GUIDELINES FOR INSTALLATION OF BACKBONE SURVEY MONUMENTS ON NPS LANDS

Introduction and Background

The University of Rhode Island and the National Park Service have partnered to create a network of stable and permanent survey monuments in ten coastal parks in the northeastern U.S. (Figure 1). This effort is part of a larger project to assess risk from sea level rise and storm surge at these coastal parks utilizing high accuracy geodetic control (August et al., 2010). These monuments (hereafter referred to as backbone monuments) would serve as reference points on the landscape from which to measure elevation typically using geodetic GPS or survey equipment (see NPS, 2011). The most accurate method of determining the elevation of critical natural or cultural resources is by on-the-ground measurement using GPS or other survey equipment (NOAA, 2010).

This document covers the installation of two types backbone monuments: brass disks affixed to a solid substrate (typically a concrete pad or bedrock outcrop) and steel rods driven to depth into the ground (Figures 2 and 3). Concrete pillar monument installation procedures can be found in NOAA, 2011 and Smith, 2010. This document is intended to be a primer in monument installation for managers and practitioners. We highly recommend that after reading this introduction, practitioners carefully read NOAA, 2011; Smith, 2010; and Floyd, 1978 for additional background information, details, and in-depth discussions of the subject. Procedures documented here are adapted primarily from Smith, 2010 and Bernsten.com.

Site Selection

Steps that need to be considered before the installation of a new monument include: research and field verification of existing monuments, gap analysis, and an evaluation of survey or project requirements (NOAA, 2011). Before installation of a backbone monument, utilize existing data and information to verify a new monument is necessary. The most robust and up-to-date database of monuments (also known as survey markers or benchmarks) is managed and maintained by the National Geodetic Survey (NGS). This database of over 700,000 monuments along with continuously operating GPS base stations are the backbone of the National Spatial Reference System (NSRS) (www.geodesy.noaa.gov). Other agencies including the NPS – Lands Office and U.S. Army Corps of Engineers may also have information and data on existing monuments. Locally, state department of transportation offices may also be an excellent resource of local monuments. Another great resource we discovered for field-verification of existing monuments is the geo-caching community. Many geo-cachers post their findings on www.geocaching.com. Additionally, DSWorld, a Google-based software package can be downloaded from www.geodesy.noaa.gov for a comprehensive all-in-one package of recent geocaching findings and recent additions to the NGS benchmark database.
The main function of a backbone monument is to serve as a known location for a kinematic GPS survey (see Henning, 2011). There are many considerations for the field-identification of a site suitable for monument installation (NOAA, 2011; Smith, 2010, and Floyd, 1978), but the primary factors for either a brass disk installation or a deep steel rod monument are (in no particular order):

1. topographically high (above predicted storm surge) and sufficient to support a tripod with a GPS receiver
2. clear view of the sky (e.g., minimal trees, buildings, topography, or other obstructions that might cause multipath of the GPS signal)
3. no above ground utility lines immediately overhead that might interfere with GPS signals
4. on approved National Park Service property
5. relatively secure and safe location

Supplies, Equipment, and Tools

There are extensive lists of supplies found in NOAA, 2011 and Smith, 2010. Comprehensive lists of supplies, equipment, and tools are difficult because of slight variations during installation procedures, site conditions, and personal preferences. However, minimal supplies are shown in figures 4 and 5.

There are many places on the Internet where supplies can be found (www.surv-kap.com, www.stakemill.com, www.forestry-suppliers.com, www.benmeadows.com and www.survey-marker.com) however we found most of what we needed at www.bernsten.com. By searching on part numbers or keywords (given in parenthesis) at Bernsten.com in the steps below, more details, part photos, and specifications on parts can be found.

Monument Installation Steps

Survey disk set in bedrock or concrete (adapted from Smith, 2010)

1. **Stamp station identification on brass disk.** The disk (or survey marker) we chose (RT35DB) was one that is designed specifically for setting in a drill hole with concrete (as opposed to a disk that sits on re-bar or other post). When purchasing, specify a pre-stamped brass disk with datum point and agency name. A unique station ID can be stamped on the disk after installation.

2. **Select a site to drill a hole.** Bedrock is the best substrate, but concrete from abandoned infrastructure (i.e., foundations of old buildings, radio towers, and aircraft landing strips) should be stable as well (Smith, 2010). Avoid concrete that is excessively cracked or crumbling or looks like it has moved due to soil moisture conditions (e.g., shrinking and swelling or frost heaves).

3. **Drill a hole.** Using eye and hearing protection, drill a hole using a hammer drill and masonry bit suitable for stone and concrete with a drill bit shank that is compatible with the drill’s
chuck (our drill used a SDS Plus shank designed for stone and concrete). We used a 36V cordless drill (Figure 6). We purchased an extra drill battery and an 800W power inverter connected to the car battery to re-charge drill batteries in remote locations. The size of the hole (as well as the size of the drill bits) will be determined by the brass disk that is purchased. If you purchase a disk with a flared stem (like RT35DB) you’ll need a drill bit that matches the max diameter of the flared stem. In our case, this was a 1 1/4 inch diameter masonry bit suitable for stone and concrete (Hitachi 728946). A new drill bit lasted through the installation of 4 brass monuments in granite before wearing out. The depth of the hole should be equal to the length of the disk stem (2 1/4 inches for the RT35DB) plus the depth to which the disk head will be countersunk (1/4 inch) for a total depth of 2 1/2 inches.

