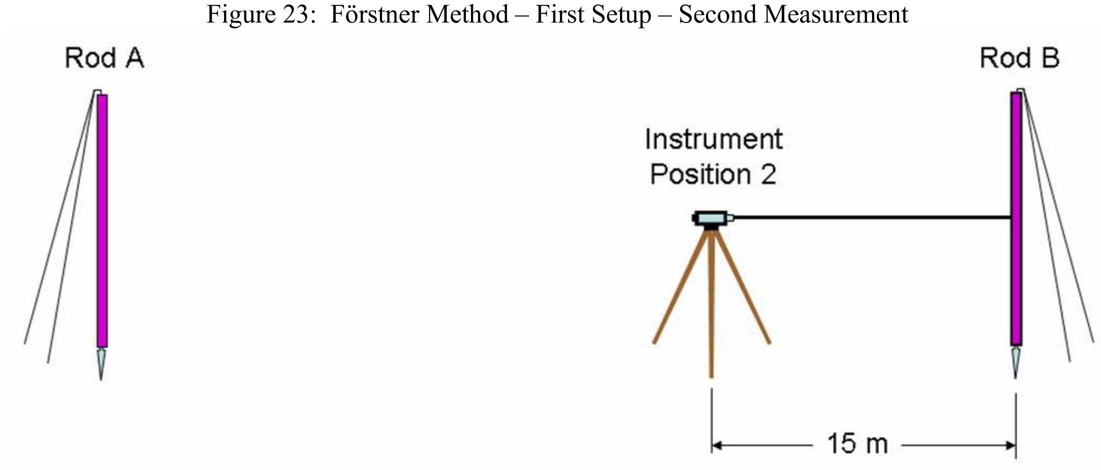


Figure 24: Förstner Method – Second Setup – First Measurement

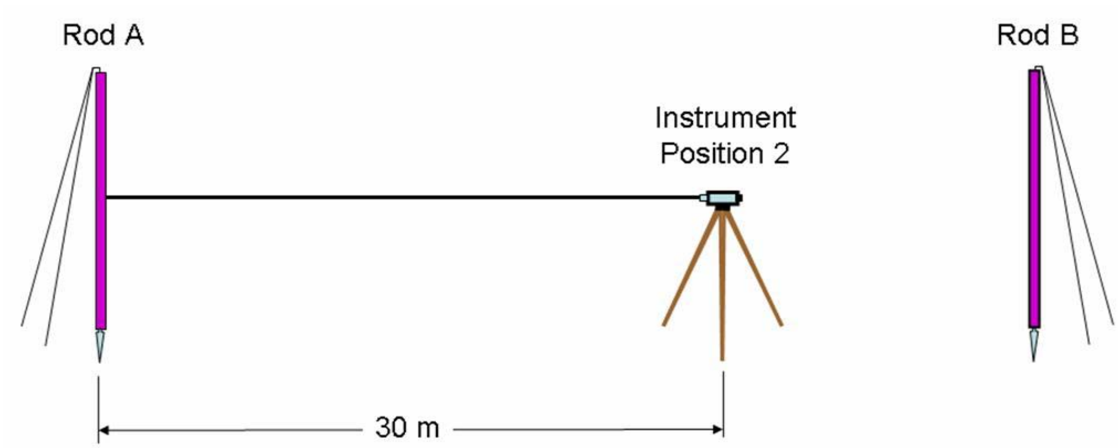


Figure 25: Förstner Method – First Setup – First Measurement

Note: Total Distance as described in Leica DNA03 manual is 45 to 60 meters total distance; the above figures use a 45 meters total distance.

Starting a Section – Measurements and Operations Procedures

Procedures (Basic)

1. Place the base plate of Rod #1 directly on the bench mark
   Note: Make sure that the turning point guide is removed from the base plate of the rod.
   Tip: Tie a piece of flagging or other indication to Rod #1 for easy identification
   Note: Special Case – Vertically Set Bench Mark – Setup using the Invar strip (see Appendix D)

   Ensure that the Rod is in contact with the bench mark and not sitting on the surrounding concrete or other obstructions.

   Note: If the bench mark is recessed, to the point where the base plate cannot come in direct contact with the bench mark, use a spacer. In order to cancel the use of the spacer, it must also be used on a foresight.

   Level Rod #1 on the bench mark using the circular level by adjust the brace poles and point the Bar-Coded Invar directly at the Level Instrument.

   Check to ensure that the circular level is in adjustment

2. The instrument – Pace distance to the instrument setup relative to the back rod (< 60 meters)

   Note: Plan for a balanced setup – distance from back rod to instrument will be the same distance as the instrument to the front rod (< 60 meters).

   Setup Instrument – gently but firmly set tripod feet into ground.

   Level the Instrument using the circular level.

3. Rod #2 – Pace distance from back rod to instrument position and then the same distance to the front rod position.

   Place a turning pin firmly into the ground ensuring no possible movement.

   Setup the Front Rod.

   Ensure the bottom center of the base plate is directly on the turning pin.

Level the rod using the circular level by adjusting the brace poles

4. Instrument – Turn ON the instrument

   Select measurement mode routine – BF (backsight and foresight)

   Enter the start of day information (Entered into Instrument and on the Backup Recording Sheet (See Appendix F)
   - Code 1 – Beginning of Day or Change in Observer or Equipment
     - Date (MMDDYY)
     - Observer Number (Specific number assigned to that observer)
     - Instrument Type (Model Number)
     - Temperature Code (0 = Celsius; 1 = Fahrenheit)
   - Code 2 – Equipment Used
     - Instrument Serial Number
     - Collimation (arc-seconds)
     - Rod #1 Serial Number
     - Rod #2 Serial Number

   Enter Start of Section information (Entered into Instrument and on the Backup Recording Sheet)
   - Code 11 – Beginning Section Information
     - SPSN number of Starting Bench Mark
     - Time (HHMM)
     - Rod Number on Bench Mark (1 or 2)
     - Starting Temperature (1 decimal place precision but with no decimal notation recorded (e. g. 34.5 should be noted as 345)

   Point instrument at back rod (Backsight) – Align the vertical crosshair with the center of the Invar Bar Coded Strip.

   Focus – Sharpest image required

   Initiate Measurement for Backsight by pushing the measurement button.

   Monitor the Measurement and Standard Deviation

   If the measurement is good, the standard deviation is less than 0.1 mm

5. Turn instrument to face the front rod (Foresight)

   Point instrument at front rod (foresight) – Align the vertical crosshair with the center of the Invar Bar Coded Strip.

   Focus – Sharpest image required

Initiate Measurement for Foresight by pushing the measurement button.

Monitor the Measurement and Standard Deviation

If the measurement is good, the standard deviation is less than 0.1 mm and the setup imbalance meets tolerance (< 5 meters).
<u>Note</u>: If this criteria is not met make adjustments (change setup balance if out of single setup balance tolerance or shorter sight lengths if standard deviation cannot be met) and re-measure.

6. Signal back rod to move forward to become the new front rod for the next setup.

7. Enter weather information only into Instrument
   - Code 33 – Gradient Temperature
     - Record Bottom Temperature (1 decimal place precision but with no decimal notation recorded (e.g. 34.5 should be noted as 345)
     - Record Top Temperature (Same format as Bottom Temperature)

   <u>Note</u>: Once recorded, the elevation has been transferred to the turning point at the front rod.

8. The instrument moves to the next setup following the same procedures described above. The previous front rod now becomes the new back rod holding the transferred elevation. The previous back rod moves forward to become the new front rod for the next setup.

   <u>Note</u>: The turning point of the old front rod (new back rod) is now carrying the elevation. It is very important not to disturb in any way the turning point holding the elevation.

Next Setup

9. Rod # 2 (new back rod)

   Turn the rod to face the new instrument position.

   Ensure the bottom center of the base plate is directly on the turning pin.

   Re-level the rod using the circular level by adjusting the brace poles.

   Hold the rod in place with the adjustable brace poles.

10. The instrument paces the appropriate distance from the back rod to the new instrument position (< 60 meters).

Setup Instrument – gently but firmly set the tripod feet into the ground.

Level Instrument using the circular level

11. Check the Accumulated Imbalance displayed in the Instrument

    Adjust distance to new front rod to compensate to keep accumulated imbalance low (< 10 meters)

    Tell new front rod to add or subtract from pacing to adjust for imbalance

12. Rod #1 (new front rod position)

    Pace from back rod #2 to instrument position and then the same distance to the new front rod position – Adjust pacing if requested to adjust for imbalance

    Place a turning pin firmly into the ground ensuring no possible movement.

    Setup the new Front Rod

    Ensure the bottom center of the base plate is directly on the turning pin

    Level the rod using the circular level by adjusting the brace poles and point the Bar-Coded Invar directly at the Level Instrument

    Note: This "Leap Frog" procedure is continued until the next bench mark is encountered. Always ensure that the same rod starting on a bench mark ends on the next bench mark, i.e., even number of setups during a section. Sometimes this requires shortening the last couple of setups to get the same starting rod on the ending bench mark.

Ending a Section

1. Instrument

   Set last foresight identifier in the Instrument to the SPSN number of the ending bench mark

   If the measurement is good – Enter final bottom/top temperature (Code 33)
   - Code 33 – Gradient Temperature
     - Record Bottom Temperature (1 decimal place precision but with no decimal notation recorded (e.g. 34.5 should be noted as 345)
     - Record Top Temperature (Same format as Bottom Temperature)

   Enter Section Ending Information (Entered into Instrument and Backup Recording Sheet)
   - Code 99 – Ending Section Information
     - SPSN Number of Ending Bench Mark
     - Time (HHMM)
     - Rod on Mark (Should be same rod as starting rod (Rod #1) – even number of setups requirement)
     - Temperature (1 decimal place precision but with no decimal notation recorded (e.g. 34.5 should be noted as 345)
     - Wind and Sun Information (e.g. 12 = Breezy Sunny Day)
       - Wind – 0 = Calm , 1 = Breezy , and 2 = Windy
       - Sun – 0 = Overcast, 1 = Partly Sunny, and 2 = Sunny

2. Record on Backup Recording Sheet – Section Observation Information
   - Total Setups
   - Total Distances (km)
   - Accumulated Imbalance (m)
   - Elevation Difference (m)

Note: Single Setup Sections – This is a very short section that only requires one setup because of the proximity of the bench marks. (e.g. Triangulation station and its reference marks, typically < 50 meters apart). This is the only case where it is acceptable to start and end with different rods.

3. If end of day or there is a change in instrumentation or observer enter Code 9999 – End of Day, Change of Observer, Change of Equipment (No Information Entries)

   If change of instrumentation or observer, start next section with a Code 1 – Beginning of Day or Change in Observer or Equipment and Code 2 – Equipment Used with the new information and begin next section with a Code 11 – Beginning Section Information

If end of day, Finalize Measurement Mode and Turn Off instrument

Important Leveling Tips

- Use of stable Turning Points is essential for accurate leveling (See FGCS Specifications, Appendix A, and NOAA Manual NOS NGS 3, Chapter 3)
- Focusing the digital instrument is very important for an accurate reading
- Start and End with the Same Rod – Even Number of Setups
- Place the Rod on the High Point and/or Center of the Disk
- Keep Imbalances as tight as possible
- Transfer elevation from backsight to instrument when foresight is setup and ready
- Backsight rod person does not move until the full setup measurements are complete and the instrument person tells the backsight rod person to move.
- Make sure the rod is placed on the turning point/bench mark and not on the turning point guide
- Do not leave the Instrument setup unattended
- Make sure the rod persons are attentive to the rods (mindful of wind to prevent falling)
    - Pace one hand on the brace pole of the rod at all times
- Protect the base of the rod to avoid damage to the base plate which could affect the accuracy of the measurements taken
- Do not touch the Invar Bar Code region of the rod – affects measurements and can damage the bar code
- When carrying the rod, be aware of the surroundings (e.g. electrical wires, traffic, doorways, windows, pedestrians, etc.)
- When using the spacer, make sure it is removed after it is used
    - Also use one on foresight to cancel the use of the spacer on the mark (backsight)
- Stabilize both tripod and turning points firmly in ground
- When reading high on a rod ensure that the upper stadia crosshair is not above the top of the Invar strip
- Double-Run all sections
- Best to run one direction of leveling in the morning and the opposite direction in the afternoon for the same section to help minimize systematic errors
- Double-Run
- Do not set instrument or rods on asphalt
- Front Rod persons should ensure a cleat line of sight to the instrument when setting up their positions.
- Don’t point the instrument at the sun
- Sun shade is very helpful when measuring

Data Transfer and Data Formatting for NGS

Use Manufacturer's manual to properly retrieve raw data from the instrument.

Note: Refer to Appendix H – Case 2 and Appendix I for Data Formatting for NGS

Note: Save a copy of the original raw data from the instrument to a separate directory. This will protect the original raw data and can provide a backup if it is necessary to reprocess the data.

Contacts

Davey Crockett
Geodetic Technician
1315 East-West Hwy.
SSMC3 Room 8438
Silver Springs, MD 20910
(301) 713-3187
davey.crockett@noaa.gov

Appendix A

FGCS Specifications and Procedures to Incorporate
Electronic Digital/Bar-Code Leveling Systems*

3.5 Geodetic Leveling

Geodetic leveling is a measurement system comprised of elevation differences observed between nearby rods. Geodetic leveling is used to extend vertical control.

