Natural Terrain Study Guide

Rural Training Center-Thailand
Community-based Education Office
166 Moo 5, Ban Wangwa, Thawangpha District
Thawangpha City, Nan Province 55140
Thailand
www.neighborhoodlink.com/org/rtcth

Publication RTC-TH-AG 2010-2

This edition printed from digital media.

Published by the Rural Training Center-Thailand
Community-based Education Office
166 Moo 5, Ban Wangwa, Thawangpha District
Thawangpha City, Nan Province 55140
Thailand
www.neighborhoodlink.com/org/rtcth

Publication # RTCTH-AG-2010-2

Published in the Kingdom of Thailand

Table of Contents

PREFACE

The current edition of the Natural Terrain Study Guide is an adaptation from previous editions used in my Geography classes dealing with environmental impact. This edition is a work in progress as it is adapted to the conditions and needs of the community-based environmental education programs of the Rural Training Center-Thailand (RTC-TH) in Nan Province, Thailand.

This publication evolved over time from a series of single lesson activities. Gradually, these were compiled based on the environmental germane to the lessons as per the Geographic Systems Model. However, the integrated character of natural systems sometimes defies such simplistic classification. So when using any specific activity (e.g. soil analysis) it behooves you to also consider the contributing factors (e.g. climate, biota, human activity, etc) even though the immediate task is to study the soil sample.

There is no doubt that revisions will be made to this work in progress. And at sometime in the future, it is hoped that some or all of this publication may be eventually translated into Thai. Anyone willing to undertake translation work will be welcome to do so on a purely voluntary basis in exchange for proper citation / credit for their effort. This is wholly consistent with the spirit and practice of volunteerism that is the heart and soul of the RTC-TH which receives no funding support from any government or non-government organization. Further, no one in the RTC-TH receives a salary or stipend. Any funds spent by the RTC-TH are the funds directly from its volunteers.

This publication is copyrighted, but is available on request in PDF which requires Adobe Acrobat Reader. We only ask that you:

1) properly cite/credit the RTC-TH as the source of the information you use;
2) that you do not alter the material in any way;
3) that you share the knowledge to help empower others for no charge for these materials

With the principle of “mutual respect and mutual benefit”, we welcome you to join us in trying to make the world a better place for all people and for all future generations.

Advisory Note

The Environmental Checklist order was modified from the original order found in the Geographic Systems Model described in the RTC-TH Publication AG 2010-1 "Introduction to Geography." The original Checklist order was determined from the perspective of the forces of nature creating the environment in which living organisms can then establish themselves.

The order of the Checklists was modified for this current publication to match the personal experience of the observer. When you first arrive at a site of interest, you are on the land surface (Lithosphere). The surface of the Lithosphere is often covered with vegetation (Biosphere) which is readily observable. Life on Earth is dependent on water (Hydrosphere). The weather and climate (Atmosphere) are observed from the land surface.

The Table of Contents is very detailed. This Guide uses numerical designators for the sections and subsections. The primary sections and subsections (leading 3 digits) are in ***boldface type***. These correspond to the Environmental spheres and the main topics for that sphere. For example, **2.0 is the Lithosphere**; **2.1 is the Lithosphere Checklist: SPSD**; **2.1.1 is Structure**, the first topic of that checklist.

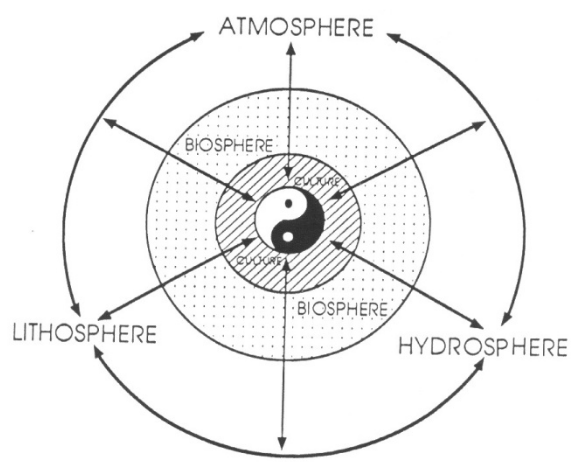
If you have other hands-on activities to add to those in this Guide, please submit them. Keep in mind that the activity should be low cost / no cost, easy to make from locally available materials (or substitutes), and can be done by people with modest educational background. If the activity comes from a copyrighted source, please provide the contact information with your submission. Send these suggestions to the e-mail address found on the cover of this publication.

Natural Terrain Study Guide

1.0 INTRODUCTION: This paper gives a general and systematic approach to describing the natural terrain. The Geographic Systems Model is the primary foundation for this paper. Each environmental sphere has a guiding checklist. The natural terrain is divided into two basic components: landform and the habitat. These are often the first things you see when looking at your surroundings. The Hydrosphere and Atmosphere profoundly affect the Lithosphere and Biosphere.

1.1 THE GEOGRAPHIC SYSTEMS MODEL is the framework for studying the natural environment. You can use it to systematically organize your observations and to detect cause and effect relationships in the natural environment. Location, Scale, and Time are the 3 basic concepts for this Model.

Location Scale Time



The Geographic Systems Model

1.1.1 Location: Start with the latitude for the site. This has major implications for climate, weather, and other factors in checklists for the Lithosphere and Biosphere. This paper focuses on terrestrial studies. If a site is located:

- on an island is basically different than one on a continent.
- near a major surface water body (oceans and large lakes) are significantly different one distant from water.
- facing north or south / east or west have different insolation rates, temperature, moisture, vegetation, and soils.
- on the windward of leeward side of a mountain or island have different climate / weather patterns affecting temperature, moisture, vegetation, and soils.

1.1.2 Scale: Most observations start at a local scale. Numerous nearby different local observations can be aggregated to develop a regional view. This puts the local site into a larger geographical context. Regions can be further aggregated to develop a global or "big picture". When doing field observations and research, assess the significance of the data you find relative to the scale of the study and in a regional and global context.

1.1.3 Time: The world changes over time. Carefully consider the affect of the time frame on your site study. This applies also applies to various scales of time (e.g. seasonal, diurnal, etc.). All data records should include the date and time of day for all observations.

1.2 THE ENVIRONMENTAL CHECKLISTS: To study the natural terrain (terrestrial environments), we start with the Lithosphere and Biosphere checklists. As terrestrial organisms, the land and other living organisms comprise our immediate surroundings.

- **The Atmosphere** checklist (LLAOATS) deals with the 7 factors controlling climate: Latitude, Land / Water Distribution, Atmospheric Circulation, Oceanic Circulation, Altitude, Topographic Barriers, and Storms.
- **The Lithosphere** checklist (SPSD) has 4 major divisions: Structure, Process, Slope, and Drainage. Use this checklist primarily when studying the surface configuration / surface materials.
- **The Hydrosphere** has a matrix based on 3 surface locations (Land, Coast / Estuary, and Ocean) and 3 water types (Fresh, Brackish, and Saline). [**Note**: There are other locations for water when using different scales. For example, on the land, water can be found beneath the surface, stored in living tissue. Water vapor (the gaseous form of water) can be found in the Atmosphere. But for now, let's stay with the more obvious surface water on the planet.]

Type	**Location**		
	L	**C/E**	**O**
F	●	⊙	⊙
B	⊙	●	⊙
S	⊙	⊙	●
●	Most abundant		
⊙	Some amount		

- **The Biosphere** has 2 checklists: CTED and SWFS.
  - CTED is used to characterize the physical setting. It has 4 major divisions: Climate, Topography, Edaphic (soil) factors, and Disruptions.
  - SWFS is used to characterize the critical habitat elements to support life: Space, Water, Food, and Shelter.

A summary matrix of the geographic systems model and the environmental sphere checklists is shown on the next page. To properly read this table, it is important to realize its organization is primarily vertical ***within*** a column. This means you should not read horizontally across the columns in the table. The information summarized in one column does not correlate or correspond to the information in another column of in the same row. The key purpose of the summary matrix is to provide an overview of the environmental checklists and the Geographic Systems Model on a single page. Comments in the particular boxes may have general reminders about connections to the other environmental checklists.

1.3 THE GENERAL SYSTEMS MATRIX is used to develop functional definitions and decipher the details of the processes and interrelationships indicated in the Geographic Systems Model. Functional definitions are given and used throughout this paper. These are not always the precise definitions for technicians, theoreticians, or academics. The goal is toward the practical and general to stimulate curiosity and wonder. The hope is to motivate you to want to learn more. Functional definitions help you to put the words into practice so you can learn by doing.

[**Note:** For further information about the General Systems Matrix, see "Introduction to Geography", RTC-TH publication AG 2010-1.]

SUMMARY MATRIX OF THE GEOGRAPHIC SYSTEMS MODEL AND ENVIRONMENTAL SPHERE CHECKLISTS

The Geographic Systems Model	LITHOSPHERE	BIOSHPERE		HYDROSPHERE	ATMOSPHERE
ABHL	**SPSD**	**CTED**	**SWFS**	**FBS / LCEO**	**LLAOATS**
Atmosphere: The non-living realm of all air on Earth, composed of mostly gases with some solid and liquid particles. *Checklist:* LLAOATS Biosphere: The living realm or all organisms on Earth composed of various combinations of solids, liquids, and gases. *Checklist:* CTED / SWFS Hydrosphere: The non-living realm or all water on Earth, composed of mostly liquid with some solid and gaseous particles. *Matrix:* FBS / LCEO Lithosphere: The non-living realm or all rock and soil on Earth, composed of mostly solid with some liquid and gaseous particles. *Checklist:* SPSD	Structure: Landforms and rock materials. Link to CTED, SWFS, LLAOATS Process: Internal and External actions making or modifying landform structures. Link to LLAOATS and CTED. Slope: Vertical and horizontal angular orientations of the surfaces of structures. These control the movement of water on a landform. Link to CTED, SWFS, and LLAOATS. Drainage: The movement of water over the surfaces of a structure to add or remove materials of the surface. Link to CTED and LLAOATS.	Climate: Light, Moisture, Temperature, and Wind as they affect soil development and plant growth. Link to LLAOATS and SWFS. Topography: Landforms and rock materials affecting insolation, temperature, and moisture for soil development and plant growth. Link to SPSD SWFS and LLAOATS. Edaphic Factors: Soil conditions affecting the grown of plants. Link to LLAOATS, SPSD and SWFS. Disruptions: Energy and materials from all spheres that disrupt natural process cycles. Link to Geog Sys Model and SWFS.	Space: The area of the habitat containing the water, food, and shelter needed by an organism in order to live. Link to CTED and SPSD Water: Water is essential to all living organisms on Earth. Link to FBS / LCEO, CTED, and LLAOATS. Food: All living organisms need nutrients to survive. The nutrients are organic and inorganic. They come from all environmental spheres. Link to CTED and FBS / LCEO. Shelter: All organisms need protection from harsh environmental conditions and other organisms that may consider them food.	There are 3 types of liquid water on the surface of the Earth: Fresh, Brackish, and Salt. Water can be found at the Earth's surface on land, at coastal / estuarine sites, and in the ocean. (Atmospheric moisture is covered in LLAOATS.) Fresh water is found mostly on Land (with some in Coast / Estuary and Oceans. Brackish water is found mostly in Coast / Estuary sites (with some on Land and in Oceans. Salt water is found mostly in Oceans (with some on Land and in Oceans	Latitude: controls insolation (solar angle of incidences, atmospheric path, photo period). Land / Water Distribution: Primary absorbers make heat for the Earth, controls temperature, moisture, pressures / lifting. *Create heat and pressure differences* Atmospheric Circulation: Pressure and Wind zones and systems, lifting mechanisms. Oceanic Circulation: Ocean currents (temperatures and directions) *Move heat and moisture around the planet.* Altitude: controls temperature, moisture, pressure similarly to Latitude. Topographic Barriers: Mountains blocking winds, can create lifting and precipitation. (Depends on wind direction and orientation of mountains.) Storms: Lifting mechanisms making precipitation. Seasonality (Time) exerts a strong influence.

Type	Location		
	L	C/E	O
F	●	⊙	⊙
B	⊙	●	⊙
S	⊙	⊙	●
●	Most abundant		
⊙	Some amount		

2.0 LITHOSPHERE: The Lithosphere is the solid rigid rock material at or near the Earth's surface. It is mostly solid with some liquid and gas. Topography is the geometry or shape (landform) of the Earth's surface materials (primary of rocks and soil). For this paper, rocks are considered part of the Lithosphere Checklist (SPSD). Soil will be discussed as part of the Biosphere Check list (CTED).]

2.1 THE LITHOSPHERE CHECKLIST (SPSD): We start the study of the natural terrain with the land surface itself. This is the most obvious part of the environment you notice as you enter the study area. Here are the key definitions for this checklist:

- **Structure** is defined as the landform (the physical arrangement of rock materials at or near the surface of the Earth). The landform can be at the same level as your point of view, above your level, or below your level. When you recognize and identify the types of rocks associated with a landform, you have a clue to the processes that made the landform.
- **Processes** create landforms and / or modify existing landforms. The forces driving the Internal processes come from inside the Earth or inside the Lithosphere. External processes derive their energy from outside the Lithosphere (e.g. Atmosphere, Hydrosphere, Biosphere).
- **Slope** is defined as the angular orientations of the surfaces of a structure. This pre-supposes the structure is exposed at the Earth's surface. Vertical angles are referenced to an assumed level (horizontal) plane (angular slope = 0°). Horizontal angles (azimuth) refer to compass directions (e.g. north, south, east, and west or azimuth number 0-360°).
- **Drainage** is defined as the movement of water over a slope (the surface of a structure). The slope (structure) controls the drainage. Drainage can remove or add material to a surface. This is an external process that can make landform structures or modify existing ones.

Topography is the collective term for the shape of the Earth's surface features. The surface can be classified and re-classified in a number of ways. The following summary table shows one systematic approach to study of topography. There are associated relative and absolute descriptive systems used in topographic studies. For casual purposes, relative terms may be easier, especially for non-scientists. For technical studies, absolute measurement systems permits more precise analyses.

Criteria	Relative	Absolute
Location / Position	North, south, east or west in relation to another place	Geographic grid coordinates (Lat /Long, UTM, etc.)
	Also see "Elevation" item in this table	
Scale:	Global, regional, local (size). Hierarchy (mountain system, mountain range, mountain).	Mathematical map scale, area coverage, volume, linear measurement calculations.
Elevation	Level, higher, lower than the observer's position and *local relief*—see Figure 1	Elevation referenced to a local point, mean sea level or a standard geoid
Drainage	In or out of a drainage basin; position relative to a water body or source	The measurement of drainage parameters (e.g. basin area, stream order, etc.)
Human alterations of the surface	Developed / Undeveloped.	The measurement / description of the land surface or feature.

The Lithosphere checklist reminds you of the connections to the key words appearing in the summary table. Look at the summary table below and review the functional definitions for Structure, Process, Slope, and Drainage. Be very familiar with how these key terms are related.

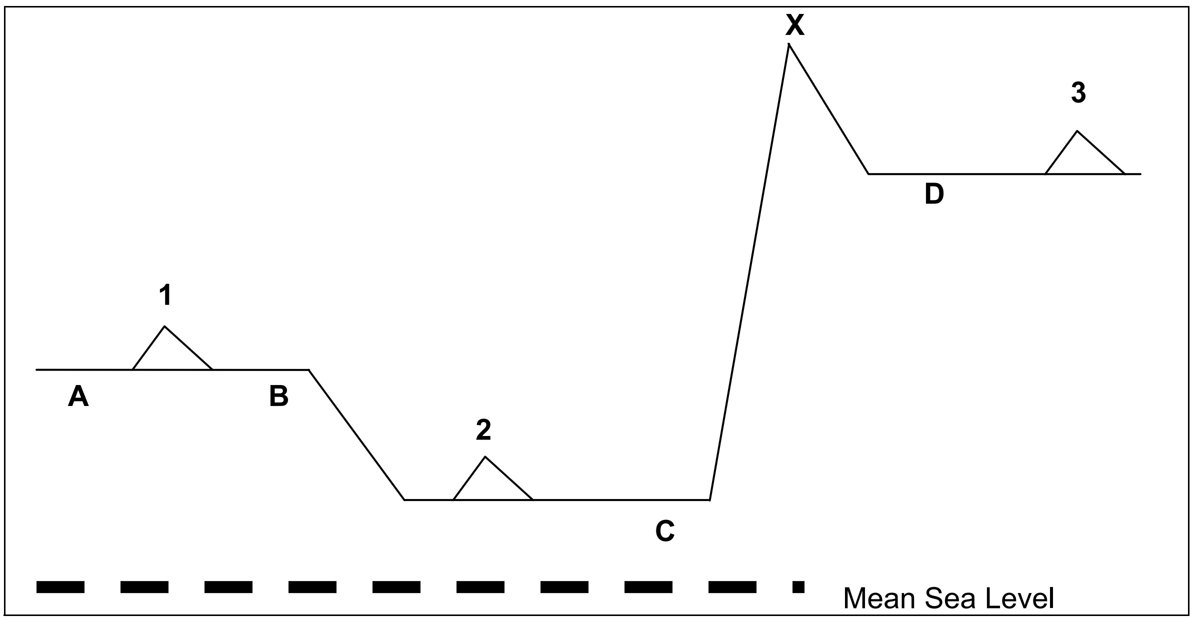
The main purpose of studying a landform is to identify the landform and to understand how it was made. Stand on the site and look at the relative vertical position to the surrounding land. Then look at your feet to identify the rock materials. The processes that made the rocks give you clues to the land forming processes. [**Note:** For additional background details, look up the key terms in the Index of a Physical Geography textbook.]

Lithosphere Checklist

Structure (Shape of the Land)	**Landform**	High (above grade)					Link to the Processes
		Level (on grade)					
		Low (below grade)					
	Rocks	Rock Type	Igneous			Link to the Rock Cycle	
			Sedimentary				
			Metamorphic				
Process (Actions that make or modify the Land)	**Internal**	Plate Tectonics	Vulcanism	Extrusive			
				Intrusive			
			Diastrophism	Warping			
				Folding			
				Faulting			
	External	Weathering	Mechanical	Rocks are fragmented		Link to CTED, LLAOATS	
			Chemical				
		Mass Wasting	Falls	Large amounts of weather material break off the structure			
			Flows				
			Slides				
			Creep				
		Erosion / Deposition	Fluvial (moving water)		Broken rocks moved		
			Aeolian (moving air)				
			Glacial (moving ice)				
			Solution (ground water)				
			Waves / Currents				
Slope (Angular orientations of the Land)	**Angle (vertical)**	Steep	Fast flow	Link to Drainage Flow Velocity			
		Moderate	Medium flow				
		Flat	Slow / No flow				
	Aspect (azimuth)	North – South					
		East - West					
Drainage (Water flow over the Land)	**Flow Velocity**	Fast	Link to Slope Angle and water volume		Links to External Process, Erosion / Deposition, Fluvial Processes		
		Moderate					
		Slow					
	Flow Direction	External (to the ocean)					
		Internal (into a basin on land; no ocean connection)					

2.1.1 Structure: The landform structure is the physical arrangement of the solid rigid rock materials at or near the Earth's surface.

2.1.1.1 Landforms are the physical shape or form of the Earth's surface. Looking from your position on the surface, a landform feature can be higher than, at the same level as, or lower than your position. The concept of ***relief*** (the vertical distance from the lowest point to the highest point in an area) is ***not*** the same thing as the ***elevation*** of the landform (usually meaning the height above mean sea level --- amsl). The figure below shows the difference between elevation and relief.



All of the points in the diagram are at different elevations above mean sea level (amsl). Points A, B, and C are level areas. Standing a point A, you see hill 1 and mountain X above your level. Standing at B, you see the same hill and mountain, but you also see hill 2 in a valley below. From point C, you see hill 2, mountain X, and plain B all above you. From point D you see hill 3 and mountain X above you. From mountain X you can see plains A, B, C, D, and hills 1, 2, and 3 below you.

Using the concept of relief, you can understand why:

- hills will always be hills regardless of their elevation above sea level.
- plains are still plains for the same reason. But other terms for specific plains help distinguish coastal plains from valleys and plateaus.
- persons wanting to climb to the top of mountain X perceive the climb differently if they stand at point C or point D even though the peak of mountain X is the same elevation amsl.
- Persons wanting to climb hills 1, 2, and 3 will always be climbing a hill even though the tops of each hill are different elevations amsl.

2.1.1.1.1 Landform Types: The principal groups are plains / plateaus, hills / mountains, and valleys / basins. Within these groups are smaller features (with less horizontal or vertical extent) such as flats, mesas, and hollows. [**Hint:** The shape of the land is your first clue to understanding the environmental setting.] Landforms are categorized according to size (vertical and horizontal) and shape.

2.1.1.1.1.1 At Grade Landforms:

- ***Plains*** are extensive areas with low relief (flat to rolling areas less than 150 m / 500 ft) often without trees. Plains occurring in valley floors are often called ***flood plains***. Flat areas near the sea are ***coastal plains***.
- ***Plateaus*** are areas of low relief (see definition of a plain) bounded by an escarpment (steep slope) on at least one side. Plateaus are often associated with mountains.

2.1.1.1.1.2 Above Grade Landforms:

- ***Hills*** have moderately high relief (150-600m / 500-2,000 ft) with limited horizontal extent overall and small rounded summit areas. Hills are lower than mountains.
- ***Mountains*** are high places characterized by steep slopes, small summit areas with local relief greater than 600 m / 2,000 ft. Normally, the summit area is extremely irregular with sharp peaks and jagged divides. Mountains are massive projections above the surrounding terrain.
- ***Mesas*** are isolated, flat-topped areas above the surrounding terrain with a greater horizontal dimension than its vertical height, but smaller than a plateau and larger than a butte.
- ***Buttes*** are isolated hills or mountains with very steep sides with a horizontal summit dimension much less than its vertical height. Buttes are much smaller than mesas.
- ***Cinder Cones*** are steep-sided conical-shaped projections above the surrounding terrain created by the accumulation of pyroclastic material ejected from a volcano often forming hills (maximum height of 500 m / 1,500 ft).

2.1.1.1.1.3 Below Grade Landforms:

- ***Basins*** are low places where the rock strata (layers) dip downward to a common central point. In many cases, the basin appears to be surrounded by mountains. The dipping rock strata are the key to defining the basin.
- ***Craters*** are bowl-shaped depressions around a volcanic vent or a hole created by a meteorite impact or explosion.
- ***Calderas*** are craters formed by the collapse of the central volcanic vent and are many times larger in diameter than the vent.
- ***Valleys*** are low elongated depressions in the Earth's surface with clearly established drainage systems between ranges of hills or mountains. Some narrow, steep-sided valleys are called ***canyons***.
- ***Hollows*** are low shallow depressions in the Earth's surface, especially small valleys or basins.
- ***Swales*** are low-lying or depressed, often wet, stretches of land.

2.1.1.2 Rocks are the firm, coherent or consolidated material forming the Earth's solid rigid crust. For the purposes of this paper, rocks are the primary material making up the landforms. Rocks are classified on the basis of their origin. (Refer to the diagram of the ***Rock Cycle*** when reading these definitions.) [**Hint:** If you know the landform structure, look down at your feet and try to recognize the rock types. They give you hints of how the processes that made the structure.]

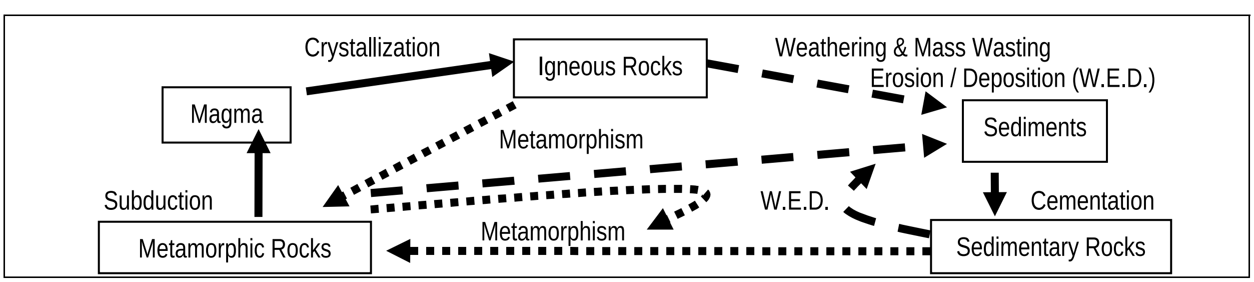
2.1.1.2.1 Rock Types:

2.1.1.2.1.1 Igneous rocks are formed when ***magma*** or ***lava*** (molten rock material inside the Earth and outside the ***crust***, respectively) cools and solidifies. These volcanic rocks can be classified as ***intrusive*** if magma cools below the Earth's surface or ***extrusive*** if lava cools on the surface (exposed to air or water). They can also be further described on the basis of crystal size (coarse / large or fine / small). Igneous rocks tend to be hard and resist ***weathering*** (breakdown to smaller particles called ***sediments***). Thus, they often give landforms a sharp and angular appearance or project above the terrain.

2.1.1.2.1.2 Metamorphic rocks are formed when igneous, sedimentary, or other metamorphic rocks are subjected to heat and / or pressure with the infiltration of magma or contact with lava. Metamorphic rocks can be classified as ***foliated*** (usually associated with regional metamorphism and orgogenesis---mountain building) or ***non-foliated*** (resulting from contact with magma or lava). These rocks can be hard or soft depending on the type of original rock, their composition and amount of deformation due to heat and pressure.

2.1.1.2.1.3 Sedimentary rocks are formed when fragments of weathered rock material (***sediments***) are accumulated by water or wind and compacted and cemented. Materially, sedimentary rocks can be ***clastic*** (composed of fragmented rock material) or ***non-clastic*** if formed as chemical precipitates. Sedimentary rocks can also be classified by location of formation: ***Terrestrial*** sedimentary rocks form on land and are usually high in silica and alumina. ***Marine*** sedimentary rocks form in the ocean and are often high in silica and magnesium. ***Lacustrian*** sedimentary rocks form in freshwater environments (lakes). Sedimentary rocks tend to be softer than other rocks and easily eroded giving landforms a smooth, rounded appearance.

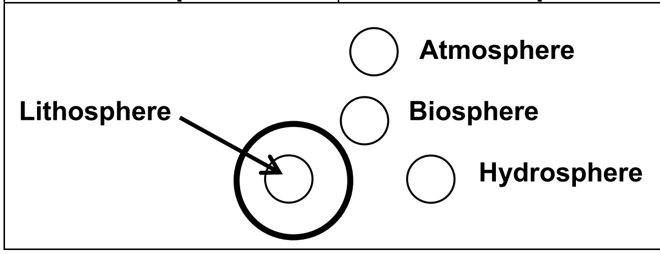
2.1.1.2.2 The Rock Cycle: The various processes (shown by the arrows) of the Rock Cycle are either External (Weather & Mass wasting, Erosion, Deposition—W.E.D) or Internal (all other processes in the diagram below). Thus, the study of the rocks and understanding their origin are the keys to knowing the processes that made or modified a landform.



2.1.2 Processes: Processes create landforms and / or modify existing landforms. You can use the Geographic Systems Model to see the relationship between the Internal and external processes. Internal processes derive their driving forces from inside the Earth or inside the Lithosphere (the solid rigid rock material at or near the Earth's surface). External processes derive their energy from outside the Lithosphere (e.g. Atmosphere, Hydrosphere, Biosphere).

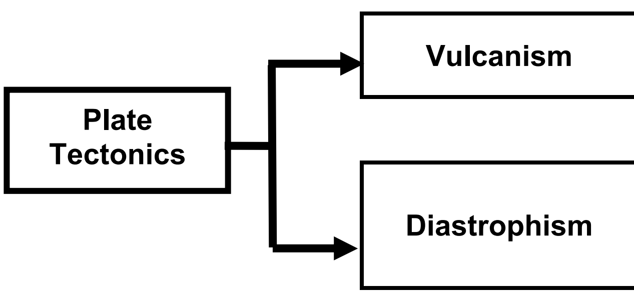
2.1.2.1 Internal Processes: The Internal Processes that create new landforms and / or modify existing landforms are summarized in the table below. The general impression is that Internal Processes create landform structures by adding new material to the surface (***volcanism***) or raising the land surface with compressive mountain building processes. However, structural collapse and subsidence can also occur to lower the current land surface. Keep this in mind as you study the Internal Processes.

Internal = inside the Lithosphere	External = outside the Lithosphere



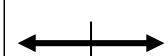
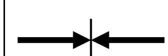
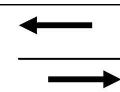
Summary of Internal Processes and Subprocess

The relationship of Plate Tectonics to Vulcanism and Diastrophism	The Relationship of the Internal Subprocesses and Basic Forces



Internal Subprocesses	Plate Forces T	C	S
Intrusive	●	●	
Extrusive	●	●	
The forces of **T**ension, **C**ompression, and **S**hearing cause diastrophism.			
Warping	●	●	
Folding		●	●
Faulting	●	●	●

- Once crustal plates begin to move, Vulcanism and Diastrophism can occur simultaneously or independently.
- Divergent and Convergent boundaries can create opportunities for vulcanism to make new plate material.
- Convergent boundaries with subduction destroys / recycles some plate material.
- Transform boundaries conservation plate material

Type of Force	Force Vectors	Plate Boundary Type
Tension		Diverging
Compression		Converging
Shearing		Transform

The Internal Processes begin with Plate Tectonic movement creating the forces of **T**ension, **C**ompression, and **S**hearing. These forces simultaneously create conditions for the subprocesses of Vulcanism (Intrusive and Extrusive) and Diastrophism (Warping, Folding, Faulting) to occur associated with the various plate boundaries.

2.1.2.1.1 Plates Tectonics / Vulcanism: The theoretical scenario involves the lithosphere (crust), the rigid upper mantle, and the molten interior of the Earth. Movement of the molten liquid interior exerts force on the overlying crustal plates producing ***tension*** (pulling apart). This weakens and fractures the crust allowing magma (liquid molten rock material) to move from depth toward the surface (***vulcanism***) creating ***igneous rocks***. As the magma cools in place underground (***plutonic activity***, creating ***intrusive*** igneous rocks), or when lava cools at the surface (***volcanism***, creating ***extrusive*** igneous rocks), new plate or crust materials (rocks) are created. ***Converging plates*** are pushed together (***compression***) forcing lighter plates upward (orogenesis) and heavier plates downward (***subduction***). ***Compression*** pushes convergent plates pushed together. When ***subduction*** occurs, so does vulcanism. Some magma rises from depth similar to the conditions at divergent boundaries. In the ***subduction zone***, older lithosphere crust is forced down inside the Earth to a depth where rocks melt and become ***magma***. Crustal weaknesses in the subduction zone let some magma (made with recycled rock materials) back to the surface to make new extrusive igneous rocks. The magma trapped underground, cools in place to make new intrusive igneous rocks. Transform boundaries (often associated with diverging plates), create ***shearing*** forces and tend to conserve crustal plate material (e.g. neither creating nor destroying crustal materials).

Summary of Plate Tectonics

Plate Tectonics	**Plate Types**	Continental	Sial (silica, alumina); Light weight, thick	
		Oceanic	Sima (silica, magnesium); Heavy weight, thin	
	Types of Plate Boundaries	Divergent	Mid-Oceanic	Vulcanism
			Continental Rift Zones	
		Convergent	Oceanic – Oceanic	Subduction Vulcanism
			Oceanic - Continental	
			Continental - Continental	Folding Faulting
		Transform	Conservation of crust	

In both divergent and convergent boundaries, magma and lava come into direct contact with existing solid rocks making new ***metamorphic rocks***.

Summary of Vulcanism

Internal Subprocess		Rock Material	Uplift	Down drop
Vulcanism	**Extrusive (Volcanism)**	Lava, extrusive igneous rocks, ash, pyroclastics; metamorphic rocks	Volcanoes (shield, composite, lava dome, cinder cone)	Crater, caldera, collapsed lava tubes
	Intrusive (Plutonic Activity)	Magma, intrusive igneous rocks, metamorphic rocks	Lacolith, dike, neck / plug	----
			Batholiths, stocks, dikes, sills, and plugs may not affect the surface.	

2.1.2.1.2 Diastrophism: The distortions occur only in the lithosphere (the layer of solid, rigid rock material at or near the Earth's surface) using the forces generated by the movement of the crustal plates: ***tension*** (pulling apart), ***compression*** (pushing together), and ***shearing*** (sliding past each other). The summary table below shows the various diastrophic subprocesses, the types of force and the associated plate boundary type. ***Warping*** involves gradual lifting or sinking of the Earth's surface relative to the elasticity of the rock materials. ***Folding*** can vary in intensity depending on the amount of force involved and the plasticity of the rock materials. ***Faulting*** breaks the rock materials when the forces exceed the elastic / plastic limits of the rock materials.

Summary of Diastrophism					
Internal Subprocess		**Direction of Movement**	**Types of Forces / Plate Boundary**		
			Tension / Diverging	**Compression / Converging**	**Shearing / Transform**
Diastrophism	**Warping**	Upwarping		●	
		Downwarping	●	●	●
	Folding	Upfold		●	
		Downfold		●	
	Faulting	Uplift		●	●
		Down drop / sag	●	●	●
		Lateral movement			●

2.1.2.2 External Processes: The External Processes that create new landforms and / or modify existing landforms are summarized in the table below. When rocks are exposed at the surface of the Earth, they are subject to ***weathering***. These ***mechanical*** and ***chemical*** process breaks down solid rock materials into smaller fragments. The smaller pieces of rock can be ***eroded*** (transported) long distances from the original weathering site. ***Deposition*** occurs when the ***sediments*** drop out of the transportation process. ***Mass wasting*** involves large quantities of weathered rock material detaching from a larger body. This is another way to get sediments into the transportation system.

At the input end of the transportation system (***erosion***), weather rock materials are being removed from the structure. Ultimately the structure size and height are reduced. On the output end of the transportation, sediments drop out (***deposition***). The addition of sediments can create depositional landform structures that increase in size and height relative to the surrounding terrain.

Summary of the External Processes and Subprocesses				
The External Processes get energy from outside the Lithosphere.				
Subprocesses	**External Processes Relationships**			**Subprocesses**
Mechanical	Weathering	→	Erosion / Deposition	Fluvial
Chemical	↓			Aeolian
Fall	Mass Wasting	→		Glacial
Flow				Solution
Slide				Wave / Current
Creep				

2.1.2.2.1 Weathering: Rocks exposed at the surface are subjected to heat and moisture from the atmosphere, hydrosphere, and biosphere---two important elements of the weathering process. Weathering is the ***mechanical*** and ***chemical*** break down of rock materials into smaller pieces. The smaller pieces of rock have a greater surface area for further chemical reactions to take place accelerating the weathering process. The rock materials can be igneous, sedimentary, and metamorphic. Each type of rock varies in hardness. But all rock materials will eventually weather. Regardless of the location, all rock materials exposed at the surface will ultimately weather to the smallest particle size called clay. Climate plays an important role. It supplies the heat and moisture. Heat and moisture affect weathering rates.

Summary of Climate to Weathering						
Latitude / Climate		**Ave Temp**	**Ave Moisture**	**Wxg Depth**	**Mech Wxg**	**Chem Wxg**
High	Polar	Low	Low	Moderate	High	Low
Upper Mid-Lat	Subarctic Humid Continental				Moderate	Moderate
Low Mid-Lat	Humid Subtropical	Moderate	Moderate			
Sub-Tropical	Dry	High	Low	Shallow	Slow	Low
Tropical	Tropical Humid	High	High	Deepest	Low	High

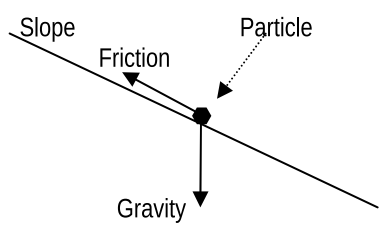
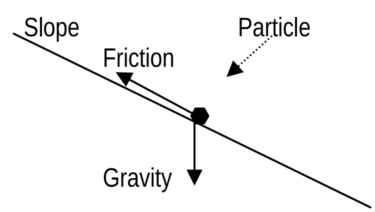
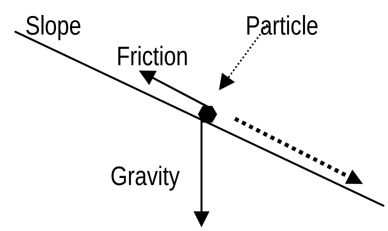
2.1.2.2.2.1.1 Mechanical weathering physically breaks rock materials into smaller pieces. These smaller pieces are readily recognizable and resemble the large original rock mass from which they came.