4. **Recess (countersink) the disk into the substrate.** Using eye and hearing protection and a hammer, chisel away enough rock or concrete so that disk is flush (even) or below the substrate (see Figures B-3 and B-4 from Smith, 2010) (Figure 7). It took us about ½ hour to countersink the RT35DB. There are drill bits that do this as well, and their use would be a time saver. However, we did not locate one that matched the diameter of the RT35DB (3 1/4 inches) and they can be very expensive.

5. **Flush the drilled hole with water to remove any debris from the hole.** Extract excess water with a turkey baster or blow out with compressed air. Clean the hole with a dry rag.

6. **Mix the hydraulic cement with water.** Using latex gloves, follow the manufacturers’ directions for mixing. It should be thick but workable. We used a quick setting (3-5 minutes) hydraulic cement used for filling cracks and preventing water seepage.

7. **Prepare the disk.** Clean and rinse the disk thoroughly to remove any dirt or grease. Turn the disk upside down and fill the stem or shank of the disk with cement and tap gently to remove any air bubbles. Also place cement on the underside of the disk.

8. **Setting the disk.** Fill the drill hole with cement and insert the cement-filled stem of the disk into the drilled hole. Rotate the disk back and forth with your fingers until the disk sets in place.

9. **Finishing.** With a damp rag, clean the excess cement around the edge of the disk but leave a slight overlap making sure that the edge of the disk is covered with smooth cement. Cement should fill any other voids in the rock or concrete pad that was left during chiseling.

10. **Clean up.** Leave the area as close to undisturbed as possible keeping in mind that the lime in cement can burn skin and kill vegetation if tools are rinsed and the water dumped on the ground.

**Steel Rod (adapted from Smith, 2010; and Bernsten.com)**

1. **Verify there are no buried utility lines at the site you plan to install rod.**
2. **Stamp an ID on the access cover (BMAC6).**
3. **Dig hole.** With a power auger (Figure 6), post hole digger, or spade and shovel, dig a round hole that is 12-14 inches in diameter and 42 inches deep (Smith, 2010, and Figure 9). Place a tarp or plastic cover on the ground and place spoil from hole on top of the tarp.
4. **Prepare the security sleeve (TSS3-Y).** Glue the endcaps with PVC cement on the security sleeve and fill with the contents of food grade grease cartridge (e.g., Belray no-tox clear grease 62250) dispensed from a grease gun (Figure 10.). The sleeve will fill with 1 complete cartridge of grease. Be careful as this can turn into a real mess. Wearing a pair of nitrile gloves, start at one end of the capped sleeve and form a tight seal around the cap and the flexible end of the grease gun with your hand. Have another person carefully pump grease into the sleeve. We found it helpful to gently tap the sleeve and to use forced gravity to distribute the grease evenly throughout the sleeve. After its filled, gently lay the sleeve on its side until it’s ready to be inserted over the installed rod.

5. **Prepare the 9/16” x 4’ rods (MSS91604).** Unscrew the threaded rod insert and clean off excess grease with a rag and solvent (e.g., denatured alcohol or acetone) and apply a generous amount of thread adhesive (LOCTITE) onto ½ of the threaded insert. Screw the insert ½ way into one of the rods. Apply thread adhesive to the exposed thread and screw on the other rod section, Lock a pair of vice-grips to each of the rod sections and tighten the two four foot section of steel rods together. All rods should be firmly tightened taking care not to break or strip the threads. At the bottom of the coupled rod section attach (using methods in this section 5) a drive point (MSS12).

6. **Driving the rods.** Hand place the rod from step 4 into the hole (drive point should be at the bottom) so that the rod is in center. Place a piece of plywood with a 9/16” hole in the middle over the top of rod and slide it down so that it rests on top of and covers the hole (Figure 8). Keeping the rod vertical, place a drive pin (M1DPA) on the top of the rod and using a sledge hammer and manual drive adapter (search on keywords ‘manual drive adapter’ at Bernsten.com), hammer the rod into the ground (Figure 11). Add additional rods as necessary. Make frequent checks for verticality with a bubble level (9-inch magnetic torpedo level) while driving and after each rod is attached. Move plywood as necessary to maintain vertical.

7. **Adding rods.** Once manual driving with a sledge hammer becomes too difficult (typically after 2 rods depending on soil type), lock the power driving adapter (search on keyword ‘PDAP’ at Bernsten.com) into the chuck of a gas powered jackhammer (Cobra Combi or similar – see Smith, 2010). Using a step ladder and help from another person(s), lift and guide the jackhammer onto the top of the rod. Start the power jackhammer and drive rod into the ground (Figure 12) adjusting throttle as necessary. Drive rods until prescribed depth is reached (see Smith, 2010; Floyd, 1978; and Bernsten.com for discussion and guidance). We also purchased a backpack carrier for the jackhammer (9238 2814 10) which is very useful when installing in remote locations.