Network Geometry

Order Class	First I	First II	Second I	Second II	Third
Benchmark spacing not more than (km)	3	3	3	3	3
Average bench mark spacing not more than (km)	1.6	1.6	1.6	3	3
Line length between network control points not more than (km)	300[a]	100[a]	50[a]	50[a]	25[b]
Minimum bench mark ties	6	6	4	4	4

[a] Electronic Digital/Bar Code Leveling Systems, 25 km
[b] Electronic Digital/Bar Code Leveling Systems, 10 km

As specified in above table, new surveys are required to tie to existing network bench marks at the beginning and end of the leveling line. These network bench marks must have an order (and class) equivalent to or better than the intended order (and class) of the new survey.

First-order surveys are required to perform valid check connections to a minimum of six bench marks, three at each end. All other surveys require a minimum of four valid check connections, two at each end.

A valid "check connection" means that the observed elevation difference agrees with the published adjusted elevation difference within the tolerance limit of the new survey. Checking the elevation difference between two bench marks located on the same structure, or so close together that both may have been affected by the same localized disturbance, is not considered a proper check.

In addition, the survey is required to connect to any network control points within 3 km of its path. However, if the survey is run parallel to existing control, then the following table specifies the maximum spacing of extra connections between the survey and the existing control.

When using Electronic Digital/Bar-Code Leveling Systems for area projects, there must be at least 4 contiguous loops and the loop size must not exceed 25 km. *(Note: This specification may be amended at a future date after sufficient data have been evaluated and it is proven that there are no significant uncorrected systematic errors remaining in Electronic Digital/Bar-Code Leveling Systems.)*

Surveys Run Parallel to Existing Control Network

Distance, survey to control network	Maximum spacing of extra connections (km)
less than 0.5 km	5
0.5 km to 2.0 km	10
2.0 km to 3.0 km	20

Instrumentation

Order Class	First I	First II	Second I	Second II	Third
Leveling Instrument					
Minimum repeatability of line of sight	0.25"[c]	0.25"[c]	0.50"[c]	0.50"[d]	1.00"
Leveling rod construction	IDS[g]	IDS[g]	IDS[g] or ISS	ISS	Wood or Metal
Instrument and rod resolution (combined)					
Least count (mm)	0.1[c]	0.1[c]	0.5 - 0.1[c,f]	0.1[d]	0.1[d]

IDS – Invar, double-scale
ISS – Invar, single-scale

[c] For Electronic Digital/Bar Code Leveling Systems, 0.40" and 0.01 mm
[d] For Electronic Digital/Bar Code Leveling Systems, 0.80" and 0.1 mm
[e] If optical micrometer is used
[f] 1.0 mm is 3-wire method; 0.5 mm if optical micrometer
[g] For Electronic Digital/Bar Code Leveling Systems, Invar, single-scale

Leveling rods must be one piece. A turning point consisting of a steel turning pin with a driving cap should be utilized. If a steel pin cannot be driven, then a turning plate ("turtle") weighing at least 7 kg should be substituted. In situations allowing neither turning pins nor turning plates (sandy or marshy soils), a long wooden stake with a double-headed nail should be driven to a firm depth.

According to at least one manufacturer's specifications, the electronic digital leveling instrument should not be exposed to direct sunlight. The manufacturer recommends using an umbrella in bright sunlight.

Calibration Procedures

Order Class	First I	First II	Second I	Second II	Third
Leveling Instrument					
Maximum collimation error, single line of sight (mm/m)	0.05	0.05	0.05	0.05	0.1
Leveling rod					
Minimum scale calibration standard	N[i]	N[i]	N[i]	M	M
Time interval between scale calibrations (yr)	3	3	-	-	-
Leveling rod bubble verticality maintained to within	10'	10'	10'	10'	10'

N – U.S. National standard
M – Manufacturer's standard

[h] For Electronic Digital/Bar-Code Systems, collimation error determinations are required at the beginning of each day (0.05 mm/m = 10 arc seconds). Collimation data must be recorded with the leveling data and the daily updated value must be used during the daily data capture.

[i] For Electronic Digital/Bar-Code Rods, until the U.S. National Standard Testing Procedure is implemented, manufacturer's scale calibration standard is acceptable, provided the data used during the calibration are furnished in digital format.

Compensator-type instruments should be checked for proper operation at least every 2 weeks of use. Rod calibration should be repeated whenever the rod is dropped or damaged in any way. Rod levels should be checked for proper alignment once a week. The manufacturer's calibration standard should, as a minimum, describe scale behavior with respect to temperature.

Field Procedures

Order Class	First I	First II	Second I	Second II	Third
Section running[k]	DR	DR	DR	DR	DR
Difference of forward and backward sight lengths never to exceed:					
per setup (m)	2	5	5	10	10

per section (m)	4	10	10	10	10
Maximum sight length (m)[l]	50	60	60	70	90
Even number of setups when not using leveling rods with detailed calibration	yes	yes	yes	yes	-
Determine temperature gradient for the vertical range of the line of sight at each setup	yes	yes	yes	-	-
Maximum section misclosure (mm)	$3\sqrt{D}$	$4\sqrt{D}$	$6\sqrt{D}$	$8\sqrt{D}$	$12\sqrt{D}$
Maximum loop misclosure	$4\sqrt{E}$	$5\sqrt{E}$	$6\sqrt{E}$	$8\sqrt{E}$	$12\sqrt{E}$
Electronic Digital/Bar Code method					
Use multiple reading option to obtain each observation - minimum number of readings[m]	3	3	3		3

DR -- Double-Run
D --- shortest one-way length of section in km
E --- length of loop in km

[k] For establishing a height of a new bench mark, double-run procedures must be used. Single-run methods can be used to relevel existing work provided the new work meets the allowable section misclosure.

[l] Maximum sight length permitted unless the manufacturer recommends a maximum sight length which is less.

[m] If the standard deviation of the mean exceeds 0.1 mm, continue making readings m until it is less than 0.1 mm or repeat observation.

Double-run leveling may always be used, but single-run leveling procedures can only be used where it can be evaluated using published height values, i.e., the difference in published height values can be substituted for the backward running.

Rods must be leap-frogged between setups (alternate setup method). The date, beginning and ending times, cloud coverage, air temperature (to the nearest degree), temperature scale, and average wind speed should be recorded for each section, plus any changes in the date, instrumentation, observer, or time zone.

The low-high scale difference tolerance for a reversible compensator is used only for the control of blunders.

Summary of Observing Sequences
(Required for first-order; optional for other orders)

Office Procedures

Order Class	First I	First II	Second I	Second II	Third
Section misclosures (backward and forward)					
Algebraic sum of all corrected section misclosures of a leveling line not to exceed (mm)	$3\sqrt{L}$	$4\sqrt{L}$	$6\sqrt{L}$	$8\sqrt{L}$	$12\sqrt{L}$
Section misclosure not to exceed (mm)	$3\sqrt{D}$	$4\sqrt{D}$	$6\sqrt{D}$	$8\sqrt{D}$	$12\sqrt{D}$
Loop misclosures					
Algebraic sum of all corrected section misclosures not to exceed (mm)	$3\sqrt{E}$	$4\sqrt{E}$	$6\sqrt{E}$	$8\sqrt{E}$	$12\sqrt{E}$
Loop misclosure not to exceed (mm)	$3\sqrt{E}$	$4\sqrt{E}$	$6\sqrt{E}$	$8\sqrt{E}$	$12\sqrt{E}$

L -- shortest one-way length of leveling line in km
D -- shortest one-way length of section in km
E -- length of loop in km

The normalized residuals from a minimally constrained least squares adjustment will be checked for blunders. The observation weights will be checked by inspecting the post adjustment estimate of the variance of unit weight. Elevation difference standard errors computed by error propagation in a correctly weighted least squares adjustment will indicate the provisional accuracy classification. A survey variance factor ratio will be computed to check for systematic error. The least squares adjustment will use models that account for:

- gravity effect or orthometric correction
- rod scale errors
- rod (Invar) temperature
- refraction--need latitude and longitude accurate to at least 6" or (preferably) vertical temperature difference observations between 0.5 and 2.5 m above the ground
- earth tides and magnetic field
- collimation error
- crustal motion
-

For Electronic Digital/Bar-Code Leveling Systems, collimation data must be recorded with leveling data and updated value must be used during data capture.

NGS PROPOSAL for an Addendum to Current
FGCS Specifications and Procedures to Incorporate
Electronic Digital/Bar-Code Leveling Systems
Version 3.1
May 15, 2001

The current FGCS Specifications contain a 10 arc-second collimation tolerance limit for electronic digital/bar-code leveling systems. If this tolerance limit is exceeded, the observations are to be reobserved, and if the tolerance limit is routinely exceeded, it is recommended the instrument be returned to the manufacturer for repair/calibration. Instrument manufacturers have stated that their new, improved digital/bar-code leveling instruments can exceed the 10 arcsecond limit and still produce results within their stated accuracy. In order to determine if the 10 arc-second specification should be revised, additional tests and evaluations are necessary to validate the manufacturers' statements. In the interim, NGS is issuing this proposal for an addendum to the existing FGCS specifications. The following are guidelines/requirements for digital bar-code leveling systems that exceed the 10 arc-second collimation tolerance limit. This proposal is consistent with manufacturers' recommended procedures.

Note: Since bar-code leveling rods are not calibrated at every increment (i.e., there are no "detailed" calibrations), first- and second-order leveling must always have an even number of setups.

For additional information, contact Edward J. McKay, National Geodetic Survey
e-mail: Ed.McKay@noaa.gov
telephone: 301-713-3191

First-Order (Precise) Geodetic Leveling

- Check that the instrument, tripod, and Invar staff are in good mechanical order (i.e., they must adhere to digital level manual guidelines),
- Allow digital levels sufficient time to adjust to the ambient temperature, (Manufacturer recommends: temperature difference in Centigrade x 2 = time in minutes required for instrument to adjust to a new temperature.),
- BFFB (Backsight-Foresight-Foresight-Backsight) sighting method (alternating),
- Sight lengths cannot exceed 35 meters,
- Setup sight-length imbalances cannot exceed 1 meter,
- Section sight-length imbalances cannot exceed 1 meter for first-order, class I; and cannot exceed 2 meters for first-order, class II.
- Collimation ("c") checks:
    - Maximum collimation value not to exceed 50 arc-seconds,

  - Collimation must be checked at the beginning and end of each day's observations (typically in the morning and afternoon),
  - During the day, collimation values must not vary by more than 2 arc-seconds, and
  - Day-to-day collimation values must not vary by more than 5 arc-seconds,

- Tripod and instrument must be shaded,

- Avoid sighting across areas with intense solar radiation,

- Do not measure when there is excessive vibration,

- Accurately focus the instrument cross-hairs on the rod,

- Do not measure when a staff section is interrupted (e.g., by branches of a tree),

- Do not measure beyond the base or top of the staff,

- Read, understand, and implement the advice and information given in the instrument's user manual, and

- Report a summary of section misclosures to the National Geodetic Survey for validation purposes.

Second- and Third-Order Geodetic Leveling

- Check that the instrument, tripod, and staff are in good mechanical order (i.e., they must adhere to digital level manual guidelines),

- Allow digital levels sufficient time to adjust to the ambient temperature, (Manufacturer recommends: temperature difference in Centigrade x 2 = time in minutes required for instrument to adjust to a new temperature.),

- BF (Backsight-Foresight) sighting method (alternating),

- Sight lengths cannot exceed 50 meters,

- Setup sight-length imbalances cannot exceed:
  - 1 meter for second-order, classes I and II,
  - 2 meters for third-order, and

- Section sight-length imbalances cannot exceed 2 meters.

- Collimation ("c") checks:
  - Maximum collimation value must not exceed 50 arc-seconds,

    - Collimation must be checked at the beginning and end of each day's observations (typically in the morning and afternoon),
    - During the day collimation values must not vary by more than 2 arc-seconds,
    - Day-to-day collimation values must not vary by more than 5 arc-seconds,
    - Tripod and instrument should be shaded in bright sunlight; avoid "one-sided" sunlight on the tripod and instrument,

- Avoid sighting across areas with intense solar radiation,

- Do not measure when there is excessive vibration,

- Read, understand, and implement the advice and information given in the instrument's user manual, and

- Report a summary of section misclosures to the National Geodetic Survey for validation purposes.

For additional information, contact Edward J. McKay, National Geodetic Survey

e-mail: Ed.McKay@noaa.gov
telephone: 301-713-3191

Appendix B

Manufacturer’s Bar Code Scale Calibrations NEDO and LAVAL Paper Documents

NEDO Calibration

Calibration of Invar Rods

Invar rods for precise levelling are examined on the comparators at the Geodetic Institute of the Technical University in Munich. The distances between the single lines on the invar tape are tested with a laser interferometer. The lines are observed with an opto-electronic double-diode (TU Karlsruhe). The observation process itself on these advanced comparators is therefore completely automated.

Determination of the scale factor in vertical position

1. **Invar rod with bar-code scale**

   The positions of 170 lines with a with of 2 mm are determined in the forward and reverse directions. The observed lines are fairly distributed along the whole invar tape.

   The nominal position and the real position are compared and the results are related to a straight line. The gradient of this regression straight line is the scale factor m_0 at the temperature of measurement, approximately 20 °C.

2. **Invar rod with line graduation**

   In this case, the position of all lines on the tape are examined and the scale factor m_0 is determined for both scales.

   A certificate of the residuals of the individual lines is supplied and a delivery on disc is also possible.

