NATIONAL GEOGRAPHIC

Basic Map & GPS Skills

How to read a topographic map, use a compass, and determine GPS locations on a map

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This booklet covers what a topographic map (topo map) is, how to use a map, and how to find your way using a compass, map and/or a Global Positioning System (GPS).

About the Basic Map Skills Booklet

If you are hiking on marked trails or bushwhacking to areas not far from trails, a good topographic map may be the only tool you need to plan and maintain your route. If you are planning to be in the wilderness for an extended period of time, you will most likely be using a compass and/or a GPS unit to help you find your way. This booklet will give you some basics about how to read a topographic map, how to use a compass, and how to determine GPS locations on a map. If you are new to navigating and orienteering in the wilderness, the Basic Map Skills booklet will be a valuable resource for learning essential terms, and for understanding how to use basic navigation tools and skills to help you find your way.

What is a topographic map?

Topographic (topo) maps present a wide range of information, making them useful to both professional and recreational map users. Topo maps use contour lines to show changes in terrain and elevation, and are often overlayed with a wide variety of information, such as roads and streets, trails, land-use boundaries, tree and vegetation cover, and camping and hiking information to show how the lay of the land interacts with other natural and human-made features. Topographic maps are used for outdoor activities, engineering, energy exploration, natural resource conservation, environmental management, public works design, and commercial and residential planning. National Geographic Maps publishes the Trails Illustrated line of topographic maps, which are customized maps for back-country and recreational use.

Creation of a Topographic Map

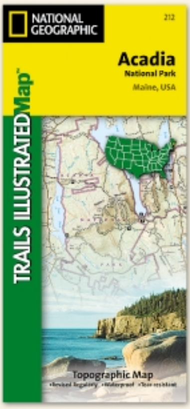
A good map is one that fits the use for which it is intended, is easy to read, understand, and use, and is visually appealing. A good topographic map provides information about land features and how they interact with other natural and human-made features. Cartography is both an art

Example of a topographic map with symbols and a science. Combining cartographic design with precise data, and using the most up-to-date data-collection and cartographic techniques is where the art and science of cartography converge.

Most topographic maps in the United States incorporate data originally collected and published by the United States Geological Survey (USGS). The USGS has produced a series of large-scale topographic maps that encompass all 50 states. The most commonly recognized of these maps are produced at a scale of 1:24,000 (1 inch equals 2,000 feet), called quadrangles.

National Geographic Trails Illustrated MapS

The development of a National Geographic Trails Illustrated map begins with a series of USGS quadrangles of a given area. These quads are merged and used as a base for a single Trails Illustrated map. National Geographic cartographers specialize in digital cartography, meaning that our maps are created using computers, and the information is stored in digital files.



National Geographic uses USGS quads as a base, building each one into a digital format. Once the USGS information is produced, National Geographic Maps adds up-to-date information such as road changes, new trails, campsites, wilderness boundaries, etc. Each set of information is digitized and stored in a separate map layer. Most Trails Illustrated maps have over a hundred different layers of information, such as roads, contours, boundaries, shaded relief, surface cover, and human-made features. Once the layers are combined, the map is checked for accuracy. The finished product creates a useful recreation and navigation tool.

National Geographic Trails Illustrated maps are revised regularly, providing up-to-date information for map users. Roads close, trails are built and rerouted, campgrounds close or move, and boundaries change. In order to ensure accuracy and reliability, National Geographic Maps publishes and revises maps in close cooperation with a wide range of land management agencies, including the National Park Service, USDA Forest Service, Bureau of Land Management, US Fish and Wildlife Service and state and local agencies, as well as in partnership with cooperating associations at all of the major national parks in the United States.

Trails Illustrated maps are designed with the hiker, backpacker, mountain biker, equestrian, and outdoor enthusiast in mind. The result is a highly-detailed and user-friendly map.

National Geographic Trails Illustrated maps are printed on Polyart®, a waterproof, tear-resistant plastic. This paper-thin plastic contains a minimum of 30% recycled material. Why print these maps on plastic? The production of paper results in over twice as much air pollution as does the production of plastic, and 200 times as much waste water. Paper production also uses around 17 times more energy.

Topographic Map Basics

Contour Lines

Topographic maps use ***contour lines*** to portray the shape and elevation of the land. Contour lines are the curved, usually brown lines that connect points of equal elevation and make it possible for a topographic map to represent three-dimensional shapes on a two-dimensional surface.

Contour lines represent topography. Index contours are the thicker, darker lines.

Shaded relief with contour lines helps to show the topography.

The space between the contour lines represents a set distance, called the ***contour interval***. If the contour interval is 80 feet, for example, the vertical distance between two adjacent contour lines is 80 feet. Contour lines closer together on the map represent steeper terrain and lines farther apart represent flatter terrain. The elevation, in feet or meters, is written on darker or thicker contour lines, known as "index" contour lines. The contour interval can usually be found near the scale, in the map legend.

Symbols

By using symbols, lines and colors, topographic maps illustrate both natural and human-made features. In order to read a map, it is important to understand what these symbols, lines and colors represent. Topographic maps identify land-use areas by using different colors of shading to represent each type of area. Typically, these shadings are identified on the legend. Trails Illustrated maps use many colors to make features easy to identify and to aid in readability. Areas shaded green usually represent vegetation, such as wooded cover (trees) or brush. Areas of blue and blue lines indicate bodies of water. Areas that are white or pale in tone are usually areas with little or no vegetation, such as desert or rocky alpine areas. Wilderness, national park, and national forest boundaries are shown with black, dashed-dotted lines tinted with colored bands. Consult the map legend for specific tint representations.

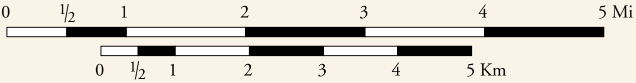
Example of symbols and what they represent

Symbols are defined in the map legend, which is found in the map margin or on the map itself. Symbols, or icons, point out features such as buildings, trailheads, visitor centers, trail use information, springs, highway numbers, or points of interest. The legend shows a symbol and defines, in words, the feature that the symbol represents. For example, the legend will show a double, dashed black line, and next to this symbol it will read "4WD Road." Another example would be a picture of a bike that reads, "Mountain Biking." If you see a mountain bike icon next to a trail on a map, it means that mountain biking is allowed on that trail.