2.1.2.2.2.1.2 Chemical weathering breaks down rock materials by altering the molecular bonds of the rock materials. The smaller pieces may not be recognizable as being a part of the original rock mass.

Summary of Weathering Processes		
Mechanical	Salt wedging	Heat, water, evaporation; resulting salt crystals expand to fracture rocks.
	Frost wedging	Freezing, water; resulting in ice expanding to fracture rocks.
	Hydraulic wedging	Waves crashing against a rocky shore forces water in pore spaces fracturing rocks.
	Root wedging	Plant roots grow and expand to fracture rocks
	Compression	Rocks falling on other rocks fracture them.
	Abrasion	Water and wind moving smaller abrasive particles against rocks wear the down the rock materials.
Chemical	Oxidation	Exposure to oxygen; esp. rocks high in iron and alumina
	Hydrolysis	Exposure to water; esp. rocks high in silica
	Carbonation	Exposure of carbonate rocks to CO_2

2.1.2.2.2 Mass Wasting is the detachment and down slope movement of a large quantity of weathered rock material under the influence of ***gravity*** and sometimes water. At the end of a mass wasting event, the materials remain in the local area.

A fundamental balance of forces between Friction and Gravity are the foundation to understanding mass wasting and the erosion / deposition processes. These relationships are summarized in the table below. The key variables are strength of the original rock material, age and degree of weathering, slope angle, amount of vegetation, amount of water, and other environmental conditions (e.g. earthquakes, etc.).

<table>
<tr><th colspan="3">Summary of Friction / Gravity in Mass Wasting / Erosion / Deposition</th></tr>
<tr><th rowspan="2">Friction = Gravity</th><th colspan="2">Friction ≠ Gravity</th></tr>
<tr><th>Friction > Gravity</th><th>Friction < Gravity</th></tr>
<tr><td>
</td><td>
</td><td>
</td></tr>
<tr><td>If the forces are equal, they are balanced and the particle remains on slope.</td><td>Friction is greater than Gravity; particle remains on slope. A moving particle could stop on the slope (deposition)</td><td>Gravity is greater than Friction; the particle moves down the slope.</td></tr>
<tr><td colspan="3">Water tends to change the balance of forces by increasing the weight of the weathered rock materials. This increases the effect of gravity. When are present, water has the added property of lubricating clays particles to decrease friction.</td></tr>
</table>

The net effect of mass wasting is to reduce the overall size of the original structure and could change the slope angle. Signs of mass wasting include an upslope scar and a bulging lobe at the front edge of the mass. The center of the descending mass tends to move faster than the sides (where friction is greater). At the bottom of the slope, the land surface is raised with the addition of the weathered rock material. Mass wasting is generally shallow, but notable cases have occurred involving substantial quantities of bedrock.

<table>
<tr><th colspan="2">Subprocess</th><th>Water</th><th>Speed</th><th colspan="2">Form</th><th>Size</th></tr>
<tr><td>Fall</td><td></td><td>No</td><td rowspan="2">Fast</td><td colspan="2">Talus cone, concave slope</td><td>35°-40° slope</td></tr>
<tr><td rowspan="2">Slide</td><td>Landslide</td><td rowspan="2">Some-times</td><td colspan="2">Creates natural dams</td><td rowspan="5">Variable</td></tr>
<tr><td>Slump</td><td rowspan="2">Medium</td><td colspan="2">Crescent-shaped scar upslope</td></tr>
<tr><td rowspan="4">Flow</td><td>Earthflow</td><td rowspan="3">Yes</td><td colspan="2">Clays accelerate process; unvegetated hillsides susceptible</td></tr>
<tr><td>Debris flow</td><td rowspan="2">Fast</td><td rowspan="2">In arid lands</td><td>Larger materials</td></tr>
<tr><td>Mudflow</td><td>Finer materials</td></tr>
<tr><td>Rock glacier</td><td>No</td><td rowspan="3">Slow</td><td colspan="2">Large, elongated in glacial areas and adjacent plains</td><td>Valley length</td></tr>
<tr><td rowspan="2">Creep</td><td>Creep</td><td rowspan="2">Yes</td><td colspan="2">Terracettes</td><td rowspan="2">Hillside</td></tr>
<tr><td>Solifluction</td><td colspan="2">Solifluction lobes</td></tr>
</table>

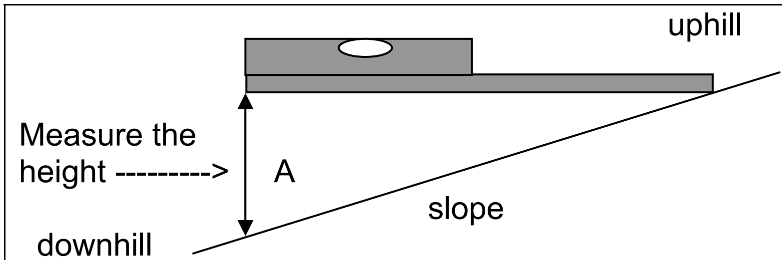
2.1.2.2.3 Erosion / Deposition: This is the transportation / delivery system of the External Processes. Loosened weathered rock materials are moved out of the local area by moving water (Fluvial---river---processes), moving air (Aeolian process), moving ice (Glacial process), dissolved in moving water (Solution Processes), or by moving water (Wave or Currents---in oceans and lakes). With water and ice, the pattern generally is removal of sediments from higher elevations to lower elevations. The slope angle controls the velocity. Faster flowing water can move larger particles. Deposition occurs when the flow velocity decreases dues to a reduction in the slope angle or water volume (and other factors depending on the transport mechanism). Aeolian processes are weather / climate dependent. Removal occurs upwind from the deposition area. Particle sizes moved by wind tend to be much smaller than those moved by non-Aeolian processes.
[**Note**: For this paper, “erosion” is a long distance transportation process. Geologists tend to use erosion to mean the detachment of rock materials from a larger body.]

Summary of Erosion / Deposition	
Fluvial (Rivers & Streams)	Particle size moved depends on the flow velocity of water. Factors involved in channelized stream flow are slope angle, water volume, water depth, channel dimensions (width, depth), channel alignment (straight vs curved), and bottom texture (rough vs smooth). Particles moved range in size from boulders to clay. Sediments can be transported regional (continental) distances.
Aeolian (Wind)	Particle size moved depends on the air flow velocity. Factors involved in wind velocity are the atmospheric pressure gradient, prevailing pressure / wind systems, surface texture, ground cover, topography. Sand-sized particles are transported near ground level (about knee high). The distance traveled is controlled by topography downwind from point of origin. Silt and clay-sized particles are airborne and can be transported at higher altitudes and travel global distances.
Glacial (Ice)	Particle sizes moved range from boulders to clay. This system requires a glacier (high latitude or altitude) and is climate dependent. At its terminus, the glacial transport system connects to either the Fluvial or Wave / Current. This can effectively reduce the size of the materials continuing in the transport system. Transportation distances range from local to regional.
Solution (Water)	The particle size transported is molecular. Ground water dissolves the minerals in the rocks and transports them away from the point of origin. The presence of water and rocks with water-soluble minerals are required for this system. Most common in humid climates and areas with limestone deposits. Distances of transport range from local to global.
Wave / Current (Ocean & Lakes)	The particle sizes moved range from cobbles to clay. Wave energy depends on atmospheric winds, so the particle sizes moved could vary seasonally with the available energy. Beach slope angles and rock materials are also influential. Wave action is localized at the beach (oceanic or lake) and move smaller particles into the currents for continued transport. Ocean currents tend to move sand to clay-sized particles regional and global distances.

2.1.3 Slope: Slope is defined as the angular orientations of the surfaces of a structure. Vertical angles are referenced to an assumed horizontal level plane (angular slope = 0°). Horizontal angles are compass directions (e.g. N, S, E, W or 0-360°). Slope affects soil development. Soil will develop deeper in flat lying areas than on slopes. Gravity tends to pull, water, soil and organic materials down slope to the valley floor or other low-lying area where they accumulate. This is a good place for soil development to occur. This also applies to CTED later in this paper.

2.1.3.1 Vertical Slope Angle: This can be calculated from topographic maps if the contour lines are clear, the contour interval is know, and you know some geometry calculations. You need to know how to read map scales, contour lines and directional / orientation information on topographic maps. That is beyond the scope of this paper. Go to **http://topozone.com** for free topographic maps you can see and print to get a rough idea of the terrain for your area. You need to know the name of the city or location and state. It may be easier to measure the slope directly in the field.

- **Measuring Percent Slope with a Home-made "Leveling Stick":** You can measure it in the field using a ruler and a bubble level ("spirit" level), a stick 50 cm long, and simple math to calculate the vertical slope angle. This method can also be used to determine if the site meets accessibility standards for people with mobility challenges (e.g. people using walkers, crutches, wheelchairs or other similar aids). This is an important legal consideration for some situations.



Equipment Needed:
- Leveling stick
- Short tape measure
- Note pad
- Pen or pencil

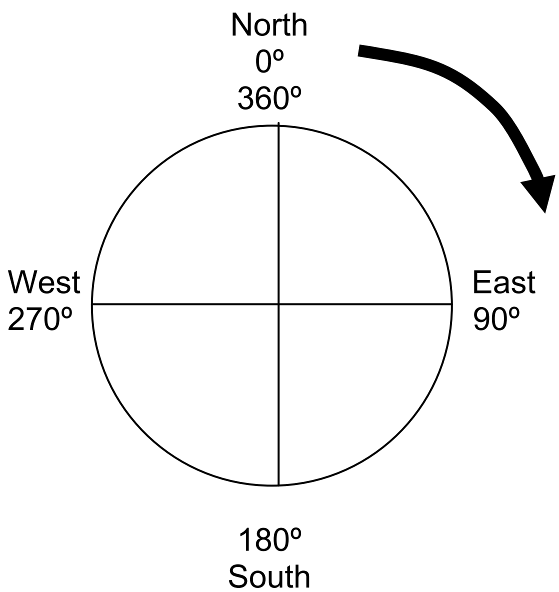
Step 1. Get the "Leveling Stick" and a tape measure with a centimeter scale.
Step 2. Assemble the "Leveling Stick" by inserting the handle into the end with the spirit level. There is a short tether to keep the two pieces together when stored.
Step 3. Use the tape measure to check the total length of the Leveling Stick is 50 cm.
Step 4. Rest the plain end of the "Level Stick" on the uphill side of the slope.
Step 5. Lift the downhill side of the "Level Stick" until the bubble in the spirit level is centered.
Step 6. Measure the height from the ground to the bottom edge of the "Level Stick" using the *centimeter* scale on your ruler. The number of centimeters multiplied by 2 is equal to the "percent" slope. This is because the "Level Stick" is made 50 cm long. "Per cent slope" is a measure of the vertical change for every 100 cm of horizontal distance. So if the height of the "A" in the diagram was 8 cm, the slope is 16%.

Note: You must multiply 8 cm X 2 because the Leveling Stick is only 50 cm long. Percent means "part of 100". So to make 50 cm = 100, you must multiply by 2. Use the table to the right convert your slope measurements.

% Grade	Ratio	Degrees
100.0%	1:1	45.0º
50.0%	1:2	26.6º
33.3%	1:3	18.4º
25.0%	1:4	14.0º
20.0%	1:5	11.3º
16.7%	1:6	09.5º
14.3%	1:7	08.1º
12.5%	1:8	07.1º
11.1%	1:9	06.3º
10.0%	1:10	05.7º

2.1.3.2 Slope Aspect: You can measure the slope orientation (the direction if faces) using a magnetic compass or by reading a topographic map. Natural energy relationships (e.g. insolation, heating, evaporation, prevailing winds, storm tracks, etc.) are affected by slope aspect.

2.1.3.2.1 Measuring Slope Aspect with a Magnetic Compass

<table>
<tr>
<td>
</td>
<td colspan="2">To Measure Slope Aspect:

Imagine you are standing in the middle of the circle in the picture on the left.

Step 1. Stand on the slope facing down hill.

Step 2. Aim the magnetic compass directly down slope, but keep the compass level so the needle swings freely.

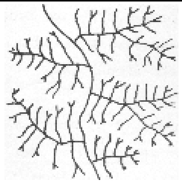
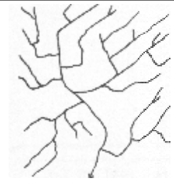
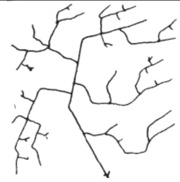
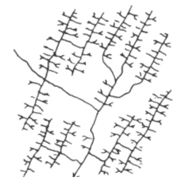
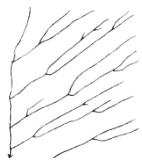
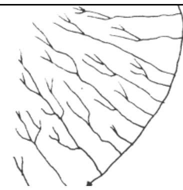
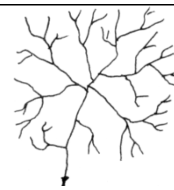
Step 3. Read off the azimuth angle in degrees ranging from 0º (starting at North) going clockwise around the circle.

Step 4. Change the azimuth number into the name of the direction using the table below. Ultra precision is not needed. The general direction is good enough.</td>
</tr>
<tr>
<td rowspan="4">For a site located at 33.93°N, sunlight is always coming from the south. So slopes facing this direction will get more direct sunlight than north-facing slopes.</td>
<td>0º & 360º = North</td>
<td>180º = South</td>
</tr>
<tr>
<td>45º = Northeast</td>
<td>225º = Southwest</td>
</tr>
<tr>
<td>90º = East</td>
<td>270º = West</td>
</tr>
<tr>
<td>135 – Southeast</td>
<td>315 = Northwest</td>
</tr>
</table>

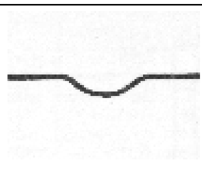
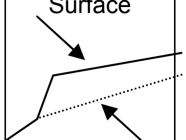
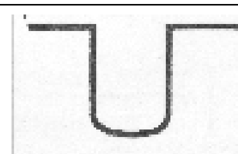
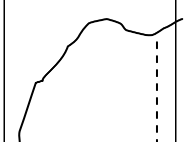
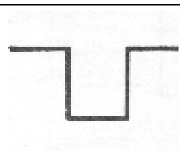
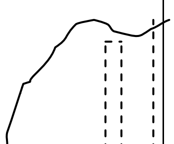
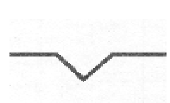
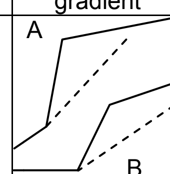
2.1.3.2.2 Measuring Slope Aspect from Topographic Maps: You need to know how to read the directional information on topographic maps (true north, magnetic north, magnetic declination). You need a protractor to measure azimuth on the maps. That is beyond the scope of this paper. For your location of interest, go to http://f6fvy.free.fr/qthLocator/fullScreen.php , then click on the "Terrain" tab (upper right part of the map area). Zoom in on your location of interest. The closer you zoom in you can begin to see topographic contour lines. You can view or print the map to get an idea of the terrain for your area.

2.1.4 Drainage is the movement of water over a slope (the surface of a structure). Gravity pulls water down slope. Drainage can remove or add material to a structure. This is an external process that can make landform structures or modify existing ones.

2.1.4.1 Erosional Areas: The slope controls the drainage. Thus, the drainage pattern helps to reveal the landform structure. The following diagrams summarize some of the basic relationships. Don't get overwhelmed by the "technical" sounding names. If you learn to recognize these drainage patterns on topographic maps, you have the basic key to the landforms in the area. Under each diagram is a brief note of what the pattern may indicate about the erosional land surface.

Summary of Drainage Patterns Relative to Landform Structures					
 Dendritic	 Pinnate	 Rectangular	 Angulate	 Trellis	 Barbed
Uniform Surface materials	High silt content; uniform slope	Thin soil; strong bedrock jointing	Bedrock faults, fractures, joints.	Steep dipping bedrock structure	Warping or uplifting of the land surface
 Deranged	 Parallel	 Radial	 Annular	 Centripetal	(No flow channels apparent) Internal
Low slope, poor drainage	Soft material; main stream may be a fault.	Dome structure or isolated hill, volcano	Possible granitic or sedimentary dome	Low point (sink); water flows to the center.	Porous rock materials, sands/gravels, or underground flow

Water is very significant in shaping the terrain. When you walk through an area, notice the cross-sectional shape of the drainage channels and the landforms cut by streams and water. Erosional actions modify existing landforms by removing weathered rock materials.

Stream Cross-Sections Relative to Surface Materials					
Cross Section	**Profile**	**Materials**	**Cross Section**	**Profile**	**Materials**
 Shallow U	Land Surface  Gully Profile	Cohesive. Clay, silty clay. Associated with lakebeds, marine terraces, clay-shale areas.	 Deep U	 Compound gradient	Moderately. Cohesive. Poorly cemented sand-clay. Coastal plains and bedrock areas.
 Rectangular	 See Note 1.	Mod. Cohesive. Silt deposits or fine volcanic ash falls.	 V-shaped	 See Note 2	Non-Cohesive. Granular materials found in terraces and outwash plains.
Note 1: Fins and pinnacles form along the upslope end of the profile.			Note 2A. Very steep profile = coarse materials, few fines. Note 2B. Less steep profile = well-graded materials		

Flowing water will carry rock, soil, and organic materials down slope. Greater the slope angles produce faster flow velocities. That means larger particles and larger load volumes can be transported. In arid conditions, when flowing water is not present, careful observation of stream deposits gives valuable clues. Stream bed cross sections, particle shapes and sizes, depositional orientation and gradation hint at flow velocities and volumes.

Other Erosional Agents		
Ice	Ice sheets can carry boulders long distances before depositing them in lateral or terminal moraines. Glacial melt water can transport finer sediments longer distances as the water joins streams and rivers.	Some of these agents operate in seasonal patterns.
Wind	Wind moving at 11 mph can begin to move sand grains. Wind can carry finer clay-sized particles thousands of miles. As the wind velocity decreases, deposition can occur.	
Waves	Waves and ocean currents can move sediments from shore areas long distances along and away from shore. As the energy of the wave or current diminishes, sediments are deposited along the shore, near offshore, or in deeper waters of lakes and oceans.	
Dissolution	Water can dissolve minerals and carry them in solution. Deposition can occur through evaporation or through chemical precipitation processes.	
The size of the particles carried by erosion is usually determined by the amount of energy in the eroding agent. As the energy is reduced, the larger particles drop out (are deposited) first, followed by the smaller particles.		

2.1.4.2 Depositional Areas occur when flow velocities of the erosional agnets diminish. The can happen when slopes decrease, water volume diminishes, winds encounter cross-winds or topographic barriers, etc. Gravity acts on the transported sediments and they can accumulate to build a landform structure (e.g. river deltas, sand dunes, alluvial fans, etc.).

2.2 LITHOSPHERE INTERCONNECTIONS:

Lithosphere			Atmosphere	Biosphere	Hydrosphere
Structure	Landform	From	Light, moisture, wind as weathering agents	Flora, fauna, organics	Moisture
		To	Heat, moisture, dust	Substrate, moisture, heat, nutrients	Runoff, sediments, dissolved minerals, nutrients
	Rocks	From	(see Landform, above)	organics	(See Landform, above)
		To	Heat, moisture, dust	(see Landform, above)	Dissolved minerals
	Rock Cycle	From	(see Landform, above)	Organic sediments	Moisture, dissolved minerals
		To	Heat, moisture, dust	(see Landform, above)	(see Landform, above)
Process	Internal	From			
		To			
	External	From	(see Landform, above)	Organic weathering agents	Moisture, weathering agents
		To	Heat, moisture, dust, gases	(see Landform, above)	(see Landform, above)
Slope	Angle	From	(see Landform, above)	Vegetative cover	(See External, above)
		To	Affects solar angle of incidence	(see Landform, above)	Affects water flow velocity, soil moisture
	Aspect	From	(see Landform, above)	Vegetative cover	(See External, above)
		To	Affects solar exposure	(see Landform, above)	(See Angle, above)
Drainage	Erosion	From	Moisture, wind	(See External, above)	(See External, above)
		To	Can change solar exposure	(see Landform, above)	(see Landform, above)
	Deposition	From	Moisture, wind	Sediment traps	Moisture, depositional environment
		To	Can change solar exposure	(see Landform, above)	(see Landform, above)
This summary table is not comprehensive. It contains general examples of the inter-relationships as examples.					

3.0 The Biosphere includes all living organisms. There are two checklists: CTED and SWFS. Use the CTED checklist to describe the physical setting. Use the SWFS checklist to see the living organisms interactions with that setting.

3.1 THE BIOSPHERE CHECKLIST (CTED): The first Biosphere checklist is abbreviated as CTED (which sounds like "See Ted"). Imagine you are in a park and want to know more about the natural history. You ask for information at the visitor center and they tell you to "Go see Ted" the friendly ranger. Each letter of this checklist has even more detail (see the chart below). CTED is used to explain the differences in the habitats and living organisms between various places on Earth at global to local scales. The Habitat checklist (SWFS) is also presented and should be used at the regional and local levels.

This section presents web site references and practical skills for conducting a preliminary site survey. There are more technical and detailed ways to do a site survey. But the methods shown here are suitable for a field recon habitat surveys.

Climate	Light	This is the energy for photosynthesis (photo period) and absorption.	Links to LLAOATS
	Heat	Temperature variations (diurnal and annual).	
	Moisture	Rainfall and snow melt providing water to an area (precipitation patterns).	
	Wind	helps to spread seeds and affects fires.	
Topography	Altitude	Affects light, heat, wind, moisture conditions for life.	Links to SPSD
	Slope Angle	Controls light, heat, wind, moisture, soil development depending on the slope steepness (vertical angle) and orientation (N-S, E-W)	
	Slope Aspect		
Edaphic (Soil) factors	Soil Color	These soil characteristics are used to classify soils. The condition of the soil greatly affects the growth and development of plants. Climate, topography, rock materials, organics, and time affect soil development.	Links to SPSD & LLAOATS
	Soil Texture		
	Soil Structure		
	Soil Chemistry		
Disruptions	Atmosphere	Materials, energy, and events from and in the environmental spheres can disrupt natural processes and life cycles of living organisms. For southern California, earthquakes, fires, flashfloods, severe storms, drought, insect infestations are considerations.	
	Biosphere		
	Hydrosphere		
	Lithosphere		

3.1.1 Climate: Get this data via reference research, or from an onsite weather station (temperature, wind speed/direction, and rainfall data).

3.1.1.1 Light: Sunrise-Sunset Data <http://aa.usno.navy.mil/>: You can calculate the photo period for your site using these data. You'll need to know the Latitude, Longitude, and time relative to Greenwich. **Note:** See www.worldclimate.com to get the Latitude and Longitude for your site.

Thwangpha, Nan Province, Thailand 19.11°N, 100.8°W, 236m (amsl)						
Season ------------>	Summer	Rainy Season				Winter
Date / Hour ------->	21 Mar	14 May	21 Jun	28 Jul	21 Sep	21 Dec
Sunrise	0504	0500	0450	0510	0520	0600
Sunset	1910	1930	1950	1940	1900	1830
Total Daylight Hrs	14:06	14:30	15:00	14:30	13:30	12:30

3.1.1.2 Light: Sunlight / Shade: Many plant guides specify the sunlight and shade preferences of a plant. You need to know the sunlight and shadow conditions of your habitat. There are no formal standards for some of these terms, but consider the functional definitions in the table below when studying the sunlight / shade patterns in your area.

Observe and record the location of the sunlight / shadow areas of your area at various times of the day (about 8-10am, 10am-12pm, 2pm-4pm) and at different times of the year (21 Mar, 14 May, 21 Jun, 28 Jul, 22 Sep, 2, Dec). If you measure the soil temperature for each time and location, you can see another effect sunlight and shade have on the habitat.

Term	Description	Significance
Full Sun	Few or no clouds in the sky; Dark distinct shadows on the ground.	Very bright light. Can get very hot and dry out bare soil. Beware of afternoon sun on south and west facing slopes or areas with high insolation angles.
Partial Sun	Patches of full sun dominate and you can see faint shadows in the shade areas.	Bright light, warm. North and east facing slopes or areas are like this in the morning. Directly exposed to morning or afternoon sun.
Partial Shade	Large areas of shade dominate, some rays of sunlight come through. No distinct shadows in the shade areas.	Light, warm-cool. North and east facing slopes or areas could be like this in the afternoon. Little or no direct morning or afternoon sun.
Full Shade	No shadows visible. May not be able to see the sky at all due to heavy overcast.	Areas shaded by mountains, , buildings, large trees, or in canyons. Little or very indirect light. These areas don't dry out due to sun exposure.

3.1.1.3 Heat and Moisture: Climate Data <http://www.worldclimate.com/>: This site has records of the Temperature (monthly and annual average Temperature, average Maximum Temperature, average Minimum Temperature, Precipitation, weather station Latitude, Longitude, and Elevation). No all data are available for all stations. This website only requires only the city/town name. In the case of places using the same name, you must read down the list to choose the place you want. Here is a summary of the data recovered for Los Angeles International Airport.

CLIMATIC SUMMARY, Thwangpha, Nan Province, Thailand
Weather station is at about 19.11°N, 100.8°W. Height about 236m (amsl)
http://www.tmd.go.th/en/province_stat.php?StationNumber=48315

		Winter		**Summer**			**Rainy Season**					**Winter**		
Item	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Ave Max Temp	°C	29.0	32.1	34.7	35.9	33.5	31.9	30.8	30.6	31.5	31.3	29.9	28.1	31.61
Ave Mean Temp	°C	20.7	23.15	26.25	28.7	28.3	27.9	27.15	26.95	27.2	26.3	23.8	20.55	25.58
Ave Min Temp	°C	12.4	14.2	17.8	21.5	23.1	23.9	23.5	23.3	22.9	21.3	17.7	13.0	19.55
Ave Precip	mm	11.0	12.6	29.2	108.0	206.2	202.4	244.1	302.3	175.6	80.4	22.7	5.9	1400.4
# days of rain		2	2	3	9	17	17	21	22	16	9	4	1	123
Note: Summer = pre-monsoon season (transition NE to SW monsson). Rainy = SE monsoon season. Winter = NE monsoon season.														
Data source: 30 year Average (1961-1990) Thawangha, Thai Meteorological Dept. http://www.tmd.go.th/en/province_stat.php?StationNumber=48315														

Some important considerations / limitations about this information:

- The weather conditions at the station may be quite different from your site due to significant local terrain variations. Your site could have a uniquely different "micro climate" from the surrounding area.
- The mathematical averages do not represent the actual conditions.
- Actual weather conditions can vary tremendously from year to year, month to month, day to day, hour to hour. Be prepared for rapid weather changes and always have an alternative or back up plan for your field activities.

3.1.1.4 Moisture: All living organisms need water to survive. For most cases, the main concern is surface hydrologic features associated with fresh, saline, and brackish (a mixture of fresh and saline) water. Surface water includes all inland waters (streams, rivers, canals, ponds, lakes, swamps, marshes, glaciers) and oceanic waters. Ground water is subsurface water. Water quantity is characterized initially as permanent or intermittent flow. Site specific units are gallons or liters per day (gpd / lpd) or hour (gph / lph). **Water quality general c**ategories are: fresh, brackish, and saline. Site specific measurements are often done for specific chemical elements / compounds in parts per million (ppm) For hydro power, the "head height" (vertical drop of a waterfall) and consistency of flow are also important. Depth and clarity are also significant for navigation and human use.

3.1.1.4.1 Watershed or Drainage Basin refers to the entire region (land surface area) contributing to the water supply for a river or lake. It is the natural unit for the study of surface drainage. The high ground forming the drainage divide (ridge) surrounding the watershed delineates the drainage basin.

3.1.1.4.2 Surface Flow includes rivers, streams, canals and associated features that serve as water supply sources, transportation routes. These can pose barriers to road/rail transportation systems as well as migratory routes. Surface flow can be ***perennial*** (permanent, year round) or ***intermittent*** (seasonal). Other forms of surface flow include seeps, artesian wells, and springs. Be aware of the need to know about the reliability of flow and availability rates / amounts of water. Longitudinal profiles, stream bed slope, and vertical drops (head height) may be critical measurements depending on the purpose of your study.

Note: Be alert to flashflood hazards in mountainous and arid areas.

3.1.1.4.3 Water Bodies are features (e.g. oceans, lakes, ponds, rivers, reservoirs) resulting fro1rm the confluence of surface drainage by storing precipitation and surface runoff and by retarding or augmenting flood flows and serving as water supply sources. In arid regions, interior drainage can result in saline lakes or dry lakes (alkali flats).

3.1.1.4.4 Wetlands are areas tracts of land inundated with water (long term or periodically) such as bogs, swamps, and marshes. In coastal and estuarine areas, tidal wetlands are often experience diurnal tidal inundation.

3.1.1.4.5 Ground Water is the water retained in the pore spaces between the soil particles and can produce a zone of saturation if sufficient water is present. ***Soil water*** refers to the water in the soil pore spaces above the zone of saturation.

Hygroscopic water is the water adhering to the soil particle itself and is not generally thought to be available to plants.

3.1.1.4.6Subsurface Flow is hard to detect. But indirect evidence may appear at the surface as caves, sinkholes, and depressions. Water is dissolving rock materials (e.g. limestone) and may begin to flow underground (a form of internal drainage).

3.1.1.5 WIND: Current Surface Wind Vectors: Check local news sources and keep your own records. Wind is significant for moving heat and moisture into and out of areas. It can also transport dust, pollen, and affect the spread of fire. Below mountain passes and canyons, strong winds can also cause severe damage to larger trees as well as have a severe drying effect on plants and soil. Wind direction and speed are controlled by a number of factors including local topography. I tend to use Accuweather because it offers 15-day forecasts. Again, be careful because the weather station's instruments may not provide measurements that are applicable to your site due to geographic variations. Some people set up their own weather station on site. (See section 4.2.3.2 for the effect of wind on trees.)

<http://www.nawcwpns.navy.mil/~weather/mugu/mesodata/analysis.html>: This site shows current wind directions and has an option to show an animated wind vector map for the previous 12-hours. There are many other weather data sources on the Internet for those seeking even more detailed weather data. Check with a nearby airport for current local weather.

3.1.2 Topography:

This involves the studying the site's general landform and its surroundings. Here is a brief summary of some equipment you will need for the following activities. **Note:** For more details, see the Lithosphere checklist SPSD.

Site Mapping	Slope Aspect	Slope Angle
Long measuring tape Ruler, Protractor, Graph paper Pencil/eraser/sharpener	Magnetic compass Notepad, pencil/pen Optional: topographic map	Leveling Stick Short tape measure Notepad, pencil/pen

3.1.2.1 General Site Orientation: Stand on the site and look around you. The surrounding land can be higher, lower, or about the same level as the site. The height of the surround land will affect the how air and water flow to and from your site. It can also affect the sunlight and shade on your site. You can make a simple sketch map to show your site relative to the surrounding area. [**Note:** A sketch map is not a precise or accurate map. It only shows the relative position of features to one another. The distances may not be accurate at all. This can be done quickly or in more details depending on your time availability and equipment.]

3.1.2.2 Vertical Life Zones: Temperature, moisture, and winds change with altitude. Temperature, especially soil temperature, seems to be a controlling factor affecting the vertical distribution of life on land. Here is a general summary of vertical life zones. This table is generalized.

3.1.2.3 Slope Angle & Slope Aspect: These were discussed in the previous section (Surface Configuration / Surface Materials). The measurements are the same.

However, the main habitat significance for slope is its influence on soil development and the temperature / moisture conditions to support living organisms.

- Slope affects soil development. Soil will develop deeper in flat lying areas than on slopes. This is because gravity tends to pull water down slope. Soil, water, and organic materials are carried down slope to the valley floor or other low-lying area where they accumulate. This is a good place for soil development to operate.

Vertical Life Zones

The great diversity of life on Earth is revealed by the vertical distribution of organisms. Some birds regularly migrate by flying over Mt. Everest. Some aquatic insects survive at the bottom of Lake Baikal (the deepest fresh water lake in the world). And there are still organisms yet to be discovered the deepest parts of the ocean.

Ocean	Coast	Land	Elevation / Depth meters	feet
		Highest birds	8,850 m+	29,036 ft+
		Tallest mtn	8,850 m	20,036 ft
		Upper limit for fauna	7,000 m	22,966 ft
		Upper limit for flora	6,500 m	21,325 ft
		Wenzhuan, China, Highest city	5,099 m	16,729 ft
		Highest agriculture	5,000m+ 3,400 m	16,404 - 11,155 ft
		Song birds	610 – 152 m	2000 – 500 ft
		Water fowl	1219 – 656 m	4000 - 200 ft
Epipelagic	Intertidal / Coastal; Euphotic; Epipelagic		0 m 200 m	0 – 656 ft
Mesopelagic	Mesopelagic; Bathyl zone	Deepest water insect, 1360 m	200m – 800 m	656 – 2,625 ft
	Benthic		1000 m	3,281 ft
Abyssal			4,500 m	14,764 ft
Benthopelagic; Benthic; Hadopelagic			4,500 m - 11,033 m	14,764 – 36,198 ft

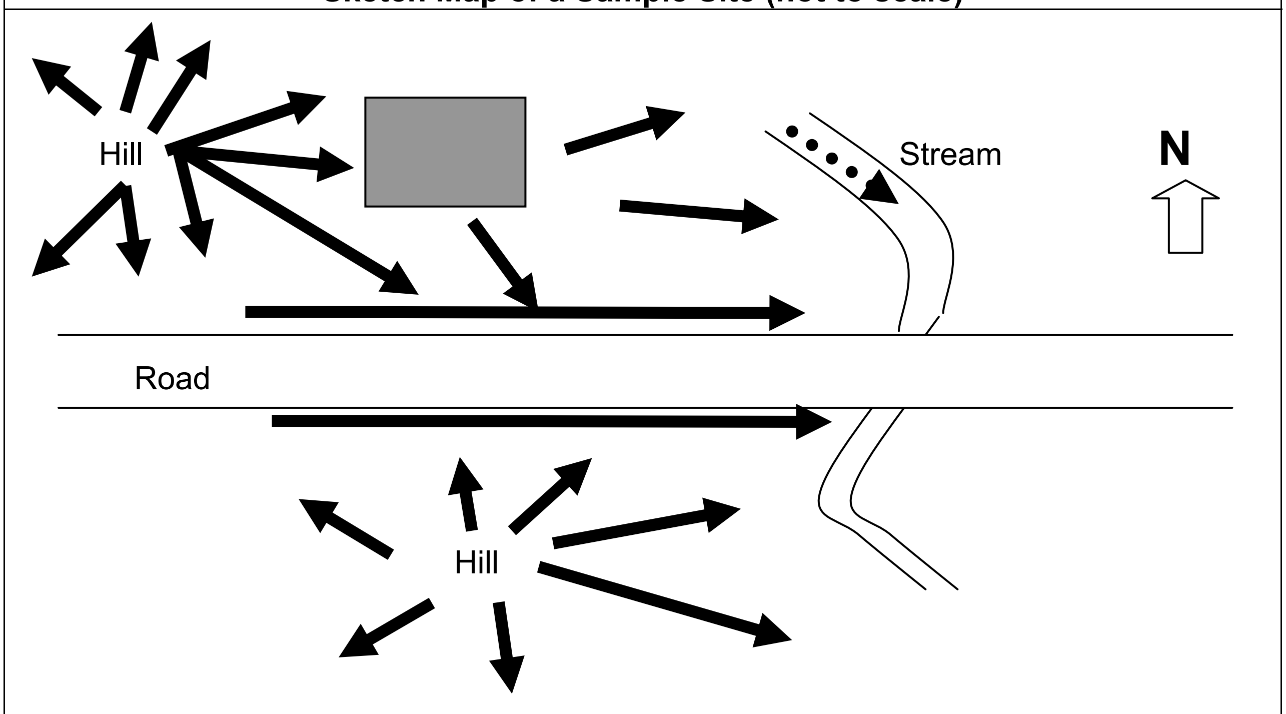
Note: Life zone terms in the ocean can be found in standard reference books or geo-technical dictionaries. Life zone terms on the land are varied. Examples of vertical zonation in California ecoregions is presented in the CTED section of this paper.