Determination of the coefficient of expansion

For the evaluation of the coefficient of expansion the graduations of the invar rods are tested at different temperatures on a horizontal comparator (only one scale for line graduation). The measurements are done in the forward and reverse directions. The respective scale factors depend of the temperatures, they are related to a regression straight line. Its gradient α_T is the coefficient of expansion.

The observations are accomplished in a cycle of 30–0–20–40–10 °C. The great differences of temperature between the single observations ensure that malfunctions of the tension module and the influence of friction between the invar tape and the housing of the rod can be detected.

TUM

Leica TUM Geodaetisches Institut, Technische Universitaet Muenchen
Arcisstrasse 21, 80290 Muenchen, Tel.: 089/2892-2850, Fax: 089/2892-3967

Endabnahme NEDO Invarlatten

Nestle & Fischer GmbH & Co. KG
Vermessungsgerätefabrik
72280 Dornstetten/Württ.

Datum: 24. 6. 96

Prüfer: Max Bittenbinder

Nummer: 027730

Teilung: ☐ cm-Doppelteilung ☐ 1/2-cm-Doppelteilung ☒ BC.

Länge: ☐ 1 m ☒ 2 m ☐ 3 m

Prüfung	geprüft und für in Ordnung befunden
Geradheit des Lattenkörpers	☒
Nullpunkteinstellung	☒
Libellenjustierung	☒
Winkligkeit der Aufsetzfläche	☒
Ebenheit der Aufsetzfläche	☒
Teilungsgenauigkeit nach DIN 18717	☒
Funktionsfähigkeit der Handgriffe	☒
Lackierung des Invarbandes	☒
Lackierung des Lattenkörpers	☒
M Sonderausführung	☐
Strebe	☐

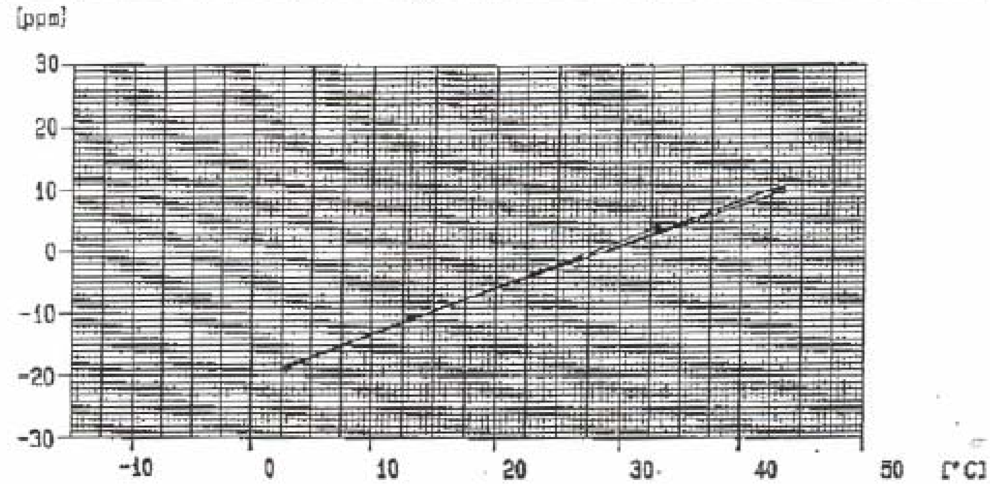
Calibration Report

Invar rod (type, No.): LEICA-GPCL2 27730   Date : 11.07.96 – 18.07.96

No. of graduations measured: 105   Order No: 96-60-408583

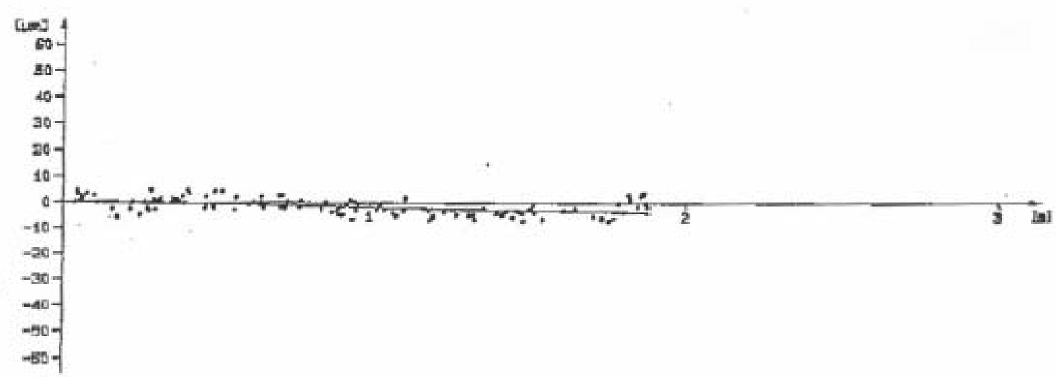
Determination of the coefficient of expansion   **Horizontal calibration position**

Measurement cycle: 30 → 0 → 20 → 40 → 10 [°C]



Coefficient of expansion: $\alpha_T = 0.74 \pm 0.02$ *ppm/°C*

Determination of the scale factor   **Vertical calibration position**



Scale factor: $m_0 = -2.37 \pm 0.49$ *ppm*   at $T_0 = 20.1$ °C

Length adjustment for vertical position of use

$$L = L'[1 + (m_0 + \alpha_T(T - T_0)) \cdot 10^{-6}]$$

L'[m] = observed rod length

T[°C] = temperature

Technical specialist: [signature]   Munich, 18.07.96

Laboratory director: Dr. U. Laues [signature]   Institute director: i. A. Dr. U. Laues [signature]

LAVAL Calibration Report

UNIVERSITÉ LAVAL

FACULTÉ DE FORESTERIE
ET DE GÉOMATIQUE

Cité universitaire
Québec, Canada G1K 7P4

Certificate of Calibration

Levelling staff no 25707

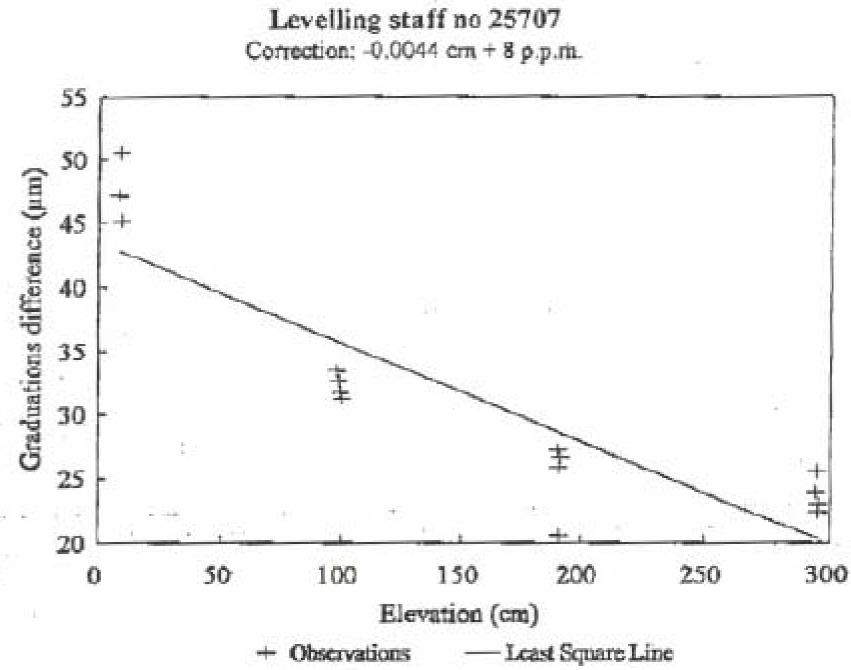
Observations (cm)	Face-Value (cm)
8.206	8.20125
8.814	8.80875
9.218	9.21375
98.520	98.51625
99.127	99.12375
99.734	99.73125
100.342	100.33875
190.454	190.45125
190.859	190.85625
191.263	191.26125
191.871	191.86875
294.134	294.13125
294.539	294.53625
294.943	294.94125
295.349	295.34625

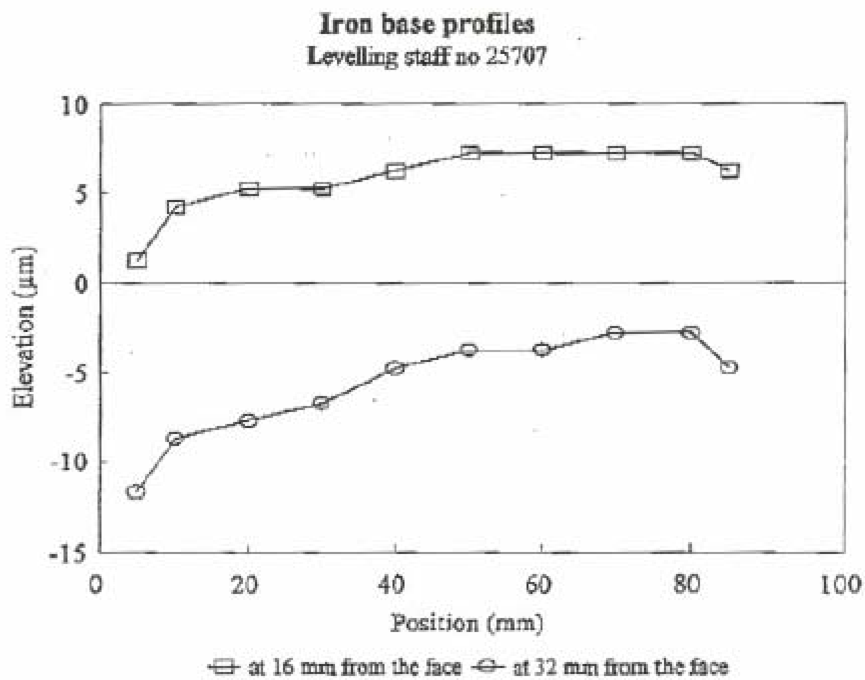
02/03/94

Head assistant
Metrology Laboratory

France Plante, Sc. Degree, l.s.
Metrology Laboratory
PEPS, Laval University
Sainte-Foy, Qc
G1K 7P4

N.B.: Observations have been made on 28/02/1994
Reference files : D:\CAL\25707.MB1 et D:\CAL\25707.SE1
Output file D:\CERTIF\MB25707.WB1


Levelling staff no 25707
Correction: -0.0044 cm + 8 p.p.m.
Graduations difference (μm)
Elevation (cm)
+ Observations
— Least Square Line


Iron base profiles
Levelling staff no 25707
Elevation (μm)
Position (mm)
at 16 mm from the face
at 32 mm from the face

UNIVERSITÉ LAVAL ← ULAVAL

FACULTÉ DE FORESTERIE
ET DE GÉOMATIQUE

Cité universitaire
Québec, Canada G1K 7P4

Calibration Temperature Certificate

April 21th , 1994

We certify that the observations on the present certificate have been made at the following temperature:

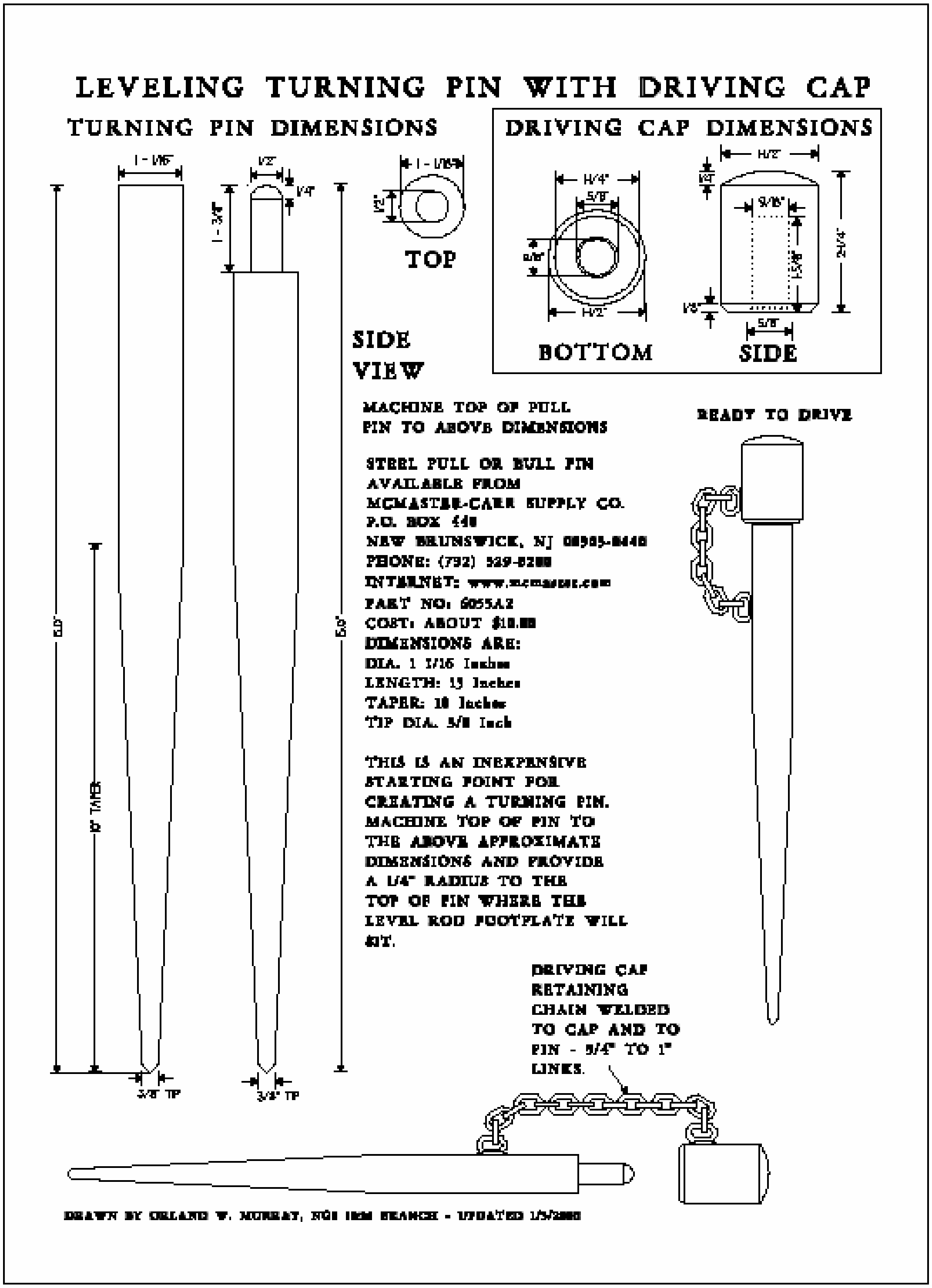
20° C ± 0.7° C

The temperature of the callbration room is controled to stay in that range.

