

2 Non-Structural Best Management Practices

2.1 Introduction

Non-structural BMPs should be identified and integrated into any stormwater management program. As with any long-term program, effective implementation of these BMPs may require establishing specific criteria and standard procedures for various types of facilities or operations, and personnel training. In many cases, these procedures are simply “common sense” applied to routine activities. The primary objective of these measures is to prevent or reduce the amount of contaminants released to surface waters; however, the pollutant reduction that can be attributed to these measures has not been quantified (WEF, 1998).

This discussion of non-structural BMPs emphasizes practices to achieve source control, and pollution containment and prevention. These BMPs can also improve the operation and maintenance of structural stormwater management systems.

The U.S. EPA recognizes the potential water quality benefits of non-structural BMPs. Proposed rules for granting NPDES permits identify the following six minimum control measures:

- Pollution Prevention/Good Housekeeping
- Illicit Discharge Detection and Elimination
- Public Education and Outreach on Stormwater Impacts
- Public Involvement/Participation
- Construction Site Stormwater Runoff Control
- Post-Construction Stormwater Management in New Development and Redevelopment

Of these measures, only runoff controls for construction sites and new development are structural measures.

Many of the varied non-structural management practices and source controls available are good examples of common sense and a stewardship ethic. Nearly any technique that reduces the potential adverse impacts of our daily activities on a watershed’s natural resources can be considered a non-structural control. The following is a brief discussion of common non-structural or source controls. Many can be incorporated in the site design, while others require a commitment of all residents for success.

Since the audience for this document consists of engineers, planners, and developers, the types of non-structural best management practices described are mainly associated with site design and development. There are many additional sources of information for other types of non-structural source control measures such as North Central Texas Council of Governments (1993), and Horner et al. (1994).

Developers, homeowner associations, groundwater conservation districts, and local governments are encouraged to establish programs to increase public awareness of ways to protect the aquifer from degradation. These programs may include information on the proper disposal or recycling of batteries and motor oil; putting together a pest and fertilizer management program; and, promoting xeriscaping and other water conservation practices. A number of communities, businesses and developments post signs to notify the public and employees that the area is on the Edwards Aquifer recharge zone. Signs posted on public road rights-of-way must meet TxDOT requirements, which can be obtained from the TxDOT district office in Austin, Texas, at (512) 832-7053

2.2 Comprehensive Site Planning

2.2.1 Introduction

Preventing problems is much more efficient and cost-effective than attempting to correct problems after the fact. Sound land use planning decisions based on the site planning principles discussed later in this section are essential as the first, and perhaps the most important, step in managing runoff problems. All new development plans (e.g., subdivisions, shopping centers, industrial parks, office centers) and redevelopment plans should incorporate non-structural management practices, including source controls, along with a comprehensive runoff management system. The following principles should be used to develop a site plan (Horner et al., 1994):

1. Every piece of land is part of a larger watershed. Since we all live downstream, a runoff management system for each development project should be based on and support a plan for the entire drainage basin.
2. The runoff management system should mimic and use the features and functions of the natural runoff system, which is largely capital, energy, and maintenance cost free. Every site contains natural features that contribute to runoff management under existing conditions. Depending on the site, existing features such as natural drainageways, depressions, wetlands, floodplains, highly permeable soils, and vegetation provide natural infiltration, help control runoff velocity, extend the time of concentration, filter sediments and other pollutants, and recycle nutrients.
3. Each development plan should carefully map and identify the existing natural system. Use natural engineering techniques to preserve and enhance the natural features and processes of a site and to maximize the economic and environmental benefits. Natural engineering is particularly effective when the runoff system is integrated into a site's landscaping, open space and recreational areas. Engineering design can and should be used to improve the effectiveness of natural systems, rather than negate, replace, or ignore them.
4. The volume, rate, and timing of runoff after development should closely approximate the conditions before development. To accomplish these objectives, two overall concepts must be considered: (1) maintaining the perviousness of the site to the greatest extent possible; and (2) slowing the rate of runoff. Give preference to runoff management systems that use BMPs to maintain vegetative and porous land cover and include on-site storage mechanisms. These systems reduce, filter, and slow stormwater runoff. Storage provisions can reduce peak runoff rates; provide settling of pollutants; lower the probability of downstream flooding, stream erosion, and sedimentation; and provide water for other beneficial uses.
5. In parking areas, pervious cover designs such as geogrid blocks and grass cover should be incorporated into the site plan. This measure is appropriate where there is

adequate soil cover and if no sensitive geologic features, including mapped or inferred faults have been identified.