- Temperatures will be warmer where on the slopes facing the sun (south-facing slopes in the northern hemisphere, north-facing slopes in the southern hemisphere; and west-facing slopes for both hemispheres). The greater the solar angle of incidence, the greater the solar absorption.
- Moisture will be greater on slopes with lower temperatures / solar insolation. Prevailing winds and dominant storm tracks are other elements to be considered. Where elevations are sufficient for snow, snow will persist on slopes with lower insolation.
- Steeper slopes will create higher water flow velocities and foster erosion. This reduces the potential to create soil and limits vegetative growth.

For a more human scale view of slope angles, the table below lists some common activities associated with slope angles.

% Grade	Slope Ratio	Angle	Some Slope Notes
100.0%	1:1	45.0º	• 60%; maximum for comfortable hiking without switch backs • 50% and more; Not desirable for building sites. • 30%-50%; Fair to Poor building sites • 45%; maximum for tracked vehicles • 10%-30%; Good to Fair building sites • 30%; maximum for trucks • 10%-12% for roads; maximum 16% • 0%-10%; Best to Good Building sites.
50.0%	1:2	26.6º	
33.3%	1:3	18.4º	
25.0%	1:4	14.0º	
20.0%	1:5	11.3º	
16.7%	1:6	09.5º	
14.3%	1:7	08.1º	
12.5%	1:8	07.1º	
11.1%	1:9	06.3º	
10.0%	1:10	05.7º	

Sketch Map of a Sample Site (not to scale)



Shaded block is the sample site. Arrows show water flow directions.

3.1.3 Edaphic (Soil) Factors): Soil is the unconsolidated material that overlies bedrock and is clearly distinguishable from bedrock. It is the accumulation of disintegrated (weathered) rock material mixed with nearly equal amounts of water and air, and a smaller portion of decayed organic material. Decomposed organics (***humus***) are very small particles and function similarly to clay in the soil. Highly organic soils are identified because they contain decomposed grass, twigs, leaves, and related plant materials. They have a characteristic dark brown to black color, spongy feel, and a fibrous texture.

Relative to the Geographic Systems Model, you can see that all four environmental spheres contribute to making soil. ***Location*** plays a role. Gravity pulls weathered rock materials, water, and decayed organic materials down slope. So soils tend to be deeper in low-lying areas and are thinner on slopes. ***Time*** is also a factor in soil development. Obviously it takes time for the soil making processes to happen. Over time, more weathering and decay can take place, and more soil can accumulate.

3.1.3.1 Soil Profile: The ***soil profile*** is one way to examine and characterize a soil sample. To see the soil profile, you dig a hole or trench in the ground. This often reveals vertical layers in the soil. The exposed layers of soil are called the soil profile. The layers are called horizons.

Simplified Soil Horizons

Master Horizons	Named for	Note
0	Organic surface materials	The actual number and thickness of the various soil horizons depends on the climate and terrain conditions of a location
A	"Above," the uppermost soil layer made from weather parent rock material below the surface.	
E	Eluviation: the process of water removing soluble minerals and microscopic particles from the A horizon downward through the soil column.	
B	"Below," the vertical zone where illuviation (deposition) of the soluble minerals and microscopic soil particles takes place.	
C	Coherent (Parent) rock materials are weathered to make smaller soil particles.	
R	Regolith; consolidated parent rock material starting to be weathered.	

Conditions vary from place to place. Sometimes the changes take place over very short distances. You can do some simple soil tests yourself. Soil can be characterized by Color, Texture (particle size), Structure (drainage, moisture, and compaction), and Chemistry (pH, moisture, and a detailed mineral / chemical analysis). This part of the paper will focus on simple soil analyses of soil color, texture, structure, and chemistry.

3.1.3.2 Soil Sampling: All soil samples should be taken from about 6 – 12 inches deep. This is the "root zone" for most plants. If you are going to use a soil-testing laboratory, be sure to get and follow their instructions (especially regarding the amount of soil needed for the tests).

3.1.3.2.1Separate Samples: You can take a number of separate samples from different places on your site. (If you have lawn and garden areas, keep these samples separate.) Get about 1-4 cups of soil from each place you want to test. Scrap off any plant materials over the soil. Put each sample in a zip closure plastic bag. Be sure the label each sample so you know where it came from on the site.

3.1.3.2.2 "Averaged" Sample: Because soil can vary so much over small areas, you can also "average" some samples, especially if they are from similar locations on the site. In some cases, separate soil samples and test results may be too much detail. This can create more work than you want for yourself. In this case, you can get averaged test results for a mixture of soil samples. Be sure you keep records of what individual soil samples you are "averaging." Simply put several soil samples into a container and mix them thoroughly before doing any testing. Don't forget to label the mixture so you know where the soil came from on the site.

3.1.3.3 Soil Color is the most obvious and noticeable soil characteristic. You can easily see soil colors from a distance. There is a very technical color standard used by U.S. soil scientists called the "7th Approximation". The summary table below is general, and therefore limited. There are many different reasons for soil colors. To simplify it, use the terms light, medium and dark to describe soil color. The second table gives some generalized interpretations for soil colors. There are various factors causing soil color. The color clues given in the next chart are general. Soil color is a very subjective and general characteristic. Do not rely on soil color alone for your analyses.

Common Soil Colors			
	Light	**Medium**	**Dark**
	White or gray	Tan or yellowish or reddish	Dark red, brown, black
Humus Clues	Light, tan; low humus content	-----	Dark colors (brown, black) indicate high organic content; good top soil if dark color near surface
Drainage Clues	-----	Red, yellow = well drained. Mixed and scattered red, yellow, gray, blue = variable drainage, periodic wet/dry, or flooding	Gray, blue = poorly drained (low oxygen)
High Salt Content	White crust at surface (in dry climates) = high magnesium and calcium salts (salinization)	-----	Black thin layer at surface (in humid climates) = high sodium

3.1.3.4 Soil Texture refers to the size of the particles in the soil. The soil texture terms (gravel, sand, silt, and clay) only refer to the size of the particles. The soil texture terms do not have any meaning about the chemical characteristics of the soil.

You can do a simple visual inspection by spreading a dry sample on a flat surface and estimating the grain sizes of the particles. You can identify coarsegrained soils. Fine-grained soils are identified by their plasticity determined by breaking and powdering a small dry sample with your fingers. Highly plastic soils can be powdered only with great effort; non-plastic soils crumble easily using your fingers.

Soil texture affects soil structure (another basic soil characteristic), soil moisture and drainage, the minerals available for plant nutrition, and how water and roots can penetrate the soil. There are two relatively easy methods you can do use to study soil texture: touch / feel and the sedimentation bottle with soil texture chart.

The basic soil particles terms are shown in the table below. In the table, the particles are graded from large (left side) to small (right side). Special equipment is needed to measure the very small particles called silt and clay. This paper teaches you two very simple, low cost methods to study soil texture.

<table>
<tr><th colspan="6">US Standard Soil Particle Size Classification</th></tr>
<tr><th colspan="6">Large--→ Small</th></tr>
<tr><th>Gravel</th><th colspan="2">Sand</th><th colspan="2">Silt</th><th>Clay</th></tr>
<tr><td rowspan="5">More than
2-50 mm
0.08-2.0 in</td><td>Very
Coarse</td><td>1-2 mm
0.04-0.08 in</td><td>Coarse</td><td>0.02-0.05 mm
0.0008-0.002 in</td><td rowspan="5">Less than
0.002 mm
0.00008 in</td></tr>
<tr><td>Coarse</td><td>0.5-1 mm
0.02-0.04 in</td><td rowspan="2">Medium</td><td rowspan="2">0.006-0.002 mm
0.00024-0.0008 in</td></tr>
<tr><td>Medium</td><td>0.25-0.5 mm
0.01-0.02 in</td></tr>
<tr><td>Fine</td><td>0.1-0.25 mm
0.004-0.01 in</td><td rowspan="2">Fine</td><td rowspan="2">0.002-0.006 mm
0.00008-0.00024 in</td></tr>
<tr><td>Very Fine</td><td>0.05-0.1 mm
0.002-0.004 in</td></tr>
<tr><td colspan="6">Special equipment is needed to actually measure the very small particles.</td></tr>
</table>

- ***Gravel*** is the term used for loose, water-worn particles ranging in size from 2 mm / 0.08 in to 50 mm / 2 in. in diameter (often mixed with sand, silt, clay).
- ***Sand*** is the size term for particles from about 0.6 cm / 0.25 in or smaller. It can be modified by the terms coarse, medium, fine. Particle shapes can be described as angular or rounded.
- ***Silt*** refers to particles smaller than sand and ranges in size from 0.006mm / 0.00024 in to 0.02 mm / 0.0008 in. It lacks plasticity and has little or no cohesion when dry.
- ***Clay*** generally consists of microscopic particles (less than 0.002 mm / 0.00008 in) with outstanding plastic and adhesive qualities. Clays vary from lean (low plasticity) to fat (high plasticity).

It is important to recognize that the terms sand, silt, and clay refer only to particle size. The terms have no meaning and give no indication of mineral or chemical composition. All types of rocks (igneous, sedimentary, and metamorphic) can be broken down to all of the different particle sizes. Other modifying terms besides coarse, medium and fine refer to the shape of the particles (angular, subangular, rounded).

3.1.3.4.1 Soil Texture Tests: Here are two tests you can do to determine the soil texture: Touch and Sedimentation Bottle.

3.1.3.4.1.1 Soil Texture by Touch For fast field recon survey, you can use your sense of touch. You literally use your sense of touch to identify the soil particle sizes to classify the soil. This is a general field test method to determine soil texture for sand, silt, and clay. Gravel is large enough to be determined by visual inspection. This procedure is summarized in a table on the next page "Soil Texture by Touch." It is a subjective estimate for some other mixture (e.g. loam, sandy clay, sandy clay loam, etc.). Two methods are given, the "Soil Ball" and the "Finger Rub". (See the summary table below.)

	Soil Ball	**Finger Rub**
Check for Sand	Get some soil in your hand and squeeze your fist tight. Slowly open your fist to see if the soil formed a ball. If not, the soil is sand. If it formed a ball, see "Check for Silt or Clay" below.	Get some soil and put it in the palm of your hand. Add a little water to form a small puddle. Use a finger to rub some soil in the puddle. If it feels "gritty", the soil is sandy. If it feels slippery, see "Check for Silt or Clay" below.
Check for Silt or Clay	Get a damp golf ball size soil sample and roll it between your two palms to make a "worm" or "rope" about 4 mm (1/8th inch) in diameter. Keep rolling the "worm" to see how long it will get before it breaks off from your hands. Then use the Finger Rub method to classify the soil.	If you think the soil may be silt or clay, rub some of the moistened slippery soil between your thumb and index (pointing) finger. Stop rubbing. Then gently lift your fingertip away from your thumb. If the sample remains smooth, the soil is silt. If the sample feels sticky or tacky, and some of it lifts up making small spikes, the soil is clay.

With finger rub, the sample feels...		**Worm / Rope Length**			
		< 2.5 cm (< 1 in)	2.5-5 - <5.0 cm (1 - <2 in)	5-7.5 cm (2-3 in)	> 7.5 cm (> 3 in)
High	Very gritty	No finger rub needed; Sand	Sandy Loam	Sandy Clay Loam	Sandy Clay
% Sand	not gritty or smooth		Loam	Clay Loam	Clay
	very smooth		Silty Loam	Silty Clay Loam	Silty Clay
Low	**<---------- % Clay ---------->**				**High**

3.1.3.4.1.2 Soil Texture by Sedimentation Bottle and Texture Chart: For more specific soil texture categories, you can use the "Soil Texture by Sedimentation Bottle and Texture Chart" method. The Sedimentation Bottle requires more time---as much as 4-5 days---and equipment. This is more suitable for a lab set up or a more stable base camp field situation. It is more common to carefully collect soil samples and carry them back to the lab for further analyses. The details are given in a summary table in the following pages of this section. The soil sample must be properly dried and prepared for the test. You need certain equipment and do some math calculations to determine the relative percentages of sand, silt, and clay in the soil.

Soil Texture Test by Sedimentation Bottle and Texture Chart (Part 1)

This is a more specific and technical classification of your soil. You will need to get some simple equipment and do some simple measurements and calculations.

Materials	Equipment	Knowledge / Skills
• Soil sample • Newspaper / rolling pin • Water • Powdered dish detergent • Old tablespoon	• Empty bottle with cap • Ruler / Calculator • Pencil / eraser / notepad • Soil texture triangle • Watch or clock • Wire screen / sieve	• Make linear measurements • Calculating percentages • Measure time • Reading and using a chart.

Step 1. Get a soil sample. Spread it on newspaper in the sun to dry for 1 – 2 days. Cover the dried soil with newspaper and gently crush it to break up any clumps. Use a wire screen / sieve to remove pebbles and any plant materials.

Step 2. Put about 1 cup / 237 ml soil into an empty water bottle. Add 1 tablespoon of powdered dish detergent to keep the soil particles from sticking together.

Step 3. Fill the bottle with water to the top. Screw the cap on tight. Shake for 3 minutes. Make sure no soil sticks together inside the bottle.

Step 4. Put the bottle on a flat, level surface and let the sediments settle.

A. Sand settles first at the bottom. This takes about 1 minute.
B. Silt settles out second on top of the sand. This takes about 1-2 hours.
C. Clay settles out last on top of the silt. This takes about 24-48 hours.

Step 5. Once all the particles settle out, measure the total sediment height in the bottle.

Step 6. Measure the thickness of each layer. Use the chart below to record the data.

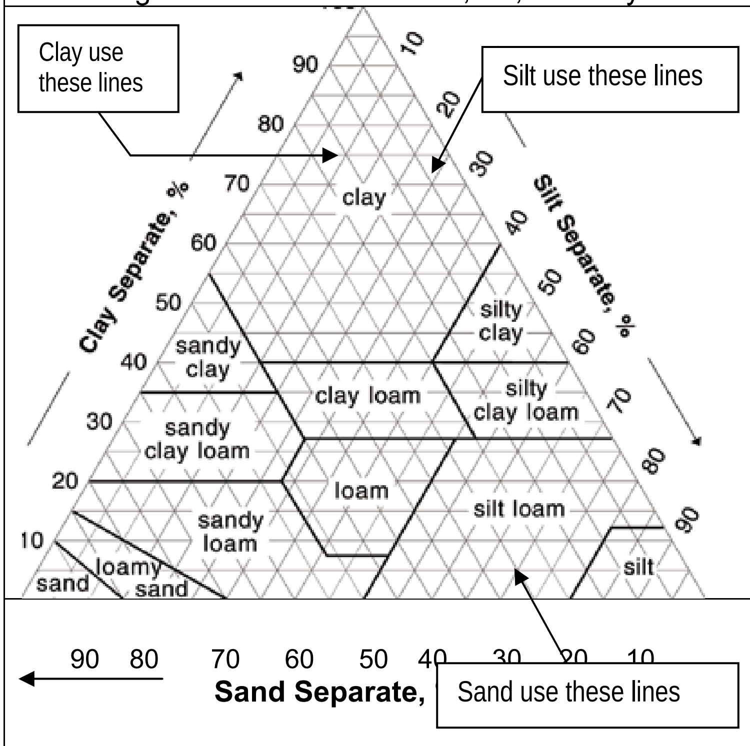
Step 7. Calculate the percentage for each separate in the total sample. (See the instructions in the table above. Be sure to double-check your calculations.

Location:					Sample ID:
Test Date:		Tested by:			Checked by:
Estimated Time	**Sediment Layers**	**Sediment Thickness**		**% of Total Sample**	**To Calculate Percentage of Total Sample:**
		mm or cm	**inches**		
24-48 hours	D. Total Height				Divide the thickness of each sediment layer (Lines A, B, and C) by the total sediment height (Line D) to get the percentage for each separate.
	C. Clay layer				
1-2 hours	B. Silt layer				Example: A = 2 in; B = 2 in; C = 1 in; D = 5 in. Then, A = 40%, B – 40%, C = 20 %. Then go to the soil texture triangle.
1-2 minutes	A. Sand layer				

You can automatically calculate the soil texture classification of your soil sample at the Pedosphere website and look for the American Texture Triangle calculation page: http://www.pedosphere.com/resources/bulkdensity/triangle_us.cfm

Soil Texture Test by Sedimentation Bottle and Texture Chart (Part 2)

Step 8. Use the % separates data with the Soil Texture Triangle. Soils are a combination of sand, silt, and clay particles. The mixture affects the soil classification. The Soil Texture Triangle uses the ratio of sand, silt, and clay to name the soil class.



To Use the Soil Texture Triangle:

Step 1. Use the % Sand from your sample. Find the % on the Sand Separate scale and follow the diagonal lines going up to the left in the chart.

Step 2. Use the % Silt from your sample. Find the % on the Silt Separate scale and follow the diagonal lines going down to the left in the chart.

Step 3. Use the % Clay from your sample. Find the % on the Clay Separate scale and follow the horizontal lines going across the chart.

Step 4. Read the name of the soil type where the 3 lines intersect.

Example: A soil sample is 40% sand, 40% silt, and 20% clay. This soil is a Loam.

3.1.3.5 Soil Structure is influenced by ***texture*** (particle size). Soil structure describes how the soil components (small pieces of rock, air, water, and humus) stick together. This affects the ability of water, air, and plant roots to move through the soil. If the spaces are too big, the soil cannot hold enough water for plants to grow. If the spaces are too small, the roots cannot get through the soil to get water, air and nutrients.

There are numerous ways to test soil structure. [**Note:** You need to know the soil texture before doing any soil structure tests.] This paper presents two tests for soil structure: the crumb test and the compaction test. At the same time, you can do an earthworm census (an surrogate soil chemistry test) and a simple percolation test (for soil compaction).

Advisory Note: The subsurface sampling portion of the crumb test for soil structure requires digging a hole 30 cm / 12 inches deep. Two other tests can be done using the same hole: the percolation test for soil compaction and the earthworm census for soil chemistry. However, these tests need to be coordinated in this order:

- Dig a hole 30 cm x 30 cm x 30 cm / 12 in x 12 in x 12 in.
- First, do the subsurface crumb test.
- Second, do the earthworm census.
- Third, do the soil percolation test. This test could take several hours and will essential render the hole unusable for the other tests.

3.1.3.5.1 Surface & Subsurface Crumb Test: Soil particles naturally clump together. This is s 3-step process to assess the soil structure.

Step 1. Check a surface sample.
Step 2. Dig a hole for subsurface samples.
Step 3. Do a crumb bottle test on both surface and subsurface samples.

Materials	Equipment		Knowledge / Skills
• Plastic Tarp (3 x 3 ft) • Soil sample • Water	• 2 clear plastic cups • Shovel and hand trowel • Ruler or short	• measuring tape • Pencil / eraser • notepad	• Able to follow instructions • Careful observation and note taking

Surface Sample Crumb Test

Step 1. Pick up a handful of soil. **Step 2.** See how it crumbles in your hand.	**Step 3.** Compare the results to the table below. **Step 4.** Record the results in your notebook.

Soil Type	Good Structure	Poor Structure
Light (sandy)	Retains shape; doesn't get powdery	Gets dusty or powdery
Heavy (clayey)	Crumbles easily	Forms big clumps; resists crumbling

Subsurface Sample Crumb Tests

Crumb Diameter

Step 1. Dig a hole about 30 cm / 12 inches deep.
Step 2. Put the soil on a tarp or in a bucket. (This will be used for the worm census.)
Step 3. Use the hand trowel to scrape soil samples from various depths from the side of the hole. Keep records about the depth for each sample.
Step 4. Examine the samples. Soil crumbs come in various sizes but are *not* discrete or separate objects like a marble. They may appear to be more like a piece of moist cake. You are looking for large crumbs about 1-3 mm / 1/32 - 1/8 inch in diameter.
Step 5. Observe and record the soil color.
Step 6. Check and record the soil moisture.
Step 7. Count the worms in the soil from the hole (See Step 2). Record the count.
Step 8. Record any other comments you have.

Crumble Bottle Test

You will need 2 clear cups for a test.
Step 1. Carefully put a handful of the soil crumb sample into each cup. One cup will remain dry. This is the control sample. The second cup is the test sample.
Step 2. Hold the test sample cup at an angle, and gently pour the water down the inside of the cup. *Be careful not to pour the water directly on the soil crumbs.*
Step 3. Put the two cups next to each other and compare the wet soil crumbs to the dry sample. If the wet crumbs hold together as the dry ones, the soil structure is good. If the wet crumbs "melted", turned to mud, and did not keep their shape, the soil has poor structure.
Step 4. Record the results.

Depth		**Crumb Diameter**	**Soil Color**			**% Soil Moisture**	**Bottle Test**		**Worm Count**
cm	inch	□ cm □ inches	Light	Med	Dark		Good	Poor	
7.5	3								
15	6								
22.5	9								
30	12								

3.1.3.5.2 Soil Compaction: This is the indicator of how tightly packed the soil particles are on your site. Highly compacted soils do not let water, air, or plant roots penetrate through it. Here are 3 simple tests for soil compaction: push rod, garden fork (for fast recon surveys), and percolation test (for soil drainage problems). It is a good idea to keep good records of the test results. Then you can notice changes in compaction conditions over time in the study area.

Materials	Equipment	Knowledge / Skills
• Plastic Tarp (3 ft x 3 ft) • Clean water	• Push Rod, Garden Fork, Shovel • Tape measure • 1 Gallon water container • Watch or clock • Pencil / eraser / notepad	• Able to follow instructions • Make linear measurements • Measure time • Careful observation and note taking

<table>
<tr><th></th><th>Push Rod Method</th><th>Garden Fork Method</th></tr>
<tr><td></td><td>Use a steel rod 46 cm /18 in long, 7 mm / 1/4 inch diameter as a soil probe.</td><td>This is similar to the push rod test but uses a garden fork as a soil probe.</td></tr>
<tr><td colspan="3">Step 1. Find a place you want to test for soil compaction.</td></tr>
<tr><td colspan="3">Step 2. Hold the soil probe perpendicular to the soil surface.</td></tr>
<tr><td></td><td>Step 3. Slowly, firmly, and gently push the rod into the soil until you feel resistance or until you see the rod begins to bend. Stop pushing before you bend the rod. If you haven’t hit a rock, mark the rod at the soil surface.</td><td>Step 3. Slowly, firmly, and gently push the garden fork into the soil. If you haven’t hit a rock, mark the blade of garden fork at the soil surface.</td></tr>
<tr><td colspan="3">Step 4. Measure and record how deep the soil probe went into the soil.
The root zone for most garden plants is about 15-30 cm / 6-12 in deep.</td></tr>
<tr><td>Soil is compacted if…</td><td>…the push rod did not penetrate to root zone without starting to bend.</td><td>…you have to stand on the garden fork or it won’t go all the way in,</td></tr>
<tr><td>Soil is NOT compacted if…</td><td>…the push rod penetrates to root zone easily</td><td>…you can push the garden fork all the way in the full length of the tines without standing on it.</td></tr>
</table>

Simple Percolation Test

This is a compaction test to see if you have soil drainage problems. Do this if you see puddles on the surface. (Be sure you completed the subsurface crumb test and the earthworm census before doing the percolation test.)

Step 1. Dig a hole 30 cm (1 foot) deep, 15 cm (6 inches) wide.
Step 2. Fill the hole with water and let it drain completely.
Step 3. As soon as the water from Step 2 has drained, fill the hole with water again.
Step 4. Record the time it takes for the water to completely drain from the hole. If it takes more than 8 hours, the soil is compacted and has poor drainage.

Easy Ways to Break Up Compacted Soil

- Adding compost to attract earthworms
- Cover bare soil with mulch
- Sheet compost compacted bare soil
- Double dig raised garden beds on the compacted area
- Use a garden fork to periodically aerate the soil. Push the fork into the compacted soil and rock the blades back and forth. Pull out the fork. Do this 2-3 times a season to help break up compacted soil.

Easy Ways to Prevent Compacting the Soil

- Avoid working, tilling wet soil
- Avoid walking on wet soil
- Avoid walking on planted areas
- Keep traffic off planted areas
- Avoid frequent plowing or roto-tilling

3.1.3.6 Soil Chemistry: It all begins with water. Plants mostly live on a liquid diet. They use water to get the soil nutrients. People commonly talk about soil fertility and think it means soil chemistry. Soil fertility is a bit more complex, but actually refers to the ability of plants to get to the soil nutrients and not the actual chemical condition of the soil. Chemical testing of soils is complex and requires specialized equipment and procedures that are beyond the scope of this paper. You will learn three simple tests. Soil moisture tells you how much water is available in the soil for plants to use. The pH test is a direct measurement of the acid or alkali condition of the soil. The earthworm census is an indirect measurement of soil health.

3.1.3.6.1 Soil Moisture by Touch and Appearance: Soil moisture is the water in the soil that is available for plants to use. When soil moisture in the root zone (about 15.3 cm / 6 in deep) is less than 50%, most garden plants will be stressed. Plants begin to wilt if soil moisture drops below 5% for sandy soils to 15% for clay soils. Soil texture and soil structure all affect soil moisture. Be sure you have completed the soil texture and soil structure tests before starting the soil chemistry tests.

Available soil moisture	**Light Texture**	**Medium Texture**	**Heavy Texture**
	Sandy	**Loamy**	**Clayey**
0-25%	Dry; loose; flows through fingers	Powdery dry; sometimes slightly crusted but easily broken to powder	Hard; baked; cracked; sometimes has loose crumbs on surface
25%-50%	Looks dry; will not form ball	Somewhat crumbly but holds together from pressure.	Somewhat pliable; will for ball under pressure
50%-75%	Tends for form ball under pressure but seldom holds shape	Forms a ball; somewhat plastic; will sometimes slick with pressure	Forms a ball; ribbons out between fingers
75% to 100%	Forms weak ball; breaks easily; will not slick	Forms a ball; is very pliable; slicks readily if relatively high in clay	Easily ribbons out between fingers; has slick feeling
100% (Field Capacity)	No free water appears with squeezing; but leaves wet outline on hand		
Saturated	Water appears on ball and hand.		

Notes:
- Make a Soil Ball: Squeeze a handful of soil firmly.
- Make a Soil Ribbon: Start with a soil ball. Then use your thumb to push the soil ball out of your hand against the side of your index finger.

Possible Mitigations	
Bare soil:	Cover with mulch to improve moisture retention
Sandy soil:	Adding compost to improve moisture retention
Clay soil	Adding compost to loosen tight soils.
Wet soil	Use raised beds to improve drainage

Source: Soil Conservation Service Bulletin No. 199

3.1.3.6.2 Soil pH Test: This simple test can be done in the field if you have the proper equipment. Using strips pHydrion test paper is an easy way to get a general idea of soil acidity (acid) or alkalinity (base). The pH scale goes from 1 (acid) to 14 (alkali) with 7.0 as neutral. Most soil nutrients are more soluble (able to be dissolved) when the soil pH is about 6.5 – 7.0. This is close the good pH range for many soil organisms, such as earthworms and bacteria (6.0-8.0). Knowing the soil pH of your site will help you select plants that will flourish better in your habitat.

Materials	Equipment	Knowledge / Skills
• Soil sample • PHydrion test paper • Distilled water	• 1 clean plastic cup • 1 old tablespoon • Watch or clock • Pencil / eraser / notepad	• Able to follow instructions • Careful observation and note taking

Step 1. Put about 1 tablespoon of soil in a clean container.
Step 2. Add distilled water and stir until the sample is as thick as a milkshake.
Step 3. Let it stand for 1 hour. Check it periodically and add water if needed.
Step 4. Put a piece of test paper in the solution. Leave it in for about 1 minute.
Step 5. Take the test strip out and rinse it with distilled water.
Step 6. Match the color of the test strip to the standard color chart that came with the test paper. Keep a record of your test results.

Soil is too Acid (pH low)		Soil is too Alkali (pH high)	
This means	**Corrective Action**	**This means**	**Corrective Action**
Phosphorus, calcium, magnesium are less available to plants	Add calcitic or dolomitic limestone Add compost and use mulch	Iron and manganese are less available to plants	Add various forms of sulfur or acidic organic matter (peat moss or pine needles

3.1.3.6.3Earthworm Census: Soil chemistry is a very complex subject. This simple field test gives a general indication of soil chemistry. It is not a substitute for a proper soil lab chemical analysis. This is an indirect indication of good soil chemistry. Earthworms are small organic tractors that move tremendous amounts of soil in a year. The more biological activity in the soil, the more earthworms you will find. Adding compost and organic materials to the soil is the easiest way to provide “food” for earthworms. In that sense, they are like people. Feed them, and they will come. Note: To save time, you can also do the subsurface crumb test and bottle crumb tests.

Earthworms effectively move about 1,363 kg of soil per 4,047 sq m (15 tons of soil per acre). The worm castings (solid wastes) add about 727 kg of soil per 4,047 sq m (8 tons of soil per acre). They make miles of tunnels that help air, water, and roots penetrate more readily throughout the soil. They also move soil and nutrients vertically in the soil column. Mulching and composting provide organic matter in soil that feeds earthworms. Earthworms (different from red worms used in worm composting) prefer 10°C (50°F) temperatures, slightly moist soils, and calcium (and therefore a neutral soil pH). During winter in mid-latitude zones, earthworms can tunnel down 1-2 m (3-6 ft) to escape the cold.

Pesticides, herbicides, and the highly soluble salts in synthetic fertilizers easily kill them. This is another good reason to reduce or eliminate these from your habitat. Besides, it’s also much safer and healthier for you and your family, too.

Materials	Equipment	Knowledge / Skills
• Plastic Tarp 1 m sq (3 ft) or a bucket • Clean water	• Shovel • Tape measure • Pencil / eraser / notepad	• Able to follow instructions • Make linear measurements • Count • Careful observation and note taking

Step 1. Take an earthworm census during a cool time of day. This minimizes stress to the earthworms.
Step 2. Pick a sample site. Measure a square 30 cm / 1 foot on a side. Dig down about 30 cm (1 foot). Put all soil on a tarp or in a bucket.
Step 3. Count the number of earthworms in the soil sample.
Step 4. Interpret the results using the table below. Keep records of your results.

Earthworm Census Count

0-3 = Poor soil	3-9 = Fair soil	10 or more = Good soil
Add organic material.	Can be improved by adding organic material.	Soil in good health.

Earthworm Test for Fertilizers and Soil Amendments:

Before you add fertilizers or soil amendments to your garden beds, do a simple "taste test" with your earthworms. After all, they will have to eat it. If they don't like it, they will leave. And who wants their hard working garden staff to leave the job site?
Step 1. Put a handful of earthworms on one end of an empty tray.
Step 2. Put a handful of fertilizer or soil amendment on the other end of the tray.
Step 3. Watch to see if the earthworms move toward it (they like it) or not (they don't).

3.1.4 Disruptions: These are events that are often characterized by sudden releases of energy, over a short span of time, and have the ability to temporarily (in some cases for long periods of time) halt or, slow natural processes and rhythms. The source of these disruptions can be any of the 4 environmental spheres. You can think of the disruptions as potential "natural hazards" for your site. Of course, there are additional hazards from human activity (e.g. industrial accidents, chemical spills, arson fires, etc.). For the moment, our focus is on the natural systems.

No place on Earth is "perfectly" safe. There are just different environmental hazards for the different places on Earth. The point is to identify these hazards and consider them when planning your habitat. This paper merely makes you aware of the need to consider these hazards. Selected Internet links are given as a partial list of possible sources for more detailed information. You need to see the location and frequency of these disruptions relative to your habitat location.

Examples of Environmental Disruptions

Atmosphere	Biosphere	Hydrosphere	Lithosphere
• Droughts & Heat waves • Severe storms & Lightning • Wildfires	• Diseases • Insect infestations	• Floods • Flash floods • Tsunamis	• Earthquakes • Landslides • Mudslides

Summary of Some Disruptions in Nan Province, Thailand

This is a brief summary table of some of the common disruptions in Nan Province. This is not a comprehensive list. As you change scale to a specific site, not all of these disruptions may occur there. This is why each site of interest must be assessed individually.

The disruptions are correlated to the seasonal calendar as an example of looking for patterns in problem solving. At a site specific level, there may be local conditions and features that may modify your list of concerns.

	Months →	Jan, Feb	Mar, Apr, May	Jun, Jul, Aug, Sep, Oct	Nov, Dec
En Sph	Type of Disruption / Seasons→	Winter	Summer	Rainy	Winter
A	Droughts & Heat waves		X		
	Severe storms & Lightning		X	X	
	Wildfires		X		
B	Diseases		z	X	
	Insect infestations		z	X	
H	Floods		z	X	
	Flash floods		X	X	
L	Earthquakes	Relatively rare and unpredictable			
	Landslides		z	X	
	Mudslides		z	X	

Notes:

- En Sph = Environmental Sphere; A = Atmosphere; B = Biosphere; H = Hydrosphere; L = Lithosphere
- Northern Thailand has only 3 seasons: Winter (cool, dry; NE monsoon) = mid-Oct to mid Feb; Summer (hot, dry; transition from NE to SW monsoon) = mid-Feb to mid-May; Rainy (warm, wet; SW monsoon) = mid-May to mid-Oct. Although the wet monsoon is a recurring phenomenon, the onset of the rainy season could vary as much as a month or so. The SW monsoon can also be intensified when a low pressure trough is located over northern Thailand. This can be further compounded when tropical depressions, storms, or typhoons enter the trough from the South China Sea and the Gulf of Tonkin.
- Symbols: X = Primary potential occurrence; z = Secondary potential for occurrence
- Wildfires: Most of the fires are started from hunter campfires or farmers land clearing fires that got out of control. Fires tend to be "creeping fires" (low to the ground) consuming leaf litter and grasses for fuel. However, climate change forecasts indicate a warming / drying trend for the region which could increase the potential for wildfires.
- Diseases: The rainy season is flu season. Rains and warmer temperatures often see marked increases of mosquitoes and associated diseases (e.g. malaria, dengue fever, and Japanese Encephalitis). Floods increase risks of typhoid, cholera, leptospirosis , and hepatitis A. Hypothermia is a potential problem. Tuberculosis may pose a threat due to overcrowded conditions.
- Floods / Flashfloods: People living near waterways and in mountainous canyon areas need to take precautions. Sudden, intense, localize downpours some distance upstream (or dam failures) can cause flashfloods in downstream areas some distance away. Hillsides cleared of vegetation (by land clearing or wildfire) can create increase runoff during rain storms and contribute to more flooding.
- Earthquakes: Nan province is not considered a seismically active area. However, any possible activity might be associated with the Pua fault zone area.
- Landslides / Mudslides: In Nan, these will most often be triggered by rainfall events. Landslides in narrow mountain canyons can create temporary earthen dams that fail resulting in flashfloods. Hillsides cleared of vegetation (by land clearing or wildfire) can create increase runoff during rain storms and contribute to more landslides and mudslides. (See RTC-TH publication AG 2010-3 to learn more about assessing potential landslide risk.)