Head Assistant
Metrology Laboratory

France Plante, *Science degree* , *Q.L.S.*
Room 00421 (PEPS) Tel.: (418) 656-7082

Appendix C



LEVELING TURNING PIN WITH DRIVING CAP
TURNING PIN DIMENSIONS
DRIVING CAP DIMENSIONS
TOP
BOTTOM
SIDE
SIDE VIEW
MACHINE TOP OF PULL PIN TO ABOVE DIMENSIONS
STEEL PULL OR BULL PIN
AVAILABLE FROM
MCMASTER-CARR SUPPLY CO.
P.O. BOX
NEW BRUNSWICK, NJ
PHONE: (732)
INTERNET:
PART NO: 6055A2
COST: ABOUT
DIMENSIONS ARE:
DIA. 1 1/16 Inches
LENGTH: 13 Inches
TAPER: 10 Inches
TIP DIA. 3/8 Inch
THIS IS AN INEXPENSIVE STARTING POINT FOR CREATING A TURNING PIN. MACHINE TOP OF PIN TO THE ABOVE APPROXIMATE DIMENSIONS AND PROVIDE A 1/4" RADIUS TO THE TOP OF PIN WHERE THE LEVEL ROD FOOTPLATE WILL SIT.
READY TO DRIVE
DRIVING CAP RETAINING CHAIN WELDED TO CAP AND TO PIN - 3/4" TO 1" LINKS.
DRAWN BY ORLAND W. MURRAY, NGS ISM BRANCH - UPDATED

Appendix D

USING THE INVAR STRIP (Drawings #3 and #4)

As stated earlier, the 60 cm bar-code invar strip is needed to establish elevations on points or marks that cannot be accessed using a standard leveling rod, such as, bench marks set vertically in foundations, bridge abutments, etc., or special elevation points required by a given survey. The index described above was designed primarily for vertically set bench marks, so it may not work for all situations.

Drawing #3 depicts using the invar strip on a vertically set bench mark disk. The 60 cm bar-code invar strip can only be observed at a distance of 20 meters or less. To use the invar strip on a vertically set bench mark, first find the point on the BM disk that will be leveled to, which on a standard NGS disk is the intersection of the horizontal line and shorter vertical line cast at the center of the disk. Hold the invar strip up the mark with the reference index close to the reference line on the disk. Set up the level instrument less than 20 meters away and at a height where when the line of sight of the leveled instrument intersects the invar strip about in the middle. Two people should hold the invar strip, one at the top to keep it plumb and one at the bottom to align the index to the mark. The strip can be plumbed in several ways:

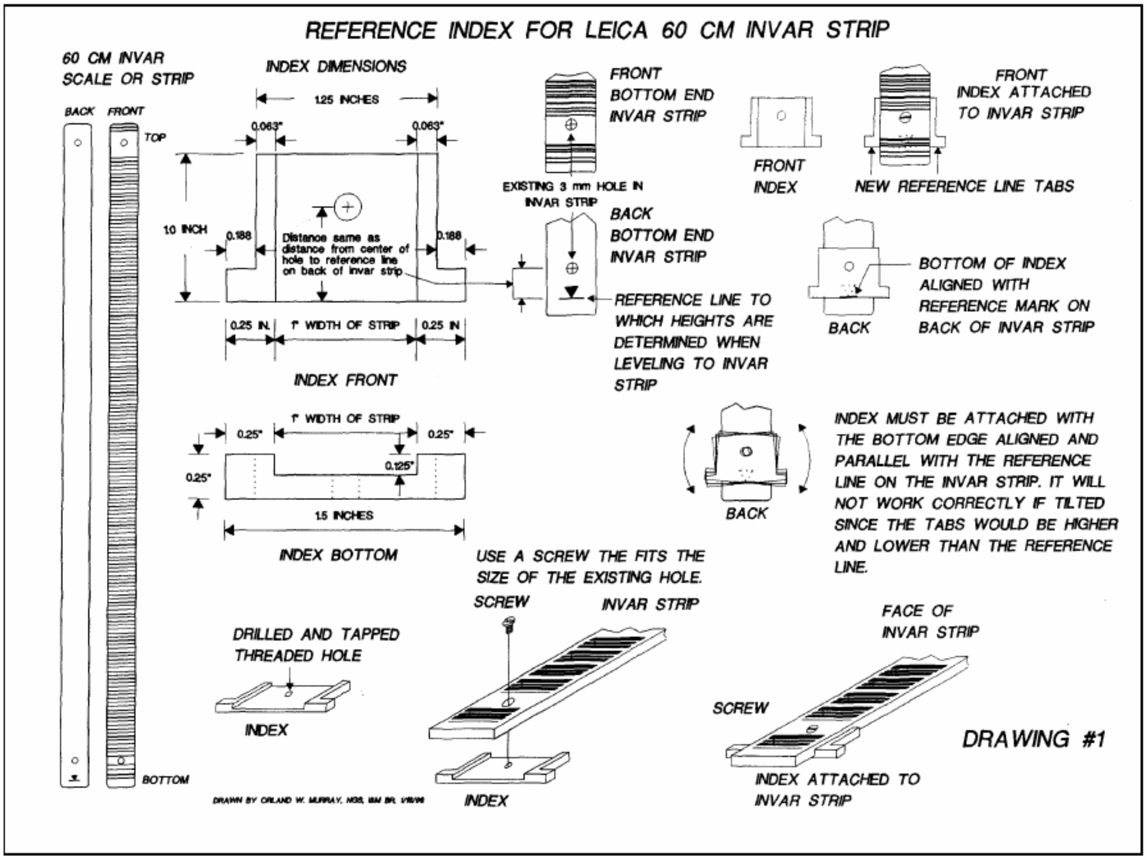
1. By observing it through the instrument and aligning the left or right edge of the strip with vertical reticle line of the instrument.

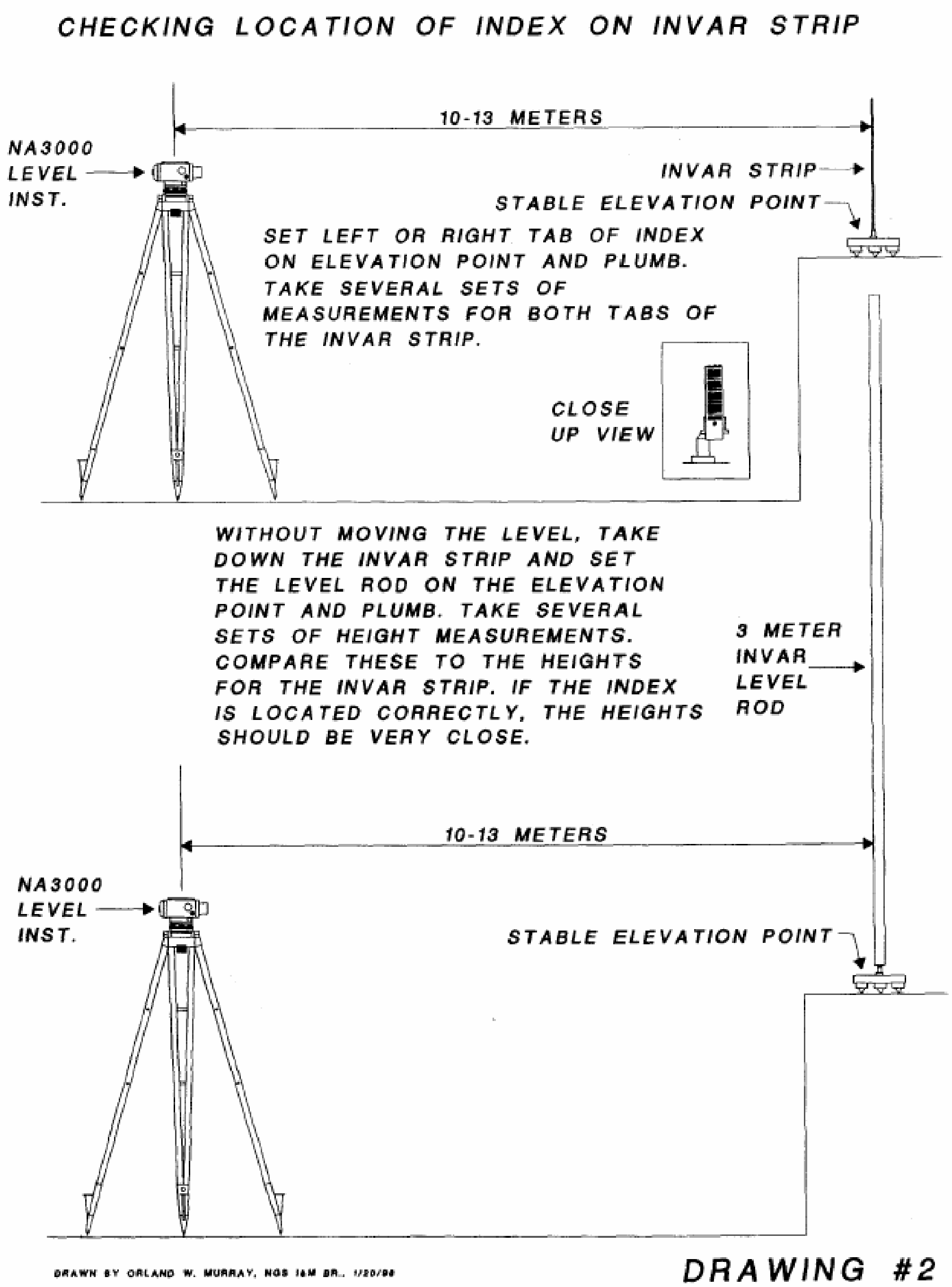
2. Use a carpenters level held up to the side of the strip.

3. Use a handheld level bubble.

When near plumb, have the person at the bottom of the strip align the bottom of one of the index tabs with reference line on the disk (See Drawing #3). Once assured the index is aligned correctly, the top person check the plumb. If all is correct, press the measure button on the level and take the measurements. Note: The invar strip can also be read in an inverted or upside down position as can the level rods. The instrument, however, must be set for inverted readings. REMEMBER, always reference measurements to the bottom edge of the index tabs, plumb the invar strip and never use the bottom edge of the invar strip as a reference line.

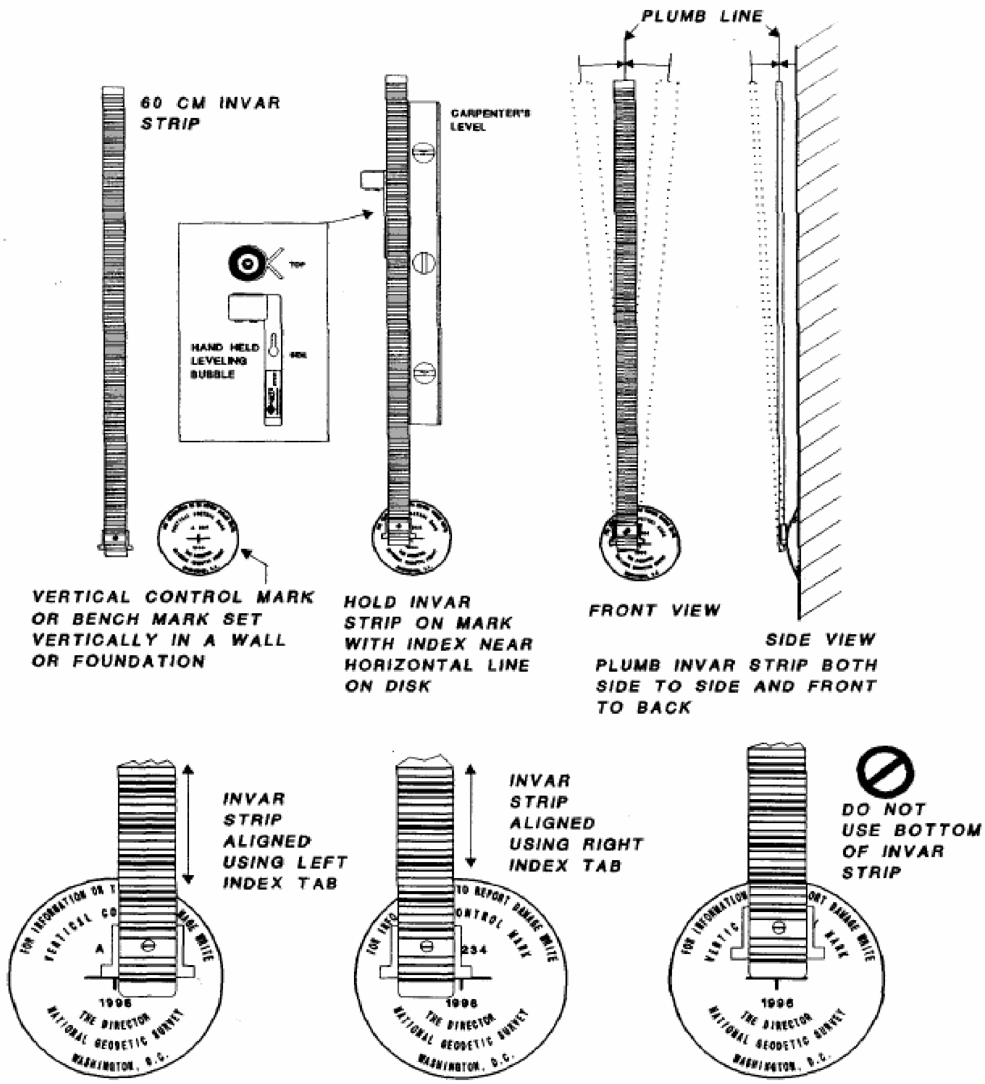
To use the invar strip on a horizontally set bench mark or elevation point, it may be necessary to use a spacer ("plug"). NGS uses calibrated metal 20 mm cylinders (See Drawing #4). Some spacers are magnetic so that they will stick to the steel footplate of a level rod. The spacers are most always used in pairs, one on the backsight rod and the other on foresight rod or invar strip. They raise the rod and invar strip equal amounts so that the difference of elevation between backsight and foresight remains correct. Remember to remove them before reading the next setup. If one is left on, an error, the height of the spacer, will be introduced into the level observations on the next setup. If only one spacer is available, place it first on the backsight rod and take the level measurements, then move it to the foresight and take the measurements.




