Some Grading and Drainage Pointers:

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A. General Factors:

Before You Start

No one learns to grade and drain sites without practice. Site grading involves so many factors you will have to try to grade a site iteratively. Expect to "go around in circles". It is normal. Experience should make the circles smaller and shorter. If you can't visualize a site from a topo map or do simple multiplication in your head, learn.

If you don't get a feel for grading in 3 to 6 months (it stops being impossible and starts being a routine) then try a different career.

First Things First

When you even start to think you may want to do a scope and fee for grading a site there are some initial steps you should take. Learn where the site is. Get the codes and design manuals for the government where the site is. In order to get a building permit your plans will need to be reviewed by these people. Ask for the drainage, grading and sensitive areas codes and the road standards or equivalents. Also ask for all the design manuals that are applicable. In addition get all the mapping you can. Read through it all and ask questions if you need to.

Understand all this stuff so you understand the level of effort that will be required before you submit a scope and fee. Look at the site and surroundings too. Look for potential fatal flaws (wetlands and other sensitive areas, closed depression, bad up or downstream drainage systems, or zoning limitations.) You must be able to advise the client of problems as soon as you can find them. You must have an adequate fee for the level of effort that will be required. Yow must also be able to advise up front if other experts will be required (wetland biologists, geotechnical engineers, etc.)

Don't do a scope and fee without design experience. If you do, you will lose money or have unhappy clients or both.

Site Layout

You will often be handed a site plan with the building, parking and walks already laid out by the architect. Some architects work with the site, but others are oblivious to the site topography. Put simply, you may get a site layout that ignores the elevation differences on the site or other problems (intrusions into sensitive areas).

Again, you must be able to see the problems or potential for problems and inform the client.

Deal With Problems Up Front

In general, if you see a problem, don't hide or ignore it, make it known to the client. It is usually possible to do so in a neutral manner that doesn't appear to be all "doom and gloom". Remember, problems usually don't go away by themselves. If they did, you wouldn't have a job. Be sure to document this stuff in writing. This includes keeping logs of phone conversations. Put your logs, memos and letters in the project directories or files.

If you find deal with problems up front you will have happier clients. If you document everything you do to identify and resolve a problem, you can ensure you will be happier too.

Grading and Drainage

Someone somewhere will try to convince you to split the design of grading and drainage apart. Don't. Grading and drainage in any environment that has rain are tied together with the closest of bonds. Together they determine how water flows on a site. They must be coordinated and done correctly in order to avoid damage the client's buildings or other facilities. Failure to consider these factors together can result in water flowing into a building, or damage to your site or other people's buildings or property.

Site grading is usually done prior to laying out the drainage piping. The first step is to route the water overland as the surface allows. Second, route the flows in subsurface pipes from catch basins to your pond or downstream system. I'd suggest reading the section on grading next.

B. Grading

As you look at a site and the plans for a site you will see paths. Water follows a path as it flows downhill. Cars follow paths (roads, drives and parking lots).
Pedestrians and handicapped people use walks, ramps and stairs, which are also paths. Some paths are above ground (grading) and some are below ground (sewer, water, storm drainage and other utilities).

This section focuses on the above ground paths.

Paths generally have limitations. For instance cars and people shouldn't have to try to climb cliffs on your site (unless it includes a climbing rock). Where paths meet on the surface they must share the same elevation. If you draw the centerline (or a line along a side) of each path on your site you will wind up with a network or web of lines and curves. Where lines intersect you will have nodes (again, where surface paths cross they must both have the same elevation). The goal is have acceptable slopes between nodes.

You will need to set elevations at the nodes and see if the slopes between the nodes are acceptable.

The design rules of the local government that will be reviewing your plans will be the most likely source of acceptable grades. However, county state and federal rules may also apply. There are also rules of thumb that experienced designers know.

You will likely find that once you get one path just how you want it; another path doesn't have acceptable grades. This is why site grading is iterative. You just keep adjusting until you get it to work, or you have to tell the architect the paths have to change. It is rare to make the architect change the paths, so you had better try real hard to get it to work out.

Once you have set the grades along these lines you can extend the grades out to both sides (full width) of each path. In areas not connected with lines you may be able to have steeper slopes.

