PART TWO
OF TWO

Ch. 6 Navigation
Ch. 7 Rock
Ch. 8 Snow

LEADER'S REFERENCE BOOK

Leadership Training Program

For LTC SEMINAR
O Level CANDIDATES:
CHAPTER 6 is required reading.
CHAPTERS 7&8 are optional.

I Level CANDIDATES:
Ch. 6 is required.
Ch. 7&8 are *recommended*.

M& E Level CANDIDATES:
Ch. 6 is required.
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Leadership Training Committee
Angeles Chapter, Sierra Club

LEADERS REFERENCE BOOK CHAPTERS 6-8 from 18th EDITION, Revised, 2015.
Page numbering is from that edition.

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6

Navigation, Route Finding, and Trip Planning

Angeles Chapter trips are quite diverse activities, ranging from hikes on well-marked and mapped trails with excellent descriptions in written guides to exploratory cross-country adventures through difficult mountain and desert terrain. The range of planning and navigational skills required to conduct these trips safely is equally extensive.

For many leaders who plan outings in well-known and well-marked territory, some of the material in this chapter will be unnecessarily complicated. Yet the moment a party steps off a trail in unfamiliar terrain, a leader with confidence in his or her navigational knowledge and practical experience using navigational skills may be essential to reach the objective and return safely; such confidence and experience often mean going beyond the "basics." This chapter, therefore, goes beyond the specifics called out for navigation checkouts to include supplemental information to enlarge the scope of the leader candidate's knowledge of navigation techniques and lore.

Advanced planning and route finding techniques are not difficult to learn in theory, but it takes practice to become proficient under the stress of real-world situations.

- Leaders must be able to plan trips that can be done in a reasonably efficient and safe manner within the time available. Planning entails selection of the route, estimation of the time required, selection of necessary equipment, screening of group members for the necessary skills and physical condition, plus contemplation of unexpected events that might require time-consuming corrective measures and fall-back plans. All of these considerations have a direct or indirect impact on the navigation aspects of the trip.
- In the field the leader must navigate and "find" the route. The leader must know where the group is and where it is going and be able to select an appropriate route to get there. Besides knowing their location on the map or being able quickly to determine their location and correlate features on the map with the terrain, leaders should also have the skill and experience to select a good route from the outset and be able to change the route if necessary as the terrain unfolds.

MAPS

Big Picture Maps

Some maps produced by the Automobile Club of Southern California are invaluable aids for the automobile part of the trip. They are updated frequently and show unimproved roads, campgrounds, locked gates on roads, many major trails and peaks, and various points of interest. The Auto Club's county map series includes coverage of Southern California mountain ranges from the Mexican border to the northern boundaries of San Luis Obispo and Tulare Counties. The Auto Club has also developed excellent maps that provide detailed coverage of Yosemite and the Eastern Sierra, as well as of Death Valley, Indian Country, and the Colorado River.

The United States Geological Survey (USGS) 1:250,000 scale maps cover an area of one degree latitude by two degrees longitude at a scale of about one inch on the map to four miles on the ground. They are topographical maps and have more terrain detail than the Auto Club maps but have less reliable road information. They are very useful in those regions beyond the coverage of the Auto Club maps.

USGS 1:100,000 scale maps (30 x 60 minute series) are now available for most of the contiguous 48 states. These topographic maps have a scale of about one inch on the map to 1.5 miles on the ground. Since USGS is no longer updating or printing the 1:62,500 scale maps (15 x 15 minute series), the 30 x 60 minute series maps provide a useful tie-in or overview for the 1:24,000 scale maps (7.5 x 7.5 minute series).

United States Forest Service (USFS) maps are helpful supplements to other maps because they show trail numbers, campgrounds, private property, fire closure areas, logging roads, and the names of some terrain features not found on topographic maps. They may be obtained by writing the particular National Forest headquarters or by visiting a ranger station in that National Forest. Many outdoors and sports stores also carry these maps.

Topographic Maps

The principal map used by the leader for detailed planning and in the field is the USGS topographic (topo) map in the 7.5′ (minute) series, with a scale of 1:24,000 (one inch on the map represents 24,000 inches, or 2000 feet, in the field). The 7.5′ map series was launched in 1945 and completed in 1992. All of the contiguous 48 states are covered by the 7.5′ map series, which has replaced the older 15′ series once maintained and sold by the USGS. Each map covers a region of 7.5′ (1/8 degree) in latitude and longitude, called a quadrangle. (The area covered by the quadrangles in California is roughly 7 1/2 x 8 miles.) Each quadrangle map has a unique name taken from some prominent feature in it. National Park and National Forest Visitor Centers, specialty map shops, and outdoors stores usually carry frequently-used topo maps of the local areas they serve. The USGS web site is http://usgs.gov, and internet orders for USGS maps can be made at http://store.usgs.gov. At the USGS store web site, a "Map Locator and Downloader" is available. This will allow you to search for and download .pdf images of all 7.5′ topo maps.

USGS 7.5′ topo maps are less available in local outdoor stores than they were in the past, particularly for areas of California more remote from Los Angeles (e.g., the Sierra). Most REI stores in Southern California carry a small selection of local topographic maps. The USGS has created a new map series called "US Topo" to replace the 7.5′ map series. In 2012, the USGS released US Topo maps for every quadrangle in California. The new maps use the same names as the 7.5′ minute map series and cover the same area with slight marginal differences caused by use of the North American Datum of 1983. (Most maps in the 7.5′ map series use the North American Datum of 1927.) The new US Topo maps can be downloaded for free on the USGS web site. Printed versions are available from the USGS for $15.00.

The US Topo map series is produced using automated and semi-automated processes and cost substantially less to produce than the handcrafted 7.5′ map series. These new digital maps are considered the "next generation" of USGS map products. The 7.5′ map series will no longer be updated.

The 2012 release of US Topo does not have the same detail of the 7.5′ map series. Future releases may address some of these shortcomings, with the next release scheduled for 2015. Significant shortcomings include

- Many common topographic map symbols are not used;
- Elevations for peaks are missing;
- Township, Range, and Section information are not included;
- Trails, buildings, and other features are not shown;
- The contour lines are not as finely shown and many small, closed contours on the 7.5 minute maps are not shown on the digital maps.

The LTP navigation program will continue to use the 7.5′ map series. These maps are superior to the new US Topo series and should continue to be available for purchase from a variety of vendors.

Caution: Some vendors sell 7.5′ topos printed on plasticized material. These are not acceptable or usable for LTP navigation practice/checkout requirements because one cannot write on them. Maps must be 7.5′ USGS topos printed on paper to correct USGS scale. For detailed trip planning and especially for navigation in the field, 7.5′ topo maps are generally used. These maps are mandatory for navigation practice and checkouts and the associated homework. For trip planning and more casual navigation, however, other topo maps are available which can be very useful. These include

- The USGS 15′ maps, while no longer updated and therefore potentially suspect with regard to accuracy of trail and road locations, are still available in books (e.g., Hetch-Hetchy, Yosemite, and Mt. Whitney) published by Wilderness Press and available in local outdoor stores. These maps, having a scale of 1:62,500, are less detailed in terms of terrain features than the 7.5′ maps. Nevertheless, in California they do cover larger areas (typically 14x17 miles) and can be very useful in planning longer trips in the Sierra. Many of these 15′ maps can be downloaded at the USGS online store.
- In addition to large-scale national forest maps, the USFS offers high quality topographic maps of several wilderness areas in Southern California (e.g., the Cucamonga and San Gorgonio Wilderness Areas). Although not as detailed as the USGS 7.5′ topographic maps, these maps are often more up-to-date and show trails not yet incorporated in the USGS maps.
- The commercially produced Tom Harrison Maps are readily available in local stores and cover both local areas and the Sierra. Typical titles (only a small sample) include *Trail Map of the Angeles Front Country, Trail Map of the Angeles High Country, Kings Canyon High Country Trail Map, Mono Divide High Country Trail Map,* and *Map of Yosemite Valley*. The scales of these maps vary but are generally not as fine as the 1:24,000 USGS topo maps (those of the Santa Monica mountains are an exception, and offer very good detail). These maps are plasticized (good for rain resistance), include a UTM grid (see Appendix A), and, unlike most other topo maps, include trail mileage information. The publisher appears to update these maps frequently.
- The commercially produced Trails Illustrated maps by National Geographic are also readily available in local stores and cover Joshua Tree National Park, the Santa Monica Mountains, Mojave National Preserve, and other areas in California. They provide valuable information, including information about park rules and regulations.

Occasionally, when the area to be traversed or viewed is contained near the edges of two maps, then two maps are necessary. The maps may be carefully folded at the edges and seamlessly taped together with write-on tape (not glossy), on both sides. Write-on tape permits lines to be drawn on the tape when plotting near the taped edges of the maps. It is almost impossible to do terrain/map recognition, to plot bearings, or to estimate distances when the maps are separate.

It is best to fold the map to show the specific area of interest and then change the folding to show new areas as the trip progresses. A map which is quickly available and needs no unfolding, especially in the wind or rain, is most useful for route following. All map-folding methods will eventually cause the corners and edges of the map to wear away, resulting in loss of the printed area. These are then not available for navigating. Special map holders, available at outdoors stores, are designed to protect maps from abrasion, wind, or water while being viewed. Re-sealable plastic bags work too.

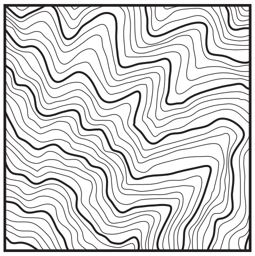
Electronic Topographic Maps

In recent years electronic topographic maps and the availability of inexpensive color printers have made “do-it-yourself” maps a viable option for the computer-literate hiker. Derived from USGS topographic maps, the electronic maps and the user-friendly software offer the leader great advantages: the ability to examine routes, calculate distances, make trail profiles, and conduct other comprehensive map studies at home. The USGS topo of interest and its surrounding quadrangles are seamlessly available at user-selected scales. Among the most useful features available are the capabilities to draw and assess the statistics of routes on the map, establish waypoints that can be transferred to GPS receivers, catalog bearings and distances to near and far peaks and other objects of interest, and determine their visibility from particular locations. These maps may include some of the marginal data (scales, magnetic declination, etc.) available on the printed topo, since they present data from many USGS maps. For the latest information on available software, contact the LTC Navigation Chair, your local outdoor store, or search for resources online.

While electronic maps offer several advantages (selectable scales, spanning quadrangle boundaries, planning tools with the home computer packages), their end product is one or more printed maps. And in this hardcopy product there are limitations as compared to the standard USGS printed 7.5′ maps:

- The quality and readability of the maps will

The keys to visualizing landforms on topo maps are the contour lines: their shape shows the shape of the land, and their spacing shows the steepness.

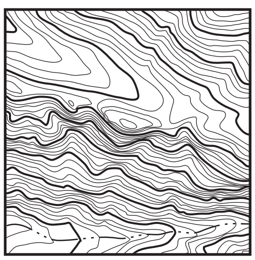


◄ **Gullies and Ridges** appear as V-shaped contours, with the V's pointing uphill in gullies and downhill on ridges. Ridges may be U-shaped.

- Gullies tend to converge downhill and ridges diverge while the opposite is the case for uphill travel.
- Ridges come together at the summit and gullies (going down) empty into bigger gullies.
- Ridges border drainage patterns; gullies are the drainage patterns.

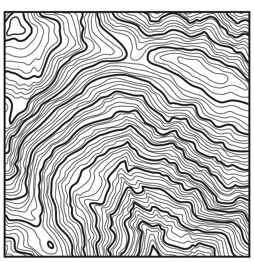
◄ **High Points (or Sink Holes)** appear as the smallest closed contours, usually within a concentric group of larger closed contours.

- The precise location of peaks is often indicated by a benchmark, elevation, or a triangle or "x" symbol.
- High points or sink holes may extend above or below the elevation of the smallest closed contour lines, up to 39 feet on 7.5 minute maps.

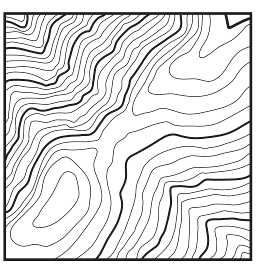


◄ **Benches and Cliffs** appear as variations in contour spacing.

- Benches show a local increase in contour line spacing because terrain flattens out.
- Contours are closely spaced for cliffs, where the terrain is very steep.



◄ **Bowls, Amphitheaters, and Cirques** appear as approximately circular contour line patterns with slight decreases in line spacing as altitude increases.



◄ **Saddles (and most passes)** are low points on ridges and appear as hourglass-shaped contours, with the higher ridge widening on both sides.

To help visualize the big terrain picture, one may trace certain contour lines, say every 1,000 feet, with colored pencils. Drawing lines along ridges reveals drainage patterns, and marking peaks with colored dots makes high points stand out.

Many terms are used to denote related landforms. Thus, we have not only gully, but couloir, chute, ravine, gulch, wash, draw, and at a larger scale, canyon, basin, and valley. Besides ridge we also have arête, rib, buttress, spur, and divide, while besides saddle there is col, notch, and pass. Each term has a different shade of meaning, but they all appear as patterns similar to their relatives differing primarily in sharpness and scale.

Figure 6-1. Topographic map terrain visualization

be limited by the capability of the printer and the paper used. Most consumer printers are limited in the size of paper that can be used; a common limit is legal size (8.5 x 14 inches). This means that a relatively small area will be printed or that a less detailed scale must be selected to allow printing of a larger area.
- Generally the marginal information printed will not be as detailed as that on a USGS map and will usually be limited to distance scales and magnetic declination information.

The electronic maps and their support software certainly add to the personal arsenal of the navigator, especially for trip planning. But the USGS 7.5′ topo maps are still the map of choice for field navigation and are mandatory for LTC navigation events. Software printed 7.5′ topos are currently not acceptable for LTP Navigation practice/checkout requirements. The maps must be USGS topos printed on paper with all margin information present.

Topographic Map Characteristics

The essential feature of a topographic map is the depiction of elevation by contour lines of constant elevation, which reveal the general shape of the terrain. One way to visualize a contour line is to consider a land area near the ocean. A contour at zero elevation corresponds to the coast line; should the sea rise by 40 feet, its level would then correspond to another 40 foot contour line on the map. On USGS 7.5′ maps contour lines are printed in brown, typically at 40 foot intervals, with every fifth line made heavier for ease of reading, typically 200 feet. Elevations of the heavy contour lines are printed in brown figures at occasional places along the lines. By their nature, contour lines on a map never cross and eventually always close on themselves, frequently in a region beyond the borders of the map. A direction straight up or down a slope is perpendicular to contour lines; a traverse at constant elevation is parallel to contour lines. Because the contours essentially provide a three-dimensional representation of the terrain presented on a two-dimensional surface, the navigator's goal is to learn to "see" the terrain form in its three-dimensions.

The contour interval, noted on the bottom margin of the map, is the vertical distance between two adjacent contour lines. For almost all 7.5′ maps the contour interval is 40 feet. Rarely, the contour interval can be 80 feet (San Jacinto is such an example in Southern California). The Malibu Beach topo has a contour interval of 25 feet and index contour lines are every four contour lines rather than the usual five. Some maps in the Sierra and the Southern California deserts are still in the "provisional" status and use metric contour intervals. Intervals are typically 20 meters (65.6 feet) in the Sierra and 10 meters (32.8 feet) or even 5 meters (16.4 feet) in the deserts. Occasionally, in gently sloping areas such as in flat desert or level towns, a supplementary contour line may be added, typically at midpoint elevation between two contour lines. The supplementary contour interval is noted at the bottom of the map. The interval can vary from map to map to map (e.g., 20 feet on the Mt. Wilson topo, 10 feet on the Stovepipe Wells topo) but will not exceed half the normal contour interval. These supplementary contour lines are thinner and lighter than a regular contour line and may also be dashed (e.g., Mt. Wilson quad).

USGS topographic maps contain a number of conventional symbols and colors to show both natural terrain features and human works. Water features are shown in blue, vegetation in green, surface features and contours in brown, man-made objects in black, and public land survey boundaries and major highways in red. Aerial photography updates of urban areas are shown in purple.

The margins of USGS topos show essential information with which the navigator should become familiar and use as needed. This information includes
- The name of the quadrangle covered by the map
- Identification of adjacent quadrangles
- Map scales
- Some basic map symbol data (e.g., regarding highways, roads, and trails)
- The contour interval (usually in feet, sometimes in meters)
- The degrees/minutes difference between UTM grid north (GN) and true north and the direction of magnetic north (MN) and its year and declination in degrees
- The date(s) the map was made and/or last revised
- The datum of the map (essential for map use with a GPS receiver, as discussed later).

Other paper topo maps will generally contain much or all of this essential data.

Coordinates and Reference Frames

Quadrangle maps have meridians of **longitude** and parallels of **latitude** as boundaries. Black tick marks 1/3 and 2/3 of the distance along each edge and four small crosses in the map interior mark intermediate meridians and parallels. These tick marks can be joined to give very accurate north-south and east-west reference lines for drawing north-south (N-S) reference lines. These N-S lines can be drawn as needed to cover the area navigated, typically about one inch apart. Because of meridians converging to the North Pole and because of the kind of projection used,

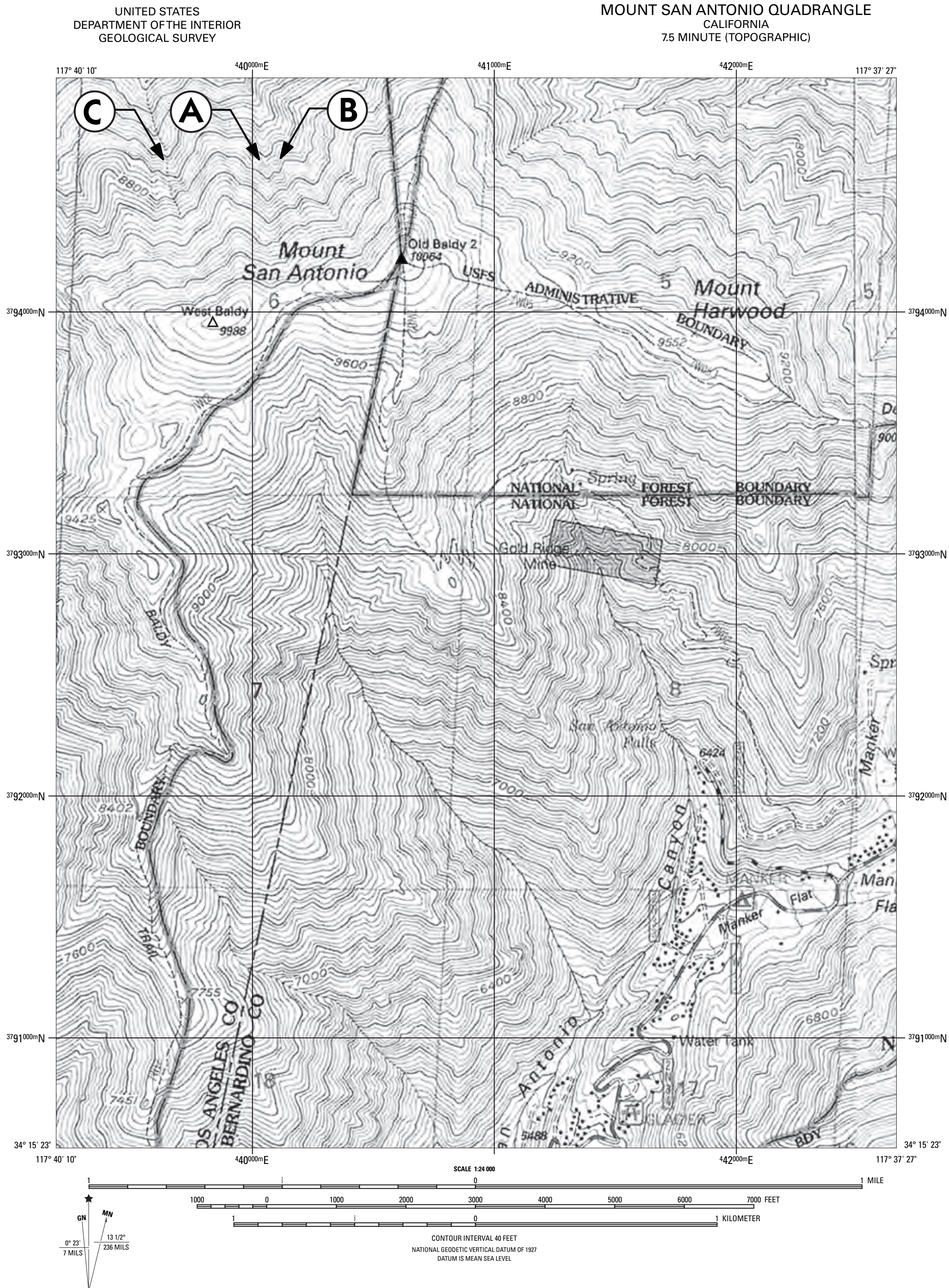


Figure 6-2. A portion of the Mt. San Antonio USGS 7.5' Series Quadrangle (reduced in size to fit this page)

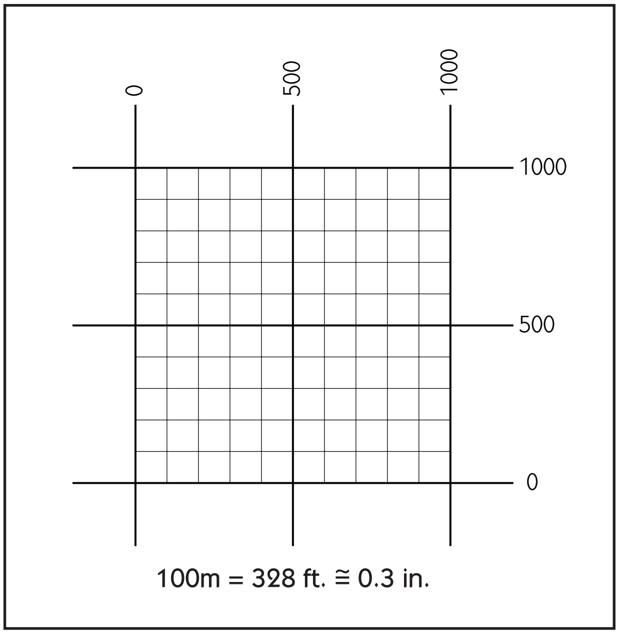


Figure 6-3. UTM template for 7.5 minute, 1:24,000 series topo

in Southern California the width of a quadrangle map at the top is slightly less than at the bottom (about 350 feet, or 2/10 inch). The two sides are not quite parallel, but both do point to true north.

Quadrangle maps show range, township, and section lines of the United States public lands survey in red. Many section lines are sufficiently close to true north to permit their use as bearing reference lines. Others are obviously skewed and unusable. For example, the north and south boundaries of Section 7 in Figure 6-2 are close to east-west, but the east and west boundaries are skewed and not usable as N-S lines. Except when skewed, sections are one square mile, so the section grid can be used as a ready scale for distance estimating. Accuracy should be checked before using any of these survey lines as N-S lines for navigation.

UTM Grid–Many quadrangle maps have the Universal Transverse Mercator (UTM) grid printed on them, providing a convenient reference system to use as a scale and for N-S lines (see Appendix A). If it is not printed on the map, the UTM grid can be constructed from the blue tick marks spaced at one kilometer intervals on the borders of the map, using a long straightedge and a fine pen. The UTM grid of one-kilometer squares (.62 mile, approximately 2/3 mile) provides an excellent framework for scaling map features relative to their on-the-ground terrain features. As a result, distances on the map are easy to visualize. For example, a distance equal to a tenth of the grid is one hundred meters (328 feet), about the length of a football field. The grids themselves provide an excellent local scale for quick assessments of distances and location. Precise distances are seldom necessary when navigating. The one-kilometer grid lines serve to calibrate the eye as attention is transferred between the map and the terrain. When GPS receiver readouts are set to the UTM coordinate system, the UTM map grid allows easy transfer to a location on the map. Very accurate location can be plotted using UTM templates such as shown in Fig.6-3. On a metric map with metric contours, it is useful to remember that 300 meters is close to 1,000 (984) feet and 1,600 meters (5,249 feet) is close to a mile.

UTM Coordinates–Location in the UTM system is defined by the two coordinates of the point, giving the easting first and then the northing (see Appendix A). The convention of east (right) first, then north (up) second starting from the southwest corner can be remembered by the mnemonic "read right up." A UTM coordinate can be expressed with several levels of precision: within one meter square area, ten meter square area, or 100 meter square area. In Figure 6-2 as an example, Mount San Antonio (Mt. Baldy) is 613 meters east of a line through the tick marks labeled 440 at the top and bottom of the map, and it is 241 meters north of the line through the tick marks corresponding to 3794 at the east and west boundaries of the map.

Since this topo is in UTM Zone 11 and Region S, the combined full UTM coordinate to the precision of one meter would be: 11S 440613E 3794241N. The digits printed in small type (superscript) denote the hundreds and thousands of meters, which are referenced to the equator (northings) and the zone meridian (eastings) and need not be listed when giving a reference on a single quadrangle. By convention, this same coordinate can also be streamlined and expressed as 40613 94241 to a precision of one meter. Expressing the coordinates to a precision of ten meters (33 feet) would be written 4061 9424; to the nearest one hundred meters (328 feet), it would be written 406 942.

The N-S UTM grid lines are aligned with true north only at the center of the UTM zone. In Southern California they may differ by as much as -2.5º at the west edge of the zone and +2.5º at the east edge of the zone; at the Equator the west and east edges of the zone are true north. The deviation between true north edges of the zone and UTM **grid north** (GN) at the center of the topo map is shown as one of three arrows in the diagram at the bottom of the map, along with the GN value in terms of degrees and minutes. The other two arrows are magnetic north, along with its declination value, and true north.

Judging Gradients of Trails and Slopes

The local steepness of the terrain is important in picking a route. It is also a safety factor in judging avalanche hazards on snow and loose rock slopes.

Slope–The slope can be expressed as the angle from the horizontal in degrees, or the ratio of elevation change to horizontal distance change as percentage. Use of slope in percentages is not very useful in a practical sense since it is not linear. Slope in degrees (0°-90°) is a linear measure, same as the azimuth and declination-clinometer scale on a compass, and is easy to understand. For the angle of repose, a 34° slope is easy to visualize and can be measured with the compass **clinometer**, but as a 67% slope it is hard to visualize, measure, or use in the field. For anyone desiring a percent slope number for trip planning purposes, it can easily be estimated by multiplying the degree slope by two. The resulting number, valid up to about 45°, is within 10% of the mathematical percent slope, which is adequate for any personal trip planning.

The spacing of contour lines is a measure of slope. For example, on a 1:24,000 scale map, 1/10 inch represents 200 horizontal feet. For an 11° slope, the vertical rise over this 200 feet is 40 feet, or one contour interval. Thus an 11° slope on this map scale has a spacing of 1/10 inch (2.5 mm). A 45° slope would rise 200 feet in 1/10 inch, or five contour intervals (one major, bold contour interval), which places the contour lines five times closer together. Fig.6-4 shows the spacing of contour lines for various degrees of slope. A scale (inch or cm) on the compass base plate provides the means to make linear measurements.

Topo maps do not provide or imply any terrain information between the contour lines. The terrain between two contour lines actually might be a slope or might be composed of a series of horizontal ledges or vertical terrain features of less than 40 feet. This effect is true of horizontal appearing narrow ridges in the high Sierra, which often are a series of jagged pinnacles and notches. It is also true in flat desert with many scattered large boulders (e.g. Indian Cove). This means that planning a trip in unknown terrain based on topo maps alone can be misleading or dangerous. Do consult leaders who have been there before, and it is always best to scout the trip in advance.

Most natural hillsides such as sand, loose dirt, scree and talus typically have slopes of up to about 34 degrees, which is called the **angle of repose**. It is a slope that is relatively safe because a human body, like a loose rock, tends to stay put rather than to slide down. But it is difficult to climb in loose scree, leading to the "two steps up, one step back" phenomenon. Rock walls and the dirt sides of stream channels may occasionally have steeper slopes, because of supporting rock or vegetation. Highway slopes are usually less than 6°, sand dunes up to about 30°, scree slopes between 30° and 40°, avalanche-prone slopes between 25° and 50°, and house stairs about 35°. Steep constructed trails have slopes in the range of 6° to 12°.

Contour Line Spacing of Slopes–With rare exceptions, the USGS English system 7.5′ topo maps show 40-foot contour lines with a heavy major line every 200 feet. For the English system, spacing of 40-foot and 200-foot contour lines at various degrees of slope is shown in Fig 6-4; spacing and values for the metric system are calibrated differently. Some topos in the Sierra have been converted to the metric system, typically with 20 meter contour intervals. Also, some metric system topos in the Sierra and the deserts of Southern California remain in the "provisional" status with hand-lettered data (vs. printed). On these topos intervals are typically 20 meters (66 feet) in the Sierra and 10 meters (33 feet) or even 5 meters (16 feet) in the deserts. Caution must be exercised when estimating slopes from the metric contour lines so as not to confuse them with the English system.

NAVIGATIONAL INSTRUMENTS

Compass

The Earth and Its Magnetic Field

The true geographic north-south pole direction (longitude lines) is defined by the axis of rotation of the earth, and its rotation is in the east direction (latitude lines) on maps. The earth also has magnetic poles which are in the general vicinity of the geographic poles. In 2012, the surface location of the magnetic north pole lay north of the Canadian arctic, at about 85.9°N latitude and 147.0°W longitude—about 280 miles from the geographic pole—and was moving north-by-northwest (NNW). In Southern California its movement resulted in the magnetic declination decreasing by one degree about every twenty years during the last quarter of the 20th century. That decrease has accelerated to about one degree every ten years as of 2012.

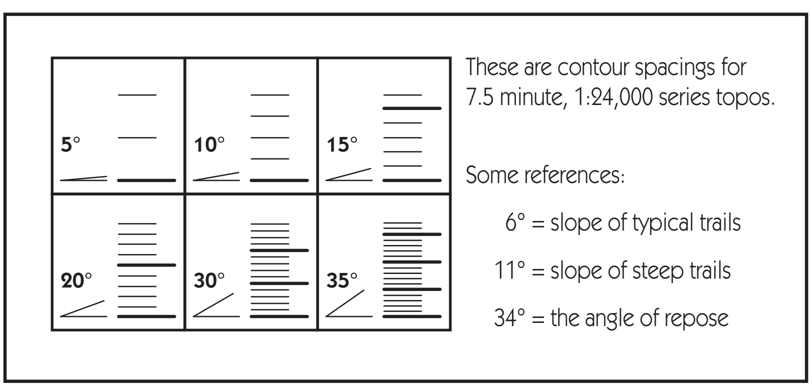


Figure 6-4. Contour line spacing of slopes

Magnetic Declination

The difference in bearing between the geographic pole and the direction the horizontal magnetic needle points to is called the magnetic declination. This varies significantly as a function of where a person is on the surface of the earth. In California the magnetic declination is to the east of true north and varies from 11.5° E of geographic true north in Blythe to 15° E in extreme northwest California. In the Los Angeles area, the declination is about 12° E, in the Southern Sierra it is about 13°, and in Yosemite it is about 13.5° E. In the eastern United States the declination is to the west of true north. A small diagram at the left bottom margin of each USGS topo map shows the magnetic declination direction, its date, and its bearing value.

Magnetic Inclination

The earth's magnetic field has another major effect on compasses, a vertical component caused by the three-dimensional center deep inside the earth's mantle. The needle attempts to follow the magnetic flux lines as they twistingly converge downward toward the area of the magnetic pole. Around the pole the magnetic flux lines and a simple magnetized needle would tend to point vertically. Far from the magnetic north pole in Southern California, the north end of a simple magnetic needle (typically red) of the compass will tend to point northward below the horizon at about 59º. This is called magnetic inclination and is caused by the same chaotic and asymmetric magma circulation that gives rise to the magnetic declination. However, we are not even aware of it when using a compass. The inclination dip of the needle is offset in compasses by counterbalancing the southern end of the needle (typically white) for the local magnetic region–so that the needle stays horizontal. On different parts of the earth, the apparent location of the magnetic pole, declination, and inclination changes in regions distant from geographic poles. Compass manufacturers have divided the earth into five magnetic regions and produce compasses with different amounts of counterbalance tailored to each region. Some manufacturers have designed a solution to this global anomaly, called global compasses. They contain an unmagnetized and bottom-weighted needle that pivots horizontally on a magnetized gimbals base (patented). The gimbal in turn rotates and pivots on a jewel base in the dial. Thus the needle is isolated from any varying vertical (inclination) magnetism effects of the different magnetic regions of the globe. A global compass can be used wherever one travels.

Local Magnetic Fields

Local magnetic fields, as well as any nearby source with iron content that may be magnetized, can affect the compass so as to distort the reading. Common local sources include a mechanical pencil, clipboard, belt buckle, another compass, watches (rarely), cars (especially a row of cars), garbage bins, or rocks containing iron ore. Man-made features like power lines, pipes, rails, and buildings influence the local magnetism. A few peaks in California, like Iron Mountain, are known to contain iron ore and distort the compass readings. More rarely, magnetized lava flows, areas of large meteor impacts, areas around a lightning strike, major earthquake faults, or even sunspot activity can influence the local magnetic fields. If in doubt, take bearings from several spots in the general vicinity to verify that the bearings do not change significantly.

The Magnetic Compass

Typically, a magnetic compass functions because of a magnetized needle that will, in the absence of interference from nearby magnetic sources, align itself along the local horizontal lines of magnetic flux. These lines ultimately converge toward the observationally averaged magnetic pole. From California, the compass sees the far away magnetic pole as a strong point source. Approaching the area of the magnetic pole, the magnetic field becomes more vertical, and weak and erratic in the horizontal direction, so as to become unreliable or useless for a compass.

Compasses for Trail and Backcountry

Compasses suitable for basic navigation feature a magnetized compass needle, pivoting on a sharp point inside a fluid-filled capsule. Starting from this point, there are a number of different compass types, varying in increasing amount of features and accuracy in use.

Most Basic–Very experienced navigators, who are also expert in terrain recognition on maps, may need only a simple compass (e.g., attached via a strap to a finger, wristwatch band, or hiking stick). By keeping track of their location on the map, they may need a compass only for general cardinal points (N-NNE-NE-ENE-E, etc.) reference.