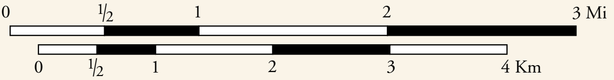
Scale

Each topographic map is drawn to a specific ***scale***. A scale is the ratio of a distance between two points on a map and the actual distance of the same two points on the ground. Scale is the amount that an area or distance has been reduced in order to be included on a map. A scale of

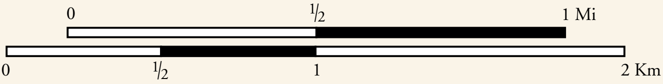
Approximate Scale 1:100,000 • 1 inch = 1.58 miles • 1 centimeter = 1 kilometer



Approximate Scale 1:63,360 • 1 inch = 1 mile • 1 centimeter = 0.63 kilometer



Approximate Scale 1:24,000 • 1 inch = 0.38 mile • 1 centimeter = 0.24 kilometer



1:250,000 means that one inch on the map is equal to 250,000 inches on the ground, or approximately four miles. Scales used on National Geographic Trails Illustrated maps vary from map to map, but most fall into the range of 1:40,000 to 1:70,000. National Geographic Maps strives to use a scale which optimizes the user's needs with a sheet size that is easy to use and to carry.

Sample 1:100,000 scale map detail

Sample 1:63,360 scale map detail

The larger the scale, the smaller the area that is covered, usually in greater detail. An example of a large-scale map is the National Geographic Trails Illustrated map of the Virgin Islands. Its 1:22,000 scale lends itself to showing this relatively small area in fine detail. A smaller scale map covers a larger area of land, and usually shows the land in less detail. An example of a small-scale map would be the National Geographic Trails Illustrated map of Denali National Park in Alaska, which is shown at a scale of 1:200,000.

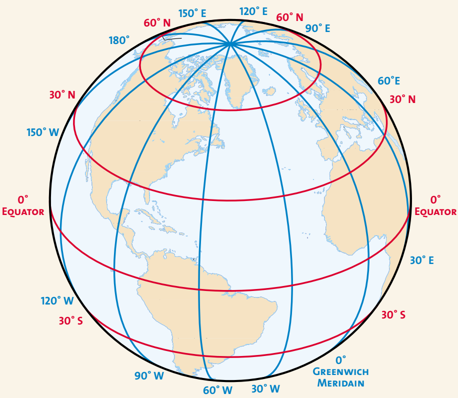
The later section, entitled *How to Measure Distance on the Map,* shows how to use the scale of the map to determine distances on the map.

Coordinate Systems

For recreational navigation purposes, Latitude and Longitude and the Universal Transverse Mercator (UTM) are the main coordinate systems to know.

Latitude and Longitude, the True Coordinate System

The Earth is divided into a grid of circular segments which are perpendicular to one another, called latitude and longitude. ***Latitude*** lines run horizontally, and are parallel to the equator. Degrees latitude are numbered from 0° to 90° north and south. Zero degrees (0°) is the equator, 90° north is the North Pole, and 90° south is the South Pole. Latitude is commonly the first number expressed in a lat/long coordinate and is often expressed in the form of degrees, minutes, and seconds, for instance: N38°47'30".



Latitude and Longitude lines (Lat/Long)

Longitude lines (also called meridians) run perpendicular to latitude lines. Their spacing is widest at the equator, and converges at the Poles. The prime meridian or Greenwich Meridian (0° longitude) runs through Greenwich, England. Half way around the Earth, the degrees meet (180° east and west) in the Pacific Ocean, just west of the Midway Islands, and just East of the Fiji Islands and New Zealand. Longitude is commonly the second number expressed in a lat/long coordinate, and is often expressed in the form of degrees, minutes, and seconds.

Degrees are often divided into minutes (') and seconds ("). Each degree has 60 minutes and each minute has 60 seconds. Seconds can be divided further in tenths, hundredths, etc. for greater and greater precision. An example of using lat/long to describe a specific point is that the National Geographic Society in Washington, DC is located at 38°54'19" N, 77°02'14" W (38 degrees, 54 minutes, 19 seconds north of the equator, and 77 degrees 2 minutes, 14 seconds west of the prime meridian).

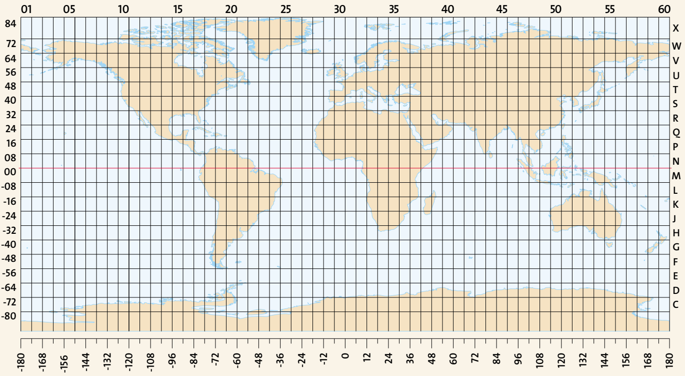
Using Latitude and Longitude on a Topographic Map

Around the perimeter of most topographic maps are small numbers showing latitude and longitude, (lat/long), with corresponding tiny lines, or ticks. By referring to the ticks and lat/long numbers you can find the exact place on the planet where you are located. The numbers on the top and bottom of the map are degrees longitude; numbers on the sides of the maps are degrees latitude. To determine the location on the map, connect the tick marks, north to south and east to west, drawing a line through your exact position on the map, and read the corresponding lat/long degrees.

Universal Transverse Mercator (UTM) Grid Coordinate System

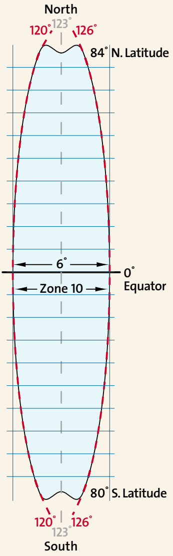
The USGS also uses a measurement system called the ***Universal Transverse Mercator*** (UTM) grid coordinate system, which divides the earth into a perpendicular grid with constant linear surface distances, in meters, between each of its grid lines in all directions. UTM was developed in order to reduce the complexity of the calculations needed to transfer a location on our spherically-shaped planet to a flat surface.

The Transverse Mercator Projection, which divides the earth like the slices of an orange and flattens the slices, introduces a negligible amount of distortion for map scales typical of most topographic maps. The slight amount of distortion of the geographical features within a zone is negligible and may be ignored by most map users. The UTM Grid Coordinate System superimposes a perpendicular grid over these earth



UTM grid showing Zone Numbers, 1 – 60, and Zone Characters, C – X slices with constant linear surface distance values between each of its grid lines in all directions. Since the pattern of UTM grid lines was superimposed on the grid zones after they were flattened, these grid lines are straight, perpendicular, and they are not distorted. This grid is designed to create a system where each location can be determined from the 0,0 point in meters or by its grid coordinates. A reference in the UTM system can be converted into a reference in another system, such as latitude and longitude using computer software.

UTM Measurements & Coordinates: EASTINGS



UTM slice, Zone 10. Longitude red, UTM grid in blue

Each UTM zone is 6° wide, and uses the central meridian as a reference. Zone numbers designate 6 degree longitudinal strips extending from 80 degrees South latitude to 84 degrees North latitude, for a total of 60 zones.