For a highway the paths are relatively simple. The only links to the outside world are the paths of the entrance and exit ramps. Lanes in opposing directions don't cross each other so there are fewer nodes where paths have to come together. (Though an elevated ramp would need to have sufficient vertical separation when crossing other lanes.) A building site is more complex and will generally have multiple surface links to the outside world through driveways and sidewalks. Those links define fixed points that you must grade to. Most building sites have a complex network of paths... more complex than a linear highway or street.

This complexity of paths is what makes site grading an iterative effort. You will have to balance the requirements of each type of path. The points where this balance is obtained are the nodes where lines connect.

Start with Points of Known or Fixed Elevation. There are points with fixed elevations that you must work from. These fixed points include where driveways from your site will enter surrounding streets and where site walks meet sidewalks. Where surface water enters or leaves your site are also usually points with fixed elevations. If the site building finished floors have been set then the building doors also are points of fixed elevation. Any existing facilities that are to remain also have fixed points at doors. The fixed points, the paths you have drawn and grade requirements for the paths form the design criteria for you to use.

Spot Elevations Are Your Initial Working Product. The site survey will feature contours to show elevations. However, what you need to work with are spot elevations.

For existing elevations you can either get the surveyor's ground shots or interpolate from existing contours. The goal is to set elevations for nodes that result in satisfactory slopes on paths between the nodes. From there you can calculate more spot elevations on those paths between the nodes and along the sides of the paths. Do not try to just draw contours for your design without doing spot elevations. They are not accurate enough. The difference between contours is measured in feet. In order to meet design requirements for most codes you will have to set elevations to tenths or hundredths of feet. Once you have set the spot elevations you can then draw in the new contour lines.

I will cover the grade requirements for different types of paths in the following sections.

Water Flows Downhill. Elevation differential (drop across the site) is the currency (money) of site grading. Unless your whole site is a pond or you are in a desert where it NEVER rains, you must move water across your site. If you lack sufficient elevation drop across a site, you can't push water across the site. If your site has too much elevation drop you will need to burn up potential energy without eroding your site (or the up and downhill neighbors).

While having slope is good for moving water, you will need flat spots for putting buildings (unless there is a daylight basement or equivalent). You will also need flat spots to put parking and ponds. This is harder on steep sites.

As you grade your site for proper surface water flow, remember ALWAYS maintain positive drainage around buildings. What this means is you should make your grading work so that even if all the catch basins plug, water will still drain away from your buildings. You want to have at least 10 and if possible 20 feet of ground around the building graded down away from the building. Then you want a drainage path off the site that will move water away from the buildings. At a minimum, I try to keep my buildings 6 to 12 inches above the highest points in the surface drainage paths that lead away from the buildings.

The rule I keep emphasizing to people is: Don't put your buildings in a bathtub! If anyone insists that you put a building in a bathtub: Explain very assertively why it is a very bad idea. Write them a letter telling them it is a very bad idea. Insist that they write you a memo or letter demanding that you do it. I have had architects try to put a building in a bathtub, but I have always talked them out of it.

The first thing to look for is where water leaves your site because you will be grading everything to aim storm water to that location. There may be multiple places it leaves the site. You are interested in places water leaves the site on the surface for your positive drainage path. You are also interested in any pipes you can send storm water to. These have the advantage of usually being lower than surface drainage paths off the site. You will need to get water to where it leaves the site. Where I live and work, one must ensure water leaves the site the same place it currently leaves the site (unless there is a new downstream approved drainage system). If there is no subsurface pipe that can carry water away from your site, any water you put in a subsurface pipe must be returned to the surface before it can leave the site. This can only be done if you have enough elevation drop for the pipe system to "daylight" or return to the surface at a lower elevation from where you put water into the pipe. If you take water from the surface and put it into a pipe using a catch basin it will drop down at least 3 feet in the catch basin. If you must daylight the pipe, you will need to find a point that is more than 3 feet lower than your lowest catch basin rim to send your surface water to. If there is a pipe you will be sending your flow to you must know the elevation at which you will connect to it.

The next thing you want to know is where water enters your site. This can be obvious, such as a stream. It can also be surfaces that drain across your site, or groundwater that shows up on the site. The groundwater is something that is best seen during a site visit after a week of rain.