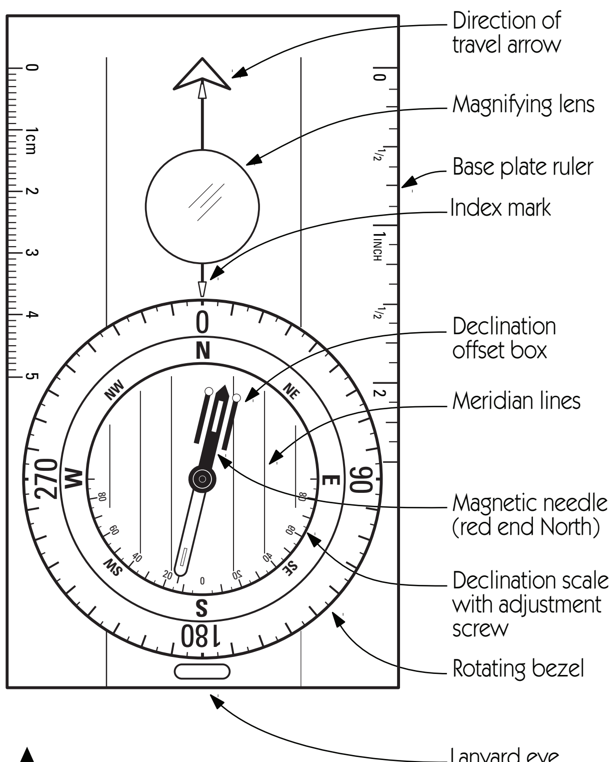
Rough Accuracy–The next compass level, capable of taking rough bearings, is a compass with a fluid-filled capsule inside a moveable dial that contains a degree bearing scale on the azimuth ring of the dial. It is mounted on a transparent plastic base plate that shows a direction-of-travel line or arrow. It probably has some meridian lines in the dial, making it possible to take and plot bearings on the map. Declination adjustment can only be accomplished by taping on a declination arrow at the bottom of the dial.

Good Accuracy–These significant-level compasses start to meet the demanding navigation needs for trail and backcountry. They have a longer base plate that carries various measurement scales to use on a topo. The dial is larger, and the degree bearing scale, capable of one-degree resolution (not bearing accuracy) by the eye, is graduated in two-degree increments. The dial has five or more meridian lines for more accurate plotting of bearings. The dial contains an orienting arrow of parallel lines to align the needle within the arrow accurately.

It is strongly recommended that the dial also contain a mechanical means to adjust for declination, which increases accuracy. The dial then also contains the clinometer needle which uses the declination scale as also the clinometer scale. The declination adjustment feature uses a small screw at the top or bottom of the dial using the small key tool on the lanyard to turn the declination adjustment scale to the desired declination in degrees. Practically, the adjustment can be made to within one degree.

This is, however, still a flat, relatively short straightedge, base plate compass referred to as a "bellybutton" compass since you must look down at the compass. Point it from your belly, then look up at the bearing object you are trying to point to. Then keep on looking down and up until you are ready to commit to a reading on the dial. In some ways this is analogous to "hip-shooting" with a handgun, instead of aiming it.

Best Accuracy–A full-featured compass (see Fig.6-5) contains a fold-out sighting mirror to achieve the best accuracy possible. Using the sighting mirror is analogous to aiming a gun vs. hip shooting. It has all the features of the "bellybutton" compass, and with the folding mirror extended, it has a straightedge to plot over two miles on a 7.5′ topo without resorting to a separate ruler. Most hikers and backpackers will carry a mirror for various purposes, including signaling and personal needs; if so, then why not add a compass to it?



▲
Base plate compass
The basic layout and features are shown in the drawing above.

Sighting compass ►
Additional features of a sighting compass are shown in the drawing to the right. The base plate compass has been enlarged relative to the sighting compass to improve clarity.

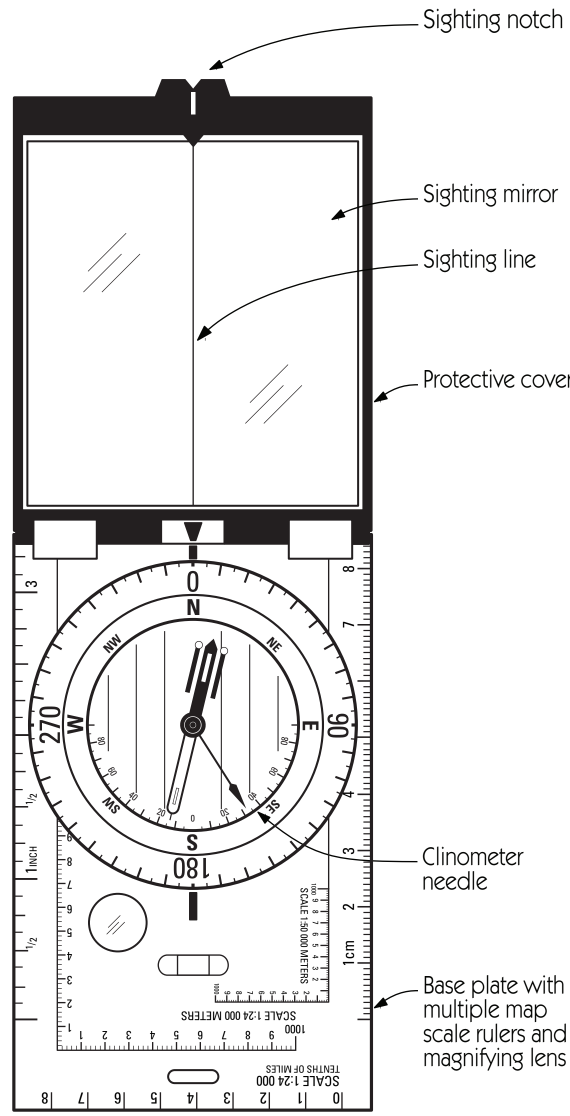


Figure 6-5. Base plate and sighting compass features

The mirror is best used with the compass held at arm's length with fingers of both hands and with the cover folded partway open (about 45º), using both thumbs to adjust the dial. Too many navigators still use and teach the carryover method from the old "bellybutton" compasses, which is to hold the compass in one hand while using the other hand to adjust the dial. This is more difficult and generally less accurate.

Slope Measurement

In the field, the compass can be used to estimate the terrain slope (washes, gullies, ridges, cliffs, mountain sides) using the clinometer needle of the compass. If the slope is ascending to your left, set the dial to 270º at the index mark, so that the meridian lines are horizontal when the base plate edge is horizontal. If the slope is ascending to your right, set the dial to 90º at the index mark. Then visually align the edge of the base plate to the slope of the terrain viewed, and read the slope angle on the declination-clinometer scale.

Without a clinometer, measuring slope is a similar but more difficult process. If the slope measured is ascending from your right to the left, set the compass dial at 360º. Align the edge of the base plate to the slope of the terrain viewed, then adjust the dial so the meridian lines of the dial are about horizontal to the eye, and read the slope angle at the index mark.

If the slope is ascending from your left to the right, align the edge of the base plate to the slope of the terrain viewed, then adjust the dial so the meridian lines of the dial are about horizontal to the eye, and read the degree number at the index mark. Subtract that degree reading from 360º to get the slope angle.

Bearings

The clockwise angle from the true north reference direction to the direction of a given line is called the bearing or azimuth. To measure a bearing in the field, point the base plate of the compass direction-of-travel arrow or sighting line toward the object of the bearing. Then rotate the dial so that the red end of the magnetic needle is directly in the middle (parallel to or "boxed in") the red end (north) of the orienting arrow or lines. For mirror compasses, accuracy is determined by having the mirror sighting line pass through the middle of the dial as seen in the mirror. The bearing is read on the dial at the index mark. While a person is learning, errors of 180 degrees in direction (i.e. dial with N-S direction reversed) can happen and can be easily corrected by adding 180º to the reversed bearing.

Bearings of Terrain Features–Any terrain feature on a topo or feature on the ground that continues in a direction for at least 200 to 400 feet (1/10 to 2/10" on topo) has a direction which is a measurable bearing; the longer the feature, the more accurate the bearing. We typically think of taking bearings on large geographical features such as mountains, saddles and notches, big rocks, and man-made objects and features. Most terrain we travel through, however, is rich with all kinds of less distinct but very useful bearing information that we refer to as local bearings. The closer the object of a bearing is, the more accurate our location on the topo.

Local Bearings–If we know where we generally are, a local bearing can precisely identify our location on a topo when the compass is aligned from our location with a known nearby feature on the topo. A local bearing can identify a segment of the trail, road, or a direction in an intermittent stream, gully, ravine, wash, or ridge. To take a local bearing, align the compass with that terrain feature and take its bearing. Then move the compass around the general map area until that bearing aligns with a corresponding feature on the map. The compass edge now passes through our location.

Compass Accuracy–What is the practical (vs. theoretical) accuracy a navigator can expect taking bearings in the field? Experienced navigators will do better than inexperienced, and users of large mirror compasses will do better than those using small, short base plate compasses. Some observed rules of thumb are

- Inexperienced navigator with small compass–within 3º to 5º range
- Inexperienced navigator with mirror compass, and experienced with large baseplate non-mirror compass–2º to 3º
- Experienced with mirror compass–1º to 2º

Navigators will find that in taking a series of repeated bearings on the same object, their results will tend to vary in these ranges. Taking a series of repeated bearings on the same object is also the only way one can get a true sense of the accuracy of his or her personal bearings technique. Should a bearing accuracy be very important, for whatever reason, averaging several repeated bearings will almost always provide a more reliable result.

Bearing on a Map–When measuring a bearing on a map, the map need not be oriented with any compass direction, and the compass straight-edge is used as a protractor. The compass magnetic needle is ignored. An edge of the base plate is aligned from one object to the other, connecting two objects, such as the navigator's present location and the object. The dial is then rotated so that the meridian lines in the dial are parallel with the true N-S lines on the map. The dial angle at the index mark is the bearing.

Locating a Feature in the Field Using a Bearing from a Map–Hold the compass with both hands and point it in the direction at which the needle is exactly parallel within the orienting arrow or marks. Be sure that the sighting line in the mirror goes through exactly the middle of the dial. The object terrain feature will be accurately identified.

Bearing in the Field, Plotted on a Map–Hold the compass with both hands and point it to the direction of the desired terrain feature in the field (either a known position or a candidate object). Adjust the dial so that the needle is exactly parallel within the orienting arrow or marks ("box" the needle). Be sure that the sighting line in the mirror goes through exactly the middle of the dial to preclude parallax. On the map align the edge of the base plate from the terrain feature in the field until the meridian lines in the dial are parallel to the N-S lines on the map. The edge of the base plate should pass close to your location; draw a line lightly on the map. This will seldom be as accurate as locating a feature in the field using a bearing taken from the map (above).

Topo N-S lines

Several kinds of north-south lines of sufficient accuracy (usually within one degree) found on various maps may be used for aligning the meridian lines of the compass dial. The left and right edges of the maps are true N-S. The north and south borders of the map have corresponding tick marks, which can be connected. All USGS topo maps have four precisely located crosses, each one third in from the edge of two map borders, which also can be connected. In many areas, UTM grids are close to N-S, and some section lines are very close to true N-S (the eye can easily identify any that are not so). In the deserts, roads often run N-S, and the eye can tell. Strong message: use your eyes as a primary navigational instrument! When accordion folded from east to west, the creases in the map can be used as accurate, but hard to see, N-S lines.

Add N-S lines–The most practical way to add N-S lines on a topo is with a ruler. Drawing accurate north-south lines on the map at about one inch intervals works best for taking and plotting accurate bearings, even with a short baseplate compass. There is no need to cover the whole map with these lines, just draw them in to cover the area you will be navigating in, and include all the terrain you will see along the way. In the area where you are navigating, measure and mark one inch intervals in line from the east or west edge of the map, then do so again about 10 inches higher or lower. Then connect the marks for accurate N-S lines.

Use of UTM Grid as N-S lines

Our local UTM Zone 11 and Region S covers an area from the Mexico border to just north of Reno and from Santa Barbara to Kingman, Arizona. In Southern California the UTM grid N-S lines vary off the true north between about -1.5º to the west and +1.5º to the east, depending on the location within a UTM region. In the northern part of the Region, the variation will be greater, up to 2°. Barstow,

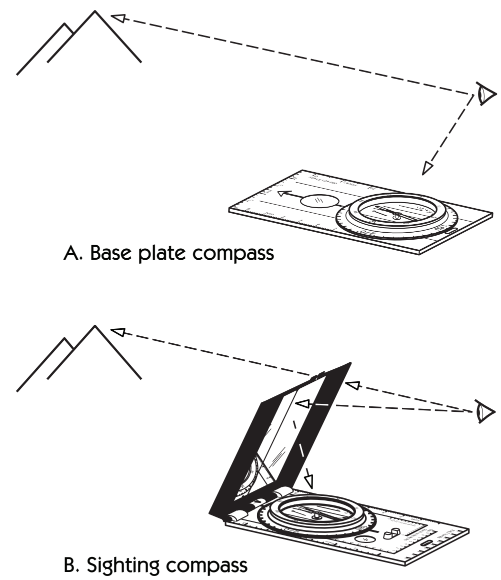


Figure 6-6. Measuring a bearing in the field

San Diego, and Death Valley are near the central meridian of Zone 11, where the grid north is equal to true north UTM. Grids may thus be very close to true N-S lines or with an appropriate GN correction can be used as accurate N-S references for plotting bearings.

Grid North (GN)–This UTM grid convergence is in effect a UTM "declination," off true north depending on the east-west location within its UTM rectangular grid. On the topo maps it is called Grid North (GN) and is identified in the lower left corner of the topo. When the UTM lines are off true north, the topo declination of the compass should be adjusted by the GN value "declination" to permit use of the UTM lines for plotting accurate bearings.

Declination Adjustment–When a UTM line is 1º (GN) off true north, the declination of the compass should be adjusted by 1º to be able to use the UTM lines accurately for taking and plotting bearings. Los Angeles is 1º west (add to topo declination) and the east end of Joshua Tree National Park is about 1º east (subtract from declination). One degree difference between top to bottom of a topo translates to a linear map difference of 4 tenths of an inch, about 800 feet on the ground. For maps with UTM grids, additional N-S lines are not necessary if you have a large mirror compass, since the UTM line spacing is adequate for large mirror compasses, as long as the declination is adjusted by the GN value. If you have a short base plate (no mirror) compass, a straightedge extension is usually necessary to take and plot accurate bearings of objects that are more than 1 mile away. Without the extension, to use a short base plate compass you need N-S lines drawn on the topo about one inch apart. A few sample locations and their declination corrections for GN are listed below.

Some Region S Locations in California	Adjust Declination
Lake Tahoe	Add 2º
Santa Barbara	Add 1.5º
Santa Monica, Kings Cyn, Mono Lk	Add 1º
San Diego, Big Bear, Barstow, Death Valley	No Change
Joshua Tree NP East, Providence Mtns (Mojave NP)	Subtract 1º
Needles, Blythe	Subtract 1.5º

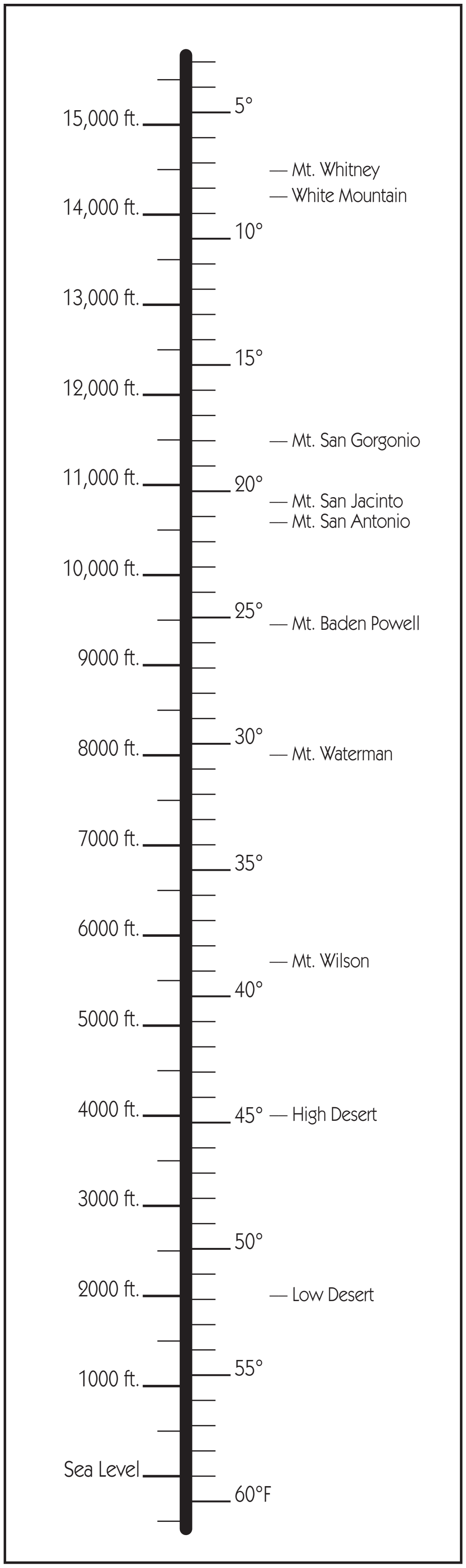


Figure 6-7. International standard temperature at various altitudes (at related features)

Altimeter

A Portable Barometer

An altimeter is a portable barometer. A barometer at home on the wall measures the air pressure and indicates changing air pressure on a millibar scale. The standard air pressure at sea level is 29.92 in.hg or **1013.25** millibars, equal to zero feet altitude at sea level. Wherever it is located, a portable barometer measures the air pressure, which is translated into equivalent feet (or meters) of elevation for the altimeter. The altimeter provides a vertical dimension to assist navigation. The altimeter nowadays can be found as mechanical devices (Thommen is the "gold standard"), in wristwatches, and on electronic devices of various functional combinations. A GPS depends on satellite signals for elevation data and is not a barometer. A few GPS models, however, also have a traditional barometric altimeter added, which also can plot pressure (elevation) over time.

Pressure Sensors

The key element of an altimeter is the pressure sensor. Since there are many different pressure sensors of varying sensitivity and accuracy, the various altimeters will differ in their performance due to inherent pressure sensor range of error, both between similar and between different instruments. Thus, on a typical navigation day in the mountains, various altimeters, even the same make and model, will vary during the course of a day in a range of 50 to 100 feet. The primary contributors are sensor sensitivity, air column temperature, micro-weather variations, and the temperature of the altimeter.

Effect of Weather

An ideal altimeter would accurately identify the elevation of our location and therefore which contour line we are on or near. Along with accurate bearings, altitude measurements can help us plot closer to our exact location. But just as compass bearings carry a range of inaccuracy, many mechanical and environmental variables also contribute to the local air pressure and altimeter reading. These make accurate altitude determinations with an altimeter less reliable than desired or imagined. Using an altimeter effectively requires an understanding of how it functions, what affects its readings, and what its accuracy limitations are. Many environmental (weather) aspects affect air pressure, which along with mechanical sensor limitations combine to affect the altimeter readouts. All the barometer can do is provide the bottom line, a lump sum pressure converted to an elevation readout. That is where the navigator's understanding of the weather and altimeter comes in.

The fact that air pressure decreases with increasing altitude in a predictable way, according to the **International Standard Atmosphere** (ISA), is the reference basis for an ideal altimeter. But altimeter accuracy seldom, and only under ideal conditions, approaches the contour accuracy of the map. USGS topo maps have a vertical accuracy requirement that 90% of the elevations be within one half of a contour interval, which is 20 feet on a 40 foot contour map. As weather pressure systems come and go, the pressure change over a few days can amount to 400-500 feet of apparent elevation change. Diurnal (day to night) changes typically account for 50 feet. On a sunny, windy winter morning in Joshua Tree the campsite elevation was observed to change 50 feet in 15 minutes! Short-term micro-weather pressure variations are caused by changes in airflow around the local terrain and offer no visible clues to the eye.

Temperature Compensation

Most quality altimeters (Thommen, wristwatch, etc.) are advertised as being "temperature compensated." But the altimeter is not compensated for changes in the air temperature—an almost universal misperception. Rather, "temperature compensation" is a manufacturer's attempt to design a mechanical or electronic compensation for errors resulting from temperature changes of the instrument itself. Ideally, this temperature compensation would allow the altimeter to have the same reading whether it is placed on a sunlit windowsill or nearby on an ice cube. Since the temperature compensation is only an approximation, the instrument's temperature will always have some effect on the readout. A wristwatch altimeter is kept at a fairly steady temperature by body heat, but an altimeter hanging from the neck or in a parka pocket will drift more due to exposure to the external environment. The same two altimeters, one in a pocket and one on a wrist, will tend to differ due to the different temperature of the instruments.

International Standard Atmosphere (ISA)

ISA defines the standard temperature at various altitudes, against which the altimeters are calibrated. The worldwide ISA profile is more representative of the average year temperature profile of Northern California weather than that of Southern California. Fig. 6-7 shows the ISA standard temperature profile ºF for altitudes up to 15,500 feet. Some geographic features are identified for reference at various altitudes.

ISA Standard Temperature

Temperature change with altitude is about 3.5ºF per 1000 feet. Therefore, the temperature component is a major contributor to pressure change. On an extreme day the temperature may be 30º to 40º above or below the ISA standard. On a hot day the air expands and is less dense, so there is less indicated altitude change than actually accomplished. The altimeter will read too low on ascent and too high on descent. On a cold day the air contracts and is denser, so more altitude change is indicated than actually accomplished. The altimeter will read too high on ascent and too low on descent. Starting near sea level in the LA basin on a hot summer day and arriving at 7,000 feet elevation in the San Bernardino Mountains, we typically find that the altimeter will read about 400 to 500 feet low. We have moved 7,000 feet higher in an air column much hotter and lighter than the ISA standard.

Air Temperature Variance

One can correct for temperature departures from ISA standard using the Correction Factor (CF) of CF = 0.0022 x Temp Variance (TV) ºF x Altitude Variance (AV) feet.

Thus, for a typical Southern California climbing day in which the temperature is about 20 degrees warmer than the standard, the altimeter after climbing 1,000 feet will read 956 feet, i.e. CF = 0.0022 x 20ºF x 1000 feet = 44 feet. The altimeter as set at the beginning will then read 44 feet too low on a gain of 1000 feet. The table below shows altitude change effect caused by temperature differences from the ISA standard profile. For temperatures warmer than ISA, the altimeter will read too low on ascent and too high on descent; for temperatures colder than ISA, the altimeter will read too high on ascent and too low on descent.

TV °F	10°F	20°F	40°F
AV 200 ft.	*	*	22 ft.
AV 500 ft.	*	22 ft.	44 ft.
AV 1,000 ft.	22 ft.	44 ft.	88 ft.
AV 2,000 ft.	44 ft.	88 ft.	176 ft.
AV 5,000 ft.	110 ft.	220 ft.	440 ft.
AV 8,000 ft.	176 ft.	352 ft.	704 ft.

* Too small to be significant or measurable

The air temperature variance is just one of a number of weather-related and mechanical criteria that affect the altimeter readout, but it is the one that can be quantified.

Accuracy

In spite of many variables, including the above, good altimeter accuracy can be achieved and maintained by resetting the instrument whenever the user is at an identifiable location on the topo map. The more frequent the reset, the more accurate the altitude reading when necessary. Resetting negates any environmental and mechanical variables. As a practical matter, to make effective use of the altimeter as a navigation instrument, the navigator should

- Reset the altimeter whenever reliable reference is available. This could include lakes, summits, trailheads, streams, forks in gullies and ridges, roads, buildings, railroad tracks, power lines, mine shafts, benchmarks, and wherever elevations actually appear on the map.
- Reset the altimeter when a good fix is available based on a combination of clues, such as good bearings.
- On days that are much warmer than the standard, expect the altimeter to indicate an altitude change to be significantly less than the real world, on ascent and descent (i.e., it will read lower than actual altitude on ascent and higher than actual altitude on descent).
- On days that are much colder than the standard, expect the altimeter to indicate an altitude change to be significantly more than the real world, on ascent and descent (i.e., it will read higher than actual altitude on ascent and lower than actual altitude on descent).

Use of the Altimeter

An altimeter can support the use of the compass and terrain recognition on the topo by adding information of the vertical dimension–elevation. Periodically resetting the altimeter at known points on the map is necessary to ensure accurate readings along the way. For example, you are hiking on a trail and come to a stream. You look at a map and see a stream that crosses the trail in two locations nearby. The stream crossing that is closest to your altimeter reading is probably your location. When crossing it, you reset the altimeter.

An altimeter can help you find your location in the absence of compass fixes. For example, your altimeter reads 7,240 feet, and looking at your topo, you see that the trail crosses this contour line in only one place. Your location is close to that point. If the trail goes up or down, crossing the 7,240 contour line in more than one place, you need to determine your location by identifying the terrain features around you.

An altimeter can also help locate your position when only one compass bearing is available. Your altimeter reading locates the closest corresponding contour line along the line of the compass bearing on the topo. This is close to your location.

An altimeter can also help you track where you are relative to your trip plan. Deep into the trip on a steep climb, it may give you the information you need to decide whether you can meet the trip objective or need to turn back.

In camp, your altimeter becomes a simple stationary barometer. It can alert you to significant changes in weather.

Global Positioning System Receivers

Consumer-oriented Global Positioning System (GPS) receivers (simply referred to as GPS) have become increasingly popular as size, weight, user-friendly properties, and costs have improved. A GPS that is designed for outdoor use can provide position fixes accurate to +/- three meters (+/- 10 feet). Because 20 feet corresponds to about 1/10 of 1/10 of an inch on a 1:24,000 scale USGS map, a GPS fix far exceeds the usable accuracy on the topo. Using data from satellite transmissions, the GPS can provide location in Universal Transverse Mercator (UTM) coordinates, which can be plotted readily on topos with UTM grid using a **UTM template**. The GPS may also be used to give a bearing and straight-line distance from one location to another. GPS fixes can help resolve ambiguities and uncertainties and increase the leader's confidence in the credibility of his position estimates derived from other techniques.

As the navigational challenges of a trip increase, the value of a GPS as an adjunct navigational instrument increases. It is especially useful in featureless terrain (such as some desert areas and snowfields); in conditions, such as whiteout or in a forest, where other terrain features become invisible; and in exploratory cross-country trips over terrain with nondescript features. Cross-country navigation across significant up and down terrain is a natural use of the GPS. By entering waypoints along a route, a leader may not only know the speed the group is traveling, but also have a reference for retracing the route. The receiver is used to record **waypoints** when at rest stops, trail junctions and important route changes. These waypoints can then provide guidance on the way back, regardless of weather or visibility conditions.

Waypoints can also be created and entered into the GPS from the trip plan which can then be used throughout the trip to provide direction and distance to the next waypoint. The **Go-To** function can then be used to lead from one waypoint to the next, creating a route to follow. The **Track** function allows a GPS to display and store the trail as one travels. The track can be used to show the return route, which can also be stored and used again at a later date.

Under some conditions the GPS does not work well. Satellite signals can be significantly reduced in steep terrain, in deep canyons, or under extensive tree cover, enough to affect normal GPS function. The GPS is a complex electronic instrument and is thus fragile, can run out of battery power, and has temperature limitations. By comparison, a compass is simple and always works as long as it is kept away from iron. For these reasons a GPS can supplement, but never replace, other navigational instruments (i.e., map, compass, and altimeter). Exclusive reliance on the GPS as the sole source of navigational guidance is strongly discouraged.

Grid Systems and Datums (see Appendix A for further discussion)

A topographic map is typically used to plot GPS coordinates. High-end GPS units with adequate storage capacity can display and use various maps which are downloaded from a PC. The GPS location coordinates are selectable from a number of formats that can be plotted on a map scale. Most commonly used coordinates are latitude/longitude and the UTM.

Most GPS receivers are intended for worldwide use. The shape of the earth as defined by a mathematical model and the local mapping reference system for various parts of the world is defined by a **datum** to provide local mapping reference systems for various parts of the world. A GPS supports a large number of datums worldwide and can compute locations in any of these mapping systems and datum bases. The user, however, must set the same GPS datum on the paper or electronic USGS map being used. If the GPS datum selected and the USGS map datum are not the same, significant errors in the field will result.

Note that the USGS 7.5 minute topo maps provide map datum information in the legend at the lower left corner of the map. While most existing 7.5′ topos were created using the NAD27 datum, it is gradually being replaced by the NAD83 datum in newer topos.

Handheld GPS Receivers

Small, lightweight GPS units with road and off-road maps can be a boon to navigators. Specific locations such as trail junctions, roadheads, caches, summits, and campsites can be entered into the GPS as waypoints prior to a trip to guide travel or during travel to guide a return. Positioning and navigation Go-To functions are universal, and high-end GPS receivers with adequate storage and memory can accept and display map downloads from PCs. These maps are typically created and sold by the GPS manufacturer (copyright and/or copy protected), but some units are compatible with other map sources. The downloaded maps are an extra-cost item. Different types of map sets are available, some for road travel and topographic maps for off-road activities. These topographic maps are usually 1:100,000 scale or 1:24,000 scale (1:25,000 for metric scale), which are equivalent to the USGS 7.5 minute topos. Some GPS models may also have barometric altimeters and electronic compasses added; these features are in addition to the basic elevation and compass features of the GPS and add little functionality with increased battery drain.

Some Factors to Consider

One may consider these factors among others in choosing a GPS unit:

- A 12-channel parallel receiver, capable of receiving up to 12 satellite signals
- Size, weight and controls layout (personal preference)
- Screen color—black and white is adequate, but a color screen improves readability in all conditions, with backlighting for low-light conditions
- Screen size—bigger screens are better
- Battery type—alkaline is common, or NiCad and NiMH rechargeables, or Lithium, which lasts longer
- Storage capacity—replaceable MicroSD cards for downloading city and topo maps to the unit from a PC.

Given the number of options available, testing a friend's GPS in the field or taking a class (try before buy) is a good idea. And there are numerous on-line sources of reviews and other information.

The various smartphones on the market are GPS enabled. A variety of mapping applications is available to transform your phone into a GPS device for hiking. Although these applications do not yet match the functionality of a full-featured GPS designed for hiking, they provide good location information. Users should be aware that some applications come with a set of maps loaded into the phone; others receive the maps via the network in real time.

While a GPS receiver cannot replace skill with map and compass, it can provide added capability and accuracy once its capabilities and limitations are understood.

Global Positioning System

A handheld GPS receiver is one piece of a three-part navigation system, consisting of the space segment (satellites), the control segment (ground stations), and the user segment (the receiver/processors).

A minimum of 24 operational satellites circle in six circular orbit planes, about 12,551 miles (20,200 km) above the earth, with a 12-hour period. The satellites are spaced in orbit so that at any time a minimum of 6 and as many as 12 satellites will be in view to a user anywhere in the world. The master control station is in Colorado Springs, with monitor stations and ground antennas located throughout the world. The GPS receivers (including processing and antennas) work worldwide, and allow land, sea, or airborne operators to receive the GPS satellite broadcasts and compute their precise position, velocity, and time. More information on the GPS system can be found at http://www.gps.gov/

GPS Operation

GPS operation is based upon satellite ranging. By measuring their distance from the group of satellites in space, user receivers calculate their position on the earth. The satellites act as precise reference points. Each GPS satellite transmits an accurate position and time signal. A GPS receiver measures the time delay for the signal to reach the receiver, which is the direct measure of the apparent range to the satellite. Measurements collected simultaneously from four or more satellites are necessary to process and solve for the three dimensions of position, velocity, and time—which provides a position location and elevation.

Accuracy

Although today's handheld GPS can achieve horizontal accuracy to within 10 feet with good satellite coverage, many factors can influence actual performance. When GPS signals are reflected off the local terrain, foliage, or structures, reception is affected in the same way FM and cell phone signals can fade in and out while one is driving in traffic in urban canyons. Receivers can be confused by multi-path reception (receiving direct and reflected signals), interruption in the line of sight to a transmitting satellite, and poor satellite distribution in the sky. For outdoors users, the effects of thick foliage in a forest and poor line-of-sight location (e.g., in a deep canyon) can significantly affect the achievable accuracy. Conversely, hiking in the desert or along a mountain ridge offers the best accuracy potential.

AIDS TO MAP USE

Maps may be carefully folded and taped together with write-on tape on both sides when used for navigating near the edges of the maps. The margin information need not be cut off, but can simply be folded under prior to taping the edges together. It is much more difficult to do terrain/map recognition, to plot bearings, or to estimate distances when the maps are used separately.

For 7.5′ maps that do not have the UTM grid overlay, which is close to true north, the UTM lines can be drawn in using the tick marks at the edges. For accurate positioning on a UTM grid, there are UTM templates that provide Northing-Easting accuracy to 1 millimeter (better than 1/20 inch, or 100 feet).

Maps may also be folded accordion style parallel to the edges, so that the folds represent N-S lines.

It is best to fold the map to show the specific area of interest and then change the folding as the trip progresses. A map which is quickly available and needs no unfolding, especially in the wind or rain, is most useful for route following. Special map holders, available at outdoors stores, are available to protect maps from abrasion, wind, and water. Re-sealable plastic bags work too.

Maps can be stored at home flat and protected in stiff cover folders available from art supply stores or can simply be rolled up.

There are map-measuring devices that utilize a little wheel to trace a route and measure the distance. A calibrated readout wheel shows the distance on maps of various scales.

There are slope angle–contour spacing scales or templates for easy assessment of terrain slope angles (see Fig.6-4).

For a visual scale reference on a 7.5′ topo in the area to be traveled through, draw a line 1 mile long (2.6′), and divide 1″ of it into 10 parts, each 1/10″ long. These "building blocks" of 1/10″ equal 200 feet exactly.

FIELD NAVIGATION

The primary goal of field navigation is to execute the trip plan effectively and safely while staying found. The leader needs to know how the group is progressing from point A to point B, which involves connecting the map to the terrain (map orientation), tracking and locating the group's position as it progresses, and leading the group towards its objective in an organized fashion.

Map Orientation

A map is oriented to the terrain when it is horizontal and the direction of its features is in line with (conforms to) the corresponding features on the ground. A map may be oriented by inspection in a number of ways, most directly by rotating the map so that corresponding map and terrain features are in line by direct observation. If an observer knows his or her current position on the map and can locate on the map some recognized terrain feature, then an imaginary line can be drawn between these two map locations. The map can then be oriented by rotating it so that this imaginary line points to the terrain feature. The map may also be oriented with a compass by placing the compass on the map with the compass N-S bearing line parallel to a map N-S line or the edge of the map. The map and compass are then rotated together until the compass indicates the map is aligned to true north. In this case the compass needle itself will be contained within and parallel to the orienting arrow. Another practical way is to draw a N-S line in the ground with a stick or the boot, then use that line as an accurate N-S reference to realign the map after having been turned in a different direction.

Position Location–by Terrain Inspection and Correlation with the Map

The group's position on a map can generally be determined in open country by establishing correspondence between the map and the observed terrain. For example, when standing on the shore of a lake, align the map so that the lake shore features on the map are in line with the actual features. It can be more difficult if one is in a canyon bottom and must identify observed side features with those shown on the map. Among trees it may be impossible.

When on trails that switchback or wind in and out of gullies or around ridges, the navigator may determine the location on the map relatively easily if one keeps track as these points are passed. Some leaders even count switchbacks or gully crossings, a simple and effective technique. Local bearings can be very useful.

Skill in estimating distances to terrain features and in estimating elevation differences helps considerably in map to terrain correlation (and vice versa) once a map is N-S aligned. For example, the fact that a cliff is judged to be 1000 feet high and three kilometers distant may help considerably in searching the map for the corresponding feature.

In climbing a ridge or slope, one can often gain an awareness for the altitude by noting neighboring peaklets or saddles that are about level with one's position and the elevation of which can be determined from the map.