For example, Zone 10 extends from 126° West to 120° West Longitude. The central meridian is 123°, halfway (3°) from the boundary meridians. As another example, Zone 14 has a central meridian of 99° West Longitude.

Eastings, longitudinal measurements within each zone, are measured from the central meridian. The central meridian has a false easting of 500,000m to assure positive coordinates. Thus, a location in Zone 10 that falls directly on the 123° meridian would have an easting of 500,000 meters written: 500000Em.

A location 10,382 meters west of the central meridian (500,000 - 10,382 = 489,618) would be written as 489618Em; likewise, a location 85,640 meters east of the central (123°) meridian would appear as 585640Em… on a GPS unit, this would be 10 Q 585640. (Note that the Q in this example is arbitrary, see Northings which describe Zone characters).

UTM Measurements & Coordinates: NORTHINGS

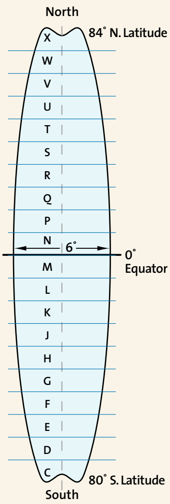
Northings are measured from the equator (with a 10,000,000km false northing for positions south of the equator). Zone characters designate 8 degree zones extending north and south from the equator.

Zones are divided into sections of latitude that are 8 degrees in height. These sections are lettered C through X, with M and N bracketing the equator. The letter designators give a quick reference as to the latitude of a point indicted by the coordinates. The letter designator is merely a help, however. While the zone number is critical, as the easting coordinate is referenced to it, the northing coordinate specifies the total number of meters from the equator, regardless of lettered zone section.

Again, eastings indicate the number of meters of longitude within the numbered zone... the same easting coordinate value will repeat for each zone. Eastings are specified as six-digit numbers.

Northings, however, are specified regardless of lettered section. Northings specify the absolute number of meters from the equator. Northings are specified as seven-digit numbers.

There are special UTM zones between 0° and 36° longitude above 72° latitude and a special zone (32) between 56° and 64° north latitude.



UTM sample slice, Zone Characters

How to Measure Distance on the Map

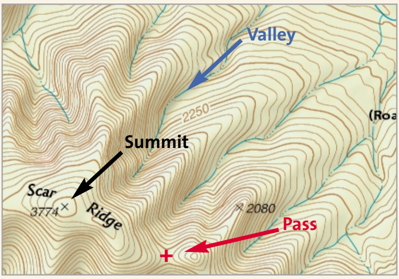
The scale in the map legend provides the means for measuring distance. On National Geographic Trails Illustrated maps, the scale is given as a fraction, such as 1:24,000 or 1:100,000, and as a bar scale, which is a ruler divided into miles and kilometers. On a map scaled at 1:24,000, one inch on the map equals 24,000 inches (or 2,000 feet) on the ground. To find a distance between two points in this example, measure the number of inches and multiply by 2,000 to get the distance in feet. Another useful tool to find distances on a map is to convert the stated scale using the following mathematical formulas.

$$\left(\frac{\text{No. inches X Scale}}{12}\right) \div 5280 = \text{miles/inch} \qquad \frac{\text{No. cm X Scale}}{100{,}000} = \text{cm/km}$$

To use the bar scale, mark off along the edge of a piece of paper the map distance between the two points for which you want to find the actual distance, then measure it against the bar scale in the map legend. Or, make a ruler by copying the map's bar scale along the edge of a piece of paper.

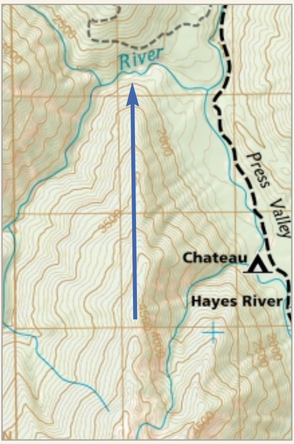
Planning Your Route

Plan your route to take advantage of the terrain. By studying the map you can find the best spot to cross a river, a trail that will lead to the base of the peak you wish to climb, or a nearby campsite.



Series of V's pointing to higher ground with streams, and hourglass shaped pass.

Contour lines reveal the path of least, or most, resistance. For example, contour lines closer together represent steep terrain. The farther apart the lines, the gentler the slope, and the flatter the terrain. Valleys, ravines and gullies are represented by a series of V-shaped lines pointing toward higher ground (greater elevations). Contour lines denoting ridges or spurs are shaped like a series of V's or U's pointing toward lower ground (lower elevations). Another easy way to interpret terrain is to look for a stream running down the middle or side of the V's. You can tell if there is a pass or a saddle in a ridge by looking for an hourglass shape with higher contour lines on each side. A peak is depicted by the innermost ring of a near-concentric pattern of contour lines. It is often marked with an X and its elevation.



A series of V's pointing to lower elevations, marked with blue line

By interpreting colors, or shaded areas on the map, a distinction may be made between wooded areas, meadows, alpine tundra, or private land. This may be useful information when looking for a campsite, a vista, or a good place to view wildlife.

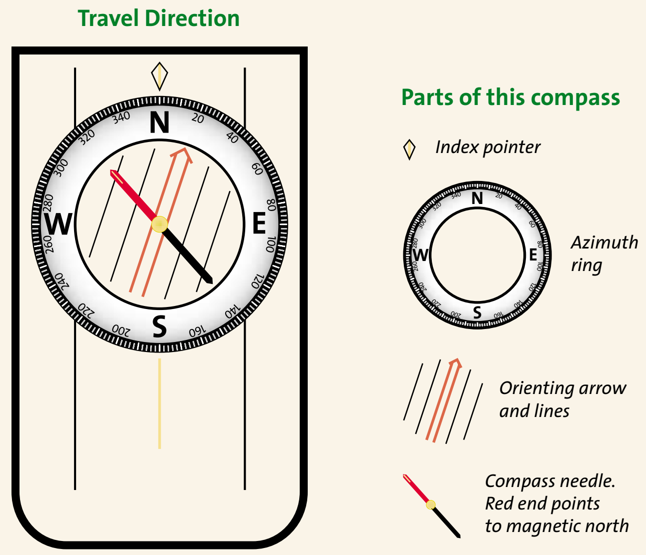
Navigation Tools and Skills

With strong map and compass skills, most outdoor enthusiasts will be able to navigate the backcountry with ease. But when conditions change unexpectedly, a thick fog or a snowstorm can obscure a landscape commonly used as a visual checkpoint. A GPS (Global Positioning System) receiver quickly pinpoints a location on the earth, providing the opportunity to navigate with a map without landmark visibility. A GPS can also be used to plot a route ahead of time, and determine the distance between waypoints along that route. This section provides an overview of how to use a compass, a Global Positioning System (GPS) device, and an altimeter.