Surface flow should have a grade of at least 2 percent (except as needed for wheelchair access). A grade of one percent on pavement will tend to have lots of puddles. Even on a perfect paving job, general dirt and debris will tend to settle and make puddles. A grade of one percent on dirt is called a wetland or pond where I live.

Swales and Ditches:

When rain hits the ground it generally flows across the ground in sheet flow for a while. Eventually, it combines into concentrated or channel flow. The distance of sheet flow is generally considered to be limited.

Once flow is concentrated a defined channel such as a ditch or swale must be designed. This requires open channel hydraulics design. Your ditches will need to be designed to carry flows that are dependent on the area draining to the ditch. Your municipality will have some sort of hydrologic method for calculating design flows. If the municipality for your project doesn't have a method for calculating the design flow, use the appropriate county or state methods.

Factors to consider are channel capacity and the velocity of the flow. The channel cover, such as grass or rock, must be selected and detailed appropriately for the maximum flow velocity to prevent erosion. In addition, low flow velocities can result in deposition. A small amount of deposition is normal and is even encouraged in bio-swales.

Ditches and swales have some advantages over pipes. The first advantage is that when you put flow into a pipe, you generally lose a few feet of elevation that you can't regain. Hence, if you have a flat site and flow leaves the site on the surface, you should use ditches, not pipes. The second advantage that ditches and swales have over pipes is that they can have a much larger capacity with moderate increases in size. Since pipes are closed at the top, capacity is definitely limited.

The main disadvantage of ditches with respect to pipes is that they create a path on the site's surface that must be devoted to the ditch and which has relatively inflexible grading demands. The longitudinal slope of a ditch is set to move the water appropriately and the side slopes are set to prevent erosion. Hence, ditches work better if they are in areas with sufficient space for their width and without other paths that cross them.

Whenever you design a ditch you want to provide sufficient freeboard above the water surface so that the ditch will not come close to overflowing during its design condition.

The minimum freeboard required in the area where I work is generally 0.5 to 1.0 feet for small to medium sized ditches.

Note that if you have a decrease in longitudinal centerline slope in a ditch or a sudden increase in roughness there may be a hydraulic jump. This can cause erosion if you don't protect the channel, and will require a deeper channel at and below the jump. There are other situations that can cause hydraulic jumps, so you should have a good knowledge of open channel hydraulics before designing ditches.

Gutters are essentially a paved ditch. Since most curbs are 0.5 feet high in the area where I work, that dimension defines the maximum allowable flow depth. With a bit of calculation, that can be related to a flow for a given

slope and with a bit more calculation the minimum number of catch basins can be determined. Note that for prolonged slopes, highway drainage manuals have good methods for calculating catch basin placement Note that local ordinances or special conditions frequently require more catch basins than the minimum number you would get from other design methods.

Catch Basin Placement:

Catch Basins are used to create low points you can drain towards or to take water out of a surface drainage path so the flow doesn't exceed width or depth criteria. If you have a pretty flat road or path you can drain towards a series of catch basins. The profile along the path will look like a series of w's with the bottoms of the w's being points where you will place catch basins. For a on a road that slopes in one direction for a prolonged distance with a gutter you will need a series of catch basins to keep the flow in the gutter from getting too wide or deep.

Highway drainage manuals have a method of calculating catch basin placement for this situation. Generally catch basins are equally spaced along a long gutter for maximum efficiency. However, there are possible situations where several catch basins may be placed in a short distance to reduce flow depth as much as is practical. In addition, local regulations may be more stringent and require more frequent catch basin spacing.

Spacing between catch basins may also be less than hydraulic considerations require because the parking and drive areas are divided into small basins just to get the grading to work.

Catch basins are points where you can't move flow along the surface any more. Note that once you put flow into a catch basin it will drop at least 3 feet below the surface elevation or rim of the catch basin. You must then find a way of getting this water off the site. You need a lower point on the surface or pipe to drain the water to. See the drainage section for more information.

At sag vertical curves with no other outlet street and highway manuals require multiple catch basins to limit ponding in event of a plugged grate.

It is normal to adjust catch basin locations iteratively to meet both surface grading and subsurface piping requirements. The general locations are usually set by surface grading considerations and the exact locations may be tweaked a bit to avoid other underground utilities or improve pipe layout.