6. Runoff should never be discharged directly to receiving waters. Runoff should be routed over a longer distance, through grassed conveyances (swales), wet ponds, vegetated buffers, and other practices that increase overland sheet flow. These practices reduce runoff, reduce stream bank erosion, allow suspended solids to settle, and remove pollutants before they reach downstream receiving waters and groundwater.
7. Plan, construct, and stabilize runoff management systems, especially those emphasizing vegetative practices, before development. This principle frequently is ignored, causing unnecessary off-site problems, extra maintenance, regrading, revegetation of slopes and grassed waterways, and extra expense to the developer. Construct and stabilize the runoff management system, including erosion and sediment controls, at the start of site disturbance and construction activities.
8. Design the runoff management system beginning with the project's outlet or point of outflow. The downstream conveyance system should contain sufficient capacity to accept the discharge without adverse downstream impacts such as flooding, streambank erosion, and habitat destruction in the stream and riparian corridor. Downstream conveyance systems may need stabilization, especially near the system outlet. Another common problem is a restricted or submerged outlet. This can cause runoff to back up and exceed the storage capacity of the collection and treatment system, resulting in temporary upstream flooding. This situation may lead to hydraulic failure of the runoff management system, causing resuspension of the pollutants and/or expensive repairs to damaged structures or property. In such circumstances, more than one outlet or an increase in the on-site storage volume may be needed.
9. Whenever possible, follow the topography to construct the components of the runoff management system. This step will minimize erosion and stabilization problems caused by excessive velocities.
10. Runoff, a component of the total water resources, should not be casually discarded but used to replenish those resources. Runoff is a misplaced resource, with location and timing determining whether it is a liability or an asset. Given the water quantity and quality problems facing our nation, we must consider runoff an asset. Treated runoff can potentially provide many beneficial uses such as irrigation of farms, lawns, parks, and golf courses; recreational lakes; industrial cooling and process water; and other nonpotable domestic uses.
11. Whenever practical, integrate multiple-use temporary storage basins into the management system. Too often, planned facilities are conventional, unimaginative, aesthetically unpleasing ponds. Recreational areas (e.g., ballfields, tennis courts, volleyball courts), greenbelts, neighborhood parks, and even parking facilities provide excellent settings for temporary runoff storage. Such areas are not usually used during

precipitation, so runoff ponding for short durations will not impede their primary functions. Curves increase the length of the shoreline of stormwater storage areas and create greater development opportunities. The increased shoreline also provides more space for the growth of littoral vegetation to provide greater pollutant filtering, more diversified aquatic habitat, and greater attractiveness.

12. Additional storage can be provided by including rainwater harvesting, which can be integrated into the building design and landscaping plan and provide irrigation for turf, plants and trees. In addition, roof tops served by a rainwater harvesting system do not need to be included in capture volumes for other onsite BMPs. Additional information on this technology is available from the Texas Water Development Board (1997). Existing stock tanks also can be incorporated into the stormwater management system, particularly if there is an existing, healthy littoral and aquatic plant community.
13. Retain vegetated buffer strips in their natural state or create strips along the banks of all water bodies. Vegetated buffers prevent erosion, trap sediment, filter runoff, provide public access, enhance the site amenities, and function as a floodplain during high water periods. They also provide a pervious strip along a shoreline to accept sheet flow from developed areas and help minimize the adverse impacts of runoff.
14. Vegetated buffer strips should also be maintained adjacent to sinkholes, caves, faults, and other “sensitive features.” Native grasses, forbs and trees adjacent to and upgradient of recharge features should be maintained or restored so that rainfall may continue to enter the subsurface. Ideally, the natural vegetated area would encompass the entire drainage area to a sensitive feature in order to maintain pre-development recharge quantity and quality. It is also beneficial to maintain down gradient areas, particularly if there is exposed, fractured rock on a gentle slope.
15. Maintain the runoff management system. Failure to provide proper maintenance reduces the system’s pollutant removal efficiency and hydraulic capacity. Lack of maintenance, especially to vegetative systems requiring harvesting or revegetating, can increase the pollutant load of runoff discharges. The key to effective maintenance is to assign responsibilities to an established agency or organization, such as a local government or homeowners association, and to regularly inspect the system to determine maintenance needs. An even better tactic is to design a system that is simple, natural, and as maintenance free as possible.
16. Provide financing mechanism for maintenance activities. All BMPs require maintenance to assure proper functioning. It is important that the entity responsible for maintenance develop a financing mechanism that will cover not only routine costs such as landscape maintenance, but also provide a fund to cover the cost of non-routine, expensive activities.

2.2.2 The Site Planning Process

Site planning requires determining specific uses for definitive land areas and planning development to achieve a community character and an amenable quality of life. To achieve this end, assemble and analyze all pertinent site information – social, ecological, cultural, economic, and political – to determine the project’s ultimate design or feasibility. Site planning can help preserve the site’s integrity and diverse natural systems. Assessing the opportunities and constraints imposed by a site’s features helps avoid or minimize potential problems and hazards, and decrease construction and maintenance costs.

Innovative development techniques, such as planned unit or cluster developments, are extremely well suited for site planning. Not only do these techniques reduce costs, they also allow greater flexibility and can incorporate natural and cultural resources into the development plan. These techniques foster a harmony between the development and existing natural systems, creating opportunities for amenities such as open space, recreation, and beauty not found in many developments.

There is currently an interest in many areas in the set of principles known collectively as “smart growth.” Several of these principles could have a direct bearing on the environmental impact of new development. Additional information and publications related to this topic are available at: www.smartgrowth.org.

Site plan contents will vary depending on local ordinances; however, site plans typically include a development plan and a street and utility layout. Most important, a site plan includes plans for grading, soil erosion and sediment control, runoff management, and landscape. Development and infrastructure plans created in harmony with the site’s constraints and opportunities greatly influence their effectiveness in protecting site and watershed resources. One should coordinate these elements to assure a logical sequencing of events. For example, a temporary sediment basin in the erosion and sediment control plan can become a permanent runoff detention basin. Additionally, all initial and final elevations in the grading plan should be consistent with facilities in both the erosion and sediment control plan and the runoff management plan.

