LESSON 1- MOVEMENT AND UTILITY SYSTEMS

- The usefulness of any parcel of land, weather urban, suburban, or rural, depends on the existence of adequate roads and utilities to serve it. This is true for a suburban or large urban site.
- The site must be readily accessible
- The primary consideration in planning the use of a site includes the adequacy of both circulation access and utility services.

Circulation access includes:
  1. pedestrian
  2. vehicular
  3. public transit movement systems

Utility services include:
  1. water
  2. sewer
  3. gas
  4. electricity
  5. communication systems

- Sustainable design planning attempts to design infrastructure and utilities that work with the natural ecosystem. Locating them in locations that compliment existing conditions through sympathetic solutions which reflect the local topography, climate and vegetation.

CIRCULATION SYSTEMS

- Vehicular circulation systems are the primary structuring element of a land use plan, often determining the location of utilities and communication networks and pedestrian circulation systems.
- In land planning and site planning, it is standard to begin laying out the site with the surface roads. This most often determines the patterns of land use and utility systems.
- Roads systems must be carefully adapted to the topography.
- Utility services are generally located above/ or below the road system.
- Surface drainage channels are usually located along side the roadways connecting to underground storm water conduits.
- As the amount of vehicular/ pedestrian flow increases, the need to organize and define the channels of flow also increases. (ex. Which streets will channel the heaviest traffic).
- As a result, those channels that carry large volumes over greater distances are often physically separated from the region served. (ex. expressways, freeways, and railroads).
Forms of Circulation (types):
1. grid
2. radial
3. linear
4. curvilinear
5. or a combination of these

A Grid System: consists of equally spaced streets or roads which are perpendicular to each other.

- Often used for its regularity, simplicity, and convenience.
- It simplifies the subdivision of land for both agriculture and urban use, along with providing a sense of orientation if not extended (vast) and sufficient landmarks are present.
- Grids can be used on sloped sites if carefully configured.
- Traffic flows can be controlled by increasing capacity in certain channels while decreasing them in others. This can direct heavier through-traffic to those channels that are capable of handling them.
- A grid system can lose its effectiveness with regard to circulation when its channels become congested. Usually before this point is reached, a freeway or expressway is introduced.

A Radial System: directs flow to or from a common center, with straight channels of circulation radiating from this center point.

- This is the typical pattern created by traditional city growth outward (radially) from the original settlement.
- This usually causes the center point, where all channels converge, to become congested. This can be alleviated by creating “by-passes” that connect outlying hubs/radials thus allowing through traffic to avoid the congested area. As a result, a radio-centric pattern is created. This can also sometimes create concentric rings around the center.

A Linear System: of circulation connects flow between two points, either along a single line or along a series of parallel lines.

- Activities can be situated along the route or be routed into loops or branches on either side. Excessive traffic along the route could ultimately cause congestion.
- A drawback to this system is a lack of focal point and the on-and-off movements from the branches or activities can impede the flow of traffic. This can cause inefficiency and be hazardous to oncoming traffic.
• This type of system is useful for restricted sites such as a narrow valley between hills, or when parallel to existing infrastructure like a railroad, canal or freeway.
• Such routes lined with business are often called “strip commercial” developments. These businesses are often visually chaotic, very inefficient in terms of land use. They serve as good “incubator spaces”, places for new businesses.

A **Curvilinear system**: responds to the topography of the land and aligns with natural contours.

• This system works best at small scales because the curving of the path reduces speeds.
• A network of curvilinear systems can conform to the natural topography of the landscape as well as be arbitrary. Most common to residential neighborhoods/suburbs.
• (PUD’s) employ this system for more interesting street layouts, better views, and site adaptability (topographic changes).

**VEHICULAR CIRCULATION**

• The development potential of land is largely determined by the system of traffic access to the land.
• Vehicular traffic flows in sequential order from low intensity to high intensity.
• Local access streets \(\rightarrow\) collector/distributor streets \(\rightarrow\) arterial streets \(\rightarrow\) freeways

Basic categories of traffic arteries are:
1. Freeways/ expressways/ motorways
2. Arterial streets/ highways
3. Collector/distributor streets
4. And Local access streets

*Freeways/ expressways/ motorways*: are designed to allow movement of large volumes of traffic between, around, or through urban areas.
• Velocity is reached because of high intervals between traffic interruptions (on-off ramps).
• All cross traffic is accomplished by overpasses and underpasses eliminating all grade level intersections which would impede traffic.

*Arterial Streets/ highways*: are continuous vehicular channels that connect with expressways by means of on-and-off ramps at carefully determined locations.
• These are typically two and three lanes wide in each direction.
• On street parking is prohibited
• Access to adjacent commercial property could be restricted
• Access to residential streets is allowed
• All crossings are controlled by traffic signals
• Typical speed limit is 35 mph
• Major intersections should be separated by at least 800’-0”
**Collector-Distributor Streets:** serve as the transition between arterial streets and the local access streets of a neighborhood.

- They provide access to adjacent residential properties
- They are usually discontinuous, thereby preventing through-traffic and reducing vehicular speed
- Curb-side parking is allowed but only at certain times of the day and may be limited or prohibited
- When *collector streets* intersect with *arterial streets*, traffic signals are used
- *Local and collector streets* are usually controlled by stop signs

**Local access streets:** provide access to low intensity uses fronting on them.

- They carry low traffic flows
- Such streets consist of loops and cul-de-sacs or combination of the two
- Unrestricted curbside parking
- Unlimited Pedestrian use

**ROAD DESIGN CRITERIA**

- Road design includes such elements as:
  1. Pavement
  2. Curbs
  3. Gutters
  4. Shoulders
  5. Walks
  6. Landscaping
  7. Border strips
  8. Lighting
  9. Signs
  10. Traffic signals
  11. And utilities

Depending on traffic intensities, the materials often used for paving and roads include (in order of preference):

1. concrete
2. asphalt concrete
3. gravel
4. decomposed granite
5. stabilized soil
6. graded and compacted earth shaped for drainage

- The paved vehicular right-of-way usually slopes from a high point at the center, known as the crown, to the sides at a rate of 1/8 to 1/2 inch per foot depending on the finish surface to provide positive drainage.
- Roads with heavier traffic are designed with a six inch curb and gutter.
- Residential streets can have 4 inch “roll curbs” or simple gravel shoulders flanked by narrow drainage devices.
- For major roads, lanes should be between 11 & 12 feet wide.
- A two lane highway with 9'-0" shoulders on either side is therefore 40-42’ wide.
- Parking lanes should be 8'-0” wide. For angled parking 2-2.5 times that is typical.
• Planting strips should be 7’-0” wide for trees and 4’-0” wide for simple ground cover. Tree wells or raised planters can be used as well.
• When designing roads, the services of a civil engineer is required
• Actual roads consist of straight sections called “tangents” which may or may not be level, and horizontal/vertical curves
• Horizontal curves generally are arcs of a circle allowing a vehicle to negotiate the curve smoothly
• There are certain types of intersections which should be avoided:
  i. An acute angle intersection (two approaching streets at less than 80-85 degrees) is difficult to negotiate and limits driver visibility.
  ii. Intersections that are (slightly) offset create difficult crossing situations and impede the intersection being crossed. Intersections with straight crossings or offsets (no less) than 150 feet are preferred.
  iii. Intersections on major arterial roads should be separated by 800’-0”
  iv. Freeway on-off ramps are usually separated by one-half to one mile
  v. On minor roads “T” intersections are permissible
• The length of a cul-de-sac should not exceed 400’-0”. There must be a minimum turn-around of 80’ in diameter.
• Maximum depth of loop streets is 700’-0”
• Maximum block length 1,600’-0”
• Minimum radii at major road intersections is 50’, minor road intersections 12’
• Types of control devices:
  i. Stop signs
  ii. Traffic signals
  iii. Turning lanes
  iv. Islands
  v. Medians
  vi. Grade separations
• When intersection volume exceeds 750 cars per hour, traffic signals are required.
• Grade separations, which are needed once traffic volume exceeds 3,000 cars per hour is the most expensive type of control and the most space consuming

When laying out roads horizontally, certain practices are commonly followed:
1. **two curves in the same direction (broken-back curves)** should be separated by a “tangent” (straight line) no less than 200’-0”
2. **two curves in opposite directions (reverse curve)** should be separated by a “tangent” (straight line) no less than 100’-0”
3. **Two curves in the same direction with different radii (degree of turn)** (compound curves) should NOT be done.
4. **Simple curves** where a circular arc connects two tangents at either end (of the arc) can have any size tangent.
Vertical curves (changes in grade/height)

- Vertical road alignment is parabolic (flattened)
- Good vertical alignment provides a comfortable transition between two different grades avoiding overly steep inclines, sudden bumps, and hollows.
- Freeways, for example, may require considerable cutting and filling which is expensive and requires extensive reshaping of the landscape.
- Sight distances are kept long, to maintain a relatively distant forward view for the driver.
- Most common type of grade separation intersection is the “cloverleaf” (type of interchange) configuration is based on a system of right turns.
- The Direct left turn interchange is used where two freeways intersect, this configuration is more complex and expensive than a cloverleaf but allows for more high speed lanes and transitions.
- Diamond intersections are used where freeways intersect secondary roads. These are economical and use little space. The important characteristic of these are ramp grades. Up-ramp slopes are usually 3 and 6 percent; down ramps are 8 percent.

Left to right (cloverleaf-right turns), (Direct-left interchange-series of lefts turns), (Diamond Interchange)

PARKING

- A desirable location for parking is to locate the onsite drive between the building and the parking area, providing a clear view of the building entrance. The approaching driver then knows where to enter the building and searches for a convenient parking stall.
- When the amount of parking exceeds 400-500 cars, a distributor drive or “cartridge drive” is needed to handle the inordinate number of vehicles. (Similar to the road around dolphin mall and Dadeland mall)
- All parking areas, surface or structured should have handicapped parking clearly marked and situated for easy building access. (less than 200 feet from entrance)
- These spaces are specified in the ADA and ANSI legislated codes.
- Parking/storage should be provided for bicycles and motorcycles as well.
- 8’-4” is a reasonable minimum width for a typical parking stall.
PARKING continued

- For parking angles less than 40 degrees, stall width may be reduced to 8’ since car doors are clear of the next car
- Stalls are generally 18’-20’ long
- The minimum desirable width for a one-way driveway is 12’-0”
- For 90 degree parking, the width of the drive is determined by the required length to get out of a stall comfortably. Typical structured cross section is 18’(stall)+24’(drive isle)+18’(stall) = 60’ wide
  Or 20’ (stall) + 24’ (drive isle) + 20’ (stall) = 64’ wide
- For angled parking characteristics see (Kaplan page 12)
- When valet or attendant parking is utilized, minimum standards can be 8’ by 18’ stall with a 20’ drive isle for 90 degree parking. This is usually a result of attendant familiarity with the facility
- In estimating total area need, it is advisable to allow for 400 SF of parking area per vehicle. Ex. For shopping centers; 3,000-4,000 SF of parking for every 1,000 SF of tenant space should be considered. Such ratios are usually specified in the local zoning ordinance
- More cars can be parked in a 90 degree configuration than a 60 or 45 degree configuration
- 60 and 45 degree configurations establish a one way circulation system and are easier to maneuver in and out of. 90 degree parking however is less dangerous to back out of because of the greater drive isle width.
- For structured parking, ramps should not exceed 15% (speed ramp)
- For slopes 10% or higher, a transition of 8 feet on either side is required, the slope would usually be half of the actual slope of the ramp. Ex. For a 10% ramp 2 sections of 5% at 8’ long on top and bottom would be required
- A ramped driveway exit rising up to a public sidewalk must have a transition section no more than 5% so as not to obstruct the driver’s view of pedestrians on the sidewalk ahead (the hood of the car)
- The parking surfaces should be sloped for proper drainage between 1% and 5%
- Parking areas used at night should be well lit, generally one-half to one foot-candle
- To calculate land versus parking costs see (Kaplan page 12)

PEDESTRIAN CIRCULATION

- The area covered by a person is approximately 3 SF
- This is based on a shoulder breadth (width) of 24” and a body depth of 18” (adult male)
- In order to move about easily in a crowd and not be touched, 13 SF is required. less area tends to impede movement
- At 7 SF or less, pedestrians move in groups rather than individually
- At 3 SF or less, movement is extremely difficult and body contact may occur
- Walking involves balance, timing and sight
PEDESTRIAN CIRCULATION continued

- Sidewalks should be no less than 5’ wide
- Collector walkways, handling larger numbers of people should be no less than 6’-10’ wide
- Because pedestrian movement follows the path of least resistance, it is quite common to see footpaths worn into the turf on a college campus. Paving these footpaths is an old and practical technique.
- The primary objectives of good pedestrian circulation design are:
  i. Safety
  ii. Security
  iii. Convenience
  iv. Continuity
  v. Comfort
  vi. Attractiveness

- To provide safety, pedestrian-vehicular separation is desirable, this can be achieved by grade-separation walkways above or below streets
- Security can be achieved through clear sight lines and well lit pathways.