Using a Compass

When traveling in the backcountry, it is always a good idea to carry a compass and know how to use it. There are several types of compasses. A basic directional compass has a magnetized needle surrounded by an ***azimuth ring***, 0-360 degrees. By simply pointing the needle to "N" north or 0 degrees, a bearing can be found. These small, portable compasses are excellent for finding a quick direction of travel and simple navigation.

A more advanced compass has a magnetized needle surrounded by a rotating vial and azimuth ring marked in 0-360 degrees graduations often every 2 degrees. Declination, discussed below, is adjusted by rotating the orienting arrow inside the vial either east or west according to the azimuth ring.



A simple compass with common part names

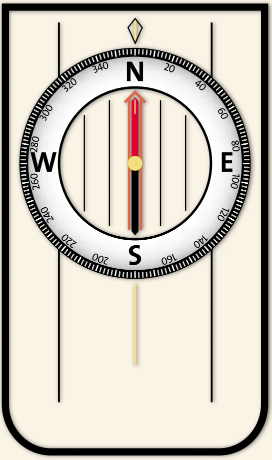
Map compasses can feature magnifiers, various map scales or a variety of sighting systems. Directional or prismatic sighting systems allow for greater accuracy when sighting to an object to take a bearing. Map compasses can be used for navigating with or without a map.

True North vs. Magnetic North

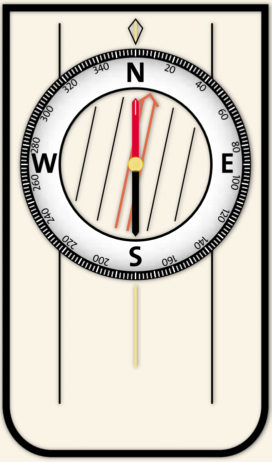
Most topographic maps are oriented to true north, meaning they are oriented along true north and south meridians of longitude. The top of the map usually points to the North Pole. On National Geographic Trails Illustrated maps the star above the compass rose points to true north.

If you are using a map and a compass, the map layout will be oriented to true north, but the compass needle will be oriented to magnetic north. You need to take this ***magnetic declination*** (the difference, in degrees, between the two norths) into account. You will find the magnetic declination symbol on a Trails Illustrated map in the compass rose, showing the direction of true north (star) as well as the direction of magnetic north (line marked "magnetic" with arrow). When traveling in the Eastern US, add degrees of declination when determining a bearing, and, when in the Western US, subtract degrees of declination.

The magnetic needle on a compass points to magnetic north when the compass is held flat. The graduated dial, orienting arrow, and sighting line will help locate East, West, South, and the points in between. The graduated dial has a total of 360 degrees. The numbers show the number of degrees from North. North is 0 degrees, East is 90 degrees, South is 180 degrees, and West is 270 degrees.



Basic compass with no declination adjustment. True north and magnetic north are are the same in this example.

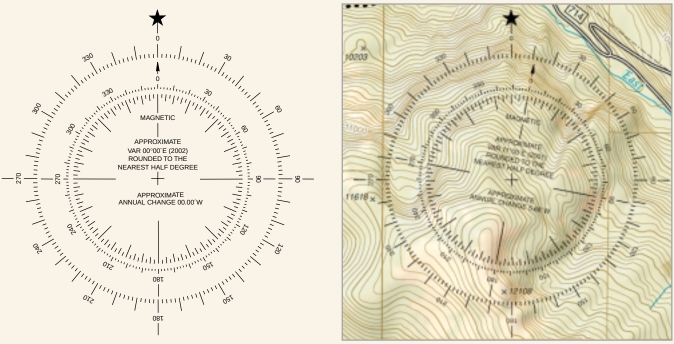


Basic compass with declination adjustment of 12 degrees East. Orienting arrow is adjusted for magnetic north. True north and magnetic north are separated by 12 degrees in this example.

Declination

As mentioned above, the earth's magnetic pole is not located at the true or geographic pole. The magnetic north pole lies south of the true north pole, causing an error in compass readings. The angle that the magnetic needle points away from true north is called declination. For very accurate compass readings, in many areas, it is necessary to adjust a compass to eliminate this deviation.

Some compasses have a built-in declination adjustment that allows automatic compensation for differences between magnetic and true



Compass Rose with no declination deviation and one with an 11° East declination on a map. True north in both instances is at the top of the page.

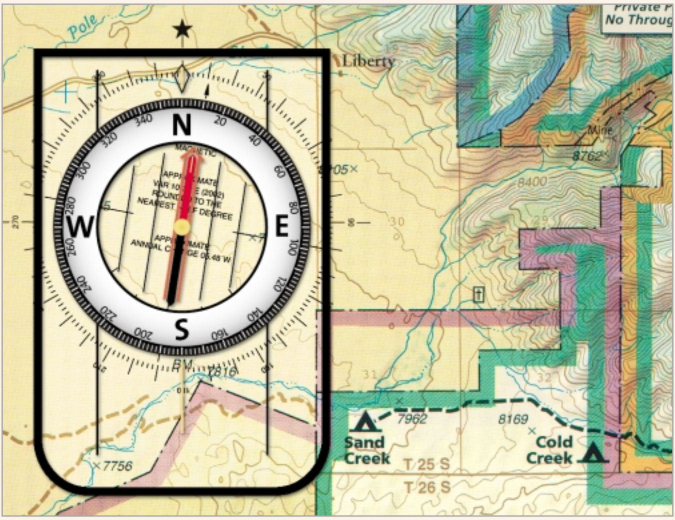
north. To adjust your compass, refer to an isogonic chart to find the declination for an area of interest or refer to the compass rose or a map declination diagram. For example, if traveling in central Colorado, there will be an east declination of about 12 degrees. Change the declination setting on the compass by about 12 degrees toward the East. The declination can be either east or west depending upon location. If the magnetic needle points west of true north, it’s called west declination. If it points east of true north, it's called east declination.

Taking a Bearing

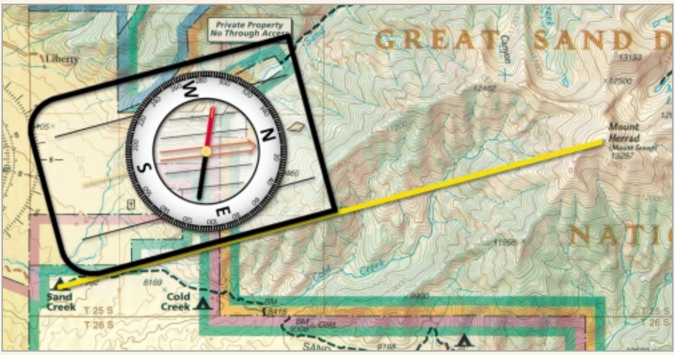
A ***bearing*** is a degree-reading or direction from the current location to another object. For example, if you are traveling in a field, and a mountain peak is directly east of your position, the bearing of the mountain would be 90 degrees. If the peak were directly south, its bearing would be 180 degrees, and if west, 270 degrees.