As one works from the map to the terrain and vice versa, all the available clues should be used. For example, one could note the width, height, direction, curvature, and length of a gully on a map and compare these features with what is visible in the gully to see what fits. Gullies A and B in Figure 6-2 diverge near 8,600 foot elevation. Gully A leads almost directly south (175°) and climbs 1,200 feet to the saddle. Gully B is slightly shallower, has a more open shape, and disappears below the saddle. The bearing is 156°, and that bearing tops out on the ridge roughly 100 feet above the saddle. Gully C generally parallels B, but is much deeper, is distinguished by an intermittent stream, and leads toward West Baldy summit. These are sufficient clues to confirm a reliable identification.

SOME RULES OF THUMB

A linear bearing error of 1° yields

92.4 feet @ 1 mile or about 100 feet @1 mile
(roughly 1/20 inch on a 7.5′ topo)

An index finger width held at arm's length

is roughly 1.5° to 2°, which yields

138 feet to 185 feet @ 1 mile
(roughly 0.07 to 0.1 inch on a 7.5′ topo)

A hand width (4 fingers, no thumb) held at arm's length

is roughly 6° to 8°, which yields

555 feet to 740 feet @ 1 mile
(roughly 0.28 inch (3/10″) to 0.37 inch (4/10″) on a 7.5′ topo)

One may estimate remaining daylight

by measuring the distance of the sun's path to the setting point on the horizon (the sun moves 15°/hr):

A four-finger-width at arm's length yields roughly 30 minutes.

Two four-finger-widths yield roughly 60 minutes (1 hour).

Position Location–by Fixes

Some map-indicated features are visible in the surrounding terrain and can accurately identify a position. These include benchmarks; section markers; prominent summits; trail junctions; trail switchbacks; trails crossing ridges, ravines, and streambeds; and man-made objects.

Map and Compass Bearings

An observer's location on the map can be determined in the field by taking at least two bearings to identified features and then plotting these bearing lines on the map. Ideally, their intersection is supposed to be the observer's location. For accuracy the bearings should be as nearly perpendicular to each other as possible. If the observer's position is known to be on some identified line such as a trail, road, gully, or ridge, then only one bearing is needed as nearly perpendicular to the known line as possible. A third bearing to another known point can be used to check and

SOME USEFUL CONVERSIONS

Attention here is confined to USGS maps with a scale of 1:24,000 (7.5´) and electronic maps that are printed on a 1:1 basis (e.g., one actual inch on the map does indeed correspond to 24,000 inches on the ground). With the variety of printing scales available with the software, a computer-generated map may not be on a 1:1 basis with the actual map published by the USGS, so some of the measures listed below will not apply. The base plates of appropriate compasses provide scales that read directly in English (miles) and/or metric (kilometers) systems that can be used to measure distances on the 1:1 map.

Linear Conversions

On the Ground		
1 kilometer (km)	=	0.6214 miles
1 mile	=	1.609 km
1 meter	=	3.281 feet = 39.4 inches
On the Map		
1 unit on the map	=	24,000 units on the ground
1 inch on the map	=	24,000 inches on the ground
	=	2,000 feet on the ground
	=	0.379 miles
2.64 inches on the map	=	1 mile on the ground
1.64 inches on the map	=	1 km on the ground
0.1 (1/10) inch on the map	**=**	**200 feet on the ground, exactly (The "building block" for 7.5´ topos)**

Pacing

When navigating in conditions of poor visibility, as in a dark night or a heavy whiteout, one must move from one point to another, keeping the segments short, limited to what visibility allows. In such conditions the ability to estimate the distance traveled by counting steps can be useful. This works best over nearly level or slightly undulating terrain. Here the word "pace" means the length of a step in walking-left foot to right foot. If one's pace is about 2.5 feet long (typical), every fourth pace marks 10 feet. Counting every fourth pace as 1, 2, 3, etc. is easier to keep track, and then multiply that number by 10 feet to get the paced distance. After a predetermined count is reached, say 100 (or 1000 feet), a second person is signaled to keep track of the 100s, and you can start counting fourth paces over again. Some military recon teams use this technique. Each individual must find the typical size of his or her own pace (that is practical to use) and own technique for keeping track of it.

usually improve accuracy of the location. The three bearings will ordinarily not intersect at the same spot but will create a bearing-bounded triangle (called an "error triangle" or "cocked hat"). The best location estimate might then be in the middle of the triangle, depending on the relative accuracy of the three bearings.

Navigation in terrain with distinctive relief with USGS maps and a compass can be done with good precision. Most of the time people achieve reasonable accuracy in taking bearings within two to three degrees. Following a bearing with an error of about three degrees will result in an offset of about 300 feet per mile. Errors of this order can to be expected when navigating over featureless terrain (desert, snow fields, etc.) with the aid of compass bearings. From a known location on the map, a bearing may be measured from the map, and the compass can be used to locate accurately the feature in the field. Conversely, a bearing may be taken to an unidentified physical feature and then plotted from the current position on the map to identify the feature in question.

Route Following

The best way to follow the planned route is to keep track of location on the map at all times, i.e. "to stay found."

A leader should look at the terrain, recognize the features on the map, and carry a mental image of movement and location on the map. Carrying the map close at hand and looking at it often, the leader is able to read the minor features shown by the fine detail in the contour lines. Trip planning and scouting the trip can be very beneficial in enhancing these skills.

Selecting visual terrain points (attack points) to walk toward for the next trip leg of the trip plan is a useful procedure. Switchbacks and other local trail wanderings are ignored in this process; it is the general trend that counts. The navigator picks out a clearly visible point on or near this trend line as an attack point and proceeds toward it. Desirable features of an attack point are that it is actually near or on the route, can be kept in view en route, and is identifiable once it is reached. If the attack point cannot be kept in view, pick a closer in-line object to serve as a local heading reference towards which the route can be directed for a given distance.

A navigator should always think ahead and predict future terrain features based on distance (or time) from a known or presumed position. For example, when hiking on a trail through timber in the western Sierra at an estimated speed of 3 miles/hour, the group crosses a small stream that they believe they have correctly identified on the map. About one mile farther the map shows another small stream crossing the trail. The leader thus predicts that the second stream will be reached in twenty minutes. The time is noted, or the stopwatch started, and if in fact a stream is reached in about twenty minutes, the leader has a strong confirming clue that the original identification of the streams and the group's previous and current positions are correct.

Dead Reckoning

Dead reckoning is the process of moving from a known point for an estimated distance in an estimated direction to reach a desired destination without visible clues along the way. The process may be done in distance, in direction, or in both. Dead reckoning is used in featureless terrain or at times of limited visibility, but can also be useful in general, even hiking along a trail.

Distance traveled is most easily obtained by estimating one's speed of travel and multiplying by elapsed time. For directional dead reckoning with limited visibility as in timber, darkness, or fog, navigators must carry a compass in hand and walk as closely as possible along a compass course. It helps to pick out an object, such as a tree or rock, which lies on the compass course and is as far ahead as visibility permits as an attack point and to walk to the object. The process is then repeated. This method gives greater accuracy than trying to follow an exact compass course, and it allows one to pick a good path and to move around obstacles. When moving over a snowfield in a fog, it may be useful to send another person ahead to the limit of visibility and then to move to the person and repeat the process.

As an example, a leader descends from a desert mountain at dusk. The automobiles are known to be out on the desert one mile away at a bearing of 85 degrees. The leader estimates that in crossing the desert, the group will move at 3 miles/hour. The leader sets the compass dial at 85 degrees, notes the departure time on a watch (or starts a stopwatch), aligns the compass needle, selects a large rock (still visible) about 1/4 mile away to home on, and starts off. After about twenty minutes of walking with a few more homing points, the group should encounter the vehicles. A better technique, however, would be to offset the chosen direction deliberately, say to 80 degrees; then there would be no doubt about which way to turn (to the right) when reaching the road. The cars would be reached about 500 feet further.

A Compass Technique– Bearing of a Local Route Segment

Navigation technique frequently is most needed in conditions of limited visibility such as in a forest, in fog, or at the bottom of a gully or valley, and especially when the leader has lost track and is not sure of his or her position. For these cases, a useful technique is to measure the bearing of the local route one is following, such as a segment of a ridge, dry creek bottom, trail, or hillside slope as a check on the presumed position. If the leader has fallen behind in the position-monitoring task, he or she may examine the surrounding terrain, take an altitude reading, and search the map for a segment with corresponding bearings or other attributes to reestablish his or her position. Also, one may ask for information from the group.

Updates along the Way

Dead reckoning and the compass-based techniques can lead to lateral drift in position as time goes by. The perceived position can be reset to actual position by using one or more of the position fixing routines. Reaching predicted attack points, monitoring the altimeter as particular altitudes are passed, and recognizing particular small-scale landforms such as gully crossings can serve this purpose. The focused leader will take advantage of any break to establish a new fix. Indeed, break locations are often planned with this in mind.

ROUTE FINDING

Leading

In the field the ability to choose a good path along a planned route grows with experience. The terrain visualization phase of the trip planning serves to put the big picture of features such as major ridges, canyons, and roads well in mind. The leader can do such good things as be alert, look around, and try to register the terrain in one's brain. Develop a two- or three-dimensional image of the terrain. Grow beyond the one dimensional, head-down, trail- or compass-following mode. The big picture in reality can often dissolve into a mess of local terrain features dominated by brush, rocks, dry waterfalls, washes, and other terrain features. These have scales that are less than a contour interval and do not show up on the map. Probably because maps do not reflect and even written guides often ignore these features, they often come as unpleasant surprises. Fortunately, with experience, one can develop a sense of the terrain from a quick observation and pick a reasonable path through brush, over talus, or up a ridge.

The "reasonable path" is actually selected by assessing the perceived possibilities. Some guidance for selecting the detailed route might be provided by past experience with different types of terrain and vegetation coverage. For essentially identical plan and profile view but different ground cover, the relative times to progress over a given plan segment could be significantly different. These unexpected conditions are not foreseen in the trip plan but should give motivation for the leader to examine alternative routes at the scene.

When attention must be devoted to solving immediate small-scale problems, the leader still must keep the big picture in focus. If for some reason the leader falls somewhat behind in knowledge of the group's exact location on the map, the position should be reacquired and verified by taking a fix at the next convenient break. On some terrain even relatively slight departures from the desired route are embarrassing at best or near catastrophes at worst. On peak climbs these often occur on the descent and can be as apparently innocuous as making (or not making) a slight turn that results in being on the wrong ridge. Even experienced leaders have made major errors atop rounded and forested peaks with no conspicuous trails, where "down" is in all directions or when clouds block all views. A back bearing here can be essential to find the right way down.

Being concerned about the return trip, on the way in the leader should stop, look back frequently, and make mental notes of key turning points. Written notes as to appearance, time, location, altitude, and other cues can help, as can leaving route markers as appropriate, such as ducks, branches, marks in the dirt made by hiking poles or other objects, and wands (all removed on the way out). Best is to record some return bearings.

In the Sierra a leader need not worry about momentary loss of the trail. If correct about the general route of the trail, one will find the trail in good time. This is an example of the old saw "Where would I go if I were a trail?" or "If I go where it makes sense, the trail will find me." On the other hand, for some local peaks on the Hundred Peaks list, staying on the route can be critical to minimize lengthy encounters with brush. A major factor in establishing HPS routes in these cases is avoidance of brush, so the route can sometimes proceed seemingly all over the place.

A leader must keep the group together and maintain visible or audible connecting ties to the rear leader (the sweep), particularly at turning points where people may go astray or with use trails that do not appear on the map or in guides and that may be misleading. Walkie-talkies are very useful. Every thirty minutes or so, one may let the rear catch up and verify that all is well. Because large groups have a peculiar tendency to spread out over the landscape during the last stages of trips proceeding across relatively flat terrain, the leader should take special precautions.

Techniques

Depth perception as to ridges and gullies can be gained by moving back and forth a few feet or by walking a few tens of feet and noting how terrain in front seems to move relative to terrain behind. On exploratory trips the seasoned members of the group may help solve the immediate problems. The leader may send out scouts as appropriate to find the best local route but should maintain control by telling them how far to go, when to come back, and how to communicate.

One must be especially careful in descending ridges to keep to the correct ridge at branch points; a mistake of a few feet at a branch point high up can lead to a mistake of a few miles at the bottom of the mountain. Streambeds diverge going up, and choice of the wrong gully can lead to a surprise at the top of a secondary ridge far from the summit objective.

A number of other techniques aid in "staying found": keeping a sense of direction and route always in the forefront; learning to track footprints and to follow one's own footprints upon return; knowing how to recognize the Big Dipper and locate the North Star; and making use of the fact that the morning sun is in the east, generally due south at local noon, and to the west as the sun sets. If one has an analog watch or a reasonably good spatial imagination, one can point the standard time hour hand at the sun to find south, which will be half way between that direction and 12

USEFUL NAVIGATION HINTS

1 For visual scale reference in the area traveled through on a 7.5′ topo, draw a line 1 mile long (2.6″), and divide 1″ of it into 10 parts, each 1/10″ long. These "building blocks" of 1/10″ equal 200 feet exactly.

2 At arm's length, index finger width subtends 1.5° to 2°, and a pinky subtends 1° to 1.5°, unique for each individual. Use what fits you.

3 One degree at one mile distance subtends 92.4 feet of linear distance, or approx 100 feet. A 3° compass error at 1 mile results in approx 300 feet linear offset for location error range.

4 At this time (2015), declination at Joshua Tree NP is 12°, at Mt. Wilson is 12°, and at Santa Barbara is 12.5°.

5 The North Magnetic Pole is in Northern Canada and moving to NNW, at double the historical rate since 2000. Currently in Southern California that translates to a declination decrease of 1° about every 12 years.

6 Take a set of three independent bearings of the same object. The resulting spread in degrees is a measure of your compass use accuracy. Also, the average of your three bearings results will tend to be more accurate than any single reading.

7 After taking a bearing in the field, point the compass back at the object to see how close to the object the bearing points. Use finger technique (2 above) to estimate degrees off.

8 For any good compass, the most import feature is a free and easy dial movement.

9 When the compass is laid on a topo, the magnetic needle "disappears," i.e. it becomes useless. There is one exception—when you are using the compass to orient the map to true North.

10 Bearing taken on a topo with N-S lines using the compass as a protractor is always accurate for identifying the correct object in the field. Bearing taken of object in the field using the compass as a magnetic instrument will almost always be less accurate.

11 To locate one's position in the field on a topo, the closer an object is, the more accurate its bearing will be for locating it on the topo.

12 When triangulating with two bearings, choose two objects whose lines of sight from your position are as close to 90° apart as possible.

13 On a topo, a single closed contour line may represent a terrain feature anywhere from 1 foot to 79 feet high. That feature is always visible, especially close by.

14 To locate and go to a destination object in the field, follow its bearing from the topo. Visually pick out a distant terrain point and walk toward it (don't lose sight of it). Then on the topo, take a reference bearing from the destination object to another object that is nearly at a right angle to the path traveled. Following the path direction, periodically check to see if the reference bearing points to the reference object yet. When it points to the reference object, you are at your destination.

15 Man-made features can and will change over time, but even a recently revised topo may not show the latest additions or deletions. An example is the North end of Boy Scout Trail on the Indian Cove topo.

16 Highlight or color-dot prominent high points on the topo that are most likely visible to the eye. This allows for easier N-S alignment of the topo and facilitates timely terrain recognition.

17 To keep a topo easily N-S aligned, draw a N-S line on the ground with a hiking pole or your boot. The topo N-S lines can then be quickly and easily aligned with the line on the ground.

18 When N-S lines have not been drawn, a map may be folded accordion style parallel to the edges, so that the folds represent N-S lines.

19 When using a topo for terrain recognition, always have it essentially N-S aligned.

20 For any UTM Region, the UTM grid N-S lines are true north only at the centerline of the region. Moving outward, they diverge to about +2.5° on the west border and to -2.5° on the east. UTM lines can be used as N-S lines for the compass, as long as the compass declination is adjusted for the UTM N-S line divergence. To west of the centerline, the UTM angle (GN on the topo) is added to the topo declination. To east of the centerline, the UTM angle (GN on the topo) is subtracted from the topo declination.

21 For 7.5' maps that do not have the UTM grid overlay, the UTM lines (instead of N-S lines) can be drawn in using the tick marks at the map edges. For accurate positioning on a UTM grid, use UTM templates or scales that provide N-E location accuracy to 1 millimeter (better than 1/20 inch).

22 Maps may be carefully folded at the edges and taped together with write-on tape on both sides. Do not cut off the map edges. Write-on tape permits lines to be drawn on the tape when plotting near the taped edges of the maps. It is almost impossible to do terrain/map recognition, to plot bearings, or to estimate distances when the maps are not taped together.

23 It is best is to fold the map to show the specific area of interest and then change the folding as the trip progresses. A map which is quickly available and needs no unfolding, especially in the wind or rain, is most useful for route following. Special map holders, available at outdoors stores, are designed to protect maps from abrasion, wind, and water while being viewed. Re-sealable plastic bags work too.

24 Copy Fig.6-4, Contour Line Spacing of Slopes onto a Vu-graph transparency. Then cut out and trim the contour spacing area to use as a template for overlay on a topo. When the template is overlaid on any topo contour lines, select the best spacing match to determine the angle of the slope on the topo.

25 The trail or dirt road dash marks on a topo are 151 feet point to point. There are 35 of these to the mile.

26 There are map-measuring devices which utilize a little wheel to trace a route and measure its distance. A calibrated readout wheel shows the distance on maps of various scales.

27 When the sun is highest around local noon, the shadow of a vertical stick points to the north.

28 At equinox in March and September, the sun is above the horizon for twelve hours. It rises at 90° East and sets at 270° West.

29 There is a natural 3:2 rule for going up a steep hill, versus coming down the hill. If it takes three hours to reach the top, it will take about two hours to come back down.

30 If you know where you are on a map but you don't know what the declination is, here is how to find it. First take an accurate magnetic bearing of an object (align the needle with the dial meridian lines). Then, on the map take the geographic bearing from where you are to the object. The difference in bearings is the declination.

31 To improve depth perception between two objects in the field, move alternately to the left and right, while observing the relative movement of inline near and far objects.

o'clock. The leader needs to keep track of how the margins built into the original pre-trip plan are faring, especially time. On longer day trips be aware of the time of sunset—information readily obtained from newspapers, weather reports, internet resources, or from most GPS receivers. Near the end of the day, the daylight time remaining can be estimated by measuring the distance of the sun's path to the setting point on the horizon in portions of four-finger hand widths. The width of the four fingers of the hand at arm's length is approximately 6º to 8º, depending on a person's width of fingers. Since the sun moves fifteen degrees/hour, each four-finger width corresponds to about 30 minutes of sunlight. It is important to remember that the sun approaches the horizon at an angle. So the 30 minutes four-finger width is measured along the path of the sun.

Stress and Emergencies

It is important to recognize that navigating becomes much more difficult under stressful conditions. Stress may occur in the leader for a variety of reasons: the party is delayed and darkness is near, the trail on the topo is wrong, the map tore or blew away, leader and party fatigue has set in, or someone in the party may challenge the leader and create uncertainty as to the location and route. Stress may destroy memory and make judgment faulty. Fatigue and stress are most manifest mentally as a reduction in one's capacity to pay attention to more than one thing at a time. Consequently, the leader must consciously work to keep cool, clear, and focused. It helps to take time, write things down, and consult with experienced and knowledgeable people in the party. Experience and preparation are the best preventatives for stress, and practice is the way to obtain experience. For example, one may practice navigating while pretending that the map or compass is lost.

If, notwithstanding trip planning and attempts to keep track of the group's progress, the leader becomes unsure of the group's location, he or she should stop and analyze the situation and not count on luck or rely on "gut feel." One should study the map and try to reconstruct what might have happened, then form hypotheses as to position by methodically looking for a match between the observed terrain and a corresponding place on the map. To get a different view, one may climb a rock or a nearby hill or send out a few group members for a short look around. One should use all available navigational techniques to support one another. Navigation is a gathering of clues, and redundancy of information is good. Does all of the evidence about position add up—bearings to features, altitude, terrain shape, gradients of local slopes and pathways of the immediate past, distances to features, size of features, bearings of local route segment, successive fixes along the route? Then, after concluding that it all adds up, the leader can compose a plan and try it out on other experienced and knowledgeable members of the group. Throughout the situation, the leader needs to maintain control, communications, and composure. Resist snap decisions and think it through.

Expect Error

Seasoned leaders recognize that none of their instrumental measurements is error free and that small errors uncorrected can, over time, turn into large errors. The most effective means to compensate for error buildup is to make appropriate fixes. These are times when a GPS receiver can come into its own.

Other methods help compensate for error buildup. Under many circumstances the easiest is to live with it, as when the group is returning to the (unseen) cars parked at the end of a desert road and the leader uses a bearing offset to assure that the group actually hits the road. When an objective is an obscure point rather than a line, the leader may use the group as a resource. When near, but somewhat before reaching the estimated point, the group may spread out, say, five scouts in a line abreast at thirty feet apart and proceed. This procedure can compensate for about a 200-foot (1/10 inch) error on the topo. The spacing and number of scouts can be adjusted to suit the circumstances. If a group approach is not pertinent, a solo search procedure can be conducted. One strategy is to start at the best-estimate location, then walk north for ten paces, east for ten paces (25 feet), south for twenty paces (50 feet), west for twenty paces (50 feet), north for thirty paces (75 feet), adding paces in this expanding pattern until the point is found. Depending on the nature of the point and circumstances, the pattern increment, e.g., ten paces in the example, can be reduced or increased. Also, when other help is available, more people can be recruited to broaden the pattern.

TRIP/ROUTE PLANNING

Trip planning is essentially an exercise in foresight by identifying possibilities and their associated pros and cons and deciding among the alternatives. A good leader selects reasonable objectives, achievable by reasonable routes. The process begins with terrain familiarization to set the scene and view the physical constraints; then proceeds to the route planning needed to get from A to B with safety, efficiency, and maximum enjoyment; and ends with contingency possibilities, developed to try to address unexpected but possible events. In developing route possibilities from the map, the planner can consult other information sources, including guidebooks, DPS and HPS guides, trip reports published in GSC newsletters, and hearsay; other maps, such as big-picture maps and those that show local interest; and trip-specific factors like the historical, natural history, geographical or geological aspects. Best is to scout the trip in advance. If this is not feasible, sources such as the above are invaluable—and can identify leaders who have recently led the same or similar routes, so they can be contacted for up-to-date information.

Terrain Visualization

On the map the leader initially locates points A (start) and B (goal). Then the planner carefully studies all the features and aspects between A and B presented on the map(s) and in other available material to develop a mental picture of the territory and its characteristics. Indeed, reading a topo map—that is, converting the map images to a good mental image of the terrain—is the heart of route planning. The converse skill of viewing the terrain and correlating this with the map is the heart of navigation by inspection. Both skills are complementary and require practice at the desk and in the field.

Software can be a great aid for terrain visualization with neighboring maps connected seamlessly, local regions magnified at will, and physical size of the areas depicted on the computer screen readily changed. Some programs even provide 3-D viewing under different lighting conditions, side by side with plan views. The planner may see the bigger picture either by zooming in and out of different scales on the computer-generated maps or by comparing the printed 7.5′ USGS map with a larger scale map which shows a broader area in less detail.

The topographic map of Figure 6-2 shows some of the distinctive landforms typical of the San Gabriel range as well as the trails to Mount San Antonio and beyond and the road through Manker Flat from Baldy Village. Cut by intermittent streams and having steep sides, the gullies exhibit the characteristic sharp uphill pointing V's on the map. The ridges, however, may be quite rounded and appear as downhill pointing U's. A similar map for the High Sierra would appear as the converse, because the principal water courses (basins) were cut by glaciers and appear as broad U's, while the ridges are frequently very narrow and appear as sharp V's. The map clearly illustrates the features of converging gullies and diverging ridges going downhill, and the converse going uphill. These are major factors to be considered in route selection.

The east-west ridge along which the trail runs dominates the general shape of the terrain in the upper middle of Figure 6-2. Small closed contour lines marking a high point are represented at West Baldy, Mount San Antonio (Mt. Baldy), Mount Harwood, and others. These peaks are further noted as high points by their elevation notations, the triangle and bench mark on West Baldy, and the x on Mount Harwood. The saddles on the ridge on either side of Mount San Antonio illustrate a characteristic necked-down appearance with contours showing high points on either side and with contours showing draws in the perpendicular direction. Other characteristics to grasp are the distances to landforms and relative elevations. For example, the map shows that Mt Harwood is about 3/4 mile (1.25km) distant and about five hundred feet lower than Mount San Antonio. When correlating the terrain in the field with the map, one should verify the presence of all of these clues.

On the color version of the map, some gullies are shown with blue line symbols for intermittent streams. This symbol is used for the more important channels in a given watershed. Most of the time in Southern California and the desert regions, no water is in any of the intermittent streams. The canyons without this marking, furthermore, may be just as prominent from the ground as those that have the marking.

Route Formulation

Route Formulation Principles–Generalities

If good route descriptions exist in reliable guides, leaders usually follow the guide. Typical local hikes and standard route HPS and DPS trips tend to fall into this category, as do trips described in the local and regional hiking guidebooks. Even in this case it is wise to plot the trip on the topo, noting roadheads, trail junctions, clearings, stream crossings, passes, and other major waypoints along with some time estimates. When actually conducting the trip, the leader should use these places as checkpoints as they are passed.

Other more navigationally intensive trips–such as in pathfinding, exploratory, or adventure hiking to new areas where specific route descriptions do not exist—require more attention to route planning.

Some general travel considerations that can be helpful in laying out possible routes include the following.

Choosing Available Trails–Any trip segment that can be done on a trail will almost invariably be less strenuous and demanding than a cross-country equivalent. Also, on trails accurate location-estimation as the actual trip progresses ordinarily requires the leader simply to pay attention to the time and have some appreciation of the average speed. Location-fixing is also simple when the group is on a trail.

Minimizing Encounters with Brush–The green colored vegetation-type-coded symbols on the map can generally be relied on to differentiate between scrub and woods, although not necessarily to the vegetation density.

With mountainside chaparral southern exposures are usually worst. Snow may cover the brush deeply enough for snowshoe travel.

Minimizing Side-Hill Travels–Side-hill traverses can be very tedious, slow, and even dangerous on steep terrain. Because they often involve much moving in and out of small gullies, traverses around in-route high points can be longer and more time consuming than a direct route over the top.

Considering Gully Routes–Gullies, including intermittent streambeds, are sometimes good travel possibilities. They tend to be more chaparral free than surrounding slopes, especially on northern exposures. Gullies provide route segments that are readily identified on the map, and they tend to have a steady gradient. The downsides of gully travel can include willows and other brush that may be present near water and unexpected dry water falls (common in the desert). Dry waterfalls can be very steep, are often quite slick, and may not show up at all on the contour map because they may be less than the contour interval in height. Gullies near and beyond the angle of repose may have rock fall problems, so careful attention should be paid to the slope angles. Finally, because gullies and streambeds diverge going up, the choice of the wrong branch can lead to unhappy consequences higher up. The conjunction of two gullies can be a crucial transition point for a route and should be defined on the route card by location and the bearing of the correct branch.

Considering Ridge Routes–Ridges are likely to be relatively brush-free and provide route segments that have one line that is readily identified on the map. Possible downsides include rocky ways, uneven and awkward terrain, impassable gendarmes, and significant exposure, especially in the Sierra. Ridges can be very unpleasant or even dangerous in the wind or bad weather, especially when lightning is about. Just as with gullies going up, diverging ridges going down require attention to assure that the right one is selected. Again, the conjunction point can be a crucial location point for the route card. Going down the incorrect ridge can be a major error.

Noting Water Sources, Good and Bad–Water replenishment sites can be helpful by reducing the water-carrying needs of the party. Because getting across larger streams can be crux points for an entire trip, crossings must be thoroughly planned. Bridges can be a great boon and may be worth miles of extra travel under high water conditions. Stream flow is shallower and slower where the stream is wider and has a lower gradient, factors that should be considered when locating a potential ford. Preparations for spring and early summer crossings of most Sierra streams and some others should include safe crossing procedures.

Planning the Return Trip–For starters, the back bearings immediately off the summit and to the roadhead should be noted for possible routes. Terminal route segments over featureless ground (like the desert) should be set up with an offset to an appropriate side of the starting point. When a GPS is available, the roadhead location can be very useful both at the start of the trip, to be sure one is really at the desired point, and at the end of the trip to the cars.

With these considerations and the terrain visualization, the leader may sketch out some possible routes. This process is aided by mentally progressing along each route, following the ups and downs, switchbacks, and ridge and stream crossings along the way–virtually hiking on the map. This thought process should also pick out orientation and route following features as possible navigational clues, clue sequences, trail junctions, check points, bearings to conspicuous objects, and back bearings that become available as one progresses along the virtual route. A leader should remember to include the small-scale features, such as gully crossings of a trail, where the trail line and the gully line define a fix, or the more gross aspects, such as switchbacks in number and sequence. Some of these points may have even greater possible value in anticipation of reduced visibility or bad weather. A catalog of the more prominent and potentially useful of these cues and clues of the virtual trip may be entered on the possible route card.

Route Formulation Principles–Details

Underlying Criteria

The most desirable route for a group is one that best satisfies the following criteria:

- **From the group's standpoint**, the selected route should proceed from A to B with safety, efficiency, and maximum enjoyment. The route must be compatible with
  1. The number in the party (without doubt, the most important and yet often the most neglected factor in mountain safety);
  2. The varieties of experience and physical condition of party members;
  3. Time constraints on the trip;
  4. The motivating objectives of the trip, like a peak climb or observation of special natural features;
  5. Projected weather variables and minimum conditions.
- **From the leaders' standpoint**, the selected route should permit a continuous high level of situation awareness. In other words, the leaders should always be aware of
  1. Current location on the map,
  2. The group and individual status,

3. Appropriate steps and alternatives to cope with the unexpected.

Trails with many junctions, routes with lots of stream crossings, or routes in heavy forest or brush can give the leaders of large, diverse groups some real challenges in keeping the group together or even maintaining a good appreciation of the group's status. The possibility of unexpected events—such as lost or strayed participants, injuries, etc.—is always present and needs to be foreseen as part of the visualization process.

The visualization process outlined above will ordinarily result in one or two feasible route possibilities, usually with one obvious favorite. The rest of the job is to finalize the details. These are covered below.

Layout of the Route on the Map and Development of Trip Statistics

The projected route should be drawn (or at least sketched out) on the map. For standard routes the DPS and HPS guides are excellent. These guides and associated topo maps ordinarily provide good starting points. Although of great value to the leader-planner, the existence of these guides can foster complacency; to be prepared, the leaders should still go through the route visualization and other preliminary steps carefully.

When more elaborate logistical plans are called for, the leader must start afresh with the maps and other pre-planning tools. This used to be a tedious process: maps were often meticulously joined to provide a seamless character, while route possibilities, distances, bearings, and profiles were fiddled with manually. Now all the manual details can easily and rapidly be accomplished with the software aids. Ideally the route should be detailed in both plan and profile views, although only the plan view is essential.

Plan View Features–Focus on trail(s) directions, junctions (including where the other trails go), major direction changes; natural or artificial waypoints; switchbacks; stream crossings; special observation points; potential rest or renewal locations; and similar points.

Marking the map with colored dots or "flags" at key points, such as tops of surrounding peaks or other visible high points can provide helpful references to aid location awareness on the trip. They can also be valuable references for rapidly aligning the map to the terrain and can provide a sequence of UTM coordinates for possible use with GPS receivers.

Handrails–In some cases possible routes can be referenced to so-called navigational "handrails." These are usually linear features on the map that lie in the right direction or orientation to be used as navigational aids or as occasional confidence builders that one is on route. Trails, ridges, and gullies are obvious examples (and may even be the route); fences, power lines, borders of fields, valleys, streams, and edges of lakes or marshes are other possibilities. Handrails can be helpful in maintaining location sense and general situation awareness. Marking the map to focus on the trends of such dominating major topographical features as ridges helps to identify potential handrails and the development of a big picture visualization of the terrain.

Finally, for backup purposes it is desirable to have a catch line (sometimes called a baseline). This is an unmistakable line, such as a road, power line, river, or lakeshore, of broad extent that lies across the trip's general direction and is thereby more or less always in about the same direction from the trip's route. Following a bearing to the catch line is a last resort when otherwise hopelessly lost. It shouldn't happen but has, especially in heavily forested areas.

Profile Features–The trip profile depicts the route in the vertical plane, essentially a plot of altitude versus distance. Such qualitative profile features as saddles or ridge crossings, stream (or gully) crossings, major gradient changes, or gradients of steep sections can all be identified from the map itself. The profile adds the quantitative details. A detailed examination of the contours enables one to select the least tiring line up a mountain. It also provides an appreciation for the shape of the land forms as seen along a specific route. Although somewhat more subtle, gradient changes can be properties of a desired route just as trails are in the plan view. The route profile provides all sorts of valuable information, including route gradients; changes to average gradient as clues for real-time progress and orientation, even as potential route markers; and actual elevation increments for energy and timing estimates along various trip segments.

Trip Statistics–The distances and elevation gains on segments of the trip are the usual quantitative descriptions of the trip. These can be obtained in various ways. Distance along trails may be obtained from published information. For cross-country or mixed routes the simplest and most accurate procedure is to use the features of mapping software programs.

Distance–Distances can be measured from the route traced on the map using several techniques. One common scheme is to break up the route into approximately linear segments and then use a ruler-like strip of paper or dividers (from a drafting set) to add up the several segments. The total length is then converted to miles or kilometers using the scales on the map. Another method uses a map measurer, a tiny wheel with dial scales calibrated to convert map lengths to actual distance at several map scales. Rolled along the route on the map, these miniature wheel measurers have the advantage that any highly curved sections of the route can be followed without appreciable error. The dashed lines depicting trails on the map provide another way to measure distance because there are about thirty-five trail dashes per mile (twenty-two trail dashes per kilometer). These are not always easy to see, but can sometimes be of value in making distance estimates. With 1:24,000 maps the map scale is small enough to show trails accurately with quite fine resolution. Therefore, all but the shortest switchbacks and other small details are usually represented, and distance measurements as reflected onto a flat plain surface can be quite accurate.

Because the distance measurement is of a route projected onto a horizontal plane, any slopes encountered will increase the actual distance. As an extreme example, consider the direct ascent up a slope of 34º, the angle of repose. Here one would travel about 20% farther than the horizontal distance. For travel on an 11º grade, the additional horizontal distance can be ignored. This disparity is not present with mapping software where the profile data gives actual distance as well as horizontal distance.

Elevation Gain–The elevation gain is the second major trip statistic, easily computed by mapping software. Otherwise the development of a detailed profile (see Trip Leg table) can be quite time consuming. One may manually construct a terrain profile or simply progress along the route on the map and tabulate all the major uphill segments using the contours. The altitude loss is not considered (although the loss will become a gain if the route returns over the same ground).

Putting It All Together

With the entire physical route, trip visualization, and key factors developed, sufficient information is available for final route assessment. At this summary level

- The physical route—general description, plan, and profile views—is in hand;
- The crux points, the key transitions in the route—such as trail to cross-country, branch points in diverging ridges and gullies (complete with bearings), trail junctions or other locations where confusion might develop, stream crossings, and rockfall or exposure areas—have been identified;
- Handrails and perhaps some attack points may have been identified.