PUBLIC TRANSIT

- In the years following world war II, American cities experienced their greatest era of growth and expansion
- The federal government created a low-interest home mortgage financing program
- In the 1950’s, it initiated the interstate highway system.
- Together, these two programs were responsible for the creation of the post war American suburb, shopping center and industrial park
- All urban transportation is public; automobiles operate on public streets, as do buses. Most rail transit systems and commuter systems are also publicly own. Therefore; the term “individual” and “collective” in reference to transportation systems are considered public systems because the recourses such as the road and/or track on which they run are public but the actual automobile is not, nor the space in which it is parked.
- No collective transit system can be operated efficiently below a population density of 30 persons per acre. Such a requirement is necessary for the proper operation of such a system.
- Outlying developments should coordinate their population densities with rail and bus transit systems to establish and make use of these resources efficiently. This is currently happening in today’s developments which wasn’t the case before.
PUBLIC TRANSIT continued

Public transit types

- *Walking*; walking speed varies from 2.5 to 4.5 miles per hour. The maximum distance that most people will walk to a destination is ¼ to ½ mile

- *Local Bus*; is useful for trips in medium density areas. Buses travel at an average of 15 to 30 miles per hour. People are willing to spent up to a ½ hour for most urban travel, whatever the mode

- *Express bus*; is useful for trips between medium density areas and at specially planned and convenient stops/terminals between high density areas. These travel at an average of 40 to 60 miles per hour

- *Rail rapid transit*; is useful for trips between medium density areas, high density areas and for short trips within high density areas. These usually travel between 40-70 miles per hour

- *Monorail*; is a one-rail system but most in fact have several rails. These have the disadvantage of only being above ground which may not be possible in central city areas. A truly useful rail rapid transit system should be capable of being above, below or at ground level and thus fully adaptable to the area it serves

- Sustainable design encourages TOD (transit oriented design) development to encourage the use of public transit and give the people of housing, commercial, and institutional developments more options for transportation. This allows property owners to save energy, invest more in their properties and spend less money on private vehicles.
PROVITIONS FOR THE HANDICAPPED

- There are at present between 18 and 20 million people with physical handicaps in the US.
- Impediments to the free movements of such persons are referred to as “architectural barriers”.
- There are several types of disabilities, each requiring special considerations in planning and design. The five most common are:
  i. **Non-Ambulatory** disabilities confine persons to wheelchairs. This type is of particular concern because it influences the physical layout and configuration of sites and buildings.
  ii. **Semi-ambulatory** disabilities cause persons to walk with insecurity or difficulty and may necessitate the use of crutches, walkers, or braces.
  iii. **Coordination** disabilities are manifested by impairments of muscle control to the limbs.
  iv. **Sight** disabilities affect sight, totally or partially, to the extent that an individual functioning in public areas is insecure and prone to injury.
  v. **Hearing** disabilities affect hearing ability. Totally or partially, to the extent that an individual functioning in public areas in insecure or prone to injury due to an inability to communicate, or to hear warning signals.

- The basic wheelchair is shown in the figure above, the electric wheelchair is 9 inches longer.
- The minimum turning space for a wheelchair is 60 inches, or 5’.

ACCESSIBLE WALK STANDARDS

- The basic wheelchair is shown in the figure above, the electric wheelchair is 9 inches longer.
- The minimum turning space for a wheelchair is 60 inches, or 5’.
• The minimum space required for two wheelchairs to pass each other is 60 inches or 5’. This suggests that all public walks should be no less than 5’ wide.

PROVITIONS FOR THE HANDICAPPED continued

• Minimum walkway gradient for wheelchairs is 1:20 or 5% with a max cross gradient of 1:50 or 2%

• Where an accessible walk crosses a curb, the width of the walk should be 3’ minimum with flared sides that slope a maximum of 1:10. Where the curb height is 6 inches, a minimum curb cut out of 13’ is necessary.

• There must not be edges or cracks greater than ½ inch.

• Whenever two walks join, they should blend to a common level. The blend should not exceed a gradient of 1:12 or 8 1/3 %

• Curb cutouts should be identified by a 1/16 inch yellow abrasive anti-slip epoxy finish applied to the entire area of the curb cutout, or by abrasive strips 1/16 inch thick and 2 to 3 inches wide

• These yellow strips and paint color should be placed wherever walkways intersect with streets no matter the type of curb or gradient treatment used.

• Where traffic islands intersect pedestrian walkways, a 3’ wide street level path (cutting through the island) must be provided.
Ramps

- Ramps should be provided wherever a vertical drop is greater than ½ inch
- As before, the gradient of the ramp must not exceed 1:12 or 8 1/3 percent. Preferably it should be 1:16 or 6 ¼ percent whenever possible.
- Ramps should be a minimum 3’ wide and not exceed 30’ in length
- At all ramp surfaces between inclinations, a 5’ long level landing must be provided.
- If a ramp rises more than 6” or runs longer than 72 inches, handrails must be provided.
- A protective curb should be provided on either side of the ramp if above finish grade.

Parking

- The spaces should be a minimum of 8’ wide with a 5’ wide access isle between every two spaces. These access isles must be connected to the accessible route present at the site.
- The handicap spaces should be as close as possible to the building entrance but never more than 200’ and clearly marked with the symbol of accessibility.
- Ratio of parking to handicap spaces:
  - i. 7 to 50 spaces = 2 handicap required
  - ii. 51 to 100 spaces = 3 handicap required
  - iii. 101 to 150 spaces = 5 handicap required
  - iv. 150 + spaces = 5 plus 2 for every additional 100 spaces

  Example: 550 spaces = 13 spaces required.
  
  \[
  \begin{align*}
  150 &= 5 \\
  400 &= 8 \\
  \text{Total} &= 13 \\
  \end{align*}
  \]

- Other handicap requirements include special non grasp hardware for doors, and other characteristics for stairs, elevators, restrooms, drinking fountains, telephones, signage, and vending machines.
- Special facility accommodations include: performing arts, school laboratories, and kitchens.
SERVICES AND UTILITIES

- The development of land for residential, commercial, industrial and community uses depends largely on the availability of various services and utilities.

- These include:
  i. Water
  ii. Gas
  iii. Electricity
  iv. Communication systems
  v. Wastewater systems
  vi. Drainage systems and
  vii. Flood control

- Other services that should be considered are:
  i. Trash collection
  ii. Fire protection
  iii. Mail distribution
  iv. Snow removal
  v. Public transit
  vi. Provisions for public health and safety

- Publicly run utilities include: water distribution, water treatment, water collection, storage, control of storm water and protection against flooding.

- Telephone service is always provided by private companies.

- Public/private services include: electricity, gas, and transportation services depending on the community.

- Private companies operate under franchise and are regulated by a government agency such as the state utility commission.

- Sustainable design planning encourages “infill” development. Rather than disturbing an existing natural site, existing building sites and utilities are used instead of creating new ones. This allows for:
  1. Possible lower first cost (reusing existing infrastructure rather than creating new systems)
  2. Less environmental impact (not disturbing an existing, undisturbed, natural open space)
  3. Creating higher density development, which more efficiently uses the infrastructure and supports nearby public transit, parks, and commercial districts
MEANS OF DISTRIBUTION FOR UTILITIES

- Some are transported in: conduits, pipes, channels, and wires.
- The area beneath the public right-of-way (roads) is the most logical and efficient location for services to buildings. These may include:
  i. Wastewater mains,
  ii. water mains,
  iii. gas mains,
  iv. electric power conduits,
  v. cable television lines and
  vi. steam mains
- Planning for underground utilities is the responsibility of the local government, which has jurisdiction over the streets. All utility requirements for the next 5 years should be installed before the street is repaired (paved). This should include the connections to property lines under the street curbs.
- When planning for underground utilities, the following should be considered:
  1. Wastewater lines should have first priority because of their gravity requirement.
  2. Locate Trunk lines (mains) in side streets rather than on a busy/major artery if possible. Negates major road closures.
  3. Trunk lines for several utilities should not all be located in the same street so if one is effected, not all are disabled at ones.
  4. Wastewater lines should be located in the center of the right of way unless width allows for two wastewater lines on either side.
- Future demands in urban areas are based on population projections.
- Stats indicate that an average of 150 gallons/person/day is required in some areas.
- Factors that can influence demand are: the amount and type of industry, climate, open space and cost.
- A water supply system’s components include: those that procure, treat, and distribute water to users.
  1. A **source**: this includes: lakes, rivers, streams, wells and coastal desalination projects.
  2. **Transmission mains**: aqueducts, canals, and pipelines which transmit raw water to treatment plants or to the distribution system of untreated water.
  3. **Water treatment plants**
  4. **Distribution systems**: these convey treated water to the users’ properties; the systems may include reservoirs and pumping stations.
  5. **Metered connections**: between the distribution system and the user’s properties.
- The type of distribution system used is determined by:
  i. The street plan
ii. Urban density

iii. The topography

MEANS OF DISTRIBUTION continued

- Water supply systems are installed in either:
  i. a branch pattern or
  ii. Gridiron Patterns; can be improved by installing a “loop header”. This ensures that supply will come from more than one direction. If one were to be compromised, the other would compensate.

- In densely populated areas, the single or dual main system is prevalent.
- Dual systems allow for connections on both sides of the street reducing cost of connecting to ones property.
- Conduits and piping used in distribution system mains may be:
  i. Cast iron
  ii. Wrought iron
  iii. Steel
  iv. Plastic or
  v. reinforced concrete (for larger sizes)

- Water main sizes depends on location:
  i. In residential areas, 6 inches is typical
  ii. High Density districts, 8 inches is typical

- Shut-off valves are usually located at the property line. Main line valves are at 500’ intervals, if one were to be compromised, only that sections would suffer.
- Fire hydrants are located 150’ apart in high density districts and 600’ apart in suburban areas.
- Public water supply is usually not available where the population is less than 1000 persons per square mile.

WASTEWATER SYSTEMS

- A wastewater system’s function is to collect and dispose of sanitary wastes from plumbing fixtures and other similar collection points.
- The design of wastewater systems involves:
  i. population projections,
  ii. industrial growth
  iii. topography
  iv. soil conditions
  v. rainfall
  vi. water quality
  vii. water reclamation

- Wastewater lines are maintained at a constant slope depending on the size of lines and capacity of flow. A velocity of 2.5 feet per second to convey solid waste materials is required. This should never exceed 10 feet per second.
- A 2% grade/slope is required to transport solids. If topographic conditions require, pump/ “drop manholes”/ lift stations are used to convey the material.
- When pump/lift stations are used over a long distance, this is considered a “force main”.
- Although wastewater lines must conform to the topography, grid patterns established by the right-of-way (roads) dictate the wastewater lines location.
WASTEWATER SYSTEMS continued

- Wastewater lines are usually the lowest structure under the right-of-way (road). Where street width prohibits, these mains can be located on either side of the street.
- Materials used for wastewater mains include:
  i. Vitrified clay
  ii. Cast iron
  iii. Plastic
  iv. Light-weight fiberglass reinforced mortar plastic
- Sections can be up to 4’ wide in (diameter) and 20 feet long
- Sequential order from smallest to biggest are:
  Laterals → sub mains → Trunk lines → Treatment plant → Outfall (release)

ELECTRICAL UTILITY FACILITIES

- Electrical power is generated primarily by turbines powered by steam produced by burning coal, oil, or gas or sometimes by water power. Some power plants utilize nuclear reactors to produce the heat to transform water to steam. These are usually away from population centers.
- Small plants that use diesel-driven generators are commonly found in small communities. Hydroelectric plants are located near water
- Substations are located so as to form “service areas”. These can be located underground, in buildings, or enclosures screened by walls, fences, or landscape. Ex. Douglas road and Bird road

TELEPHONE AND TELEGRAPH

- Telephone trunk lines are generally placed in underground conduits in street right-of-ways. Local lines may be located on poles, generally shared with power lines.
- Fire and police alarm systems are closely related to telephone systems.
- Wires from alarm or call boxes are generally placed in underground conduits.