Developing a site plan requires a careful step-by-step analytical approach, which often includes the following steps:

- Conduct a site evaluation. Assess existing natural and cultural features and determine suitability for the proposed development activity.
- Develop site maps. These allow visual inspection and analysis of site features and their relationship to alternative site development plans.
- Collect additional information. This is needed to finalize conceptual plans.

- Review site plan goals. Goals should properly address requirements of state and local laws, ordinances, permitting regulations, comprehensive plans, and land development codes.
- Develop and integrate the individual components of the site plan. Each component should include goals, desired performance, design considerations for chosen BMPs, operation and maintenance needs, costs, and scheduling.

2.2.3 Preserving Natural Runoff Conditions

Minimize Impervious Surface Area

Limiting impervious area is the most effective way to preserve a site's predevelopment runoff characteristics. Local codes may specify the maximum proportion of impervious cover allowed. Techniques for reducing the amount of impervious cover include:

- Reduce building setbacks, which reduces the lengths of driveways and entry walks. This technique is most applicable along low-use residential roads where traffic noise is not a problem.
- Reduce street widths by eliminating on-street parking or reducing lane width is most applicable to residential neighborhood roads.
- Install sidewalks on one side of roads or combine them with bicycle trails/walkways that go through backyard easements or natural areas. Whenever possible, these trails should be made of pervious materials.
- Use pervious pavement materials, such as pervious asphalt or pervious concrete, gravel, or combinations of geotextiles with sand, gravel, and sod. Take care when using pervious pavements to prevent clogging. Special design, preparation, batching, pouring, and finishing procedures, along with long-term maintenance needs, require that these pervious pavements be used appropriately.
- Use alternative development designs, such as cluster development, to reduce the length of roads, sidewalks, and other impervious areas.

Preserve and Mimic the Natural Runoff System

Traditionally, runoff systems were built solely to convey runoff away from homes, buildings, and developed areas as quickly as possible, with little regard for its effect on downstream land or water resources. These traditional systems rely on connected impervious surfaces and conveyances to quickly remove stormwater from developed areas. It is now widely acknowledged that disconnecting impervious cover can reduce the

amount of runoff and improve the water quality. An example of disconnected impervious cover would be directing roof runoff to vegetated areas rather than to driveways or directly into storm drain systems. Site designs that include vegetated filter strips around individual buildings and other impervious areas can reduce the need for more complex stormwater controls such as sand filters which are more expensive to construct and maintain. These vegetated areas help preserve the natural runoff system. Some of the techniques that mitigate the impacts of increased impervious cover include:

- Routing roof runoff to pervious areas, such as lawns, grassy swales, or depressed landscaped areas. Avoid connecting downspouts directly to storm drains or discharging downspouts onto parking lots, driveways, or other impervious areas.
- Capturing roof runoff (rainfall harvesting) for use in landscape irrigation.
- Protecting floodplains, wetlands, natural depressional storage areas, and sensitive features identified in the geologic assessment of the Water Pollution Abatement Plan. Incorporate them into the final runoff management plan.
- Using grassy swales instead of storm sewers as runoff conveyances, especially in residential developments. Swales, especially those with check dams or raised driveway culverts where allowed, encourage runoff capture. Use public education to teach citizens that water standing in a swale for a day is not bad and to prevent citizens from altering or using swales to dispose of yard materials or other garbage.
- Using depressional landscaping techniques that allow small areas, including landscaped islands within parking lots, to provide some storage and infiltration.
- Placing storm sewer inlets in grassy areas instead of paved areas. For example, a successful treatment system within a shopping center parking lot consists of landscaped areas around the perimeter that includes a grassy swale adjacent to the curb line. Regularly spaced curb openings (curb cuts) allow runoff to flow off the parking lot into the swale. The swale conveys runoff toward a storm sewer inlet, and then to a wet detention basin.

2.3 Pesticide and Fertilizer Management

2.3.1 Introduction

Pesticides are chemicals used to repel, control, or eliminate undesirable plants, animals, or insects. They are poisons by their very nature and may endanger human health even when applied according to label directions. The three types of commonly used lawn and garden pesticides include herbicides, which control weeds; insecticides, which control unwanted insects; and fungicides, which control plant diseases.

All pesticides must be registered by the U.S. Environmental Protection Agency before they are allowed on the open market. However, registration does not insure that pesticide formulations have been tested adequately for health and environmental effects. Additionally, “inert ingredients,” which generally constitute the largest percentage of a pesticide product, are not identified on the label, although they may be chemically active and toxic. While these materials may be even more toxic than the pesticide itself, health data and labeling information for inert ingredients is not currently required by the EPA because they are not added to the formulation to kill the target pest. Inert ingredients include solvents, emulsifiers (chemicals which help keep the formulation in solution), surfactants (chemicals which facilitate passage through cell membranes/walls), and stickers/spreaders (chemicals which increase adherence and coverage of the formulation).

Other problems associated with pesticide use include direct contamination of storm drains with pesticide runoff, contamination of groundwater during recharge events, drift from lawn applications, unknown effects when chemicals combine (synergist effects), possible resistance to the chemicals by pests, and the killing of beneficial non-target species, including the pest’s natural predators.