Sighting a bearing or aiming the compass at an object differs from one compass to another. Accuracy increases when the object being sighted, the magnetic needle, and the azimuth ring can be read at the same time. Compasses with prismatic sighting allow this to be done. The magnetic needle and azimuth ring are read in a mirror while the object or direction is sighted.

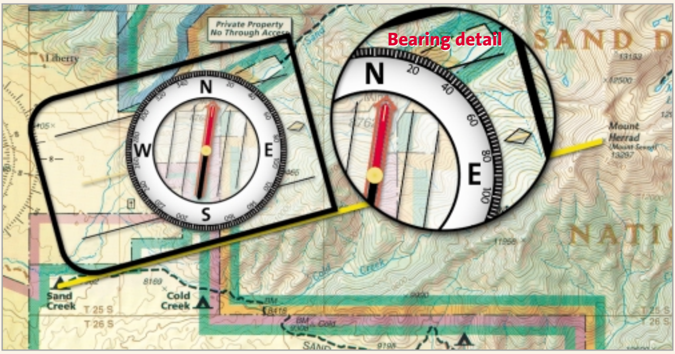
With a basic or directional compass, the compass is simply aimed at an object or in a direction, and the bearing is read at the azimuth ring closest to the sighted object. To take a bearing, hold the compass level, with the sighting line pointing toward the object on which you are taking a bearing. With the sighting line pointing straight to the object, carefully turn the dial until the orienting arrow and magnetic needle (usually red) are lined up. Be sure the arrow and needle are lined up correctly and not backwards. The bearing to the sighted object is now the degree reading indicated at the sighting line.



Set the compass's declination for your area. Note that the magnetic north and declination are aligned, (10.5° E in this example), while true north is at the top of the page and map.



Next, from your location (Sand Creek Campground in this example) mark a line on the map to your point of interest (Mount Herrad in this case) and lay the compass along this line in the travel direction. (The straight edge of the compass, especially one with a folding cover, may span the map distance without needing to draw a line). Without a map aim the compass as precisely as possible by sight. Note the difference now between magnetic north red needle and the orienting arrow.



Now turn the azimuth ring so the orienting arrow and the compass needle are aligned. The value that the index pointer shows is your bearing to that location (75° East Northeast in this example).

Obtaining Your Bearings from a Map

Topo maps have a diagram showing the magnetic declination angle. On National Geographic Trails Illustrated maps, the declination angle is incorporated into the compass rose. Ensure that the compass being used is adjusted for that angle. If a bearing of a particular spot on the map is desired, place the compass on the map so the long edge of the base is on a line from the present location to the desired destination. Hold the compass steady, rotate the dial so the N on the dial is pointed north on the map. The present bearing now appears on the dial at the sighting line.

Pick the compass up and hold it in a horizontal position so the magnetic needle is free to rotate. In order to align the orienting arrow with the magnetic needle, rotate in the current location until the arrow and needle are aligned. The compass now indicates the direction of travel required to reach the desired destination.

Using a GPS Unit

The Global Positioning System

About 20 years ago, the Department of Defense developed the ***Global Positioning System***, a high-tech simulation of the ancient method of navigating according to the position of the stars. They launched 25 satellites into orbit. These satellite "constellations" have a steady orbit, so GPS receivers use them as fixed points from which to determine their own position. The satellites transmit coded radio signals which are picked up by GPS receivers. When a GPS receiver locks onto the nearest satellite, it determines how long it takes for the coded signal to reach it. Using this figure, the GPS calculates its physical distance from the satellite. With a distance reading from at least three satellites, a GPS unit can pinpoint its current position on the earth, similar to the way a hiker determines where he is on a map by referencing three or more distinct locations. This is called triangulation. With a reading from a fourth satellite, a GPS can determine altitude.

The government's primary purpose for GPS is as a navigational system for military use. It is also widely used for surveying and mapping by industries that rely on position information. With the new hand-held GPS receivers, GPS satellite information can be accessed by anyone — backpacker or sea kayaker, pilot or mountaineer. With this device, anyone can find a location in a matter of minutes and plot a route with several waypoints.

To some, a GPS may seem like just another gadget to add to the closet full of outdoor gear. True, it may not be an essential item for most backpacking trips, but for the serious mountaineer, curious backpacker or orienteering enthusiast, it can be a good supplement to the map and compass. By getting a location fix on your favorite spots, the coordinates can be marked on your map for a quick reference for a return trip.

Plotting a Route with GPS

Typical GPS unit

When using a GPS for the first time always refer to the GPS instruction manual for set-up and initialization information. Initialization may need to be repeated if the GPS is moved more than 300 miles while it is turned off.

To plot your route ahead of time, use a map to determine a set of appropriate coordinates (called waypoints) along the planned route/trip. Give each waypoint a name that is recognizable or unique. A great planning tool is National Geographic's TOPO! software. TOPO! provides seamless topographic coverage of entire states, and enables you to trace out a route, create an elevation profile, choose and name waypoints, and upload trail information directly into the GPS.

Waypoint (blue text) for Kokomo Pass on a Trails Illustrated map.

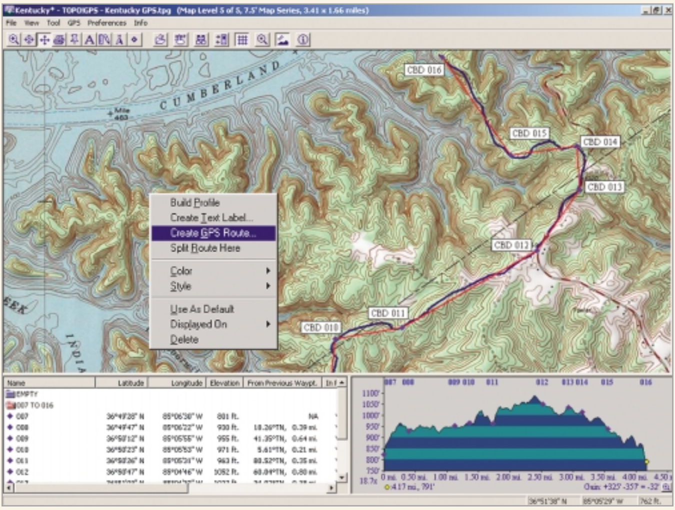
Latitude and longitude as well as UTM coordinates are located along the map border of National Geographic Trails Illustrated maps. Selected GPS waypoints are also shown. When used with map datum NAD27 (North American Datum 1927), these coordinates represent an approximate location fix. National Geographic Maps show the coordinates of prominent places, such as trailheads, roads, lakes, emergency locations, or water sources, for your convenience. If a National Geographic Maps waypoint is input into a GPS, a bearing and a distance toward that position will be given.

Traveling along the planned route, each time the GPS is turned on it will give coordinates for the current position. A GPS will also provide a bearing and straight line distance to the next waypoint. This information is more useful when used in conjunction with a map.