CATV

- Cable antenna televisions is popular in urban areas that lack conventional TV broadcast facilities, or where building heights, topographical features, mineral deposits and other conditions make conventional reception unsatisfactory.

GAS UTILITY SYSTEMS

- Gas utility systems are located within the right-of-way (road) under the sidewalk area on both sides of the street, or in alley, or rear lot easements.
- Regulating stations are located in various parts of the community.
- In residential areas, they are often located in underground vaults.
• If natural gas is not available, it can be manufactured in a facility along with storage tanks which are located in industrial areas.
• Gas systems are distributed in the same way as water systems. (see page 15)
• The primary pipe is welded steel; some incorporate cast iron since these were the first to be used by the gas industry. Because the steel pipe is buried, corrosion can occur, to alleviate this problem asphalt, coal, tar, and extruded and taped plastic compounds are used to control corrosion.
• Additional equipment needed for gas systems are:
  i. Valves
  ii. Pressure regulating systems
  iii. Flow meters
  iv. Compressor stations

FLOOD CONTROL AND DRAINAGE SYSTEMS

• Sustainable design encourages building above the 100-year flood elevation.
• “Storm water” refers to the flow of water on ground surfaces or drainage channels produced by rainfall or melting snow. It must be collected, stored, and conducted to its eventual outlet so as to avoid water damage.
• The management of surface drainage may involve regulation of density, minimizing paved surfaces, maximizing planted areas, careful grading to ensure gentle slopes and positive flow, and utilize ditches, check dams, and culverts.
• A storm drainage system consist of the :
  i. Drainage surface
  ii. Open gutters
  iii. Ditches
  iv. Underground pipes (usually made of vitrified clay connected to manholes and fed by inlets)
• Drainage pipes bigger than 42 inches are made of concrete
• Today, storm drainage systems are separate from wastewater systems to ease the load on treatment plants and prevent overloading the sanitary waste conduit.
• Once the water enters the “inlet” water is conducted by short branch lines to the main storm drain. These junctions are generally located at manholes 500 feet apart. Manholes are also located at the ends of the lines and at each change in direction. The lines usually have enough slope to promote high velocity self cleaning. This may be 0.3 % minimum which develops flow speeds of about 2 feet per second. Anything over 10 feet per second should be avoided.
• Drainage systems are generally in the right-of-way (road), but sometimes it is necessary to obtain an easement to pass through private property.
LESSON 2- SITE ASSESSMENT AND SITE WORK

- The exact location of the site, as well as its orientation, topography, existing vegetation and subsoil conditions all influence the design of the building, including the materials and methods of construction.
- All potential sites should be verified for satisfactory size, topography, orientation, and access as well as the availability of utilities such as water, electricity and gas.
- All site restrictions imposed by city, state, federal regulations such as zoning, easements, and subsurface rights must be investigated.
- Perhaps the most important of all site factors should be a soil investigation to verify that the soil is adequate to support the intended structure.
- The land forms and ground slopes effect a buildings:
  - Foundation
  - Drainage
  - Microclimate
- Vegetation can affect a sites:
  - Microclimate
  - Views
  - Solar radiation
  - Sound travel
- Exterior sounds can affect the:
  - The orientation of a building
  - The choice of materials
  - Sound control methods employed
- Orientation of a building can affect:
  - The solar radiation received on the structure
  - Availability of natural ventilation for the spaces
  - Potential views from the building
  - Ease of access to the site

CLIMATE

- The climate of a region is substantiated with data collected over many years which includes:
  - The range and distribution of temperatures
  - Hours of sunshine
  - Wind direction and velocity
  - Precipitation
  - Humidity factor
- The climate of a region can be altered by local conditions (microclimate) which include:
  - Topography influences
  - Surrounding structures (ex. Rows of buildings creating a wind tunnel effect, or “shaded urban canyons”)
  - Exposure (daylight...)
  - Ground cover (types of vegetation)
  - Site elevation (above sea level)
  - Bodies of water (lakes, streams, brooks, ponds, ocean etc...)
CLIMATE-continued

- People are most comfortable (comfort zone) within a narrow range of related conditions including:
  - Temperature (65 to 75 degrees)
  - Humidity (30% to 60% relative humidity)
  - Air movement
  - Air quality
- Comfort zone scenarios:
  - At higher temperatures, mechanical cooling is necessary.
  - At lower temperatures, mechanical heating is necessary.
  - At excessively low humidity’s, moisture must be added to the air.
  - At excessively high humidity’s, moisture must be removed to maintain comfort.
- The architect with the help of a mechanical engineer has the responsibility of designing for indoor climate comfort.
- Sustainable design encourages a holistic approach that allows the architect to understand all the environmental issues (climate, sunlight, soil conditions, etc.) before initiating the design process.

Orientation

- The ideal orientation for a structure in the northern hemisphere is lightly east of south, since the south side of a building receives more radiation in winter and less in summer.
- The east and west sides receive low morning sun and late afternoon sun in the summer.
- The north side of a building receives little-to-no sun in the summer and winter. An advantage to northern light is its relatively even intensity making it ideal for program relating to artists studios and architectural drafting.

The sun’s path

- The angle of the sun is at it’s highest during the summer solstice (June 21st).
- The angle of the sun is at it’s lowest during the winter solstice (December 21).
- The angle of the sun is at the midway point at (March 21st and September 22nd).
- Sun control in the form of overhangs, fins, or louvers are widely used to limit the amount of solar radiation entering a building in the summer month. Whatever their design, they should admit light and views, exclude the sun’s heat and glare during the warmer months, but admit solar heat during the winter.
- The use of sun shields outside of a building is far more effective than trying to reflect or absorb the heat after it contacts the building surface.
- Properly designed sun shading devices can reduce heat gain and lower air conditioning costs by 15 % or more.
The sun’s path-continued

- Low buildings can be shaded by deciduous trees, which block the summer sun while permitting the winter sun to enter.
- Trees may also be placed to intercept winter winds while allowing cooling summer breezes to pass.
- Trees also:
  - Reduce noise
  - Filter air
  - Reduce glare
  - Provide a feeling of privacy and protection
  - And serve as a good aesthetic feature

Northern Latitudes:
- In the northern hemisphere, the sun’s path is predominantly on southern facades.
- Heat transmission through walls is most important in the northerly latitudes.
- In northern latitudes, for sun control, a longer overhang is needed to compensate for the lower sun angles.
- In northern latitudes, horizontal overhangs are effective for southern exposures.
- Vertical fins are effective when used on east and west exposures.

Southern Latitudes:
- Heat transmission through roofs is most important in the southerly latitudes.
- In southern latitudes, sun control can be obtained with short overhangs.

Winds

- Wind intensities and directions vary widely in different parts of the country. Data collected over the past 50 years has been used as the basis of a wind speed map as well as a table of wind pressures.
- Most areas have a basic wind speed of 70-80 mph. This equates to a pressure of 13-17 pounds per square foot at a height of 30 feet. According to the UBC tables.
- Higher wind speeds occur on the gulf coast from Florida to Texas and on the Atlantic coasts where buildings must incorporate structural systems that are designed to resist very high wind forces.
- Wind loads increase with height, while at ground level, wind loads decrease to almost zero.
- The shape and orientation of a structure also affect wind load pressures.
- Wind pressure is expressed in pounds per square foot (PSF), and varies as the square of the wind velocity in miles per hour (MPH).
- Ex. A wind velocity of 70 MPH causes a wind pressure of about 13 PSF. If the wind velocity doubles, the wind pressure increases fourfold to about 50 PSF.
- Wind direction and intensity must also be considered in relation to climate and the effect it may have on a building’s heating and cooling systems.
- Analysis should be made between winter winds, which should be blocked as much as possible and cooling summer winds which should be allowed and utilized as much as possible.
- Tree windbreaks are particularly effective in protecting large downwind areas.
Winds-continued

- Protection from winter winds improves outdoor comfort, as well as reduces the heating requirements for buildings that are protected.
- High-rises can have detrimental effects on wind patterns as they relate to spaces around the buildings. Tall buildings act like wind breaks, part of the wind blows up and over the roof, and part flows down the face of the building, creating a vortex near the ground. Open plazas at the ground level of large building, while aesthetically pleasing, can be quite uncomfortable at certain times. A similar effect occurs when the ground level of a building is open. The open spaces acts as a wind tunnel’s increasing wind velocity substantially.

Fenestrations

- Windows allow for:
  - Views into a space as well as to see out
  - Allow natural light to enter
  - Allow the admittance of fresh air (if operable).
  - Allow solar radiation to enter

- The sustainable design approach has taught us that occupants need better control of their internal environment than formally believed.
- Glass allows for solar energy to enter a building, and this energy can be a useful source of natural heating during the colder months.
- Glass has a heat loss factor of up to 20 times greater than an insulated wall.
- The glass area of a building is one of the most critical elements with respect to heat gain and heat loss. This can be overcome by the use of:
  - Multiple glazing
  - Heat absorbing or reflective glass
  - Sun control devices
  - Smaller window openings

- Day-lighting, a technique used in the sustainable design approach, combines natural sunlight with dimmed overhead lighting to reduce energy costs and indoor lighting heat loads.

EXTERIOR MATERIALS

- In order to reduce heat gain in summer and heat loss in winter, the roof and walls of buildings must be insulated.
- The measure of heat transfer through a material is the U-Factor which is the number of BTU (British thermal Units) per hour that passes through one square foot of wall or roof.
- The U-Value indicates the speed of the transfer; a low U-value indicates slow heat loss or gain. A high U-value indicates rapid heat low or gain.
- Thermal Inertia is the ability of a material to store heat.
EXTERIOR MATERIALS—continued

- Heavy materials absorb and store peak heat loads and later release them when the outside temperature drops. Concrete and masonry have high heat storage capabilities. These materials are best suited for places with high temperature differentials such as Phoenix Arizona. The heat is stored during the day and released at a slow pace at night allowing for a more balanced environment.
- In hot-humid environments such as Miami, the use of wind and breezes is prevalent in design.
- Cold-temperate climates like New York should have heavy materials on the west facing façades to delay the impact of late afternoon heat and adequate insulations on all other walls.

![Diagram showing thermal inertia and insulation]

- Cold climates require the same treatment as Cold-Temperate climates only with higher insulation values.
- Rigid insulation should be used at edges of slabs on grade to prevent heat loss in cool and temperate areas. Un-insulated slabs, however, are satisfactory in warmer climates.
- Climate causes deterioration of materials in a variety of ways:
  - Rain
  - Humidity
  - Frost
  - Sun exposure
- Metal corrodes near the ocean and therefore its use should be limited unless the required maintenance can be provided.
- In extremely dry temperature areas, wood tends to split and check.
- In hot-humid areas, wood is subject to mold and fungi which makes it extremely vulnerable.
SOLAR HEATING AND COOLING

- In recent years the potential for energy shortages has stimulated the investigation of alternative energy sources.
- Heating buildings with solar energy is favorable versus conventional heating in terms of cost effectiveness.
- Cooling with solar energy is more difficult. No complete heating and cooling system has yet been built and operated economically.
- Sustainable design encourages architects to explore innovative technologies such as: solar hot water heating.
  - PV (photovoltaic) paneling for electrical production
  - Active and passive solar design for heating and cooling
  - Fuel cell for electrical production
  - Ice storage for “off-peak” cooling.