8. **Finishing the datum point.** There are a couple of different options for finishing the datum point. The NGS (Smith, 2010) recommends cutting the steel rod and rounding smooth the top with a grinding machine (Figure 13). A punch hole (dimple) is then punched in the top to provide a centering point. We chose the Bersten.com method whereby the rod is driven 5 inches below the surface of the ground and using epoxy, a datum point (MSSDP1) is attached and firmly tightened with vice-grips to the top of the rod. If a drive pin is used during rod installation, the integrity of the top of the rod is mostly maintained (i.e. it is not
damaged or mushroomed by the jackhammer) then there is no need to cut the rod. If the rod was driven to substantial resistance (see Other Considerations section below), there might be some slight rounding of the top-edge of the rod (mushrooming). Using a metal file, file this edge smooth.

9. **Install the grease-filled sleeve.** Insert the greased sleeve over the top of the datum point until the sleeve is about 3 inches below the datum point. If the rod was driven to substantial resistance or refusal, you may encounter some resistance sliding the capped-sleeve over the datum point. Do not force the sleeve. Remove the sleeve and file the top-edge of the rod where the datum point is attached until smooth. The capped sleeve should slide over the datum point more easily after filing. Be prepared to wipe away excess grease from the end of the sleeve and datum point.

10. **Back-fill with clean sand.** Cover and tape sleeve and datum point with a plastic bag and using Figure 13 as a guide back-fill the hole with sand.

11. **Placing the logo cap and PVC pipe.** Using epoxy, glue the access cover (BMAC6) onto the top of a pre-cut 6” diameter 2 ft long PVC pipe. Place the cap and PVC pipe assembly over the datum point and sleeve making sure the datum point is centered and that the cap is at or near the surface of the ground (Figure 14). Fill the PVC pipe with clean (washed) sand to within 7” of the top of the PVC pipe or 1” from the top of the sleeve.

12. **Adding the concrete collar.** Mix concrete in a 5 gallon bucket. To keep the top of the access cover free of concrete, cover with a plastic grocery bag. Pour in the hole and around the PVC pipe about 1 inch from the ground surface (Figure 15). Remove grocery bag and tap and rotate access cap and PVC pipe assembly to remove any void or air bubbles that might have formed during the pouring of the concrete.

13. **Clean up.** Leave the site in the condition in which it was found. Dirt from the hole should be disposed of.

14. **Calculate GPS coordinates.** Using a handheld GPS device accurate to 1-3 meters, capture the coordinates of the monument for the purpose of navigating back to the site.

**Other Considerations**

1. **Rod depth and costs.** Rod stability is a vital consideration when installing this type of monument. The NGS recommends driving rods until the rate into the ground slows to one foot/minute with a 55-lb jack hammer (see Smith, 2010). This is known as ‘substantial resistance’. When installing these monuments in coastal areas with sandy Holocene deposits that in some cases may be many hundreds of feet thick, substantial resistance may not be reached until several hundred feet of rods have been used. And with a cost of about $6/foot (as of January, 2012) it could cost several thousand dollars for a monument in these coastal areas. For our project, we consulted with a state NGS advisor and determined that a depth of 80 feet (or substantial resistance whichever came first) would give us a mark that would be stable enough to withstand instability caused by freeze-thaw or other surficial factors.
2. **Permits and Paperwork.** Because the installation of these monuments involves some ground disturbance, you’ll need to fill out a Scientific Research and Collecting Permit (https://science.nature.nps.gov/research/ac/ResearchIndex).

3. **Wait 30 days before measuring location with a geodetic GPS to let concrete dry and monument to settle.**

References


Figure 1. There are ten coastal parks that are part of this study.
Figure 2. A steel rod monument driven to depth with a security sleeve.

Figure 3. A brass disk drilled into bedrock.
Figure 6. Drill a hole using a cordless hammer drill. A sharp drill bit and extra batteries are essential (video).

Figure 7. Using a hammer and a chisel, chip away at the substrate to recess the disk (video1, video2).
Figure 8. Using a power auger (pictured) or spade, dig a hole 42” deep.

Figure 9. The hole after it is finished.
Figure 10. Use a grease gun to fill the security sleeve.

Figure 11. The plywood helps stabilize the rod in the hole during manual and power driving.
Figure 12. Using a gas powered jackhammer, drive the rods into the ground (video).

Figure 13. If necessary, a portable band saw (A) can be used to cut the rod (B) if it has been driven to refusal. A portable power grinder (C) can then be used to round the datum point.
Figure 14. (from Smith, 2010; to convert cm to inches, multiply by 0.394). Diagram of rod installation.

Figure 15. Use a plastic bag to protect the access cover from the poured concrete.