Example of waypoint coordinates (blue text) along a user defined trail (red) from TOPO! mapping software.

When the GPS provides a bearing, it allows for easy orientation to the next waypoint along the route. Since the GPS distance reading is a straight-line distance, which is often not the most convenient route to travel in the backcountry, it is important to be able to interpret the topography of the land that lies ahead before the next waypoint. For example, a lake may be 3.5 miles away as the crow flies, but the steep, exposed switchbacks and the 1500' elevation gain on route to the lake must be considered.

The fact that a GPS can pinpoint a near exact location is really the most valuable feature for hikers and other land-based, recreational users. When the weather is stormy and visibility is limited, a GPS can provide coordinates of a fixed position. Once these coordinates are located on a



Another example of GPS data from before or after a trip. Uploading and downloading waypoints to mapping software, such as TOPO!, can provide more information and detail.

map, and a quick evaluation of the topography and surrounding area is made, it can then be decided whether it is better to move on, turn around, or remain in the current location. In some cases, such as less than ideal satellite position, a hand-held GPS position fix can be off by 15 meters or more. 15 meters is less than .02 in. or .5 mm on a Trails Illustrated map at a scale of 1:32,400. This margin of error is really quite insignificant in most cases.

A GPS needs to have a “clear view” of the sky in order to give its most accurate reading. Thick forest and narrow canyons may obstruct the receiver’s view of the satellites, and it does not function well indoors. Cold weather may also affect the LCD screen and battery life.

Other Features

Most GPS units can display your speed of travel and the estimated time of arrival at your destination. Some GPS units will even display the position of the sun and the moon. A GPS can monitor a traveled course over ground, or the direction traveled, and it will identify travel errors, such as crossing back over the traveled route. GPS units rely on batteries, and to avoid batteries dying during a trip, it's a good idea to turn the GPS on only when it is needed to check navigation. Be sure to carry additional batteries on long trips.

Using an Altimeter

Another useful tool for finding a current position on a map is an altimeter. An altimeter determines altitude or elevation with respect to a reference level, usually sea level, by means of measuring air pressure. Air pressure decreases when ascending (gaining elevation) and air pressure increases when descending (losing elevation). The altimeter reads the changes in air pressure in feet or meters, and displays the corresponding elevation. With this elevation reading it is then possible to locate the corresponding contour line on the map. Then, distinctive features such as a stream that crosses that contour line, or a nearby peak or ridge can be identified, providing a position fix related to the map.

Remember that changes in temperature and variations in air pressure caused by weather can affect an altimeter’s readings. Carry an altimeter in an outside pocket on your pack so it remains exposed to current air temperatures. The weather, which causes shifts in barometric pressure, will constantly alter the readings on an altimeter. The best way to maintain accurate readings is to adjust the altimeter whenever possible. When traveling through an area with an elevation marked on the map, check the altimeter and reset it.

Map, Compass & GPS Glossary

A

altimeter — an instrument that measures altitude or elevation with respect to a reference level, usually mean sea level, by means of air pressure.

azimuth — a direction, measured clockwise in degrees (0 degrees- 360 degrees), from a north-south reference line. An azimuth can also be referred to as a bearing, and it can be referenced to true north, grid north or magnetic north. The reverse direction is called a back azimuth or back bearing.

azimuth ring — the dial on a compass, marked with zero to 360 degree markings, increments often by 2 degrees.

B

bearing — an azimuth; a horizontal angle, measured from 0 to 90 degrees, fixing the direction of a line or direction of travel with respect to either a north or south direction. True bearings are based on true north. Magnetic bearings are referenced to magnetic north. Can also refer to the direction between two waypoints.

bench mark — a relatively permanent material object, natural or human-made, with a known elevation. A bench mark can be used as a reference point when navigating a route or in determining the elevation of nearby land features.

C

cartography — the art, science and technology of making maps, including construction of projections, design, compilation, drafting, and reproduction.

cliff — the high, steep face of a rocky mass. On a topographic map, a cliff is portrayed by contour lines placed very close together or merging into a single line. The closer the contour lines are to each other, the steeper the slope.

clinometer — a feature found on some compasses that allows the compass to measure vertical angles, like the slope of a hill. It can also be used as a level.

contour interval — the difference in elevation, in feet or meters, between two adjacent contour lines. This figure can be found near the scale on National Geographic Trails Illustrated maps.

contour line — a line on a map that connects points of equal elevation. The vertical distance between contour lines is equal to the contour interval. An index contour line is heavier and darker than the contour lines and is commonly every fifth contour line. It is periodically broken by numbers showing elevation. Lighter-colored or thinner intermediate contour lines are located between index contours. On areas of the map where there is little local relief, there may be supplementary contour lines; light or broken lines placed there to show the shape of land which might not otherwise be perceivable because its contour interval is too large to show the topography. They generally represent half the map's contour interval. A depression contour line denotes an area that is of lower elevation than surrounding terrain. It has small hachures pointing inward.

coordinate — a system of numbers and letters to describe a location on earth. Every position has a unique coordinate. The coordinate system determines the grid and how the coordinate is written (Lat/Long, UTM).

Course Over Ground (COG) — the direction, reported in true or magnetic north values, in which a GPS receiver and the person operating it are moving with respect to the earth.

D

datum — (pl. datums) a reference system for surveying which involves using a plane, level, line, etc., from which to calculate heights and depths. A vertical datum is a level surface to which heights are referred. The horizontal datum is used as a reference for position. Position coordinates are assigned to actual locations based on an underlying ellipsoidal model of the earth used for drawing the map. Typical USA Datums are WGS84 and NAD27.

depression — a natural or man-made hole in the ground which may have a wet center. On a topographic map, it is represented with a depression contour line (small hachures pointing inward), showing that it is of lower elevation than surrounding terrain.

drainage — the entire area drained by a river and all its tributaries; a small valley.

draw — a small, natural depression; a gully; the upper part of a small stream valley.

E

elevation — the vertical distance of a point above or below a reference surface, such as sea level.

Estimated Position Error (EPE) — a GPS receiver will calculate the error that may be present in its calculated position.

Estimated Time En route (ETE) — the amount of time remaining until arrival at a destination, which depends upon the speed of travel toward the destination.

Estimated Time of Arrival (ETA) — the time of day of arrival at a destination, which depends on the speed of travel toward the destination.

G

Geometric Dilution of Precision (GDOP) / Positional Dilution of Precision (PDOP) — the accuracy of a GPS receiver's readings can be diluted by unfavorable satellite position. A GPS receiver determines position by triangulation, much like a hiker determines his/her position on a map, visually, by finding the bearings of three landmarks, drawing an imaginary line between himself and each of the landmarks, and determining his position as the point where the lines intersect. If the landmarks are too close together, or they're obstructed from view, the hiker won't get a very accurate idea of his position. When the GPS satellites that are being received are clustered too close together, or most of the satellites are blocked by terrain or other obstacles, the positional accuracy determined by the receiver is diluted. The wider the angle between satellites, the better the measurement. Good GPS receivers will analyze the angles between all of the satellites available and choose the four that are best positioned to reduce the margin of error.