CHECKING LOCATION OF INDEX ON INVAR STRIP
10-13 METERS
NA3000 LEVEL INST.
INVAR STRIP
STABLE ELEVATION POINT
SET LEFT OR RIGHT TAB OF INDEX ON ELEVATION POINT AND PLUMB. TAKE SEVERAL SETS OF MEASUREMENTS FOR BOTH TABS OF THE INVAR STRIP.
CLOSE UP VIEW
WITHOUT MOVING THE LEVEL, TAKE DOWN THE INVAR STRIP AND SET THE LEVEL ROD ON THE ELEVATION POINT AND PLUMB. TAKE SEVERAL SETS OF HEIGHT MEASUREMENTS. COMPARE THESE TO THE HEIGHTS FOR THE INVAR STRIP. IF THE INDEX IS LOCATED CORRECTLY, THE HEIGHTS SHOULD BE VERY CLOSE.
3 METER INVAR LEVEL ROD
10-13 METERS
NA3000 LEVEL INST.
STABLE ELEVATION POINT
DRAWN BY ORLAND W. MURRAY, NGS I&M BR., 1/20/98

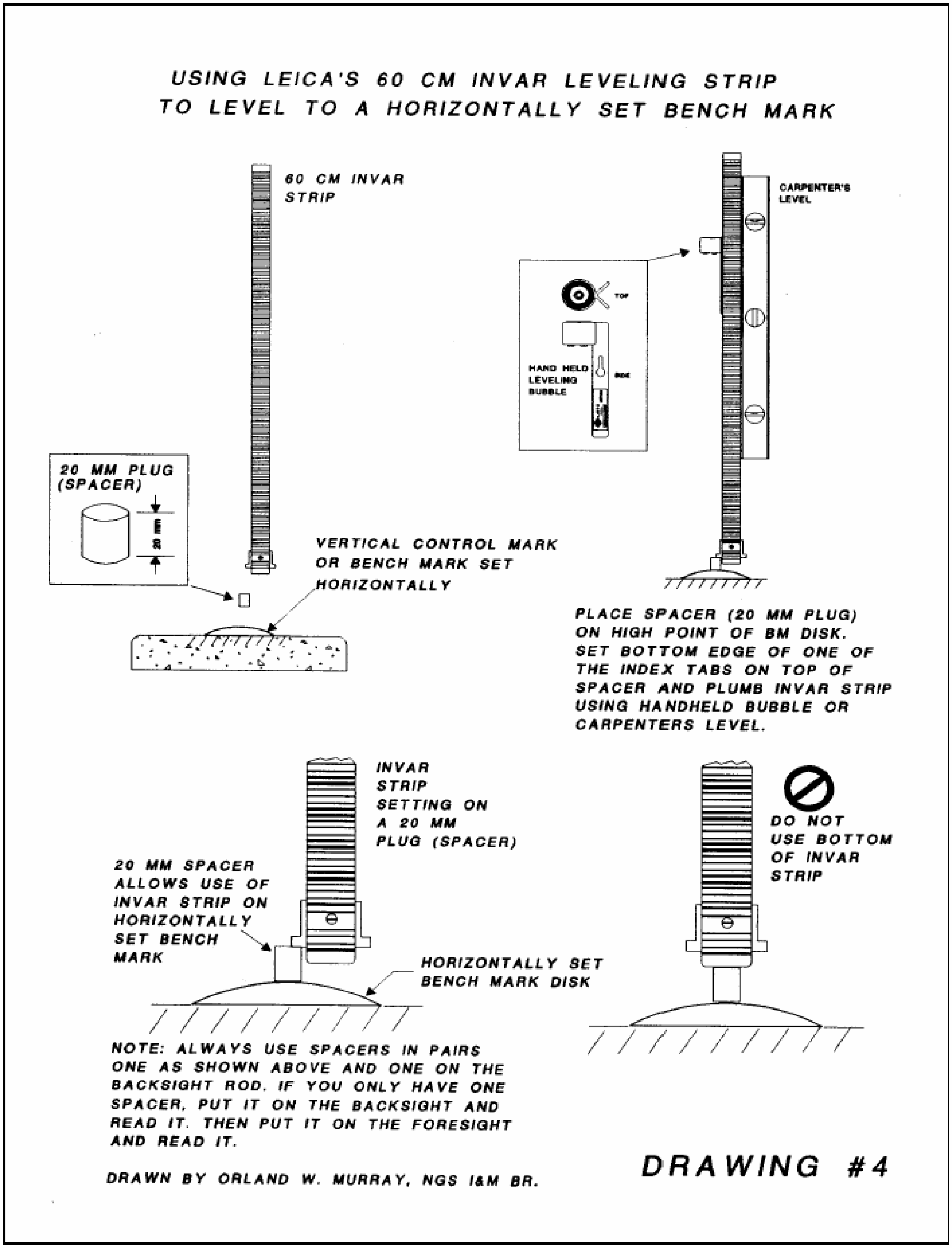
DRAWING #2

USING LEICA'S 60 CM INVAR LEVELING STRIP
TO LEVEL TO A VERTICALLY SET BENCH MARK



WHILE KEEPING THE INVAR STRIP PLUMB, ADJUST IT UP AND DOWN UNTIL THE BOTTOM EDGE OF THE INDEX REFERENCE TAB IS ALIGNED WITH INTERSECTION OF THE HORIZONTAL AND VERTICAL LINES ON THE VERTICAL CONTROL MARK. USE TWO PEOPLE TO PERFORM THIS PROCEDURE. ONE CAN HOLD AND PLUMB THE INVAR STRIP, WITH THE OTHER ADJUSTS THE INDEX TO THE BENCH MARK. DO NOT USE THE BOTTOM OF THE INVAR STRIP AS THE REFERENCE POINT. USE ONLY THE BOTTOM EDGE OF EITHER OF THE TABS ON THE INVAR STRIP INDEX. (DRAWN BY ORLAND W. MURRAY, NGS)

DRAWING #3


USING LEICA'S 60 CM INVAR LEVELING STRIP
TO LEVEL TO A HORIZONTALLY SET BENCH MARK
60 CM INVAR STRIP
CARPENTER'S LEVEL
HAND HELD LEVELING BUBBLE
20 MM PLUG (SPACER)
VERTICAL CONTROL MARK OR BENCH MARK SET HORIZONTALLY
PLACE SPACER (20 MM PLUG) ON HIGH POINT OF BM DISK. SET BOTTOM EDGE OF ONE OF THE INDEX TABS ON TOP OF SPACER AND PLUMB INVAR STRIP USING HANDHELD BUBBLE OR CARPENTERS LEVEL.
INVAR STRIP SETTING ON A 20 MM PLUG (SPACER)
20 MM SPACER ALLOWS USE OF INVAR STRIP ON HORIZONTALLY SET BENCH MARK
HORIZONTALLY SET BENCH MARK DISK
DO NOT USE BOTTOM OF INVAR STRIP
NOTE: ALWAYS USE SPACERS IN PAIRS ONE AS SHOWN ABOVE AND ONE ON THE BACKSIGHT ROD. IF YOU ONLY HAVE ONE SPACER, PUT IT ON THE BACKSIGHT AND READ IT. THEN PUT IT ON THE FORESIGHT AND READ IT.
DRAWING #4
DRAWN BY ORLAND W. MURRAY, NGS I&M BR.

Appendix E

Recovery Sheets – Station Description/Recovery Form

Filled out – Station Description/Recovery Form

NATIONAL GEODETIC SURVEY STATION DESCRIPTION / RECOVERY FORM

4-char ID: BALD   Designation: BALD 2 RESET

PID: QE2736   Alias:

Country: (USA / USA)   State: OR   County: LINCOLN

Latitude: N 44 49 49.17802 "   Longitude: W 124 03 56.23447 "   Elevation: 17.0 (meter ✓ / ft)

Original Description (check one):	
❐ P	Preliminary (mark has not been set yet)
❐ D	A newly set mark
☑ R	A recovered mark
Established by: (NGS / CGS / Other:) Oregon DOT	
Date: Chief of Party (initials): ???	

Recovery Description (check one):	
❐ F	Full description of a station *not* in the database
☑ T	Full description of a station *in* the database
❐ M	*Partial* description of a station in the database
Recovered by: (NGS / Other:) Oregon DOT	
Date: Chief of Party (initials): CFS	

Monument Stability (check one):	
☑ A	Of the most reliable nature; expected to hold well
❐ B	Will probably hold position and elevation well
❐ C	May hold well, but subject to ground movement
❐ D	Of questionable or unknown reliability

Recovery Condition (check one):	
☑ G	Recovered in good condition
❐ N	Not recovered or not found
❐ P	Poor, disturbed, or mutilated
❐ X	Surface mark known destroyed

Setting Information:	
Marker Type: (Rod / Disk ✓ / Other)	
Setting Type: (Bedrock ✓ / Concrete / Other:)	
✓ / N / ?	Monument contains magnetic material?

Stamping: BALD 2 1991	
Agency Inscription: (NGS / CGS / Other:) Oregon DOT	
Rod Depth: (m/ft)	Sleeve Depth: (m/ft)
Monument is: (flush ✓ / projecting / recessed) (cm/ft)	

Special Type (check all applicable):	
❐ F	Fault monitoring site
❐ T	Tidal Station
☑ --	Control Station: (FBN / CBN ✓ / Benchmark ✓)
❐ --	Airport Control Station: (PACS / SACS)
✓ /N	Mark is suitable for GPS use?

Transportation (check one):	
☑ C	Car
❐ P	Light truck (pickup, carry-all, etc.)
❐ X	Four-Wheel Drive Vehicle
❐ __	Other (SnowCat, Plane, Boat; describe)
✓ /N	Pack Time (hike) to mark? (hh:mm): 00:03

See Back of Form to add Text Description

General Station Location: The station is located in about 10 km south from Lincoln Bay, 13 km north from Depoe Bay, and at the US101 Boiler Bay wayside rest area.

(Describe general location; include airline distances to three towns or mapped features.)

Ownership: The station is on the property of Oregon State Department of Parks and Recreation.
(name, address, phone of landowner)

To Reach Narrative: To reach the station from the intersection of US routes 5 and 101 in Depoe Bay, go north on US 101 for 1 km to the south entrance of the Boiler Bay wayside. Bear left on entrance road for 0.4 km to the parking area on the left. Pack northwest inside fence for about 90 meters to end of fence and the station on the right.

(Leg-by-leg distances and directions from major road intersection to mark)

Monument Description and Measurements: The station is set into drill hole in bedrock, 7.6 m south from the north fence corner, 8.8 m east from the west fence corner, and 3.6 m southeast from the northwest end of the outcrop.

(Add at least three measurements to permanent, identifiable, nearby objects; and a description of the monument size, shape, height, etc.)

NOTE: - Include a pencil rubbing, sketch, or photographs of mark.