MECHANICAL EQUIPMENT

- As previously mentioned, heating building with solar energy is possible but heat must be provided through mechanical means.
- The cost of heating is related to the difference between the outdoor winter design temperature and the indoor design temperature. Ex.
  - The outdoor design temperature for Boston, MA is 0 degrees Fahrenheit.
  - 20 degrees Fahrenheit in Los Angeles, CA
  - 40 degrees Fahrenheit in Miami, FL
- The design temperature is a working number and, technically, is not the lowest temperature ever recorded for an area.
- Desirable indoor temperatures vary with different programs.
  - Gymnasiums generally have low indoor temperatures.
  - Hospital rooms generally have high indoor temperatures for frail patients.
- Indoor temperatures vary with the season of an area, generally being higher in winter and cooler in summer.
- Hot-humid areas generally do not need heating; however, cooling and dehumidifying the air and reducing heat gain are of prime importance.
WATER

• Water is more than a physical necessity—it is a vital part of the landscape both aesthetically and emotionally.

Uses of water

• Water has many functions in site design. Some are aesthetic in nature—the still water of a lake is soothing and evokes a feeling of serenity. However the body of water need not be natural to have a strong impact; the rigid geometry of a reflecting pool may also provide a contemplative setting.
• Water also moderates the microclimate of a site.
• The sound of falling water may be used to mask urban noise from cars and other sources, as in Freeway Park in Seattle.
• The site planner may have to consider the conflicting needs of recreational users, swimming vs. power boating.

Water in site design

• Wherever a body of water exists, the land near it is very desirable, and this is reflected in the high price of waterfront property.
• Any body of water should be preserved, protected, enhanced and left undisturbed whenever possible.
• Polluted surface runoff should be treated or filtered before being allowed to flow into a body of water. Natural drainage channels should be maintained whenever possible and provide detention swales or ponds to prevent flooding.
• Waterfront property can be enhanced by limiting development along the shoreline, thereby creating attractive open space, as well as a much longer effective shoreline set back from the water.
• For water bodies, it is often desirable that its shape be natural and curvilinear, rather than artificial and geometric unless its location such as in an urban setting dictates its shape.
• Views of water can be enhanced by merely limiting the views such that the entire body of water cannot be seen from any point. This adds a sense of mystery and appeal.
• Where possible, the banks of ponds should be left undisturbed unless required to prevent erosion. Such bank treatment may consist of:
  - stone
  - reinforced concrete
  - treated lumber
  - steel
• Freeboard: is the distance between the water surface and the crest of the banks. This should be where the highest expected water level will be. The freeboard should also be high enough to resist the highest wave action.
Streams
- A stream is always part of a natural drainage system, and therefore, it should not be disturbed.
- Vegetation near banks and shorelines should not be disturbed, because the removal of such vegetation could result in loose soil and may be susceptible to erosion.
- When establishing a crossing over a body of water, location should be determined by:
  - Span distance (the shorter the span the better, where the water body is the narrowest)
  - Where the banks are stable to receive structure
  - As the highest expected flood level
  - If the highest area is not feasible, the structure should be designed to resist “dynamic action” of floodwaters.
  - In areas of long spans and additional piers in the water will be necessary, such piers should be oriented with their long dimension parallel to the flow of water.
- An open manmade channel is also a stream, usually lined with concrete. Such channels are most efficient when straight, without curves or bends, and with a constant width and depth.

Waterfalls and fountains
- Each waterfall is unique and creates a different effect. The interaction of water, light and sound is always spectacular and is usually a focal point of a space.
- A fountain is perceived as a cool element, making it particularly attractive in a warm, dry climate.

Water cycle
- All water on the earth, under the ground, and in the atmosphere is part of one unified system called the hydrologic or water cycle.
  - Precipitation: water that falls on the land as rain or snow.
  - Runoff: water that flows over land which empties into a stream and eventually into the ocean.
  - Infiltration: water that soaks into the ground.
  - Transpiration: water that evaporates into the atmosphere.
- Site planning is concerned with all of these hydrologic processes, particularly runoff and infiltration. When a site is developed, the amount of runoff increases.
Water cycle - continued

- Site development generally entails the removal of some vegetation, thus decreasing the amount transpiration. When a site is developed with buildings, streets, and parking areas, these reduce the ability of the precipitation to infiltrate the land and transpiration to occur resulting in more surface runoff (runoff coefficient).
- This situation can be remedied in several ways:
  - The runoff can be channeled to the drainage system immediately.
  - Rainfall can be held in a detention pond on site and released gradually to avoid overloading the drainage system which could result in flooding. This is usually required by the local zoning ordinances. It says that the flow of rainwater from the site should be equal to the original flow prior to development. Sustainable design strategies encourage this approach because the presence of wetland vegetation on the sloped banks can help filter the water naturally.

Potential Flooding

- Urbanization has a similar effect on the hydrologic cycle: the amount and speed of runoff is increased, the runoff is warmer and contains pollutants, and the stream which eventually carries the runoff is visually impaired as a result of erosion and pollutants.
- The relatively flat land within which a stream flows is called a floodplain. The level of flooding is measured in the extent and frequency that a particular area floods. For example, a 10-year-storm suggests that level of storm water is likely to occur every 10 years, or 10% chance in any given year. Note: 100-year-storm= 0%
- Thus, floodplains should be limited to open space uses, such as recreation and agriculture. If the area should be developed, establish the most logical magnitude floodplain (ex. 10-20-30-100-year floodplain) and set the floor elevation above that level.
- Low-density housing is often permitted, providing the occupants are aware of the potential hazard and the structures are elevated above flood level.
- In floodplains:
  - The water table is usually high, near the surface.
  - Drainage is generally poor.
  - The soil is usually deep and uniform. Heaving, expansion and contraction happens regularly in these areas because of the presence of moisture making it unsatisfactory or building foundations but excellent for agriculture. The rivers in floodplains are usually meandering.
  - A conventional solution for this circumstance is manmade concrete channels or canals like south Florida and Los Angeles.
Underground water

- Underground water is found either in the zone of aeration (the higher zone) or the zone of saturation (the lower zone). The zone of aeration contains both water and air between soil grains and voids.
- The groundwater table is the transition between these two zones.
- This is usually a sloping surface which fluctuates seasonally and roughly follows the ground surface.
- In places where the water table is high, about 6 inches, construction excavation must be braced and kept dry by pumping. Basements must be waterproofed and designed to resist hydrostatic pressure. Underground structures must be designed to resist uplift and the bearing capacity of the soil is usually compromised.

- “Underground rivers” or permeable material through which water flows is called an aquifer.
- Sand, gravel, sandstone and some limestone’s are generally good aquifers. Clay, shale and metamorphic or igneous rock are poor aquifers.

PLANTS

- Plants are an important site design element and provide beauty and vitality to the outdoor environment.
- Indigenous (native) plants are usually easier to maintain and often provide functional benefits such as:
  - Filtering storm water before entering water bodies.
  - Providing habitats for local wildlife.
- The site planner must take into account the seasonal characteristics and growth patterns, and realizes that the plant this is placed in the ground today will look different next month and next year.

Defining space

- All living organisms in the environment draw their sustenance (food or drink) from the soil.
  - Ex. Trees
  - Shrubs
  - Ground cover
  - Lawn—all plants
Defining space-continued

- Since native plants are well suited to their site (by their very existence), they should be preserved whenever possible unless there is an overriding reason to move them.
- When defining space, plants are subtle. Trees or shrubs may provide a feeling of vertical enclosure, without actually enclosing an area.

Trees - *trees enclose, direct and connect* ...

- With deciduous trees;
  - The spatial definition is much stronger in the summer than in the winter, when the trees have lost their foliage.
  - Closely spaced trees may also provide a horizontal enclosure, or ceiling.
  - In addition to forming enclosures, trees may visually connect structural elements such as buildings.
  - They can also channel/direct people into spaces.

- Plants can at as screening devices (screening the service area of the vignette) a cluster of tall, dense trees may provide privacy for an outdoor terrace. While trees block the view into the terrace, they also block the view from the terrace. Thus separating it from its surroundings.
- Unattractive site elements may be visually screened by planting: most people would rather look at a back of trees than mechanical equipment or parked cars.
- When screening unwanted views or elements, evergreens are most effective throughout the year.
  - Trees block both the sun and wind.
  - Trees act as natural air conditioning by cooling, humidifying, and filtering the air.
  - They create sheltered zones by reducing wind speeds.
  - Trees and other plantings help control erosion, destructive runoff and flooding.
  - They absorb sound.
  - They provide a habitat for birds and many other species of wildlife.
- In general, when designing the landscape, trees should be grouped in clusters as in their natural state, not spaced regularly or too far apart. Unless in an urban setting to where grid patterns are present.
- Smaller trees and shrubs are:
  - used to subdivide the site into smaller areas
  - They visually connect the various site elements
  - Define paths and roads
  - Add visual interest
The stability of a building depends on the bearing capacity of the soil upon which it sits.

- Soil composition determines a soil’s weight bearing capacity.
- Soil is formed by the chemical decomposition of rock:
  - Water
  - Air
  - Temperature action on the rock
  - Decay of vegetable and animal matter
- A variety of these processes has resulted in the top layer of the earth’s surface.

**Soil types (size)**

- Rock, often referred to as bedrock, is the solid material that forms the earth’s crust. It is the strongest support for the foundations of structures.
- Shale/ slate: are fine textured soft rocks.
- Boulders are detached portions of bedrock.
- Decomposed rock is pieces of disintegrated rock mass which were originally solid.
- Hardpan: is a consolidated mixture of gravel, clay, and sand, and it is a good foundation base for buildings
- Gravel (1/4-3.5 inch): consists of granular rock particles ranging in size from ¼ inch to 3 ½ inches. Anything larger is a cobblestone and if still larger, a boulder.
- Sand (.002-1/4inch): consists of loose granular rock particles ranging in size from .002 inch to ¼ inch. Sand and gravel are course grained soils that provide an excellent base for building foundations as well as drainage capabilities. Very permeable.
- Silt (.002 or less): is a fine-grained sedimentary material deposited from running water.
- Clay: is a fine grained, firm cohesive material formed from the decomposition and hydration of certain rock. Clay is plastic when wet and relatively hard when dry. Clay is impervious and swells when in the presence of water and shrinks when dry. Not recommended for building foundations.
SOIL EXPLORATION AND TESTING

• The principal reason for all subsurface exploration is to establish the intrinsic characteristics of the soil.
• To understand a site’s soil conditions, the architect generally requests a subsurface exploration of the site.
• The test pit and soil load tests are two methods that offer immediate results.
• Other tests that involve boring into the earth include:
  ▪ Auger borings
  ▪ Wash borings
  ▪ Core borings
  ▪ And dry sample borings

Test pits

• Test pits are simple excavations that allow direct visual inspection of the actual soil conditions.
• Open pits allow close-up examination of the soil layer’s, as well as access to undisturbed samples for laboratory testing.
• Any substantial excavation for test pits is costly and generally not dug below the water table.

Soil load tests

• A platform is erected on the site and loads are increased incrementally until settlement becomes regular under subsequent loadings. The total test load is usually double the contemplated design load.

Borings

• **Auger borings** are designed to bring up soil samples by means of an ordinary 2-2 ½ inch auger fastened to a long pipe or rod. The auger usually stops at the first obstruction. This method is most effective in sand or clay and cannot exceed 50 feet.

• **Wash borings** are useful in locating bedrock when the soil in too compact to use an auger. These borings are made with a 2 to 4 inch diameter pipe that is driven into the soil and contains a smaller jet pipe through which water is forced. The material washed up is often thoroughly mixed, reducing the dependability of the sample. Another drawback is that boulders can be mistaken for bedrock. This system can penetrate all other materials and can be extended downward 100 feet or more.

• **Core borings** are more costly than most other methods but are also the most reliable. They can penetrate all materials and reach great depths to bring up complete cores of materials through which they pass. Core borings are made with a diamond drill that is sufficiently hard to cut through rock.
Borings-continued

- **Dry sample borings**: utilize a drive pipe with a special split sampling pipe at the tip instead of a drill. It driven down approximately five inches, then lifted out, and the contents removed and stored. Soil samples are removed every 5 inches and tested in a laboratory for testing.
- For large structures, a site plan with the building footprint is used by the structural engineer to indicate the number, size and location of the test borings to be made. Soil analysis is made by a soils engineer or agency that is generally subject to approval by the local building department.