Global Positioning System (GPS) — a global navigation system that is based on triangulation from a constellation of 24 satellites orbiting the earth. A GPS receiver pinpoints its position on earth by measuring its distance from the satellites. It does so by calculating the time it takes for a coded radio message to pass from the satellite to the GPS unit. A GPS unit needs at least three measurements to determine its exact position.

GOTO — a function in which the GPS receiver guides you to a predetermined location. You will need to give the receiver the exact coordinates for the location. The GPS receiver will then determine its location and give you a bearing and distance you will need to travel to arrive at the destination.

H

hachure — tiny, short lines used to represent relief features. Each hachure line lies in the direction of the steepest slope. Lines that are closer together or wider denote steeper slopes, and lines that are farther apart or thinner denote gentler slopes. These are often shown perpendicular to contour lines.

heading — the direction of travel. In order for a GPS receiver to give an accurate heading it needs to be moving. If standing still, the GPS will probably give an inaccurate heading.

L

latitude — the distance north or south of the equator of a point on the earth's surface. This distance can be measured in degrees, minutes, and seconds. Lines (parallels) of latitude circle the earth horizontally and are parallel to one another. One minute of latitude equals one nautical mile.

longitude — the distance east or west of the prime meridian of a point on the earth's surface. Longitude can be measured in degrees, minutes and seconds. Lines (meridians) of longitude create a geographic grid around the world and are not parallel, but rather converge at the poles.

M

magnetic declination — the difference, in degrees, between true north and magnetic north. A map is almost always oriented to true north (North Pole) and a compass is oriented to magnetic north, which is located about 1300 miles south of true north, in Northern Canada, northwest of Hudson Bay. The agonic line is an imaginary line that passes through both magnetic and true north (this line currently travels in a southeasterly direction through the U.S. from near the Great Lakes to the deep south). Along this line it is not necessary to adjust a compass for magnetic declination. West of the agonic line, magnetic declination is east of true north. In the east, it is west of true north. On National Geographic Trails Illustrated maps, the declination symbol is incorporated into the compass rose, and shows the degree of deviation in that particular geographic area. To adjust a compass when east of the agonic line, add degrees of declination in order to get a true north bearing. When west, subtract the number of degrees of declination.

magnetic north — the area to which all compass needles point, located roughly 1300 miles south of true north. Magnetic north moves west slightly each year due to the earth's rotation and the friction created between the earth's liquid center and the outer layers of the earth.

map features — the physical features, such as terrain, vegetation, and hydrography (water), and the cultural, or man-made features, such as buildings, roads or trails, that appear on most topographic maps.

map projection — the systematic arrangement of the earth's spherical or geographic coordinate system onto a plane; the process of transforming a globe into a flat map with the least amount of distortion; a transformation process. There are several different projection processes which may be used depending on the area to be mapped and other factors.

map projection deformation — results when a spherical surface is transformed to a flat surface.

meridian — an imaginary line that circles the earth, passing through the geographic poles and any given point on the earth's surface. All points on a given meridian have the same longitude.

O

orienteering — using an accurate, detailed map and a compass to navigate to points in the landscape.

orienting arrow — on a compass, the red or black outlined arrow. Used with the red end of the magnetic needle north to determine your bearing or direction of travel.

P

parallel of latitude — a circle on the surface of the earth that is parallel to the equator. All points on a given parallel have the same latitude.

position fixing — determining your position on a map in terms of its coordinate system. This can be done visually, by referencing the terrain and comparing it to contour lines and other map features, by compass triangulation, or by using a GPS receiver. An elevation value above sea level can also be included by using an altimeter or GPS.

prime meridian — the meridian of longitude 0 degrees that runs through Greenwich, England, and is used as the origin for measurements of longitude.

prismatic compass — a compass with a mirror which allows the user to see both distant objects and the compass face at the same time. This is the most accurate type of hand-held compass.

Q

quadrangle — a four-sided area that is bounded by parallels of latitude and meridians of longitude and is used as an area unit in mapping. A quadrangle, or quad, is the area shown on one of the standard topographic sheets published by the USGS.

R

relief — changes in terrain; elevations or depressions in the land. *(See topography).*

relief shading — a technique for showing the ups and downs of the land portrayed on a topographic map. The process makes land look three-dimensional by the use of graded shadow effects. Traditionally, maps are shaded as though the light source is coming from the upper left.

ridge — a long, narrow stretch of high ground.

route — a series of waypoints that will lead from the start to finish of a trip. The GPS receiver will guide the user from one waypoint, in the route, to the next until the final destination has been reached.

S

saddle — a dip between hilltops or along the crest of a ridge.

scale — the distance between two points on a map as they relate to the distance between those same points on the earth. A map in large scale (e.g. 1:5,000) covers a smaller area in greater detail. A small-scale map (e.g 1:1,000,000) covers a larger surface area in less detail.

sighting line — the line that you sight along to take a bearing.

slope — when land deviates from the horizontal plane, it has slope. On a topographic map, the closer the contour lines are placed together, the greater the slope of the land being portrayed. When the contour lines are closer together at the top than at the bottom of a land feature, the slope is concave in shape. When the contour lines are further apart on the top of a land feature and closer together at the bottom, the slope is convex in shape; gentle on top and steeper toward the bottom.

Speed Over Ground (SOG) — the speed at which the GPS unit and the person operating it are moving with respect to the earth's surface.

spur — a small ridge.

T

topography — relief of the land surface; the graphic portrayal of that relief in map form by the use of contour lines.

tracks — a random coordinate, saved by the GPS unit in a tracklog, along the path of travel as long as the GPS is turned on and has locked onto the satellites.

triangulation — the method of determining your position on a map with a compass and intersecting lines. By taking compass bearings on two or more known features on the terrain, then plotting those bearings as lines on a corresponding map, one can determine his/her approximate position on the map as the point where the lines intersect. Triangulation is more accurate when three or more features are used to take bearings, and the features are spaced reasonably far apart.

true north — the geographical North Pole. Reference direction established relative to the North Pole of rotation.

U

Universal Transverse Mercator grid (UTM) — a grid coordinate system that appears on most USGS maps. It provides a perpendicular grid with constant linear surface distance values between each of its grid lines in all directions, except near the poles. The UTM system divides the area of the earth between 84 degrees N and 80 degrees S into 60 zones. While coordinates reported in latitude/longitude degrees are often called true coordinates, those reported in terms of the UTM grid are referred to as northings and false eastings. This is because they are referenced to a rectangular grid. Each point can be referenced in meters from the origin of this grid. UTM coordinate numbers are in meters, making this system advantageous for estimating distance.

W

waypoint — a checkpoint, also the coordinates of a location.