Described by: John Q. Surveyor Phone:(301)713-3194 e-mail: jqs@ordot.gov

Blank – Station Description/Recovery Form

NATIONAL GEODETIC SURVEY STATION DESCRIPTION / RECOVERY FORM

4-char ID: __________ Designation: ______________________________________

PID: _____________ Alias: ____

Country: (USA / ______) State: __________ County: ________________________

Latitude: N ____ ° ____ ' ______ " Longitude: W ____ ° ____ ' ______ " Elevation:________ (meter / ft)

Original Description (check one):	
❒ P	Preliminary (mark has not been set yet)
❒ D	A newly set mark
❒ R	A recovered mark
Established by: (NGS / CGS / Other:)	
Date: Chief of Party (initials):	

Recovery Description (check one):	
❒ F	Full description of a station *not* in the database
❒ T	Full description of a station *in* the database
❒ M	*Partial* description of a station in the database
Recovered by: (NGS / Other:)	
Date: Chief of Party (initials):	

Monument Stability (check one):	
❒ A	Of the most reliable nature; expected to hold well
❒ B	Will probably hold position and elevation well
❒ C	May hold well, but subject to ground movement
❒ D	Of questionable or unknown reliability

Recovery Condition (check one):	
❒ G	Recovered in good condition
❒ N	Not recovered or not found
❒ P	Poor, disturbed, or mutilated
❒ X	Surface mark known destroyed

Setting Information:	
Marker Type: (Rod / Disk / Other)	
Setting Type: (Bedrock / Concrete / Other:)	
Y / N / ?	Monument contains magnetic material?

Stamping:	
Agency Inscription: (NGS / CGS / Other:)	
Rod Depth: (m/ft)	Sleeve Depth: (m/ft)
Monument is: (flush / projecting / recessed) (cm/ft)	

Special Type (check all applicable):	
❒ F	Fault monitoring site
❒ T	Tidal Station
❒ --	Control Station: (FBN / CBN / Bench mark)
❒ --	Airport Control Station: (PACS / SACS)
Y /N	Mark is suitable for GPS use?

Transportation (check one):	
❒ C	Car
❒ P	Light truck (pickup, carry-all, etc.)
❒ X	Four-Wheel Drive Vehicle
❒__	Other (SnowCat, Plane, Boat; describe)
Y /N	Pack Time (hike) to mark? (hh:mm):

See Back of Form to add Text Description

General Station Location: The station is located in ______________________________

____

____

____

____

______________________________(Describe general location; include airline distances to three towns or mapped features.)

Ownership: ____

____(name, address, phone of landowner)

To Reach Narrative: To reach the station from the intersection of ______________________

____

____

____

____

____

______________________________________(Leg-by-leg distances and directions from major road intersection to mark)

Monument Description and Measurements: The station is ______________________

____

____

____

____

____

____

____

________ (Add at least three measurements to permanent, identifiable, nearby objects; and a description of the monument size, shape, height, etc.)

NOTE: - Include a pencil rubbing, sketch, or photographs of mark.

Described by:____________________ Phone:(_____)_____________ e-mail:_____________

Appendix F

DIGITAL GEODETIC LEVELING – BACKUP RECORDING SHEET

LINE	PROJECT	FILENAME	PAGE
L-			of

SURVEY ORDER	SURVEY CLASS	TIME ZONE CODE	TEMP PROBE TOP HGT	TEMP PROBE BOTTOM HGT
			1.3 m	0.3 m

CODE 1 – BEGINNING OF DAY OR CHANGE IN OBSERVER / EQUIPMENT

INFO 1 DATE(MMDDYY)	**INFO 2** OBSERVER #	OBSERVER INITIALS	**INFO 3** INST TYPE	**INFO 4** TEMP CODE

CODE 2 – EQUIPMENT USED

INFO 1 INST SERIAL #	**INFO 2** COLLIMATION "	ROD CODE	**INFO 3** ROD 1 S/N	**INFO 4** ROD 2 S/N

CODE 11 – BEGINNING SECTION INFORMATION

SPSN #	BENCH MARK STAMPING	**INFO 1** TIME (HHMM)	**INFO 2** ROD / MK	**INFO 3** TEMP	DIR F / B

CODE 99 – ENDING SECTION INFORMATION

SPSN #	BENCH MARK STAMPING	**INFO 1** TIME (HHMM)	**INFO 2** ROD/ MK	**INFO 3** TEMP	**INFO 4** W / S

SECTION OBSERVATION INFORMATION

TOTAL SETUPS	TOTAL DISTANCE KM	ACCUMULATED M	ELEV DIFFERENCE M

	CLOSURE	REMARKS
F		
B		
DIF		
ALW'D		

TIME ZONE CODES

Q = UTC-4 HOURS =EDT
R = UTC-5 HOURS =EST, CDT
S = UTC-6 HOURS =CST, MDT
T = UTC-7 HOURS =MST, PDT
U = UTC-8 HOURS =PST

TEMPERATURE CODE

0 = CELCIUS; 1 = FARENHEIGHT

OTHER INFORMATION CODES

CODE 33 – GRADIENT TEMPERATURE
INFO 1 = BOTTOM PROBE TEMP; INFO 2 = TOP PROBE TEMP
(NO DECIMAL PLACE; 288 FOR 28.8 C)

CODE 9999 – END OF DAY, CHANGE OF OBSERVER OR EQUIPMENT
ALL BLANK – NO INFO ENTRIES

MAX SECTION MISCLOSURE (MM)

1,1 = 3√D; 1,2 = 4√D; 2,1 = 6√D; 2,2 = 8√D; 3 = 12√D (D = KM DISTANCE)

WIND AND SUN INFORMATION

WIND – (0) CALM (1) BREEZY (2) WINDY
SUN – (0) OVERCAST (1) PARTLY SUNNY (2) SUNNY

NOTES: IDENTIFY POSITIVE OR NEGATIVE (+ OR -) FOR ACCUMULATED IMBALANCES AND ELEVATION DIFFERENCES

PERSONNEL
OBSERVER: ______________________________

ROD 1: ______________________________

ROD 2: ______________________________

Appendix G

ADJUSTING THE LEVELING BUBBLES (TOPCON DL-101 AND BAR-CODE RODS)
TOPCON DL-101 LEVEL BUBBLE

Although the DL-101 is a self-leveling instrument, the leveling bull's-eye bubble should be kept in good adjustment to assure the working range of the compensator is maintained. If the range is exceeded, the error message "Cmpe Err" will appear in the display of the DL-101.

To adjust the bubble, center it in the circle and then reverse the instrument 180 degrees. If it stays in the circle, it is good for that axis. Next, rotate the level 90 degrees and check it. If the bubble is in good adjustment, it should stay in the circle when the level is rotated a full 360 degrees.

To adjust the bubble, level it in one axis, then rotate 180 degrees. Using the small adjusting pin included with the level, turn the screw or screws on the bottom of the instrument case that align with the axis until half the amount the bubble is out is removed. Re-level the instrument and rotate 180 degrees. If ok, check the axis at 90 degrees. Keep adjusting until the bubble stays in the circle regardless of where the level is turned.

BAR-CODE RODS LEVELING BUBBLES

Adjusting the leveling bubbles on the rods can be accomplished most easily by the following method. See diagrams on the following page.

Step 1. Setup the rod and center the bubble in the bubble circle. Set up the DL-101 at a distance from the rod where most of the rod is in the field of view. Level the DL-101.

Step 2. Using the level tangent knob, align the vertical crosshair along the left or right side edge of the rod or invar strip. If the rod is level (plumb), the vertical crosshair and the edge of the rod or invar strip should be in aligned and parallel throughout the vertical length of the rod.

Step 3. If the vertical crosshair and the edge of the rod are not in parallel alignment, have the rod-person adjust the rod until it is in alignment. The rod bubble will most likely be no longer centered.

Step 4. Using an adjusting pin, have the rod-person turn the screw or screws beneath the bubble until the bubble is centered in the circle and the rod is still aligned with the vertical crosshair of the level.

Step 5. Next, have the rod-person turn or rotate the rod 90 degrees to the DL-101 and center the bubble with the brace poles. Check the vertical crosshair alignment with the edge of the rod casing.

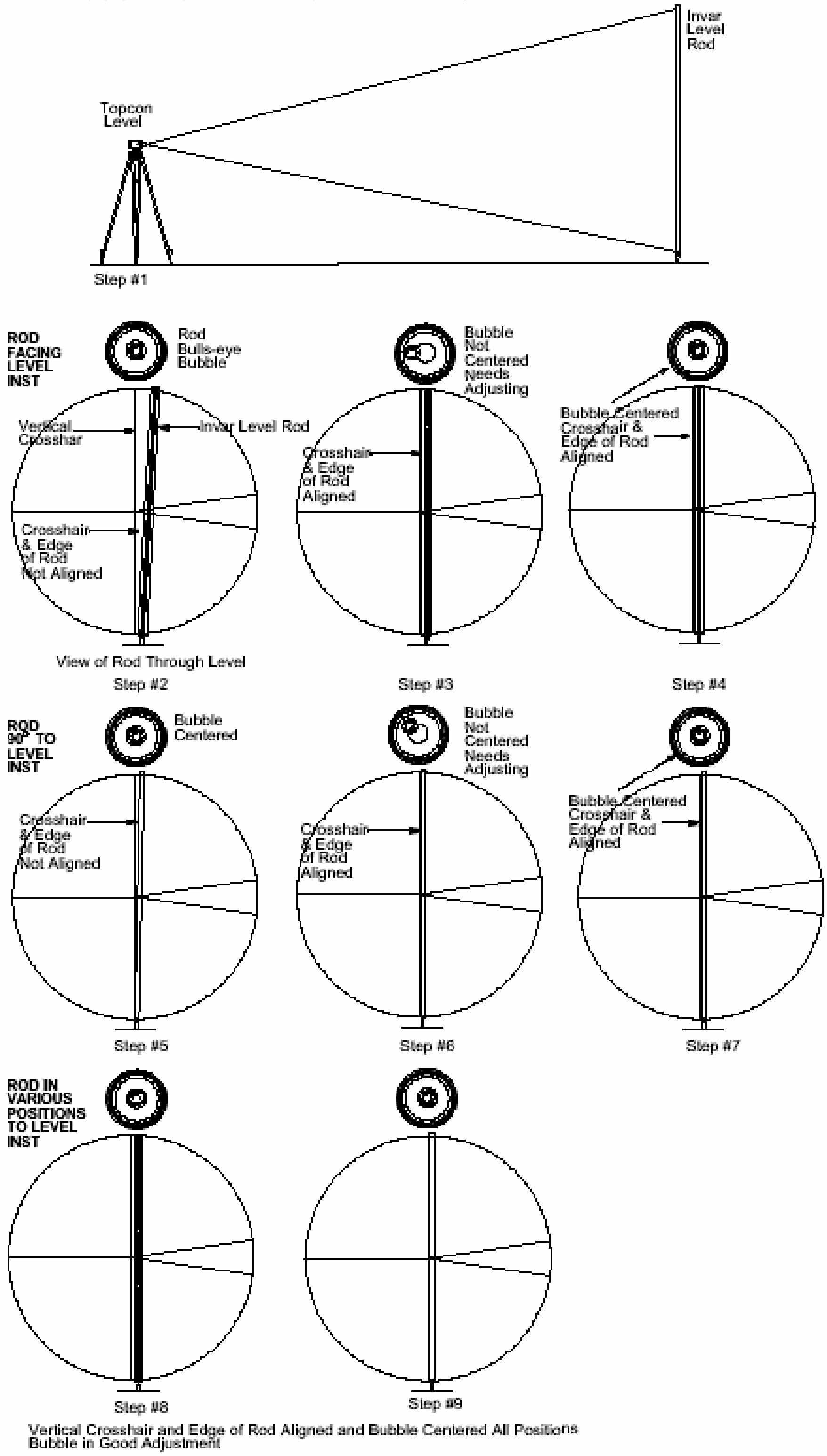
Step 6. If the edge of the rod is not in alignment, have the rod-person adjust the rod until it is in alignment. The rod bubble will most likely be no longer centered.

Step 7. Using an adjusting pin, have the rod-person turn the screw or screws beneath the bubble until the bubble is centered in the circle and the rod is still in alignment with the vertical crosshair of the level.

Steps 8 & 9. Keep rotating and checking the rod until it stays vertical aligned in all positions and the bubble is always centered.
Bear in mind that because the location of contact point between the rod's footplate and the turning pin is generally not perfectly centered below the rotation point where the brace poles are attached, the rod may go out of plumb when reversed or rotated. It is important to always re-level the rod after turning it. When turning a rod resting on a turtle, care must be taken not to disturb the turtle.

Check the bubbles, at least once a week, or whenever the instrument or rods are banged or dropped.

ADJUSTING INVAR ROD LEVELING BUBBLES



Appendix H

<u>Note</u>: CASE 3 Pretains to Digital Leveling Data Processing Procedure

Online documentation/software available via internet:

"Blue Book" –
http://www.ngs.noaa.gov/FGCS/BlueBook/

DOS-based PCvOBS software –
ftp://ftp.ngs.noaa.gov/pub/pcsoft/pcvobs/

DOS-based VFPROC software –
ftp://ftp.ngs.noaa.gov/pub/pcsoft/vfproc/

DOS-based na2vbbk software –
ftp://ftp.ngs.noaa.gov/pub/pcsoft/na2vbbk/

Please note that the old description format is being phased out as of December 31, 2001. If WDDPROC is used to key descriptions, be sure that program WCHKDESC is run on the final .DSC file and that its output message file is "ERROR"-free. "WARNING" messages are acceptable, but please review them to see if they can be resolved.

New D-FILE descriptions software
(e.g., WDDPROC, WINNEWABS) –
http://www.ngs.noaa.gov/PC_PROD/DDPROC4.XX/ddproc.index.html

If your State has an NGS Advisor, please coordinate your leveling project with him or her. For example, after initial reconnaissance, send your leveling project plan to him or her for pre-approval. See online State Geodetic Advisor/State Geodetic Coordinator information at: http://www.ngs.noaa.gov/ADVISORS/AdvisorsIndex.shtml

For L-Number (Accession Number) requests, please contact:
Sharon Faber
Phone: (301)-713-3184, extension 118
Fax: (301)-713-4327
Email: Sharon.Faber@noaa.gov

The data that are required for a project's submittal to NGS are dependent upon the hardware and/or software you use to collect and process leveling data in the field. See CASES below.