Not All Pedestrians Are Rock Climbers, So what are the limits of pedestrians?

I've seen sidewalks on steep hills that slope at 20 percent or more. Realistically, people don't walk that slope very easily and, as of my first writing this, the UBC limits you to 1:8 or 12.5 percent. Stairs slope at around 60 percent (however you need 4 foot long landings every 12 vertical feet). Ramps for handicap access are limited to 1:12 or 8.3 percent with a maximum of 2.5 feet of vertical rise between landings. There are also requirements for handrails, kick plates and other features. I've just mentioned a few requirements, as I understand them, so you have some comparisons to work with.

The regulations you will have to design to are covered in the Uniform Building Code (UBC), the Americans with Disabilities Act (ADA) and any local codes. Design to these codes is NOT optional. You must do it. In particular, I have been told that the ADA is a civil rights act, so failure to meet it can be a criminal act (got my attention). My impression is that the ADA makes E & O insurance firms very nervous.

What routes must be handicap accessible? My commentary may now be out of date. You should find out what the answer is for where you live. The ADA commentary for Washington State, where I live gives multiple answers depending on the use of the building (residential, commercial, etc.). Obviously from handicap parking to the building doors (at least some of the doors) must be an accessible route. Other paths should be accessible wherever possible. Check the requirements in your area with local authorities. The slope and other dimensional requirements for accessible routes are so stringent that correctly identifying the routes up front is important. These paths and their slopes need to be thought about early in the design process. Other paths will likely be more flexible and more easily altered later in the process.

Note that I have been told in one town that the UBC requires that some buildings have 20 foot wide accessible routes (walks) up to the building's primary entrance. Talk to your local inspector and plan reviewer about this requirement (it may be open to interpretation).

Not All Cars Are Monster Trucks

The requirements for vehicles form the second most stringent set of design criteria for most sites. A vehicle needs to be able to turn and to not scrape bottom on the roadway. Fire trucks are often one of the most important design vehicles. There may be vehicles that are common to your site that have particular limitations. Ask your client what will be driving on your site. Your horizontal curves, vertical curves and vertical slopes must not exceed what is allowed for your design vehicles. Your local codes will have both the vertical and horizontal alignment requirements that must be met. You may need to be more stringent if you have a design vehicle with particular needs.

I will review what is common practice for typical sites where I work (Washington State). Note that these grades and requirements may now be out of date, as I haven't been grading a lot in the last several years.

Handicap parking and the adjacent access isle must slope no more than 1 percent. Cross slopes on other ordinary parking should be limited to fewer than 5 percent if possible to prevent car doors from hitting adjacent cars too easily. Gas station filling areas are generally not sloped more than one percent maximum. This is so that a car is less likely to roll away and rip out a hose. Filling areas are also generally paved with Portland cement concrete, as it isn't damaged by gasoline as asphalt is.

For drives and roads you are likely to have local codes indicating maximum slopes. Architectural Graphic Standards also covers information for parking and drives and has info on some design vehicles. For roads, state and AASHTO standards cover grades. If there are absolutely no standards I generally limit the slopes on drives with slow speeds and for cars only to a 20 percent maximum. In general bigger vehicles can not deal with sudden grade changes, steeper grades and sharper curves.

The rate of change in grade is important for vehicles. On roads and highways this is generally important because vertical curves limit the available sight distance and because the vertical accelerations can be uncomfortable. In driveways the rate of change in grade can be much more extreme than on highways because of the low speeds. However, there are still limits because it is possible to "bottom out" or scrape the pavement with a vehicle (as anyone with a low trailer hitch knows).

The longer the wheelbase and the less the ground clearance of a vehicle, the more likely a vehicle is to "bottom out" and scrape the pavement. You need to select design vehicles and not change the grade more than they can handle. Local codes may provide some guidance. AASHTO and Architectural Graphics Standards (at least the old copy where I work) cover vehicle dimensions. What will cause a vehicle to bottom out can vary from a sudden change of 3 to 4 percent (long vehicle) up to 10 percent (shorter car). I personally usually try to limit grade changes to 2 percent in twenty feet when possible. More severe slope changes should be considered carefully depending on your design vehicle.