Soil properties

- Some properties for which soil may be tested include:
  - **Specific gravity**, to determine void ratio
  - **Grain size** (for granular soils), to estimate permeability, front action, compaction, and shear strength.
  - **Grain shape** to estimate shear strength
  - **Liquid and plastic limits** (in cohesive soils), to obtain compressibility and compaction values.
  - **Void ratio**, to determine compressibility
  - **Unconfined compression** (in cohesive soils), to estimate shear strength.
- Based on these tests, a written soils report in prepared in which the soils engineer recommends the type of foundation to be used and the allowable soil bearing pressure.

**SOIL AND SITE PROBLEMS**

- Common soil problems may consist of:
  - Inadequate bearing capacity
  - Subsurface water
  - Shrinkage
  - Slippage
  - In some parts of the country—unpredictable earth movement due to seismic forces.

Settlement

- Settlement of buildings must be carefully considered, except when the structures foundations are on solid bedrock where little or no settlement can occur. As dead load is added to the structure, it compresses the soil beneath the footings, reducing the void volume and causing settlement.
- Slight uniform settlement throughout the structure is not considered serious.
- Differential settlement may cause serious cracks or even. For a number of reasons, settlement may continue for several years after a building is completed.
SOIL AND SITE PROBLEMS—continued

Front action

- In cold climates, the freezing and subsequent thawing of soil may cause the ground to heave the in tern places stress on a buildings foundation, which can lead to serious damage. The extent of frost action depends on the soil type and geographic location. In areas of such occurrence, foundations should be located below the frost line.

Earth movement

- Earth movement is more likely to happen with clay subsoil, as clay may swell when wet and shrink when dried. Near the surface, where variations in moisture are common, there may be considerable earth movement. Because of this, footings that are close to the surface (above five feet) are more likely to have structural problems versus footing located at a greater depth.
- The moisture content of clay beneath an already existing building can also be affected by an adjacent excavation if precautions for such moisture are not accounted for. This can cause further settlement or slippage of the subsurface clay either of which can lead to serious damage.
- Sloping layers of earth can also cause problems, as they tend to move as a mass when subjected to excessive rain or moisture. This is evident in older structures that have a slight tilt.

SOIL DRAINAGE

- Many severe soil problems are caused by the presence of moisture, both at and below grade. This can result in:
  - A reduction of a soil’s load bearing capacity.
  - Leakage of water into a building (hydrostatic pressure, capillary action)
  - Disintegration of certain building materials.
  - Because of this, all subsoil investigations and water table evaluations must be considered before any excavation or construction is attempted.
Water table

- The level below which all soil is saturated with groundwater is known as the water table. (see page 10)

- In general, the water table roughly follows the ground surface, although, its level can fluctuate due to seasonal changes and construction on the surface such as paving for a parking lot or foundations for structures.

- Building foundations should be located well above the sites water table to avoid potential damage due to hydrostatic pressure or capillary action. This can be avoided by diverting subsurface away from a structures foundation using a drain tile system or also known as a French drain. Drain tiles have a minimum dimension of (6 inches) and are laid in gravel or another kind of porous bed at least (6 inches) below the lowest slab. Tiles (open joints between tiles) should be covered with wire screening to prevent clogging followed by course gravel or stone backfill.

- Slabs on grade not subject to hydrostatic pressure are often placed over a gravel fill several inches think to prevent water from being drawn into the slab via capillary action. A waterstop is a preformed sheet of metal which unifies the floor slab with the exterior wall thus creating a water tight seal preventing any water from entering the structure.

Drainage

- Drainage of surface water (or runoff) involves directing water away from all structures.
- This is accomplished by reshaping or modifying the contours of a site to channel water gradually away from high to low elevations.
- Methods used include:
  - Gutters
  - Flumes
  - Berms
  - Gentle warping of paved surfaces
- These conduct water to:
  - Yard drains
  - Catch basins
  - Underground storm drain lines
- These eventually lead to discharge locations such as (natural ponds, detention ponds, or city wastewater mains).
SOIL MODIFICATION

- Soil can be altered in a variety of ways in order to improve its consistency, dependability, and bearing capacity.
- Under normal conditions, bearing capacity can be increased simply by deepening or increasing the bearing area of a footing.
- The use of proper drainage techniques can also improve the physical characteristics of soil, especially where the soil is affected by subterranean water flow.
- If the subsoil is soft or contains organic fill, the undesirable materials should be removed and replaced with compacted granular materials (Fine sand, course sand, gravel...
- If excavation and replacement is too costly, the existing soil can be consolidated (mixed) with new soil brought to the site (sand, gravel, crushed rock) to increase the bearing capacity. The mixing of existing soil with new soil creates a Hardpan-type soil material that can be artificially produced.
- The density of soil is a rough measure of its strength. Thus soil improvement often involves a reduction in void volume.
- Soil compaction can be achieved through the use of heavy equipment such as a sheep’s-foot roller.
- Reaching the right level of compaction is critical, as over compacting increases strength but can cause the structure to be unstable and result in serious heaving of the earth.
- All soil modifications and improvements intended to increase bearing capacity should be reviewed by the local building department prior to the start of any work.

TOPOGRAPHY AND DRAINAGE

- When considering a site, it is necessary to determine which areas are most suited for specific uses such as:
  - Buildings
  - Roads
  - Path
  - Parking areas
  - Drainage
- Where possible, cut and fill should be balanced in order to avoid the expense of either importing or exporting soil.
TOPOGRAPHY AND DRAINAGE –continued

Drainage

- On-site drainage systems must be connected to existing natural drainage systems.
- When development occurs on a site, the natural drainage system is disturbed. This requires that a new system be introduced that can sustain the new runoff coefficient or be re-designed to have the original systems capacity.
- Design of such drainage patterns is called surface water management.
- Water that does not seep into the ground is called runoff and it must be drained away from all roads, buildings, and any other areas of activity to prevent flooding or erosion.
- The design of surface water management is based on:
  - The runoff coefficient (amount of runoff to be carried away)
  - Intensity and duration of storms
  - Size of area to be drained
  - Characteristics of the area (soil porosity, slope and vegetation cover).
- The rate of surface water runoff increases as streets, paving, parking areas, and roofs replace the existing natural ground surface.
- Surface water drainage systems are based on the category of storm expected once very 5, 10, 25 or more years. (ex. A shopping center may be design according to a 25-50 year storm).

Drainage systems
Drainage systems-continued

- A “sheet flow” system consists of a surface of pavement or plantings which water flows over as a sheet and conducted towards a gutter. For this to occur, a ½ to 2% sloped grade is required.
- Land adjacent to buildings requires a minimum 2% grade to channel water away from the buildings foundation.
- Drainage ditches should be sloped between 2% and 10% to channel water efficiently by never over 25% slope. Slopes steeper than 50% usually have other vegetation such as Ivy and cannot be maintained (mowed).
- Slopes greater than 50% should be avoided due to the likelihood of erosion and rapid runoff. This rapid water can be controlled with check dams but this method can become costly. All slopes should have positive drainage and drained depressions to avoid water stagnation.
- To avoid erosion and surface flow, runoff can be channeled in underground conduits. These should be sufficiently sloped for self cleaning, normally a minimum of 0.3 percent. They should be deep enough to avoid damage by surface elements such as vehicles or freezing. Three or four feet for colder climates (frost line) is recommended.

Recommended slopes fir different activities:

- Sustainable design encourages infrastructure such as swales for surface drainage, which not only carry water but also contain native wetland vegetation that filters and cleans the storm water as it moves through the grasses.
- Underground water may be carried in subsurface drain lines with open joints, which allows water in the soil to be drained.
- Drainage lines are made of:
  - Clay tile
  - Plastic (PVC)
  - Sloped like storm drains
Ground slope

- Ground surface slopes are generally classified as:
  - Level grades (slopes under 4 percent)
    - Relatives flat
    - Supports any construction or activity
  - Easy grade (slopes between 4 and 10 percent)
    - Are suitable for construction
    - Supports most activates
    - These are moderate and require considerable effort to climb or descend.
  - Steep grades (slopes 10 percent or more)
    - Very difficult for construction
    - Needs complicated/ unique foundations
    - Very expensive
    - Utility connections may be complicated
    - May be unsuitable or suitable for limited activity only.

- Standard slopes:
  - Max desirable slope for grassy recreational area. (3 percent)
  - Walks adjacent to buildings, (4 percent ) = (4'-0” for every 100'-0” of horizontal distance)
  - Parking areas, (5 percent)
  - Streets used by vehicles should not exceed, (10 percent)
  - Slopes of turf should be kept under 25 percent to facilitate mowing and maintenance.
  - Unpaved slopes less than 1 percent to not drain well.
  - If slope is too steep or too flat, regarding may be required. The cost of grading may be excessive and may deem the development economically unfeasible.
  - Roads should not exceed a 10 percent gradient; a 15 percent slope approached the limit as vehicle can climb for a sustained period.
Understanding topography

- Topography refers to the surface features of an area.
- By analyzing topography, one can determine:
  - Building locations
  - Road systems
  - Utilities systems
  - Surface water drainage patterns
- Topographic maps are prepared by surveyors and civil engineers.
- Topography is indicated by contour lines on a plan.
- Each contour line indicates the elevation by a number adjacent to the line.
- The elevation change between lines or elevations is called the “contour interval”.
- For legibility, the smaller the scale of the map, the larger the contour interval.
- To find the slope between contour intervals, use:
  \[ G = \frac{v}{h} \times 100. \]
  Where the “V” is the vertical distance between contours and “H” is the horizontal distance.

- In general, changes in natural topography should be kept to a minimum. If grading should be required, the amount of cutting should be equal to the amount of filling if possible.
- Grading plans show the existing grades at property lines, as well as the grade for the sites structures, roads, and landscape features.
SITE PREPARATION

- Prior to construction, a site must be cleared of all undesirable materials. These might include:
  - Existing structures
  - Underground footings
  - Foundation falls
  - Existing utilities lines disconnected and capped or relocated
  - Vegetation, trees, root systems and tree stumps must be dug out or grubbed because in time they will decay leaving voids on the ground that could cause damaging settlement once a building is placed there.
- Plant material that is to remain undisturbed must be protected.
- At early stages of site preparation, corner stakes or batter boards (wood, strings and wires) are used to locate building lines on the site.
- Before grading beings, the tip 6 inches of soil (topsoil) are removed and stockpiled on the site. At the conclusion of construction, this topsoil is spread over the area as a final landscaping base which forms the finish grade.

EARTHWORK

- Excavation may be performed by hand or more generally by machines, and includes:
  - The digging of basements
  - Trenching for footings
  - All other required removal of soil (existing tree removal, existing utility, existing footings and piles...)
- During excavation, permanently cut slopes should not exceed a slope of 1.5 horizontal to 1 vertical or 66 percent.
- Permanently filled slopes should be no steeper than 2 to 1, unless substantiated by soil tests or geotechnical data.
- A cubic yard of earth weights more than a ton, therefore unstable soil situations must be avoided.
EARTHWORK-continued

Grading

- Grading is the alteration of a site's contour, usually by means of power equipment.
- Rough grading: is the addition or removal of earth prior to the start of construction.
- Finish Grading: is the final distribution of earth at the conclusion of construction. This is usually accurate to within 1 inch and represents the final shaping of a site's contours.

Backfill

- Backfill: is earth that is replaced around a foundation or retaining wall after the concrete forms have been removed. When applied, it should be deposited in layers of 6 to 12 inches in depth and thoroughly tamped and compacted to avoid settlement. (see right)
FOUNDATIONS

- The foundation of a building is the part of its structure that transmits the building’s loads to the soil.
- Footings are those parts of a building foundation that are widened to spread the load over a large area of soil.