Pesticides can directly enter the groundwater system through spills around a poorly cased well, back-siphonage into domestic wells during spray tank/container filling, or improper disposal of pesticide containers. Another less direct contamination route is pesticide movement through the soil into groundwater.

The chemical characteristics of a pesticide, particularly water solubility, adsorption, and persistence, determine a formulation’s potential to contaminate groundwater. Solubility (ability of a chemical to dissolve in water) varies greatly among pesticides. The greater the water solubility, the greater the potential to leach, or “seep down” into the water table. Leaching can be particularly damaging if the pesticide is highly toxic. Adsorption (the physical/chemical interaction or bonding of pesticides with the soil) prevents or retards leaching into groundwater by holding the pesticide in the surface soil where breakdown primarily occurs.

Persistence is the ability of the pesticide to resist degradation or “breakdown” as it moves through the soil. Sunlight, soil organisms, and reactions with minerals or natural

chemicals facilitate breakdown in the surface soil. The persistence is measured in half-life (the amount of time for half of an amount of chemical to degrade). For example, if a pesticide has a half-life of two weeks, one percent of it will still be present in the soil after 12 weeks. The simpler compounds produced as a result of this degradation process may be either more or less hazardous than the parent compound.

The Edwards Aquifer Recharge Zone is characterized by caves, sinkholes, faults, fractures, and other permeable geologic features that create avenues for surface water to enter the aquifer. The same system that enables recharge to occur also provides a greater potential for contamination. Prevention is the best policy! Don't provide an opportunity for access to groundwater in the first place. *The decision to use pesticides involves a willingness to tolerate some degree of risk.* Consequently, pesticides should be used only as a last resort and then in small quantities in areas removed from sensitive geologic features, wells, or springs.

The active ingredients in currently available pesticides fall into four categories: traditional petroleum-based pesticides, insecticidal/herbicidal soaps, botanical pesticides, and biological controls.

- Petroleum-based pesticides have been available since the 1940's and work in a variety of ways. Some of these products attack an insect's nervous system while others affect various plant growth processes. Residues from some of these products are resistant to chemical breakdown and have been detected in groundwater and surface water.
- Insecticidal and herbicidal soaps have been used since the 1700's and have been further developed since 1980. These naturally derived products effectively disrupt the cell walls of insects and plants, resulting in dehydration and eventual death. These products degrade rapidly and are generally non-toxic to humans and animals.
- Botanical pesticides are derived from plants and have been used for centuries. They were widely used in the 1940's, until the newly developed synthetic pesticides became popular. Pyrethrum (extract of *Chrysanthemum cinerariifolium*), Rotenone (extract of derris root), and Sabadilla (derived from the seeds of *Schoenocaulon*) are the most commonly recognized examples of this group. These pesticides degrade very quickly and leave no residues. However, they are potent and should not be used casually.
- Biological controls target a specific host and are generally microorganism based. Other types of biological controls include insect pheromones (chemical secretions which elicit responses in another individual of the same species) and insect growth regulators. Biological controls are virtually non-toxic to insects other than the target pest, leaving the pest's beneficial predators and parasites unaffected. Two of the more widely known microorganism forms include *Bacillus thuringiensis* (BT) for worm and caterpillar control, and

Bacillus popilliae (milky spore disease), for eradication of Japanese Beetle grubs.

Excessive or improper application of fertilizers can contribute to algal blooms in receiving waters and can cause human health problems. A fertilizer management plan should be developed for all landscaped areas. This plan should include:

- A soil or plant tissue testing program to determine the types and amounts of fertilizer required for healthy vegetation
- The use of soil amendments and organic fertilizers
- Application rates and procedures
- Landscaping plan and areas of application and areas where fertilizer use will be avoided.

Vegetated buffers adjacent to water bodies are particularly effective when there is minimal use of fertilizers and pesticides within the buffer. The use of these materials should be avoided within 25 feet of open waterways or sensitive geologic features.

Grow Smart, Grow Safe: A Consumer Guide to Lawn and Garden Products (Dickey, 1998) is an excellent reference that identifies the least toxic products for lawn and garden. For more information about this guide contact the King County Water and Land Resources Division, Seattle Washington at (206) 689-3064.

2.3.2 Integrated Pest Management

Organic gardeners regard plant disease and insect infestation as a symptom, rather than the cause, of a plant problem. Affected plants may be stressed or poorly adapted to the area or struggling with soil imbalances. Recent pesticide application may have destroyed beneficial insect predators and upset the natural predator/prey balance. Rather than attempting to completely eliminate a problem, organic methods focus on re-establishing the natural harmony and balance which keeps diseases and insect pests and predators in check.

Integrated pest management (IPM) is an ecological and economical approach to pest control that utilizes various strategies, including organic gardening techniques, to manage pests. An IPM integrates of mechanical, biological and chemical controls. These combined strategies are more effective in the long term than any one strategy used by itself.

There are several basic steps involved in conducting a successful IPM program.