There are a couple of places you are likely to exceed the amount of grade change that is good. The first is at driveway entrances (curb cuts). These usually feature a sudden rise of 6 inches in 5 feet or 10 percent. If you drop down from the back edge of the side walk at the driveway, it is possible to have an instantaneous crest slope change considerably over 10 percent (quite bad). The second case involves catch basins. Catch basins have pavement from opposite sides with opposing slopes for a sag instantaneous slope change. If the slope on both sides of a catch basin drain towards it at 2 percent, the slope change at the catch basin is 4 percent (add slopes together). For this reason relatively small slopes at a catch basin can yield a large slope change.

Vertical Curves Made Easy

For driveways there is a simple way to "fake" a vertical curve. Vertical curves are parabolas, which have a constant rate of change in slope. (From calculus you should remember that the derivative is a constant for parabolas.)

A parabolic vertical curve can be faked in without a lot of calculations.

Start at one end of the path on which you want to place a vertical curve. Divide the path into increments of 10 to 20 feet to the other end. Start with a slope and elevation at each end. Working towards the middle from each end, increment the slope in each increment of length by a set amount. For instance if you are going down and the first 20 feet slopes down at 2 percent (0.40 ft of elevation loss), the second twenty feet can slope at 4 percent (0.80 feet loss). The third twenty feet could slope at 6 percent (1.2 ft of loss). You will want to synchronize the slopes once you reach the middle working in from both ends.

Work from both ends in this manner until the remaining length in the middle matches the adjusted slope on the innermost length increments you have worked in from each end. You may need to adjust the amount of slope change applied in each length increment. An iteration or two is normal.

Unpaved Areas

Unpaved areas are generally covered with landscaping and lawns. Lawns to be cut using a rider mower must have a limited slope. However, in general the unpaved areas are good places to put significant grade changes that can not be accommodated elsewhere. The limit of slopes for erosion control in the area where I work is customarily 2 horizontal to 1 vertical (50 percent). The allowable side slope is reduced to 3:1 in waterways. Other jurisdictions do not allow slopes these steep in certain cases. The bottom line is that slopes must be stable and not easily eroded once vegetative cover is established. Your friendly geotechnical engineer will be able to help you with stability issues. Erosion characteristics depend on the soil and the type of cover (your job).

I try to give unpaved areas a minimum slope of 2 percent or more. If you don't drain an area well it will become a wetland or pond. Only do that if you intend to. Steeper slopes can be covered with rockeries. Note that rockeries have limits (see local codes and talk with your geotechnical engineer). Also note that rockeries are NOT a structural wall. The structural engineers I know refuse to talk about them. I view a rockery as an erosion protection measure that works on relatively steep slopes. Whether that slopes is stable or not is a separate issue that must be answered by a geotechnical engineer.

Erosion Control

You must provide surface cover for your site that can't be eroded by the water or wind. There are books and organizations that cover this subject well. Be careful to cover every square inch of your site, including during construction. You need to be careful that your contractor doesn't just "go through the motions". I have seen more silt fence than I care to remember not toed in, but NOT on my site! There are many Best Management Practices

(BMP's) for erosion control. I will just give a few comments.

Tarps have difficulties. They can be displaced by the wind unless your anchoring is stout and perfect. They also tend to create larger amounts of concentrated flow, so there is a higher potential erosion where flow runs off the tarps.

Straw is neat stuff. A few inches of straw creates a cushion for rain drops, absorbs some water, and makes it easier for grass to grow up through. It can be blown away by high winds and may not be what you want if you don't want grass growing in an area. But I really like straw.

Hyroseeding is ok, but requires suitable weather for grass to grow, watering during dry periods for the grass to grow. The site grading must also be quite refined and rain not too intense as hydroseeding is sensitive to concentrated flow.

Mattings of various sorts are available. Find local examples of matting used in the same ways you want to verify it works, if possible. Some matting, used properly, can deal with concentrated flows. Some mattings appear to be pretty hard for seeds to grow up through.

Successful implementation of erosion control measures requires proper detailing and proper installation. Good ideas are not enough. Proper selection and installation are essential.

Successful erosion control throughout construction requires adaptability. If one BMP or strategy falls short, you need the flexibility to get another put in place. Always be ready with another idea if what you are doing fails in some way. Have a plan B, and a plan C. More than many other aspects of design, erosion control benefits from the engineer visiting or being on site continuously to provide alternatives.