3.2 HABITAT: A place or type of site where a plant or animal naturally or normally lives and grows. All living organisms have a habitat, a place they call "home." This "home" can be described in various ways. The CTED checklist primarily focuses on the general Biosphere components or background for a habitat (see Section 3.1). SWFS (sounds like swifs) stands for Shelter, Water, Food, and Space. The SWFS checklist is specifically used to study the relationships of the organism to its habitat. CTED and SWFS both apply to the Biosphere. Both are subsets of the Geographic Systems Model.

[**Note:** The Geographic Systems Model is a conceptual diagram showing the world as four basic parts: Atmosphere, Biosphere, Hydrosphere, and Lithosphere. All of the environmental spheres are highly inter-connected. This is a holistic view of the world.]

3.2.1 Habitat Checklist (SWFS): Habitats can be characterized using the Geographic Systems Model at different scales (levels of details) and times (both on daily and seasonal changes.). Every habitat is located some place on Earth. Its location (the area or ***space*** that surrounds that place) provides the basic needs for organisms to survive (***water, food,*** and ***shelter***). You can remember these 4 basic parts by using the first letters of each of the parts: SWFS (sounds like SWiFs) for **S**helter, **W**ater, **F**ood, and **S**pace.

3.2.1.1 Shelter: Shelter can be anything that protects the living organism from the harsh conditions of the environment (including predators) and for rearing young. The main concern is maintaining critical body temperatures for survival. This depends on the organism and its primary habitat (which could be any of the environmental spheres, not just the Biosphere). Some organisms find shelter in crevices or rock piles, others weave nests from grass and twigs. Still others make their shelter by building shells in which to live. Shelters are most often found in the lithosphere, hydrosphere, and biosphere. Some organisms take to the air to escape their predators.

3.2.1.2 Water: There is an obvious link to the hydrosphere. There are less obvious links to the atmosphere (precipitation), lithosphere (soil moisture, ground water, surface run off, glacial ice), and biosphere (biological storage and transpiration). The entire water cycle should be considered.

3.2.1.3 Food: The form of the nutrients and nutrient media varies with the life form. Nutrient materials are found in all environmental spheres. In a larger sense "food" is any form of matter (solid, liquid, or gas) that can be used to sustain life by providing energy for an organism. Here is a simplified model for the food-nutrient flow: Primary producers (plants), Primary Consumers (plant eaters, herbivores and omnivores), Secondary Consumers (eaters of plant eaters, carnivores and omnivores), Tertiary Consumers (eaters of wastes / dead, detritivores and decomposers). Depending on the organism, it may find its nutrients in any of the environmental spheres.

3.2.1.4 Space: The area providing the water, food, and shelter for organisms extends through the lithosphere, hydrosphere, biosphere, and atmosphere. A description of the habitat is often displayed on a map representing the real world.

Some Key Considerations Using SWFS				
	Atmosphere	**Biosphere**	**Hydrosphere**	**Lithosphere**
Shelter	Shelter types / locations, materials, seasonal patterns, key predators, and competing organisms.			
Water	Precipitation and water in transit	Biostorage (water in organisms)	Water sources, quality, quantity, availability, usage	• Drainage basin • Surface water sources • Subsurface water
Food	Food sources, gathering methods, locations, seasonal patterns, distances from "home" and competing organisms.			
Space	• Altitude • Air for breathing • Repository for exhaled gases • Place for food gathering, escape and transportation	• Ecosystems • Sources of food • Predators • Life cycles	• Location of water • Distance from shore • Depth from surface	• Surface area / range • Distance to food / "home" • Distance / depth to water • Elevation zone

Note: The detailed activities of how to apply SWFS to a specific site can be found in Section 3.3.1.

3.2.2 Habitat Types / Ecoregions:

The World Wildlife Fund (WWF) classifies habitats into 14 major groups. These are characterized as different areas of the world that share similar environmental conditions, habitat structure, and patterns of biological complexity, and that contain similar communities and species adaptations. The major habitat groups are listed below and correlated to the major 7 Biogeographic Realms (Afrotropical, Australasia, Indo-Malayan, Nearctic, Neotropical, Oceania, and Palearctic) to show the unique faunas and floras of the world's continents and ocean basins of each major habitat type. The major habitat groups are further subdivided into 238 ecoregions. [**Note**: This classification seems to bear some bias toward terrestrial areas with the exclusion of Antarctica, curiously classified as part of the Marine Habitat and listed as an ecoregion. Oceania is the prime representative of the ocean basins in this list. The other ocean basins are subdivided and included in the ecoregions list.]

The boundaries for the Biogeographic Realms are often delineated along natural barriers---deep ocean water, major mountain chains, desert lands--- to the movement of terrestrial animals. Some of these barriers can appear and disappear over time. (For example, the land bridge across the Bering Straits during the Ice Age.)

The complete list of the WWF ecoregions on their website listed in the table below. These represent the most distinctive examples of biodiversity for a given major habitat type identified within each biogeographic realm. They are defined using these parameters: species richness, endemism, higher taxonomic uniqueness (e.g., unique genera or families, relict species or communities, primitive lineages), extraordinary ecological or evolutionary phenomena (e.g., extraordinary adaptive radiations, intact large vertebrate assemblages, presence of migrations of large vertebrates), and global rarity of the major habitat type.

World Wildlife Fund Habitat Types

Terrestrial Habitats	Biogeographic Realms						
A total of 14 Major Habitat Types reflect the diverse array of organisms adapted to life on land. These habitats range from the wettest of forest types to the driest and hottest desert conditions. Moreover, terrestrial communities represented here include the full extent of continental topographic relief. These range from mangrove forests by the sea to the alpine meadows of the Himalayas.	Afrotropical	Australasia	Indo-Malayan	Nearctic	Neotropical	Oceania	Palearctic
(1) Tropical and Subtropical Moist Broadleaf Forests	X	X	X		X	X	
(2) Tropical & Subtropical Dry Broadleaf Forests	X	X	X		X	X	
(3) Tropical & Subtropical Coniferous Forests				X	X		
(4) Temperate Broadleaf & Mixed Forests		X	X	X			X
(5) Temperate Coniferous Forests				X	X		X
(6) Boreal Forests / Taiga				X			X
(7) Tropical & Subtropical Grasslands, Savannas & Shrublands	X	X	X		X		
(8) Temperate Grasslands, Savannas & Shrublands				X	X		X
(9) Flooded Grasslands & Savannas	X		X		X		
(10) Montane Grasslands & Shrublands	X	X	X		X		X
(11) Tundra				X			X
(12) Mediterranean Forests, Woodlands & Scrub	X	X		X	X		X
(13) Deserts & Xeric Shrublands	X	X		X	X		X
(14) Mangroves	X	X	X		X		
http://www.panda.org/about_wwf/where_we_work/ecoregions/global200/pages/list.htm							

<table>
<tr><th colspan="6">The Marine Habitats</th></tr>
<tr><td>Polar</td><td colspan="5">Antarctic
Arctic</td></tr>
<tr><td rowspan="3">Temperate</td><td colspan="3">Shelves and Seas</td><td colspan="2">Upwelling</td></tr>
<tr><td colspan="5">North Temperate Indo-Pacific</td></tr>
<tr><td colspan="3">North Temperate Atlantic
Mediterranean
Southern Ocean</td><td colspan="2">South Temperate Atlantic
South Temperate Indo-Pacific</td></tr>
<tr><td rowspan="3">Tropical</td><td colspan="3">Coral</td><td>Central
Indo-Pacific</td><td>Eastern
Indo-Pacific</td></tr>
<tr><td>Western
Indo-Pacific</td><td>Central
Indo-Pacific</td><td>Eastern
Indo-Pacific</td><td>-----</td><td>Eastern
Tropical Atlantic</td></tr>
<tr><td>Western
Tropical Atlantic</td><td>-----</td><td>-----</td><td>-----</td><td>-----</td></tr>
</table>

Every habitat site is nested in the context of its ecoregion (a major world area that supports a characteristic flora or is characterized by a prevalence of one or more climax vegetation types). There are other classification schemes for ecoregions. Crowley and Bailey (in the Goode's Atlas) used ecological – climatic zones to classify the major ecoregions. The names of the climate zones and the associated natural landscapes may be more familiar to you.

The specific names used are different, but all have unmistakable common links to climate and location. This is the key to all of the ecoregion names. These common denominators give credence to the Geographic Systems Model and the associated checklists (LLAOATS, CTED, SWFS, FBS/LCEO, and SPSD).

Ecoregions: Types of Natural Landscapes (after Crowley and Bailey)		
The major divisions are ecological-climatic zones. Subdivisions are based on macro vegetation and altitudinal zonality. (A map of these ecoregions is presented in Goode's World Atlas.)		
Arctic / Subarctic Zone		
A1	Icecap	
A2	Tundra Province	Arctic Ocean moss grass tundra; moss-lichen (typical tundra)
A3	Tundra Altitudinal Zone	Polar desert
A4	Subarctic Province	Dark evergreen forest; needleleaf taiga, mixed coniferous and small-leafed trees
A5	Subarctic Altitudinal Zone	Open woodland and woodland tundra
Humid Temperate Zone		
H1	Moderate Continental Province	Mixed coniferous and broadleaf forest
H2	Moderate Continental Altitudinal Zone	Coastal and alpine forest; open woodland
H3	Warm Continental Province	Broadleaf deciduous forest
H4	Warm Continental Altitudinal Zone	Upland broadleaf and alpine needleleaf forest
H5	Marine Province	Lowland, west-coastal humid forest
H6	Marine Altitudinal Zone	Humid coastal and alpine coniferous forest
H7	Humid Subtropical Province	Broadleaf evergreen and broadleaf deciduous forest
H8	Humid Subtropical Altitudinal Zone	Upland, subtropical broadleaf forest
H9	Prairie Province	
H10	Prairie Altitudinal Zone	Upland mixed prairie and woodland
H11	Mediterranean Province	Sclerophyll woodland, shrub, and steppe
H12	Mediterranean Altitudinal Zone	Upland shrub and steppe
Dry and Desert Zone		
D1	Tropical / Subtropical Steppe Province	Dry steppe, desert shrub, semi-desert savanna
D2	Tropical / Subtropical Steppe Altitudinal Zone	Upland steppe and desert shrub
D3	Tropical / Subtropical Desert Province	Hot, lowland desert at subtropical and coastal locations
D4	Tropical / Subtropical Desert Altitudinal Zone	Desert shrub
D5	Temperate Steppe Province	Medium to short steppe grassland
D6	Temperate Steppe Altitudinal Zone	Alpine meadow and coniferous woodland
D7	Temperate Desert Province	Midlatitude rainshadow desert
D8	Temperate Desert Altitudinal Zone	Extreme continental desert steppe
Humid Tropical Zone		
Tr1	Savanna Province	Seasonally dry forest, open woodland, tall grass
Tr2	Savanna Altitudinal Zone	Open woodland steppe
Tr3	Rainforest Province	Constantly humid, broadleaf evergreen forest
Tr4	Rainforest Altitudinal Zone	Broadleaf evergreen and subtropical deciduous forest

3.3 FLORA (VEGETATION) includes all plants growing on the surface of the Earth, ***terrestrial*** (on land), ***arboreal*** (on other flora), or ***aquatic / marine*** (in or on the water). Aquatic / marine plants can be ***planktonic*** (free-floating) or ***sesial*** (anchored to the bottom). Plants are readily noticed in the landscape. Generally, they are anchored in place, lacking the motility of animals. Their obvious association with the landscape makes it natural for us to use this relationship to help delineate the natural regions. Additionally, Köppen used vegetation as surrogate weather stations for his climate classification scheme.

3.3.1 Terrestrial Vegetation Classification: Vascular Plants are most commonly found on land. They are called the "true" plants. They have well-defined body parts (stem, root, leaves) and a well-developed system to transport liquid nutrients throughout the plant. The following vascular plant terms are summarized in a table on the next page. US Dept of Agriculture Plant Growth Habits Codes and Definitions are listed on another page. These codes can be used for field notation.

- **Basic Descriptive Forms:** The simple descriptive terms start with common English names for plant forms: Tree, Shrub, Vine, Grass, Forb. These terms are defined in the table on the next page.
- **Basic Dichotomy (Woody vs. Non-woody):** Trees, shrubs, and vines have permanent woody stems. Grasses and fords have non-permanent, non-woody, though rigid stems.
- **Foliage of Woody Plants:** These descriptive terms commonly appear in the literature: Broadleaf Evergreen, Broadleaf Deciduous, Needleleaf Evergreen, Needleleaf Deciduous, and a mix (usually specified) of any of these.

<table>
<tr><th colspan="7">Relationship of Simplified Vascular Plant Summary to USDA Plant Codes</th></tr>
<tr><th></th><th colspan="2">Trees</th><th>Shrubs</th><th>Vines</th><th>Grasses</th><th>Forbs</th></tr>
<tr><td rowspan="8">USDA codes</td><td colspan="2">TR</td><td>SH, SS</td><td>VI</td><td>GR</td><td>FB</td></tr>
<tr><td colspan="6">Other USDA Codes not directly correlated to the Simplified Vascular Plant Summary</td></tr>
<tr><td rowspan="3">NP
Non-vascular Plant</td><td>HN</td><td>Hornworts</td><td colspan="3" rowspan="3">Small, inconspicuous, green, non-vascular plants often growing in moist places.</td></tr>
<tr><td>LV</td><td>Liverworts</td></tr>
<tr><td>MS</td><td>Mosses.</td></tr>
<tr><td>LI</td><td colspan="5">Any climbing plant that roots in the ground, especially in tropical areas.</td></tr>
<tr><td>LC</td><td colspan="5">A combination of fungi and algae often occurring as crusty patches or bushy growths on tree trunks or rocks or bare ground etc</td></tr>
<tr><td>UN</td><td colspan="5">Unknown</td></tr>
</table>

Note: The conservative approach in field work is to err on the side of caution. If you are not sure about the plant identification, ***do not misidentify it.*** Indicate it is "UN" unknown, then photograph or sketch it, assign an arbitrary code to it (e.g. UN-1, UN-2, etc.). Use the same code each time you encounter that plant. Later, others may be able to positively identify the plant. You can "back fit" the proper ID code to your field notes. The classification of plants is a difficult and diverse subject well beyond the scope of this paper. The general tems used here permit "speed reading" of the landscape. Closer, more detailed on-site studies may require the use of a more detailed botanical classification system.

3.3.1.1. Vegetation Description: The following terms are suggested for use because the "simple" categories lend themselves to: 1) "speed reading" of the environment from a moving vehicle down the highway; 2) a more human-scale easily handled by casual observers lacking a science background. This helps create and maintain a comfortable learning environment. It is easier to build a firm foundation of environmental awareness. So, as you drive down the highway, look out the window and try to figure out the form of the most common vegetation you see. Here is a brief summary of the basic physical forms. A simplified Vascular Plant Summary Table was compiled and is presented following this discussion. To help simplify field observation notes, the US Department of Agriculture plant growth habit codes and definitions are also provided.

[**Note:** You need to make some adjustments when using these "tools." They come from different sources, were created for different reasons, and therefore do not correlate neatly between the schemes.]

3.3.1.1.1 Trees are perennial woody plants at least 3 m / 10 ft high with a single woody stem and a definite crown shape (when mature). Trees are either ***deciduous*** (dropping their leaves seasonally or in times of drought) or ***evergreen*** (retaining their leaves year round). In very simple terms, a tree has a central woody trunk, branches, and leaves. Other types of trees include needle leaf evergreen, broadleaf evergreen, broadleaf deciduous, and combinations of these. ***Scrub*** refers to a variety of plants that are stunted due to climate or soil conditions. Scrub includes cactus, mesquite, sagebrush, oak and others.

3.3.1.1.2 Shrubs are plants forming the undergrowth in open forests. In arid and semi-arid regions, they comprise the dominant vegetation. They are characterized by having multiple woody stems and are shorter than trees. You might simply say a shrub is like a tree: branches and leaves but no central woody trunk.

3.3.1.1.3 Grasses includes all kinds of non-woody plants. In low latitudes, grasslands are called ***savannas****.* In the middle latitudes, the terms ***prairie*** or ***steppe*** are used. Grasses can be described as ***tall*** (> 2 m / 6 ft high) of ***short*** (< 2 m / 6 ft high). You might say grasses are all leaf with no branches or central woody trunk.

3.3.1.1.4 Field crops comprise the predominant class of cultivated plants. Vine crops and orchards are common but not widespread. Crops can be arranged in rows or can have continuous coverage over a field (e.g. pastures, alfalfa, etc.). Cultivated areas ranges in size from small plots to vast expanses. Climate and terrain as well as social factors influence cultivated field sizes and configurations (e.g. contour plowing, terraces, irrigation systems, etc.). Seasonal variations also affect the times when field are used for planting, cultivating, and harvesting.

Vascular Plants: Simplified Summary

These plants have rigid stems enabling them to support themselves on land.

Woody (trees and shrubs)			Herbaceous (grasses and forbs)	
A woody stem that is perennial or that lives for many years with these other characteristics:			No permanent woody stem, with these other characteristics:	
Trees	**Shrubs**	**Vines**	**Grasses**	**Forbs**
• one erect perennial self-supporting stem (trunk) • trunk diameter at least 7.62 cm / 3 in at a point 1.37 m / 4.5 ft above the ground • a definitely formed crown of foliage • a mature height at least 3.96 m / 13 ft • includes both gymnosperms and angiosperms	• several perennial stems that may be erect or may lay close to the ground • stem diameter no more than 7.62 cm / 3 inches in • rounded, bushy shape • smaller than a tree	• perennial stems that cannot support themselves. • Vines use other plants or objects to rise above the ground or they lie along the ground. • Vines attach themselves to other objects with tendrils or by twining. woody perennial stems, rarely large in diameter	• annual or perennial herbs with fibrous roots and, often, rhizomes. • stems are soft, always noded and are typically hollow and swollen at the nodes, although many genera have solid stems. • The leaves have two parts: a sheath surrounding the stem (called the culm in grasses); and a blade, usually flat and linear. • The flowers are of a unique form, the inflorescence being subdivided into spikelets each containing one or more tiny florets. (In other flowering plants the inflorescences are clusters of separate flowers, never spikelets.) • The dry seed-like fruit is called a caryopsis, or grain.	• Any perennial, broad-leafed herbaceous little plant that is not a grass or grass-like or a brush with • broad, net veined leaves, • a soft, solid stem rather than permanent woody stem, • often grows low to the ground • succulent leaves organized in a circular whorl about its base • annual flowers are often large, colorful, and showy
In adverse conditions, trees may to be shrub-like.		Considered a shrub in some classifications.	Form the climax vegetation for low precipitation regions.	It includes wildflowers and plants which some refer to as "weeds".

Foliage

	Evergreen	Mixed	Deciduous
Broadleaf Wide leaf, network vein pattern **Needleleaf** Narrow leaf, veins parallel	Leaves stay green or shed a few at a time so tree appears to be green	Mixed Broadleaf / Needleleaf evergreen and deciduous	Leaves dropped at specific times of year or under stressful conditions

The classification of plants is a difficult and diverse subject well beyond the scope of this paper. The general tems used here permit "speed reading" of the landscape. Closer, more detailed on-site studies may require the use of a more detailed botanical classification system.

Plant Growth Habits Codes and Definitions (after US Dept of Agriculture)			
Code	**Description**	**Definition**	**Notes**
FB	Forb/herb	Vascular plant without significant woody tissue above or at the ground. Forbs and herbs may be annual, biennial, or perennial but always lack significant thickening by secondary woody growth and have perennating buds borne at or below the ground surface. In PLANTS, graminoids are excluded but ferns, horsetails, lycopods, and whisk-ferns are included.	Applies to vascular plants only. Federal Geographic Data Committee (FGDC; http://www.fgdc.gov/) definition includes graminoids, forbs, and ferns.
GR	Graminoid	Grass or grass-like plant, including grasses (Poaceae), sedges (Cyperaceae), rushes (Juncaceae), arrow-grasses (Juncaginaceae), and quillworts (Isoetes).	Applies to vascular plants only. An herb in the FGDC classification.
LC	Lichenous	Organism generally recognized as a single "plant" that consists of a fungus and an alga or cyanobacterium living in symbiotic association. Often attached to solid objects such as rocks or living or dead wood rather than soil	Applies to lichens only, which are not true plants.
LI	Liana	Climbing plant found in tropical forests with long, woody rope-like stems of anomalous anatomical structure.	Applies to vascular plants only. Mutually exclusive with VI (Vine). A shrub in the FGDC classification.
NP	Nonvascular	Nonvascular, terrestrial green plant, including mosses, hornworts, and liverworts. Always herbaceous, often attached to solid objects such as rocks or living or dead wood rather than soil.	Applies to non-vascular plants only; in PLANTS system this is groups HN (Hornworts), LV (Liverworts), and MS (Mosses).
SH	Shrub	Perennial, multi-stemmed woody plant that is usually less than 4 to 5 meters (13 to 16 feet) in height. Shrubs typically have several stems arising from or near the ground, but may be taller than 5 meters or single-stemmed under certain environmental conditions	Applies to vascular plants only.
SS	Subshrub	Low-growing shrub usually under 0.5 m (1.5 feet) tall, never exceeding 1 meter (3 feet) tall at maturity.	Applies to vascular plants only. A dwarf-shrub in the FGDC classification.
TR	Tree	Perennial, woody plant with a single stem (trunk), normally greater than 4 to 5 meters (13 to 16 feet) in height; under certain environmental conditions, some tree species may develop a multi-stemmed or short growth form (less than 4 meters or 13 feet in height).	Applies to vascular plants only.
UN	Unknown	Growth form is unknown	
VI	Vine	Twining/climbing plant with relatively long stems, can be woody or herbaceous.	Applies to vascular plants only. Mutually exclusive with LI (Liana). FGDC classification considers woody vines to be shrubs and herbaceous vines to be herbs.

3.3.1.2 Natural Vegetation: A.W. Kuchler shows the general global patterns. After so many years of human interaction, it is difficult to know what is "native" or "natural" vegetation. The "potential natural vegetation" map is a conceptual construct of dominant vegetation communities without human influence. These set the context for local field studies.

Natural Vegetation after A.W. Küchler

The vegetation classification is based on a dichotomy of woody vs herbaceous plants with subdivisions for broadleaf / needleleaf and evergreen / deciduous. All group codes (capital letters) refer to trees except G and L.

B	Broadleaf evergreen trees	Smaller letters modify the immediately preceding group code.	
D	Broadleaf deciduous trees		
E	Needleleaf evergreen trees	**b**	Vegetation largely or entirely absent
M	Mixed broadleaf deciduous and needleleaf evergreen trees	**i**	plants sufficiently far apart they frequently do not touch
N	Needleleaf deciduous trees	**p**	growth singly in or in groups or patches
G	Grasses and other herbaceous plants	**s**	shrub form, min. ht. 1 m / 3 ft
L	Herbaceous plants other than grass	**z**	dwarf shrub form, max. ht. 1 m / 3 ft

(A map of A.W. Küchler's Natural Vegetation is presented in Goode's World Atlas.)

B	Broadleaf evergreen trees
Bs	Broadleaf evergreen shrub form, min. ht. 1 m / 3 ft
Bsp	Broadleaf evergreen, shrub form, min. ht. 1 m / 3 ft, growth singly in or in groups or patches
Bz	Broadleaf evergreen dwarf shrub form, max. ht. 1 m / 3 ft
Bzi	Broadleaf evergreen dwarf shrub form, max. ht. 1 m / 3 ft, plants sufficiently far apart they frequently do not touch
D	Broadleaf deciduous trees
Di	Broadleaf deciduous trees, plants sufficiently far apart they frequently do not touch
Ds	Broadleaf deciduous shrub form, min. ht. 1 m / 3 ft
Dsi	Broadleaf deciduous shrub form, min. ht. 1 m / 3 ft, plants sufficiently far apart they frequently do not touch
Dsp	Broadleaf deciduous shrub form, min. ht. 1 m / 3 ft, growth singly in or in groups or patches
Dzp	Broadleaf deciduous dwarf shrub form, max. ht. 1 m / 3 ft, growth singly in or in groups or patches
DsG	Broadleaf deciduous shrub form, min. ht. 1 m / 3 ft, Grasses and other herbaceous plants
DG	Broadleaf deciduous trees; Grasses and other herbaceous plants
DBs	Broadleaf deciduous trees, Broadleaf evergreen shrub form, min. ht. 1 m / 3 ft
E	Needleleaf evergreen trees
Ep	Needleleaf evergreen trees, growth singly in or in groups or patches
G	Grasses and other herbaceous plants
Gp	Grasses and other herbaceous plants, growth singly in or in groups or patches
GBp	Grasses and other herbaceous plants, Broadleaf evergreen trees, growth singly in or in groups or patches
GD	Grasses and other herbaceous plants, Broadleaf deciduous trees
GDp	Grasses and other herbaceous plants, Broadleaf deciduous trees, growth singly in or in groups or patches
GDsp	Grasses and other herbaceous plants, Broadleaf deciduous trees shrub form, min. ht. 1 m / 3 ft, growth singly in or in groups or patches
GSp	Grasses and other herbaceous plants, Semideciduous broadleaf evergreen and broadleaf deciduous trees, growth singly in or in groups or patches
L	Herbaceous plants other than grass
M	Mixed broadleaf deciduous and needleleaf evergreen trees
N	Needleleaf deciduous trees
ND	Needleleaf deciduous trees, Broadleaf deciduous trees
S	Semideciduous broadleaf evergreen and broadleaf deciduous trees
Ss	Semideciduous broadleaf evergreen and broadleaf deciduous shrub form, min. ht. 1 m / 3 ft
SsG	Semideciduous broadleaf evergreen and broadleaf deciduous shrub form, min. ht. 1 m / 3 ft, Grasses and other herbaceous plants
Szp	Semideciduous broadleaf evergreen and broadleaf deciduous dwarf shrub form, max. ht. 1 m / 3 ft, growth singly in or in groups or patches
SE	Semideciduous broadleaf evergreen and broadleaf deciduous trees, Needleleaf evergreen trees

3.3.1.2.1 Vegetation Communities are associations of plants in an area. For recon field plants. The dominant plant often gives the name to the community. Three general classification schemes for vegetation are the biome (global scale), the Life Zones (derived from the National Park Service studies based in the Grand Canyon), and the California Communities (necessary due to the tremendous variety of environments here). These three classification methods are mentioned here because they often appear in textbooks and reference materials for southern California. The National Park Service (NPS) uses the Life Zone terms in many of the parks in the western states, though it may not always apply to all parks.

Vegetative Community Classification Correlation
After Schoenherr, 1992.

Biome After Clements and Shelford	**Life Zone** After Merriam, 1892.	**California Communities** After Munz and Keck, 1959
Tundra	Arctic-Alpine	Alpine
	Hudsonian	Subalpine Forest
	Canadian	Lodgepole-Red Fir Forest
		Yellow Pine Forest
Coniferous Forest		Pinyon-Juniper Woodland
	Upper Sonoran	Oak Woodland
		Desert Chaparral
		Upper Chaparral
		Lower Chaparral
Scrub		Coastal Sage Scrub
		Joshua Tree Woodland
		Blackbrush Scrub
		Alkali Sink
		Shadscale Scrub
	Lower Sonoran	Creosote Bush Scrub
		Sagebrush Scrub
Desert		Cactus Scrub
Grassland		Valley Grassland
Temperate Deciduous Forest		Riparian
		Mixed Evergreen Forest
Temperate Rain Forest		Coast Redwood Forest

Note: Gray shaded areas indicates no correlative term exists in that system.

3.3.1.2.1.1 The California Communities are better suited to the diverse ecological conditions in California. Consider the variety of habitats due to 4,413 m / 14,777 ft of relief in the State. Badwater in Death Valley is well below sea level (about –86 m / –282 ft). Mt. Whitney is the highest peak in the conterminous US (about 4,418 m / 14,495 ft). California extends nearly 10º in latitude (about 32º N to 42º N). Then add the differences that occur due to proximity (shoreline) or distance from the ocean (averaging 274 km / 170 mi.). Add to this the rain shadow effects of the coastal ranges and the Sierra Nevada. This diversity of climates / microclimates creates a great range of habitats in California. A summary table shows the relationship of the various terms of the three vegetative community classifications.

Controlling factors in southern California start with moisture. Slope angle and aspect, weather systems, elevation, and soils all play a role. Vertical zonation is evident as it correlates with temperature-moisture variations.

3.3.1.2.1.2 The Transverse Ranges show distinct vertical zonation between the North vs South-facing slopes.

Transverse Ranges: Vertical Zonation after Schoenherr, 1992.			
North Slopes	**San Gabriel Mtns.**		**South Slopes**
Alpine	3353 – 3658 m	11000 – 12000 ft	Alpine
Subalpine	3048 – 3353 m	10000 – 11000 ft	Subalpine
Lodgepole	2743 – 3048 m	9000 – 10000 ft	Lodgepole
	2438 – 2743 m	8000 – 9000 ft	Yellow Pine
Yellow Pine	2134 – 2438 m	7000 – 8000 ft	
	1829 – 2134 m	6000 – 7000 ft	
	1524 – 1829 m	5000 – 6000 ft	Upper Chaparral
Pinyon Woodland	1219 – 1524 m	4000 – 5000 ft	Lower Chaparral
Juniper Woodland Desert Chaparral	914 – 1219 m	3000 – 4000 ft	
Joshua Tree woodland	610 – 914 m	2000 – 3000 ft	
Saltbush scrub	305 – 610 m	1000 – 2000 ft	
Alkali Flat	0 – 305 m	0 – 1000 ft	Coastal Sage Scrub

3.3.1.2.2 Site-Specific Vegetation Observations: At the field site, it is time to shift scale and get more details. Your preparatory research about the most common vegetation types and species helps you to identify and find those common plants. You can also do some of the following observation activities:

Summary of Site-Specific Vegetation Observations				
Location	Map / coordinates	Grid	Standard	
			Local	
	Vertical Zonation	Altitude	Amsl / Local relief	By altimeter or topo map
		Aspect	Windward / leeward	Magnetic compass or topo map
	Distribution	Linear transect survey	Continuous	Use to detect plant community boundaries
			Interrupted	
		Quadrat survey	Random	Use to detect plant density
			Systematic	
			Stratified	
			Fixed plot	
Tree Measurements	Tree	Height	Sight ruler	
			Shadow / inclinometer	
	Trunk	Diameter	Diameter at breast height (DBH):	Age estimation
	Crown	Shape	Profile view	Ground level perspective
			Aerial view	For working with aerial photos
		Width	Straight line	
			Plan Plot	
		Foliage	Present	
			Absent	
	Roots	Critical root zone	Estimated	Can be 3 x canopy width
		Root depth		Most tend to be shallow (3-6 in)
	Undergrowth	Type	Identify species	
		Height / width	Tape measurement	
		Distribution	Quadrat survey	

3.3.1.2.2.1 Vegetation Transect Line surveys are used detect the presence / absence of a particular species and detect a particular gradient or linear pattern along which plants communities change (e.g. detect transition zones and plant community boundaries). (**Note:** This is a practical application of contrast, the difference between phenomena. See the "Contrast" paper in this Guide.)

The transect line can be continuous or interrupted depending on the purpose of the survey, the level of detail desired, and other site and project factors (e.g. time, costs, terrain, vegetation density).

- Continuous transect line surveys are more detailed, have higher data densities, require more time, and cover shorter distances in a set time.
- Interrupted transect line surveys sample at regular intervals (e.g. 1m, 3 m, or 5 m) along a line, have lower data densities, take less time, and can cover longer distances in a set time.
- "Belt" transect line surveys are a variant of the interrupted transect line survey. Instead of sampling points along the line, a quadrat is centered at the sampling interval along the line. This gathers more data than the interrupted transect. (See details in the Quadrat Survey section below.)

Line Transect Type	Sampling Pattern	Data Density	Relative Time
Continuous		Highest	Slowest
Belt		↕	↕
Interrupted		Lowest	Fastest

The procedures for doing line transect surveys are summarized in the table below. The General Procedures apply to all types of transect line surveys. Specific differences are listed under the various types of transect line surveys.

Line Transect Survey: General Procedures		
• A straight survey line is defined and marked with a tape or rope. Set the line at right angles to a suspected boundary or transition zone area to optimize contrast. • Use of continuous or interrupted method is based on habitat and purpose of study. • No deviation from the transect line is permitted. • All plants touching the line are recorded. • Data a plotted on a graph to show spatial distribution and frequency of occurrence.		
Continuous Line Transect		Interrupted Line Transect
Identify / record every species touching the line.	Specific Procedures	Sampling interval (e.g. 1 m) along the line.
High plant density sampling for short distances	Favorable conditions	Low plant density sampling for long distances
Long distances in high vegetation density sites; can be tedious and time consuming; species ID may be a problem.	Unfavorable conditions	High vegetation densities with long sampling intervals; can miss some species
Continuous Belt Transect		**Interrupted Belt Transect**
Set a distance to either side of the line for sampling along the entire length of the line.	**Specific Procedures**	Center a quadrat at the sampling interval marker. Repeat this for all points along the line.

Suggested Quadrat Screen Sizes	
2m quadrats	woodland habitats
$20m^2$ or larger	taller grasslands / shrubby habitats
$0.5 - 1.0m^2$	short grassland or dwarf heath
$0.25m^2$	moss
Note: Be sure to record the quadrat size and shape in your field notes.	

3.3.1.2.2.2 Vegetation Quadrat surveys reveal the kinds of plants are present / absent in a habitat and the quantities of the species.

The most common quadrat is a square frame, about 1 m x 1 m on a side. Use of a standard size quadrat makes it easier to compare samples that are uniform in size and shape. The plant type and size, as well as the vegetation in the study area determines the quadrat size.

You can make a simple, lightweight quadrat frame using plastic pipe. If you don't cement the pieces together, the quadrat frame can be collapsible and portable.

For longer term monitoring projects, fixed plots can be established. Repeated monitoring of the same plots help to document change over time.

Quadrat Survey: General Procedures

- Determine / record quadrat size.
- Determine number of quadrat samples to be taken in total study area.
- Determine sampling method (e.g. random, systematic, or stratified).
- Set quadrat frame over area to be sampled.
- Identify and count the number of species inside the quadrat frame.
- Repeat until you get the total number of quadrat samples for the study area.
- Summarize distribution of all species inside the frame by relative %.

	Random	Systematic	Stratified
When to use	• Vegetative cover is fairly uniform • Study area is very large • limited time to do the study	• clear environmental gradient exists • need to see change over distance	• significant patches of vegetation exist that would be missed by other methods
Procedure	• place quadrat frame on ground • estimate % coverage for each plant species • repeat sampling a number of times • sample sites must be randomly picked	• Use the Line Transect Interrupted Belt surveys method. • The sampling interval along the survey line is the sampling center point for placing the quadrat. • All plants in the quadrat on both sides of the line are recorded. • Repeat quadrat placement on all sample interval points along the line. • Data a plotted on a graph to show spatial distribution and frequency of occurrence. [**Note:** Fixed plots can be set for long term monitoring projects.]	• estimate % coverage for each plant species • get quadrat samples of vegetation patches
Sampling sites	• Lay map grid over study area; number the grid cells. Use random number table to select cells to be sampled • Random walk; pick numbers from 0-360 corresponding to magnetic azimuth; use random number table to get number of paces to walk along the azimuth before sampling		# quadrats needed in species patches = total area of species patch x total # quadrats to be sampled divided by total area of habitat

3.3.1.2.2.3 MEASURING TREES

3.3.1.2.2.3.1 MEASURING TREES HEIGHT USING THE SIGHT RULER METHOD: In many cases, it is not practical to climb a tree to measure its height.