Shallow foundations

- When soil near the surface has sufficient bearing capacity, the most economical foundation to use would be a “shallow spread footing”.
- A “column footing” is a square or rectangular pad of concrete that spreads the column load over a sufficiently large area so the bearing capacity of the soil is not exceeded.
- A “wall footing” is a continuous spread footing that serves the same purpose as a column footing only this time under a wall.
- A “combined footing or cantilevered footing” is a column footing when it is adjacent to a property line. Since the property line prohibits the footing from being its actual size, it is combined with the nearest interior column to compensate for the lack of area intended for bearing capacity.
- A “mat footing or Raft footing” is essentially one large footing upon which the building rests and spreads the load over the entire building area. Used in areas of poor soil or low bearing capacity when piles are too costly. Spread footings are usually ruled out by this point.
- A “boat footing” is similar to a mat footing in concept but its function is different, its depth and load from the building above would equal the amount of excavation removed from the site thus making the soil less susceptible to settlement. In theory: “the soil would behave as if the building was never there, in a sense, there are no additional loads for settlement to occur”. “One cubic yard of soil weighs more than a ton”.-from previous section. “Soil displacement”.

Deep foundations

- **Piles** are used when surface soils have insufficient bearing capacity to support spread footing. These are driven into the ground until bedrock is reached to provide for a firm base upon which to transmit loads.
- Piles are driven into the ground by:
  - Steam
  - Air
  - Diesel hammers that drop from four feet
  - They can also be jetted into place with high pressure water jets (this method is usually avoided because of the danger of over excavating)
- A pile may transmit loads to the underlying soil by:
  - Skin friction
  - End bearing, under the pile tip (where the soil is supported by rock or firm subsoil).
Deep foundations-continued

- A pile may be made of:
  - Wood
  - Steel
  - Concrete
  - Composite of two materials

- The choice of pile materials depends largely on the magnitude of load and presence of moisture because of the potential for deterioration.
- Concrete piles are the most suitable material under all conditions. Especially where permanence is a factor.
- Pile bearing capacity can be determined by:
  - pile-driving formulas
  - Static pile formulas
  - Pile load tests-these are the most dependable
- Another type of deep foundation pile is a vertical shaft drilled into the ground and then filled with concrete. There are two types of drilled shaft piles:
  - If the load is transmitted by friction; it is a “drilled pile”.
  - If the load is transmitted by end bearing, it is a “Drilled caisson”. In this type, the bottom is enlarged or belled.

Caissons and cofferdams

- Box-like structures used where very wet or soft soils are encountered are also called caissons. They provide methods of constructing foundations below water level, and may be formed from:
  - Timber
  - Steel (sheet piling)
  - Concrete
- For underwater projects, water-tight sheet is constructed. The water is then pumped out, and the foundations are then poured. This installation is known as a cofferdam.
TEMPORARY SUPPORTS

- During the construction of a foundation, it is often necessary to provide temporary supports or shoring for:
  - Excavating earth
  - Existing structures (sheeting, bracing, and or underpinning...)
- “Sheet piling” is a temporary wall of: (to retain soil around excavation)
  - Wood
  - Steel
  - Precast concrete
- A “Slurry wall” is a type of sheeting in which a narrow trench is filled with a slurry, or soapy mixture, of bentonite clay and water, which resists the pressure of the earth.
  Process:
  - Excavate trench
  - Add slurry
  - Lower reinforcing steel into the slurry
  - Concrete is pumped into the bottom of the trench
  - Slurry is removed as concrete rises and recycled for later use on another job.
- “Bracing” is used to brace the sheeting to resist the soil pressure.
- A common method of bracing is the use of diagonal “rakers”. This method is rarely used because these elements tend to interfere with the excavation process.
- There soil conditions permit, “tiebacks” into the surrounding soil or rock can be used in place of rakers.
- “Underpinning” is used for supporting existing foundations or walls being extended downward to a deeper level. There are two methods for achieving this:
  - Needle beams
  - Pipe cylinders with hydraulic jacks
SITE IMPROVEMENTS

- Site work involves improvements to the site that are not related to the building/structure.
- Some of these improvements include:
  - Roads
  - Walks
  - Fences
  - Walls (retaining walls)
  - Lighting
  - And other common landscape features.
- Roads and parking areas are most often constructed from
  - concrete
  - Asphalt

Asphalt paving

- Asphalt is one of many bituminous products that come from asphaltic petroleum.
- Asphalt can be applied in a hot or cold state as a layer over a prepared foundation. This is usually a sub-base of course crushed stone or gravel covered by a base of finer aggregate. The finer aggregate fills the voids in the course stone.
- Once applied, the layers of aggregate are rolled and tamped followed by the application of a 2 to 3 inch thick layer of asphalt.

- **Asphaltic concrete:**
  - It is applied in a hot state
  - It consists of cement and aggregate mixed in a plant
  - It is spread over a firm foundation
  - Rolled while still hot

- **Cold laid asphalt:** same principles as above only cold liquid asphalt and aggregate are used.

- **Asphalt macadam:**
  - It is applied in a hot state
  - It has a base of crushed stone
  - Gravel
  - Slag compacted to a smooth surface
  - Asphalt/emulsion are then sprayed on top in controlled quantities.
  - Fine aggregate is then added and rolled to fill voids in crushed stone.
SITE IMPROVEMENTS-continued

Other paving materials

- Materials often used for pedestrian walks include:
  - Concrete
  - Asphalt
  - Brick
  - Stones cobbles
  - Granite sets
  - Flagstones

- **Brick paving**: is a very popular and durable surface for pedestrian traffic. It can be laid over sand or cement but better when laid on a concrete slap foundation.

- **Cobble stone**: is often used for decorative effect. Rounded riverbed stones from 2 to 4 inches in diameter are the most popular. They are usually set in cement mortar.

- **Granite sett**: are small, rectangular or square blocks of granite that are set in a cement mortar to produce a very durable paved surface. Old cities were usually paved in this matter.

- **Flagstones**: are thin slabs of slate, bluestone of soapstone. They are available in many surface textures, rough, smooth, and various colors. They can be installed over a sand bed, or with mortar on a concrete slab.

![Notable paving patterns](image1)

![Types of retaining walls](image2)
LANDSCAPING

- Landscaping completes, links, and harmonizes the connections between buildings, open spaces and natural features, and human beings.
- The landscape design must consider:
  - Climate
  - Light
  - Weather
  - Orientation
  - Scale
  - Program

- Bright light sharpens or emphasizes details. Shadows define surfaces. Twilight creates unifying composition. Weather changes the appearance of an outdoor space considerably.
- In a building, a room 15 feet square may feel quite comfortable, while an outdoor space of the same size may feel very small.
- In addition to the earth, rock and water, the landscape designer uses:
  - Trees
  - Shrubs
  - Ground cover
  - Plants

- Because trees and plants require many years to mature, the planner must exercise great care in preserving existing vegetation.
- Planting is often the first item to be eliminated when budget problems appear. Much care should be taken, therefore, to retain existing plants and trees in the total landscape plan.
- In the selection and placement of plants, the designer must consider such criteria as:
  - Suitability
  - Visual effect
  - Future growth patterns
  - Spacing
  - Overall pattern

- Plant material can be used effectively in landscaping to reduce the effects of climate extremes:
  - Vegetation filters the sun.
  - Groundcover controls radiant heat from the ground.
  - Trees and shrubbery can block solar radiation, prevent heat gain.
  - They can filter, reduce, or obstruct unwanted winds. Reduce heating expenses.
  - Plant material can affect the rate of evaporation of moisture from the ground.

- Plant material can control the effects of solar radiation, wind, precipitation and humidity which effects human comfort during the day and at night.
- Indigenous plant materials provide the designer with numerous choices of vegetation to influence the climate within the project area.
- Vegetation may absorb as much as 90 percent of the light energy which falls upon it.
- It can reduce wind speed to less than 10 percent.
- It can reduce daytime temperatures by as much as 15 degrees.
LANDSCAPING-continued

- Intelligent planting and landscape design can reduce the effects of climate in the following ways:
  - Trees may be used to screen winds
  - Conifers are more suited to control winter winds than deciduous trees
  - Trees can be used to direct wind flow, and to increase ventilation in desired areas.
  - Vegetation, particularly needle-leafed trees, capture moisture, reduce fog, and thus increase the amount of sunlight reaching the ground.
  - Deciduous trees screen out direct sunlight in the summer while allowing it to pass in the winter.
  - Planted areas are cooler during hot days and have less heat loss during the night.
  - Indigenous vegetation is usually less costly, has a higher survival rate, and will required less maintenance.

SITE DEVELOPMENT COSTS

- An architect usually strives to produce the best architectural solution for the least amount of money. Consequently, decisions made during the design phase must consider not only the aesthetic qualities, but also its initial expense and maintenance cost throughout its useful life.
- To be successful, the architect must:
  - evaluate alternative site development schemes
  - select the best solution
  - estimate various options
  - and compare costs and their impact on the total project budget
- The architect should be familiar with materials, systems, and construction operations.
- The architect must evaluate and prioritize materials and systems and select those that are most responsive to the specific needs of the program.
SCOPE, QUALITY, AND COST

• The design of a site, no matter how large or how small, is affected by the
  ▪ Scope of its development,
  ▪ The quality of its materials
  ▪ And the limitations imposed by the project budget

• Scope quality and cost can never be fixed. There should always be leeway for adjustment. One or two should always remain variable. Ex. If both scope and quality are rigidly defined in the program, then budget must remain flexible.

• Initial installation cost is most apparent during the development of a project.

• Maintenance costs may have a greater impact on the total cost over the life of the project. This requires estimating initial cost and the cost to maintain or replace the material or system over a period of time, and compare one system against another.

• Aspects of site work would include:
  ▪ Demolition of existing buildings, site improvements, and natural features such as trees, rock outcroppings, etc., to make room for new development.
  ▪ Earthwork, including cut, fill, compaction, etc., to prepare a site for buildings, roads, and other improvements.
  ▪ Foundations, considering the effect of soil conditions and topography on the cost of footings.
  ▪ Utilities, including the installation of new services as well as the excavation of existing lines to provide the necessary service to a site.
  ▪ Paved roads and walkways
  ▪ Landscaping
  ▪ Lighting to illuminate roads, walks, paved areas, parking areas, and recreational areas.
  ▪ Site furniture, including benches or other seating, plant containers and sports equipment.

Initial cost

• Site construction costs are influenced by the cost of labor and materials, the efficiency of the contractor to managing the project and the technology utilized to accomplish the work.

• Two factors that affect site development costs:
  ▪ Characteristics of the site (soil conditions, topography, anything existing...)
  ▪ The design of its development (efficiency, scope, quality...)

• Unfavorable site conditions such as a high water table, problems of access, poor soils or steep slopes may result in excessive site development costs.

• The less work required in preparing a site for a building, least amount of cost.
Initial cost-continued

- The ideal situation for site development would include:
  - A site that neither steeply sloped not completely flat
  - A site with good natural soil, capable of supporting normal building loads, free of organic materials, un-compacted fill, or rock within a few feet of the surface.
  - A site that has favorable natural drainage.
  - A site with a regular geometric shape and be served by the required utilities located close to its property lines.
- The architect should incorporate site improvements that enhance the environment, and select materials and systems that create an aesthetically pleasing, low-maintenance, well-balanced design.