- Plant native species. Native plants encourage the presence of native insects and microorganisms that maintain plant health and vitality without chemical fertilizers and pesticides.
- Utilize nature's dynamic system of checks and balances to your advantage by developing healthy soil; planting well-adapted and pest-resistant varieties; maintaining proper fertility; and watering properly. Monitor weed, insect, and disease problems.
- Do some background reading on pest control for the plants you grow. Learn how to identify pest insects and know their life styles so that treatments can be administered most effectively (see recommended list on page 3-13).
- Establish a level of acceptable damage. A few chewed leaves do not constitute a real threat to your plants.
- Check for pest damage early and often. Treat only when close monitoring indicates that the pest situation will cause unacceptable damage.
- If pest populations are high enough to cause unacceptable damage, use all available means of control, but start with the method that is least damaging to naturally occurring beneficial insects.
- For chemical control, choose the most species-specific and most effective product available.

The major disadvantage of conventional insecticides is the ability of the pest to develop resistance. Resistance is the result of a forced genetic change in an insect population caused by casual and over frequent use of a pesticide. When a pest has developed the ability to resist one class of chemicals, it often has the ability to quickly develop resistance to others. Over 600 different types of insects, weeds, and plant diseases have shown resistance and many cannot be controlled with today's pesticide formulations. Resistance of this magnitude does not occur with biological controls, which utilize the pest and predator/parasite relationship. These relationships have evolved together over millions of years, each adapting to changes in the other.

Another serious drawback to using chemicals is that most are not host specific and will kill every insect in the area, including beneficial predators. When all the beneficials are killed, the population of secondary pests increases rapidly, often creating greater damage than that of the primary pests. In addition, insects and other biota residing within caves may also be affected. The U.S. Fish and Wildlife Service has listed numerous endangered species of karst invertebrates in Travis, Williamson Counties and Bexar Counties.

Improper use of chemical pesticides can harm these species and result in consultation with the USFWS.

The combination of resistance, secondary pest problems, and legal liability has increased the cost of chemicals. Comparatively, natural pest control is less expensive over the long term despite the fact that initial costs are commonly higher.

If you are using or plan to use a professional pest control or lawn care service, try to find a company that is familiar with IPM practices and will work with you in selecting the least toxic methods available. An IPM program will focus on biweekly or monthly monitoring of pest populations instead of routine monthly spray services. Pest treatments should occur only if there is evidence that a pest problem is developing. If traditional pesticide application methods are recommended, examine the suggested services and chemicals closely, keeping in mind any detrimental health or environmental effects. All of the least toxic pesticides listed are available to commercial applicators. Even if the applicator is not familiar with the product, it can easily be obtained from a local chemical supplier.

The City of Austin has an IPM Plan Assistance Packet. Other suggested reference sources for starting an IPM program are:

- National Wildflower Research Center, 4801 LaCrosse Avenue, Austin, Texas 78739-1702. (512) 292-4100. The Wildflower Research Center is a non-profit research and educational organization committed to the preservation and reestablishment of native plant species in planned landscapes. The Center's Clearinghouse has numerous fact sheets with species recommendations, the names of native plant nurseries, and contact information for native plant organizations.
- Comal County – Texas Cooperative Extension, 1323 S. Water Lane, New Braunfels, TX 78130-6971, Phone: 830-620-3440, <http://comal-tx.tamu.edu>.
- Bexar County – Texas Cooperative Extension, 3355 Cherry Ridge, #212, San Antonio, TX 78230, Phone: 210-467-6575, <http://bexar-tx.tamu.edu>.
- Kendall County – Texas Cooperative Extension, 210 E. San Antonio, #9, Corner of Blanco and Saunders, Boerne, TX 78006, Phone: 830-249-9343, <http://kendall-tx.tamu.edu>
- *Grow Smart, Grow Safe: A Consumer Guide to Lawn and Garden Products* by Philip Dickey, (Washington Toxics Coalition, 2002).
- *Common-Sense Pest Control* - Considered “the guidebook” of Integrated Pest Management, it offers least toxic pest control solutions for your home, garden, pets, and community. Shows how to identify pest problems and finds the most appropriate and least toxic solution. (Shelia Daar, Tauton Press, 1991)

- *A Field Guide to the Insects of America, North of Mexico* - One of the Peterson Field Guide series. This is an introductory insect identification field guide. (J. Borner, Houghton-Mifflin Company, 1974)
- *Rodale's Color Handbook of Garden Insects* - Field guide that enables you to identify almost any insect inhabiting the orchard or vegetable garden. Over 300 color photographs of insects in their egg, larval, and adult stages. (Anna Carr, Rodale Publishers, 1991)
- *Rodale's Chemical-Free Yard and Garden* - The ultimate guide to organic gardening. Safe gardening products and techniques; pest control and fertilizing recommendations for vegetables, flowers, fruits, trees, and shrubs; and a system for making the switch to chemical-free gardening. (Anna Carr, Rodale Publishers, 1991)

2.3.3 Mechanical Controls

Mechanical control of pests in an IPM program involves the use of lures, traps, baits, and barriers. These measures avoid the use of any chemical that might have an adverse impact on the environment. These controls include:

Hand picking. Arm children with cans filled with soapy water and pay them to collect unwanted pests. (A penny a bug for the kids and a soapy death for the offending insect.) Be sure your children are apprehending the right insects! Another manual removal alternative is the rechargeable bug collector, which vacuums bugs off of leaves and into a sealed disposable cartridge lined with a nontoxic sticky gel. A small portable hand vacuum is equally effective. To kill the collected insects, remove the bag, enclose it in a sealed plastic bag, and place in the freezer for 24 hours. This method can also be effective in helping control indoor flea infestations.