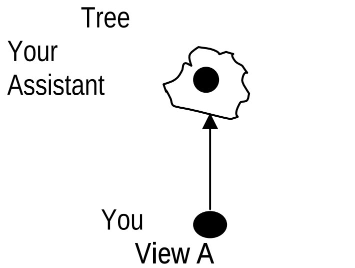
Materials: Long measuring tape, ruler, field notebook.

Procedure:

Step 1. Have your assistant stand next to the trunk of the tree you are measuring. See View A (in the diagram on the next page).

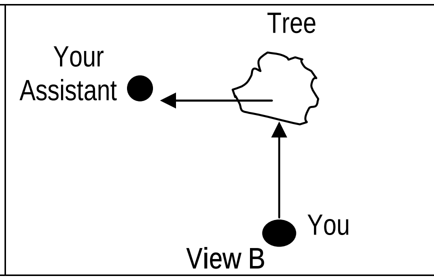
Step 2. Fully extend your arm, hold the ruler perpendicular to the ground. . Close one eye and sight along your arm to the treetop. Read the height of the tree in inches on the ruler.

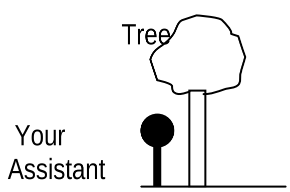
Step 3. Turn the ruler parallel to the ground. Have your assistant walk out from the tree the distance on the sight ruler equal to the height of the tree (in inches). See View B. (in the diagram on the next page). The estimated tree height is the actual distance from your assistant to the tree. Use the long measuring tape to determine the distance from your assistant to the tree.



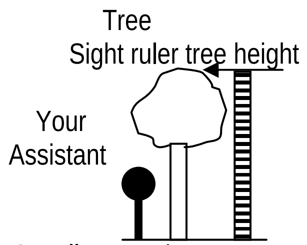
Proper Conditions for this method:

- You must be able to stand next to the object to be measured.
- The ground must be fairly level.
- There must be open space so you can see the object from a distance

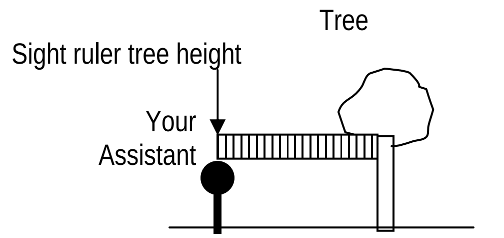




Step 1. Have your assistant stand next to the trunk of the tree you are measuring. See View A.



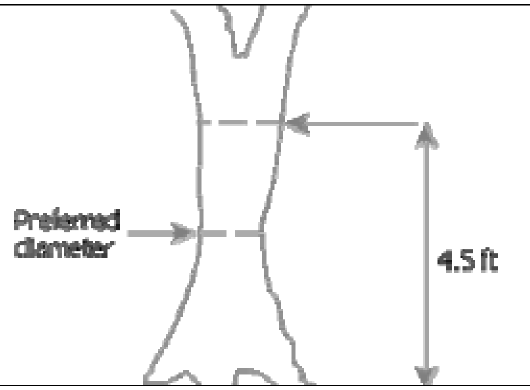
Step 2. Fully extend your arm, hold the ruler perpendicular to the ground. . Close one eye and sight along your arm to the tree top. Note the height of the tree.



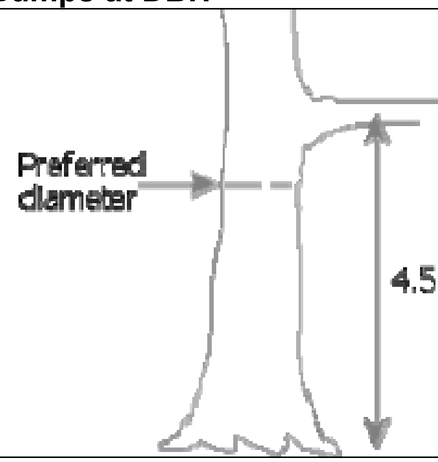
Step 3. Turn the ruler parallel to the ground. Have your assistant walk out from the tree the distance on the sight ruler equal to the height of the tree. See View B. The estimated tree height is the distance from your assistant to the tree.

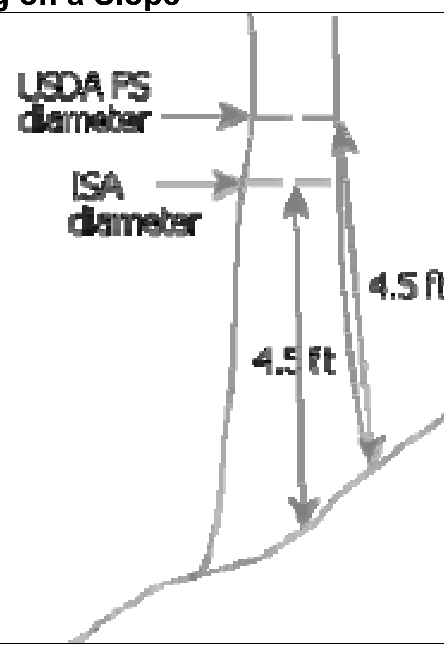
3.3.1.2.2.3.1.21 Simplified Diameter at Breast Height DBH) Measurements: In the US, tree diameter is usually measured at 4.5 ft (137 cm) above ground level. This height is called DBH (Diameter at Breast Height). The concept is simple, but the variability of trees and field conditions introduces some complexities and challenges. Remember, the functional definition of a tree means the trunk diameter must be at least 7.62 cm / 3 in. A special tape measure can be purchased for this measurement called a diameter tape. For our purposes, you can use a common tape measure to calculate the diameter or compile a reference table. Below is a series of illustrations show how to do DBH measuring for different field situations:

<table>
<tr><th colspan="2">Tree Trunk Tapered Below DBH</th></tr>
<tr><td>The tree tapers so the trunk diameter at a point below DBH is actually smaller than the diameter at DBH.

Measure diameter at the smallest point and record the height at which diameter was measured on the data sheet.</td><td>
</td></tr>
<tr><th colspan="2">Tree Has Branches or Bumps at DBH</th></tr>
<tr><td>Measure DBH below the branch or bump.

Some references say to measure a foot below the branching point, which assumes this point is the smallest diameter of the trunk below DBH.

Record the height of the actual measurement.</td><td>
</td></tr>
<tr><th colspan="2">Vertical Tree Growing on a Slope</th></tr>
<tr><td>There are several commonly accepted ways to find the DBH height.
US Forest Service: Use DBH from the ground on the upper side of the slope.

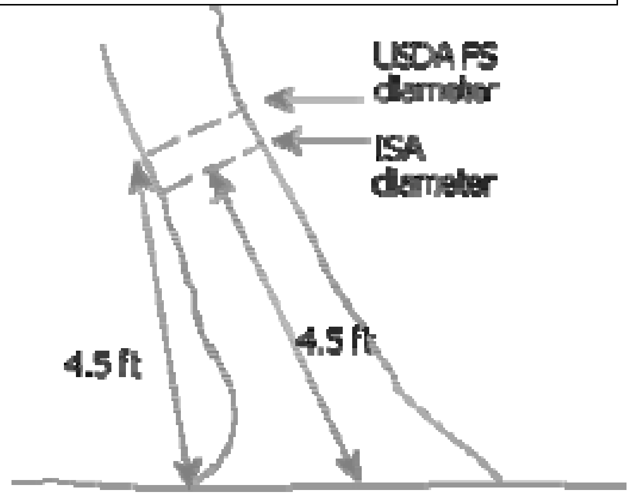
International Society of Arboriculture's (ISA): DBH at the midpoint of the trunk along the slope. This can be a subjective call more prone to error than finding the upper side of the trunk.</td><td>
</td></tr>
<tr><td colspan="2">Adapted from Swiecki, T. J., Bernhardt, E. A. (2001). Guidelines for Developing and Evaluating Tree Ordinances. http://phytosphere.com/treeord/index.htm.</td></tr>
</table>

Tree Leans

US Forest Service: measure DBH up the stem in the direction of the lean.

ISA: measure DBH from the midpoint of the lean.

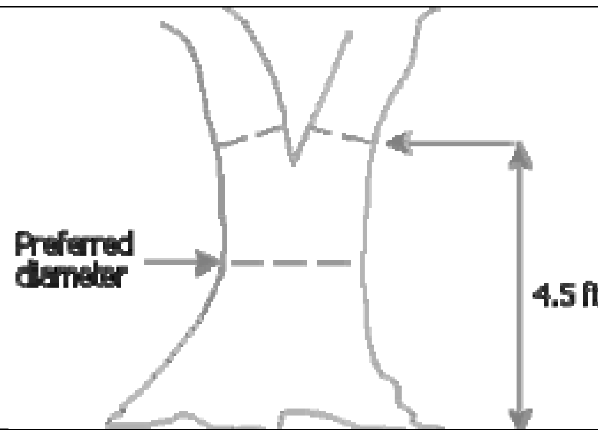
USFS method is probably less prone to error and more readily repeatable by different observers.



Tree Forks Below or Near DBH

Measure DBH at the narrowest part of the main stem below the fork.

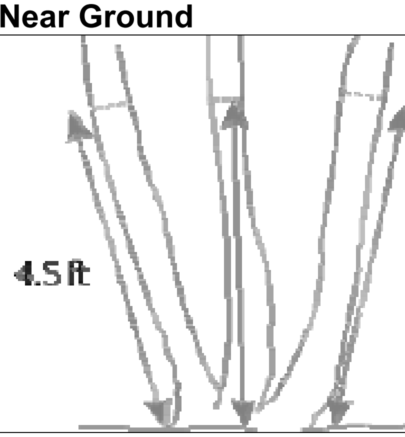
Report the actual height of the measurement and the height of the fork (e.g., 3 ft diameter @ 2 ft [Forks @ 4 ft]).



Tree With Multiple Trunks Near Ground

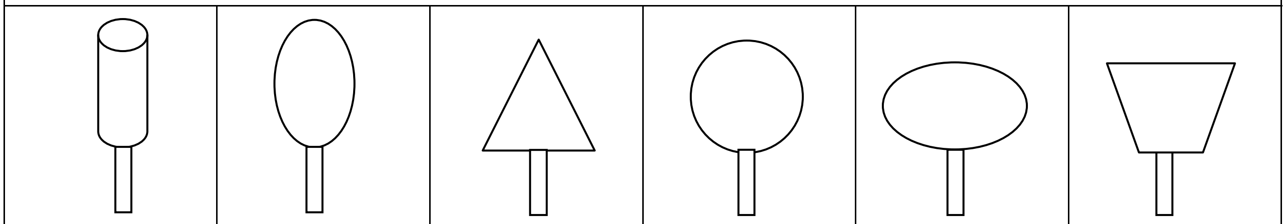
Measure DBH of each trunk separately, using the principals shown in situations above.

Report the DBH for this tree by taking the square root of the sum of all squared stem DBHs.



Adapted from Swiecki, T. J., Bernhardt, E. A. (2001). Guidelines for Developing and Evaluating Tree Ordinances. http://phytosphere.com/treeord/index.htm.

3.3.1.2.2.3.3 Describing Tree Crown Shape (Profile View): These general tree crown shape descriptions are presented as a means of developing you critical field observation skills. The shapes are idealized. Tree crowns can vary widely. The use of these standard terms can make it easier for others to recognize and locate a tree that you have described.

DESCRIPTIVE TERMS FOR BASIC TREE CROWN SHAPES					
					
Columnar	Oval	Pyramidal	Round	Spreading	Vase-shaped

Note: Tree Crown Shape (Aerial View): This can be important when using remote sensing images. However, it is beyond the scope of this Guide.

3.3.1.2.2.3.4 Measuring Tree Crown Width

- **Straight Line Method:** This is a simple and fast method to measure tree canopy width. It is suitable for rapid recon surveys.

  Equipment: Long measuring tape.

  Step 1. Stand under branches and leaves that reach furthest from the trunk. This outer limit is sometimes called the drip line.
  Step 2. Measure the distance from this point to the center of the tree and then go beyond to the opposite point out from the trunk. If necessary, move a little to one side to avoid having the trunk deflect the measuring tape from being a straight line.

- **Plan Plot Method:** This method requires more time, but gives a much more detailed and accurate measurement of tree canopy width. Tree canopies are not symmetrical and even all the way around the tree. Various environmental factors cause tree canopies to be asymmetrical. Plan plots can be used to assess tree shade potential, tree replacement or loss impacts, and hazards potential. Normally, the measurement of canopy width is taken only on woody species under 4cm / 1.57 in DBH. If trees are widely spaced, canopy width measurements may be more important especially for environmental monitoring of ecosystems.

  Equipment: Long tape measure, magnetic compass, protractor, graph paper, and pencil.

  Procedure:
  Step 1. Select a tree for measurement. Get oriented to the cardinal directions. Use a magnetic compass if necessary to plan the measurements. All canopy distance measurements will be done along these direction lines. Decide if the measurements will be made only in the 4 cardinal directions (N, E, S, W) or with the intermediate points as well (NE, SE, SW, NW). The choice is determined by the asymmetry of the tree canopy and the allowable time for the survey.

Step 2. One person stands at the tree and holds one end of the long tape. Starting at the North direction line, the second person walks along the direction line to the drip line of the tree. Note and record the distance.

Step 3. Repeat the distance measurements from the tree to the drip line along the other direction lines.

Measure Canopy Width

Tree	Shrub

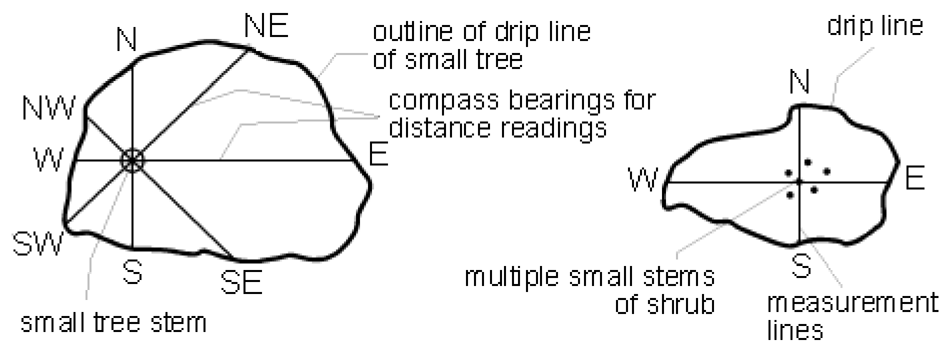
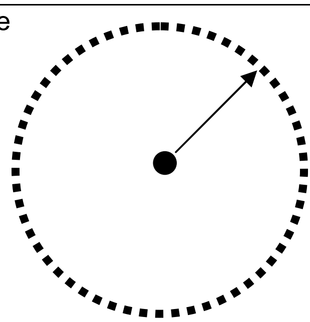
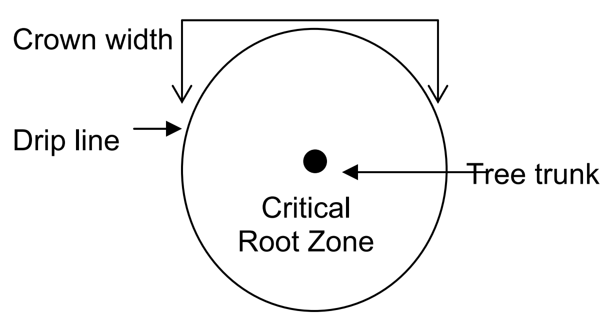


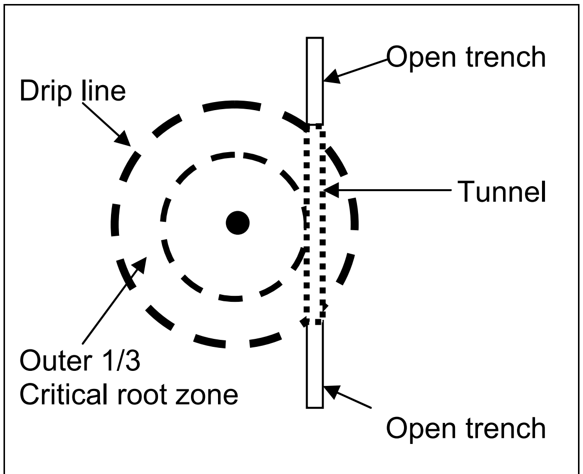
Figure source: http://www.eman-rese.ca/eman/ecotools/protocols/terrestrial/vegetation/page67.html

3.3.1.2.2.3.5 Foliage: In the case of deciduous vegetation, the periods of when leaves are present or absent should be recorded. As with most data, the level of detail varies with the study. For example, just knowing that the tree is evergreen or deciduous indicates there will be a period when no leaves are present. If you indicate leaves are absent from Oct to Mar, that is more detailed than just saying the tree is deciduous. If the records stated late Oct to early Mar, the time frame is more specific. Even more specific would be the 3rd week in Oct to the 2nd week of Mar. However, considering the variation in weather, any more detail may not be of practical use.

3.3.1.2.2.3.6 Critical Root Zone: Once you know the tree's DBH or the crown width, you can locate the critical root zone.

If You Know The DBH	If You Know The Crown Width
Not to scale 	
• Get the DBH. • Use 0.3 m (1 ft) radius for 2.5 cm (1 in) of trunk DBH to calculate the Critical Root Radius • If a tree's DBH is 25.4 cm / 10 in, its critical root radius is 3- 4.6 m / 10 - 15 ft.	• Plot the tree trunk location. Then draw a larger circle representing the canopy. Be sure to show how far the branches extend. This is the drip line. • The Critical Root Zone lies between the tree trunk and the drip line.

Avoid any tilling (for cultivation) or digging / trenching (for construction) in the critical root zone can damage the tree's roots. Avoid any activity that compacts the soil in this area. Compaction reduces soil porosity and permeability. This restricts root access to water, air, and soil nutrients. A healthy root system produces a healthy tree. Damaged root systems can lead to the death of the tree. This can take up to 6 years or more to occur.



Tunneling under the critical root zone.

If moving heavy equipment is necessary in the critical root zone, placing a thick layer of mulch can reduce the impact and compression of the soil. Know the tree crown width and pay particular attention to the tree branches.

Obviously, any digging / trenching can easily damage or kill tree roots. If this kind of work must be done near trees, layout the work so it passes through the outer 1/3 of the critical root radius. Trench up to the drip line. Tunnel under the critical root zone to minimize damaging the tree roots.

3.3.1.2.2.3.7 Root Depth varies with the type of tree. Some trees have deep tap roots with limited horizontal extent. Most tree roots spread horizontally lie in the top 12 to 18-inches of soil. A healthy root system will naturally lead to a healthy tree. About 90 - 95 % of a tree's root system is in the top 1 m (3 ft) of soil. More than 50% is in the top 0.3 m (1 ft) of soil.

3.3.1.2.2.4 Undergrowth: The plants found here tend to be herbaceous (grasses and forbs). These can occur under tree canopies (forested and wooded areas) and in more open areas without tree cover. These plants have shorter life cycles than trees. This makes them more sensitive indicators of environmental change. Undergrowth plants provide habitat for other organisms. Any changes in these plants will affect the overall ecology of the area.

3.3.1.2.2.4.1 Species Identification: You need to consult plant guide books to help identify the undergrowth species. [**Note:** In some jurisdictions, plants on public lands are protected. For some species, protection may extend on private lands as well. This means you cannot legally collect, cut, or take any plant samples or parts of plants without permits. Photography and drawing may be your main field collecting tools.]

3.3.1.2.2.4.2 Height / Width: Use measuring tapes to get the vertical and horizontal dimensions of the vegetation.

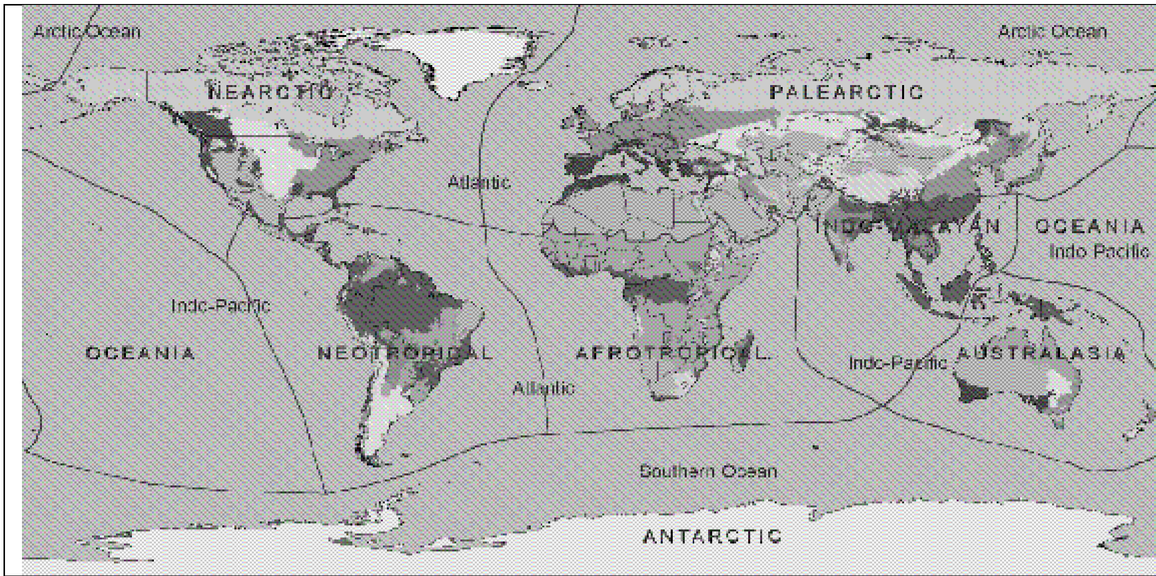
3.3.1.2.2.4.3 Distribution: You can use transect line or quadrat surveys to study the distribution of undergrowth plants.

3.4. FAUNA (ANIMALS): The associated fauna (animals) may or may not be readily observed. Some fauna have limited ranges from their "home" while other range widely (global migrations). Animal motility (the ability of self-propelled locomotion) allows for handling a wider range of environmental variability than a plant. The diversity of sizes and forms (microscopic to "elephantine"; single cell to multi-cellular) is so extreme it is difficult to define animals via common characteristics other than having motility and being heterotrophs (eaters of plants and other animals; unable to synthesize nutrients from the abiotic environment). Otherwise, animals share life characteristics of plants (response to stimuli; need for nutrients, air, water; input of nutrients, output of wastes; reproduction, growth, death; requiring a habitat; having an optimal thermal range). In southern California, you may not see larger mammals during the day. Indirect evidence (e.g. tracks, droppings, strands of fur caught on bushes, etc.) may be you only evidence of their presence.

3.4.1 Global Distribution: Globally there are 7 Biogeographic Realms (Afrotropical, Australasia, Indo-Malayan, Nearctic, Neotropical, Oceania, and Palearctic), sometimes called zoogeographic regions. [**Note:** Various researchers have devised a number of classifications. This discussion uses the World Wildlife Federation terms.] A general pattern observed relates to animal numbers and sizes. Tropical regions have a great number of species, but relatively small numbers for any one particular species. Cooler regions have smaller number of species, but the individual organisms tend to be larger. Animals have the advantage of movement over plants and can avoid environmental extremes through behavior patterns (e.g. hibernation / estivation, migration / residence, diurnal / nocturnal).

Realm	Characteristic Fauna
Afrotropical	Most diverse vertebrates, greatest number of mammals (many endemic); many affinities with Palearctic and Indo-Malayan realms.
Australasia	Most unique fauna of all realms; few vertebrates (only 9 mammal families, 8 are endemic); diverse birds (parrots / pigeons are most diverse here), few fresh water fish and amphibians.
Indo-Malayan	Similar to Afrotropical, but less diverse; some endemics (some shared with Palearctic, Australian, and western parts of Oceania); many color birds, numerous reptiles, venomous snakes most numerous
Nearctic	Many reptiles, but otherwise sparse diversity, though fresh water fishes stand out ; more or less a transition zone between the Neotropical and the Palearctic realms. Some researchers have suggested an aggregated term "Holarctic" for the Nearctic and Palearctic.
Neotropical	Rich, distinct fauna assemblages; large number of endemic mammals, birds very diverse / numerous
Oceania	Very limited fauna assemblages.
Palearctic	Sparse diversity, only 2 endemic species; birds are widely distributed; some affinities with Nearctic, Afrotropical, and Indo-Malayan / western Oceania.

3.4.2 Animal Classification / Description: You don't have to be an expert in zoology to make good animal observations. You just need to watch carefully, and note patterns in behavior. Think in terms of general classifications (mammals, reptiles, birds, insects, etc). Other systematic descriptors involve size, color, activity (movement, feeding, resting, etc.). With practice, your descriptions become more detailed and precise. The basic taxonomy for classify animals starts with vertebrate / invertebrates.



General Summary of Terrestrial Fauna

Animals	• are heterotrophic - meaning they obtain nourishment by digesting plant or animal matter • are multi-cellular organisms with organs or tissues • are motile or have a motile stage of life • have a larval or embryonic stage of development	Vertebrates	Warm-blooded	Mammals
				Birds
			Cold-blooded	Reptiles
				Amphibians
				Fish
		Invertebrates		Sponges
				Cnidarians
				Flat worms
				Round worms
				Mollusks
				Segmented worms
				Arthropods
				Echinoderms

3.4.3 Basic Interactions: The animals interact with their environment in different ways. The basic interactions involve finding shelter, water, food. These activities take place in a designated space (their range). They must find all of these needs and rear young in order to survive as a species. The general living arrangements with other plants and animals forms their habitat.

The next table is a general summary of who eats who or what. Generally, the more noticeable animals will be plant eaters (herbivores), flesh eaters (carnivores; who usually eat plant eaters and other flesh eaters), and some that eat both plants and flesh (omnivores). This forms the basis for predator – prey relationships.

Herbivores Plant-eaters	**Omnivores** Eat both plants and flesh	**Carnivores** Flesh eaters
• Plants are generally abundant • Plant-based diets can be low in nutrients and difficult to digest. • Complex digestive systems containing microorganisms break down the plant substances, turning them into nutrients that the animal can absorb	By consuming both plants and flesh, omnivores have a wider range of food for sustenance than either herbivores or carnivores.	• Meat is difficult to obtain. • Flesh of other animals is nutrient-rich and easy to digest it • Finding and capturing this kind of food calls for keen senses such as acute vision or a highly developed sense of smell

In some cases, the relationships between organisms (includes both plants and animals) is based on a stronger, longer lasting term. Symbiosis occurs when two species form longer lasting bonds. The types of symbiotic relationships are summarize in the table below.

<table>
<tr><th colspan="4">Symbiotic Relationships Summarized
(These apply to both plants and animals.)</th></tr>
<tr><td rowspan="3">Symbiosis</td><td rowspan="3">Most of the interactions between species involve food. These interactions are often brief:
• competing for the same food supply
• eating (predation)
• avoiding being eaten (avoiding predation)

Symbiosis is when two species live in close association for long periods and at least one member of the pair benefits from the relationship. The other member may be:
• injured = parasitism
• relatively unaffected = commensalism
• may also benefit = mutualism.</td><td>Mutualism</td><td>Each species benefits in the relationship.</td></tr>
<tr><td>Commensalism</td><td>A relationship in which one organism consumes the unused food of another.</td></tr>
<tr><td>Parasitism</td><td>A parasite lives on or in the body of another organism (the host) from whose tissues it gets its nourishment, and to whom it does some damage
• Animals are parasitized by viruses, bacteria, fungi, protozoans, flatworms (tapeworms and flukes), nematodes, insects (fleas, lice), and arachnids (mites).
• Plants are parasitized by viruses, bacteria, fungi, nematodes, and a few other plants.</td></tr>
</table>

3.4.4 Energy-Nutrient Flow in the Biosphere occurs through a complex food web. You should avoid using the phrase "food chain" from your natural systems vocabulary. Chains are linear features requiring sequential processing. In the example below (Figure A), you can see the significance of the linear model. It literally shows that only the insect eats the plant, only the rat eats the insect, and only the cat eats the rat. Since I have seen cats eat insects, I know this linear model is incorrect.

Food webs have multiple paths / connections providing alternatives (see the Figure B). It is a multiple-choice world. There are various species of bird, insect, rat, and cat that eat plants. Some plants (e.g. Venus fly trap), birds, rats, and cats eat insects. When you examine a food web, you find many organisms have variety in their diet. If one type of food is not available, they have an option. Admittedly, some organisms have more options than others. But this is what survival is about.

Human activities that disrupt these energy / nutrient flows obviously "impact" the flora and fauna---and ultimately the abiotic components of the environment as well. The Geographic Systems Model shows interconnections to essentially assure you that "what goes around comes around." If human actions destroy a food source for an organism, the affect on us may be immediate or slow, direct or indirect. But there will be an impact. History has shown that some people were not aware their actions were negatively impacting future generations. And there are cases of people not being aware impacted by their own actions (or the prior actions of previous generations). Environmental education plays a vital role in making people aware.

Figure A

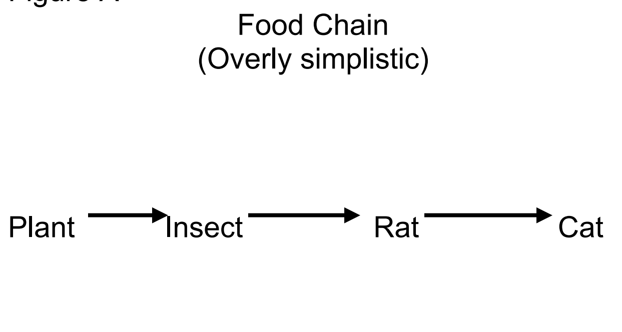
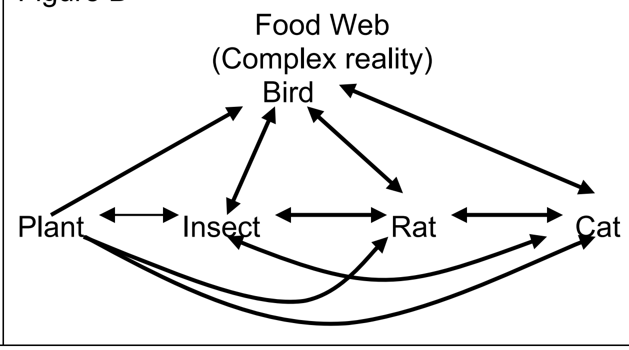
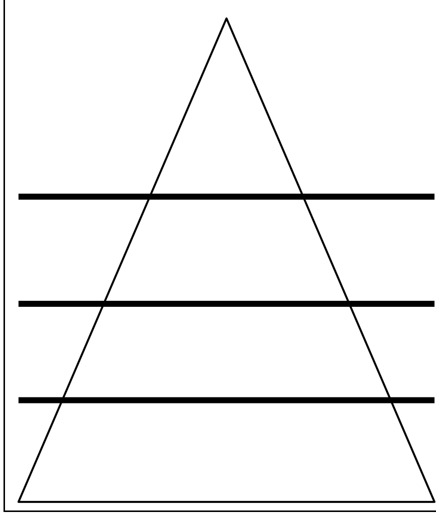


Figure B



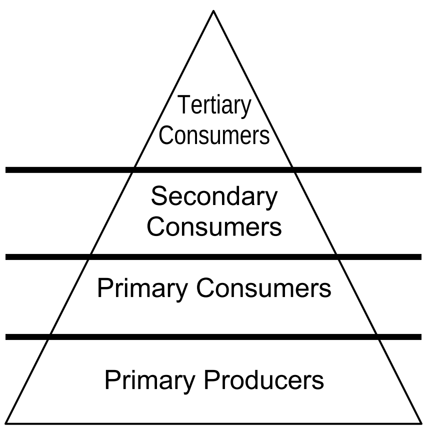
3.4.4.1 Trophic Levels are the hierarchical arrangement of organisms based on a similar distance from the level of primary producers. This is most often presented in the form of a pyramid structure. In some systems, there may be as many as 5 trophic levels, though 3 to 4 are most common. Organisms do not "fix" 100% of the energy in the food they consume. Energy is lost with each conversion (moving up to the next trophic level. A key point to note is the base of the food pyramid is broad. It takes many "lower" level organisms to support each individual at a higher level.

Note: An organism's position in the trophic hierarchy depends on its relationship to other organisms in an ecosystem / habitat. Depending on the scale of the study, the line up of the players can change. Careful field observation is critical in defining and understanding these relationships.

	50 – 90% of energy is fixed	**Decomposers Consumers**: Consumer dead materials reducing them to basic elements. **Tertiary Consumers** (secondary carnivores, omnivores): Consume primary carnivores, herbivores, and plants.	**Heterotrophs**
		Secondary Consumers (primary carnivores): Consume primary consumers (herbivores).	
	20 – 60% of energy is fixed	**Primary Consumers** (herbivores, omnivores**)**: Consume primary producers (plants).	
	0.1% solar energy fixed	**Primary Producers (*autotrophs*)**: Able to synthesize nutrients from the abiotic environment	

Small changes in the environment that impact primary producers resound through the food pyramid. If something were to destroy a certain number of primary producers, a certain number of primary consumers would perish. How stable is the asymmetric food pyramid in diagram B? The instability seems obvious.

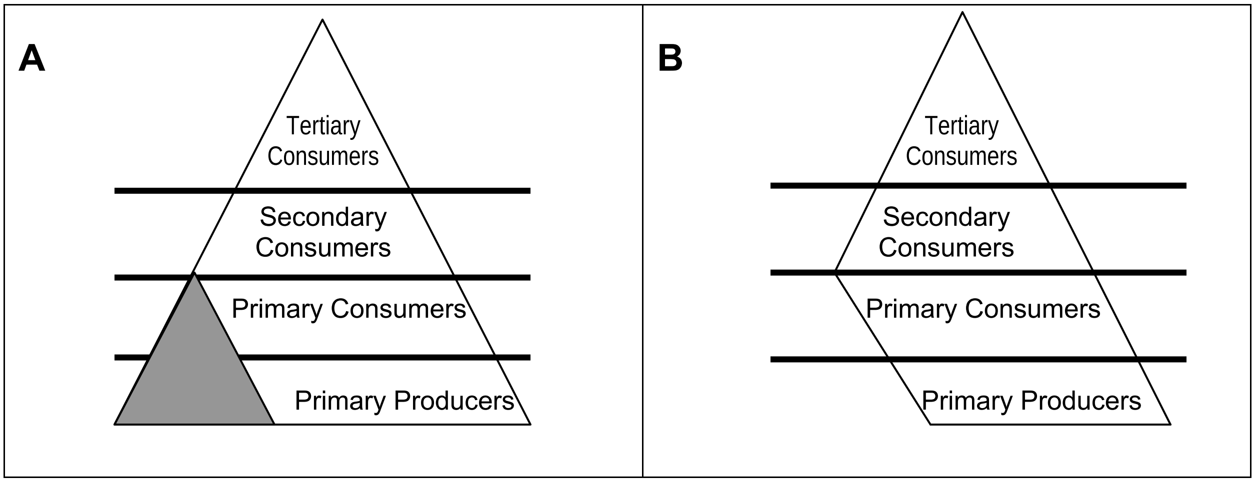
3.4.4.2 Bioconcentration: The dangers of bioconcentration of toxic substances in the environment can be seen using the Food Web and the Trophic Levels of the Food Pyramid. Consider the example in the table below. The original application of a pesticide may be sufficiently diluted to be of little or no hazard to an organism at a higher trophic level. The complexity of the food web may mask the real danger to the ecosystem. Each higher trophic level of the Food Pyramid consumes a large quantity of lower level organisms so secure sufficient energy to sustain itself. Toxins that accumulate in tissues can increase in concentration over time and produce negative effects.