Considering the crux points and other characteristics of the route, the planner can finalize the route details and markers. Some of these transition and/or crux points may also be candidates for GPS waypoints. One should include route markers that can be useful for mid-course fixes or in emergencies. The route markers should then be formally incorporated into **trip leg table**.

Estimates of Time, Speed, and Distance

In trip planning and in some aspects of field navigation estimating the time required to travel a given distance or, conversely, to estimate the distance traveled in a measured time is desirable. The basic technique is the same; one estimates speed and divides it into distance to obtain time required or multiplies estimated speed by measured time to obtain distance traveled. For this reason, a watch is a vital navigation instrument.

Time can be determined from the trip plan statistics. Rest stops, lunch breaks, signing peak registers, and other stops need to be added. Five minutes per hour may be sufficient for breathers for tigers, but ten minutes is more realistic, with 15 to 30 minutes for snacks and lunch.

Formula times should be increased for long trips to account for fatigue as well as squiggle factors such as brush, soft snow, talus and scree, high winds, swamps, downed trees or brush, and avalanche path debris that will slow the speed and increase the time considerably. Times for fighting through thick brush or floundering through deep snow could be four hours per mile or more.

Besides fitness levels, individual differences among the participants can significantly change the trip time required. Speeds for descending vary considerably among individuals. A group which might vary 25% in ascending time could vary 50% or more in descending times, depending on the terrain and the group. This is partly the effect of relatively greater fatigue on the weaker participants. Individuals also vary greatly in their ability to descend talus blocks, loose scree, and snow slopes. Generally speaking, the larger the group, the longer the trip time; an approximate time addition is one percent per person. For a group of twenty-five people, the total trip time should be increased by about 25% over that estimated by the formulas.

Bottlenecks can further add a major amount of time for a large group. For example, thirty people each taking two minutes to cross a stream will add one hour for zero distance traveled. Fifteen people each taking six minutes to be belayed up and down a twenty-foot 3rd-class pitch will add three hours to the round-trip time.

In arriving at time estimates, navigators should measure their own performance under various conditions in order to calibrate themselves relative to the simple procedures. Because so much of navigation in the field relies on dead reckoning (speed x elapsed time), navigators should also develop their skill in speed estimation. It is often convenient to think of speed in terms of minutes/mile or minutes/kilometer. Thus, 3.0 mph is twenty minutes/mile or fifteen minutes/kilometer. A kilometer is the distance equal to one side of a UTM grid square.

Some general caveats are necessary. First, all of the schemes use formulas, which have been simplified by using rounded off approximations, which are good enough. Second, because of the variables of the route conditions and group effects on speed, the estimates can provide only rough guidance. And third, the most important variable not included is the leader-planner's own judgment and experience. Stated another way, time estimates can be made for a particular trip using all the schemes; the estimates will all be different; and, most likely, all will differ in detail. But they will provide a pattern that, when leavened with the leader-planner's past experience and judgment, permits a decent estimate to be made prior to the trip. Again, this estimate can be logically modified during the trip to account for the real situation. One must not take any one estimate or plan too seriously.

Naismith Rules

The Naismith Rules are used to estimate the time it takes to do a trip or a trip leg for hikers or for backpackers. They consider both distance and elevation gain. The Naismith time is accurate when it is possible to walk over unobstructed firm terrain in a straight line or on a good trail. Otherwise, additional time must be considered in addition to the Naismith Rules. This additional time accounts for terrain difficulty and is estimated separate from the basic Naismith Rules by utilizing the Squiggle Factor below.

Naismith Hiker Rule

The Hiker Rule estimates the time to travel a specified distance and climb a specified elevation gain when traveling on a good trail carrying a typical daypack. It assumes a rate of 3 mph, plus another hour of travel time for each 2,000 feet of altitude gain. As a reference time to build on, it does not take into account off-trail (cross-country) travel and other factors. The terrain difficulty requires additive times to the Hiker Rule and is addressed via the Squiggle Factor. The Hiker Rule is

$$T = D/3 \text{ mi} + H/2{,}000 \text{ ft.}$$

T is time, the distance is expressed as D for all types of travel, and H is elevation gain (uphill only) in thousands of feet. D/3 means travel is at 3 mph. H/2,000 means an elevation gain of 2,000 feet adds one hour of travel time. The altitude term should be ignored for downhill segments, but the downhill terrain difficulty is addressed by the Squiggle Factor.

Naismith Backpacker Rule

The Backpacker Rule estimates the time to travel a specified distance and climb a specified elevation gain when traveling on a trail carrying a typical backpack. It assumes a rate of 2 mph, plus an hour of travel time for each 1,000 feet of altitude gain. As a reference time to build on, it does not take into account off-trail (cross-country) travel and other factors. The terrain difficulty requires additive times to the Backpacker Rule and is addressed via the Squiggle Factor. The Backpacker Rule is

$$T = D/2 \text{ mi} + H/1000 \text{ ft.}$$

Again, T is time, the distance is expressed as D for all types of travel, and H is elevation gain (uphill only) in thousands of feet. D/2 means travel is at 2 mph. H/1,000 means an elevation gain of 1,000 feet adds one hour of travel time. The altitude term should be ignored for downhill segments, but the downhill terrain difficulty is addressed by the Squiggle Factor. The slower travel reflects the effects of carrying a heavier load.

Squiggle Factor

A squiggle factor, as used in the Angeles Chapter LTP Navigation arena, allows for considering and applying to trip planning any terrain or trail conditions that impede a wilderness traveler.

Whenever it is not possible to walk from one point to another in a straight line or on a trail or over unobstructed terrain and at a desired reference speed, we need a squiggle factor to apply in our trip planning. Since we use the Naismith Rule to estimate time, the reference speed is three mph for hiking and two mph for backpacking. The squiggle factor time is then added to the Naismith time to account for all types of terrain difficulty in the real world that we walk through. A simple Naismith time is on a good trail or over solid ground with no impediments.

The expression "cross-country" (XC) is widely used and misused. Nobody ever defines what XC means, other than it is off-trail. Hence, it is a catchall that does not mean much. Using the squiggle factor concept, however, allows planning to include specifics of real terrain. A squiggle factor can be used to account for all types of off-trail terrain. Terrain aspects that slow our progress include brush and trees, sandy ground (desert, washes, and beaches), wet or slippery ground (including scree slopes, pine needles, and wet rock), rock-strewn ground, and boulder-covered ground. Included are easy and difficult non-technical bouldering. A dry waterfall in a canyon choke point might require 15 minutes or much longer to overcome! The following are some range estimates based on experience, to be added to basic Naismith trip legs:

- Baseline is a solid ground with no impediments;
- Typical desert terrain requires a squiggle factor of 10 to 15%;
- Wooded terrain requires 10 to 20%, with slope 20 to 40%;
- Wet and rock strewn ground might be 10 to 30%;
- A sandy wash or a beach might require 20 to 40%;
- Easy bouldering might be 25 to 50%;
- More difficult bouldering might be 100+%;
- Wet rock might be 20 to 200% (or not passable at all!);
- A steep scree slope might be 50 to 100+%;
- Wet terrain is always more difficult than dry;
- Time required for significant choke points like dry waterfalls or serious scrambling on boulders can only be determined by scouting and personal experience.

As one gains experience over varied off-trail terrains in different locales, the judgment for selecting appropriate squiggle factors for trip segments becomes easier. Squiggle factors are rational estimates, never precise, and are difficult to select until you have seen the ground you will be hiking on.

Can a squiggle factor apply to trails also? Yes, if the trail is sandy, a wet grade, or rocky requiring balance and careful planting of feet, a squiggle factor needs to be considered. Just as cross-country does not describe the condition of the terrain, so the word trail does not guarantee a solid path without impediments.

Physical conditioning and number of participants are important but should be addressed separately from the squiggle factor in trip planning.

Sample LTP Trip Plan

A detailed trip plan to show Advanced (E) level LTP Navigation requirements fully is provided below. It is not meant to be a requirement in all its detail at the Basic (I/M) level of navigation checkout and certainly not for beginner-level practice. Many basic-level students will create a modified plan approaching this sample. Many others will use a less-detailed approach to arrive at essentially the same trip plan with similar results. There is no "right" or "wrong," just how well the student has thought through the route and terrain and whether one has significantly missed or underestimated the plan. That is part of the learning process.

There are three parts for LTP Navigation checkout: a comprehensive written exam mailed to candidates before the checkout, a homework assignment to prepare a detailed trip plan prior to the checkout day, and most importantly the navigation exercises in the field. The trip plan requires a detailed and well-thought-out approach, documented in three parts: first, a topo marked with the proposed trip route and any alternate routes; second, a chart showing details of distance, elevation, and time for about 15 trip legs, which describe the whole route; third, a trip-leg-elevation diagram showing the elevation profile of the trip.

A detailed homework sample that meets all current LTP requirements is shown in Fig. 6-8, Trip Route Plan; Fig. 6-9, Trip Leg Table; and Fig. 6-10, Trip Leg Elevation Profile. A blank Trip Leg Table form can be found in Appendix C. Using the Queen Mtn 7.5′ topo, the route starts at Utah Trail road, at the 2,800 foot contour line, just before the North Entrance Station of the Joshua Tree National Park (JTNP). The route proceeds generally westward to the top of the Queen Mountain range at over 5,000-foot level. It then turns northward into 49 Palms valley and down the 49 Palms Canyon to 49 Palms Oasis. From there it continues northward to the parking lot at the end of the 49 Palms Canyon Road. The general route can be reconstructed on the topo from the Trip Leg Table, by following the General Geographic Direction and Trip Leg Distance information for each leg.

Trip Route Plan

The actual 7.5′ topo with the route drawn in is shown in reduced size in Fig. 6-8. The route selected is generally based on choosing the apparently easiest approach as indicated by the spacing of the contour lines. This is particularly important not only going up the mountain but also going down through the canyons. Going uphill in a ravine with an intermittent stream may not always be best because it may contain dry waterfalls or big boulders blocking the way. Areas of relatively flat terrain are always preferred. Areas where the contour lines are very "jiggly" should be avoided, because they indicate vertically haphazard terrain that is probably difficult to traverse, like the JTNP Wonderland of Rocks. Trip legs and their length are selected according to similar terrain. Going uphill, portions of similar but not necessarily identical steepness would be a trip leg. Generally flat areas and portions of lesser steepness can be trip legs. Similarly, trip legs going downhill or through a canyon should be of comparable steepness. Generally, trip legs will be in the range of 0.5 to 1 mile. The trip should be divided into 10 to 15 trip legs to ensure that differences in terrain are adequately addressed along the route.

Trip Leg Table

The table is best constructed using a spreadsheet software application (e.g., Excel). The chart can easily

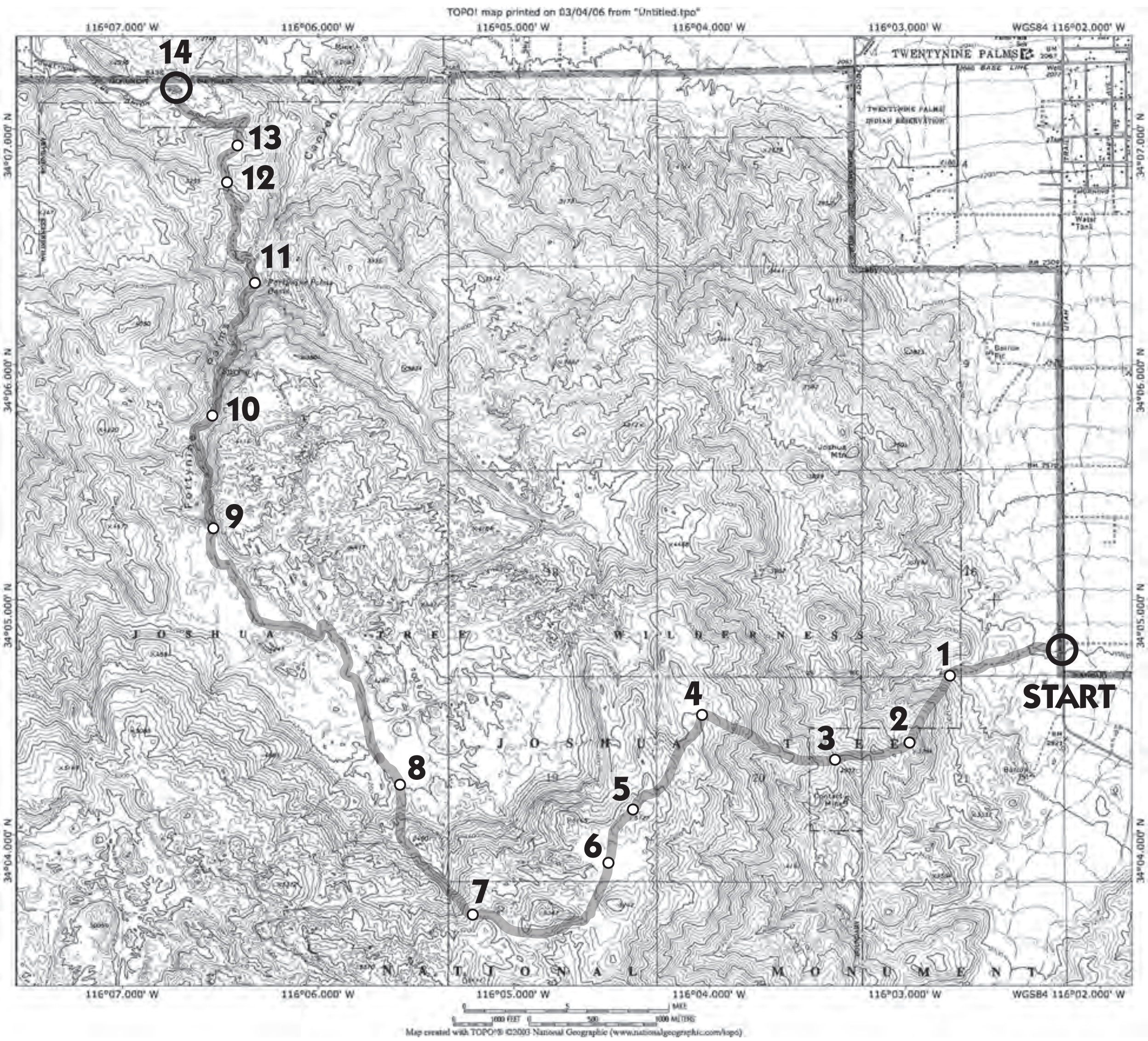


Figure 6-8. Trip route plan
A digital or hard copy of the full-size map may be obtained from the LTC Navigation Chair.

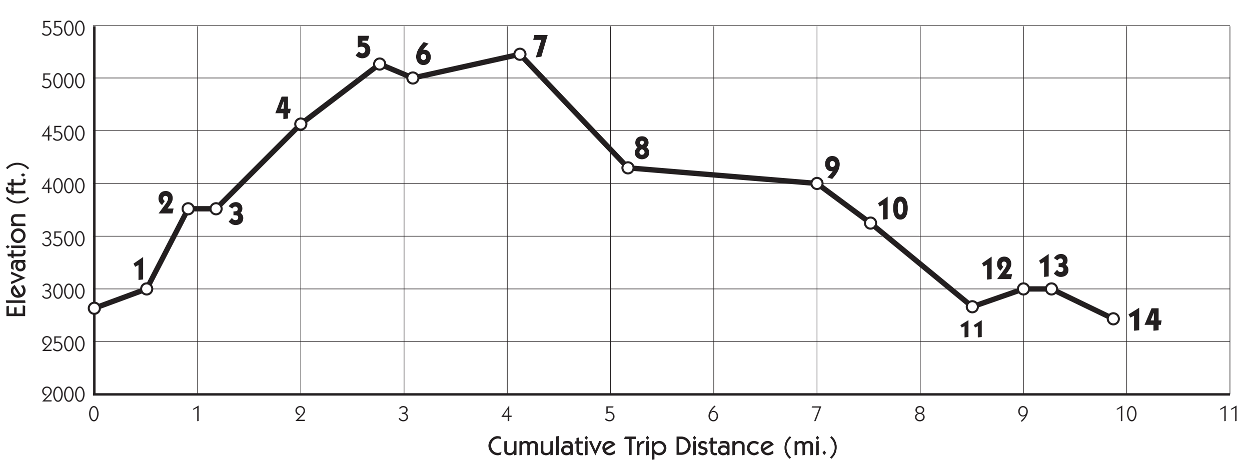


Figure 6-10. Trip leg elevation profile

Trip Leg	Description of Leg	Geograph. Direction	Leg Dist. (Mi.)	Cum. Dist. (Mi.)	Elev. (Ft.)	Leg Elev. Gain (Ft.)	Leg Elev. Loss (Ft.)	Ave. Slope (°)	Naismith Time (Min.)	Squiggle Factor (%)	Adj. Time (Min.)	Cum. Time (Min.)	Cum. Time (Hrs.)	Comments and Break Times
	START – 6:00 AM at roadhead				2,800									
1	Road to mountain	WSW	0.5	0.5	3,000	200		5°	16	5%	17	17	0.3	Trailhead at road
2	To top of x3784	SW	0.4	0.9	3,784	784		25°	32	200%	95	112	1.9	
	BREAK										10	122	2.0	Short break & snack
3	Hilltop traverse	W	0.4	1.3	3,800	116		5°	11	25%	14	136	2.3	
4	To top of plateau	WNW	0.7	2.0	4,560	760		20°	37	200%	110	246	4.1	
	BREAK										10	256	4.3	Short break & snack
5	To highpoint	SW	0.7	2.7	5,120	560		8°	31	20%	37	293	4.9	
6	To viewpoint – 49 Palms Valley	SW	0.4	3.1	5,000		-120	5°	8	10%	9	302	5.0	
	LUNCH										30	332	5.5	Lunch with a view
7	Top of canyon	WSW	1.1	4.2	5,200	200		2°	28	15%	32	364	6.1	
8	To Bottom of canyon	NNW	1.0	5.2	4,200		-1000	25°	20	100%	40	404	6.7	
	BREAK										10	414	6.9	Short break & snack
9	49 Palms Valley	NW	1.8	7.0	4,000		-200	0°	36	10%	40	454	7.6	
10	To 49 Palm Canyon Flats	N	0.5	7.5	3,600		-400	10°	10	100%	20	474	7.9	
	BREAK										10	484	8.1	Short break & snack
11	To 49 Palm Oasis	NNE	1.0	8.5	2,800		-800	10°	20	150%	50	534	8.9	
	BREAK										10	544	9.1	Short break & snack
12	Up to plateau	N	0.5	9.0	3,000	200		3°	16	10%	18	562	9.4	
13	Flat trail	NNW	0.3	9.3	3,000			0°	6	0%	6	568	9.5	
14	To parking lot	NW	0.6	9.9	2,700		-280	5°	12	0%	12	580	9.7	End at road
	FINISH – 5:06 PM			**9.9 mi.**		**2,820 ft.**	**-2800 ft.**		**283 min.**			**666 min.**	**11.1 hrs.**	**+15% for group size**

Date: 3-27-05 Sunrise: 5:38 AM Moonrise: 7:09 PM Moon Phase: Full Sunset: 6:01 PM Moonset: 6:35 AM Weather Report: Mostly sunny - High ~80°F, Low ~45°F Water: 3 qt. + expect some at Oasis

Figure 6-9. Trip leg chart

be constructed manually, but it simply takes longer and lacks the advantage of the software basic math formulas, which facilitate calculations and changes. The columns in the chart provide a clear and understandable accounting of various trip leg parameters. As such, not all of them are necessary to arrive at a rational trip plan. The English system is commonly used and universally understood, but the metric system can work equally well. The columns are discussed below.

- Serially number each Trip Leg, with a short description to identify each. Identify any peaks, benchmarks , or geologic and manmade features.
- Give a General Geographic Direction for each trip leg. This can be useful in locating the trip leg on the topo or recreating the route on another topo. Examples are N, NNE, NE, ENE, E, etc.
- Identify the Trip Leg Distance in miles; one decimal place is usually adequate. The distance in miles is used as the D value in the Naismith formula. Do consider trail nonlinearity, such as multiple switchbacks.
- The Cum. Distance at each trip leg provides a cumulative tracking of the trip progress.
- The Elevation in feet identifies the altitude at each trip leg start and finish.
- The Trip Elevation Gain in feet for each trip leg is used as the H value in the Naismith formula. It is also helpful to track the Trip Elevation Loss along the route. Even though elevation loss along the route is not used in the Naismith calculations, it provides more understanding of the route. Since the gain and loss amounts are independently estimated, the two totals may not be quite equal.
- The Average Slope in degrees estimates the average slope of each trip leg as a general measure of overall difficulty.
- Naismith Time in minutes gives the result of using the formula $T = D/3 + H/2000$. D is distance in miles, and H is elevation gain in feet.
- The Squiggle Factor is an estimated terrain difficulty factor, which can be used to account for all types of terrain impediments encountered. It is added as a percentage increase over the basic Naismith time calculated. See the Squiggle Factor sidebar for description.
- The Adjusted Time in minutes is the Naismith Time with the Squiggle Factor percentage time added. It represents a more realistic time to traverse a trip leg, considering the terrain encountered. Specific times are added for short breaks and lunch. The short breaks become naturally longer toward the end of the trip.
- The Cum. Trip Time in minutes at each trip leg provides a cumulative tracking of the trip progress. Periodic translation into hours provides a useful reference.

For planning reference, at the bottom of the chart are provided the sun and moon rise/set times and the weather report for the trip day. It is important to consider water availability and how much water to carry for the day. For the reference date of 27 March, there are 12 hours and 23 minutes between sunrise and sunset, which gives reasonable daylight for the 11.1 estimated hours of the trip. Without any mishaps (the 15% group size factor), the trip would finish about 4:00PM. It is interesting to note that the time adjusted for terrain difficulty is about twice the basic Naismith time estimate.

The trip plan should also consider some optional route segments where appropriate, depending on the terrain. Turn-back points should be identified in the event of an emergency or deteriorating weather that compromises the trip plan. With rain, the rocks become wet and slippery, and on slopes and in canyons it may become too dangerous to continue so that it may be necessary to bivouac overnight. The ten essentials, clothing, and any shelter equipment can then become essential for survival.

A good trip plan table can also be summarized on a route card for easy reference.

Trip Leg Elevation Profile

The trip plan elevation profile is best constructed using spreadsheet software such as Excel. With Excel, select menu "Chart-Chart Type–XY (Scatter)" and choose the curve desired. The various length Cum Distance values will be accurately plotted on the X-axis against the corresponding elevation values.

As always, the profile can easily be constructed manually, but it may take longer and not look as pretty, which is fine for the homework. It shows the major ups and downs along the way and can be useful in timing breaks and checking the time progress along the way.

Route Cards: A Useful Planning Option

In contrast to the LTP Trip Plan, which is tailored for the I-, M-, or E-level leader candidate, the Route Card approach allows for a less rigorous trip planning solution. The route card approach considers all the basic elements of trip planning, but arranges the relevant information in a more informal manner. It also adds some key "handrails" reference information, which will help the leader stay on course at key points on the route. Often less focused on the technical aspects of trip planning, it can include some information on the geology, flora, and fauna along the route, as well as historical points of interest. Some trips are ideally suited to include ample time to "smell the flowers," as distinct from the peak-bagging end of the spectrum. One can tailor a route card to individual needs and preferences, provided that it contains all necessary trip plan information.

A route card is a sequential listing of details that define a navigational scenario for a trip. It provides an organized trip plan, including provision for recovery from unanticipated events. Because leaders differ greatly in their styles, route cards can range from casual mental checklists to masterpieces of logistical planning. For trips over unfamiliar or cross-country terrain, the very process of preparing a written route card can provide an organized structure for planning and executing the trip. Part of the process is to extend the planning focus beyond the ideal route outline to considerations of situations and poor conditions that depart (for whatever reason) from the nominal envisioned at home. This foresight can be valuable to support safe operations by the leader under stressful conditions that might be encountered during the trip. In any case, the preparation of a route card is a good practice for trip leaders who intend to lead new routes or who wish to rejuvenate and add to their experiences about familiar routes.

From the logistics standpoint the preparation of a route card is a desirable end result of the trip planning process because it reflects essentially everything the leader has considered. After the trip, the entry onto the card of corrections or additional comments can provide a log as well as a guide for future trips.

Elements of a Route Card

The Route Card is the culmination of the trip planning process. It summarizes the organized navigational scenario, in sequence, and includes such things as

- Basic segments of the trip (these are at least partly defined by the points listed below);
- Transition points—such as trail junctions; branch points for gullies on ascent and ridges on descent; major gradient changes as with entry/exit of a significant gully; stream, ridge, power-line crossings—that can serve as easy location fixes are useful for the leader's on-going dead-reckoning-based awareness of exactly where the party is on the map;
- Intermediate guidance objects to home in on or take direction from;
- Crux points that are not already identified as transition points, e.g., key waypoints for conditions of bad visibility or unexpected events. Note that poor visibility for the party as a whole can often be anticipated, as with cross-country travel in heavily forested areas, so terminal locations and route bearings between them become entries in the route card. Crux points also include escape points that provide for recovery from unanticipated events like injuries or party separation that may require changes in the conduct of the trip;
- Points of interest (POI) along the way, such as overlooks and natural history objectives;
- Any other waypoints that might be useful to the leader to maintain situational awareness and assure reasonable congruence between the actual trip and the plan.

NAVIGATION CHECKOUT

Objective

The navigation checkout objective is to determine that the LTP candidate has the required knowledge and skill to navigate in the mountains or deserts and to do route planning and route finding at the particular level of the checkout (Basic I/M or Advanced E). The ultimate objective is safety, to ensure that a candidate who has successfully completed a checkout can lead a group in the field with sufficient navigation prowess for the level of outing undertaken. In all checkouts, candidates need to demonstrate their problem solving, decision-making, and judgment—the leadership skills—as well as their technical skills. Technical skills alone are not sufficient to pass.

Knowledge

The candidate is expected to know the material contained in this chapter at a level sufficient to pass a comprehensive written exam mailed prior to the checkout. Before the checkout event, the candidate will be asked to prepare a selected trip plan as homework and then to explain the reasoning for the choice of route, terrain analysis, and detailed time estimates to an examiner during the day of the checkout. Since not all Chapter 6 material is covered in the exam and field demonstrations (GPS is an example), the checklists below have been provided as guidance for checking off at the I/M and E levels. If an LTP candidate feels slighted in not passing, he/she is strongly encouraged to continue, gain experience, and then pass with confidence. Just barely passing may be demeaning to a candidate's self-worth and reputation. Repeat practices and/or checkouts are strongly encouraged.

I/M Level Checkout

Field demonstrations ("noodles") and written/oral exams may include

- Knowledge of topographic map symbols, colors, and marginal information (revision date, magnetic declination, grid vs. true north);
- Knowledge of the primary map grid systems used in the United States (Lat/Long and UTM);
- Identifying basic geographic features (hills, saddles, depressions, ridges, etc.) from their contours on the map;
- Orienting the map with true North-South using two techniques; demonstrating the ability to realign the map to N-S quickly during an en route stop;
- Locating prominent terrain features on the map and identifying them in the field (with and without using a compass);
- Locating visually prominent features in the field and identifying them on the map (with and without using a compass);
- Locating a complex visual skyline in the field and tracing it on the topo map;
- Demonstrating knowledge of the various types of compasses available, their principal elements, and their advantages/limitations;
- Demonstrating basic knowledge of magnetic declination and how to deal with it when using a compass to take bearings with respect to true north;
- Taking a bearing from one's location to a distant object with sufficient and repeatable accuracy (e.g., 3 degrees or better) and knowing how one can improve it;
- Demonstrating use of the compass as a protractor to measure bearings on the map to an accuracy of one degree;
- Demonstrating the use of multiple bearings to identify one's location on the map by triangulation, discussing how to select the best objects to use for such bearings, and the use of more than two or more bearings to improve positional accuracy;
- Demonstrating and/or explaining the use of the compass to take local bearings;
- Discussing the rule of the "V"s;
- Describing alternate approaches (no compass) for estimating true north in the field (e.g., sun, stars, glaciers, moss on trees, man-made objects);
- Describing different aspects of trip planning and travel time estimation, including Naismith hiker and backpacker rules and use of squiggle factor; estimating the squiggle factor in the areas where the checkout is conducted;
- Using terrain recognition to identify one's location on the topo map and to estimate the accuracy of the result based on the surrounding terrain, discussing how to use the compass to verify the result and which technique is likely to give the more accurate answer at one's location;
- Demonstrating one's ability to follow an instructor-specified route from point-to-point (the "nav noodle"), using the techniques above in a combination best suited to the area;
- Discussing techniques for dead reckoning in circumstances of poor visibility or where one cannot see the destination (e.g., finding a car parked along a road);
- Discussing the pros and cons of a GPS.

E-Level (Advanced) Navigation Checkout

The skill of the E-level candidate is expected to be advanced and comparable to that of an LTC navigation examiner. No ambiguity is recognized for competency at the E-level navigation checkout; marginal performance is not acceptable.

The E-level candidate is expected to know all material identified above regarding navigation principles and use of the map and compass and to be able to demonstrate this knowledge in the field. The E-level candidate, however, is expected to exhibit a higher degree of proficiency (for example, by taking more accurate and repeatable bearings to distant objects using a compass and by an ability to correlate finer terrain features with the topo map).

In addition, the E-level candidate must understand the theory and function of the barometric altimeter, including how the readings can be affected by macro- and micro-weather phenomena. The candidate must demonstrate use of altimeter, in synergy with map and compass, during field demonstrations on the day of the checkout. To that end, E-level checkouts are conducted in locations that have significant elevation changes to demonstrate use of the altimeter.

Finally, the E-level candidate must demonstrate a basic understanding of the GPS device. This basic understanding can be satisfied by attending one of the GPS courses offered by the Leadership Training Committee or some reputable commercial offering of at least four hours duration with some hands-on practice in the field. During the checkout, the candidate may be asked to use a GPS to demonstrate such knowledge.

SUGGESTED READING

Burns, Bob, and Mike Burns. *Wilderness Navigation: Finding Your Way Using Map, Compass, Altimeter, & GPS.* 2nd ed. Seattle: The Mountaineers, 2004.

Dept of the Army, *U.S. Army Map Reading and Land Navigation Handbook.* Guilford, CT: Lyons, 2004.

Fleming, June. *Staying Found: The Complete Map and Compass Handbook*. 3rd ed. Seattle: The Mountaineers, 2001.

Kals, W. S., and Clyde Soles. *Land Navigation Handbook: The Sierra Club Guide to Map, Compass & GPS.* 2nd ed. San Francisco: Sierra Club, 2005.

Kjellstrom, Bjorn, and Carina Kjellstrom Elgin. *Be Expert with Map and Compass: The Complete Orienteering Handbook*. 3rd ed. Hoboken: John Wiley & Sons, 2010.

Letham, Lawrence. *GPS Made Easy: Using Global Positioning Systems in the Outdoors*. 5th ed. Seattle: The Mountaineers, 2008.

Wells, Darren. *NOLS Wilderness Navigation.* 2nd ed. Mechanicsburg, PA: Stackpole Books, 2013.

For LTC SEMINAR
O Level CANDIDATES:
CHAPTER 6 is required reading.
CHAPTERS 7&8 are optional.

I Level CANDIDATES:
Ch. 6 is required.
Ch. 7&8 are *recommended*.

M& E Level CANDIDATES:
Ch. 6 is required.
Ch. 7&8 are required.

7

Rock Climbing

This chapter outlines the skills, knowledge, and equipment required to lead groups competently on 3rd and 4th class rock. It describes the procedures, requirements, and standards for the LTP rock checkout. As the *Leader's Reference Book* is not intended to stand alone, it also provides references to rock climbing information, which is readily available in standard sources. Those sections relevant mainly to E candidates are prefaced with an (E).

SAFETY COMMITTEE REQUIREMENTS

The LTC trains and certifies leader candidates to general standards set by the Safety Committee, (i.e. a 3rd class rock outing requires an M-rated leader, 4th class an E-rated leader). An E leader may perform several protected moves such as might be encountered on a 5th class summit block, again presuming safety is not compromised. Conversely, an M leader should not normally plan rappels on steep terrain where most of the rappeller's body weight is borne by the rope. Recovery from an emergency in such a rappel is one of the technical requirements of the E checkout. Therefore, planned vertical rappels on backcountry outings are outside the scope of an M trip.

In order to comply with Safety Committee standards, the M and E checkouts are aimed toward the difficult end of the 3rd and 4th class spectrum. Technical multi-pitch 5th class climbing remains outside the scope of E outings.

SCOPE OF THE LTP ROCK CLIMBING PROGRAM

LTP candidates must not be beginners and are expected to gain at least some of the required skill on their own, on climbs or training sessions scheduled by other Angeles Chapter organizations, or at the many commercially provided classes and courses now available. The LTP, however, does offer training and practice associated with most workshops and checkout sessions. This chapter describes the checkout procedures in sufficient detail for candidates to measure their own readiness for a successful checkout.

The LTC has authorized certain persons to schedule and conduct LTP rock checkouts. These rock examiners are appointed by the LTC Rock Chair as the need arises and on the basis of their experience and skill with the concurrence of the LTC Chair. No others are authorized to perform LTP checkouts, although other staff may be used in a support role. Only a few selected examiners are authorized to give E checkouts. All checkouts require an advance reservation with the E-rated rock examiner leading the outing. E checkouts must be approved by the LTC Rock Chair beforehand.

The preferred method of checkout is attendance at a scheduled event. The LTC sponsors several M-level and E-level checkouts per year, which are shown on the LTP Schedule (available at the LTP website http://angeles.sierraclub.org/ltc). The notes on the LTP activities calendar give more details on specific trips. The end of this chapter provides details on LTP checkouts.

Typical locations for rock practice and checkout climbs are Stoney Point (Chatsworth), Mt. Rubidoux (Riverside), Joshua Tree National Park, the San Gabriel Mountains, and the Sierra Nevada wilderness and nearby areas.

ROCK CLIMBING REFERENCES AND SOURCES OF LTP INFORMATION

Additional rock climbing information is included in the references in the Bibliography at the end of the book, as well as in this chapter. Candidates are held responsible for this type of information. In addition, they must possess a broad knowledge base, which should be obtained from participation in actual climbing trips.

ROCK LEADERSHIP

Leader's Responsibility

The leader's job is to provide direction and motivation, which safely allow all participants, including the leader, to enjoy their mountaineering experience. Individual goals, even on a rock trip, may include peak bagging, experiencing nature, exercising, socializing, or just leading people–a wide spectrum of possible interests. The leader should provide a boundary, a framework, in which all participants can most fully meet their own expectations with the maximum possible safety margin. The leader should maintain a balance between enthusiasm for climbing and the needs of the participants within the group.

M leaders must be able to climb at the highest standards of 3rd class rock with an ability to follow up to at least 5.2, and E leaders must be able to climb at the highest 4th class level with the ability to follow at 5th class rock up to a 5.6 rating. Because they must be able to do this under the most severe pressures of group responsibility and leader fatigue, the LTC requires leaders to have personal climbing skills above the rating levels at which they expect to lead so that they have enough reserve to handle out-of-the ordinary situations.