Pre-coated Insect Trap Kits. Especially effective for aphids, white flies, gnats, fruit flies, thrips, and other flying pests. (Local nurseries, mail order) For anything that crawls up a tree, shrub, or vine. Use sticky bands or Tanglefoot glue to prevent ants from getting to the honeydew and eating aphid, scale, and mealybug predators. Also effective against tent caterpillars, gypsy moths, and cankerworms. (Local nurseries)

Roach/Mouse Glue Traps. (Local nurseries, grocery stores)

Pest Lures (attracts specific pests). Attracts codling moths, gypsy moths, cabbage loopers, corn earworms, apple maggots, yellow jackets, and houseflies. (Local nurseries)

Beneficial Lures (attracts predator insects). Attracts predatory wasps, ladybugs, and lacewings.

Copper Sheeting. Strips of copper can be placed around tree trunks, pots, or the sides of planter beds to effectively kill and discourage slugs and snails. You can either purchase paper-backed sheeting or make your own strips from copper sheeting sold at hardware stores. For maximum effectiveness, keep vegetation from bridging the copper or else snails and slugs will cross over. (Local hardware stores)

Diatomaceous Earth. Natural grade only. (Two grades of diatomaceous earth are available for different applications. Natural grade diatomaceous earth is appropriate for pest control purposes and can be obtained at local nurseries.) Diatomaceous earth is the naturally mined, ground-up silicon skeletons of microscopic one-celled plants. The fractured skeletal particles have very sharp edges that puncture and dehydrate soft-bodied insects, such as ants, aphids, and slugs. The resulting dehydration is intensified by the particle's ability to absorb up to four times its weight in liquid. Avoid inhalation by wearing a protective mask, as it is irritating to the respiratory tract. If applying to a pet's coat for flea/tick control, remember to shield your pet's nose also. Safe to ingest, it is used in animal food as an anti-caking agent and for internal parasite control. Diatomaceous earth will kill ants, roaches, drywood termites, fleas, bees, crickets, ticks, spiders, snails, and slugs. (Local nurseries)

Beer/Yeast & Water Traps. Snails, slugs, and pillbugs cannot resist fermented yeast. Beer, non-alcoholic beer or a homemade slug brew (1 cup of water, 1 tsp. sugar, 1/4 tsp. yeast) is equally effective. Use empty cans open at one end, jars and old plastic containers as traps. Dig holes the size of containers throughout your garden or around the affected plants. Sink the traps into the ground with the top rims flush with ground level. Slugs will take the bait and fall into the traps and drown. To prevent beer-loving pets from robbing the bait, construct a pit trap from a half-gallon size coffee can. Cut a rectangular opening a third of the way up the side of the can. Sink the can into the ground to the level of the opening, leaving the plastic cap on the can.

Boiling Water. Applying boiling water to fire ant mounds can effectively destroy smaller infestations. It is important to do this early in the morning, when temperatures are cooler and the colony has moved to the top of the mound.

Crushed Dill Mulch. Effectively repels most pests.

Row Covers. Buy them or make your own from discarded pantyhose. Row covers will provide a barrier between insects and your plants while allowing moisture and sunlight through. (Local nurseries)

Mulch. Mulch can be used to control weeds.

Propane Weeders. These devices use heat to kill weeds.

2.3.4 Biological Controls

When relying on predator/prey controls, it is important to remember that natural enemies will not appear until their food source, the pest, is present. Biological controls include:

Bacillus thuringiensis. Effective against caterpillars and worms, including webworms and tentworms. *Bacillus thuringiensis* (BT) acts as a bacterial stomach poison and must be ingested by the pest. For maximum effectiveness it is important to carefully follow the label directions. This product degrades very rapidly in sunlight, within one to several days. Since consumption determines who dies, repeated applications may be necessary. Completely safe for all non-target species.

Bacillus thuringiensis israelianis kills black flies, fungus gnats, and mosquitoes. House flies and stable flies are affected.

Bacilus popillae eradicates Japanese beetle larvae, and certain other lawn grubs for up to 25 years.

Introduction of Beneficial Predator Insects. You name a pest, it has a predator (including fire ants)! Beneficial nematodes, ladybugs, and lacewings are all available for purchase at nurseries, online, by phone, or via mail order.

Plant Ornamentals/Annuals Which Attract Native Beneficial Predator Insects. Cosmos (White Sensation and Sunny Red), Marigold (lemon Gem), Zinnia (Cut and Come Again), Morning Glory, Canytuft, Anthemis, Tansy, Caraway, Dill, Fennel, Spearmint, Buckwheat, and Coriander. Most of these plants can be grown easily in pots.

2.3.5 Recommended Chemical Controls

Alternatives to Traditional Synthetic Insecticides

- Boric Acid. An inorganic dust containing boron that acts as a slow-acting stomach poison and results in starvation. It must be ingested and takes 5-10 days to act. Kills plants if applied directly to them. Must be kept from children and pets. Effective against roaches.
- Pyrethrum Powder. Crushed *Chrysanthemum cinerariifolium*. Pyrethrums are broad spectrum insecticides and will kill beneficials as well. However, since degradation begins within hours, the overall impact on the entire community is minimized.
- Piperonyl butoxide. (PBO) A broad-spectrum insecticide which normally contains pyrethrum and diatomaceous earth. Piperonyl butoxide is a synergist which is also registered as a pesticide. There is controversy surrounding PBO

because some studies of chronic human exposure suggest nervous system damage.