If erosion control is important to you and your client, consider having the contractor bid on a unit cost basis. That way, you can ask the contractor to do more work with a known price for a known area or length. Yeah, I know people will disagree with me, but this is the method I have seen work the best where it was the most important (in a municipal watershed). Just be careful not to seriously underestimate quantities if you use unit costs.

C. Drainage:

Drainage Systems
Design of storm water systems requires knowledge of hydrologic calculations and open channel hydraulics. The Mannings Equation is perhaps the most used item. However, one must also be able to do backwater and pressure flow calculations in some cases. In general, only an experienced civil engineer can avoid all the potential pitfalls.

In addition to the general engineering knowledge you will need to find codes and regulations that tell you design and construction regulations or guidelines. These can vary for each municipality. However, my experience is that many agencies have similar regulations. You must learn all the relevant regulations so well that you internalize them and apply them in your design.

If a locality lacks regulations, county or state regulations may apply. Try your state or county highway or transportation departments as starting points. Don't ask me about federal projects...

In general, I start a site civil design with an overview, then grading, then the drainage system. Then I iterate or backtrack until I can find the best balance of factors. This page will cover the design of the subsurface piping system.

You will want to collect drainage from catch basins, yard drains, and drain them through any necessary treatment and detention structures to a downstream release point. The first important fact to know is where that downstream release point is or will be.

Disclaimer

Remember, this is free advice, and is by definition worth nothing. As a design professional you are required to use your own judgment, not mine. If you are not a design professional, find one. Usually these designs must be done by licensed professionals. Good Luck.

System Failure

In the end, you should always design an overland flow route that can carry the maximum design flow safely from any point in your pipe system. That means there must be enough freeboard and you must protect against erosion on and below your site. My goal is to make the failure of my drainage system an annoyance, not a damaging or endangering occurrence. This involves the site grading. Hence, you will be refining your site grading and your drainage pipes to work and fail gracefully together.

Detention Pipes and Vaults

A detention pond site needs to be on the lowest usable part of the site which is relatively flat. The side slopes for berms to make the pond are generally regulated, along with freeboard and top width, or subject to good engineering practice (ask your geotech engineer if in doubt). Hence, extremely steep areas are not good for ponds.

If your municipality does not have regulations requiring a child proof fence around ponds and internal areas with limited side slope so a person could extract themselves, it is my opinion that you should consider these items to be good design practice.

Vaults and detention pipes are easier to place, but more expensive.

The sizing methods for ponds and vaults vary a bit. The Santa Barbara Urban Hydrograph method is prevalent. The weakness of this and other event based methods is that they don't consider the effect of back to back storms. When it comes to storage volumes that can be an important consideration. I live and work in the Seattle area, where it can rain for weeks in spurts of several days at a time. If the detention can't fully drain between storms, the storms are effectively one larger storm. Fair warning, I now do long term continuous sewer modeling as part of my job, so my bias is in that direction.

Drainage Pipe Layout - Connect the Dots

The cheapest way to layout pipes is a dendritical or tree like form with the trunk at the outlet (or detention/treatment structures).

One reason to use a different layout is if you lack sufficient elevation drop over the course of a pipe run to maintain slope. As I said in the site grading section, you need elevation drop to move water. Elevation drop is like money in the bank that you spend to make water move. Keep careful track how you use the drop.

There are lots of other factors that will also influence your pipe layout. That is why grading and drainage are strongly tied together and tend to be designed in iterative cycles.

Pipe sizes (diameters) are standardized. Get some manufacturer's catalogs if you have questions. If there are not regulations, I tend to use 4 inches as a minimum from a downspout, 6 inches as an undesirable minimum elsewhere and 8 inches as a preferred minimum. In the area where I work, 8 inches tends to not clog as much as smaller pipes.

However, leaf and branch characteristics where you work may make the non-clog size different.

In the area where I work, generally two feet of backfill is the minimum acceptable cover over a pipe. The freeze depth is considered to be 18 inches around here. This means that the pipe invert (inside bottom) is at least 3 feet down. If you want to get this water back on the surface downstream, you need at least 3 feet of elevation drop, plus whatever you need for the pipe slope.