Long range costs

- Evaluating alternative materials and systems must include a comparison of maintenance costs as well as initial installation costs.
- Initial installation costs represent a fraction of the entire cost of a project over the period of its useful life.
- Value analysis is a systematic method of obtaining optimum value for every dollar spent, considering all project expenditures, including construction, maintenance, operation, and replacement.
  - Ex. A durable paving material may be more appropriate where heavy use is anticipated then less expensive paving, which must be resurfaced at more frequent intervals. Heavy duty paving for roads may cost 50 percent more than light duty asphalt paving; however, if it lasts twice as long before requiring replacement, it will be 25 percent more cost effective for each life cycle of the material. Summary:
    - Pay more upfront=better quality/ more durable material, less cost over the lifecycle of the material.
    - Pay less upfront= less quality/ less durable more frequent replacement which equals more cost over the lifecycle of the material.
- Ability to make comparative cost choices is critical:
  - Ex. The installation of a poured concrete paving slab over buried utility lines that require frequent maintenance is less cost effective/efficient than placing these utilities in a concrete trench with removable concrete covers, for easy access.
  - A concrete slab would have to be demolished and repaved every time maintenance was required meaning more unnecessary costs, whereas, a removable concrete cover would save that re-occurring expense.
SCOPE, QUALITY, AND COST—continued

Cost control

- Cost-effective design utilizes a logical approach to siting buildings and other improvements, resulting in an efficient physical organization of the site. For example:
  1. **Locate buildings along gentle sloping terrain; avoid steeply sloping land.**
     - Minimizes cost of grading and excavation for footings...
     - Minimizes the use of retaining walls, roads, utility runs ...
     - Avoids unconventional building footings.
     - Provides ease of access.
  2. **Locate buildings where positive natural drainage exists.**
     - Avoids redirecting surface flow by excessive regarding
     - Avoids installation of expensive storm drainage systems
     - Do not locate buildings at the bottom of the hill; otherwise, expensive methods of water interception would be required to avoid flooding.
  3. **Arrange vehicular circulation systems to follow contours (parallel) on the site rather than to oppose them (perpendicular).**
     - Minimizes costs of earthwork, construction of banks, berms, and retaining walls.
     - A long meandering approach road that follows the contours of the site is less costly and more efficient than a short road cutting straight through the site because of earthwork required for the latter option.
  4. **Locate paved parking lots on relatively level ground, rather than sloping ground.**
     - Avoids excessive reshaping of the land terracing, steps, and ramps to connect the various levels, and complex storm drainage systems.
  5. **Locate buildings so they relate to the new and existing utility systems.**
     - To minimize utility runs
     - Minimize excavation and trenching for service runs
     - Amentias not requirement utilities such as tennis courts can be located further from the utilities.
  6. **Locate site improvements to utilize existing vegetation.**
     - Avoids removal of trees, and plants and their replacement with costly new landscaping.
     - Uses shading from trees (mature deciduous trees). Place buildings north of them.
  7. **Avoid locating improvements over rock, organic soil, or areas of high water table.**
     - To minimize costly excavation and foundation problems.
     - Avoids the need to use blasting
     - Avoids water intrusion and heaving issues
  8. **Coordinate the location of new with existing facilities including buildings, roads, walks, and other improvements in the development of a site design concept.**
     - Avoids costly unnecessary demolition and replacement of existing improvements.
     - Try to use existing utilities and roads to minimize replacement.
     - Demolition costs should be included in the project development budget.
SCAPE, QUALITY, AND COST-continued

Cost control-continued

9. Select appropriate finish material for the site improvements, including paving of roads, walks, plazas, play courts, etc. retaining walls, planter walls, seating and other site furniture.
   - Using the example from before:
     - Ex. A durable paving material may be more appropriate where heavy use is anticipated then less expensive paving, which must be resurfaced at more frequent intervals. Heavy duty paving for roads may cost 50 percent more than light duty asphalt paving; however, if it lasts twice as long before requiring replacement, it will be 25 percent more cost effective for each life cycle of the material.
       Summary:
       - Pay more upfront=better quality/ more durable material, less cost over the lifecycle of the material.
       - Pay less upfront= less quality/ less durable more frequent replacement which equals more cost over the lifecycle of the material.
       - Ex. The installation of a poured concrete paving slab over buried utility lines that require frequent maintenance is less cost effective/efficient than placing these utilities in a concrete trench with removable concrete covers, for easy access.
       - A concrete slab would have to be demolished and repaved every time maintenance was required meaning more unnecessary costs, whereas, a removable concrete cover would save that re-occurring expense.

10. Select indigenous plant material for landscaping.
    - For all reasons stated previously: local plants will last longer, require less maintenance and less replacement.

11. Select site lighting systems in consideration of capital costs, energy costs and replacement lamp and labor costs:
    - For same reasons stated above:
      - Use comparative analysis to determine the best lifecycle option, initial cost option, maintenance and replacement.
ZONING

• The first American zoning ordinance was passed in New York City in 1916 to limit the size, height and shape of new skyscrapers so that the adjacent streets would not become permanently shaded canyons.

• Most zoning statues in the 1920s dealt with physical development. They divided cities into districts of different uses, with uniform regulations for each. See page 74.

• In “Cumulative zoning” multi-use districts allow residences to be built in commercial zones and residential and commercial uses to be built in industrial zones, not the case with 1920 standards.

• The ordinances of the 1920s also regulated the height and bulk of buildings along with setback lines. The intent of these acts was to allow the owner to develop the land as long as the specific restrictions of the ordinance were not violated.

• The enactment of the model land development code recognized:
  - Aesthetics
  - Environmental problems
  - Preservation of historical sites as planning and development factors.

• In New York City, developers commonly add plazas at the ground level of office towers, in return for permission to erect taller buildings.

• Zoning ordinances often restrict the height and size of buildings, as well as their location on the site.

• They may prescribe setbacks from property lines, limit percentage coverage of the lot area, restrict the number of dwellings per acre (density), and require a specific amount of off-street parking, as well as numerous other possible regulations.

Zoning envelope

• The volume within which a building may be placed is sometimes referred to as the “zoning envelope”. This is an imaginary tent-like space inside which the building may be placed in any location, so long as it does not penetrate any imaginary surface.
ZONING-continued

Setbacks and yards

- A zoning ordinance often regulates the distance between a street and a building, as well as between buildings.
- The main purpose of such restrictions are to:
  1. provide building interiors with natural light and ventilation
  2. Inhibit the spread of fire from one structure to the next.
  3. Minimize conflicts between street traffic and off street activities.
- These ordinances also allow for future street widening and create open space to blue sky.
- A setback is the horizontal space adjacent to a property line into which a structure may not project. Setbacks provide a sense of openness, as well as light and air. They may also be required for off-street parking, or they may be for aesthetic reasons.

Height limitation and variable setbacks

- Zoning ordinances may limit the number of stories in a building, its height in feet above street level, or both.
- The height is usually measured from grade, which may be defined in various ways, depending on the local zoning ordinances. The way in which grade is defined in the wording may affect the number of stories permitted, particularly on a sloping site.
- Height limitations are more common in residential zones than in commercial or industrial zones.
ZONING—continued

Land coverage

- Other restrictions include (land coverage) and the ratio of total usable floor space to total site area “floor area ratio (FAR)
- Land coverage is expressed as a maximum percentage of total available land area that may be covered by a building or buildings.
- Open land may be used for surface developments, such as:
  - Parking
  - Plazas
  - Recreation and other types of landscape space
  - Level or depressed courtyards
- The purpose of these restrictions is to encourage the retention and development of open space to enhance the environment through the admittance of light and air, and to provide planed areas to relieve the hard surfaces of buildings. Sidewalks and streets.

Floor area ratio (page 79)

- The floor area ratio (FAR) is the ratio of the floor area of a building to the total area of the site. The purpose of an (FAR) ordinance is to control the amount of site development and to restrict the bulk of a building, in order to encourage openness, light and air, especially in urban areas. (see examples on page 79)
- According to the zoning ordinance, floor area may be either the net usable space, excluding stairs, elevators, and other similar spaces, or the total gross of the building, depending on the ordinance.

Off-street requirements

- Many cities require an owner a development to provide a minimum number of off-street parking spaces for a buildings tenants and visitors.
- In residential zones, these are often expressed in parking spaces per dwelling unit.
  - Ex. 2 bedroom requires 2 spaces
  - Ex. 1 bedroom requires 1 space
  - Two spaces are normally the minimum
- In commercial zones, the requirement is usually stated as one space per as specific number of usable floor area. (see example on page 80)
- In some cases where space in limited, it may be possible to satisfy the parking requirement on a separate site, provided it is located within a prescribed distance from the building site.
- Some districts also require certain amount of area for loading and unloading of service vehicles, particularly in the case of hospitals, hotels and institutions.
FLEXIBLE ZONING

- The purpose of flexible zoning is to overcome the rigidity of traditional zoning and make the regulations relevant to changing patterns of development. Most zoning ordinances continue to reflect the basic principles of the traditional ordinances of the 1920s. (see 35 above)

- Examples of flexible zoning can include:
  - Conditional use permit
  - Planned unit development (cluster concept)
  - Floating zone
  - Incentive zoning (bonus)
  - Contract zoning

- When zoning ordinance cause an unintentional hardship (unfair restrictions) to an owner of a specific land parcel, the owner can consider using a “variance”. Theoretically, a variance is granted when the literal application of an ordinance would cause an undue hardship in the proposed development of a site. Under certain circumstances, a zoning board might grant a variance allowing an owner to violate the specific ordinance if it is not too drastic and the justification is reasonable.

- In zoning, “conditional use permit” allows for flexibility within a district. It allows a non-conforming use to be implemented in an area where otherwise that use would not be permitted. To be considered, it has to go through a special hearing and certain conditions are met. It has to be considered in the public’s best interest to be allowed. Ex. Hospital in a residential area.

- The granting of a conditional use or special use permit does not, however, change the zoning of the particular parcel of land. If the development is abandoned, the conditional use would no longer apply and the property would revert to its original district designation.

Rezoning

- The only alternative available to a landowner who cannot meet the requirements for a conditional use permit is to seek rezoning of the property. Rezoning however, can cause hardships to neighboring property owners.

- Rezoning small individual lots results in “spot zoning”, which may alleviate an owners hardship. There are times, however, when rezoning is accomplished through political manipulation, rather, than for legitimate reasons.

Contract zoning

- This is an agreement between a developer and local government to restrict usage or height or to provide additional setbacks or buffers, over and above what is required by the ordinance, in return for certain benefits, and is called contract zoning. Ex. Addition restrictions in addition in return for being granted a conditional use.
FLEXIBLE ZONING-continued

Bonus or incentive zoning

• In some cities, zoning requirements may be waived if the developer provides bonus features, as in a large public plaza on the ground level in exchange for addition floors and building height. This in a sense also increases the value of the property for the owner because of added amenities for building tenants.

• Incentives can be given for variety of reasons:
  ▪ Street widening
  ▪ Providing unobstructed views
  ▪ Inclusion of theaters and retail space in office buildings
  ▪ Provisions of walkways for public use (such as a pedestrian bridge)
  ▪ Preservation of open space.
The following glossary defines a number of terms, many of which have appeared on past exams. While this list is by no means complete, it comprises much of the terminology with which candidates should be familiar. You are therefore encouraged to review these definitions as part of your preparation for the exam.

A
Access Right  Right of an owner to have ingress and egress to and from a property.
Accessible Parking  See Handicapped Parking.
Accessory Building  A building or structure on the same lot as the main or principal building.
Aesthetics  The study or theory of beauty.
Air Rights  The rights to the use or control of space above a property.
Altitude  The angle that the sun makes with the horizon.
Aquifer  An underground permeable material through which water flows.
Azimuth  A horizontal angle measured clockwise from north or south.

B
Barrier-Free  The absence of environmental barriers, permitting free access and circulation by the handicapped.
Bearing  In surveying, a direction stated in degrees, minutes, and seconds as an angular deviation east or west from due north or south.
Bearing Capacity  The ability of a soil to support load.
Bench Mark  A relatively permanent point of known location and elevation.
Berm  A convex-shaped bank of earth.
Boundary  The legal recorded property line between two parcels of land.
Buffer Zone  An area separating two different elements or functions.

Buildable Area  The net ground area of a lot that can be covered by a building after required setbacks and other zoning limitations have been accounted for.
Building Line  A defined limit within a property line beyond which a structure may not protrude.
Building Envelope  The enclosure that contains a building's maximum volume.

C
Catch Basin  A drainage device used to collect water, with a deep pit to catch sediment.
Circulation  The flow or movement of people, goods, vehicles, etc., from place to place.
Climate  The generally prevailing weather conditions of a region throughout the year, averaged over a series of years.
Coefficient of Runoff  A fixed ratio of total rainfall that runs off a surface.
Collector Street  A street into which minor streets empty and which leads to a major arterial.
Combined Sewer  Sewer that carries both storm water and sanitary or industrial wastes.
Comfort Zone  Any combination of temperature and humidity in which the average person feels comfortable.
Compaction  The reduction of soil volume by pressure from grading machinery.
Condemnation  Taking private property for public use, with compensation to the owner, under the right of eminent domain.
Conduction  The transfer of heat by direct molecular action.
Conduit  Pipe or other channel, below or above ground, for conveying pipelines, cables, or other utilities.