- Synthetic pyrethrum, potentially more toxic than pyrethrum. Broad spectrum insecticide.
- Pyrethrum (higher percentage than Perma Guard™ Household formula), diatomaceous earth, piperonyl butoxide. Broad spectrum insecticide.
- Potassium salts of fatty acids, citrus aromatics, and inerts. Can be applied up to the day of harvest. Insecticidal soaps are more effective against slower moving, soft-bodied, sucking insects, such as aphids, scale, white flies, and thrips. Generally bees, wasps, and flies are more mobile and relatively unaffected. Do not mix your own detergent solutions, as the phosphate content of dishwashing detergent may vary and prove harmful to the plant.
- Synthetic hormonal growth regulator for fire ants. Degrades rapidly when exposed to water. Alkalinity also speeds breakdown.
- Extract of derris root. Not for casual use. Broad spectrum insecticide which is toxic to non target species. Very toxic to fish. Degrades rapidly.
- Nicotine sulfate solution of poultry pests, aphids, leafhoppers, thrips, scale, and other sucking insects. Also recommended as a foliar fungicide. **EXTREMELY TOXIC**. Easily absorbed through the skin and there can be problems with drift. Not intended for casual use.
- Sabadilla Dust. Powder of Sabadilla lily seeds. The powder must make physical contact with target pest. Sabadilla is four times less toxic to mammals than Rotenone. Degradation occurs within 24 hours of exposure to sunlight. Sabadilla is a broad spectrum insecticide and is toxic to bees, spider, ladybugs, other beneficial insects, frogs, and fish. Alkaloids absorbed through the skin can result in a rapid and dangerous drop in blood pressure.

Chemical Alternatives to Synthetic Herbicides

- Soap-based nondiscriminate herbicides which are especially effective for seedlings.

Chemical Alternatives to Traditional Synthetic Fungicides

- Sulfur Dusting Powder. Miticide and fungicide. Will burn foliage at temperatures over 85° F. Controls black spot and powdery mildew.
- A magnesium and zinc-based fungicide that controls powdery mildew and black spot. Does not have the foliar burn problems associated with sulfur.
- Sodium Bicarbonate (Baking Soda)/Potassium Bicarbonate. These chemicals may be used either alone or together to control black spot. Use four teaspoons per gallon of water. Effectiveness increases with use of a sticker/spreader.

2.3.6 Traditional Chemical Controls

Traditional chemical controls should be applied only as a last resort; when the situation will cause unacceptable damage and if the benefit of using it exceeds the environmental and health costs. Guidelines for the use of these materials include:

- Consider solubility, adsorption, and persistence factors in pesticide selection. (Consult the County Extension Office, State Department of Agriculture or obtain a Material Safety Data Sheet from the supplier or manufacturer). Choose the least toxic option and purchase only the amount you require.
- Restrict applications to the smallest area possible. Treat only infested plants or areas for the shortest possible time. If feasible, simply prune out the affected area and dispose of the infested material in a bucket of insecticidal soap.
- Do not apply pesticides outdoors when rain is forecast.
- Exercise care when applying pesticides in close proximity to adjacent storm drains. Drift and runoff are likely to occur when materials are applied to the edge of a curb. Pesticide residues can run off into storm drains, contaminating lakes and streams, and poisoning aquatic life.
- Conduct any activity involving pesticides as far from wells, springs, and other sensitive features as possible. This includes storing, mixing, or loading pesticides, and rinsing containers.
- Install back flow prevention devices to minimize back-siphonage. Keep hose ends out of chemical tanks.

If pesticide spills or accidents occur, notify the responsible local or state personnel immediately (State Department of Agriculture, TCEQ, or municipal spill response teams). DO NOT hose down the area. For small spills, remove the impacted soil and the area surrounding it, contain in several small plastic bags and place in trash. For spills on

walkways lay down soil or absorbent material (kitty litter, vermiculite, sawdust); remove material; and discard as above. Wash with biodegradable detergent and water, and collect water with additional sorbent, vacuum, or other method.

Read and follow label instructions exactly. Labels provide legal as well as product information. Using more than the specified amount of pesticide will not increase its effectiveness. It may constitute illegal misuse and can result in harm to plants, the environment, and you. Make sure the product is used on the designated application area (soil, leaves, edible fruit) and is appropriate for your specific plant and pest control problem.

You should not purchase or use pesticides if you are unwilling to follow all label directions and safety and environmental precautions.

Triple rinse container immediately after emptying (some pesticides are very difficult to rinse after they have dried out), and crush or puncture top and bottom of containers to prevent reuse.

Return rinse water to pesticide spray tanks and apply to affected area according to the application instructions, or use the rinse water to mix new spray solutions of the SAME pesticide.

DO NOT pour pesticides on the ground, flush down a drain or toilet, or pour out on the sidewalk.