<u>CASE 1</u>:
For leveling observations recorded using an MCV data logger and the DOS-based VFPROC programs VERREC/NEWREC…

a. Please send the following data on a diskette or CD:

REQUIRED –
Binary .HA files (created by old DOS program DESC before 01/01/2002)
-OR-
ASCII .DSC files (created in new D-FILE format with WDDPROC software)

Binary .HGF files (created by VFPROC program VERREC and used as input to program NEWREC)

ASCII .RPT files (created by VFPROC program NEWREC)

Binary .HGZ files (created with program PCvOBS and modified using VFPROC programs MAKEFILE and ABSTRA –OR- WINNEWABS)

ASCII .ABS files (created by VFPROC program ABSTRA -OR- WINNEWABS)

OPTIONAL –
ASCII INST.DAT file
Binary .ROD files
ASCII .INX file (description index output by VFPROC program COMPRESS -OR- WDDPROC program WDESC)

b. Hard copy data:

REQUIRED –
Rod calibration documents
(if leveling rods were purchased or recalibrated since last leveling data were submitted to NGS)

OPTIONAL, but RECOMMENDED –
Release letter, including general information such as:

1. Unusual occurrences during observations, explanations of warning messages still existing in .RPT or .ABS files, or problems encountered during any analysis and/or preliminary field adjustment.
2. What datum (27 or 83) was used for latitudes/longitudes keyed into the binary (.HA) descriptions, if any. If both datums were used, please explain further.
3. Whether level collimation is internally applied or not, if a digital level was used.
4. The beginning and ending dates that should be entered on the **10** record of the VERT OBS-type files (.HGF, .HGZ) after running READFILE.

OPTIONAL, if available –
Network diagrams.
Analysis information such as loop misclosure sketches, new-minus-old comparisons.
USGS topographic quad maps with new marks plotted thereon.

CASE 2:

For leveling observations recorded with a digital level instrument following Charles Whalen's procedures AND processed with his NABOOK or DIBOOK/DINI10 software (supplemented with NGS's VFPROC programs MAKEFILE and ABSTRA -OR- WINNEWABS)…

Contact information for Charles Whalen:
Phone: (301)-774-2498
Email: chaswhalen@erols.com

a. Please send the following data on a diskette or CD:

REQUIRED –
Binary .HA files (created by old DOS program DESC before 01/01/2002)
-OR-
ASCII .DSC files (created in new D-FILE format with WDDPROC software)

ASCII .DAT files – AFTER editing (used as input to program NABOOK or DIBOOK/DINI10)

ASCII .BOK files (created by program NABOOK or DIBOOK/DINI10)

ASCII NA.DO file
ASCII HEADER.BLU file

Binary .HGZ files (initially created with program NABOOK or DIBOOK/DINI10 and processed through VFPROC programs MAKEFILE and ABSTRA –OR- WINNEWABS)

ASCII .ABS files (created by VFPROC program ABSTRA –OR- WINNEWABS)

OPTIONAL –
ASCII INST.DAT file
Binary .ROD files
ASCII .INX file (description index output by VFPROC program COMPRESS -OR- WDDPROC program WDESC)

b. Hard copy data:

REQUIRED –
Rod calibration documents
(if leveling rods were purchased or recalibrated since last leveling data were submitted to NGS)

OPTIONAL, but RECOMMENDED –

Release letter, including general information such as:

1. unusual occurrences during observations, explanations of warning messages still existing in .RPT or .ABS files, or problems encountered during any analysis and/or preliminary field adjustment.
2. what datum (27 or 83) was used for latitudes/longitudes keyed into the binary (.HA) descriptions, if any. If both datums were used, please explain further.
3. whether level collimation is internally applied or not, if a digital level was used.
4. the beginning and ending dates that should be entered on the **10** record of the VERT OBS-type files (.HGF, .HGZ) after running READFILE.

OPTIONAL, if available –
Network diagrams.
Analysis information such as loop misclosure sketches, new-minus-old comparisons.
USGS topographic quad maps with new marks plotted thereon.

<u>CASE 3</u>:

For leveling observations recorded with a LEICA (NA2000 or NA3000-type) digital level instrument using its internal software AND processed though NGS's program na2vbbk
(supplemented with NGS's VFPROC programs MAKEFILE and ABSTRA -OR- WINNEWABS)…

a. Please send the following data on a diskette or CD:

REQUIRED –
Binary .HA files (created by old DOS program DESC before 01/01/2002)
-OR-
ASCII .DSC files (created in new D-FILE format with WDDPROC software)

ASCII .DAT edited files (used as input to program na2vbbk)
NOTE: Please list in your release letter the na2vbbk command options you used. Specify Observation Type (2 = BF; 4 = BFFB), Weather System (WS = Wind/Sun or SW = Sun/Wind), and Temperature Scale C = Celsius or F = Fahrenheit).

ASCII .RPT files (field book created by program na2vbbk)

Binary .HGZ files (initially created in ASCII format with program na2vbbk, edited by submitter (e.g., instrument/probe heights added, time zone codes added, observer numbers converted, file header and ending records added), and then processed through VFPROC programs MAKEFILE and ABSTRA –OR- WINNEWABS)

ASCII .ABS files (created by VFPROC program ABSTRA -OR- WINNEWABS)

OPTIONAL –
ASCII INST.DAT file
Binary .ROD files
ASCII .INX file (description index output by VFPROC program COMPRESS -OR- WDDPROC program WDESC)

b. Hard copy data:

REQUIRED –
Rod calibration documents
(if leveling rods were purchased or recalibrated since last leveling data were submitted to NGS)

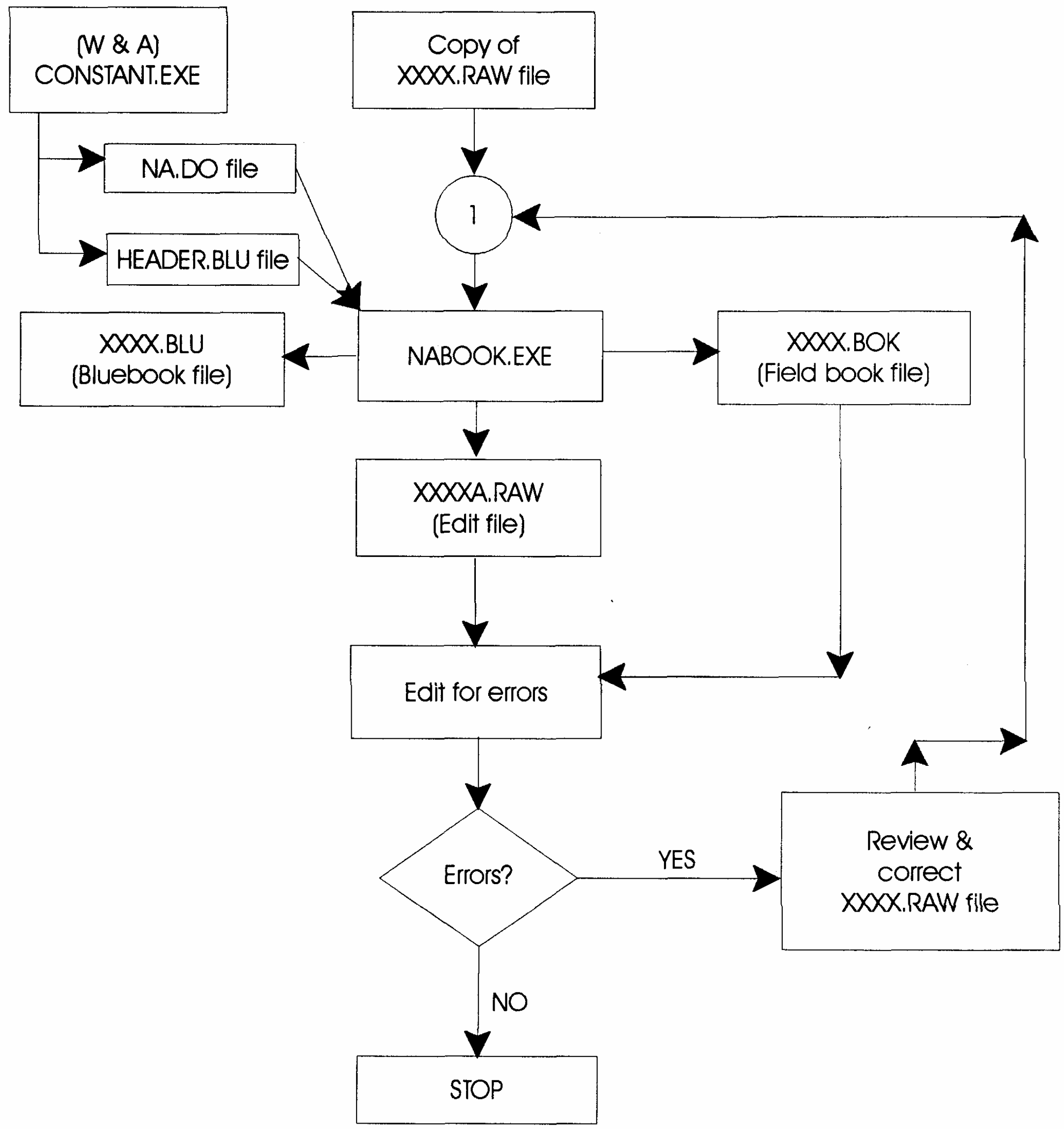
OPTIONAL, but RECOMMENDED –
Release letter, including general information such as:

1. Unusual occurrences during observations, explanations of warning messages still existing in .RPT or .ABS files, or problems encountered during any analysis and/or preliminary field adjustment.
2. What datum (27 or 83) was used for latitudes/longitudes keyed into the binary (.HA) descriptions, if any. If both datums were used, please explain further.
3. Whether level collimation is internally applied or not, if a digital level was used.
4. The beginning and ending dates that should be entered on the **10** record of the VERT OBS-type files (.HGF, .HGZ) after running READFILE.

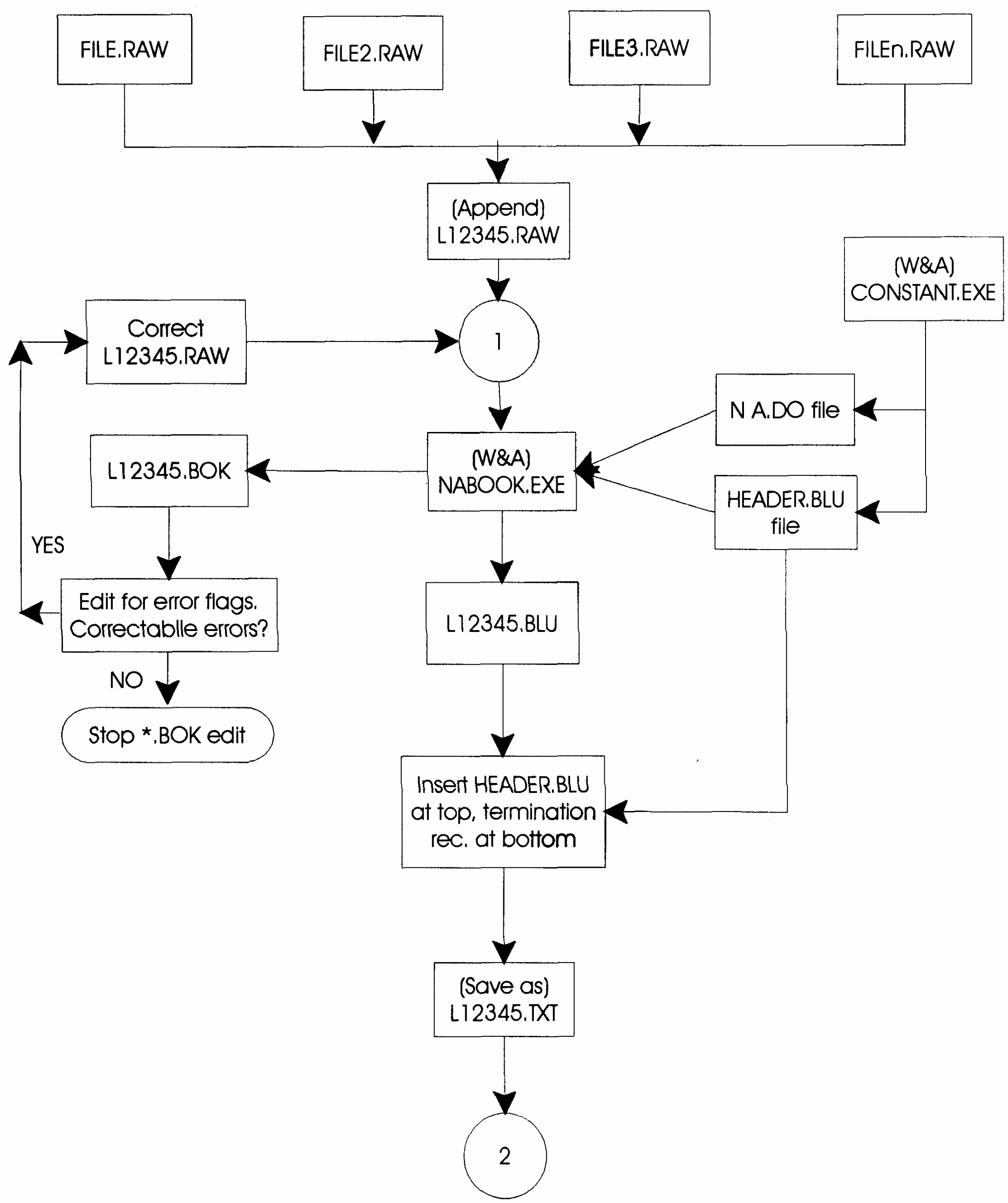
OPTIONAL, if available –
Network diagrams.
Analysis information such as loop misclosure sketches, new-minus-old comparisons.
USGS topographic quad maps with new marks plotted thereon.