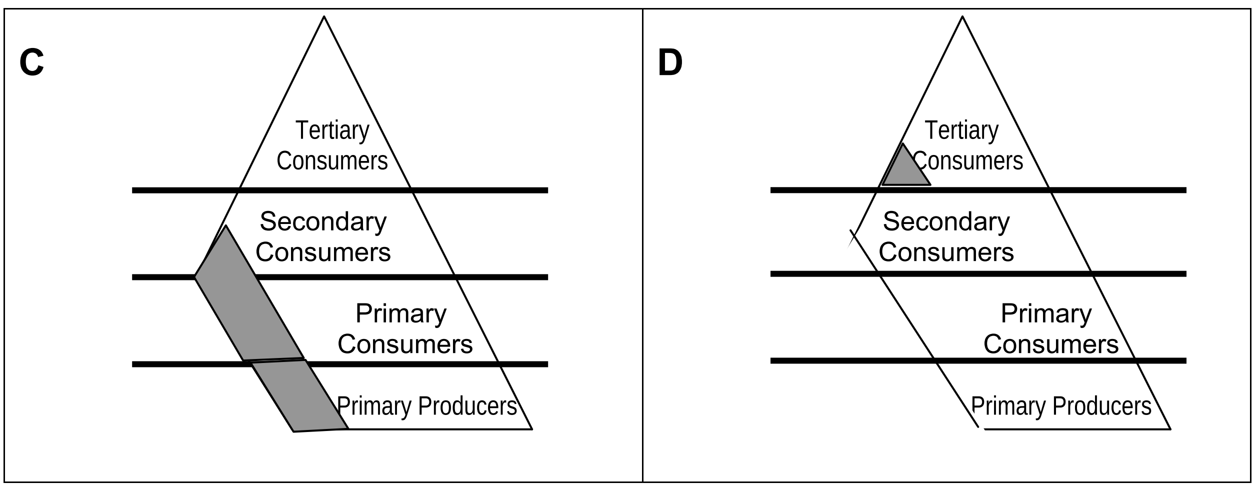
Bioconcentration Units	Consumption	
1000	10 Secondary Consumers	• This diagram is simplified to convey the point. • Not all toxins accumulate in tissues. • Nutrient / energy fixation in not 100%, so the math of bioconcentration may not be so arithmetic. • The concept is valid though the math in the example is greatly simplified.
100	100 Primary Consumers	
1	1000 Primary Producers	
0.001	Leaves coated with 0.001% concentrate	

3.4.4.3 Collapsing Food Pyramids: Human settlement often entails clearing the land of the natural vegetative cover (the native plants). This affects the native primary and secondary consumers and leads to impacts in the native ecosystems. Many of the interactions of the numerous and diverse organisms (some too small to be of casual notice or to the unaided eye) are unknown at the time of the settlement. Environmental impacts due to ignorance are still impacts. Sometimes the true impact may not be realized until a generation or more.

The diagrams below illustrate how a reduction of organisms at the primary producer / consumer levels impacts a food pyramid. (**Note:** The diagrams are purely illustrative and are not based on any mathematical proportions.) In Figure A, the shaded area represents a portion of the pyramid where a segment of the primary producers and consumers decrease affecting a segment of the primary consumers. The imbalance is evident. This reduces the food supply for the secondary consumers. The effect is not immediately seen, but it is shown in Figure B. It is obvious the food supply for the secondary consumers is less than it was before the die off shown in Figure A. And, reading between the lines, there will be a future impact on the tertiary consumers.



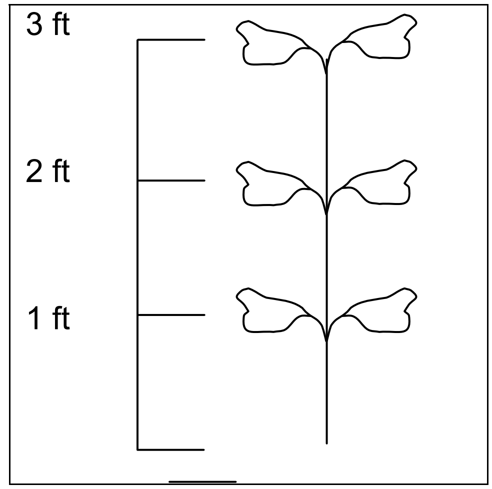
The impacts from Figure A result in the obviously unbalanced food pyramid in Figure B. In time, it can cascade to the secondary consumer level (see Figure C). can begin to evident over time. And in time, the diminished number of secondary consumers will also affect some of the tertiary consumers. Overall, the food pyramid in Figure D is not as well balanced as the starting food pyramid in this series. But it is clear it takes longer for the effects of change to be noticed at higher trophic levels.



3.4.4.4 Site Specific Observation Activity: When you get to the main destination (the field site), it is time to shift scale and get into more detail (remember, scale is a part of the Geographic Systems Model). You will need to do some preparatory research about the most common animals and species found at that site. Prepare your notes. Then, when you get on site, you can learn to identify and find those common animals. You can also do some of the following observation activities:

- Search for direct and indirect evidence of animal activity;
- Bird observations / counts (best done early morning or early evening)
- Insect observations / counts (consider light traps at night)

Insect / Plant Observation:



Step 1. Find a plant with some insects on it.
Step 2. Identify the plant (if possible) or put a tag on it with a number and use the temporary number ID for the plant until you can identify it.
Step 3. Make a simple sketch of the plant to show the main stem and its main branches. Make a note of its height. (See the example to the right.)
Step 4. Start to look for insects on the plant. Start at the top and work your way down.
Step 5. When you see an insect, make note of:

- Do you know what it is? If not, give it a code number (e.g. if it is the first bug you see, call it Bug #1.) Make a rough sketch of it. You don't have to make a perfect drawing. But try to see the basic body shape, number of legs, wings, antenna, etc.
- Its location on the plant:
  - Height
  - On the stem or a leaf
  - On the top or bottom of the leaf
  - At the center or the edge of the leaf
  - At the tip of the leaf or where the leaf joins the stem
- What color was it?
- Does it have wings?
- What size is it? (length, width)
- What was it doing? (Sitting still, eating, laying eggs)
  - If it was eating, what was it eating? (leaf—what part?; stem/stalk? Flower? Seeds? Roots?)
  - If laying eggs? What color? How many? What pattern? What shape was an egg?
    - (Try to check back to see when the eggs hatch. Keep track of the weather—temperature—and mark a calendar.)
    - When the eggs hatch, what came out? What color are they? What did the babies do? How did they move? How big are they?
- How did it move? (Fly, hop/jump, walk, crawl)
  - Where did to move to?

This is all part of how scientists start to study insects. Farmers need to know what insects want to eat their crops. So, if you start to make observations in your garden, you are starting to be a scientist.

- Observe other animal / plant interactions (e.g. nesting / egg laying sites, resting, eating / pollinating, etc.)

You don't have to be an expert in zoology to make good animal observations. You just need to watch carefully, and note patterns in behavior. Think in terms of general classifications (mammals, reptiles, birds, insects, etc). Other systematic descriptors involve size, color, activity (movement, feeding, resting, etc.). With practice, your descriptions become more detailed and precise.

3.5 BIOSPHERE CONNECTIONS:

Biosphere			Atmosphere	Hydrosphere	Lithosphere
Climate	Light	From	Sunlight	Reflected & Absorbed Sunlight	
		To	Reflected sunlight; converts to heat energy		
	Moisture	From	Precipitation, fog, humidity	Surface / subsurface water	Soil moisture
		To	Evapotranspiration	Bio-storage	Soil moisture; evaporation
	Heat	From	Winds		Geothermal and re-radiation
		To	Radiant energy	Heat transfer by conduction	
	Wind	From	Heat, moisture, pressure, winds		
		To	Heat, moisture, pressure, winds, seeds, pollen		
Topography	Altitude	From	Heat, moisture	Moisture	Landforms
		To	Heat, moisture, pressure	Affects heat, moisture	Topographic barrier to winds
	Slope Angle	From	Insolation, moisture, winds	Weathering, erosion, deposition agents	Landform surface orientation
		To	(See Altitude, above)	Runoff, surface / subsurface accumulation	Sediments, soil depth
	Slope Aspect	From	(See Slope Angle, above)	(See Slope Angle above)	(See Slope Angle above)
		To	(See Altitude, above)	(See Slope Angle above)	Sediments
Edaphic (Soil) Factors	Soil Color	From	Precipitation, gases	Moisture, acids	Minerals
		To	gases	Minerals, gases	Compounds, gases
	Soil Texture	From	Weathering, erosion, deposition agents		Weathered rocks
		To	Affect absorber surface	Evapotranspiration	Affect absorber surface
	Soil Structure	From	Precipitation	Moisture	Sediment particle size
		To	(See Soil Texture, above)	Evapotranspiration	Compaction, soil moisture
	Soil Chemistry	From	Heat, precipitation, gases	Moisture, gases	Minerals, gases
		To	Gases	Effects on water pH and hardness	Chemical weathering
Disruptions	Matter & Energy from all environmental spheres	From	Severe storms / heat / winds, drought, lightning	Floods, Tsunamis	Earthquakes, Mass Wasting, Volcanic eruptions, Flashfloods
		To	Wildfires, greenhouse gases, toxic wastes	Eutrophic conditions, toxic wastes	Biological infestations / invasions, toxic wastes
This summary table is not comprehensive. It contains general examples of the inter-relationships as examples.					

4.0 THE ATMOSPHERE: The Atmosphere is a non-living environmental sphere composed of mostly gases with some solids and liquids. The Atmosphere surrounds the planet. It extends about 10,000 km / 6,000 miles above the surface. Most of its gases (98%) are found below an altitude of 26 km / 16 mi. About 50% of the atmospheric gases are found below 6.2 km / 3.8 mi above the surface. Our studies focus on weather and climate. Weather is the current condition or state of the atmosphere. Climate is a summary compilation of weather records.

4.1 THE ATMOSPHERE CHECKLIST (LLAOATS): This checklist helps you determine what causes the climate / weather of a place or to explain the similarity or differences in climate between two or more places. The Key Factors listed are considered to be the major climate controls. Climate depends on weather data. The key weather variables are temperature, moisture, and pressure / winds. They are directly linked to the Lithosphere and Hydrosphere. Links to the Biosphere occur at more detailed levels (see the Biosphere checklists).

GENERAL ATMOSPHERE SUMMARY CHECKLIST				
Key Factors *	**Location**	**Scale**	**Time**	**Notes**
Latitude	Position North-South of Equator	Degrees-minutes-seconds	Diurnal and annual	Affects solar altitude, azimuth, and insolation quantity and intensity
Land / Water Distribution	Globally, more water than land	Northern hemisphere has more land than water	Diurnal and seasonal temperature changes and patterns	Heats / cools faster than water
	Water or islands	Southern hemisphere has more water than land		
Atmospheric Circulation	Pressure Systems	High / Low; Global,	Semi-permanent, seasonal, and diurnal	Transport mechanisms for heat and moisture around the planet.
	Wind Systems	regional, local		
Oceanic Circulation	East or West side of basin; Equatorial or Polar regions	Pelagic (global) or coastal (regional / local)	Seasonal / diurnal temperature changes; seasonal storm patterns	
Altitude	Land surfaces above or below sea level	Elevation vs. local relief	Diurnal temperature changes	Similar to latitude
Topographic Barriers	Mountain axis perpendicular to winds	Regional or local extent of mountains	Seasonal / regional and diurnal / local changes	Regional / local wet / dry conditions
Storms	Transient atmospheric phenomena	Sizes range from hurricanes to local thunderstorms	Seasonal patterns & storm duration	
Note: Functional definitions for the Atmosphere Key Factors should be derived from the textbook reading assignments.				

DETAILED ATMOSPHERE SUMMARY CHECKLIST

Key Factors *	Sub Factors					Notes
Latitude	Angle of incidence	Solar altitude	Controls intensity of insolation			Controls sunlight reaching Earth's surface
	Atmospheric path length	Atmospheric attenuation				
	Hours of daylight	Controls amount of insolation				
Land / Water Distribution	Global overview	More water than land surface				Explains diurnal and seasonal temperature and moisture differences on Earth (Surface temperatures can also affect atmospheric pressure)
		More land in northern hemisphere				
	Differential heat capacity	Land heats / cools faster than water				
		Water heats / cools slower than land				
	Land	Continent	Interior	>16-32 km from sea	Warmer, drier	
			Coastal	<16-32 km from sea	East: Warmer, moister	
					West: Cooler, drier	
		Island (See water)	Windward side	Lifting air, cool, moist		
			Leeward side	Sinking air, warm, dry		
	Water	Includes ocean coasts and lake shores	Cooler, moister			
Atmospheric Circulation	Pressure Zones	Wind Zones	Semi-permanent zones Characteristics			Atmospheric vertical and horizontal transport mechanisms for heat and moisture around the planet.
	Polar High		Very cold, sinking dry air	Zones shift seasonally following the ITC		
	↙	Polar Easterlies	Cold, dry air			
	Subpolar Low		Lifting, cooling air			
	↗	Westerlies	Warm, moist air			
	Subtropical High		Sinking, dry, warming air			
	↙	Tradewinds	Warm very moist air			
	Equatorial Low		Lifting, cooling air			
Oceanic Circulation	Ocean currents	Flow direction	Northern hemisphere: clockwise			Surface transport heat poleward; can modify coastal temperatures 16-32 km / 10-20 mi inland
			Southern hemisphere: counterclockwise			
		Water temperature	Warm along Equator and west side of ocean basin			
			Cool on east side of ocean basin approaching Equator			
Altitude	Temperature	Inversely related to altitude				Similar to latitude
	Moisture	Can be inversely related; see Topographic barriers				
Topographic Barriers	Windward side	Lifting, cooling air, more precipitation				Different temperature / moisture patterns
	Leeward side	Sinking, warming air, dry (rain shadow)				
	Venturi effect	High wind areas at mountain passes				Different wind speeds
Storms	Extra-tropical	Fronts / tornadoes to local thunderstorms				Seasonal patterns & storm size / duration
	Tropical	Typhoons / hurricanes to local thunderstorms				

Note: Functional definitions for the Atmosphere Key Factors should be derived from the textbook reading assignments.

4.1.1 Latitude is the angular distance north / south of the Equatorial Plane, measured to a maximum of 90°, and delineated by imaginary lines called parallels constructed parallel to the Equatorial Plane.

- At an average distance of 93 million miles from the Sun, the rays of light reaching the Earth are assumed to be parallel.
- The Earth rotates on its axis as it revolves around the Sun.
- The Earth's axis is tilted 23.5° from a perpendicular with the Plane of the Ecliptic.
- Latitude affects the quantity and quality of insolation (light energy) on Earth by controlling the:
  - angle of incidence at the Earth's surface;
  - atmospheric path length (i.e. amount of atmospheric attenuation);
  - number of daylight hours in a 24-hr day.

Solar Angle and Intensity

- Sun light perpendicular to a surface (the vertical ray) is the most intense beam of insolation.
- The vertical ray shifts from 23.5° N to 23.5° S through the year.

Relative Annual Insolation in the Northern Hemisphere

	Angle of Incidence			Atmospheric Path Length			# Daylight Hours		
Latitude	Jun	Eqnx	Dec	Jun	Eqnx	Dec	Jun	Eqnx	Dec
90°	+ 23°	0°	Below horizon	Long	Long	-----	24		0
45°	+ 68°	+ 45°	+ 21°	Short-Med	Medium	Long	>12-<24	12	>0 -<12
0°	+ 66°	+ 90°	+ 66	Medium	Short	Medium	12		12

4.1.2 Land / Water distribution: If latitude were the sole factor for temperature variations, then all places at the same latitude (on the same day of the year and the same hour of the day) would have the same temperature. The unequal distribution of land and water at various latitudes is a significant factor in explaining the temperature difference on Earth.

- The surfaces of the Earth (land and water) are the primary absorbers of light.
- Absorption converts light to heat.
- The different heat capacities of land (solid) and water (liquid) cause temperature differences on Earth.
- Temperature differences at the Earth's surface are ***one*** way to create pressure differences.

Planet Overall	**Northern Hemisphere**		**Southern Hemisphere**	
About 75% water, 25% land.	More land than water. Greater temperature variation		More water than land Less temperature variation	
Differential Heating / Cooling	**Annual Variation**		**Diurnal Variation**	
	Summer	**Winter**	**Day**	**Night**
Land (solid) heats / cools faster than water.	Warmer; Heats faster	Cooler; Cools faster	Warmer; Heats faster	Cooler; Cools faster
Water (liquid) heats / cools slower than land	Cooler; Warms slower	Warmer; Cools slower.	Cooler; Warms slower	Warmer; Cools slower.

Land		**Water**		
Continent	Interior	Great temperature ranges; can be warm and dry.		
		Lake shore	Milder temps, higher precip	
		West coast	Milder temps, foggy coast, lower precipitation	See Oceanic Circulation
		East coast	Warmer, wetter	
Island	Windward side		Orographic lift, cooler, wetter	See Atmospheric Circulation
	Leeward side		Rainshadow; warmer, drier	

4.1.3 Atmospheric Circulation is the vertical and horizontal movement of air. Moving air can transport heat and moisture in the atmosphere and around the Earth. Variations in the vertical and horizontal movement patterns are associated with annual and diurnal fluctuations in thermal energy.

Atmospheric Pressure is the weight of a column of air (with no vertical motion) at the surface.

- Pressure differences cause winds to flow from high to low pressure.
- The Coreolis Effect is caused by the Earth's rotation. It applies to all objects suspended / moving in a fluid.
    - The apparent deflection is to ***right*** in the no**R**thern hemisphere (left in the southern hemisphere).
    - It is strongest at higher latitudes and higher velocities.

High Pressure	Characteristics	Low Pressure
Anticyclone	Technical Name	Cyclone
Descending (sinking) air	Vertical Air Movement	Ascending (lifting) air
Adiabatic warming	Adiabatic Process	Adiabatic cooling
Diverging	Horizontal Air Movement	Converging
Clear skies; Fair weather	Sky Conditions	Cloudy skies; Stormy weather

Winds: Horizontal Air Movement

Global	Regional	Local
Polar Easterlies Westerlies Tradewinds (Global and Regional)		Land / Sea Mountain / Valley
	Monsoons	
	Katabatic (Regional and Local)	
	Foehn / Chinook / Santa Anas (Regional and Local)	

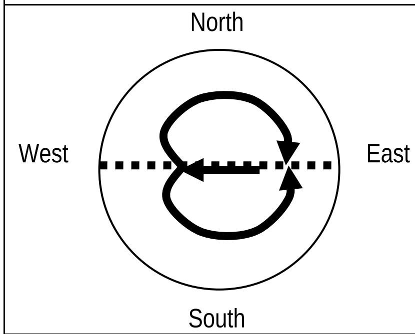
Atmospheric Lifting Mechanisms: Vertical Air Movement

	Causal Factor	**Typical Location**	**Results**
Convective	Warm surface temperature	Over land in summer	Thunderstorms
Orographic	Winds forces to rise over mountains	Mountains perpendicular to the prevailing wind flow	Orographic intensification of precipitation; rainshadow effect
Frontal	Mixing of warm & cold air masses in the mid-latitudes	Subpolar Low; 60° N / S	Mid-latitude (extra tropical) cyclones
Convergent	Confluence of the NE / SW Tradewinds in the Tropics	ITC; 25° N - 20° S	Tropical cyclones

Generall Correlation of Latitude, Pressure, Winds, Lifting Mechanisms and Storms

Latitude Number	**Latitude** Name	Pressure Zone	Wind Zone	Lifting Mechanism	Storms Types
90°N	North Pole	Polar High	Katabatic winds	None	Blizzards
66.5°N	Arctic Circle		Polar Easterlies	Frontal	Extra-Tropical
60°N	Subpolar Zone	Subpolar Low			
45°N	Mid-Latitudes		Westerlies	Possible seasonal Orographic & Convective	
30°N	Subtropics	Subtorpical High			
25°N			Northeast Trades		Tropical
23.5°N	Tropic of Cancer				
0°	Equator	Equatorial Low (ITC)		Convergent	

4.1.4 Oceanic Circulation is the horizontal and vertical movement of water in the ocean basins on Earth. Moving water can transport heat energy around the globe from areas of heat surplus to areas of heat deficit. The Coriolis Effect causes major surface ocean currents in the northern hemisphere to move in a clockwise pattern and a counterclockwise pattern in the southern hemisphere.

General Oceanic Circulation	Characteristic	West Side of Basin	East Side of Basin
	Relative Temperature	Warm	Cool
	Surface Flow	West and north	South and west
	Vertical Flow	Down welling	Upwelling

4.1.5 Altitude

Altitude and latitude control temperature similarly. As altitude / latitude increase, temperature decreases.	
Altitude	Increase altitude from sea level up, temperature decreases about 3.5º F / 1000 ft.
Latitude	Increase latitude from the Equator toward the Poles, temperature decreases.

4.1.6 Topographic Barriers

• Topographic barriers (i.e. mountains) block the horizontal movement of air. • If aligned perpendicular to the surface wind flow, the mountains force the air to rise (orographic lifting). This can trigger the precipitation making process.	
Mountains	Check location and alignment orientation.
Winds	Check season and flow (or storm) direction relative to orientation of mountains.

4.1.7 Storms (relative to Nan Province, Thailand)

All storms are cyclones. They all have the low pressure systems characteristics.			
Location	Latitude	Northern hemisphere tropics	
	Land	Summer convective thunderstorms; Rainy season low trough over northern Thailand intensifying the SW and NE monsoons.	
	Water	SW monsoon from Andaman Sea; NE monsoon feeds tropical depressions, storms, typhoons into the low pressure trough over northern Thailand.	
Scale	Regional	SW and NE monsoonal wind system	
	Local	Orographic intensification of precipitation depending on azimuth of approaching storm.	
		Summer convective lifting can be very localized	
Time	Summer	Hot / dry period; mid-Feb to mid-May.	
	Rainy	Warm / Wet period; mid-May to mid-Oct	
	Winter	Cool / dry period; mid-Oct to mid-Feb.	
Vertical motion		Rising air; Adiabatic cooling process; Cloudy sky conditions	
Horizontal circ.		Cyclonic about the Low	
Surface winds		Converging	
Storm Track		SW monsoon	Approaches Nan from SW to S
		NE monsoon	Approaches Nan from SE, E, NE
Storm Velocity		Rate at which the storm moves; don't confuse with wind speed. Fast storms move ~40 km/h.	

4.2 WEATHER OBSERVATIONS: Local on-site weather has a more direct influence on you. The basic weather observations are defined and summarized in the table below.

Basic Weather Observation Terms	
Temperature	The measurement of the amount of heat that is present.
Measured Temperature	The temperature measured on the thermometer. It is also called the "dry bulb temperature."
Sensible Temperature (Your Description)	This is the temperature you feel. It is your opinion and is not a measurement. It may be different than the temperature on a thermometer.
Estimated by Using Insects	The estimated temperature by observing insect activity. (See the "Insect Temperature Reference Table.")
Pressure	The measurement indicating rising (lifting) or subsiding (sinking) air.
Barometric Pressure	Direct measurement using a barometer.
Wind	The horizontal movement of air.
Wind Speed	How fast the air is moving horizontally at the Earth's surface.
Wind Direction	The direction from which the wind is coming. Turn so you feel the wind blowing directly on your face; then give the compass direction.
Relative Humidity	The ratio of water vapor in the air to the amount that could be present at that temperature, if the air was saturated.
Clouds	Masses of very small water droplets or ice crystals suspended in the air.
Cloud Type	Clouds are generally grouped by the altitude where they are found (low, middle, high). They are also named by their shape or form (cumulus, stratus, cirrus, cumulonimbus). Use the Cloud reference table to get the cloud letter codes and names.
Cloud Height	Tells how high the lowest cloud layer is above the ground.
Cloud Cover	The sky condition relative to how much is covered by clouds.
Precipitation	The form and relative intensity of water (liquid or solid) falling from the sky. (See the terms in the Precipitation Terms reference table.)

4.2.1 Temperature: The standard practice is to measure air temperatures in the shade. The typical diurnal temperature pattern shows lowest daily temperatures occurring just before dawn. The highest temperatures are typically at mid-afternoon.

4.2.1.1 Dry bulb Temperature is what most people think about when they hear the word "temperature." This is the amount of heat contained in air that is not saturated (i.e. relative humidity is not 100%).

4.2.1.2 Wet bulb Temperature is the temperature from a special thermometer with a saturated cloth wick. It provides the basis for calculating relative humidity.

4.2.1.3 Normal or Environmental Lapse Rate (6.5ºC / 1000 m): The temperature of air at any given altitude is cooler than the temperature at the Earth's surface. This can be calculated by doing some simple calculations:
Step 1: Get the current surface temperature.
Step 2: Get the altitude above sea level (in meters) for the height in the atmosphere.
Step 3: Divide the altitude by 1000.

Step 4: Multiply the result of Step 3 by 6.5°C.
Step 5: Subtract the result of Step 4 from the current surface temperature in Step 1.

Sample Problem: You are on the beach where it is 23.9°C and want to know the temperature of the air at the top of a mountain 3,000 m amsl.
Step 1. The current surface temperature = 23.9°C
Step 2. The mountain top is at 3,000 m amsl.
Step 3. Divide 3,000 by 1000 = 3
Step 4. Multiply 3 X -6.5°C = 19.5°C
Step 5. Subtract 19.5°C from 23.9°C = 4.4°C. So if you are going to the top of the mountain, dress accordingly.

4.2.1.4 Dry Adiabatic Lapse Rate (9.8ºC / 1000 m): As air rises from the Earth's surface it cools adiabatically (cooling by expansion) at a rate of 5.5°F/1000 feet. Air lifted from the Earth's surface is usually not saturated (relative humidity is less than 100%).

4.2.1.5 Dew Point Temperature: The ***dew point temperature*** is the temperature at which the relative humidity equals 100% (***saturation***). The water is still vapor as the air is holding all of the moisture it can possibly hold at this temperature.

4.2.1.6 Wet or Saturated Adiabatic Lapse Rate (4.9ºC / 1000 m): Once condensation begins in the atmosphere, (i.e. air lifted from the surface gets to an altitude where it reaches the dew point temperature), further lifting causes the condensing air to release the latent heat stored from the evaporation process. As the heat is released, the rising air cools slower adiabatically (4.9°C/1000 meters rather than the previous 9.8°C/1000 meters.

- **Calculating the Dew Point Temperature:** The ***dew point temperature*** is the temperature at which the relative humidity equals 100% (***saturation***). This is important because this is the temperature when water vapor (the gaseous form of water) begins to change to a liquid form; in other words, ***condensation*** begins at the dew point. The air temperature and relative humidity at any given time on any given day is different. So the dew point temperature will also be different from hour to hour or day to day.

You can use this information in a number of ways: 1) to estimate the height of the low clouds; 2) estimate when condensation will form (and get your camping gear wet over night); 3) estimate if your hike or climb will get into the cloud layer on a mountain (which helps you to prepare the proper clothing and equipment).

Step 1. Get the dry and wet bulb temperatures. Record the time of day.
Step 2. Calculate the wet bulb depression by subtracting the wet bulb temperature from the dry bulb temperature.
Step 3. Get the dew point temperature reference table. Look up the dry bulb temperature on the left hand column.

Dew Point Sample Problem: The dry bulb temperature is 30°C; wet bulb temperature is 28°C. The difference between the dry and wet bulb temperatures is 2°C. What is the relative humidity?
Step 1. Find 2°C (the difference between dry and wet bulb temperatures) along the horizontal scale across the top of the chart; go down that column.
Step 2. Find 30°C (the dry bulb temperature) along the vertical scale at the left of the chart; go across that row.
Step 3. Find the intercept of these two in the center of the chart (27). The dew point temperature is 27°C

DEW POINT TEMPERATURE CHART (°C)

Dry Bulb Temperature (Air Temperature °C)	Dry Bulb temperature minus Wet Bulb temperature in °C: 0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	7.5	10.0	12.5	15.0	17.5	20.0
-20	-25	-33														
-17.5	-21	-27	-38													
-15	-19	-23	-28													
-12.5	-15	-18	-22	-29												
-10	-12	-14	-18	-21	-27	-36										
-7.5	-9	-11	-14	-17	-20	-26	-34									
-5	-7	-8	-10	-13	-16	-19	-24	-31								
-2.5	-4	-6	-7	-9	-11	-14	-17	-22	-28	-41						
0	-1	-3	-4	-6	-8	-10	-12	-15	-19	-24						
2.5	1	0	-1	-3	-4	-6	-8	-10	-13	-16						
5	4	3	2	0	-1	-3	-4	-6	-8	-10	-48					
7.5	6	6	4	3	2	1	-1	-2	-4	-6	-22					
10	9	8	7	6	5	4	2	1	0	-2	-13					
12.5	12	11	10	9	8	7	6	4	3	2	-7	-28				
15	14	13	12	12	11	10	9	8	7	5	-2	-14				
17.5	17	16	15	14	13	12	12	11	10	8	2	-7	-35			
20	19	18	18	17	16	15	14	14	13	12	6	-1	-15			
22.5	22	21	20	20	19	18	17	16	16	5	10	3	-6	-38		
25	24	24	23	22	21	21	20	19	18	18	3	7	0	-14		
27.5	27	26	26	25	24	23	23	22	21	20	16	11	5	-5	-32	
30	29	29	28	27	27	26	25	25	24	23	19	14	9	2	-11	
32.5	32	31	31	30	29	29	28	27	26	26	22	18	13	7	-2	
35	34	34	33	32	32	31	31	30	29	28	25	21	16	11	4	
37.5	37	36	36	35	34	34	33	32	32	31	28	24	20	15	9	0
40	39	39	38	38	37	36	36	35	34	34	30	27	23	18	13	6
42.5	42	41	41	40	40	39	38	38	37	36	33	30	26	22	17	11
45	44	44	43	43	42	42	41	40	40	39	36	33	29	25	21	15
47.5	47	46	46	45	45	44	44	43	42	42	39	35	32	28	24	19
50	49	49	48	48	47	47	46	45	45	44	41	38	35	31	28	23

- Use the hygrometer to get the Dry Bulb and the Wet Bulb Temperature. Example, Dry Bulb = 30°C, Wet Bulb = 28°C.
- Subtract the Wet Bulb temperature from the Dry Bulb temperature. Example, 30°C – 28°C = 2°C.
- Find the column for 2°C across the top of the chart. Locate 30°C in the Air Temperature column at the left side of the chart. Find the intersection of the column and row to get the Dew Point Temperature. For the example of 2°C and 30°C, the Dew Point Temperature is 27°C.
- Divide 27°C by 10°C = 2.7 X 1000 m = 2700 m (the altitude of the bottom of the clouds)

4.2.1.7 Temperature by Insects: All living organisms exist and function within a range of temperatures. If the temperatures exceed the maximum / minimum tolerance range, the organism dies. As the temperatures approach the tolerance limits, many animals reduce their activity to alleviate the environmental stress on their bodies. Some researchers have found specific examples of insect behavior corresponding to specific temperatures. Some of these “insect thermometers” are given in the table on the next page.

<table>
<tr><th colspan="7">INSECT TEMPERATURE REFERENCE TABLE
(From Natural History after studies by Cleve Hallenbeck)</th></tr>
<tr><th colspan="2">Katydid Calls</th><th colspan="2">Cricket</th><th colspan="3">Black Field Cricket</th></tr>
<tr><th>Sound</th><th>Temp</th><th>Chirps / min</th><th>Temp</th><td colspan="3" rowspan="4">Step 1. Count the number of cricket chirps for 14 seconds.
Step 2. Add the count to 40.
Step 3. The result is the temperature reading in ºF; then convert to ºC.</td></tr>
<tr><td>Kay Tee Did It</td><td>24.4ºC</td><td>194</td><td>29.4 ºC</td></tr>
<tr><td>Kay Tee Didn’t</td><td>23.3 ºC</td><td>172</td><td>26.7 ºC</td></tr>
<tr><td>Kay Tee Did</td><td>21.1 ºC</td><td>151</td><td>23.9 ºC</td></tr>
<tr><td>Kate Didn’t</td><td>19.4 ºC</td><td>129</td><td>21.1 ºC</td><td rowspan="4">All Insects</td><td rowspan="2">Quiet</td><td>Above 40.6 ºC</td></tr>
<tr><td>Kate Did</td><td>17.8 ºC</td><td>108</td><td>18.3 ºC</td><td>Below 4.4 ºC</td></tr>
<tr><td>Katy</td><td>16.7 ºC</td><td>86</td><td>15.6 ºC</td><td>Helpless</td><td>1.7 ºC</td></tr>
<tr><td>Kate</td><td>14.4 ºC</td><td>65</td><td>12.8 ºC</td><td>Dormant</td><td>0 ºC</td></tr>
<tr><td>(No Katydid call)</td><td>12.8 ºC</td><td>43</td><td>10 ºC</td><td rowspan="3">Some Other Insects</td><td>Bees stay still</td><td>Over 39.4 ºC</td></tr>
<tr><td></td><td></td><td>22</td><td>7.2 C</td><td>Cicadas start to sing</td><td>28.9 ºC</td></tr>
<tr><td></td><td></td><td>0</td><td>4.4 ºC</td><td>Ants stay home</td><td>12.2 ºC</td></tr>
</table>

4.2.2 Pressure / Wind

4.2.2.1 Barometric pressure: Barometer is derived from the Greek words *baros* (weight) and *metron* (measure). So a barometer, literally, is weighing the atmosphere. Atmospheric pressure indicates vertical air movements and cloud cover conditions associated with rising (low pressure, cloudy skies) and sinking air (high pressure, clear skies). Differences in pressure cause wind, which moves from high pressure to low pressure. More significant than the actual pressure measurement is the air pressure trend (change over time). This combined with wind direction and cloud types (all observed over time) provides the basis for weather forecasting.

There are some basic sources for barometric pressure information. Be careful using these sources. They are often reported using a city name. It may or may not be in the same location as the weather station reporting the data. Your location may or may not correspond to the city or the weather station locations. Local topography can affect the specific pressure measurements.

- **Daily weather reports** (via radio, TV): Not all weather reports are the same. So look for one that actually reports the barometric pressure in relative or absolute terms.
- **Internet Weather Sites:** Various government and commercial weather sites are on the Internet. Government sites tend to be free. Commercial sites offer basic information free, but charge for advanced information services.
- **An On-site Barometer:** You can make or purchase a barometer to keep at home or at the study site. To get full benefit of the purchased barometer you record, you need to calibrate it. This means getting an actual barometric pressure reading from a nearby official weather station or airport. If you use a radio ' TV source or the weather station is far from you, the calibration (and your data) will be less precise. However, the pressure trend is more useful. An uncalibrated barometer will give you the ability to determine the rate of pressure change. This information refines your ability to predict weather changes.

4.2.2.2 Making a Water Bottle Barometer: Here is a simple barometer you can make to get “relative” barometric pressure readings.

Materials: A bowl, water, plastic bottle, index card, tape, and marker. The bowl should be deep enough to hold the bottle upright. The bottle should fit into the bowl vertically, but fit loosely without toppling over.**Procedures:**

Step 1. Fill the bowl ½ full with water.

Step 2. Fill the bottle ¾ full with water.

Step 3. Cover the mouth of the bottle with your thumb. Invert the bottle. Put it into the bowl. Be sure the mouth of the bottle is under water. Remove your thumb. Let the water in the bottle settle.

Step 4. Vertically center the index card on the water level in the bottle. Half the card should be above the water line and half below.

Step 5. Use the marker to draw an “Index” (reference) water line. Write a “+” (plus) and the word “high” above the water line. Write a “-“ (minus) and the word “low” below the water line. .

4.2.2.3 Barometric Pressure Discussion / Interpretation:

- Air pressure pushes down on the surface of the water in the bowl. The force is sufficient to keep the water in the bottle. Remember, standard atmospheric pressure is about 1.0335123 kilogram-force/square centimeter or 14.7 pound-force/square inch (PSI).
- Changes in air pressure (from the time you set up your barometer) will cause the water level in the bottle to change. Higher air pressure pushes water up into the bottle. Lower air pressure lets water flow out of the bottle.
- Your barometer only shows relative air pressure changes (up = higher than before you set up the barometer; down = lower than before the set up). You don't really know the exact barometric pressure measurement.
- The simplistic interpretation of your home made barometer results are:
  Lower Pressure = warmer, cloudier, wetter weather.
  Higher Pressure = cooler, clearer, drier weather.