Planning M and E Rock Trips

Rock trips pose a few special planning problems. The leader must determine whether the proposed climb is within the approved Safety Committee limits of 3rd or 4th class. The climb should also be within the leader's real limits and abilities. In addition, the leader must screen the participants carefully to ensure that they are qualified to make the climb. Restricted trips on rock—all E-level and all M-level trips on which a rope is expected to be used—require prior approval, and all participants must be Sierra Club members (see chapters 3 and 4 for more information and the Mountaineering Outing application in Appendix C).

Climbers soon discover that climb ratings are somewhat subjective. Class 3 is often defined as easy rock climbing requiring use of hands on most moves; a rope should be available for some climbers. Class 4 is defined as moderate climbing requiring a rope for safety; anchors may be needed. Some definitions state that a fall on 3rd class would probably not be fatal, whereas a fall on 4th class probably would be. Exposure is not factored into class 3 or 4 ratings, but a long, steep and exposed class 3 climb, such as Middle Palisade, can be a "no fall" zone where a fall could be lethal. Rather than relying solely on class ratings, leaders need to recognize safety factors based upon the terrain and the ability of their participants and adjust their risk management plan accordingly. In actuality, each climb is a unique problem, and the main value of ratings is an experientially gained knowledge of what the climbing community has in mind, in a general way, when it assigns a certain rating.

A leader should not automatically assume that having obtained an M rating, he or she is ready to lead any climb that someone has labeled as being class 3. A long 3rd class ridge at 14,000 ft on Mt. Russell in the Sierra is a totally different situation than a 3rd class move on Strawberry Peak in the San Gabriels. Initially, the M rating should be viewed as a license to practice leading. Skills will most likely be enhanced with practice.

Probably the best source of information for climbs commonly done by the Sierra Club is back issues of climbing section newsletters such as the Sierra Peaks Section *Echo*. The climbing sections of both the Angeles and Loma Prieta Chapters of the Sierra Club also post excellent online climbing archives at their web sites. Many experienced climbers have rather complete files and can supplement them with personal recollections. The Sierra Peaks Section and Desert Peaks Section peak lists contain fairly accurate difficulty ratings for each peak when climbed by the easiest route.

Guidebooks also provide a fundamental source of information. Especially outside of California, they often can use a variety of systems to rate climbing difficulty, systems which then need to be translated into our familiar Yosemite Decimal System. Perhaps the most complete discussion of rating systems is that given in *Mountaineering: The Freedom of the Hills*.

Guidebooks are notorious for underrating climbing difficulty. Any description written prior to about 1960 is apt to be grossly understated by modern standards, perhaps reflecting a feeling that anything that could be climbed in mountaineering boots could not be very hard. Remembering that mountaineers really did do some hard climbs before 1960 and that the rating systems have changed, look on such ratings with a skeptical eye,

Although a trip as planned may be moderate, any number of things can happen suddenly which can make a climb much harder, with a higher effective rating. For this reason LTP candidates must demonstrate climbing ability above the level they plan to lead. These factors include snow or rain, ice on the route, high wind, fog or whiteout, darkness, unforeseen difficulty, losing the route, climber

CLIMBING MATERIALS

All climbing must be done with dynamic climbing ropes that are UIAA approved. The use of static ropes, utility cord, and webbing in place of a dynamic climbing rope can produce fatal fall factors on even very short falls.

Prusiks are generally made of kernmantle type utility cord of 5 mm to 6 mm diameter. The cord must be very flexible; some brands are not and may not conform to and thus not lock on the climbing rope. Because Gemini cord is too stiff and Spectra has a very low melting point, they should not be used for prusiks. Other friction knots such as Klemheists can be made from tubular webbing. Experimenting with the performance of sizes and brands under safe conditions is highly recommended.

For slings, 1 inch tubular nylon webbing is recommended. Ends of all nylon rope, cord, and webbing should be hot cut or melted after cutting to prevent unraveling. Commercially sewn slings, available in various lengths, eliminate the presence of the knot, which weakens the sling. Some common lengths are listed here that fit average-sized climbers. Lengths here and elsewhere in the LRB refer to “as cut” lengths.

Slings, 1-inch nylon webbing:		Prusiks, kernmantle cord:	
5 ft, 3 in	Single short anchor sling	3 ft, 5-6 mm	Self-belay
9 ft	Double long anchor sling	5 ft, 5-6 mm	Self-belay
10 ft	Parisian Baudrier	8 ft, 5-6 mm	Foot loop
30 ft	Anchor building	20 ft, 7 mm	Cordelette

Commercial climbing harnesses are light and inexpensive and are preferred over swamis with or without a seat sling and over bowlines on a coil for both safety and comfort. Have at least two locking carabiners and various regular carabiners, a belay/rappel device, ample runners, and prusiks.

The leader must require helmets on class 3 rock whenever a rope is used as well as higher-level rock and anytime on climbs that are known to have rockfall hazard. Some leaders may wish to require helmets on class 3 rock even when a rope will not be used; this is a wise safety practice.

Instruction on the use and tying of runners can be found in *Mountaineering: The Freedom of the Hills*. Commercial sewn runners are also discussed.

Make prusik loops (or other friction knots) from 3 to 5 feet of 5 to 6 mm utility cord, using a double fisherman’s knot.

(E) A suggestion for a starter rack is to use a set of stoppers, hexes, and some spring-loaded camming devices (SLCDs) particularly for the medium to larger sizes. *Mountaineering: The Freedom of the Hills* discusses the use of chocks and types of equipment racks.

"freak out," climber fall or injury, climber inexperience, and climber fatigue.

Trip Write-ups

For safety's sake and for the enjoyment of qualified participants, the leader is required to set certain minimum standards for a 3rd or 4th class rock trip. The trip offering should be as explicit as possible in describing the technical difficulty of the rock climbing and should define the minimum participant qualifications. Further, the participants should be asked to substantiate their qualifications in writing. All questionable responses require follow-up by the leader. Experienced leaders know that it requires a lot of work to screen potential participant lists, but the extra work is rewarded in the field.

Prior to the trip, participants should be sent accurate information on the planned rock climbing activities. This can serve as one more final self-check on the part of the participants to determine whether they are truly ready for the trip. The leader should indicate the required rock equipment; a suggested list will be found in the sidebar on page 107.

Leadership on the Trip

A well-planned trip is already off to the right start. Before leaving the roadhead, the leader should make sure everyone has the required equipment and distribute any group climbing equipment equitably. Use spare moments during the trip to become better acquainted with each participant's personal climbing history. Later, when the group is on the rock, the leader will want to determine who can be counted on for responsible roles, such as scouting and belaying, and who is apt to need special encouragement or help. Belaying is especially critical and cannot be delegated to unqualified persons. The leader must exercise control over and provide appropriate limits for overconfident and disruptive people. The leader may need to abort a trip and should not hesitate to do so.

In general, the leader should not be tied down to a routine task. The leader's job is to make sure the outing all comes together, and on a rock trip that takes a lot of overall supervision. Likewise, the leader's physical position may not necessarily always be at the head of the group, either going up or down. For example, if the group has one outstandingly weak member, the leader may temporarily have to spend some time coaching and encouraging that person; this is one task that is not always easy to delegate.

Injury and rescue are beyond the scope of this chapter, but emphasis on safety can reduce the likelihood of injury.

Safety on Rock

Participants expect and deserve an adequate margin of safety on climbs sponsored by the Sierra Club. Risk containment is perhaps the leader's most serious responsibility, requiring pre-trip planning, active trip leadership, mountaineering expertise, and mature judgment. For added safety all participants on class 3 and higher terrain

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FALL FACTOR

When a leader fall is caught, the climber, belayer, rope, protection, and anchor system are all subjected to a violent jolt. Fall forces are potentially dangerous, yet they can be reduced significantly by managing the fall factor.

The severity of the fall force actually depends on two things. One element is the length of the drop, which is usually twice the distance the climber ascended above the last point of protection. The climber can minimize the drop by placing protection frequently or before a risky move.

The second factor is the length of the rope running between the climber and the belayer. Modern climbing rope is designed to absorb shock force by stretching. The climber's distance from the belayer determines the shock-absorbing capacity: a long run of rope can stretch a great deal and absorb a lot of energy, but a short run of rope can absorb relatively little.

A hypothetical example demonstrates how these two elements work together. A climber leaves a ledge and ascends 10 feet over an exposed face before falling with only 10 feet of rope paid out. The fall factor is 20 feet of fall divided by 10 feet of rope, which yields a severe 2.0. Theoretically, 2.0 is the largest fall factor a climbing team can experience. If the same climber places protection and falls from just 5 feet above the last placement the fall factor is 10 divided by 10, or 1.0. If the second scenario occurs farther up the pitch, from 5 feet above protection but with 50 feet of rope paid out, the fall factor is 10 divided by 50, which yields a relatively mild fall factor of 0.2.

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when a rope is used or in an area where a significant rockfall hazard is present are required to wear climbing helmets. Some leaders may wish to require helmets on class 3 rock even when a rope will not be used.

How do people get hurt on rock? *Accidents in North American Mountaineering*, published yearly by the American Alpine Club, gives insight. By far, the majority of accidents occurred on rock terrain, with the initial cause being mostly due to a fall or slip on rock. Much smaller percentages were due to falling objects, rappel and anchor failure and equipment failure in that order. Contributory causes summarized in *Accidents in North American Mountaineering* include climbing unroped, exceeding abilities, inadequate equipment, climbing alone, bad weather, darkness, party separated, exposure and/or exhaustion, faulty rope, no helmet, failure to test holds, placed no protection, improper tie-in to the rope, waist harness failure, rappelling off the end of the rope, and miscellaneous, including such bizarre incidents as asphyxiation by rope after a fall, drug overdose, and tripping on equipment and falling. Each issue of *Accidents in North American Mountaineering* includes a description and analysis of accidents that occurred during the year, ranging from one paragraph to several pages. Reading these accident reports may be the best way of learning about risk reduction short of serving in a mountain rescue organization. They are highly recommended.

A leader has at least some control and responsibility over almost every category of contributory cause listed in *Accidents in North American Mountaineering*. Indeed, in hindsight the majority of accidents covered could have been prevented or minimized by effective risk management by the leader. For example, darkness and exhaustion are most often results of inadequate planning or participant screening. Active leadership could even uncover inadequate personal gear such as a decrepit climbing harness.

Rockfall is a very common hazard, but one which is often controllable through group discipline. On high angle slopes, the leader can switchback so that climbers are never above one another. Where chutes are unavoidable, the leader can send one, two, or three climbers at a time in closely-bunched groups. The leader can keep the area below a rappel clear of other climbers. No matter the difficulty of the climb, helmets should be made mandatory on climbs where rockfall potential exists and are now required by the Sierra Club on all climbs of class 3 and higher when a rope is used. Again, the key to effective risk management is active leadership.

All safety precautions must be weighed against the time required to implement them. In some cases, such as when there are conflicting hazards such as rockfall and lightning, the leader must carefully weigh alternatives such as choosing lowering with a Münter hitch belay over rappelling.

ROCK TECHNIQUES AND EQUIPMENT

Climbing

Learning to rock climb is largely experiential but can be enhanced through study. Many excellent climbing books and videos illustrate the do's and don't's of climbing, and rock gyms and classes are available to climbers today. Leader candidates can use them to review the various moves and skills which must be demonstrated during the LTP rock checkout, such as friction climbing, liebacks, edging, counter-force, stemming, and jams. For most climbers, good jamming technique in cracks does not come naturally but must be learned and practiced. Crack climbing includes finger cracks, hand and fist cracks, off width cracks, and chimneys, all of which should be practiced.

For leaders, however, good climbing technique is only one of the required leadership skills. They must also have the skill to recognize participant weakness and take corrective action before safety margins are reduced. This recognition involves monitoring of individual performance to detect fatigue, fear, overconfidence, or lack of required skill, then taking appropriate action.

Inexperienced climbers sometimes over-estimate the quality of rock. On most peaks, the rock is often only a whisper away from becoming debris. In such cases it is appropriate to shelve advanced climbing techniques and remember the old adage about always having three points of contact with the rock. Climbers should test all potential handholds by pulling or striking them with the base of the palm before committing weight to them. Water and gravel often trap the unwary, especially when climbers are descending smooth slabs. Here the leader can encourage extra caution with words or the belay rope and remind participants throughout the trip to "climb with your eyes," to evaluate holds before moving.

Belaying

The cornerstone of modern roped climbing is the belay, consisting of rope, anchor, belayer, and climber. Belays must be used on all 4th and 5th class climbs. When should one belay on 3rd class climbs? Abilities differ, as do attitude and strength; if anyone on a climb wants to rope up, he or she should be belayed with no argument. Weather is a major factor, as wind can make balance poor, cold loosens the grip, and rain or snow can make holds treacherous. A long climb, poor coordination, illness, or nervousness can make a climber who was strong and sure an hour earlier suddenly very shaky; a leader should watch for these signs and rope up.

When screening participants, a leader should be aware that those whose experience is limited to roped practice climbs frequently feel uncomfortable on low difficulty rock when it is combined with mountain exposure.

Mechanical devices such as ATCs used with harnesses are most commonly used to belay climbers on 3rd, 4th and higher class terrain. The ability, however, to establish a belay without equipment using techniques such as the hip belay remains a necessary skill in case of emergencies or lost equipment. The leader must be familiar and knowledgeable with the various models of belay devices and harnesses that may be encountered on their outings, as well as belay, rappel, and anchor techniques that do not require equipment.

Although a bowline on a coil is adequate for easy 3rd class climbs, participants should normally be required to have a harness if a significant amount of roped climbing is anticipated during an outing. If a climber is injured and must hang for a prolonged period of time, a harness provides for greater safety. The harness economizes on the climbing rope and offers the potential of saving time with large groups. The climbing rope should be tied to the harness using a figure eight follow-through; that is the required method in the LTP. Experienced trip leaders sometimes ask their participants to clip in to the climbing rope using a locking carabiner. A locking carabiner connected to the harness and to a figure-eight knot in the rope may be acceptable for an occasional belay in mountaineering, especially when a large group is involved and the climbing required is less than a rope length or uses a fixed line. The locking carabiner method of attaching the climber to the rope, nevertheless, is usually not used to avoid the risk of an unnecessary link in the belay chain.

Traditionally, the climbing signals are "On belay? Belay on. Climbing. Climb. Off belay? Belay off." A variation can be used when a leader has anchored in at the top of a pitch and pulls in the rope until the second yells "That's me" to indicate that there is no more rope instead of "On belay?" When ready, the leader will then say, "Belay on" without further prompting from the second. The remainder of the signals stay the same. As a reminder, the belay is not established until the leader says "Belay on."

Good anchors are the cornerstones of belayed climbing. Without them the safety of the rope is merely an illusion. Two good anchors should always be sought. A useful acronym to remember when building an anchor is SRENE. Anchors must be *solid, redundant*, and *equalized*, and have *no extension*.

On most 3rd class climbing, one solid anchor plus a bombproof seat is acceptable. On select occasions, an experienced leader may be able to belay safely with only a body anchor, but this places great responsibility on the leader's judgment. The whole point of belaying in the first place is to insure against mistakes and unknowns, and everyone is fallible.

With only a body anchor, the leader forfeits the comfort of relaxing or shifting during a lengthy belay, and it makes a fallen climber tie-off impossible. These considerations generally mean that all 3rd class belays should be anchored, except for an occasional upper belay on a short, easy, but exposed slope where the climber can be lowered back easily to a secure position. A body anchor should not be used where there is a chance of a dynamic fall such as when traversing or rappelling.

Natural anchors include large boulders, rock protrusions, and live trees at least two inches in diameter. The fastest, easiest, and safest anchor is usually a runner over a solid horn or around a sturdy tree. Runners or the climbing rope itself can be placed around the anchor. Runners are often better for rope economy and the increased friction and stability of 1 inch webbing; they also protect the rope from abrasions, tree sap, and cuts. Also the use of a cordelette can provide a great connection to natural as well as artificial anchors.

Anchors must hold regardless of where or in which direction the belayed climber might fall. More than one belayer has been injured because of a side pull or because of too much slack between the anchor and belayer, which allowed a falling climber to pull the belayer off position.

Where a fixed rope is used, climbers should attach their harness with both a locking carabiner and a friction knot attached to separate short slings. Anchor points should preferably be placed at rest positions so that the climber may safely move the tie-in around the anchor point.

A fallen climber may be tied off a number of ways. The leader must be able to handle a tie-off with available equipment. Leaders should always look for safe, quick, and bombproof anchors on which a climber tie-off can be accomplished with a minimum of difficulty and contortions. The leader also should be familiar with belaying with a Münter hitch or a belay device connected either to the harness or directly to the anchor.

(E) When anchoring with chocks or nuts, the leader must distinguish between the terms "strength" and "security." Strength refers to the ability of a chock to withstand loads, provided it stays in place; security, on the other hand, refers to the ability of a chock to stay in place. No one would use a tiny wired chock for a belay anchor because it would not have the required strength. Even large wired chocks, however, sometimes do not make good belay anchors, especially where the anchor must stay in place over a long period of time or there is a lot of activity at the belay station. Side forces on the stiff wire tend to rotate or dislodge such wired chocks. Artificial protection always should be connected to the rope with an intermediate sling or runner and carabiner to prevent the protection from dislodging as a result of rope drag. Advanced anchor techniques also include the use of opposition to increase the security of a single chock placement and the use of a cordelette to construct an equalized anchor composed of multiple chocks.

Rappelling

LTP candidates are trained and tested on the dulfersitz rappel because of its traditional importance and because no special equipment is needed. Leaders should also be acquainted with the arm rappel.

Mechanical rappel devices are most commonly used by climbers, and leaders should be familiar with their use. Tuber devices like the ATC are now very common. Leaders should also be able to rappel with a Münter hitch. Leaders should be familiar with using the various belay/rappel devices and also be sure that the participants are using them correctly.

Rappelling is a hazardous affair, and mistakes are often lethal. To minimize risk, leaders should become familiar with the objective hazards of rappelling and be able to tell at a glance if participants are using suitable gear and suitable technique. The leader not only needs to know how to dulfersitz but also needs to recognize the correct setup on someone else. In the dulfersitz, the rappeller should lead downward with the leg under which the rope runs to avoid losing the wrap. Also, keeping both hands on the rope allows one to maintain rope control.

Friction knot self-belays, such as the Auto Block, can offer some safety but have shortcomings. Inexperienced persons frequently allow the friction knot to become jammed, sometimes out of their reach. At the other extreme, a falling climber may inadvertently cling to the friction knot so that it fails to jam when needed. Tests and accidents, particularly with cavers, have shown that a partially jammed friction knot can melt through after two or three feet of slippage. Finally, a climber cannot hang for long if a swami belt or a bowline on a coil is being used, so a reprieve from a fall on a steep slope is short lived.

Although the LTP teaches and tests for the friction knot self-belay, leaders should be aware of the drawbacks and risks. In situations where rock fall is not a hazard and a rappel device is used, pulling on the lower end of the rope can control or stop the descent (known as an army-belay or firefighter's belay)

Rappel anchors need to be bombproof. Use two or even three anchors to be sure. Too much is at stake to depend on old rotten slings that someone else has left behind or to be too cost conscious to leave behind a backup chock.

To safeguard against overrunning the rappel, two knots, one in each strand, are used, allowing the two strands to untwist individually and facilitating retrieval.

M candidates are required to rappel down a near vertical slope which has an easy transition at the lip. E candidates are required to rappel over a sharp transition onto a vertical wall where all of their weight is borne by the rappel rope.

Prusiking

Prusiking is useful for a rappeller who must reverse the descent for some reason; a second climber following a hard pitch; a leader recovering from a fall on an overhanging wall; and rescue work, particularly in crevasses. Proficiency must be demonstrated during the E checkout.

(E) With practice and prusiks or other friction knots properly sized to the climber, prusiking can be relatively efficient. Otherwise, it can be a slow, strenuous process. Climbers should carry prusiks on all climbs on which a rope will be used. They can be used on rock as well as on all climbs with crevasse hazards.

(E) A prusik or other friction knot may be rigged and used a number of ways. In most rock climbing situations where special equipment has not been brought, two normal prusiks are used. One is attached to the climbing rope with a prusik knot and to the harness at the waist with a locking carabiner. The second or foot prusik is attached also with a prusik knot to the climbing rope below the first. The second prusik can be extended with a runner for a foot or feet to stand on, which can be made more secure with a girth hitch to fit the foot or feet. The foot prusik should be backed up by a runner to a locking carabiner on the waist harness in case the waist prusik fails. While it is preferred that a normal prusik (or other friction knot) be used for the feet, applicants may use a Texas prusik with two leg loops. A third prusik should be carried to assist the climber to get back over the start of the rappel where the rope goes over a lip.

(E) Chest harnesses are typically used when the climber has a heavy pack or is traveling on a glacier. While the waist harness takes the body weight, the chest harness prevents the climber from inverting.

(E) Using a tree limb or garage rafter, one may adjust the rig using trial and error. Standing on the foot prusik, one raises the waist prusik, sits on the waist prusik, and slides up the foot prusik. The waist prusik should not be so long that it is out of reach, and the foot prusik should not be so close to the waist prusik that it can be slid up only a few inches at a time.

(E) If problems are encountered prusiking over a lip, a third prusik may be attached to the rope as high as possible above the lip, perhaps by working a carabiner under the loaded climbing rope to allow insertion of the prusik. A runner then can be attached to the third prusik and stood on if necessary.

FORCE MULTIPLICATION

Belays and rappels are often rigged with multiple anchors to provide a safety margin by dividing the load among two or more anchor points. Proper construction is critical because incorrect rigging can produce the opposite effect and expose each anchor to forces many times greater than intended. Forces are multiplied by the geometry of the system and by the methods used to connect the parts. These two factors must be understood in order to avoid overloading the entire system.

Multiplication by Angle–If one anchor could be placed above another, perfectly in line with the direction of the load and identically tensioned, each anchor would support 50% of the force. This arrangement is rarely possible, and as anchors spread farther to the left and right of each other, the force carried by each anchor increases. Figure 7-4 shows that the downward force on each anchor in a basic “V” arrangement is combined with a lateral force that pulls the anchors toward each other. The graph in Figure 7-5, which plots the force on each anchor, clearly shows that loads increase dramatically as the “V” angle widens.

Multiplication by Method–Force multiplication by angle is charted on the table in Figure 7-6, which also compares “V” construction with a triangular sling. The triangular sling, shown in Figure 7-7, links the two anchors directly to each other, increasing the lateral pull between them and nearly doubles the multiplication caused by the angle alone. Forces generated by the triangular sling can be extremely dangerous, yet there may be times when only one sling is available for the job. Tying the sling off to each anchor with clove hitches or other appropriate stop knots isolates the anchors and makes the entire system behave like a “V” (see Figure 7-7). If the sling running between the two anchor points is slack and the stop knots are secure, the anchor system will only be subjected to force multiplication by the angle, as seen in the “V” arrangement.

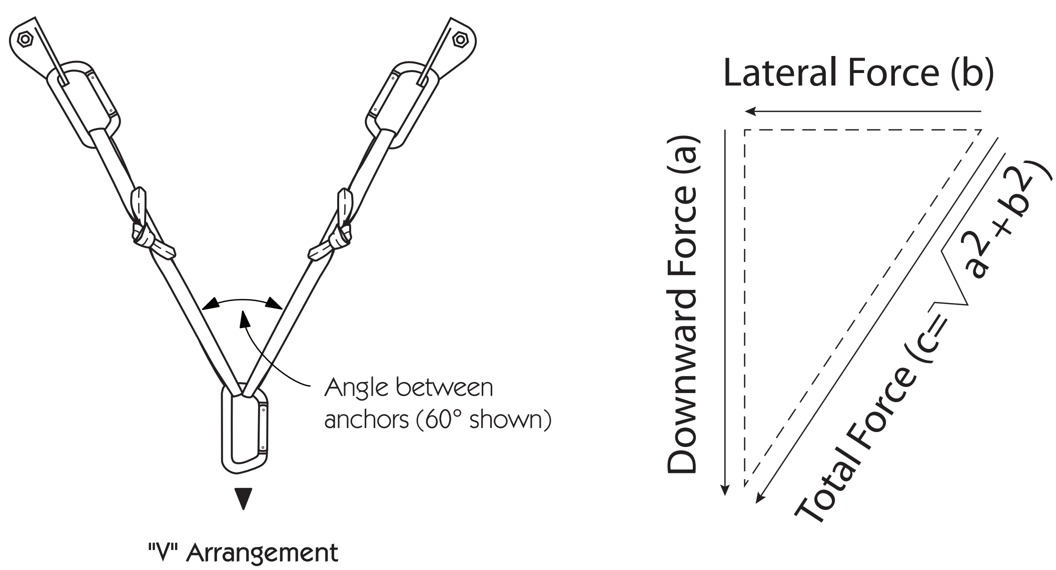


Figure 7-4. Force multiplication on each anchor. The vector lines demonstrate that the total force (c) is always larger than the downward force (a), and increases as the angle between the anchors increases. (All anchors are shown as bolts for convenience.)

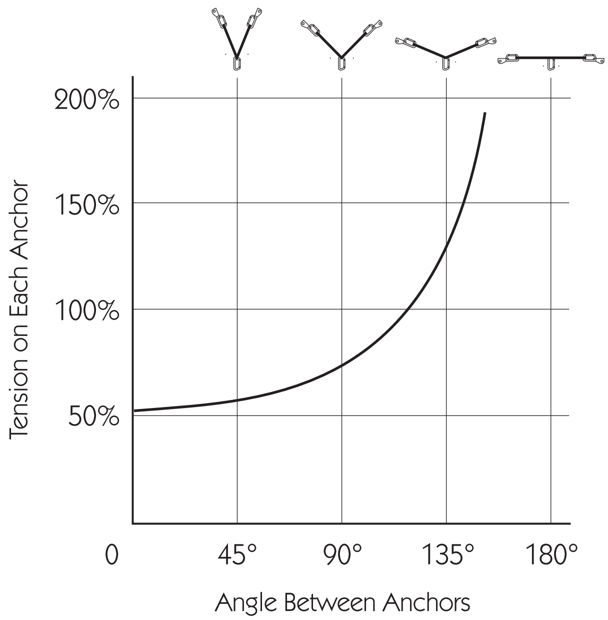


Figure 7-5. The angle-dependant force on each anchor in a "V" arrangement.

Angle Between Anchors	Force on Each Anchor "V"	Force on Each Anchor Triangle
0°	50%	70%
60°	60%	100%
90°	71%	130%
120°	100%	190%
140°	150%	290%
150°	190%	380%
160°	290%	570%
170°	580%	1100%

Figure 7-6. The force on each anchor increases as the angle at the bottom of the connecting sling increases.

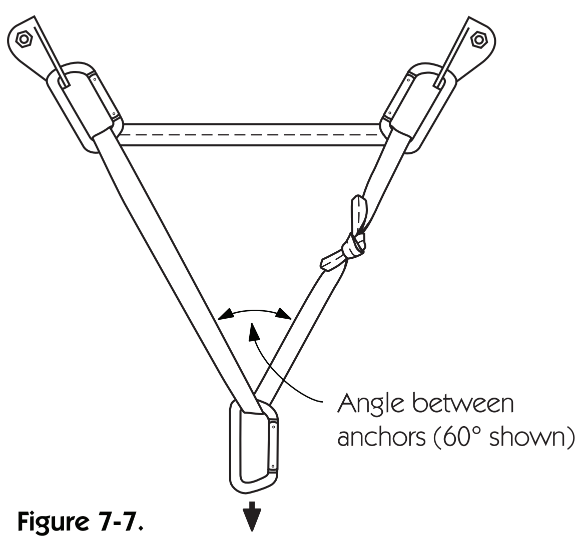
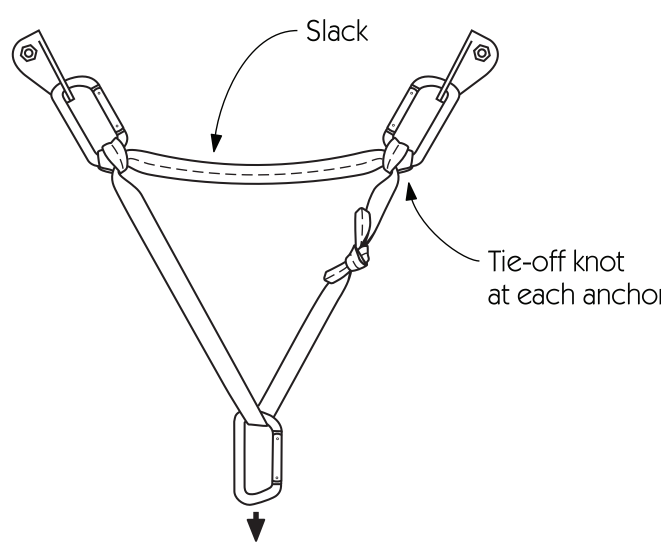


Figure 7-7.

DANGEROUS!
Do Not Use This Triangle Arrangement
See text on page 112.



A triangle sling with the anchors tied off behaves like the "V."

(E) Before trusting one's weight to the prusiks to climb up the rope, the climber must tie off to the rappel rope as a backup in case something should go wrong. Never trust one's life to one prusik! The tieoff loop must be placed so that a fall would be caught by the rope before the climber would hit the ground. This is known as tying in short. Additional loops may be tied as the climber ascends the rope to minimize the potential dynamic fall distance.

(E) The prusiking procedure is probably the most difficult part of the E checkout and must be practiced until the climber can perform it smoothly and efficiently. When prusiking is called for, a rappel may have been aborted or a climber may be injured so that time and proficiency could be critical.

ROCK CHECKOUT

General Information

The M- and E-level rock checkouts are designed to evaluate a candidate's technical readiness to lead M- and E-level provisional rock outings. The checkouts include more than the minimum requirements necessary for the successful completion of a rock outing. Situations can change rapidly in the mountains and can dramatically alter the course of action needed to complete the objective safely. The objective itself, typically a peak ascent, may change from a seemingly benign scramble to an urgent self-rescue on difficult terrain in deteriorating conditions. Rock leaders must be prepared to address the higher technical demands of unplanned events as they escalate.

The checkouts are not meant to be a simple checklist of tasks that are checked off as they are completed. The evaluator will be looking for demonstrations of leadership, as well as the confidence that comes from a thorough knowledge of the material. The best way to learn what is required in a checkout is to attend one or more LTP rock practices where the exercises will be explained and demonstrated by examiners and practiced by participants.

Climbing helmets and harnesses are required of all participants at all LTP rock practices and checkouts. LTP provides climbing ropes and gear for participants' use at practices, but checkout candidates must use their own rope and gear. It is unrealistic to assume that a candidate has the knowledge and experience necessary to be an effective rock leader without ever owning his or her own rope and gear. LTP does not provide a list of gear or materials necessary to complete the checkouts; however, all of the materials needed for a checkout will be demonstrated at LTP rock practices. Putting together your own rack of gear for the checkout, or preparing the right gear for a provisional outing is a vital part of the leadership learning process.

The latest LTP calendar lists scheduled workshop and checkout dates. All M checkouts are by advance reservation with the scheduled trip leader.

Other than some basic exposure to rock climbing, no specific rock experience requirements are prerequisite to attending a rock workshop. The M checkout typically requires at least three or four days of formal teaching sessions and some outside experience in climbing in addition to participation on several M-level trips involving rock climbing. E candidates are expected to be experienced mountaineers. All participants must be current Sierra Club members, and no beginners may participate.

The normal and preferred method of checkout is for the candidate to attend a scheduled LTP checkout session. At each scheduled checkout, the Rock Chair endeavors to schedule enough examiners to perform the reserved checkouts. Other experienced personnel are often used as assistants. Checkouts begin the first thing without practice beforehand during that session.

(E) All E checkouts are by advance reservation with the LTC Rock Chair, not the trip leader. Candidates must send their qualifications and are expected to have mastered the checkout exercises before the checkout. Candidates should plan to devote the entire day to the rock checkout.

Candidates are tested for skill, judgment, leadership, and knowledge, with emphasis on skills demonstration. Examiners will, however, weigh heavily judgment, knowledge, and leadership factors. Submitting a detailed resume of the candidate's rock and mountain experience is to his or her advantage for the checkout.

The assessment of judgment is a subjective process. A candidate may satisfy all other checkout requirements but be subjectively perceived as needing additional experience and the judgment that develops with it. All doubt will be resolved in favor of the many outing participants, who may rely on the candidate for their safety.

Candidates must demonstrate knowledge of basic and technical rock-climbing details (for M and E respectively) contained in the references listed in the Bibliography, plus relevant material from this chapter.

If the candidate is successful, the examiner will forward the signed-off checkout form to the Rock Chair, who will in turn forward the candidate's name to the LTC Administrative Chair. No action is required by the candidate.

The candidate must complete all checkout procedures at a single checkout. Failing this, the candidate must repeat all procedures at a future checkout. As soon as candidates demonstrate that they are unable to complete correctly any checkout procedure, they will be told that the procedure has been failed, that the checkout may be attempted again on a future date, and that the rest of the day may be spent in rock practice specifically designed to help develop the necessary skills. The trip leader will endeavor to assign assistants for this purpose if available, but the first priority is given to the checkout.

Candidates are expected to be ready for the checkout procedures. Formal checkouts require a considerable amount of volunteer time from the limited list of certified rock examiners, and candidates are requested not to use formal checkouts as de facto practice climbs.

The LTC Rock Chair has the final approval of an LTC rock checkout but welcomes correspondence relating to the effectiveness of the rock checkouts.

The following paragraphs describe the requirements and standards for M and E-level checkouts. This material plus the checkout forms themselves should give the candidates enough insight to evaluate their readiness for the checkout or to identify areas which require more practice.

M- and E-Rock Requirements and Standards

Candidates are required to wear a climbing helmet and climbing harness during the checkout. Candidates must use their own ropes and gear for the checkout. Examiners must insure that whenever candidates and participants are climbing, rappelling, or being lowered from a belay, they are secured with a backup belay.

Knots

A rock candidate will need to know about eighteen climbing-related knots. Many more knots are used in rock climbing, but these are some of the most commonly used. Candidates will not only need to demonstrate how to tie each knot, but they will be asked to explain their primary use in rock climbing.

Climbing and Downclimbing

Many of the checkout exercises involve rock climbing. Candidates will be evaluated throughout the checkout on their climbing ability as well as their comfort level on the rock. M- and E-level Sierra peaks typically require just as much downclimbing as climbing up. For some less experienced outing participants, downclimbing can be daunting and unnerving. Rock leaders will need to be able to guide participants of varying ability over difficult terrain by identifying unsteady participants and giving them the confidence they need to get down safely and quickly. This may involve demonstrating how to downclimb a difficult section, identifying where the good hand and foot holds are, and providing a comforting spot and assuring encouragement from below.

Top-Roped Climbing

The top-roped climbing exercise will evaluate a candidate's climbing ability on the more vertical terrain of 4th and low 5th Class rock. The candidate will demonstrate how to belay a climber with a belay device, and how to catch a falling climber with the device. The candidate will also instruct a climber in the proper belay technique, safety checks, and climbing commands.