Appendix I

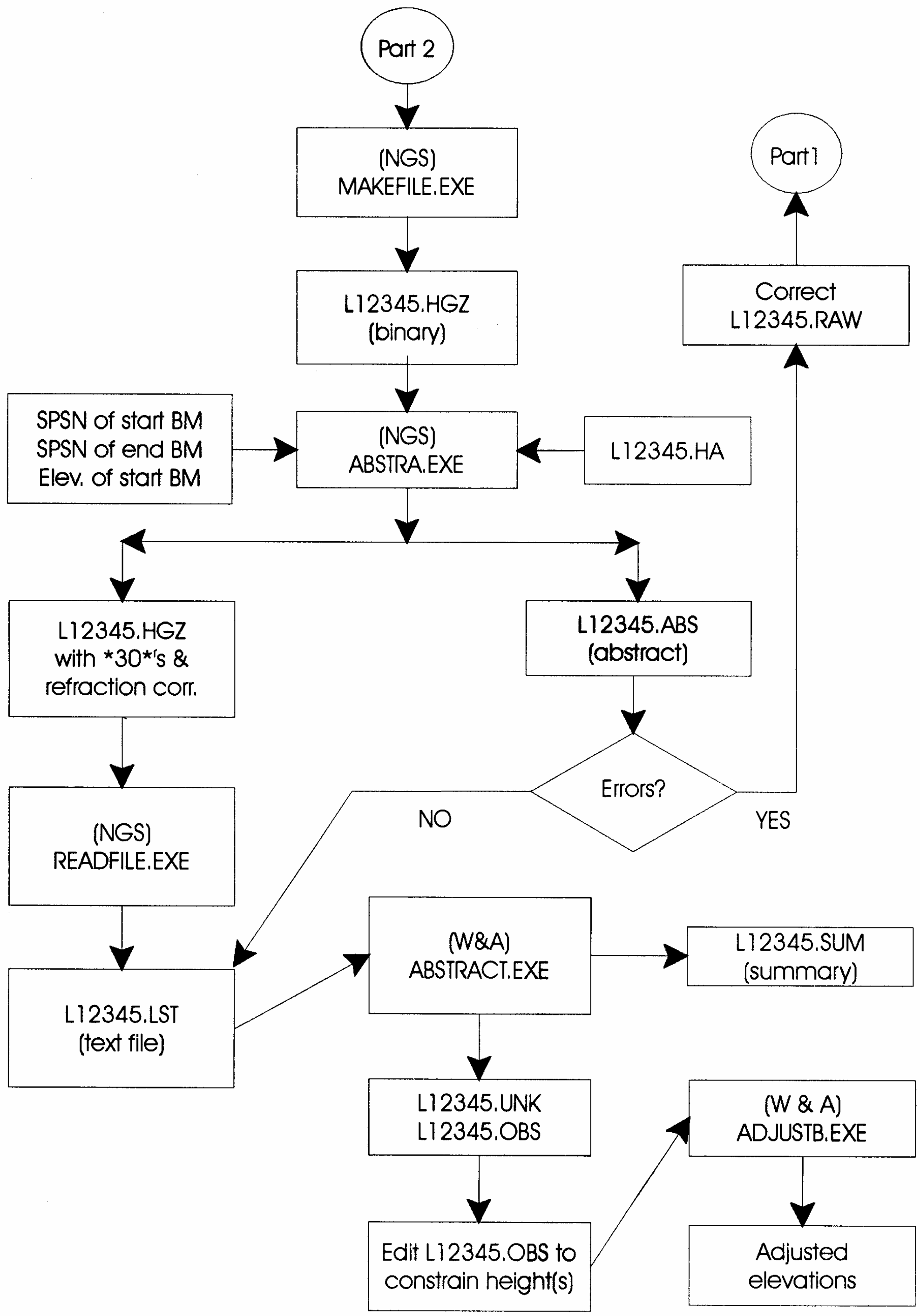
DAILY PROCESSING OF NA2000/3000 DATA FROM THE FIELD



PROCESSING NA2000/3000 DATA BY LINE OR PART OF SURVEY, PART 1



PROCESSING NA2000/3000 DATA BY LINE OR PART OF SURVEY, PART 2



Glossary

Basic Geodetic Leveling Glossary

Available on-line at:
http://www.ngs.noaa.gov/CORS-Proxy/cocoon/glossary/NGS_Glossary.xml

Geodetic Leveling

(1) Leveling to a high order of accuracy, usually extended over large areas, to furnish accurate vertical control for surveying and mapping.
(2) The same as definition (1), but with the provision that systematic errors in the leveling are reduced to tolerable limits by applying corrections to the measurements during reduction of the data.

Precise Leveling

(1) A particular category of leveling.
(2) Leveling done with careful and frequent adjustment and calibration of the instruments used.

Leveling Network

A collection of level lines connected together to form a network of loops or circuits extending over a region. Also called a vertical control network, a vertical network, or a level network.

Leveling Line

A unit of field work consisting of bench marks and temporary bench marks connected by chains of differential leveling.

Level Line

A set of measured differences of elevation, presented in the order of their measurement, and the similarly ordered set of points to which the measurements refer. It is also customary to refer, loosely, to either the set of points or the set of measured differences as a level line. The meaning intended by such use must be ascertained by context.

Level Loop

A closed circuit of measured differences of elevation between connected bench marks that form a chain starting and ending on the same point.

Section

(1) The portion of a level-line that is recorded and abstracted as a unit, and constitutes a self-consistent and self-sufficient set of measurements of differences of elevation. A section always begins and ends on either a temporary or permanent bench mark, whether the mark is part of the main level-line or is on a spur from a level-line. In the case of a spur to a point whose elevation is determined by taking an additional foresight, the section must begin on a

temporary or permanent bench mark and end at the point on which the leveling rod was held when the additional foresight was taken. (2) The segment of a leveling line consisting of two neighboring markers connected by a *running*.

Single-Run Leveling

Leveling done by proceeding from the starting point to the final point of a level line without leveling back to the starting point

Double-Run Leveling

Leveling done by proceeding from starting point to final point and then returning to the starting point in the opposite direction. Usually, the same general route is taken on returning as on going out, and points occupied in the morning on the forward part of the journey are occupied in the afternoon on the returning part. This and other precautions are intended either to cancel or to identify systematic errors as well as to reduce random errors.

Spur Line

(1) A level line that is connected to a leveling network but is neither part of the principal leveling network nor is it part of a loop.
(2) A level line run as a branch from the main level line, either to determine the elevations of bench marks not conveniently reached by the main level line or to connect with tidal or other previously established bench marks. The spur is used for obtaining checks on old leveling either at the beginning or end of a line of levels or at intermediate junctions along the new line of levels.
A branching level line that is run from a bench mark on a spur line is called a double-spur line or a double-spur. Similarly, a branching level line that is run from a bench mark on a double-spur line is called a triple-spur line, and so on.

Invar Leveling Rod

A leveling rod having the graduations marked on a strip of invar. The strip is set into the face of the rod, firmly attached to the rod shoe at the bottom of the rod, and held in place by guides and a spring at the top of the rod. Invar leveling rods are used in first-order leveling.

Leveling Unit

A surveying team consisting of the smallest number of people ordinarily needed for leveling. A leveling unit consists of at least three people--an observer and two rodmen. Normally a recorder also goes along with the unit. The National Geodetic Survey has added a fifth person to the leveling unit to pace off the distances from rearward leveling rod to leveling instrument to forward leveling rod. A person whose duty it was to hold an umbrella over the instrument was formerly a standard part of the complement. Also called observing team, observing crew, observing unit, and level unit (jargon). The term "party" is used by the U.S. National Geodetic Survey for a group of leveling units, but "leveling party" is also commonly used synonymously with leveling unit.

Leveling Adjustment

Determining corrections to measured elevations, or differences between elevations, of points in a leveling network so that the resulting elevations or differences in elevations are the best obtainable under the given conditions of observation. The adjustment removes the inconsistencies in a network that result from accumulation of small random and systematic errors.

Orthometric Correction

The quantity added to an observed difference of elevation to correct for the error introduced when level surfaces at different elevations are not parallel. Usually called orthometric correction.

Rod Correction

The quantity added to an observed difference of elevation to correct for the error introduced when the intervals on the leveling rods are not actually of the length indicated by the numbers on the graduations. Usually called a rod correction. It is traditionally used as a correction to scale.

Temperature Correction

The quantity added to an observed difference of elevation to correct for the error introduced when the leveling rods are used at a temperature different from the temperature at which they were calibrated. Usually called a temperature correction.

Collimation Factor

(1) The factor $c*$ or c in Mayer's or Bessel's formula. It is also called the *collimation error* and is equal to the angle between the optical axis of a telescope and a vertical plane through north.
(2) The tangent of the *level collimation error*. The term is used in this sense by Schomaker and Berry (1981) who refer to it also as "C" or "C-factor". The relation between it and the collimation correction factor is given by

$$C_R = C_{SB}\,\beta$$

where C_R is C (collimation correction factor) as defined in Rappleye (1948), C_{SB} is the collimation factor as defined above, and β is the *stadia factor*.

Collimation Correction Factor

The quantity $C = -[(H^b - H^f)_1 - (H^b - H^f)_2] / [(I^b - I^f)_1 - (I^b - I^f)_2]$.
In this formula, H is a height read on a leveling rod, I is the corresponding stadia intercept; superscripts b and f denote the backward and forward leveling rods, respectively; and subscripts 1 and 2 denote positions 1 and 2 of the leveling instrument with respect to the leveling rods. In position 1, the leveling instrument is about 10 m from the backward leveling rod and about 50 m from the forward leveling rod; in position 2, the leveling instrument has been moved forward to within 10 m of the forward leveling rod and so is about 50 m from the backward leveling rod. The collimation correction factor, multiplied by the ratio of *stadia intercept* to horizontal distance (or divided by the *stadia factor*) gives the tangent

of the angle from the line of sight in the *leveling instrument* to the horizontal plane, and is approximately the correction needed to make the line of sight horizontal. Also called the level constant and the C-factor.

Collimation Error

The angle between the actual *line of sight* in an optical instrument and the position the line of sight would have in a perfect instrument. There are several different interpretations of this definition.
The angle between the actual line of sight and a line through the second (rear) nodal point of the objective and perpendicular to the axis of rotation. This interpretation, commonly accepted in surveying, is applied to theodolites, meridian instruments, transits, and levels, and is synonymous with error of collimation.

Level Collimation Error

The angle from a horizontal plane to the line of collimation of a telescope when all leveling devices indicate that the line of collimation should be level. The angle is considered positive upwards. Also referred to as collimation error.

Circular Level

A spirit level in which the inner surface of its upper part is ground to spherical shape. The outline of the bubble formed in such a level is circular, and the graduations are concentric circles. This form of spirit level is used where precision is not critical, such as for plumbing a level rod or for setting an instrument in approximate position. Also called universal level or bull's-eye level.

Hand Level

A small *leveling instrument,* designed to be held in the hand, in which the spirit level is so mounted that the observer can see the bubble at the same time that he observes an object through a telescope. The bubble is viewed by means of a prism or mirror in the telescope. The instrument is used in reconnaissance for surveys, in taking cross sections and in other work where great precision or accuracy is not required.

References

NOAA Manual NOS NGS 1, *Geodetic Bench Marks*, by Floyd, Richard P., September 1978, 50 p., available on-line at http://www.ngs.noaa.gov/PUBS_LIB/pub_index.html.

NOAA Manual NOS NGS 3, *Geodetic Leveling*, by Schomaker, M. Christine and Berry, Ralph Moore, August 1981, 209 p., National Geodetic Information Branch, N/NGS12, SSMC3 Room 9202, National Geodetic Survey, NOAA, Silver Spring, MD 20910.

NOAA Technical Memorandum NOS NGS 34, *Corrections Applied by the National Geodetic Survey to precise Leveling Observations*, by Balazs, Emery I. and Young, Gary M., June 1982, 12 p., National Geodetic Information Branch, N/NGS12, SSMC3 Room 9202, National Geodetic Survey, NOAA, Silver Spring, MD 20910.

FGCS Publication, *Input Formats and Specifications of the National Geodetic Survey Data Base*, Volume II, Vertical Control Data, September 1994, 46 p., available on-line at http://www.ngs.noaa.gov/PUBS_LIB/pub_index.html.

FGCS Publication, *FGCS Specifications and Procedures to Incorporate Electronic Digital/Bar-Code Leveling Systems*, Version 4.0 July 15, 1994, 6 p., available on-line at http://www.ngs.noaa.gov/PUBS_LIB/pub_index.html.

NOAA Geodetic Publication, *Geodetic Glossary*, by National Geodetic Survey, September 1986, 274 p., available on-line at http://www.ngs.noaa.gov/CORS-Proxy/cocoon/glossary/NGS_Glossary.xml.