If the surface over the pipe is planar (a sheet) then if both ends of the pipe are deep enough, the middle is too.

However, this is not usually the case. Hence you must be careful that every point along the whole of every pipe has sufficient cover. Pipes are, from this point of view, subsurface paths that do NOT intersect each other or come too close to the surface or the paths on the surface. If you have ANY uncertainty whether there is sufficient cover over a pipe or there may be a pipe conflict you should draw a profile (a vertical cross section showing the ground surface along the route of the pipe and the pipe itself. In some municipalities, counties or states, profiles are required for all pipes.

Low cover (shallow) pipes are possible, but are more likely to be dug up or damaged. Try to maintain sufficient cover. Consider ductile iron and controlled density fill as protective measures for shallow pipes.

Digging deeper to place pipes costs more, so generally pipes are kept as shallow as possible within limits.

Pipes are generally sized to carry the design flow and also sloped to provide a minimum velocity.

When pipes are increased in size, generally the crowns (inside tops) of the pipes are matched if possible. So the invert of the larger downstream pipe is dropped. Alternatively, if the pipes stay the same size, you should consider dropping the elevation between a structure inlet and outlet by 0.2 feet or so to deal with energy losses in the manhole (you should do the hydraulic calculations for the losses until you get familiar with how much loss occurs through a manhole).

In the area where I work, minimum allowed pipe slope is generally 2 percent. However, you should also consider whether sufficient velocity is provided at a common flow to flush out heavy particles. In the area where I work the minimum acceptable velocity during such a flow is considered to be 3 feet per second. Remember, if your pipe is backwatered by a detention system, velocities will be lower.

Extremely steep pipes also pose a problem as high velocities can cause problems such as air entrainment. This can get complex. However, one method to consider is to moderate the slopes of pipes and use drop manholes instead to use up excess elevation drop. However, drop manholes can be very bad if you have a lot of entrained air as they tend to trap air. The trapped air can then act like a valve and squeeze off the flow. It is bad to have a drop manhole that is below a steep pipe or which has a diameter that is not much bigger than the flow cross-sectional area. See your local, county and state standard drawings to see if drop manholes are allowed and how they are detailed.

Drainage Inlets

Water must be able to get into your pipe system. There are different ways of ensuring it can get in. Some municipalities require a certain type of inlet per a given area of pavement. Others only allow a certain flow depth before an inlet is used to reduce the depth. In sags (bathtubs) multiple inlets may be required or advisable to provide redundancy for safety. For instance secondary inlets may be required with the rims set a few inches above the primary inlet.

Inlet types are often regulated by code. They can be called inlets, catch basins, yard drains and other things.

Where I work, generally catch basins have grates and manholes have solid covers.

The elevation of the inlet grate is called the rim in the area where I work. This is sometimes depressed around 0.1 feet below the surrounding pavement to make it easier to get water into the system. If the pavement settles (how good is the compaction) a depressed inlet is less of a problem.

Other Structures

The most important thing is to make a drainage system maintainable by providing access. Manholes or catch basins are used to provide access at points where the direction of pipes changes or where the size changes. In addition, since only a limited length of pipe can be cleaned, a manhole, catch basin or clean out must be provided periodically along a pipe run. Note that some municipalities require manholes at these points, not catch basins or clean outs. The politically correct version of manhole is maintenance hole (still abbreviated MH).

Plans and Specs

I'd suggest getting the standard specifications and drawings and CAD standards from the municipality within which you are working. This will show you a lot. Make sure to include the required details and notes. If you leave out required details or notes, getting a permit gets difficult. Make sure to put enough information on your plans and specs to limit the number of questions a contractor might ask. Each opportunity to ask a question is an opportunity to claim a changed condition and ask for more money. However, showing the same information in two or more places is also risky. As you revise drawings, the risk is that you will fail to update all occurrences of the information.

Consider using tables of information whenever possible. I tend to work in excel and export tables of pipe materials, sizes, structure types, rims and inverts to CAD. This makes revisions easier too, just replace the tables.

Conclusion

Remember, this is free advice, and is by definition worth nothing. As a design professional you are required to use your own judgment, not mine. If you are not a design professional, find one. Usually these designs must be done by licensed professionals. Good Luck.