Leave No Trace Ethics

Please learn, practice, and pass on Leave No Trace outdoor skills and ethics. Following Leave No Trace principles will help protect precious backcountry resources.

Plan ahead and prepare

- Know the regulations and special concerns for the area you will visit.
- Prepare for extreme weather, hazards, and emergencies.
- Schedule your trip to avoid times of high use.
- Visit in small groups. Split larger parties into groups of 4-6.
- Repackage food to minimize waste.
- Use a map and compass to eliminate the use of marking paint, rock cairns, or flagging.

Travel and camp on durable surfaces

- Durable surfaces include established trails and campsites, rock, gravel, dry grasses, or snow.
- Protect riparian areas by camping at least 200 feet from lakes and streams.
- Good campsites are found, not made. Altering a site is not necessary.

In popular areas

- Concentrate use on existing trails and campsites.
- Walk single file in the middle of the trail, even when wet or muddy.
- Keep campsites small. Focus activity in areas where vegetation is absent.

In pristine areas

- Disperse use to prevent the creation of campsites and trails.
- Avoid places where impacts are just beginning.

Dispose of waste properly

- Pack it in, pack it out. Inspect your campsite and rest areas for trash or spilled foods. Pack out all trash, leftover food, and litter.
- Deposit solid human waste in catholes dug 6-8 inches deep at least 200 feet from water, camp, and trails. Cover and disguise the cathole when finished.
- Pack out toilet paper and hygiene products.
- To wash yourself or your dishes, carry water 200 feet away from streams or lakes and use small amounts of biodegradable soap. Scatter strained dishwater.

Leave what you find

- Preserve the past. Examine, but do not touch, cultural or historic structures and artifacts.
- Leave rocks, plants, and other natural objects as you find them.
- Avoid introducing or transporting non-native species.
- Do not build structures or furniture, or dig trenches.

Minimize campfire impacts

- Campfires can cause lasting impacts to the backcountry. Use a lightweight stove for cooking and enjoy a candle lantern for light.
- Where fires are permitted, use established fire rings, fire pans, or mound fires.
- Keep fires small. Use only sticks from the ground that can be broken by hand.
- Burn all wood and coals to ash, put out campfires completely, then scatter cool ashes.

Respect wildlife

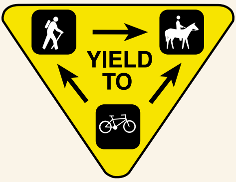
- Observe wildlife from a distance. Do not follow or approach them.
- Never feed animals. Feeding wildlife damages their health, alters natural behaviors, and exposes them to predators and other dangers.
- Protect wildlife and your food by storing rations and trash securely.
- Control pets at all times, or leave them at home.
- Avoid wildlife during sensitive times: mating, nesting, raising young, or winter.

Be considerate of other visitors

- Respect other visitors and protect the quality of their experience.
- Be courteous. Yield to other users on the trail.
- Step to the downhill side of the trail when encountering pack stock.
- Take breaks and camp away from trails and other visitors.
- Let nature's sounds prevail. Avoid loud voices and noises.

For more information on Leave No Trace, call 800-332-4100 or visit www.LNT.org

Share the Trail



Multiple use trails are successful when users cooperate and abide by the rules. Please follow these guidelines:

All users

- Stay on established trails, even when wet, muddy, or rutted.
- Know which trails are open to your method of travel.

Hikers

Encountering Other Trail Users

- Stand off the trail and downhill from passing horses. Listen for rider instructions.
- Keep pets leashed and under control when passing other trail users.

Cyclists

Riding Rules & Techniques and Trail Conditions

- Control your speed at all times. Be ready to stop quickly.
- Avoid skidding, as it shows poor technique and erodes trails.
- Ride on open trails only. Follow private land and seasonal trail restrictions.
- Waterbars prevent erosion; riding around them accelerates erosion. Ride over them.
- Avoid riding in muddy conditions, as tires create soil grooves that accelerate erosion.

Off-Road Preparedness

- Be smart: wear a helmet. Carry first aid suitable for remote rides.
- Be prepared: carry plenty of water, food, and tools including a patch kit and pump.

Encountering Other Cyclists

- Downhill riders should yield right-of-way to uphill riders.
- Be considerate of novices and family groups.

Cyclists Encountering Hikers:

- Cyclists should yield to all other trail users.
- Communicate with other trail users so they know your intentions.

Cyclists Encountering Horses:

- Encounters with horses on a trail can be dangerous; use caution.
- Avoid sudden movements or loud noises to prevent "spooking" horses.
- Cyclists should dismount for oncoming horses and allow horses to pass.
- To pass a horse on a trail, dismount bike and let the rider know your intentions.

Equestrians

- Be especially careful on bike trails when visibility is limited.
- Communicate: let other trail users know if your horse is safe to pass.
- Use high, dry trails after wet weather instead of low or streamside trails.
- Horses should walk through puddles to prevent the widening of muddy spots.

Survival Tips

Let a responsible person know where you are going, when you expect to return, and what to do if you don't. Sign in at trail registers.

- Be Prepared! Carry the Ten Essentials:

  1. Map and compass
  2. Waterproof matches
  3. Candle or firestarter
  4. Extra water
  5. Extra food
  6. Pocket knife
  7. Sunglasses
  8. First aid kit
  9. Extra clothing and rain gear
  10. Flashlight (spare bulb, batteries)

- Plot your progress on the map as you travel. Know where you are at all times.
- Prepare your trip with the expectation that you may have to spend an extra night or two in the wilderness if you become lost or injured.
- If you must spend an unexpected night out:
  - Stay where you are and don't wander, as you will waste energy and may be harder to find.
  - Dress with any additional clothing to stay warm. Use clothing and shelter to stay dry.
  - Light a fire, as it will keep you warm and help rescuers locate you.
  - Locate a water source near your camp.
  - Pile grass or brush around you for protection from wind and cold.
  - Do not sit directly on the ground. Use your pack or some other insulator to protect yourself from heat loss.
  - Relax! Many people have survived several nights with minimal gear.

"A map is the greatest of all epic poems. Its lines and colors show the realization of great dreams."

Gilbert Grosvenor, Editor, National Geographic, *1903-1954*

Basic Map Skills

What is a topographic map?

Finding your way with a topo map

Navigating with a map, compass, and GPS

Glossary of map, compass, and GPS terms

Also includes Leave No Trace Ethics and more!

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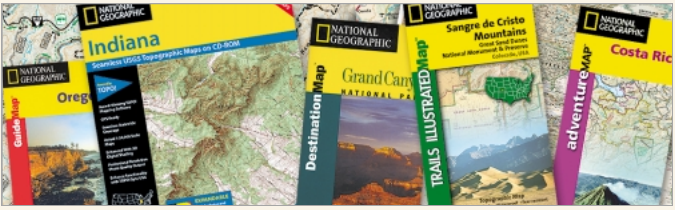

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