Instruction, teaching a participant a technical component, is an often-overlooked leadership quality. Even experienced outing participants can have memory lapses under duress. Fear and uncertainty often adversely affect concentration. Participants may have trouble remembering how to tie a particular knot; they may fumble with belay or rappel set ups; they may lose confidence in their climbing ability. Taking the time to teach them effectively through these incidents, rather than just doing something for them, is time well spent in context with the outing as a whole.

Unanchored Belay

The checkouts are structured so that the belays, anchors, and rappelling progress from using the least amount of gear to more complex scenarios requiring more gear. Rock leaders need to know when a quick sitting hip belay is sufficient and when situations demand more secure anchors. Saving time by using just the right amount of gear can be a safety factor in getting the group back to camp quickly, but real safety should never be compromised by time constraints.

Throughout the checkouts there will be repeated flaking, uncoiling, throwing, and coiling the climbing rope, done in the context of a climbing scenario. Rope management is an important time saving factor in the mountains. Time spent untangling a rope mess is time wasted. Candidates must demonstrate proficient rope handling during each exercise.

Considerations for a secure sitting hip belay include a secure position where the belayer can be braced with one or both feet, a stable area where rocks and debris will not be released on climbers below, and an area sufficient to manage all of the participants comfortably and safely.

During all of the belaying and rappelling exercises, the candidate must verify safety checks, utilize proper climbing commands, and demonstrate good rope handling and group management.

Anchors

Proficiency at anchor building comes first from knowledge—learning how to build anchors and learning how to find them in the mountains—and second, from lots of practice.

A multipoint anchor is one that utilizes more than one anchor point. A natural anchor is any suitable object found in nature, such as a large tree or a large rock. An equalized anchor is one that ties two or more anchor points together in such a way that the down force from a falling climber is equal on each anchor (which also achieves redundancy). A master point is the equalized knotted loop where the climber ties in to the anchor. A redundant master point has more than one loop so that if one fails, the other will back it up–it can be easily achieved with a BHK knot.

Anchored Belay

Anchored belays are required when the terrain or exposure is such that the belayer might be at risk of being pulled off when belaying a falling climber. This is a judgment call that the rock leader must make based upon knowledge and experience; when in doubt, build an anchored belay. Another important reason to use an anchored belay is that there is a possibility that the belayer will need to tie off the belayed climber and escape from the anchor. This may be required if a climber falls and is injured and cannot continue; the leader (belayer) must then secure the climber to the anchor and effect a rescue.

An anchor is simply a way to tie the belayer and the climber securely to the earth. An anchor can be a large tree, a large rock, a piece of climbing protection securely placed, or a combination of all three tied together at a master point.

A redundant anchor is more than one anchor tied together at a master point. It could consist of a rope tied around a tree and a runner looped around a rock; when tied together at a master point, one of the anchors may fail under a heavy load from a falling climber, but the other anchor will hold.

The master point is where the redundant anchors are tied together, where the belayer secures himself to the anchor (clove hitch), and where the belay is attached (Münter hitch). Redundancy at the master point is achieved by tying a BHK knot instead of a simple overhand knot

Redundant anchors may not always be necessary on an outing. Just as the leader must make a judgment call about whether to use a sitting hip belay or an anchored belay, he or she must also decide if the anchored belay requires redundancy. This decision must also be made from a knowledge and experience base; when in doubt, build a redundant anchor. For the purpose of the checkout, all anchors must be redundant.

Tying off a fallen climber with a Münter-mule knot can be one of the most challenging hitch-knot configurations to learn, but once learned, it is one of the easiest to remember. The Münter hitch has become the standard in the rock climbing community for belaying a climber up from below to an anchor. The belay can be tied off securely, allowing the belayer to leave the anchor, and the belayer can easily undo the tie-off and re-establish the belay, without ever compromising the climber's safety.

(E) Before establishing a redundant anchored belay, E-level candidates must be belayed while leading a class 4 pitch up to a suitable belay site. A class 4 pitch requires protection placements to insure the leader's safety in the event of a fall. Protection placements may be natural anchors such as slings around a secure rock formation or tree and/or any number of nuts, chocks, or camming devices placed in cracks or pockets in the rock. E-level candidates will be evaluated on the effectiveness of their protection placements by their choice of location as well as the correctness and security of each piece. Use of extensions is important to keep the rope running as straight as possible to reduce rope drag.

Rappelling

In the mountains, rappels are usually not belayed. For the purpose of the checkouts, however, all rappels must be belayed. The belay is a safety precaution that is easily achieved in the context of the checkout environment. Typically, the examiner will belay the candidate during rappels.

On an outing with several participants, belaying rappellers is unnecessary and can use up twice as much time. If the leader or a climber is unsure of the climber's ability to complete a rappel safely, the leader should lower the climber from the anchor with a Münter hitch.

Rappelling is arguably the most dangerous thing climbers will do in the mountains. During rappels, climbers must surrender their hold on the rock and put their trust solely in the equipment they use and their ability to use it. When climbers have their hands and feet on the rock, climbing or downclimbing, roped or unroped, they are able to make choices, sometimes taking calculated risks, other times retreating to safer, more comfortable ground. During a rappel, the choices a climber can make are severely limited. If something goes wrong during a rappel, such as anchor failure, a climber is at the mercy of gravity.

The most dangerous part of a rappel is at the anchor when the climber must insert the rope into the rappel device. It takes two hands to do this, which leaves the climber vulnerable because the feet are the only two points of contact on the rock. This precarious situation is compounded by the fact that rappels are usually set up because of steep or unstable terrain that is deemed unsafe to downclimb. Climbers can minimize their risk at this time by first securing themselves to the anchor with a personal anchor tether.

Commercially made personal anchor tethers are available with different names and configurations, but one can easily be made with a double length sling girth hitched to the harness with a locking carabiner to clip in to the anchor master point. When the rappeller clips into the anchor, he or she will have hands free to set up the rappel device safely. When the climber is ready to rappel, with the break hand securely on the rope, he or she unclips the carabiner from the anchor.

The Dulfersitz rappel is a very old, minimalist, but effective rappel technique that does not utilize a harness or a rappel device. It can save a lot of time but should only be used on short, relatively low angle rappels. For the purposes of the checkout, a harness and personal anchor tether must be used, as well as a backup belay.

An Auto Block is a safety system used during rappels that backs up the break hand and locks onto the rope, halting descent if a rappeller loses control of the break hand.

The Münter hitch is a versatile configuration that is most commonly used for belaying but can also be used to rappel if a climber loses his or her belay/rappel device.

(E) E-level candidates must not only rappel over an overhang, but they must also ascend the rope over the overhang with friction hitch prusiks. Prusiking is a term used to describe a way of ascending a climbing rope with two or more friction hitches attached to the rope and the climber's harness. Prusiking can be done with a prusik hitch or a klemheist hitch. Rock leaders should be familiar with both hitches. A hitch, unlike a knot, is releasable and moveable, allowing a climber to ascend a rope by weighting a waist prusik, thus unweighting the foot prusik to allow the foot prusik to be moved up the rope. Then, the climber stands up on the foot prusik, unweighting the waist prusik so that it can then be moved up the rope. This process is repeated until the climber reaches safety at the top. Near the top, if the rope is weighted tight against the rock the prusiks may not slide up the rope; it may be necessary to attach a third prusik above the overhang to unweight the rope.

Fixed Lines (E)

(E) E-level candidates must set up a horizontal fixed line for a traverse. A fixed line is a climbing rope that is anchored at both ends of the traverse or ascent. There must also be several interim protection placements (or anchors) at various points along the rope. Leaders must demonstrate and instruct a climber on how to travel along the rope with a self-belay. A self-belay on a fixed line traverse may be achieved by attaching a personal anchor tether to the rope with a locking carabiner. Passing the anchor points may be achieved by clipping the tether through the anchor carabiner, or by using an additional tether on the rope; a lead tether is clipped ahead of the anchor point before the trailing one is removed and reattached. The climber must never be unattached to the rope until the end of the traverse or ascent.

(E) E-level candidates must also set up a fixed line for an ascent. Leaders must demonstrate and instruct a climber on how to travel along the rope with a friction hitch self-belay. Unlike a traverse, a fixed line ascent may have the potential for a lengthy fall. A tethered carabiner self-belay would not stop such a fall. A friction hitch, such as a prusik or klemheist attached to the rope and clipped to the harness with a locking carabiner, must be used on vertical or ascending fixed lines, or whenever there is the potential for an unrecoverable fall.

SUGGESTED READING

American Alpine Club, *Accidents in North American Mountaineering.* Golden, CO: American Alpine Club, annually.

Eng, Ronald C., ed. *Mountaineering: The Freedom of the Hills*, 8th ed. Seattle: The Mountaineers, 2010.

Long, John. *How to Rock Climb.* 5th ed. Guilford, CT: Falcon, 2006.

Long, John, and Bob Gaines. *Climbing Anchors.* 2nd ed. Guilford, CT: Falcon, 2006.

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Luebben, Craig. *Rock Climbing Anchors: A Comprehensive Guide.* Seattle: The Mountaineers, 2006.

Luebben, Craig. *Rock Climbing: Mastering Basic Skills.* Seattle: The Mountaineers, 2004.

Luebben, Craig, and Clyde Soles. *Knots for Climbers.* 3rd ed. Guilford, CT: Falcon, 2011.

Soles, Clyde. *The Outdoor Knots Book.* Seattle: The Mountaineers, 2004.

For LTC SEMINAR
O Level CANDIDATES:
CHAPTER 6 is required reading.
CHAPTERS 7&8 are optional.

I Level CANDIDATES:
Ch. 6 is required.
Ch. 7&8 are *recommended*.

M& E Level CANDIDATES:
Ch. 6 is required.
Ch. 7&8 are required.

8

Snow Climbing

Chapter 8 discusses some aspects of snow climbing with information drawn principally from the references listed in the Bibliography, especially *Mountaineering: The Freedom of the Hills*. This chapter is not a substitute for the information in the references; therefore leaders are urged to study the references and become familiar with them.

Snow climbing leaders need to understand that there are many variations in techniques. This particularly can apply to simplified methods sometimes taught by guide services to clients so as not to overwhelm the novice with many techniques or ways to react. The novice climber in this situation may come away with a rather distorted view of proper technique in some situations, thinking that what has been taught is the "best" and not realizing that compromises were made.

Notably, leaders should consider that just because something is described in print does not mean it is without potential hazard. Leaders are likely to encounter various opinions about attaching, grasping, and using the ice axe for climbing and glissading. Climbers will invariably argue that their own preferences are the safest. Each practice may offer benefits and potential risks. Leaders should understand these issues thoroughly, gain practical experience using the various options, and make sure methods employed by trip participants are used correctly.

This chapter represents a compilation of "standard of care" techniques for most climbing situations encountered by the M- or E-rated leader. Those sections relevant to E candidates are prefaced with an (E).

M AND E SNOW CLIMBING

"Snow climbing" and "ice climbing" are sometimes discussed separately, but the line of separation is somewhat arbitrary since snow is really ice mixed with air and can be found in various conditions ranging from fluffy new powder to hardened snow pack barely penetrable with the axe. Several terms may be helpful in understanding the terminology in the literature. Alpine ice (AI) is frozen precipitation (snow) that has undergone a metamorphosis under the influence of time, pressure, and temperature changes. Water ice (WI) has frozen directly from a liquid state, even though it may have originated from snow or alpine ice before it became liquid. Technical ice climbs may be rated with a prefix AI or WI followed by a number 1 through 8. For purposes of M and E snow climbing, which is done usually as part of climbing a peak in the Sierra Nevada, most climbs would be rated AI1 or less (unrated). The reference books discuss snow climbing with crampons in the chapters on ice climbing. As the term is used here, "snow climbing" includes travel over very hard snow where crampons may be used.

A distinct difference in snow climbing compared to rock climbing is the increased importance of judgment. A rock route typically will have a rating of class 3, class 4, or the various subdivisions of class 5. Given constant good weather conditions, this rating and the associated degree of difficulty will be virtually the same day after day. Snow climbs do not fit so nicely into these categories. For example, the lowest rating for a snow climb would be AI1, which would include slopes up to 50 degrees. Most climbs on Sierra peaks are not this steep. Also complicating the issue is that the same route will change from hour to hour during the day with fluctuations in temperature and weather. The leader must recognize that climbing conditions vary with hardness of snow as well as steepness of the slope. A 45 degree slope with soft snow may be much less difficult than a 30 degree slope with an icy surface and no run out. A route climbed in the cold morning may be more—or less—difficult in the warm afternoon sunshine. Because of these variables, leader experience and judgment are especially important on snow slopes. The leader's experience is more important than knowing the degree measure of the slope. As a result, it is best not to judge differences in M- and E-level snow slopes based only on slope steepness. Some guidelines, however, may be presented to distinguish between the two levels (M and E) for the purpose of training, checkouts, trip listing, participant screening, and chapter approval of trips. The actual climbing of snow or ice may be fairly straightforward, but judging the conditions can be difficult.

M Category (class 3)

M category snow climbing should really be synonymous with class 3 rock climbing. The kind of climbing envisioned as the core of the M level is that found in the High Sierra from late spring into summer on slopes that without snow cover would be class 1 or 2. M-level snowfields would generally be consolidated with negligible avalanche or crevasse hazard. M trips typically require skill with an ice axe and ability to use crampons in the flat foot technique. Rope use would be equivalent to that in 3rd class rock climbing, and rappelling may be done using the same techniques as in rock climbing. Belaying the lead climber during the ascent, as would occur in class 4 or exposed climbing, is for the most part beyond the M level.

E Category (class 4 or 5)

E category snow climbing should be synonymous with class 4 or class 5 rock climbing. This extends snow climbing conditions beyond the M level, in which use of a rope becomes necessary for most climbers and/or exposure becomes significant. The E level also includes glacier travel with crevasse hazard and bivouac survival risk; therefore crevasse rescue is a required skill. E trips may use simultaneous roped travel or fixed ropes for ascending, and belay of a leader who is above the belayer may occur.

Route Selection, Planning, and Survival

Selection of climbing route, terrain, weather, importance of speed, and alpine (pre-dawn) starts are important considerations for the leader. References in the bibliography discuss these variables and how each will affect the climb. The snow climbing leader should be knowledgeable of these variables and the hazards associated with them.

These hazards may contribute to a forced bivouac. Because a bivouac is a possibility, the leader must know what to do. This includes seeing that participants have proper clothing and equipment prior to starting the trip. A snow shovel may be a great help. Bivouac gear includes means for isolating the climber from the snow and gear that provides a windbreak and chill protection. A snow cave or other emergency shelter may need to be constructed.

Leading

The snow climbing leader must have the personal skill to climb under varied conditions. Much of the M or E snow checkout pertains to these skills. Snow climbing skill, however, is not sufficient; the leader must also have leadership ability and sound judgment. The leader observes trip participants, corrects improper techniques being used, gives encouragement, and stops any dangerous activities or moves. Requiring each individual to demonstrate the necessary skill before entering hazardous terrain may be warranted. When in doubt, the leader should modify the objective or route, turn people back, or cancel the trip.

TREKKING POLES

Use of trekking poles for hiking has become more common in recent years. They are effective tools for maintaining balance and can absorb some of the shock delivered to the knees during descents. They are not, however, substitutes for an ice axe. When the snow is hard or the slope steepens, one must ask if an arrest can be accomplished with trekking poles. If the answer is no, put the poles away and get out the axe.

When traversing slopes with trekking poles, some participants forget to adjust the length of their poles or choke up on a pole. This means that the uphill hand is held high. Because this position can be quite fatiguing over time, a good rule of thumb is to hold the poles in a way that keeps the hands below the level of the heart.

Holding the uphill pole perpendicular to the slope, rather than vertically, improves balance on a traverse because the pole keeps the climber from falling inward on the slope. When a climber falls inward, the feet tend to lose traction and slip outward. Grasping the pole along the shaft (choking up) and holding it perpendicular to the slope or more horizontal helps maintain balance and tends to engage the pole in the snow if the climber slips.

ICE AXE

General

Climbers have differing views on using and holding the ice axe. Most issues have several sides. Proper resolution or compromise depends upon snow conditions, slope, individual skill, climbing experience, exposure, and personal preference. The LTC avoids rigid prescriptions but offers some summary observations and urges leaders to try the various techniques and use those appropriate to the circumstances. Leaders should be able to observe participants who utilize a number of techniques and know the strengths and limitations of each technique. The leader also should know the ice axe parts and variations in styles and design.

Length

A long axe is hard to handle, particularly on steep slopes, and is awkward to carry on a pack. On the other hand, a short axe is a less secure self-belay device for an anchor when using the shaft. It is hard to use in the cross-body position and is a poor cane for all around use, especially when going downhill facing forward. For M and E snow climbing in the Sierra Nevada, an axe long enough to reach from the palm of the hand to about the ankle is a good compromise.

Tether and Leash

A climber should never drop the axe. On even moderate slopes, a dropped axe may be a lost axe with serious consequences. The LTC requires some form of attachment to the axe. This is not simply an “idiot” attachment to prevent losing the tool, but a very useful piece of gear. A leash connects the axe to the wrist. A tether connects the axe to the waist or other fixed body part, typically a sling around the upper body or a harness. A leader should know the advantages and disadvantages of each technique since participants may prefer one to the other. Always use anchor-worthy materials for attaching the ice axe.

A wrist leash is typically long enough so that the axe can be carried in either hand with the leash attached to only one wrist. This allows the climber to move the axe from hand to hand on switchbacks without removing the leash. Step chopping or technical climbing may call for a leash that is long enough to support the hand and prevent dropping the axe. Support is provided by passing the leash around the shaft of the axe, making a hitch near the spike, and attaching the loose end to the wrist.

Some climbers use an axe with a short leash attached to a glide ring that slides up and down the shaft. Glide rings tend to interfere with rope handling during boot axe belays. A short leash that is wrapped around the head of the axe keeps the axe head firmly in the climber’s grasp, even if the grip is lost during a fall. A short leash, however, must be changed from wrist to wrist when the climber changes direction on switchbacks, temporarily breaking the climber’s safety attachment to the ice axe. This constant switching causes delay in the climb as the climber pauses to shift the leash from hand to hand with gloves.

Leashes can be used for belays, provided the leash webbing is anchor-worthy and proper knots are tied. Long leashes can be attached directly to the climber, while short leashes require separate slings to give the necessary length. A long wrist-type leash is often used with the wrist loop carabiner-clipped to a separate sling that runs around the climber’s body.

A tether is tied to the axe head at one end and attached to the climber’s body at the other. The tether should be long enough to permit unrestricted use of the axe in any grasp, but not so long as to be a trip hazard. A tether allows the climber to move the axe from hand to hand. A tether, however, can interfere with clothing changes, pack straps, and the climbing rope. Regaining control of a tethered ice axe can be difficult if the climber lets go during a fall.

Sharpness of Edges

For typical snow climbing in the Sierra, the edges of the axe may be somewhat dull and still be quite functional. Obviously, the more ice-like the surface, the sharper the edges must be to be useful. In LTP arrest practice sessions, the use of protectors on the adze is mandatory.

Grasp

How should one grasp the axe? The answer depends on many factors, including the climber's preference. The reference books have figures showing various techniques.

Much hiking and climbing is done with the axe in the cane position. The self-belay grasp has the palm of the hand over the adze. This is a good grasp on the axe because the pick is pointed away from the body. The self-belay grasp allows firm placement of the axe for self-belay, particularly on long sustained snow climbs where the hand can tire. If a climber slips, a self-belay is the first line of defense. If the self-belay fails, the climber must switch over to the self-arrest grasp in order to arrest. The preferred grasp should be practiced until self-belays and self-arrests are accomplished reliably and immediately under stressful, real-world conditions.

SNOW CLIMBING

Step Kicking, Ascending, and Descending

Kicking steps is an integral part of a snow climb. Changes due to snow conditions happen as weather changes and the sun warms the snow. The leader is constantly evaluating the snow and the team as the climb proceeds. On descent, the leader must be competent in use of the plunge step, self-belay while heel kicking, and step kicking when facing into the slope using the axe in stake position or low dagger position.

Step Cutting

The leader must be able to cut steps with reasonable facility. Occasionally in making a snow climb, a small patch of ice or hard snow may be encountered. The party may not have crampons, or it may be quicker to chop steps rather than to put on and take off crampons. Sometimes a snow slope is topped by a short pitch of a steeper slope or small cornice. The leader may need to chop comfortable steps up the short pitch for the party.

Self-Belay

A self-belay is an ice axe planted with the shaft in the snow, which is used for support and to which the climber clings if a slip occurs. The first line of defense regarding a slip is not to fall at all. This means that during the climb the climber pays attention continuously to balance and planting the feet and the axe firmly. If a slip occurs, the climber should immediately use the self-belay with the properly planted axe.

Self-Arrest

Self-arrest is a learned technique that should be mastered in all its possible modes of occurrence. This includes holding the axe in the right or left hand. The arrest should be practiced from a fall resulting in slides with head first, with feet first, on one's back, on one's belly, with and without pack, and with different grasps of the axe when the slide begins. One must also know how to arrest without the axe. Normally, one should strive to achieve an arrest quickly before picking up much speed in the fall.

Self-Arrest with the Ice Axe in Soft Snow

If a fall occurs in soft snow on moderate slopes and the self-belay gives way or is not used for some reason, an arrest must be initiated. The pick of the axe alone may not arrest a slide in soft snow. In soft snow it is desirable to use the part of the ice axe with the most surface area to engage the snow, namely the shaft. The general idea is to end up in a sitting position facing down the slope as in a sitting glissade.

The hand on the spike end of the shaft presses the shaft of the axe into the snow, while the hips and body push against the shaft to engage the broad side. The upper hand grasps the axe head in the preferred grasp with the pick pointing away from the body, and the heels of the feet dig in.

This arrest technique has several advantages. First, the widest part of the axe shaft is contacting the snow. Second, the climber is facing down the slope, seeing what is happening and where he or she is going rather than facing directly into the snow. Finally, the heels of the feet can dig into the snow very effectively due to the strength of the leg muscles.

Self-Arrest with the Ice Axe in Hard Snow

Self-arrest while wearing crampons is done by lifting the feet up so that the crampons do not touch the snow. When practicing a hard snow arrest, one should not wear crampons and must have a safe runout. A technique for hard snow arrest while wearing crampons is to be on one's side with the knees slightly bent, looking down the slope for upcoming obstacles with feet up off the snow. The pick of the axe is engaged into the hard snow; the shaft is held by the other hand up off the snow surface, forcing the pick into the hard snow. The advantage to this technique is that the climber now sees where he or she is going.

Self-arrest from a fall on hard snow or when the climber is wearing crampons is well described in *Mountaineering: The Freedom of the Hills*. All techniques should be practiced in the various starting positions until they become second nature.

Glissading

Glissading is a fast and enjoyable way to descend, but control must be maintained. Visibility of a safe descent to the bottom of the slope is essential. Three postures are used: standing, crouching, and sitting. The standing glissade is the hardest to learn. The crouching glissade keeps the climber dry but is tiring to the legs. The sitting glissade is easy but wet.

In the sitting glissade, the ice axe may be held in the self-belay or self-arrest grasp. The other hand engages the shaft into the snow. If the self-belay grasp is used, the pick points away from the climber's body, and the fingers of the hand grasping the head of the axe wrap nicely around the adze. This position protects the climber from the points of the adze and is a very natural position. If the snow consistency or slope suddenly changes, however, a self-arrest may be necessary, and the grasp must be switched over to the self-arrest grasp to perform the arrest.

Using the self-arrest grasp during the glissade allows the climber to arrest immediately without changing the grasp. Using this grasp during a sitting glissade, however, creates an awkward hand position and requires considerable attention to keeping the pick pointed safely away from the body. The choice of grasp is up to each climber. Leaders must know the ramifications of each grasp and make sure participants know how to glissade and arrest correctly.

CRAMPONING

Usage

When the steepness of the slope and hardness of the snow do not permit secure footing by kicking steps, steps can be cut or crampons can be used. Step cutting for extended periods is very slow and requires a great deal of energy. Unless only a few steps need to be cut or crampons must be put on and taken off repeatedly, crampons are generally safer and faster than step cutting. At the other extreme, the snow can be so soft that it balls up under crampons, making cramponing slower than climbing without crampons and increasing the chance of a fall.

Flat Footing

The flat foot (or French technique) uses ice axe placement and direction changes that are similar to those for step kicking, with the exception that the feet are flat on the snow so that all crampon points are utilized. Flat footing requires bending the ankles. As the slope becomes steeper, the toes point more downhill. On moderate slopes, the axe is used in the cane position. As the slope steepens, other techniques with the axe should be used, such as the stake position or cross-body position.

Descending while wearing crampons is done with a variety of foot and ice axe techniques that match the conditions. For easy slopes one simply walks down using the ice axe in the cane position. On steeper slopes, a diagonal path using the cane or cross-body position may be better. Other ice axe techniques for descent include the support and banister positions. The leader should be aware of additional techniques shown in the reference books and their accompanying advantages and disadvantages.

Front Pointing

(E) On very steep hard snow, front pointing (or German technique) may be the preferred technique. The ice axe can be used in the low dagger position, high dagger position, traction position, or anchor position. Front pointing may be useful for one or two steps in changing direction in a normal flat-footed zigzag ascent. A useful compromise between flat footing and front pointing is the three o'clock (or American) technique, in which one foot is in a front point position while the other is in a flat footed placement. The feet can be switched as needed and should be changed frequently before extensive fatigue occurs.

Mixed Climbing

Frequently, a snow climb will require some scrambling over rock while wearing crampons. Although this dulls the crampons, the dulling usually is not significant for most snow climbs done in the Sierra. With modern alloy steel, the points should not bend or break. This is not true for aluminum crampons. Because putting on and taking off crampons is very time consuming, keeping crampons on over short distances on rock is a significant time-saving practice.

ROPED TRAVEL

Simultaneous Roped Travel

(E) Ascending or descending snow slopes simultaneously while roped is faster than climbing by a succession of belays, but it has the hazard of the domino effect of "one fall, all fall." If a climber falls, he or she should yell "falling," and the other climbers should go into an arrest position. Simultaneous roped travel is used primarily on glaciers with crevasses; however, it can be useful in aiding a tired, weak, injured, or inexperienced climber. Unanchored rope travel on snow slopes other than glaciers is discouraged except when there is sound reason for roping and traveling together. Another alternative is for the leader to fix the rope as he or she moves up or down the pitch. The rope can be fixed with anchors in the snow, such as pickets, and fixed at each end. The members of the team then clip onto the rope with a friction knot or ascending device and move along the rope. The trailing climber then cleans the gear as he or she follows. This technique requires carrying some extra gear, and climbers should be reminded not to step on the rope with crampons.

Glacier Travel

(E) For glacier travel the entire team must pay attention to rope management. All climbers should use a proper body harness. Each climber should carry friction knots or ascenders attached in a ready position on the rope. Depending on the climber's position on the rope team, methods of attaching to the rope vary. The E leader needs to know the different set-ups in tying a leader, middle person, or trailing climber into the rope.

BELAYS AND ANCHORS

Belayed climbing can be done when the climbing slope dictates, a climber is nervous, or the consequences of falling are serious. A variety of belay positions and anchors can be used, each with advantages and disadvantages. The appropriate anchor to use and its security are highly dependent on the particular snow conditions, the equipment available, the skill of the team, and the expected load the anchor might need to handle. Most snow anchors compared to those used on rock are relatively weak, but generally so are the forces generated by a fall. For snow it is best to use two or more independent anchors whenever possible and reasonable. To keep shock loads to a minimum, dynamic belays are preferred. Slack in the rope system is another critical factor that can increase the shock load to an anchor or a climber trying to hold an arrest. For this reason, slack should be kept to a minimum for most roped travel.

Anchored Sitting Hip Belay

(E) The anchored sitting hip belay is a secure belay and fairly easy to do for most leaders. Its disadvantages include the time necessary for preparation, cold conditions of sitting in the snow, and difficulty in exiting the belay hook-up if a belayed climber needs help.

Boot Axe Belay

The boot axe belay technique is quick. It has several variations: the "C" or the "S" technique, depending on how the rope is wrapped around the boot. The "C" and the "S" variations differ significantly in the rope handling, but not much in the actual anchor performance since the weakness in this belay is not the rope friction across the axe and the boot, but the tendency of the axe to come out of the snow. This means that placement and control of the axe during the belay or holding a fall are critical.

Standing Carabiner-Ice Axe Belay

The standing carabiner-ice axe belay has easy rope handling, uses the dynamic addition of the belayer's body, and is more secure than the boot axe belay. It takes slightly longer to set up than the boot axe belay, and a carabiner and sling are required. If the climber uses a properly tied leash on his or her axe, it can immediately become the sling, and all that is needed is the carabiner. Both the boot axe and standing carabiner belays require sinking the length of the ice axe shaft, which may not always be possible.

Planted Ice Axe

A planted ice axe can be used with the leash or tether for a quick self-belay. When ice axes are planted vertically in the snow for use as anchors, however, they tend to pop out under load, so the axe must be held firmly in place by hand or some other means. The anchor's strength is also dependent on the snow conditions.

Bollard

A bollard can be an excellent anchor with the advantage that no extra equipment is needed, although padding may be useful to keep the rope from slicing off the bollard or freezing in place. It usually takes a long time to set up. The strength of a bollard varies greatly, depending on the hardness of the snow, especially the underlying layers where the rope engages the snow. If a bollard is used as an anchor for a rappel, a separate sling should be used, not the climbing rope because it could freeze in place.

Buried Ice Axe

An ice axe buried horizontally with a tie into the middle of the shaft and the pick down can be a very secure anchor, depending on snow conditions. It is another type of deadman anchor.

Snow Pickets and Flukes

(E) Pickets and flukes are good anchors but require carrying the extra gear. Snow flukes are difficult to place and have few advantages over pickets and therefore are seldom used. Pickets are versatile and can also be buried as deadman anchors.

Crevasse Rescue

(E) The first action following a crevasse fall is to keep others from falling in. If roped, the other climbers immediately go into self-arrest. It must then be determined whether the fallen climber can climb out on his or her own or must be rescued. Anchors are placed, and rope team members have specific roles to assist the fallen climber or set up a rope system for hauling. If the fallen climber is unable to help, he or she must be hauled out using a system of pulleys. Leaders should know the single pulley, "Z" pulley, and the "CZ" pulley techniques. Because these techniques may be quite complicated and time-consuming to use in a real situation, practice is mandatory to maintain a level of proficiency with these techniques. Redundant anchors with belays and in-crevasse assistance to the victim should be used if equipment and personnel are available.

AVALANCHES

Snow climbing leaders must be able to identify avalanche hazards. These include local conditions, topography, weather, snow accumulation, recent snow activity, and a host of other issues. A leader should study the references and be thoroughly familiar with the various conditions that can change a safe slope to an unsafe one.

SNOW CHECKOUT

For the purposes of snow checkouts, snow consistency is identified as soft or hard, the difference being that on hard snow secure boot steps cannot be easily stomped into the snow and step cutting or crampons may be required for safe travel.

Snow slopes are identified as low, moderate, and high angle. On low-angle slopes that do not require the use of an ice axe to arrest a slide, one may use trekking poles to aid balance and ease travel. On high-angle slopes or hard snow it may be difficult or impossible to arrest a slide with an ice axe. E-level exercises on high-angle slopes should be performed with a rope belay. Climbing helmets must be worn when using the ice axe and when arrests are practiced.

Snow checkouts, like any Sierra Club activity, should be performed with safety as the foremost consideration. The snow checkout location is selected carefully with safety in mind. Any self-arrest slope must have a safe runout in case a candidate cannot arrest the slide. An experienced climber should test the runout first by glissading to the bottom. If any danger is detected, another location should be chosen. Arrests shall be performed and evaluated in conditions where sufficient momentum can be achieved to require the use of an axe to arrest a slide. The ice axe pick must always be pointed away from the body. The adze of the axe during practice or a checkout should be covered with a thick layer of duct tape or some other suitable material to prevent possible injury.

Leadership

The LTP candidate is required to have leadership ability and judgment sufficient to lead a party safely with reasonable speed. The candidate is expected to have read and be familiar with the material in the reference books. The candidate may be confronted with situations to sort out during the checkout. The snow examiner will evaluate all pertinent aspects of the candidate's knowledge, skill, judgment, and leadership ability. Also evaluated are basic skills with ropes, knots, belaying, rope handling, and rappelling, as well as the speed and expertise with which all of the above are accomplished.

E-Level Requirements

The E-level leader is expected to be more skillful, knowledgeable, and experienced with snow climbing than the M-level leader. In particular, this applies to arrests, rope handling, anchors, bivouacs, avalanche, and general overall judgment on situations. The E checkout will include situation responses. The checkout examiner will give each E candidate a variety of situations that require the candidate to come up with feasible solutions. In most cases these will be created by the checkout leader in a realistic way so that the situations will be self-evident. The candidate is then expected to use available resources and people to solve the problem(s) presented. The element of time is stressed, and, of course, there may be more than one solution to a particular problem. The checkout leaders grade and observe candidates for accuracy, speed of response, technical competence, decisiveness, and awareness of other factors which may be present (rock fall, weather, and party condition).

SUGGESTED READING

Eng, Ronald C., ed. *Mountaineering: The Freedom of the Hills*, 8th ed. Seattle: The Mountaineers, 2010.

Lowe, Jeff. *Ice World: Techniques and Experiences of Modern Ice Climbing*. Seattle: The Mountaineers, 1996.

Moynier, John. *Avalanche Aware: Safe Travel in Avalanche Terrain, 2nd ed*. Helena, MT: Falcon, 2006.

Westwide Network: Avalanche forecasts and safety information. Website: http://www.avalanche.org

APPENDIX A: MAPPING SYSTEMS AND UTM COORDINATES

Latitude and longitude have been used to locate positions on the earth for centuries. While most people learned about latitude and longitude in school, the Universal Transverse Mercator (UTM) coordinate system, which is an important feature on USGS topo maps, may be relatively unfamiliar. UTM references were indicated by tick marks in the margins of USGS topos prior to 1989. Maps printed since then are often overlaid with a grid of UTM reference lines, which are spaced in metric intervals. Learning the UTM system goes hand in hand with adapting to the metric system: both offer convenience and can be learned with a little effort.

Latitude and Longitude

Any point on the earth can be located by measuring two geographic coordinates, latitude and longitude, which are actually angles. Latitude is the angle between the point in question and the equator; longitude is the angle between the point and the prime meridian, which runs through Greenwich, England (see Figure A-1).

Latitude and longitude are measured in degrees, minutes, and seconds of arc either north or south of the equator and either east or west of Greenwich. Latitude parallels are always true east and west, and meridians of longitude are always true north and south. USGS topo maps use latitude parallels and meridians for their borders, and the slight distortion of the meridians, which converge at the poles, can be seen on a 7.5 minute map, where the upper border is slightly shorter than the bottom.

Universal Transverse Mercator (UTM)

UTM offers several benefits over latitude and longitude. The system is based on a square grid with linear dimensions rather than angular relationships; the basic unit is the meter rather than degrees, minutes, and seconds. This means that the distance between any two points is always described in terms of distance instead of angles. The UTM grid is printed in one-kilometer squares on many newer USGS topo maps, and coordinates describe the distance east, then north of certain reference points (see Figure A-2). All coordinates are positive numbers, and because they are metric, they use convenient decimal units rather than sixty seconds, sixty minutes, and 360° of arc.