4.2.3 Wind Velocity & Direction: Wind velocities affect the environment and living organisms. Generally, heat and moisture are moved around the planet by wind. Surface ocean currents are driven by wind. Generally, winds tend to blow stronger in the afternoons than in the mornings.

Of particular importance for humans is the effect of windchill. Linked with high relative humidity, wind can effectively make you feel colder than the measured temperature. In extremely cold conditions, this can pose health risks and ultimately be life threatening.

You can make a subjective visual estimation of wind velocities using the Beaufort Scale of Wind Effects on Land. Admiral Sir Francis Beaufort of the British Royal Navy developed the scale in 1805. Originally the wind effects were for sailing ships. It has been revised and modified over time, and also adapted to land. Although it is subjective, the functional definitions for the "Wind Effects on Land" are fairly detailed and definitive. Wind speed measuring devices give a objective measurement. The price varies directly with the complexity and technology used. Two devices are included here, both relatively low tech. The first device is home made. The second, the Dwyer Wind Gauge, can be purchased.

4.2.3.1 The Beaufort Wind Scale: To use the wind scale follow these simple steps.

Step 1. Make a careful observation of the effect of the wind on your immediate surroundings.

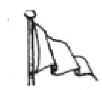
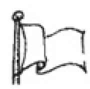
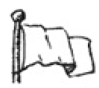
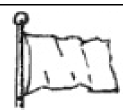
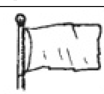
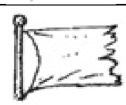
Step 2. Match your local observation to the written descriptions in the left column of the chart.

Step 3. Follow the row across to the right in the chart to get the official WMO (World Meteorological Organization wind velocity term for your observed local wind velocity.

Step 4. Continue across the row to the right to get the estimated numerical wind velocity in miles per hour (mph), kilometers per hour (kph), or the wind Force Number (used in special fields to describe wind velocities).

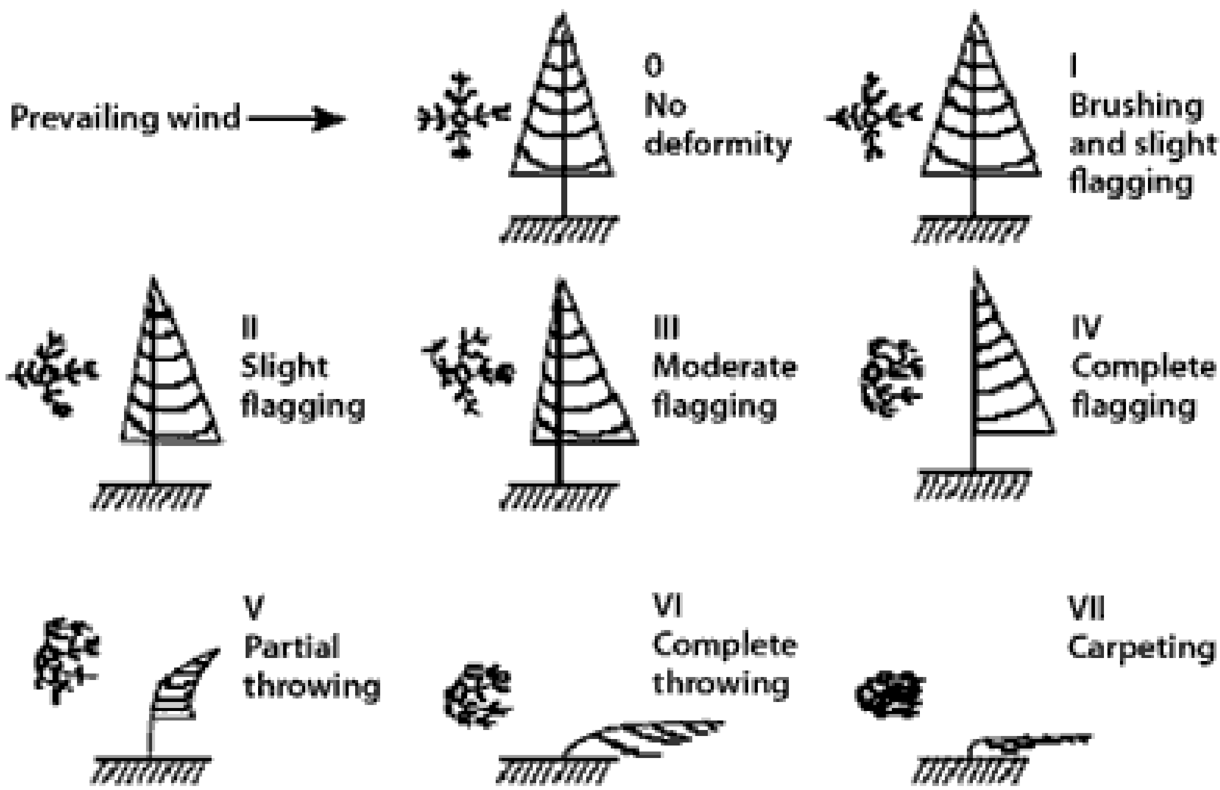
The RTC-TH Modified Beaufort Wind Scale

Description	Flag	WMO	MPH	Km/h	Knots	Force	Psu lbs/sq ft

		term					(Kg/sq m)
		Report wind speed in knots to all flight crews					
Calm; smoke rises vertically	---	Calm	<1.0	<1.5	<0.9	0	0.006266 (0.003059)
Smoke indicates wind; flag hangs limp, wind vanes do not move		Light air	1-3	1.5-6	1-3	1	0.02924 (0.01428)
Wind felt on face, leaves rustle, flag stirs, wind vanes move		Light breeze	4-7	6-12	4-6	2	0.142 (0.6934)
		5 Knts max tailwind for helicopter take off					
Leaves and twigs in constant motion; flag occasionally extends		Gentle breeze	8-12	12-20	7-10	3	0.3759 (1.835)
		10 Knts ideal for helicopter flight operations					
Dust and paper fly; small branches move; Flag flaps		Mild breeze	13-18	21-29	11-16	4	0.8145 (3.977)
		20 Knts maximum gusts for helicopter flight operations					
small leafy trees begin to sway; white crested wavelets appear on lakes/ponds; Flag ripples,		Fresh breeze	19-24	30-39	17-21	5	1.504 (7.342)
Large branches move; wires whistle; umbrellas hard to use; Flag snaps		Strong breeze	25-31	40-50	22-27	6	2.485 (12.13)
Whole trees sway; hard to walk; Flag extended		Near gale	32-38	51-61	28-33	7	3.822 (18.66)
Twigs and small branches broken; cars veer on roads; Flag tatters		Gale	39-46	62-74	34-40	8	5.597 (27.33)
Slight structural damage occurs (roof shingles blow off)		Strong gale	47-54	75-87	41-47	9	7.769 (37.93)
		45 Knts maximum winds for helicopter flight operations					
Trees broken or uprooted, considerable damage to buildings		Storm	55-63	88-101	48-55	10	10.53 (51.39)
Wide spread damage caused	---	Violent storm	64-72	102-114	56-63	11	13.78 (67.3)
	---	Hurricane	>73	>115	>63	12	>13.78 (>67.3)

Disclaimer: Wind pressure values are the upper limits for a wind category. Use of the wind pressure data to calculate tower/antenna wind loads are at your own risk. RTC-TH and HSØZHM assume no liability for the use of this data.

4.2.3.2 Griggs-Putnam Index of Deformity: This index is an approximate of the dominant wind conditions affecting trees. The chart below shows an overhead and profile view of a tree. Dominant consistent prevailing winds in an area affect tree growth. This estimate of wind speed by observing trees is more suitable to assessing sites for wind energy potential. The Beaufort Wind Wind Scale should be used for weather observations and reports for estimate wind speeds.



Griggs-Putnam Index of Deformity

Speed	I	II	III	IV	V	VI	VII
mph	7-9	9-11	11-13	13-16	15-18	16-21	22+
km/h	11-14	14-18	18-21	21-26	24-29	26-34	35+
m/s	3-4	4-5	5-6	6-7	7-8	8-9	10+
knots	6-8	8-10	10-11	11-14	13-16	14-18	19+

4.2.3.3 Making and Using a Home-made Wind Speed Indicator: You can make a simple wind speed indicator to take actual field measurements.

Materials Needed: Semi-circular protractor, a ping-pong ball, 20 cm / 8 in of strong thread, transparent tape, scissors, and a marking pen.

Procedures:

Step 1. Tape one end of the thread firmly to the Ping-Pong ball.

Step 2. Tie the other end of the thread to the center of the protractor base line. (Note: The protractor base will be the top when you use the wind speed indicator. The ping-pong ball should hang down so the thread crosses the protractor scale. The wind speed will be indexed to the degree scale on the protractor.

Step 3. To calibrate the wind speed indicator, find an open area without traffic. Be sure it is a calm day---or do this early in the morning when the winds tend to be calm. Have a friend drive while you ride in the car. Open the window. Start slowly. Have the driver hold a steady speed at 5 mph. Watch the indicator string on the ping-pong ball and record the angle on the protractor scale. Repeat this for each speed increment in the table.

Protractor Angle	Wind Speed			Protractor Angle	Wind Speed		
	km/h	mph	knots		km/h	mph	knots
	0	0	0		48	30	26.1
	8	5	4.3		56	35	30.4
	16	10	8.7		64	40	34.8
	24	15	13.0		72	45	39.1
	32	20	17.4		80	50	43.5
	40	25	21.7		88	55	47.8

Step 4. You can repeat the calibration procedure to verify the results. The table below is a rough check to validate your results.

Protractor Angle	Wind Speed			Protractor Angle	Wind Speed		
	km/h	mph	knots		km/h	mph	knots
90°	0	0	0	50°	48	30	26.1
	8	5	4.3	40°	56	35	30.4
	16	10	8.7	30°	64	40	34.8
80°	24	15	13.0		72	45	39.1
70°	32	20	17.4	20°	80	50	43.5
60°	40	25	21.7		88	55	47.8

Procedure to Measure Wind Velocity Using a Home-made Wind Speed Indicator:

Step 1. Hold the wind speed indicator by one end of the protractor base so the base is at the top is parallel to the ground. The ping-pong ball indicator string should line up at 90° if the wind is not blowing.

Step 2. Point the wind speed indicator directly into the wind. Stand to one side. This way your body will not disturb the airflow over the wind speed indicator. Read the angle of the farthest downwind position of the indicator string. Record it in your field notebook.

Step 3. Take a total of at least three measurements to average the results. The wind is not always blowing steadily. You can report the average wind speed and the maximum "gust" during the time of your observations.

Step 4. Use the calibration table to convert the indicator string angle to the estimated wind speed. Record the data in your field notebook.

Discussion: Actual calibration of your home made wind speed indicator should be done using a purchased wind speed indicator or anemometer. Local site conditions (e.g. proximity to buildings, vegetation, etc.) and general site topography (e.g. landforms) will affect wind speed measurements.

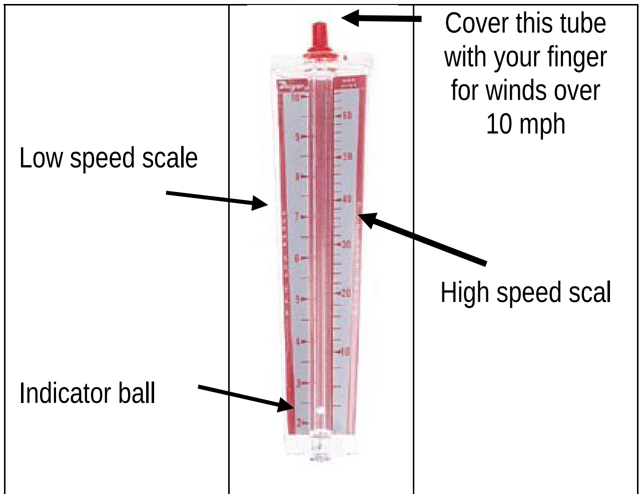
4.2.3.4 DWYER WIND GAUGE MEASUREMENTS: The Dwyer Wind Gauge is a portable and reliable tool to measure wind speed in the field. This is a hand held instrument. As the wind blows, the white indicator ball in the tube moves up with high wind speeds, and drops down with low wind speeds. Because the wind does not blow at a constant velocity, you have to subjectively judge when to read and record the position of the indicator ball. With practice, you gain proficiency using the device.

If you take several readings, carefully noting the maximum and the minimum wind speeds during the measurement interval, you can mathematically calculate the average wind speed. This would be a more accurate depiction of the wind speed.

Step 1. Find a clear open area away from buildings and other structures that might block or amplify the wind.

Step 2. Stand facing into the wind. Hold the Dwyer wind meter perpendicular to the ground with your arm fully extended.

Step 3. Watch the tiny white ball in the Dwyer wind meter. If the ball stays within the scale 0-10 mph, read the wind velocity based on the position of the white indicator ball. If the ball is off scale at the top, place a fingertip over the red plastic pipe at the top of the wind gauge. Then read the position of the white indicator ball.



Dwyer Wind Gauge

Step 4. Repeat Steps 2 & 3 until you have taken at least 3 measurements. Watch for the maximum and minimum wind speeds. Use the table below to record your data.

Step 4. Calculate the average wind speed. Add the three measurements together. Divide the sum by 3 to get the average wind speed.

DWYER WIND GUAGE DATA LOG					
Location:				Date:	Time:
Recorded by:				Wind Direction:	
Obs #	Wind Speed	Max	Min	Use this area for your calculation.	
1					
2					
3					
Total					
Average					

4.2.3.5 Windchill Index: High wind speeds combined with low temperatures effectively reduce the sensible temperature. When cold air flows over your body, it removes from you heat by conduction. These conditions make you feel colder than the temperature you see on the thermometer. Cold, windy conditions can pose a threat to your survival.

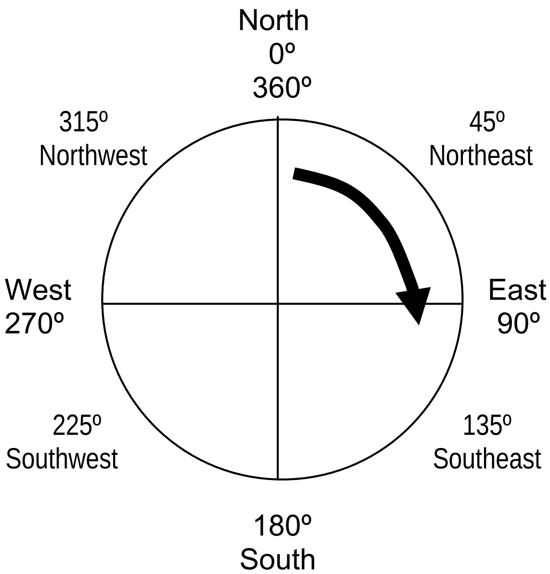
The table below summarizes the windchill effects for various temperature and wind speeds. The risk categories are also shown at the bottom of the table. When working outdoors in cold, windy conditions, be very aware of the potential for windchill hazards. Under these conditions, it is best to work in teams with at least one person designated to monitor the windchill conditions AND to watch the other team members for signs of frostbite.

Wind Speed (km/h)	**Wind Chill Table**														
	Dry Bulb Temperature (°C)														
	1.7	-1.1	-3.9	-6.7	-9.4	-12.2	-15.0	-17.8	-20.6	-23.3	-26.1	-28.9	-31.7	-34.4	-37.2
8	0.6	-2.8	-6.1	-7.2	-11.1	-13.9	-17.8	-20.6	-23.3	-26.1	-29.4	-32.2	-35.0	-37.8	-41.1
16	-5.6	-8.9	-12.2	-16.1	-19.4	-22.8	-26.1	-30.0	-32.8	-36.7	-40.0	-43.3	-46.7	-50.0	-53.3
24	-8.9	-12.8	-16.7	-20.6	-23.9	-27.8	-31.7	-35.0	-38.9	-42.8	-46.1	-50.0	-53.9	-57.8	-61.1
32	-11.1	-15.6	-19.4	-23.3	-27.2	-31.1	-35.0	-39.4	-43.3	-47.2	-51.1	-55.0	-58.9	-62.8	-66.7
40	-13.3	-17.2	-21.7	-26.1	-30.0	-33.9	-37.8	-42.2	-46.1	-50.6	-54.4	-58.9	-62.8	-66.7	-71.1
30	-14.4	-18.9	-23.3	-27.8	-31.7	-36.1	-40.6	-45.0	-48.9	-53.3	-57.2	-61.7	-65.6	-69.4	-73.9
48	-15.6	-20.0	-24.4	-28.9	-32.8	-37.2	-41.7	-46.7	-50.0	-55.0	-58.9	-63.3	-67.2	-71.7	-76.1
64	-16.1	-20.6	-25.0	-29.4	-33.9	-38.3	-42.8	-47.2	-51.1	-56.1	-60.0	-64.4	-68.9	-73.3	-77.2
72.4	-16.7	-21.1	-25.6	-30.0	-34.4	-38.9	-43.3	-47.8	-52.2	-56.7	-61.1	-65.0	-69.4	-74.4	-78.3
Zone	**1**	**2**	**3**												
Wind Chill Zones:	**1 = Very Cold** Travel can be dangerous in overcast conditions due to possible sudden storms.					**2 = Bitter Cold** Temporary shelters are unsuitable and dangerous. Travel only in heated vehicles.					**3 = Extreme Cold** Exposed flesh freezes as range begins. This poses the danger of frostbite and possibly death.				

4.2.3.6 Wind Direction is an important weather variable. Keeping records of the change in wind direction over time can help forecast the weather. The key factor to watch for is the pattern of change in the wind direction to see if the winds are veering or backing (see the table on the next page).

4.2.3.6.1 Naming Winds: Winds are named for the direction from which they come. Thus, a north wind is blowing from the north going to the south.

4.2.3.6.2 Measuring Wind Direction with a Magnetic Compass: You can measure the wind direction using a magnetic compass (very handy when moving around to different locations in the field) or make a wind tell-tale (if you have a fixed weather observation station.

<table>
<tr>
<td>


</td>
<td>
To Measure Wind Direction:
Imagine you are standing in the middle of the circle in the picture on the left.

Step 1. Stand facing the wind (looking into the direction from which the wind is blowing).

Step 2. Aim the magnetic compass directly into the wind, but keep the compass level so the needle swings freely.

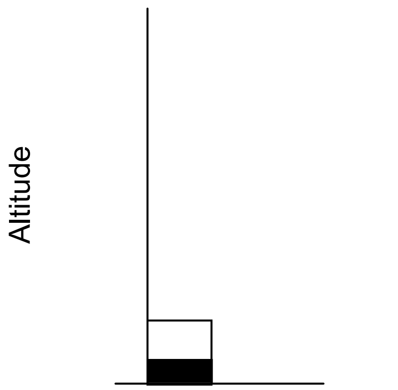
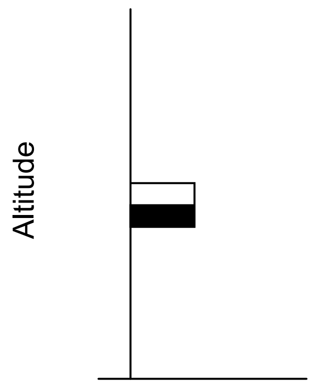
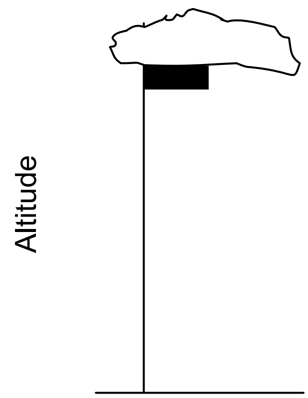
Step 3. Read off the azimuth angle in degrees ranging from 0º (starting at North) going clockwise around the circle.

Step 4. Change the azimuth number into the name of the direction using the table below. Ultra precision is not needed. The general direction is good enough.
</td>
</tr>
<tr>
<td>Veering Winds</td>
<td>Backing Winds</td>
</tr>
<tr>
<td>A veering wind that turns clockwise with height. It is associated with dynamic lifting because a south wind in transports warmer air to the north. The magnitude of warm air lifting is a function of wind speed and the pre-existing thermal gradient. Weak winds will result in weak lifting. Winds often veer ahead of cold fronts (in the warm sector of a mid-latitude cyclone).</td>
<td>A backing wind is a wind that turns counter-clockwise with height. A backing wind is associated with cold air advection (sinking cooler air). Winds back behind cold fronts.</td>
</tr>
</table>

4.2.4 Moisture

4.2.4 Moisture is any form of water in the atmosphere. Water can take the form of a solid, liquid, or gas at normal atmospheric temperatures and pressures. Gaseous water (water vapor) is most commonly reported as relative humidity in weather reports. Solid and liquid water is reported as precipitation. You can get these data from local radio and TV weather reports. However, the actual weather station recording the data may not be in the local area of your study site. In that case, you need to make on-site measurements.

4.2.4.1 Relative Humidity is the measurement of the moisture in the air stated as a ratio to the amount of moisture that could be held if the air were saturated. Air temperature affects relative humidity. Warm air can hold more moisture than cold air. Since air temperature decreases with altitude, relative humidity can increase as air rises from the surface. Liquid water at the surface can be changed to a gas (evaporated). If the air is lifted and cooled sufficiently, condensation occurs. The water vapor changes from gas back to liquid. This is a simplified explanation of cloud formation. Generally, as the air rises and cools, the actual amount of moisture in the air remains the same. The water holding capacity of the air is decreased, so the relative humidity increases.

Air at the surface	Air rising from the surface	Air at the LCL
		
Air at the surface starts off at a given temperature and given amount of moisture = a certain relative humidity.	As it rises, the air temperature decreases reducing the ability of the air to hold water; the relative humidity increases.	At some altitude (the Lifting Condensation Level), the air becomes saturated (relative humidity = 100%). Clouds can begin to form

4.2.4.1.1 Diurnal Relative Humidity Pattern: Temperature is a controlling factor for relative humidity. The general diurnal pattern at the Earth's surface is for higher relative humidity early in the morning when surface temperatures are lowest, and lower relative humidity in the mid-afternoon when surface temperatures are the highest.

4.2.4.1.2 Measuring Relative Humidity with a HYGROMETER: A hygrometer is an instrument for measuring relative humidity. There are various models available. These instructions are for a hygrometer with two thermometers: a dry bulb and a wet bulb. It is not very portable. It would normally be permanently attached to a wall. If it is outdoors, it should be placed in the shade.

The water reservoir supplies water to saturate a cloth wick wrapped around the base of the wet bulb thermometer. As the water from the cloth wick is evaporated, heat is removed from the wick, lowering the temperature. It is important to keep an ample water supply in the instrument. Clean water must be used to avoid contaminating the wick. Mineral encrustations on the wick will affect the evaporation rate and lead to erroneous readings.

Regular monitoring of the hygrometer should be coordinated with the other weather observations. If only one observation can be done each day, standardize the readings to 9 am local time each morning.

Procedure:

Step 1. Fill the water reservoir with CLEAN, FRESH water.

Step 2. Be sure the wick on the wet bulb is clean and thoroughly wet.

Step 3. Set up the hygrometer in a shady location. [**NOTE**: Watch the wet bulb thermometer carefully. When the temperature stops decreasing, get the wet bulb temperature.]

Step 4. Record the dry and wet bulb temperatures using a standard format (see the sample below).

Step 5. Calculate the difference between the two temperatures. (**Note**: Subtract the wet bulb temperature from the dry bulb temperature. Usually, the wet bulb temperature will be lower.)

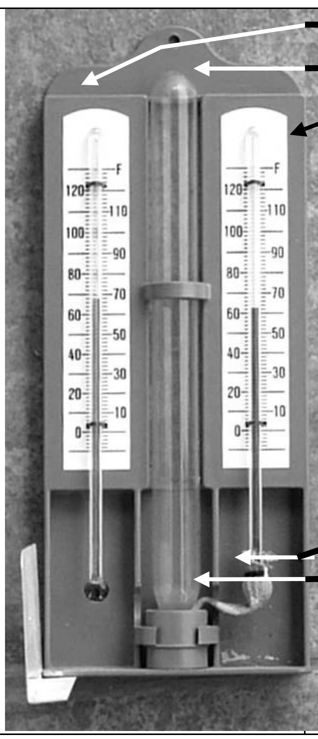
Step 6. Get the Relative Humidity Table (see next page).

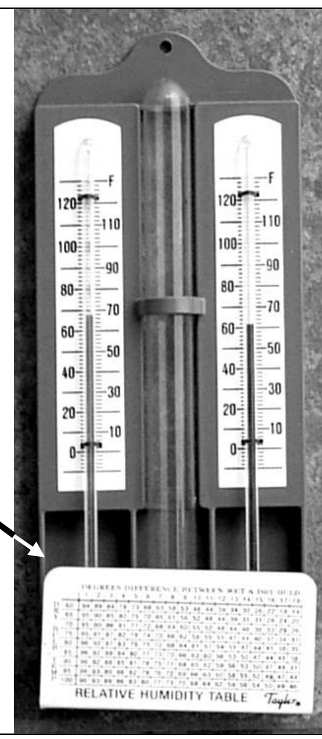
Step 7. Find the difference between dry and wet bulb temperatures along the horizontal scale of the chart.

Step 8. Find the dry bulb temperature along the vertical scale of the chart.

Step 9. Find the intercept of these two in the center of the chart. This is the relative humidity; record this on your worksheet.

Location:		Date:
Recorded by:		Time:
Measurement	Hygrometer	Use this space for your calculations
A. Dry Bulb Temperature		
B. Wet Bulb Temperature		
C. Dry-Wet Bulb Temp.		
% Relative Humidity		
Step 1. Read and record the wet bulb temperature in row B. Step 2. Read the record the dry bulb temperature in row A. Step 3. Subtract the wet bulb temperature (B) from the dry bulb temperature (A); write the result in row C. Step 4. For the hygrometer, use the psychometric table to find the relative humidity. For the sling psychrometer, use the sliding scale on the instrument.		





Dry Bulb – Wet Bulb Thermometer with open case showing the water bowl and wick.	Dry Bulb – Wet Bulb Thermometer with closed case showing relative humidity table.

Relative Humidity Chart for °C Temperatures

Dry Bulb Temperature (Air Temperature °C)	Dry Bulb Temperature minus Wet Bulb Temperature in °C																	
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	7.5	10.0	12.5	15.0	17.5	20.0	22.5	25.0
20	70	41	11															
-17.5	75	51	26	2														
-15	79	58	38	18														
-12.5	82	65	47	30	13													
-10	85	69	54	39	24	10												
-7.5	87	73	60	48	35	22	10											
-5	88	77	66	54	43	32	21	11	1									
-2.5	90	80	70	60	50	42	37	22	12	3								
0	91	82	73	65	56	47	39	31	23	15								
2.5	92	84	76	68	61	53	46	38	31	24								
5	93	86	78	71	65	58	51	45	38	32	1							
7.5	93	87	80	74	68	62	56	50	44	38	11							
10	94	88	82	76	71	65	60	54	49	44	19							
12.5	94	89	84	78	73	68	63	58	53	48	25	4						
15	95	90	85	80	75	70	66	61	57	52	31	12						
17.5	95	90	86	81	77	72	68	64	60	55	36	18	2					
20	95	91	87	82	78	74	70	66	62	58	40	24	8					
22.5	96	92	87	83	80	76	72	68	64	61	44	28	14	1				
25	96	92	88	84	81	77	73	70	66	63	47	32	19	7				
27.5	96	92	89	85	82	78	75	71	68	65	50	36	23	12	1			
30	96	93	89	86	82	79	76	73	70	67	52	39	27	16	6			
32.5	97	93	90	86	83	80	77	74	71	68	54	42	30	20	11	1		
35	97	93	90	87	84	81	78	75	72	69	56	44	33	23	14	6		
37.5	97	94	91	87	85	82	79	76	73	70	58	46	36	26	18	10	3	
40	97	94	91	88	85	82	79	77	74	72	59	48	38	29	21	13	6	
42.5	97	94	91	88	86	83	80	78	75	72	61	50	40	31	23	16	9	2
45	97	94	91	89	86	83	81	78	76	73	62	51	42	33	26	18	12	6
47.5	97	94	92	89	86	84	81	79	76	74	63	53	44	35	28	21	15	9
50	97	95	92	89	87	84	82	79	77	75	64	54	45	37	30	23	17	11

- Use the hygrometer to get the Dry Bulb and the Wet Bulb Temperature. Example, Dry Bulb = 30°C, Wet Bulb = 28°C.
- Subtract the Wet Bulb temperature from the Dry Bulb temperature. Example, 30°C – 28°C – 2°C. Find the column for 2°C across the top of the chart.
- Locate 30°C in the Air Temperature column at the left side of the chart.
- Find the intersection of the column and row to get the % relative humidity. For the example of 2°C and 30°C, the relative humidity is 86%.

4.2.4.1.3 Heat Stress Index: During the summer, if you know the air temperature and the relative humidity, you can use the table below to determine the Heat Stress Index. Every living organism has a range of temperatures it can tolerate. When the temperatures get to the extremes, either too high or too low, the organism may die. If the temperatures are to high, people are subjected to heat stress related discomfort, illness, and possibly death.

Generally, higher relative humidity conditions effectively make you feel warmer than the measured temperature shown on a thermometer. This is due to the fact that your body uses evaporation to cool itself. When the relative humidity is high, evaporation is slowed. This effectively reduces the ability of your body to cool itself. As you internal temperature rises, so does your discomfort level.

To avoid the dangers of heat stress illness, do the obvious: stay out of the sun and minimize physical activity. Can you understand why drinking iced beverages is not an effective practice to keeping yourself cool?

Heat Stress Index (Sensible Temperature)

Air Temp	Relative Humidity								
	10%	20%	30%	40%	50%	60%	70%	80%	90%
46°C	44°C	49°C	57°C	66°C					
43°C	41°C	44°C	51°C	58°C	56°C				
41°C	38°C	41°C	45°C	51°C	57°C	65°C			
38°C	35°C	37°C	40°C	43°C	49°C	56°C	62°C		
35°C	32°C	34°C	36°C	38°C	42°C	46°C	51°C	58°C	
32°C	29°C	31°C	32°C	34°C	36°C	38°C	41°C	45°C	50°C
29°C	27°C	28°C	29°C	30°C	31°C	32°C	34°C	36°C	36°C
27°C	24°C	25°C	26°C	26°C	27°C	28°C	29°C	30°C	31°C

Danger Level	I Caution	II Extreme Caution	III Danger	IV Extreme Danger	---
Heat Index	27-32°C	32-40°C	40-54°C	Above 54°C	Relative humidity rarely observed
Heat Syndrome	Fatigue possible with prolonged exposure and/or physical activity	Sunstroke, heat cramps, or heat exhaustion possible with prolonged exposure and/or physical activity	Sunstroke, heat cramps, or heat exhaustion likely; heat stroke possible with prolonged exposure and/or physical activity	Heat / sunstroke highly likely with continued exposure	Generally not applicable but conditions would be extremely dangerous

- Use a hygrometer placed in a shaded position about 1.2 m / 5 ft above the ground.
- Air Temperature is read from the Dry Bulb Thermometer.
- Relative Humidity is calculated using the Relative Humidity Table. This requires the following data: Air Temperature and the Temperature Difference between the Dry and Wet Bulb readings.

4.2.5 Cloud Observations:

4.2.5.1 Cloud Identification: Clouds are classified on the basis of their altitude (height above the ground) and their general shape. Fog can be considered clouds that are low to the ground. [**Note**: There are some significant differences how fog and clouds are made. But their physical appearance is similar.] Clouds classified on the basis of their altitude and shape.

There are 3 general altitude groups: low (ground level to 2,000 meters), middle (2,000-6,000 meters) and high (6,000-12,000+ meters). Some clouds extend vertically across these layers. The vertical development is so significant these clouds are put into a separate category.

The basic terms for cloud shape include: ***cumulus*** (Latin for "heap") usually found from 300-1,525 meters; ***cirrus*** (Latin for "curl") found above 6,000-12,000+ meters and often signal an approaching storm; ***stratus*** (Latin for "spreading out" or "layered") found at low altitudes (600-2,000 meters) often signaling bad weather is coming; ***nimbus*** (Latin for "rain") low clouds that bring rain. There are also combination terms that modify the basic terms: ***alto*** (Latin for "high") can be combined to form ***altostratus, altocumulus*** which are middle altitude clouds with a stratus or cumulus form.

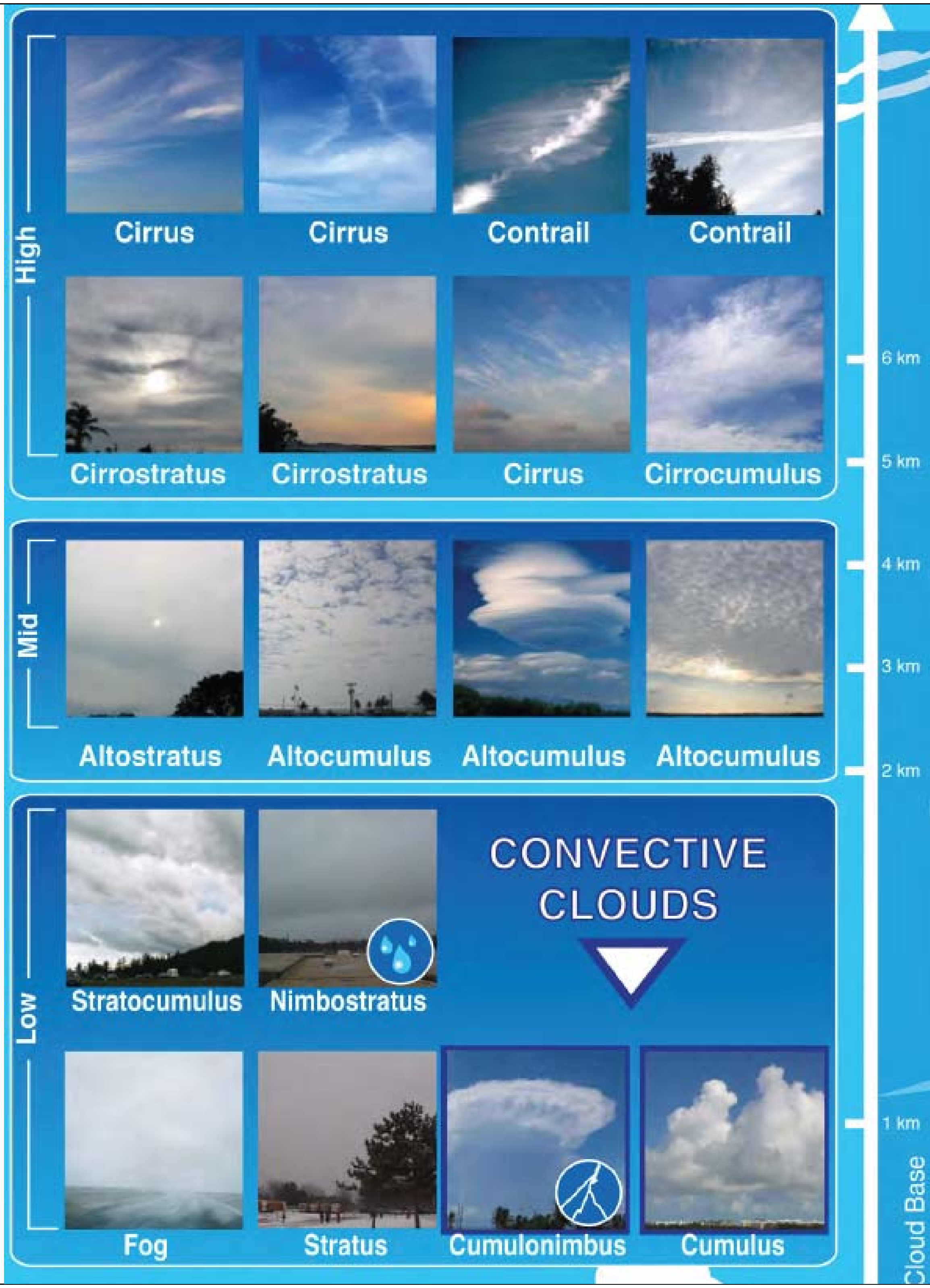
CLOUDS

Code	Name	Description	Altitude m	Altitude ft	Class
Ci	Cirrus	Delicate, wispy, feathery; streaky, stringy; slow moving; doesn't block the sun; mares tails—large ice crystals extending down	6,000 to 12,000	20,000 to 40,000	HIGH **(ice)**
Cc	Cirrocumulus	Thin sheets or closely packed small puffs without shadows; "mackerel" sky			
Cs	Cirrostratus	Whitish veil, usually fibrous; makes halo around the sun or moon.			
Ac	Altocumulus	Layer of separate cloud masses; fit closely in geometric pattern; blue sky visible between masses; white or gray on shaded side; associated with bad weather.	2,000 to 6,000	6,500 to 20,000	MIDDLE
As	Altostratus	Extensive, eve, gray layer over entire sky; gray, smooth bottom; sun is a bright spot; associated with bad weather.			
St	Stratus	Dense, dark gray layer; uniform base	Ground to 2,000	Ground to 6,500	LOW
Ns	Nimbostratus	Dense, dark gray layer with precipitation (rain or snow); thick enough to block the sun			
Sc	Stratocumulus	Distinct gray masses (long rolls, right angles to the wind and cloud motion) with patches of open sky, flat tops; often associated with fair or clearing weather; but snow flurries or rain are possible from individual cloud masses.			
Cu	Cumulus	White, wooly mass, flat base, lumpy top; gray or dark on shaded side or bottom; small clouds associated with fair weather.	300 to 1,525	1,000 to 5,000	VERTICAL
Cb	Cumulonimbus	White, anvil shaped top; very dark base; vertical dimension greater than horizontal; heavy rainfall, thunder, lightning, gusty winds, hail possible; strong updrafts	300 to 12,000	1,000 to 40,000	

FOG

Code	Name	Description
Fr	Radiation Fog	Often associated with a temperature inversion; bottom layer of air (closest to ground) cools below the dew point.
Fa	Advection Fog	Warm, moist air moves over a cold surface (snow, ice, or cool ocean current) and cools below the dew point.
Fo	Orographic Fog	Warm, moist air is forced upslope and is cooled below the dew point.
Fe	Evaporation Fog "Steam Fog" "Sea Smoke"	Evaporations adds water vapor to air that is already cool and near saturation (high relative humidity); cool air passing over warm water increases the relative humidity so that evaporation adds the needed water vapor to attain saturation.
Note: Fog is sometimes called "clouds close to the ground." Sometimes it is considered precipitation (as is the case with this observation form).		