Conforming Use  Lawful use of a building or lot that complies with the provisions of the applicable zoning ordinance.

Coniferous  Describing a cone-bearing tree or shrub. See Evergreen.

Context  The circumstances or elements which surround a particular development.

Contour  A line on a plan that connects all points of equal elevation.

Contour Interval  The vertical distance between adjacent contour lines.

Convection  The transfer of heat by the movement of a liquid or gas, such as air.

Corner Lot  A land parcel that fronts on two contiguous streets. The short side is generally considered to be the front of the lot.

Covenant  A restriction of the deed which regulates land use, aesthetic qualities, etc., of an area.

Cross Section  See Section.

Crown  The central area of a convex surface, such as a road.

Cul-De-Sac  A short road with an outlet on one end and a turnaround on the other.

Culvert  A length of pipe under a road or other barrier used to convey water.

Curb  A raised margin running along the edge of a street pavement, usually of concrete.

Curb Cut  A depression in a curb that provides vehicular access from a street to a driveway.

Cut and Fill  In grading, earth that is removed (cut) or added (fill).

D  Dead-End Parking  A circulation layout in which cars are unable to circulate in a continuous one-way flow from the entrance to the exit of a parking area.

Deciduous  Describing trees that shed their leaves annually, as opposed to evergreen.

Dedication  Appropriation of private property for public use together with acceptance for such use by a public agency.

Deed  A written instrument that is used to transfer real property from one party to another.

Degree Days  The number of degrees that the mean temperature for any day at a particular location is below 65°F.

Density  A measure of the number of people, families, etc., that occupy a specified area.

Discharge  Flow from a culvert, sewer, channel, etc.

Disposal Field  A system of trenches with gravel and loose pipes through which septic-tank effluent may seep into the surrounding soil. Also called Drainage Field or Absorption Field.

District  Any section of a city in which the zoning regulations are uniform.

Drainage  (1) The capacity of a soil to receive and transmit water. (2) The system by which excess water is collected, conducted, and dispersed.

Drainage Field  See Disposal Field.

Drip Line  An imaginary line on the ground described by the outermost branches of a tree.

Driveway  A vehicular path generally leading from a public street to a structure on private property.

Drop-Off  An area adjacent to a vehicular drive where pedestrians may safely exit (or enter) a car.
Dwelling Unit  An independent living area which includes its own private cooking and bathing facilities.

E
Earthwork   See Grading.
Easement   A limited right, whether temporary or permanent, to use the property of another in a certain way. This may include the right of access to water, light and air, right-of-way, etc.
Ecology   The study of the pattern of relations between organisms and their environment.
Effective Temperature   The sensation produced by the combined effects of temperature, relative humidity, and air movement.
Effluent   Partially treated liquid sewage flowing from any part of a disposal system to a place of final disposition.
Elevation   The vertical distance above sea level or other known point of reference.
Eminent Domain   The right of a government, under the police power concept, to take private property for public use.
Encroachment   Part of a building or an obstruction that extends into the property of another.
Envelope   See Building Envelope.
Environment   The natural and man-made things, conditions, and influences surrounding a person, community, or place.
Erosion   The process by which the surface of the earth is worn away by the action of natural elements, such as water and wind. Also known as Weathering.
Evergreen   Having green leaves throughout the year, as opposed to deciduous.
Excavation   The digging or removal of earth.
Expansive Soil   Clay that swells when wet and shrinks when dried.

F
Finish Floor Level   The completed floor surface on which building occupants walk.
Finish Grade   The elevation of the ground surface after completion of all work.
Floodplain   The land surrounding a flowing stream over which water spreads when a flood occurs.
Floor Area Ratio (FAR)   The ratio of the floor area of a building to the area of the lot.
Flow Line   The path down which water flows.
Front Yard   The minimum legal distance between the front property line and a structure.
Frontage   The length of a lot line along a street or other public way.
Frost Line   The deepest penetration of frost below grade.
Function   The natural or proper purpose for which something is designed or exists.

G
Geology   The science that deals with the physical history of the earth.
Grade   The elevation at any point. See also Gradient and Grading.
Gradient   The rate of slope between two points on a surface, determined by dividing their difference in elevation by their distance apart.
Grading   The modification of earth to create landforms.
Greenbelt   A belt-like area around a city, reserved by ordinance for parkland, farms, open space, etc.
Greenhouse Effect   The direct gain of solar heat, generally through south-facing glass walls and roofs.
Groundwater Level   The plane below which the soil is saturated with water. Also called Groundwater Table or Water Table.
H

Hachure A shading technique used to depict ground form.

Handicapped Individuals with physical impairments that result in functional limitations.

Handicapped Parking Spaces designated for physically handicapped persons, consisting of a typical space with adjacent access aisle no less than five feet wide. Also known as Accessible Parking.

Humidity The amount or degree of moisture in the air.

Hydrologic Cycle See Water Cycle.

I

Indigenous Native to a particular region.

Infiltration The process by which water soaks into the ground. Also called Percolation.

Insolation The amount of solar radiation on a given plane.

Interchange The junction of a freeway with entering or exiting traffic.

Interpolation Determining an unknown value between known values.

Intersection The point at which two streets come together or cross.

Invert Elevation The elevation of the bottom (flow line) of a pipe.

L

Land Coverage The ratio of the area covered by buildings to the total lot area, expressed as a percentage.

Landscaping The conscious rearrangement of natural outdoor elements for function and pleasure.

Latitude The number of degrees north or south of the equator of a particular point on the earth's surface.

Legal Description Designation of boundaries of real estate in accordance with one of the systems prescribed by law.

Limit Line Any line beyond which development is prohibited.

Loop Street A minor street that comes off a major street, runs for a short distance, and then returns to the major street.

Lot Line The boundary line of a lot.

Lot Area Total horizontal area within the lot lines of a parcel of land.

M

Macroclimate The general climate of a region.

Manhole An access hole in a drainage system to allow inspection, cleaning, and repair.

Metes and Bounds A formal description of the boundary lines of a parcel of real property in terms of the length and direction of those lines.

Microclimate The climatic characteristics unique to a small area, caused by local features.

Multiple Dwelling A building containing three or more dwelling units.

N

Neighborhood A community of people living in a general vicinity. The area can generally support an elementary school.

Network A system of circulation channels which covers a large area.

90-Degree Parking A pattern of vehicle storage in which car stalls are arranged at a right angle to the access lane. Also known as Perpendicular Parking.

Non-Conforming Use A particular use of land or a structure which is in violation of the applicable zoning code. Generally, if the use was established prior to the code rule which it contravenes, it may continue to exist.
O
Off-Street Parking  Space provided for vehicular parking outside the dedicated street right-of-way.
One-Way Traffic  A circulation system in which all vehicles move in the same direction.
Open Drainage  The removal of unwanted water by means of surface devices.
Orientation  A position with respect to the points of the compass.

P
Pad  An approximately level building area.
Parallel Parking  A pattern of vehicle storage in which car stalls are arranged parallel to the access lane, as in conventional street parking.
Parking Lot  An open space for the storage of motor vehicles.
Parking Stall  A space in a parking lot marked off for the storage of a single motor vehicle.
Party Wall  A wall built on the dividing line between two adjoining parcels, in which each owner has an equal share of ownership.
Passive Solar System  A heating or cooling system that collects and moves solar heat without using mechanical power.
Perculation  See Infiltration.
Perpendicular Parking  See 90-Degree Parking.
Plane Surface  A topographic configuration created by straight, evenly spaced contours.
Planting Strip  A landscaped strip of ground dividing a pedestrian walk from a street.
Police Power  The legal power of a government to authorize actions which are in the best interest of the general public.
Precipitation  Water that falls on the land as rain or snow.
Principal Building  A building that houses the main use or activity occurring on a lot or parcel of ground.
Property Line  A legal boundary of a land parcel.
PUD  A planned unit development, similar to a cluster development but larger in scale including, in addition to housing, commercial and industrial developments.

R
Radiation  The process by which heat or other energy is emitted by a body, transmitted through space, and absorbed by another body.
Rational Method  A method for computing approximate storm water runoff.
Rear Yard  The minimum legal distance between the rear property line and a structure.
Relative Humidity  The ratio of the actual amount of moisture in the air to the maximum amount of moisture the air could hold at a given temperature.
Restrictions  Limitations on the use of property defined by covenant in deeds, by private agreement, or by public legislative action.
Retaining Wall  A wall constructed of timber, masonry, or concrete designed to resist the pressure of the earth mass with which it is in contact.
Retention Pond  An area used to retain and hold runoff water during a storm. The water is held until it is able to drain naturally.
Ridge  A narrow convex land configuration represented by contours pointing downhill.
Right-Of-Way  A strip of land granted by deed or easement for a circulation path.
Runoff  The surface flow of water from an area.
Section  The representation of a structure as it would appear if cut through by an intersecting plane to show its internal configuration. Also known as a Cross Section.

Septic System  A sewage treatment system consisting of a tank and filtering system.

Setback  The minimum legal distance between a property line and a structure.

Sewer  An underground pipe or drain used to carry off excess water and waste matter.

Sheeting  A thin layer of water moving across a surface. Also called Sheet Flow.

Side Yard  The minimum legal distance between side property lines and a structure.

Silt  A fine-grained soil whose particles are 0.05 to 0.002 millimeters in diameter.

Site Planning  The art or science of creating or arranging the external physical environment.

Slope  The inclination of a surface expressed as a percentage or proportion.

Sludge  Accumulated solids that settle out of the sewage, forming a semi-liquid mass on the bottom of a septic tank.

Soil  A natural material, formed of decomposed and disintegrated parent rock, that supports plant life.

Soil Boring Log  A graphic representation of the soils encountered in a test boring.

Solar Zoning  An ordinance controlling the mass and shape of buildings, which permits the penetration of sunlight between buildings.

Split Lot  A lot that comprises more than one zone.

Spot Elevation  The exact elevation at a key point on the ground or on a structure.

Spot Zoning  Zoning that differs from the pattern of the surrounding area.

Stall  See Parking Stall.

Story  The vertical portion of a building included between the surface of any floor and the surface of the floor next above.

Subsidence  The sinking of land.

Summit  The highest point of a land mass, represented by concentric contours.

Sun Chart  A map of the sky showing the path of the sun, from sunrise to sunset, on the 21st day of each month.

Surcharge  Earth which is above the top of a retaining wall level.

Surface Water  Water that runs along the surface of the ground, as opposed to below ground.

Swale  A graded flow path used in open drainage systems.

Switchback Road  A road that doubles back on itself with a hairpin curve.

Topography  The configuration of the earth’s surface.

Topsoil  The upper six to eight inches of soil, which contains humus.

Transpiration  The process by which water vapor escapes into the atmosphere from plants.

Trench Drain  A linear drainage device used to collect and conduct water.

Uniform Slope  A topographic configuration created by evenly spaced contours.

Utility Easement  A legal right-of-way enabling a utility company to run service lines over private property.

Valley  A narrow concave land configuration represented by contours pointing uphill.
Variance  The special permission granted to the owner of a parcel of land waiving certain specific restrictions when the enforcement of these would impose an unusual or unreasonable hardship on the owner.

Vegetation  All the plants, shrubs, and trees of a particular place.

W

Water Cycle  The general pattern of movement of the water on, under, and above the earth. Also called Hydrologic Cycle.

Water Table  See Groundwater Level.

Way  Street, alley, or other thoroughfare or easement permanently established for passage of persons or vehicles.

Weathering  See Erosion.

Windbreak  A structure or plant which, because of its form and location, reduces wind velocities.

Wind Shadow  The area near the bottom of the leeward side of a hill, where the wind velocity decreases to almost zero.

Y

Yard  Open, unoccupied space on all sides of a building, based on the required setbacks.

Z

Zone  Area established by a governing body for specific use, such as residential, commercial, or industrial use.

Zone of Aeration  The zone below the ground in which the spaces between soil grains contain both water and air.

Zone of Saturation  The zone below the ground in which all of the spaces between soil grains are filled completely with water.

Zoning  The legal means whereby land use is regulated and controlled for the general welfare.

Zoning Ordinance  Exercise of police power by a government in regulating and controlling the character and use of property.