The UTM system can be used without understanding the details of its creation, but knowing how the scheme works is important. Imagine slicing the earth like an orange into sixty equal wedges. Peel the skins away and lay them flat. These flattened skins are the basic representations of the earth's surface used in the UTM. Notice that imaginary lines running up the center of each section are the only straight north-south lines (meridians) on the map slices (see Figure A-3). Every other north-south line curves from the equator toward the poles. Likewise, the equator is the only true east-west line; all other east-west lines are slightly distorted when the orange peels are flattened.

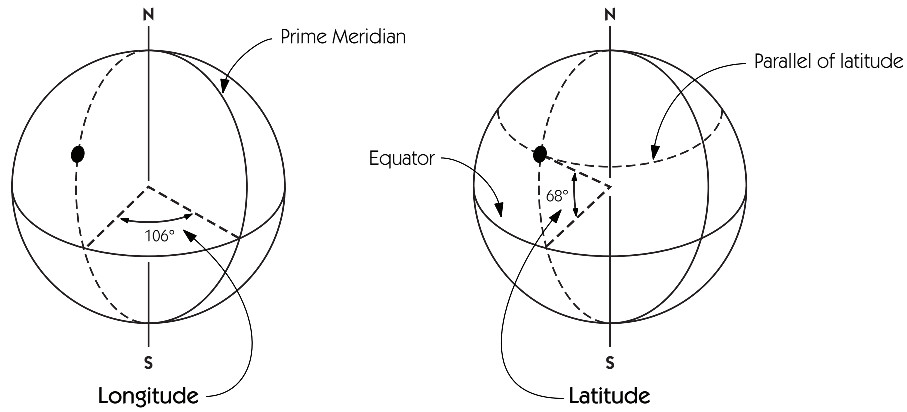


Figure A-1. Latitude and longitude are angles or arcs measured from the equator and the prime meridian.

A UTM rectangular grid, measuring one million meters wide by twenty million meters tall, is laid on top of each section. These dimensions are slightly larger than the slices of the earth, so the rectangle is positioned dead center over the orange peel slices with the straight meridian line at the rectangle's half way (500,000-meter) mark (see Figure A-4). The rectangle is divided into 1km squares. USGS topo maps indicate how far from true north the local grid lines run with the designation "GN" (grid north) in the magnetic declination legend on the lower margin.

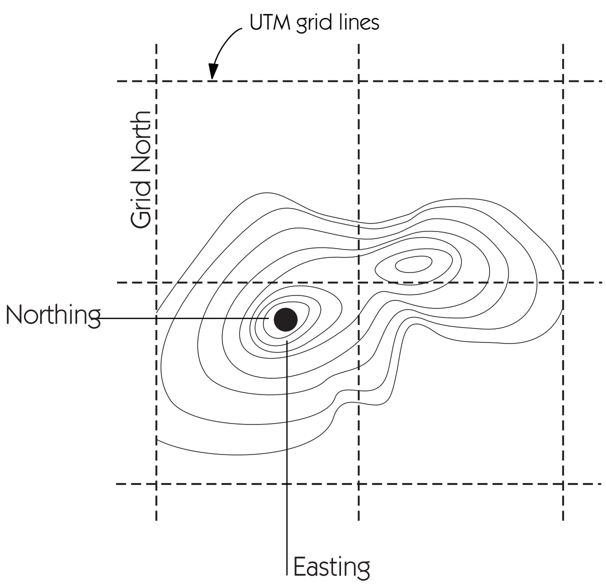


Figure A-2. UTM coordinates are distances referenced to a grid overlaid on a map.

Zones, Eastings and Northings, and Bands

The earth's surface has now been divided into sixty equal segments and each segment has a metric grid overlay. Making each point on the earth unique, however, requires a bit more. Each strip of earth surface is called a "zone," and the zones are numbered from 1 to 60 beginning at the international date line (180° longitude) and proceeding easterly. Zone 1 covers 180° to 174° W longitude; zones 10 and 11 cover California.

The coordinates of any point within a zone are simply the distances in meters from certain reference points. The distances are referred to as "northings" and "eastings." Northings are measured from the equator and eastings are measured from the 500,000m meridian at the center of the zone.

In the Northern Hemisphere, the northing values are natural measurements north of the equator, which is zero. To avoid negative numbers in the Southern Hemisphere, northings decrease from 10,000,000 meters at the equator. Since eastings are measured from the 500,000m meridian, locations west of the meridian are less than 500,000; those east are more than 500,000 (see Figure A-5). Because the UTM rectangular grid is wider than the orange peal slice of earth, eastings can never be close to zero.

The Northern and Southern Hemispheres are further differentiated by a series of horizontal bands, which are 8° of latitude high. These begin at 80°S latitude (the Polar Regions are ignored). The southernmost band is labeled "C," and the bands progress alphabetically northward through band "W" at 72°N (the letters "I" and "O" are

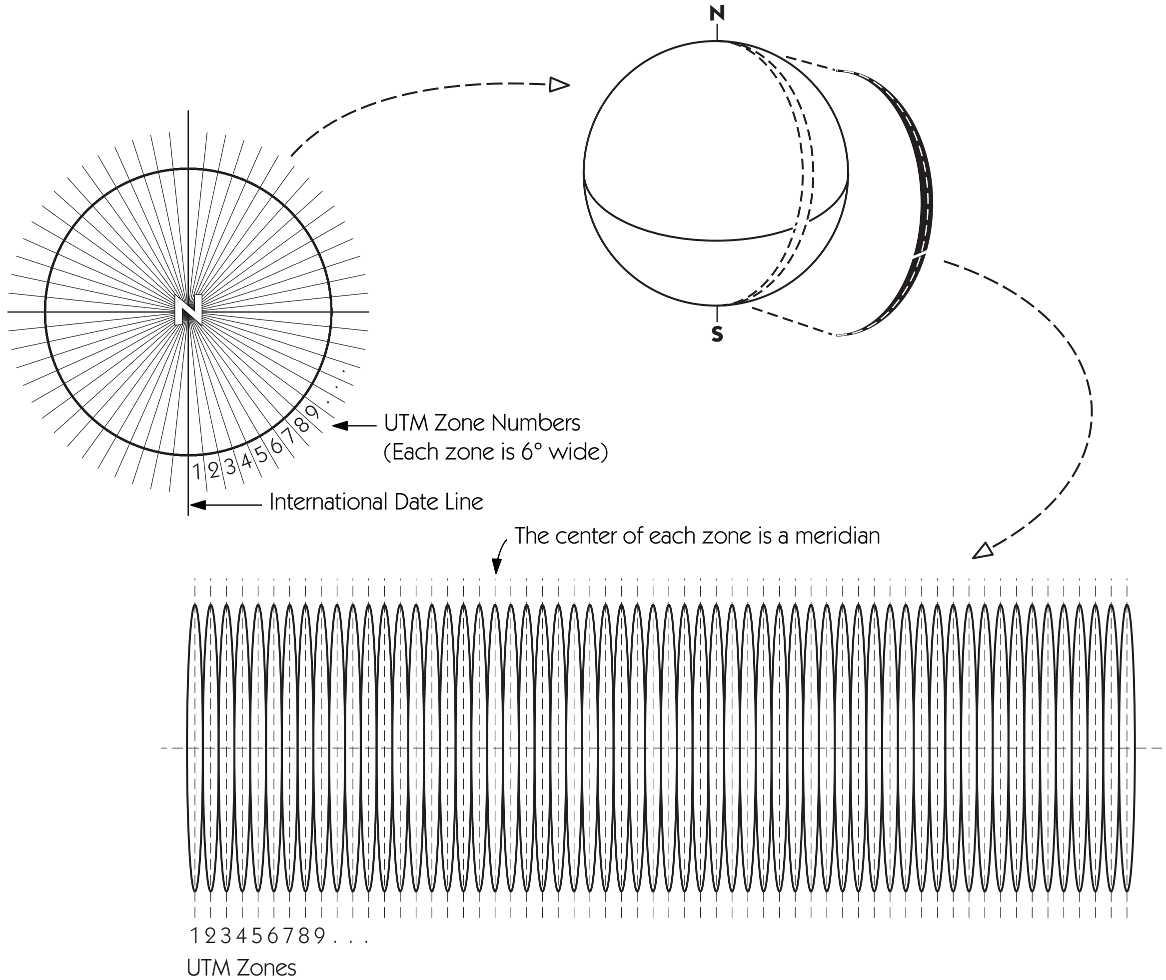


Figure A-3. Slicing the earth like an orange and pealing away the skins creates 60 UTM zones.

omitted to avoid confusion with the numbers "1" and "0"). Band "X," which is wider than the other bands (12°), is the northernmost and terminates at 84°N latitude (see Figure A-6). California is in two bands, with S changing to T at 40° N latitude, about 70 miles north of Lake Tahoe. Band references prevent any ambiguity as to northings, but can be ignored for most navigation. GPS receivers will usually interpret bands automatically once the proper hemisphere is specified.

Datums

The map datum is the final complexity backcountry navigators need to understand. The earth is not a perfect sphere, so a datum, which is a mathematical model of the earth, describes exactly how a map's grid overlay is positioned on the globe. Most GPS receivers default to the World Geodetic System of 1984 (WGS84) datum, but it is not the only datum that hikers are likely to encounter. Two other systems, the North American Datum 1983 (NAD83) and North American Datum 1927 (NAD27) are commonly seen on the margins of USGS topo maps. NAD27 is gradually being phased out.

Selecting the correct datum for use with a GPS receiver is important; otherwise, coordinates may be off by tens or even hundreds of meters. USGS topo maps often indicate how to convert their coordinates from one system to the other. For example, for a map using an NAD27 grid, "move the projection lines 10 meters north and 84 meters east to place on the North American Datum 1983." GPS receivers may allow selection from as many as 100 different datum systems and usually make the necessary conversions automatically. Hikers using GPS receivers to navigate in the field must select the datum specified on their maps.

For example, consider how the location of Mt. Whitney is represented by different datums. The geographic

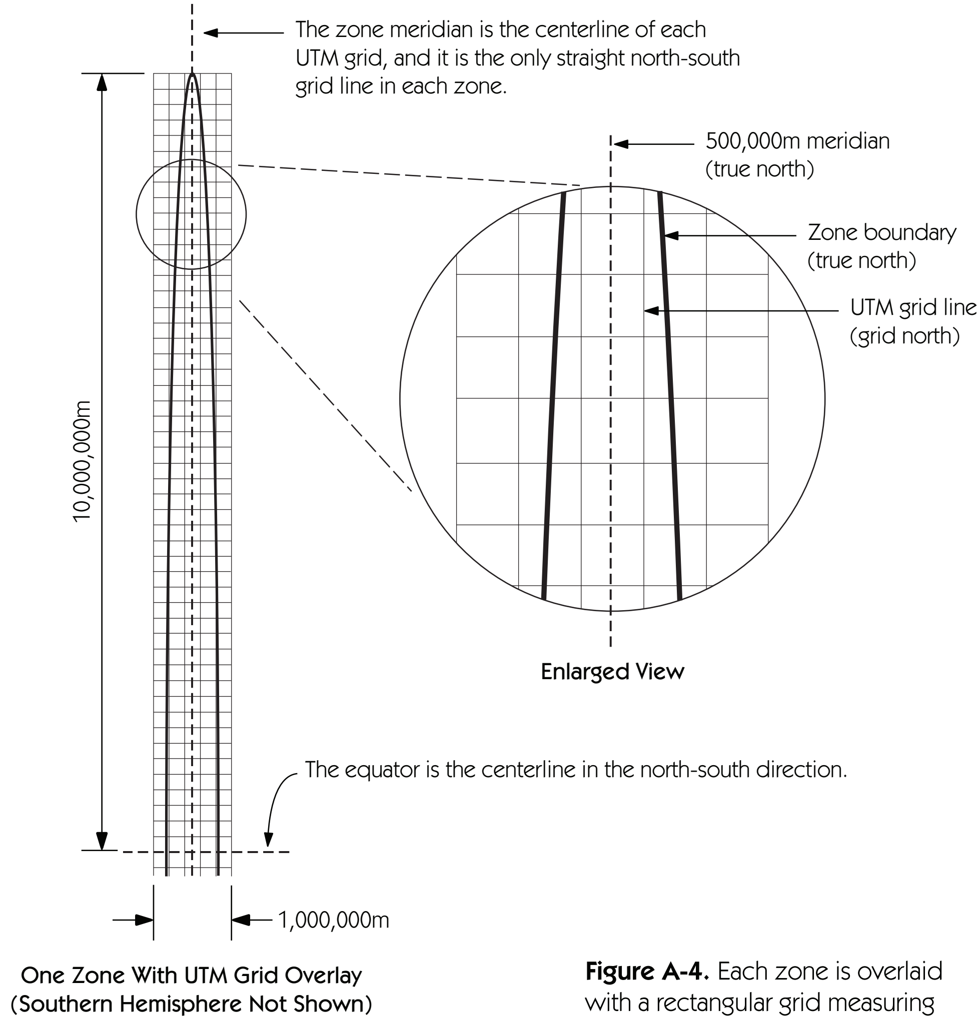


Figure A-4. Each zone is overlaid with a rectangular grid measuring 1,000,000m wide x 20,000,000m tall.

coordinates of the summit are

36° 34' 45" N and 118° 17' 33"W.

In UTM coordinates it is in zone 11, band S. At this point it is necessary to pick a datum. With the NAD83 datum the location is

Easting 384,356 meters and
Northing 4,048,961 meters.

With the NAD27 datum, the location is

Easting 384,436 meters and
Northing 4,048,764 meters.

These two points appear to be 212 meters (about 700 feet) apart if the wrong datum is used.

Shorthand Notation Used With UTM Coordinates

The complete location of Mt. Whitney summit, according to the NAD 83 datum, would be written as

11S 384356 mE 4048961 mN.

Easting is always given first. Some GPS receivers drop the band letter (S in this case) and display the location as follows:

11 3 84 356
40 48 961.

The final digit, representing meters, will be dropped if the precision is only to within ten meters. Likewise, the last two digits will be dropped if the precision is only to within 100 meters.

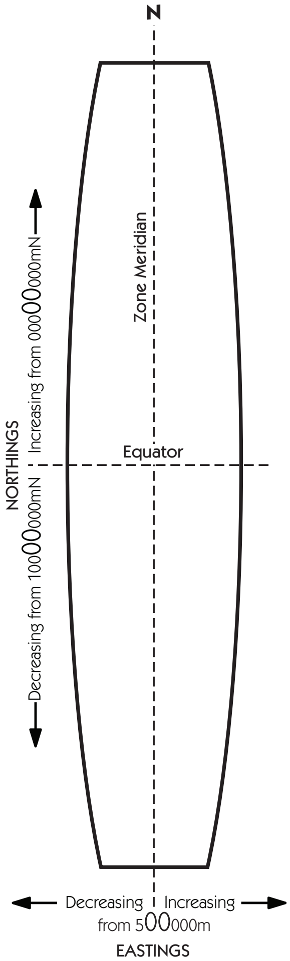


Figure A-5. References for eastings and northings (the zone diagram has been widened for clarity)

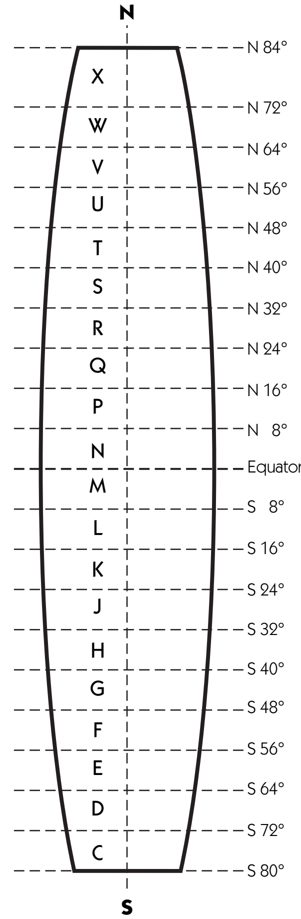


Figure A-6. UTM bands (the zone diagram has been widened for clarity)

A USGS topo map would show a tick mark along the edge of the map area at the 384th 1km easting grid line and at the 4048th 1km northing grid line in the zone, among others. These ticks would be marked

384 and 4048 respectively on a 7.5 minute map.

The superscripted numerals indicate resolution that is too coarse to be useful on this particular map. If these ticks happen to be cardinal on a particular topo, they might be marked more completely as follows to emphasize the 1 km grids and their principal digits.

384000 mE and 4048000 mN

Locating a Point on a Map Using UTM Coordinates

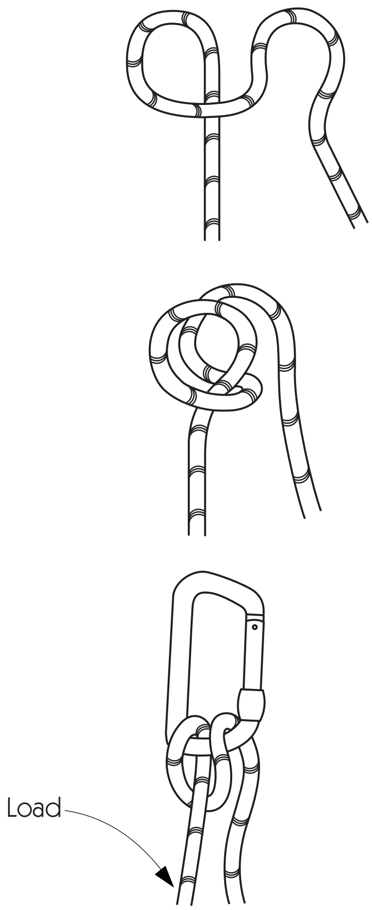
Here is where the UTM system shows its convenience. The summit of Mt. Whitney is located to the east (right) of the 384 grid line, about 1/3 of the way to the 385 grid line. This establishes the east-west location. Whitney summit is also above the 4048 grid line, almost to the 4049 grid, which gives the north-south position. If the UTM grid lines are printed on the map, the location is easy to plot by eye. The 1:24,000 (or 1:25,000 metric scale) scale on compass base plates, or the 1,000 meter scale in the map's margins can also be used to plot the position accurately.

Appendix B: Illustrations

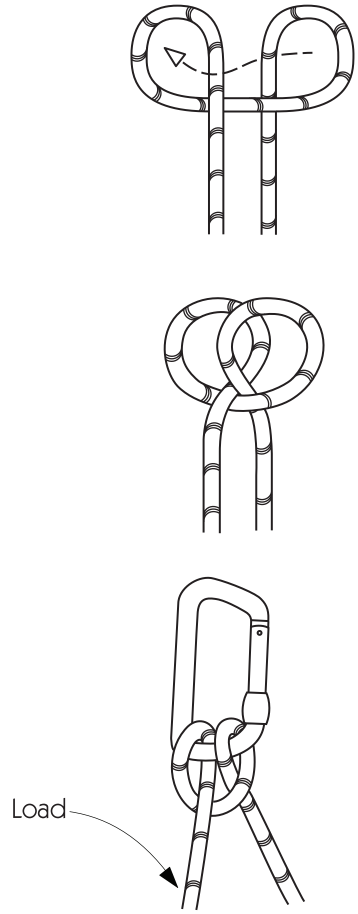
Knot Completion and Inspection

Casual knot tying creates unnecessary hazards. A loose or sloppy knot is liable to come untied during a climb or under the sudden force of a fall. Strands may slip, become crossed, and even twist into unintended knots. Poorly tied knots, furthermore, can be difficult to inspect.

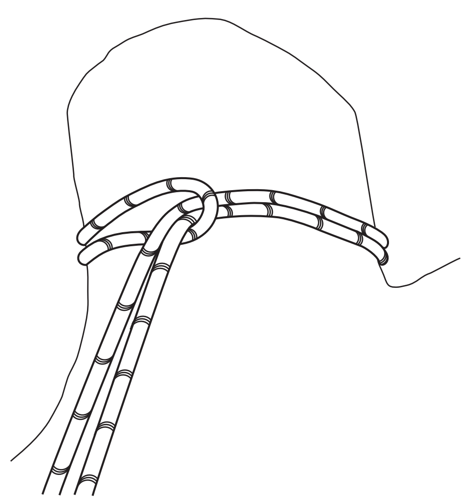
Dressing knots and tying proper finishing knots are fundamental principles of safe climbing. Dressing means working all the parts together, aligning the strands correctly and pulling everything tight. A finishing knot, such as the double overhand (half a double fisherman), provides a safety lock and reinforces reliable completion habits.



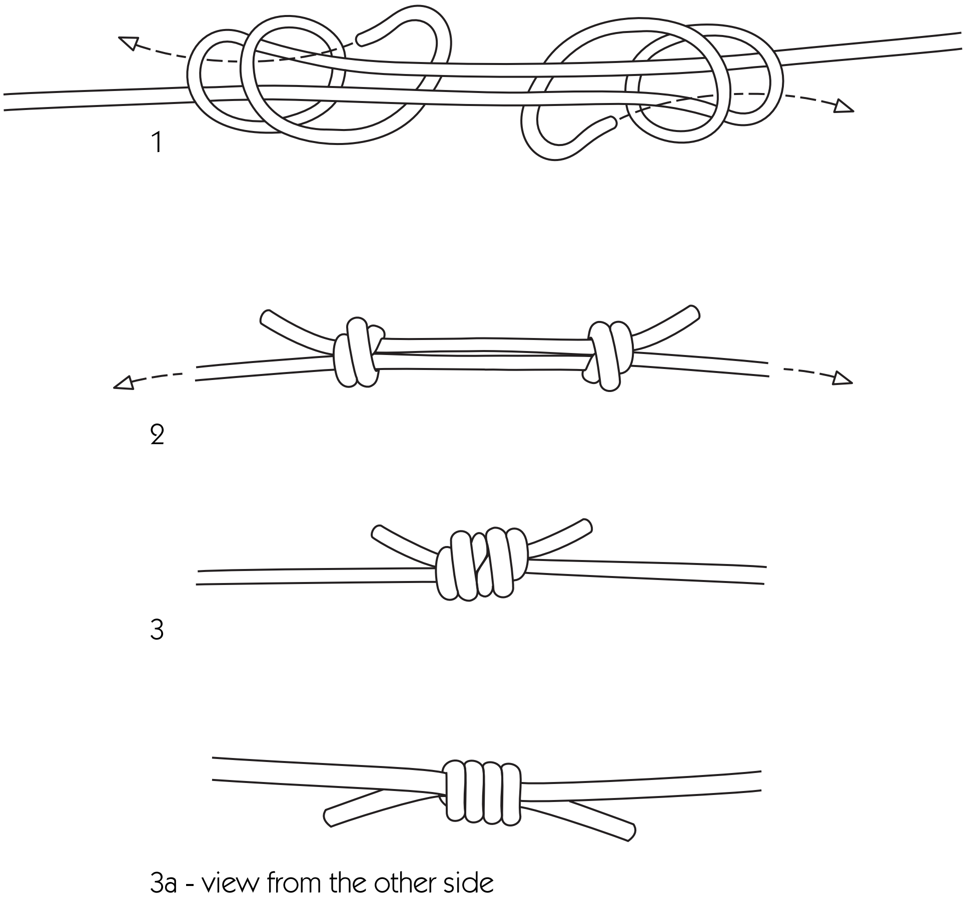
Münter Hitch



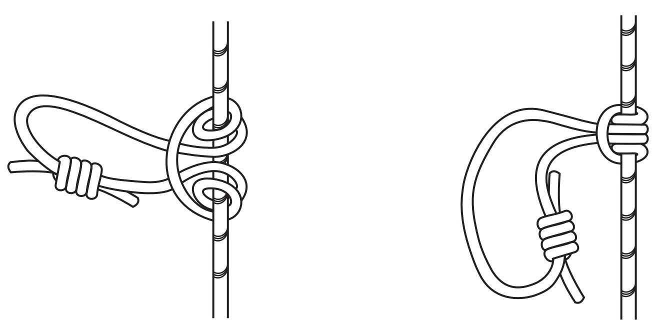
Clove Hitch



Girth Hitch



Double Fisherman's Knot
(also called the "Barrel Knot")



Prusik Knot

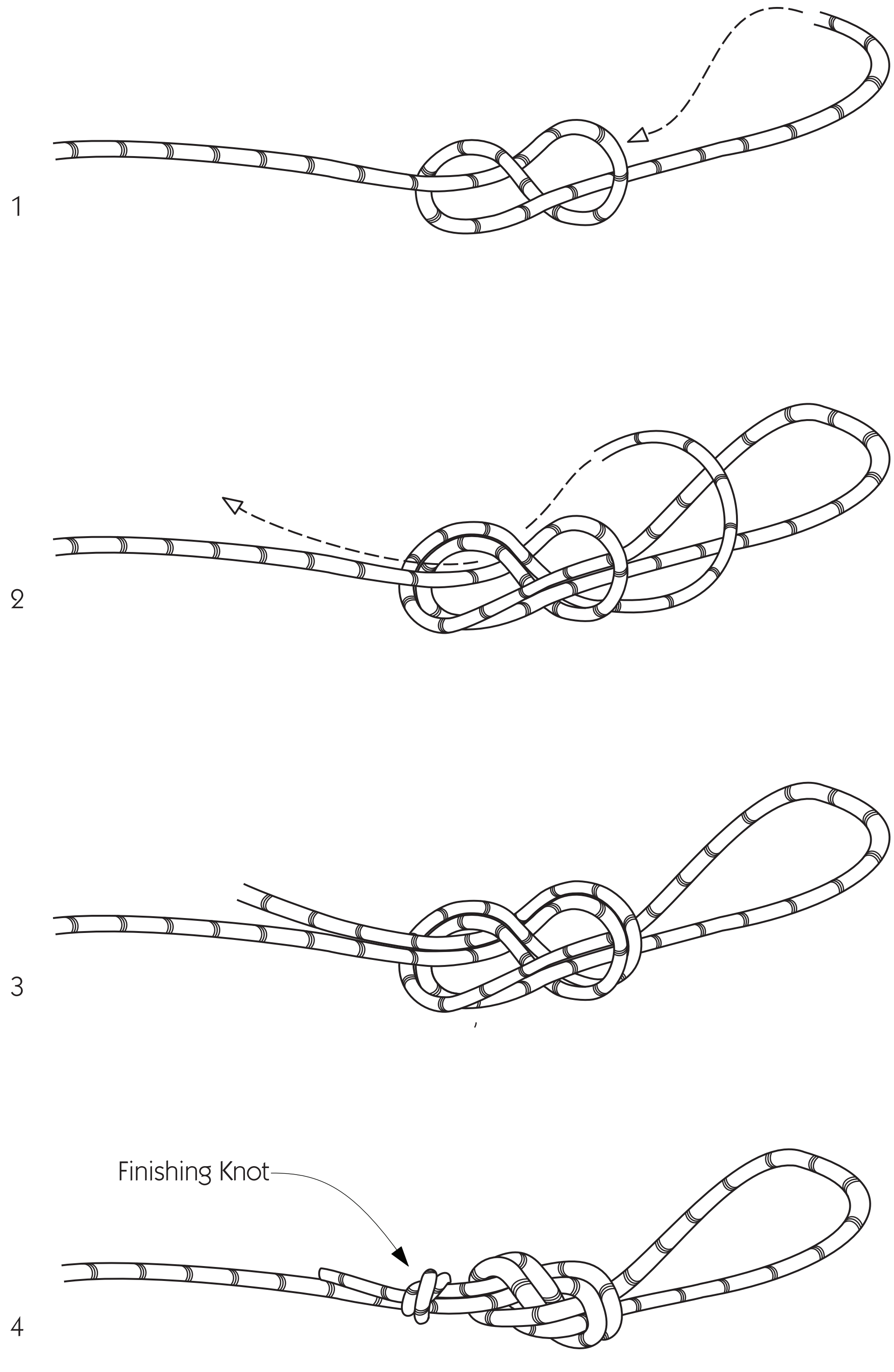


Figure 8 Followthrough

(Knots are drawn to show how they are tied, so the knots are not always shown fully dressed.
Be sure all the parts are properly placed and tightened and the rope does not cross itself unnecessarily.)

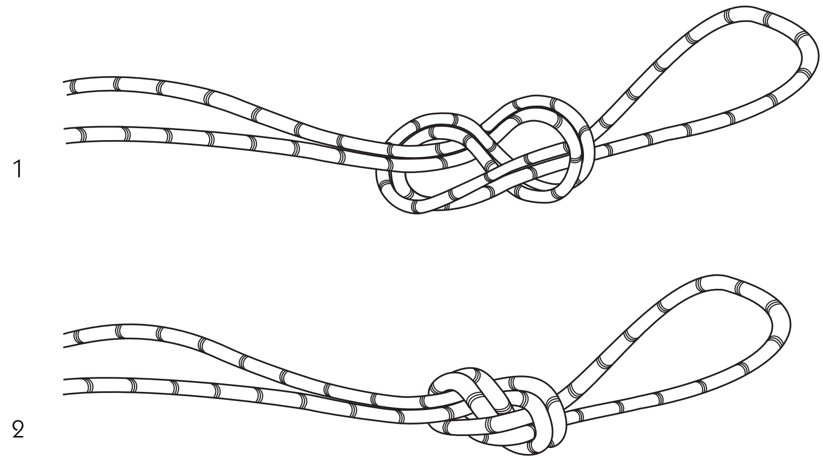
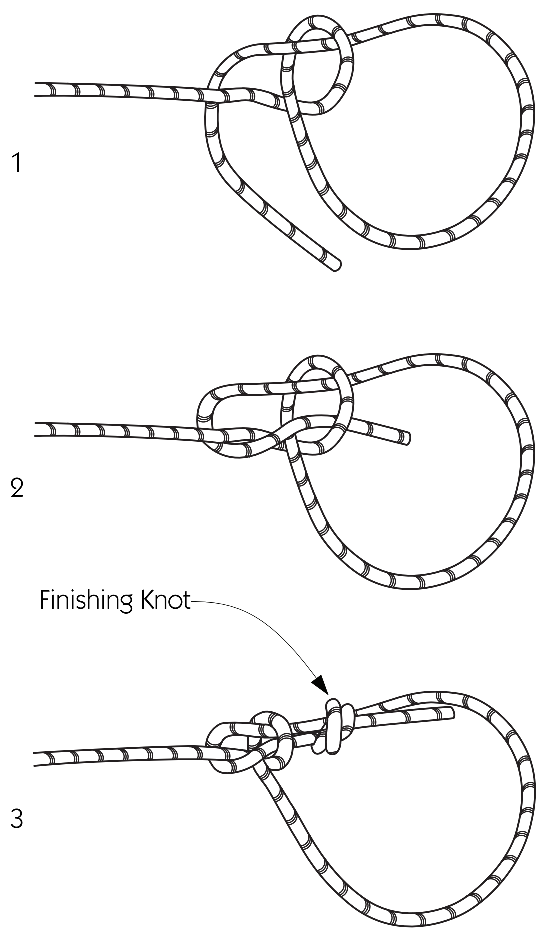
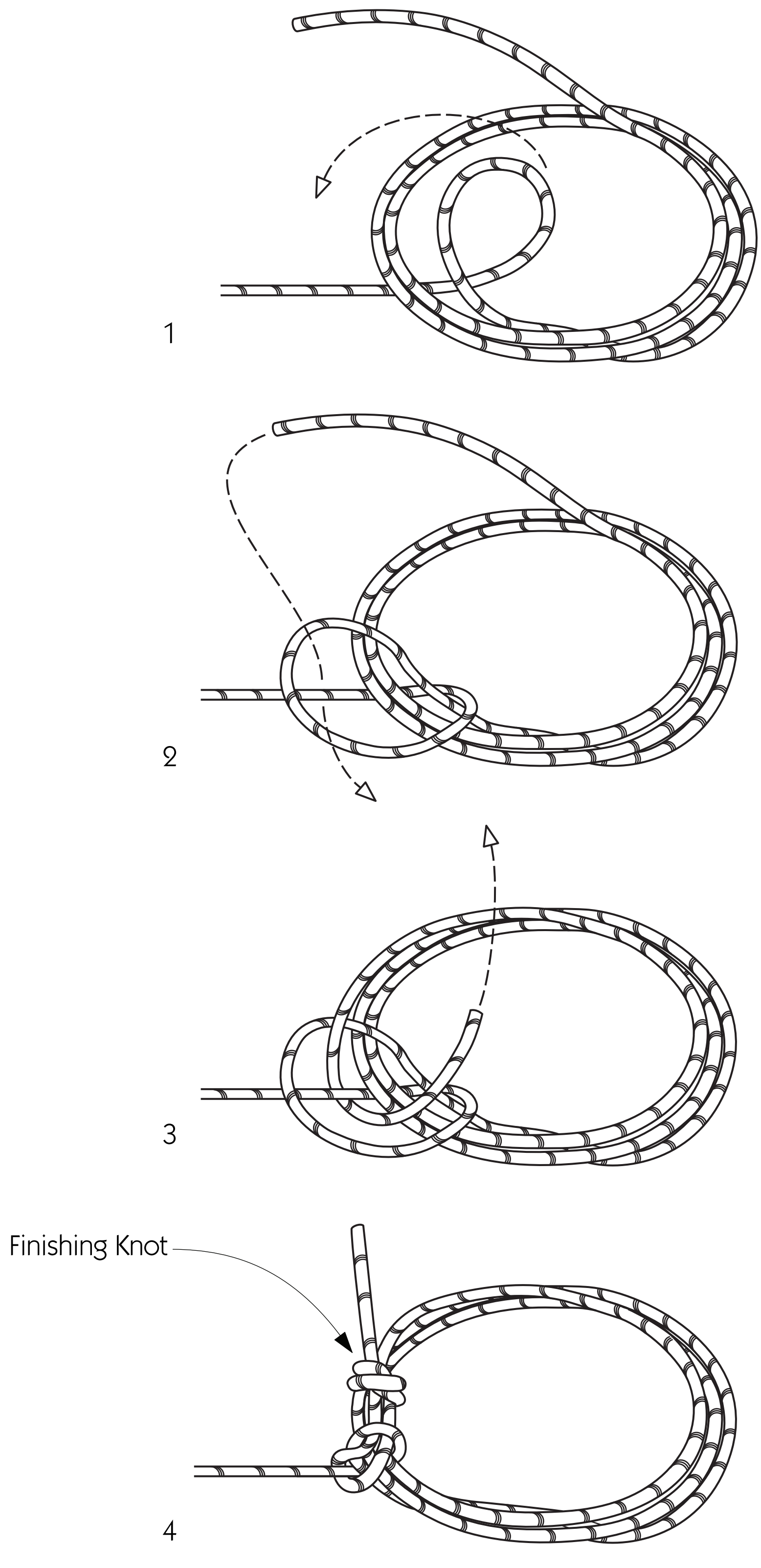