Cloud Identification Chart



Excerpted from www.weather.gov//os/brochures/cloudchart.pdf

Procedure:
Step 1. Look up and observe the general appearance of a cloud.
Step 2. Try to recognize its basic shape: puffy (***cumulus***), thin and flat (***stratus***), or thin, whispy and curly (***cirrus***). Compare its appearance to the examples and the text descriptions in the accompanying materials.
Step 3. Try to estimate its height---low, medium, or high.
[**Note:** Keep good observation records. Some types of clouds will often appear before a storm arrives. This can be a very useful weather prediction method.

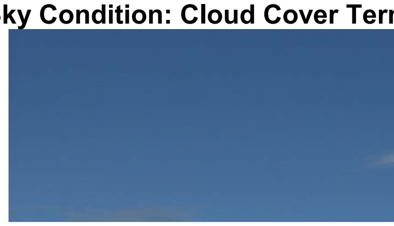
4.2.5.2 Estimating Cloud Base Height:
4.2.5.2.1 Using Topographic References: If you know the height of the mountains in your area, you can use them as a guide to estimate the height of the clouds. Use a topographic map to help determine local elevations for this method.

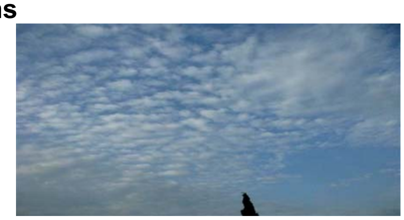
4.2.5.2.2 Using Adiabatic Lapse Rates and the Dew Point: Air lifted from the Earth's surface is usually not saturated (relative humidity is less than 100%). As it rises, it cools adiabatically (cooling by expansion) at a rate of 9.78°C/1000 m. If you know the temperature and relative humidity conditions at the surface (your location), you can estimate the height of the clouds over your location.
Step 1. Measure the air temperature and relative humidity for your location.
Step 2. Calculate the dew point temperature.
Step 3. Subtract the dew point temperature from the dry bulb temperature.
Step 4. Divide the result (the wet bulb depression) by 9.78.
Step 5. Multiple this result by 1000 to get the estimated height (in meters) of the base of the clouds overhead.

4.2.5.3 Estimating Sky Cover The amount of clouds covering the sky overhead can reduce the amount of solar energy getting to the ground. This affects surface temperatures, solar intensity for alternate energy. Changes in the amount of cloud cover can also give advanced warning of changing weather conditions.

Sky Condition: Cloud Cover Terms

Procedure: Use the following terms to reporting sky cover. Be sure to look at the entire sky overhead and from horizon to horizon all around you.


Clear: Sky is blue with no clouds or very few small clouds


Scattered: Sky is blue, but small patches of clouds are present.


Cloudy: The sky is covered mostly with clouds and a few blue patches.


Broken: Large patches of clouds, but patches of blue sky can be seen between the clouds.


Overcast: Clouds cover the sky; no patches of blue can be seen.

4.2.6 Precipitation is any form of solid or liquid water falling from a cloud. Precipitation is often measured using a rain gauge (except for snow, which is recorded by depth on the ground). The rain gauge should be placed in an open area, preferably over a grassy surface so rain drops won't splash into the collector. You should check the rain gauge at about 9am each day for a 24-hour period.

4.2.6.1 Make A Simple Rain Gauge: You can make a simple rain gauge using empty plastic bottles.

Materials: a large empty plastic bottle (about 1 liter); a smaller plastic bottle (less than 1 liter; it must fit inside the larger bottle); a pair of scissors.

Procedures:

Step 1. Cut the top off a large bottle about two thirds of the way up.

Step 2. Turn the top upside down and put it into the bottom part like a funnel.

Step 3. Cut the top off the smaller bottle to make a collecting cup. (The height is determined by the space inside the larger bottle. The collector cup should fit under the "funnel" opening of the larger bottle to catch the rain.)

Step 4. Place the small bottle inside the bottom part of the large bottle.

Step 5. Place the rain gauge in an open space and away from trees and buildings. You can set it on the ground. But make sure it doesn't tip over or get blown over by the wind. Or you can mount it to a pole no more than 1 m / 3 ft above the ground.

Step. 6. The rain gauge must be checked daily at the same time each day. Weather observers use a standard time of 9 am local time. Dew can collect inside the rain gauge and lead to false readings. So don't let the dew accumulate between your rain gauge readings.

4.2.6.2 Estimating Distance to a Storm can be easily done using the "Flash / Boom" method.

Step 1. Watch for lightning flash; count seconds (Time) until hearing the thunderclap.

Step 2. Use the reference table below or divide the Time (in seconds) from Step 1 by:

- 3 to get the distance in kilometers (km)
- 5 to get the distance in miles (mi)

Lightning Hazard: When the flash and thunderclap are almost instantaneous, you may be in trouble. People have been struck by lightning 30-45 miles away from a thunderstorm.

Lightning Safety:

- Avoid being on mountain tops, ridges, tall structures, next to single tall trees, open areas, on / in water, or in direct contact with any metal objects. If out in the open, find and kneel (***do not lie down***) in the lowest spot possible.
- Seek shelter in steel frame buildings or buildings with metal pipe / plumbing systems or in a vehicle (keep windows closed). Keep away from windows. Do not use or handle any electrical equipment or touch any metal.
- Wait for 30 minutes AFTER hearing the last thunder before leaving shelter.

"Flash – Boom" Time-Distance Table						
# Seconds	km	mi		# Seconds	km	mi
1	0.33	0.20		11	3.67	2.20
2	0.67	0.40		12	4.00	2.40
3	1.00	0.60		13	4.33	2.60
4	1.33	0.80		14	4.67	2.80
5	1.67	1.00		15	5.00	3.00
6	2.00	1.20		16	5.33	3.20
7	2.33	1.40		17	5.67	3.40
8	2.67	1.60		18	6.00	3.60
9	3.00	1.80		19	6.33	3.80
10	3.33	2.00		20	6.67	4.00

4.3 WEATHER FORECASTING: Although radio / TV weather reports are readily available, they have three primary shortcomings:

- They tend to be general wide area forecasts that may not apply to the specific local conditions at your site.
- The weather station data used may be distantly located to your site.
- Local terrain conditions could vary significantly over a short distance so that even a nearby weather station data may not always apply to your site.

For these reasons, you would be wise to learn to observe the sky conditions overhead and have an idea of the impending weather. There are numerous cases of families on a picnic deciding to take a walk or a hike only to find themselves stranded due to rapidly changing weather conditions. Mountainous areas are well-known for fast changes of weather.

There are two basic simplified weather forecasting methods presented in this paper: Wind and Cloud Method and the Barometer (Pressure) and Wind Method. (Note: If needed, review the previous sections of this paper for details on how to measure wind speed, wind direction, and how to identify clouds.)

4.3.1 Forecasting With Wind And Cloud Data: Follow these basic steps to a simple weather forecast using the following steps:

Step 1. Determine the true wind direction. (**Note**: This requires adjusting local magnetic compass measurements for the proper magnetic declination.)

Step 2. Watch for the pattern of change in the wind direction over time.

Step 3. Identify the cloud formations. Keep a log and watch for changes over time.

Fair Weather	Changing Weather	Stormy Weather
Cumulus	Cirrus Cirrostratus Cirrocumulus	Altocumulus Altrostratus Cumulonimbus Nimbostratus
	Stratus or Stratocumulus	

Step 4. Determine if the cloud density (overall cloud coverage of the sky) is increasing or decreasing.

- Thickening clouds can indicate wet weather is on the way.
- Thinning clouds or breaks in clouds can indicate clearing is on the way.

Step 5. Determine if the cloud height is increasing or decreasing. (Note: Cloud types are grouped by altitude; low, middle, high.)

- Decreasing clouds heights can indicate wet weather is on the way.
- Increasing cloud heights can indicate a break in weather with clearing on the way.

Step 6. Combine the cloud identification and wind direction change information and use the Wind and Cloud Forecasting Summary Table below for a simplified forecast.

WIND AND CLOUD FORECASTING METHOD						
Equipment needed to complete this form [ ] Magnetic compass [ ] Cloud chart [ ] Pen / Pencil				Optional equipment [ ] binoculars [ ] camera [ ] sketch pad		
Time of Observations			**Wind Dir.**	**Cloud Type**	**Your Forecast**	
Morning	0600	6 am			Time:	
Mid-morning	0900	9 am			**Forecast:**	
Noon	1200	12 pm				
Mid-afternoon	1500	3 pm				
Evening	1800	6 pm				
Note: Wind direction is the direction the wind comes from; W = blowing from the west.						

Cloud-Wind Forecasting Summary Table (Adapted for the western US)				
Clouds		**Wind Shift**	**Weather Forecast**	
W of Mtns	**E of Mtns**		**W of Mns**	**E of Mns**
Stratus Stratocumulus	None	NW to W to SW	Rain possible from coast to mtns.	Fair
Stratocumulus Stratus; (SE winds)	-----	SE to S	Rain possible from coast to mtns	Fair
Cumulus or Clear; (S winds)	-----		Fair	
Clear skies		NE to E	Fair	

Brief Summary of Cloud Types and Conditions			
Cumulus	Cirrus	Stratus	Nimbostratus
Rain possible especially on hot summer days and clouds get thick and dark.	Storm coming in the next 24-48 hours.	Bad weather approaching when clouds are stretched out in calm flat layers; drizzly rain	Rainstorm likely when dark gray clouds are low, cover the sky widely; drizzly rain
Stratocumulus	Altocumulus	Altostratus	
Widespread, drizzly rain.	Settled weather conditions.	Changing weather.	
Note: *This method was developed for mid-latitude areas and may not be the same for Nan Province.*			

4.3.2 Forecasting With Pressure And Wind Data: (See summary table on next page.)

Step 1. Watch for changes in barometric pressure.

- Rising pressure indicates a trend toward fair weather.
- Steady pressure (little or no change) indicates present weather condition will continue.
- Falling pressure indicates a trend toward stormy weather.

Step 2. Determine the rate of change in barometric pressure. The common terms used are:

- Slowly = less than 3 mb change in 3 hours (0.885 in Hg / 3 hrs)
- Moderately = 3-6 mb change in 3 hours (0.885 to 0.177 in Hg/3 hrs)
- Fast (rapidly) = more than 6 mb change in 3 hr (more than 0.177 in Hg/3hrs)
- Steady = little or no change

Step 3. Determine the true wind direction. (**Note**: This requires adjusting local magnetic compass measurements for the proper magnetic declination.)

Step 4. Watch for the change in wind direction over time.

Step 5. Combine the barometric pressure measurement, the rate of change in barometric pressure, with the change in wind direction. See the summary table below for a simplified forecast.

BAROMETER & WIND DIRECTION FORECASTING METHOD

Equipment needed to complete this form	Optional equipment
[ ] Magnetic compass [ ] Cloud chart [ ] Pen / Pencil	[ ] binoculars [ ] camera [ ] sketch pad

Time of Observations			Barometer	Wind Dir.	Your Forecast	
Morning	0600	6 am			**Time:**	
Mid-morning	0900	9 am			**Forecast:**	
Noon	1200	12 pm				
Mid-afternoon	1500	3 pm				
Evening	1800	6 pm				
Wind direction change		☐ Veering ☐ Backing				

Note: Wind direction is the direction the wind comes from; W = blowing from the west.

Sea Level Press In Hg	Wind Dir	Forecast
30.1 to 30.2 Steady	SW to NW	Fair with slight temperature changes for 1 or 2 days.
30.1 to 30.2 Rising fast		Fair followed in 2 days by warmer temperatures and rain.
30.1 to 30.2 Falling slowly		Warmer with rain in 24 to 36 hrs.
30.1 to 30.2 Falling fast		Warmer with rain in 18 to 24 hrs.
30.2+ Stationary		Continued fair with no decided temperature change.
30.2+ Falling slowly		Slowly rising temperature and fair for 2 days.
30.1 to 30.2 Falling slowly	S to SE	Rain within 24 hrs.
30.1 to 30.2 Falling fast		Wind increasing in force with rain within 12 to 24 hrs.
30.1 to 30.2 Falling slowly	SE to NE	Rain in 12 to 18 hrs.
30.1 to 30.2 Falling fast		Increasing wind with rain in 12 hrs.
30.1+ Falling slowly	E to NE	Summer: light winds, rain may not fall for several days Winter: rain within 24 hrs.
30.1+ Falling fast		Summer: rain probable within 12 to 24 hrs. Winter: rain or snow with increasing winds from NE.
30.0 or less Falling slowly	SE to NE	Rain will continue 1 to 2 days.
30.0 or less Falling fast		Rain with high wind; clearing and cooler in 24 hrs.
30.0 or less Rising slowly	S to SW	Clearing within a few hours; continued fair for several days.
29.8 or less Falling fast	S to E	Severe storm of wind and rain or snow imminent; clearing and colder in 24 hrs.
29.8 or less Falling fast	E to N	Severe NE gales and heavy rain or snow followed by winter cold wave.
29.8 or less Rising fast	Going to W	Clearing and colder.

Notes on Barometer changes

Slowly = under 3 mb/3 hours (0.885 in Hg/3 hrs)
Moderately = 3-6 mb/3 hours (0.885 to 0.177 in Hg/3 hrs)
Fast (rapidly) = over 6 mb/3 hr (more than 0.177 in Hg/3hrs)
Steady = little or no change

Pressure Conversions

Inches Hg to Mb		Mb to Inches Hg	
30.2	1023.7	1023	30.1785
30.1	1020.3	1019	30.0605
30.0	1016.9	1016	29.9720
29.8	1010.1	1009	29.7655

4.3.3 Some Weather-wise Sayings: Over time, consistent observations persisted to the point that popular sayings were devised.

- Rainbow in the morning, sailors take warning; Rainbows at night, sailors delight.
- Winds that swing with the sun, and winds that bring the rain are one. Winds that swing around the sun, keep the rain storm on the run.

4.4 ATMOSPHERE INTERCONNECTIONS

Atmosphere	Biosphere	Hydrosphere	Lithosphere
Latitude	Controls the quantity and quality of solar energy		
Land / Water Distribution		Source of atmospheric heat driving the atmospheric circulation	
Atmospheric Circulation			
Oceanic Circulation	Redistributes heat / moisture, nutrients around the globe		Land masses impeding water flow
Altitude	Affects heat / moisture availability	Affects moisture availability	Landforms
Topographic Barriers	Affects heat, moisture, wind for organisms	Affects heat / moisture in an area	Mountains
Storms	Environmental impacts due to amounts of energy and water deposited in relative brief but intense intervals		
This summary table is not comprehensive. It contains general examples of the inter-relationships as examples.			

5.0 HYDROSPHERE:

About 70-75% of the Earth's surface is water. This paper is primarily concerned with water sources on land. The Hydrologic Cycle explains the circulation of water through the world. It views the realm of water as a closed system. Water is unique on Earth. It is the only form of matter that occurs in all 3 physical states (solid, liquid, and gas) under normal atmospheric temperature and pressure conditions.

Evaporation changes water (liquid, at the surface) to vapor (gas, in the atmosphere). Condensation changes the vapor back to liquid and solid. Precipitation returns the water to the surface of the Earth (land and oceans). Runoff and discharge from land areas ultimately enter the oceans.

Water pollution, potential and actual, from specific point sources and non-point sources are major environmental concerns. Ironically, Earth is predominantly a water planet. Yet only recently have experts acknowledged that about half of the people in the world can get clean drinking water each day! Next to air, water is critical to our daily survival.

5.1 THE HYDROSPHERE MATRIX (FBS / LC/EO): The Hydrosphere guide is a matrix rather than a checklist. The three broad categories of water quality are Fresh, Brackish, and Saline. On a global scale, these types of water can be found in three different locations on Earth: Land, Oceans, and the Coastal / Estuarine areas (the transition between Land and Ocean). (See the summary table below.) At a detailed level, it is possible to find all three types in all three locations. This is a good example of Yin-Yang. For example, most salt water is found in the oceans. But the Great Salt Lake (in the US) and the Dead Sea (bordering Jordan and Israel) are on land. Off the coast of Lombok (Indonesia), local villagers take their boats out to sea to collect fresh drinking water to carry back to their homes. Fresh water is coming up from under the sea floor through a lava tube and rises to the ocean surface.

GENERAL HYDROSPHERE SUMMARY MATRIX

Key Factors *		Location	Scale	Time	Notes
Water Quality	Fresh	Mostly on land, but some in coastal and ocean sites.	Largest unit is smaller than the oceans.	Variable from year round to seasonal	Fresh water is limited in supply and location.
	Brackish	Mostly coastal and estuarine but some interior continental and ocean sites	Most are smaller than regional scale.		Brackish water is of marginal value to people.
	Saline	Mostly oceanic but some continental interior and coastal / estuarine sites	Largest of water bodies but can also occur as small units.	Largest bodies are permanent	Saline water is available in abundance.

DETAILED HYDROSPHERE SUMMARY MATRIX

	Feature	Natural	Constructed	Data	Notes
Surface Water	Watershed	Drainage basin	-----	• Name, • Location, • Dimensions • Surface soil / rock • Vegetation cover • Flow characteristics • Discharge volume • Water utilization	Permanence / seasonality for water availability is the critical concern Potential and actual pollution / contamination of water is an important consideration
	Water courses	Streams, rivers, creeks, brooks	Canals, aqueducts, irrigation channels		
	Water bodies	Oceans, lakes, ponds, glaciers, snow fields	Ponds, reservoirs		
	Wet areas	Swamps, marshes	Flood control / recharge basins		
	Wet spots	Seeps / Springs	Outfalls, well heads		
Ground Water		Aquifers, artesian wells, geysers		• Depth • Type / amount • Flow rate	
		Water table	Wells		
		Soil moisture			

5.2 STREAM PROFILING is a method used to get graphic description of a stream channel. The procedure is similar for both longitudinal (following the long axis of the stream channel) and cross-sectional (extending across the stream from on bank to the other) profiles

Equipment: 2 stakes, mason's cord (or strong string), a string level, a long measuring tape, a short measuring tape, notebook, graph paper, pencil / sharpener / eraser.

5.2.1 Profile Measurement Procedure:

Step 1: Set up the stakes so a string can be stretched between them to cover the transect to be surveyed.

Step 2: Tie the string to one stake. Stretch the string to the other stake and wrap it around the stake and hold it in place. Do not tie it yet.

Step 3: Attach the string level to the string. Move the untied end of the string up or down as needed to make the string line level. Then tie off the string to the second stake.

Step 4: Use the long measuring tape to determine the distance between the stakes.

Step 5: Select a sampling interval along the transect line. The more points you sample, the more accurate the profile. But this also means more time needed to make the measurements.

Step 6: Mark off the sampling interval on the transect string.
Step 7: Start at one stake. Use the short measuring tape to measure the distance from the leveled string to the stream bed surface. Once you have all the data, you can plot the profile.

5.2.2 Profile Plotting Procedure:

Step 1. For convenience, select an appropriate scale to permit plotting the entire length of the profile on a single sheet of standard graph paper. Be sure to use the same scale for the horizontal and vertical axis to get a true perspective.
Step 2. Layout a horizontal line representing the transect level string line.
Step 3. Label the end points (stakes).
Step 4. Convert the field measurements to the plot scale.
Step 5. Plot the sample measurements vertically down from and perpendicular to the horizontal transect line.
Step 6. After plotting all of the sample measurements, connect the ends of the sample plots. This line represents a profile of the stream bottom.

5.2.3 Longitudinal Profile: For a longitudinal profile, extend the transect line along the long axis of the stream. This type of profile has three basic uses:

- Determining the general slope angle of the stream bed (stream gradient).
- Determining one of the 4 critical measurements needed for a stream discharge calculation. [**Note:** If conducting a study for stream discharge calculation, this is also a good time to use the 2 transect end stakes as reference markers measure the stream velocity. Stream flow velocity is one of the 4 critical measurements needed to calculate stream discharge.]
- Determining Stream Head: This measurement is often needed to assess the hydro power potential of a stream. Generally, a vertical drop of 3 m / 10 ft is the minimum needed for pico / micro hydro power projects. [**Note**: Sufficient water volume is also needed to sustain a hydro power unit.]

5.2.4 Cross-Sectional Profile: For a cross-sectional profile, extend the transect line across the stream channel (from one bank to the other) essentially at right angles to the longitudinal axis of the stream bed. This type of profile has two basic uses:

- Determining the general contour of stream bed cross-section.
- Determining one of the 4 critical measurements needed for a stream discharge calculation. [**Note:** If you are doing the cross-section profile as part of a stream discharge calculation, you also need to measure the water depth at the same time as the vertical sample measurements taken along the horizontal transect line. The water depth would be another of the 4 critical measurements needed for a stream discharge calculation. The cross-sectional area combined with the longitudinal profile is an estimate of the water volume for the sampled distance along the stream bed.]

5.3 STREAM FLOW MEASUREMENT: If you have the estimated water volume for a section of stream, you only need the stream velocity to calculate the stream discharge. Depending on the reliability of the stream flow, repeated measurements over time will reveal the seasonal peaks and troughs of the annual stream flow pattern. **Steam flow velocity** is affected by a number of factors. Among them: water depth, water volume, stream gradient, stream channel alignment, stream bed width, stream bottom texture, and sometimes wind velocity (among others).

Equipment: 2 stakes, long measuring tape, stop watch, notebook, pencil / sharpener / eraser, Red colored food dye or juice powder, cup, an orange (fruit)

5.3.1 General Procedure:

Step 1: Select a relatively straight section of stream.
Step 2: Place 2 stakes a minimum of 3 m / 10 ft apart.
Step 3: The “marker” is put into the middle of the stream flow at the upstream stake. At the same time, a person with the stopwatch is at the down stream stake and starts the stopwatch. [Note: The type of marker used depends on the flow volume or water depth. See Sections 5.3.1.1 and 5.3.1.2 below for details.]
Step 4: As the marker passes the down stream stake, stop the stopwatch and record the time. Repeat this until you have 3 measurements to average.
Step 5: Repeat Steps 3-4, but place the marker into the water closer to each bank. Make 3 measurements for each bank.

5.3.1.1 Low Flow Volume or Shallow Water Conditions: Use the “dye” marker. Mix the juice power or food color with water. Do not dilute it very much. A darker color will be easier to see and track. The color intensity will be diluted by the stream water.

5.3.1.2 High Flow Volume or Deep Water Conditions: Use the orange. An orange has about the right buoyancy to maintain a low profile while floating in the water and not be adversely affected by wind.

5.3.2 Stream Discharge: To calculate the stream discharge, you will need to know:
• The stream’s cross-sectional area in m^3 (see Section 5.2.4)
• The stream’s average flow velocity in m / sec (See Section 5.3.1)

Calculation Procedure:
Step 1: Divide the distance by the average stream flow velocity to get the stream velocity in meters / second (from Section 5.3.1)
Step 2: Get the total cross-sectional area (in m) for the stream (see Section 5.2.4)
Step 3. Calculate the total stream discharge (in m^3 / sec) by multiplying the total stream cross-section (in m) by the average stream velocity (in m / sec)
Step 4. Calculate the corrected total stream discharge by multiplying the result from Step 3 by the appropriate correction factor from the table below.

Sandy or muddy stream bottom = 0.8	Rocky stream bottom = 0.9

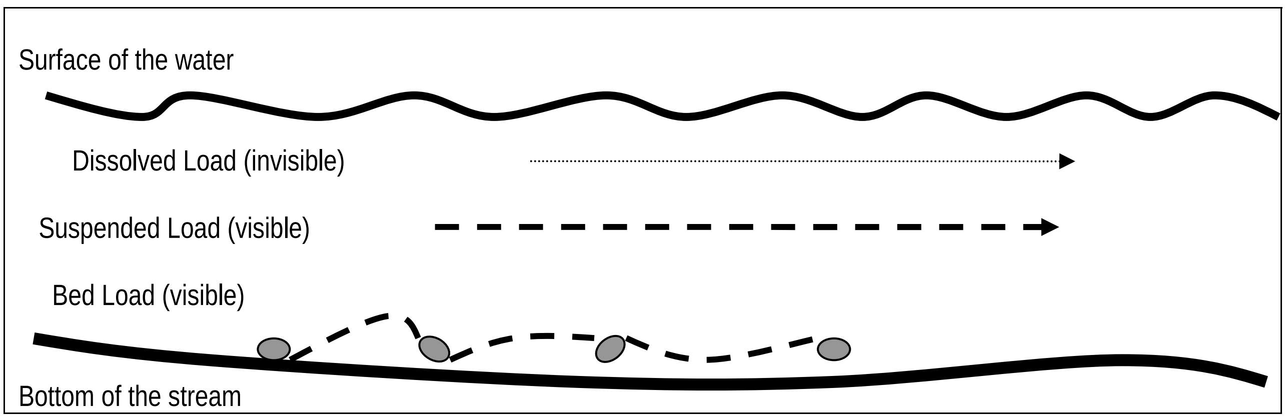
5.4 WATER QUALITY:
There are much more detailed water chemistry measurements that can be used, but they are beyond the scope of this paper. The quick field recon methods below are only the beginning.

5.4.1 Visual Clarity:
This is a subjective (non-quantifiable) judgment rating method.

- **Transparent (Clear):** The water is transparent while in its natural condition (not viewed in a container). So if you can see the bottom of a shallow stream or pond, it is probably clear. For deeper water, you should not see any murkiness or coloration in the water.

- **Translucent (Milky or Cloudy):** You might be able to see the bottom of a shallow stream or pond, but not clearly. The water has a milky or cloudy appearance that prevents you from seeing details clearly. The water is translucent.
- **Opaque (Muddy):** The water is opaque or has a reddish or muddy color to it. It is not possible to see the bottom of a shallow stream or pond.
  [**Note:** If the water has a particular color (e.g. green, grey, etc.), make a note of the color in your observation log.]

5.4.2 Sediment Load: Moving water carries materials (visible and invisible)in different ways. Dissolved minerals can be anywhere in the water and are invisible. They can be carried at any flow velocity. The largest sediments are contained in the bed load of the stream. These are moved either by traction or saltation. Finer particles (e.g. sand, silt, clay) can be suspended in the water and above the stream bed.



5.4.2.1 Estimating Suspended Load: This procedure is primarily intended to provide a first approximation of the effectiveness of soil erosion reduction efforts. The key is to get estimates of the suspended load before and after implementing soil erosion management programs. A reduced suspended load could be the first indicator of a successful program.

Equipment: water collection bottles (1 liter capacity or more); large funnel, large processing bottle / container (capable of holding the funnel), coffee filter, scale (units in grams).

Procedure:

Step 1: Collect a series of water samples from the stream and keep accurate information about each sample (e.g. collection date, time, and background information concerning prior rain events and relative position to the area of the soil management effort). [**Note:** The location (e.g. center of the stream in terms of width and depth, or close to the bank, etc.) of the sample can affect the results.]

Step 2: Weigh a clean, dry coffee filter. Record the weight on the filter paper itself, label the coffee filter with the water / sediment sample ID.

Step 3: Place the labeled water filter in the funnel. Then place the filter / funnel combination in the processing container.

Step 4: Making sure the water / sediment sample ID matches the coffee filter ID. Record the amount of water in the sample. Pour the sample water into the filter / funnel combination. Let all the water drain out of the filter / funnel combination.

Step 5: Remove the filter paper from the funnel. Dry it thoroughly.

Step 6: Weight the dried processed filter and record the weight.

Step 7: Use the results from Step 6 to calculate the weight of sediment per liter of water.

5.4.2.2 Change Analysis: Repeated measurements from the same location over time can show any suspended sediment load changes over time. Keep in mind, the flow velocity affects the ability of the stream to transport material. Be sure to take measurements at both low and high stream flow periods to get a more accurate characterization of the stream load.

5.4.3 Odor / Smell: Various factors affect the odor of water. Bad smelling water is obviously not desirable. However, no smell does not necessarily mean good quality water. The main concern is change over time, especially if the water begins to have an odor when it previously did not. Try to describe the odor to the best of your ability (e.g. it smells like rotten eggs---this indicates the presence of hydrogen sulfide, a product of organic decomposition).

5.4.4 Measuring Ph Using Litmus Paper: This indicates the acidity or alkalinity of the water. It is a coarse measurement and may not be accurate enough to permit comparisons over time.

Step 1. Use a clean strip of litmus paper for each test.

Step 2. Dip the end of a strip of pH paper into the water sample.

Step 3. After about two seconds, remove the paper, and immediately compare the color at the wet end of the paper with the color chart provided with that pH indicator. [**Note**: The color chart is posted in the “Our Papers” section of the RTC-TH Website (www.neighborhoodlink.com/org/rtcth). Look for the article “pH Test Notes”. You will need to be close to a computer / monitor in order to compare the litmus paper to the chart.]

Step 4. Write down the pH value and color.

Pollution and contamination pose real and serious threats to our water supply and ultimately our lives. The hidden threat is our careless attitudes about water use bordering on abuse. Water conservation should be a priority, especially in southern California. In this sense, water is like money. It is easier to hold on to the money in your hand than to try to put more money in your hand. It will be far easier to save clean drinking water than to clean contaminated water for drinking.

6.0 SUMMARY:

The Geographic Systems Model (with the attendant environmental checklists) and the General Systems Matrix help to guide studies of our complex environment. The basic components were briefly described with notes indicating key linkages between the checklists.

It takes practice to thoroughly review a study site. Repeated practice in using the checklists hones your observation skills over time. It doesn't happen overnight, and it certainly doesn't come easy. Usually no one person will be able to carry the full load alone. Teamwork helps. Brainstorming and open communication (constructive discourse) brings forth the synergy of a team effort.

5.1 NO SIMPLE ANSWERS: Be fully prepared to not find the "single" correct answer at the end of your quest (assuming it has an end---they usually are ongoing sagas). The most likely end will be a range of solution alternatives forcing you to make hard choices resulting in short term gains at the expense of long-range goals, or making sacrifices today for uncertain future long term gains. Nothing is guaranteed. Conditions are in flux and continue to change, even as you observe and measure them

5.2 ENVIRONMENTAL IMPACTS: Environmental balance prior to human existence is not well known. Today, we can find clear examples of serious human impact of the environment. Efforts to re-establish a "balance" pose serious challenges for us. The functional definition of that balance is yet unknown. Our knowledge is very limited.

There seems to be one clear indicator of human impact on the environment: the disruption of nutrient / energy flows as they affect the well-being and survival of other species. It is difficult to restrict environmental impact to the physical components of the environment (e.g. soil erosion). All parts of the environment are inextricably woven together in the immense tapestry of life on our planet.

This paper presented a number of systematic checklists to guide your observations of the natural environment. Comparative studies based on these systematic observations over time can help to document positive and negative human impacts on the environment.

7.0 SELECTED LIST OF REFERENCES

Better Homes and Gardens. 1979. Complete Guide to Gardening. Des Moines, IA: Meredith Corporation.

Gershuny, G. 1993. Start with the Soil. Emmaus, PA: Rodale Press.

Headquarters, Department of the Army. 1972. Field Manual: Military Geographic Intelligence (Terrain). FM 30-10. Washington, D.C.

Hynes, E. 1994. Improving the Soil. Emmaus, PA: Rodale Press.

Kohnke, H. & D.P. Franzmeier. 1995. Soil Science Simplified. Prospect Heights, IL: Waveland Press, Inc.

Lee, G.K. 2004. Student Survival Guide to Physical Geography. 3rd Edition. Los Angeles: Overnight Press

Lee, G.K. 1999, revised 2002. "Simple Slope Measurement Using a Leveling Stick" Technical Paper SEP-L5a. Van Nuys, CA: Earth Systems Science, Inc.

Lee, G.K. 1994, revised 2003. "Natural Terrain Study Guidelines". Technical Paper SEN-E2. Van Nuys, CA: Earth Systems Science, Inc.

Lee, G.K. 1984, revised 2001. "Simple Magnetic Compass Use". Technical Paper.

Maloney, E.S. 1994. Chapman Piloting. 61st Edition. New York: Hearst Marine Books.

Martin, D.L. & G. Gershuny, Eds. 1992. The Rodale Book of Composting. Emmaus, PA: Rodale Press.

Nancarrow, L. & J.H. Taylor. 1998. The Worm Book. Berkeley, CA: 10 Speed Press.

Pidwirny, M. 1999-2004, Fundamentals Of Physical Geography. Department of Geography, Okanagan University College, British Columbia, Canada.

Smyser, C.A. 1982. Nature's Design: A Practical Guide to Natural Landscaping. Emmaus, PA: Rodale Press.

Snodsmith, R. 1988. Tips from the Garden Hotline. New York: Gallahad Books.

South Coast Air Quality Management District. 1993. CEQA Air Quality Management Handbook.

Stell, E.P. 1988. Secrets to Great Soil. Canada: Transcontinental Printing

Wirth, T. 1984. The Victory Garden Landscape Guide. Boston: Little, Brown, and Company.