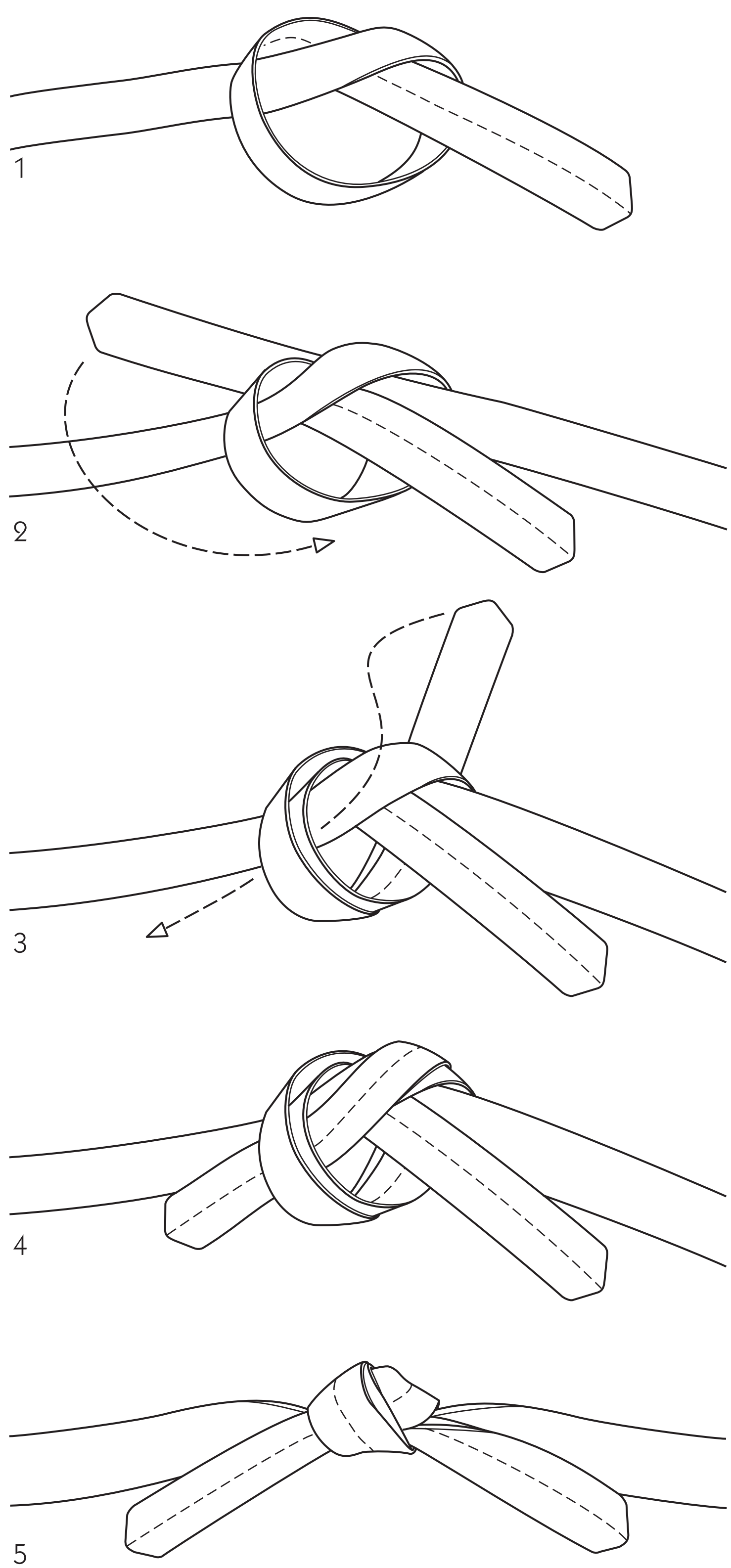
Figure 8 On A Bight



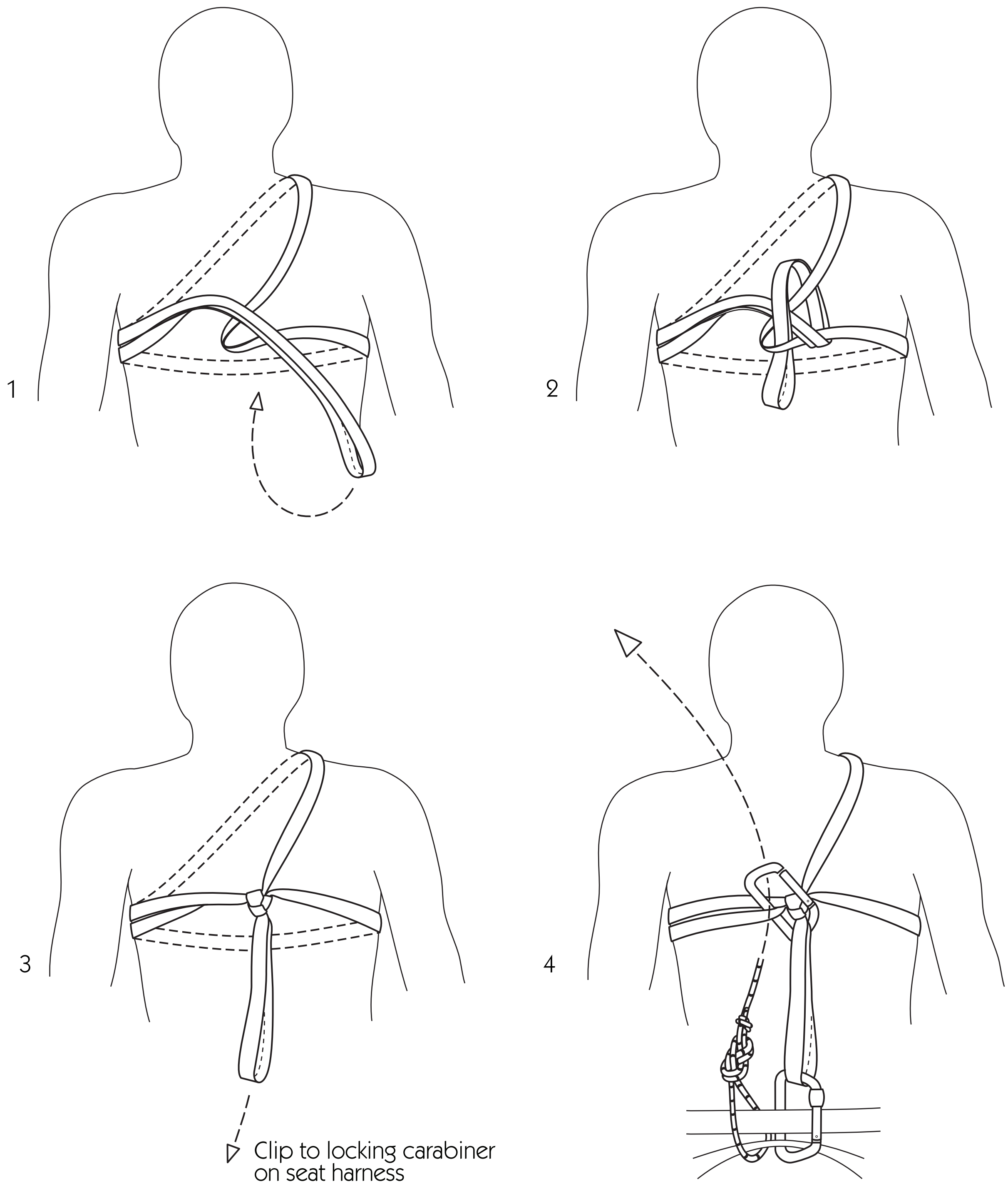
Bowline
(Tighten and dress the bowline and finishing knot)



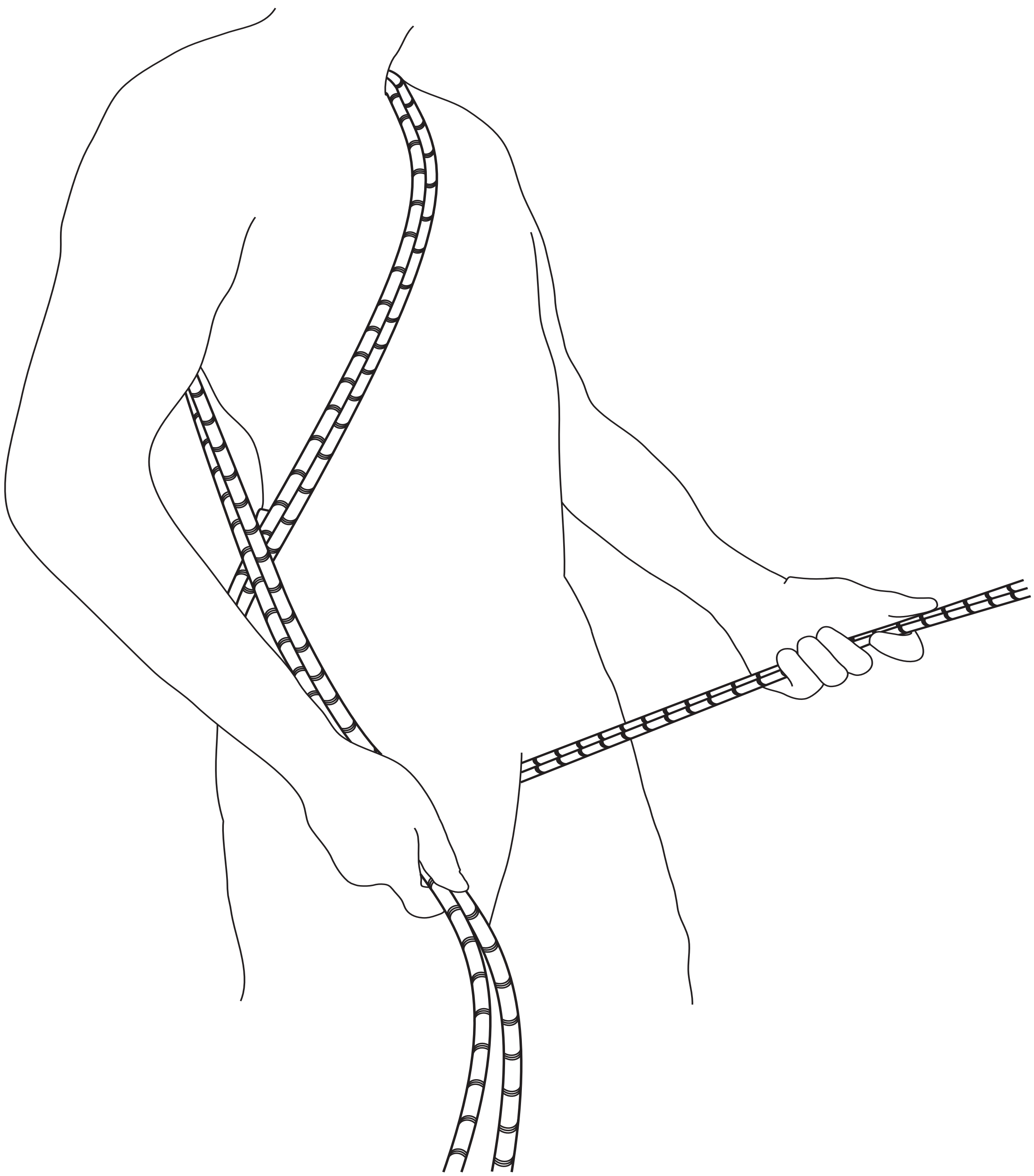
Bowline on a Coil
(Always leave long tails on knots and finishing knots.)



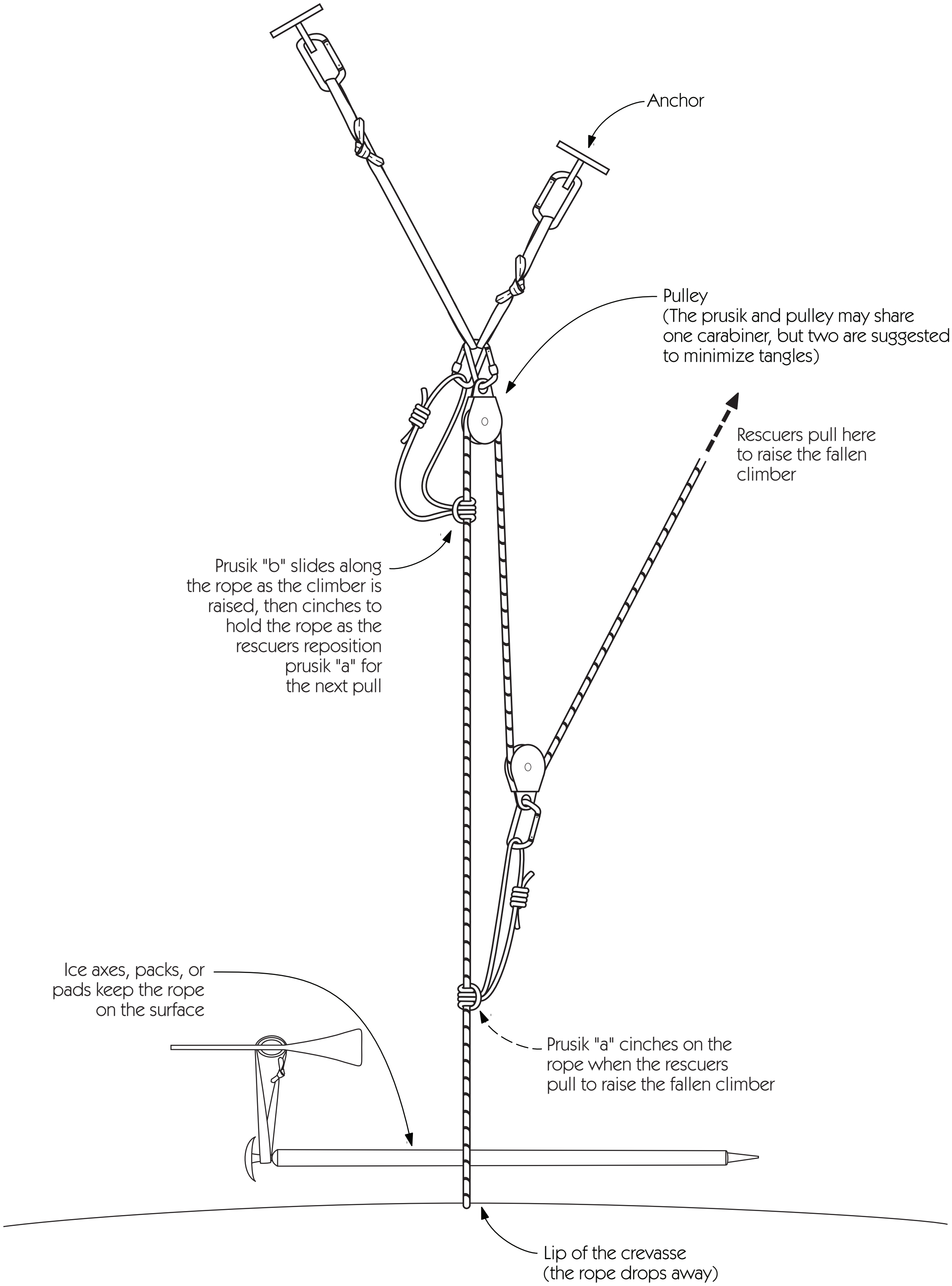
Overhand Followthrough
(also called the "Water Knot")



Parisian Baudrier
(also called the "Parisian Chest Harness")



Dulfersitz Rappel
(Clothing with neck covering must be worn to prevent severe rope burn.)



Z-Pulley System

(Distances between components have been shortened to show the entire system. In addition, use a separate, independent backup belay for the fallen climber.)

APPENDIX D: SAMPLE ROUTE CARD

Background Information and Statistics for Mount San Antonio Climb from Manker Flat

The route to Mount San Antonio (Mt. Baldy) from Manker Flat via the San Antonio Ski Hut is used here to provide a specific example of trip planning considerations and is the basis for an elaborate version of a route card. Ordinarily, the climb is about as routine a day hike as one can imagine. Under good visibility conditions there are essentially no route finding problems, and the climb is typically just a pleasant exercise. If something unexpected happens, however, to benight the party or if the visibility or weather conditions change, the climber can be faced with some very difficult and dangerous circumstances. Then this common walk in the park can become a survival and route-finding challenge.

The trip planning elements developed below are intended to take all these factors into some account and include the leader's homework in researching many of the interesting features encountered on the trip that can enhance the enjoyment of the participants. Then, the example route card developed is deliberately made elaborate enough to account for worst-case conditions, including such unexpected events as major changes in the weather and/or visibility. The example is overkill for such a simple outing but is intended to illustrate the process.

Route Considerations— Manker Flat via the San Antonio Ski Hut

Route, Crux Points, Alternate Routes Down

All have all been incorporated into the route card.

Trip Statistics

- Data from HPS Guide: "8 miles round trip; 3900' gain; 5-6 hrs r.t.; Strenuous"
- Data from MapTech, Route Profile: 7 miles round trip; 3892' gain
- Energetics: E = 100[10+R+2C+4H] = 100[10+8+4(3.9)] = 3,360 kilocalories
- Time estimate by Naismith's Rule: T = D/3+H/2 = 8/3+3.9/2 = 4.62 hrs = 4 hrs 37 minutes, all on trail, with no allowance for cross country.
- Time estimate by 600 cal/hr: T = (3360)/(600) = 5.6 hrs = 5 hr 36 minutes

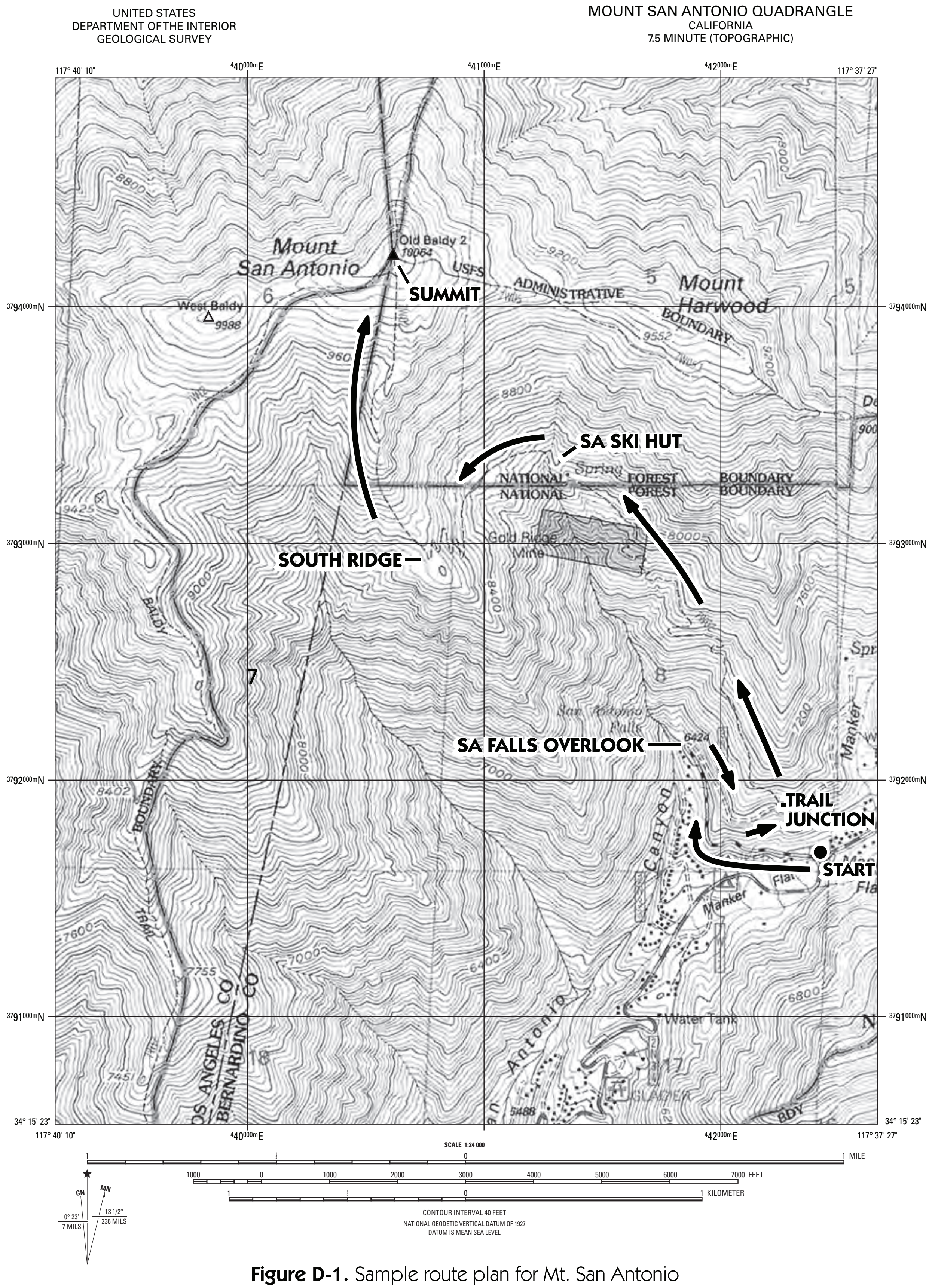


Figure D-1. Sample route plan for Mt. San Antonio

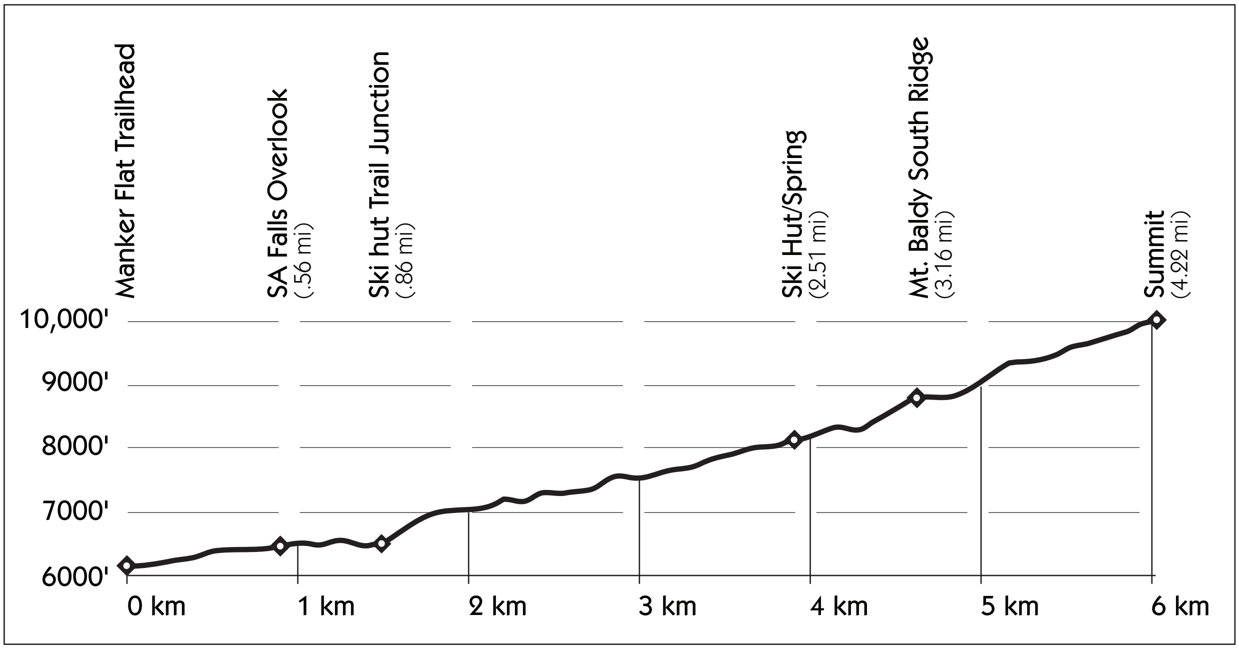


Figure D-2. Sample trip profile: Manker Flat to Mt. San Antonio

TRIP TABLE: MT. SAN ANTONIO FROM MANKER FLAT VIA BALDY BOWL

Leg	Destination	Distance (kilometers)	Gain (feet)	Travel Time (Naismith)	Additional Time	Total Leg Time	Elapsed Time	Notes
1	Mt. SA Falls Overlook	.90 km (.56 mi)	240 feet	.35 hr (0:21 min)	.08 hr[1] (0:05 min)	.43 hr (0:26 min)	.43 hr (0:26 min)	[1] 5 min. clothing break
2	Ski Hut Trail Junction	.50 km (.30 mi)	200 feet	.23 hr (0:14)	.00 hr (0:00)	.23 hr (0:14)	.66 hr (0:40)	
3	SA Ski Hut/ Spring	2.65 km (1.65 mi)	1,600 feet	1.46 hr (1:28)	.17 hr[2] (0:10)	1.63 hr (1:38)	2.29 hr (2:18)	[2] 2 - 5 min. rest/split breaks
4	Mt. Baldy South Ridge	1.05 km (.65 mi)	560 feet	.54 hr (0:33)	.08 hr[3] (0:05)	.62 hr (0:38)	2.91 hr (2:56)	[3] 5 min. rest break (catch up)
5	Summit	1.70 km (1.06 mi)	1,340 feet	1.10 hr (1:06)	.00 hr (0:00)	1.10 hr (1:06)	4.01 hr[4] (4:02)[4]	[4] Minor difference due to rounding off
-	**Summary**	6.80 km (4.22 mi)	3,940 feet	3.68 hr (3:42)	.33 hr (0:20)	4.01 hr (4:02)	4.01 hr[5] (4:02)	[5] 25 min. longer than Route Card (breaks)
6	On Summit	.00 km	0 feet	.00 hr (0:00)	.50 hr[6] (0:30)	.50 hr (0:30)	4.51 hr (4:32)	[6] Lunch, sign register
7	Return to Manker Flat	6.80 km (4.22 mi)	0 feet	1.70 hr (1:42)	.17 hr[7] (0:10)	1.87 hr (1:52)	6.38 hr (6:24)	[7] 2 - 5 min. rest breaks
-	**Summary**	13.60 km (8.44 mi)	3,940 feet	5.38 hr (5:24)	1.00 hr (1:00)	6.38 hr (6:24)	6.38 hr[8] (6:24)	[8] Longer than in HPS Guide & Route Card

Figure D-3. Sample Trip Table. Time estimates on this table were made using km for distance. Calculations made using miles will differ slightly because the conversions in the Naithsmith Rules are rounded off. Rest breaks average 5 min./hour.

Trip Table

For more extended trips a more elaborate breakdown of the trip plan statistics can be useful. Typically this is presented in a tabular form that might include time allowances for rest and split breaks, lunch, etc. A sample trip table is given in Figure D-3. The careful reader will notice that several time estimates for this trip are slightly different. These depend primarily on the estimation method used and whether or not breaks are included.

Other Trails to/from San Antonio Summit

From Manker Flat via Devil's Backbone ("Southeasterly" from the summit): The route up this trail from Manker Flat starts as on the route card, but does not turn off on the ski hut trail. Continue on ski lift access road to Baldy Notch (7,802'). About 200 yd NE of the lodge is a junction. Left turn (towards WNW) leads to the Devil's Backbone Trail to the summit. A right turn (SE) is the road leading to Thunder Mtn. (14 mi r.t., 3,900' gain; 6-7 hrs r.t.; E = 3,960 kcals)

From Mount Baldy Village via Bear Canyon Trail ("Southerly" from the summit): Parking area on Bear Canyon Road opposite the Mt Baldy Lodge (4,200). At 1.75 mi (5,560') Bear Flats stream crossing. Three miles further (4.75 mi, 9,000') pass the "narrows." Another 1.62 mi, arrive at Baldy Summit (10,064). (6.37 mi one way, 12.75 mi r.t.; 5,864' gain; 10-12 hrs r.t.; E = 4,620 kcals) Contrast this time with an early record set by a Pomona College athlete in 1904 of 1 hr, 49 minutes to the top. Someone has surely done even better since then because various competitive runs have been made up the peak along several trails.

From Blue Ridge, Wright Mountain Area via North Backbone Trail ("Northerly" from the summit): From Blue Ridge Road junction with trail to Pine and Dawson (8310') proceed up steep, unmaintained, trail for 5 mi. to the summit. (10 mi. r.t., 1,754' gain; E = 2,700 to 3,200 kcals because of cross-country aspects)

Interesting Points on the Way

San Antonio Fault–Some evidence of the trace of the left-lateral strike slip San Antonio Fault is seen just a few yards above the locked gate near the starting point. The careful observer will note that some water-loving trees (anomalous vegetation) on the slope above the road appear to be quite out of place. Their water need is partially supplied by enhanced seepage through their base on faulted rock. Examined in more detail, at the beginning of the road is the mixed gneiss and migmatite characteristic of the San Antonio Canyon Group. A bit further along the roadcut shows an exposure of mylonite and then switches to Pelona Schist.

San Antonio Falls Overlook–The falls are a pleasant sight, but the rocks about them are dangerous and somewhat unstable areas to climb on. The springs above the ski hut are the main water source, reinforced by the drainages funneling the waters from the bowl into this particular gulch.

Geological Point of Interest–At the San Antonio Falls Overlook and further along the lower Ski Hut Trail, the view to the west shows the Vincent Thrust Fault, one of the oldest faults within the San Gabriels. It is marked by a southward and southwestward dipping zone of shear planes and mylonitic rocks–exposed on the high ridges to the west. Pelona Schist (from ocean floor sediments) is now on the bottom, topped by about 2,000' of mylonite, and then by the Vincent Thrust migmatite. This appears to represent northward thrusting of plutonic rocks over the Pelona Schist, probably in the early Tertiary (~60 million years ago). The Vincent Thrust Fault exposed quartz veins with some show of minerals within the vein. Gold and pyrite have similar freezing points ~600 to 700°C, so they tend to be close to each other along quartz veins that intrude joints as the last mobile melted material in the entire complex. Not surprisingly, there was a series of little gold and silver rushes in the San Gabriels near the turn of the 20th century.

Gold Ridge Mine–This mine is near the head of San Antonio Creek about 1.5 miles above the falls at about 7,400 feet, somewhat lower and across the canyon from the Ski Hut. It was started in 1897 by F. O. Slanker and W. I. Grable, who had a crusher and other equipment packed in. Claims were filed in July, and by August over one hundred people were living in the area. A few buildings were built; the fieldstone lower walls of one and the foundation of another still exist. The ore was so low grade and the cost of production so high that the project was shortly abandoned. In 1900 J. A. Way and C. R. Johnson took over the mine and dug a 600-foot adit. They sold out to a Los Angeles concern in 1904. The adit was drilled in the deformed rocks between the Pelona Schist and the mylonitic rocks of the Vincent thrust fault zone. A rotary mill, powered by a gasoline engine, was packed in to process the ore removed from the adit. The higher production rate of low-grade ore still did not pay off well enough. The end came in 1907 when huge avalanches destroyed the Gold Ridge houses and machinery, although some remains of the crusher and bits of the mill are still in place.

San Antonio Ski Hut–This Sierra Club jewel is the result of some remarkably energetic and inspired ski mountaineers. Dr. Walter Mosauer, an Austrian professor of zoology at UCLA and the "father of Southern California alpine skiing," was the teacher and guru of a small group of mainly college students comprising the "Ski Mountaineers of California." Starting in 1932 the group took many trips to the area of the Baldy bowl in pursuit of their avocation. Mosauer suggested that a ski hut be built in the area to provide overnight accommodations. He was also instrumental in organizing the Ski Mountaineering Section of the Sierra Club. Under the Club's auspices, a Forest Service permit was issued, and the first San Antonio Ski Hut was built in 1935 with the volunteer labor of Sierra Club members. George Bauwens, who made the first ski ascent of San Antonio, designed the hut and supervised construction. A fire in 1936 destroyed the hut, but it was rebuilt the same year. It has served the Club in many ways ever since.

Summit Lore (the Name)–Although uncertain just when it was first given, Phil Townsend Hanna notes that "Legend has it that it was named for Saint Anthony of Padua second-handed through Antonio Maria Lugo (1778-1860). Lugo was born at San Antonio de Padua Mission and christened there with St. Anthony's name by Junipero

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ROUTE CARD: MOUNT SAN ANTONIO FROM MANKER FLATS VIA BALDY BOWL

Manker Flats, [6,160 ft; 11 442378 E, 3 791658 N] to the **San Antonio Falls Overlook** [441821 E, 3792166 N] – 0.9 km (0.56 mi)

Proceed past the gate on the paved ski lift access road (initial bearing 280 deg). A few yds past the gate are rock changes and vegetation signs of the left-lateral San Antonio Fault. The overlook provides an excellent view of the falls.

San Antonio Falls Overlook to **Ski Hut Trail Jct** [6600 ft; 442208 E, 3791900 N] – 0.5km (0.3 mi)

Continue on the access road to the junction with the faint trail** to the Ski Hut on the left. [1.4 km (0.87 mi.) total to this point]

Ski Hut Trail Jct to **San Antonio Ski Hut and Spring** [8,200 ft; 441359 E, 3793283 N] – 2.65 km (1.65 mi)

Steep trail proceeds past a trail register about 75 yds from the junction, then turns to a bearing on-average of 330 deg to the spring (last reliable water) and the Sierra Club San Antonio Ski Hut. On the way there are good views of the Vincent Thrust Fault W across the canyon. At about the 7800 ft level one may be able to pick out some of the remains of the Gold Ridge Mine across the canyon to the W.

Ski Hut to **Mt Baldy South Ridge**** [8760 ft; 440869 E, 3792850 N] – 1.05 km (0.65 mi)

Cross the Baldy Bowl on an occasionally ducked, easy-to-follow use trail on an average bearing ranging from 260 until about the middle of the bowl, shifting to about 200 deg up the steep switchbacks leading to the ridge. (Back bearing from ridge jump-off to Ski Hut is 050°.)

Baldy South Ridge to the **Summit** [10064 ft; 440599 E, 3794245 N] – 1.7 km (1.06 mi)

Proceed up the ridge (bearing 322) along a use trail to about 9000 ft; [440502 E, 3793327 N], where the ridge direction shifts, and continue along a bearing averaging 005 deg to the summit.

Ascent Summary Statistics 3900 ft gain, 6.8 km (4.25 mi) total; 3 hrs 35 min by Modified Naismith Rule.

Possible Crux Points (indicated by **):

Going up –

1. The junction with the faint trail (on the left) to the Ski Hut (0.87 mi from Manker Flats, 6,200') is sometimes missed.

Going down –

1. From the summit start off to the south, avoiding confusion with the other trails converging at the summit;
2. On the Baldy South Ridge the route overlooks San Antonio Canyon and the Ski Hut. In poor visibility (weather, nightfall, etc.), depart from the ridge at 8,760' and proceed down the steep switchbacks.

Alternative Routes Down

A viable shortcut to the level of the Ski Hut is a scree run down the Baldy Bowl on a SE heading. This is a run of about 1,600-1,800 ft on generally good scree with many previously run routes.

Trip Leg	Description of Leg	Compass Rose Direction	Trip Leg Distance (mi.)	Cum. Distance (mi.)	Elevation (ft.)	Trip Leg Elevation Gain (ft.)	Trip Leg Elevation Loss (ft.)	Average Slope (XX º)	Naismith Time (minutes)	Squiggle Factor (%)	Adjusted Time (minutes)	Cum Trip Time (minutes)	Cum Trip Time (hrs.)	Comments & Break Times
	START – _____ AM													
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11														
12														
13														
14														
15														
														+___% *for Group Size*
	TOTAL													
	FINISH – _____PM												Trip time = _____ Hours	
	Date													
	Start Time				Finish Time									
	Sunrise				Sunset									
	Moonrise				Moonset				Moon Phase					
	Weather Report								Water Required					

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