Traditional synthetic petroleum based insecticides include:

- Carbaryl. Moderate reversible cholinesterase inhibitor. Acetylcholine is a chemical that plays an important role in the transmission of signals between nerve cells. It acts by binding to the receiving nerve cell and turns the nerve's switch "on," causing it to fire. Cholinesterase is an enzyme that inactivates acetylcholine, essentially allowing the nerve cell to recover by turning the switch "off." Cholinesterase inhibitors prevent the body from producing cholinesterase, resulting in the nerve's switch being locked in the "on" mode. This inhibition can be either reversible (atropine is antidotal) or permanently irreversible. Carbaryl has been detected in the groundwater of six states.
- Acephate. Broad spectrum insecticide, often used for fire ant control. Irreversible cholinesterase inhibitor. Rapid environmental degradation. EPA requires a 24-hour re-entry period for agricultural uses (NCAMP 1991).
- Chlorpyrifos. Irreversible cholinesterase inhibitor. Chlorpyrifos adheres tightly to soil and is not expected to leach. Soil persistence is estimated between 60-120 days (Howard, 1991). Depending upon the soil type, microbial metabolism may have a half-life of up to 279 days. The EPA is conducting a special review of Chlorpyrifos and has requested additional data

from registrants to fully assess its environmental fate and ability to affect ground water. Detected in the groundwater of eight states.

- Diazinon. Prohibited for use on golf courses and sod farms since 1986 due to frequent bird mortality but still permitted for home use. The toxic effects to birds following brief short-term exposure to Diazinon has resulted in the EPA listing acute exposure as “very likely toxic” to birds. The native soils in the Edwards Recharge Zone are very alkaline. While Diazinon breaks down more rapidly in alkaline environments, the major soil degradate is more persistent. Diazinon’s potential to contaminate groundwater is unknown. Detected in the groundwater of seven states.
- Malathion. Moderate reversible cholinesterase inhibitor. Stored Malathion breaks down into malaoxon, which is considerably more toxic than the parent compound. Detected in the groundwater of four states.
- Horticultural Oils. More temperature flexible than traditional dormant oils, many of the lighter formulas can be used safely when temperatures are between 70 -100° F. Horticultural oils physically act on insects at all stages of their development by smothering them. They have a slight residual life and are easier on beneficial species than other traditional broad spectrum pesticides.

Traditional synthetic herbicides include:

- Glyphosate. Some glyphosphates contain a surfactant, which is much more acutely toxic than the herbicide itself. It is for postmergent use only and degrades very quickly.
- Dactal. Contaminated with dioxin and hexachlorobenzene (possible human carcinogens) in the manufacturing process. Dactal metabolites were the most frequently detected pesticide in the EPA’s 1990 national groundwater survey. Detected in the groundwater of 10 states.
- Atrazine. Used in most weed and feed formulations; it is the most widely used herbicide. Persistent in water. Targeted for special review by EPA because of its ability to contaminate groundwater. Atrazine has a high potential for movement and a low potential to undergo degradation. No adequate studies are available on the health risks to humans. Detected in the groundwater of 28 states.
- Dicamba. For pre- and post-emergent use. Persistence, drift, and leaching are problems. If spraying Dicamba in your yard, be aware that it will readily volatilize and may kill your neighbors’ plants as well. The acute toxicity of Dicamba is still being debated. The EPA considers it to present a low acute

toxic risk for home use when compared to Silvex and 2,4,5-T, whose use has been suspended. Others believe it is borderline between moderately and very toxic. Detected in the groundwater of 11 states.

- 2,4-Ds State imposed limited use. Under the Texas Pesticide Regulations, only licensed or supervised individuals are permitted to use chemicals in this group. Although biodegradation is rapid, groundwater leaching is highly likely in alkaline soils. Detected in the groundwater of 18 states.

Traditional Synthetic Fungicides

The microbial degradation of fungicides is inhibited due to the nature of the product. Only two fungicides, PCNB and Chlorothalonil have been detected in groundwater in the United States. Primary concerns regarding fungicides are related to detrimental health effects associated with the metabolites. Application instructions should be followed precisely.

2.4 Housekeeping Practices

Practices that reduce sources of potential pollutants in runoff should be undertaken by all watershed residents. Public education is vital to acceptance and use of these practices.

Street or parking lot sweeping. Some reduction in the discharge of chemical constituents, sediment, and litter to stormwater from street surfaces and parking lots can be accomplished with an intensive (at least twice weekly) street-cleaning program. Street sweeping has been found most effective for stormwater quality improvement in commercial business districts and intensely developed areas (Washington State Dept of Ecology, 1992). The reduction in solids and other materials resulting from an aggressive street sweeping program can reduce the maintenance requirements of structural runoff controls and provide aesthetic benefits to area residents. Solids collected by street sweepers must be disposed of properly, commonly in municipal landfills.

Improvements in the design and use of street sweepers may offer hope for additional reduction in stormwater loads. The four types of sweepers currently being used include:

- Mechanical street sweepers
- Vacuum street sweepers
- Regenerative air street sweepers
- Advanced high efficiency sweepers

Mechanical broom sweepers are more effective for removing litter and other large particles. On the other hand, vacuum sweeper inlets must be close to the ground to provide sufficient suction and consequently are not effective for litter removal, but collect more of the smaller particles responsible for much of the chemical constituent load in

stormwater runoff. Regenerative air sweepers are similar to vacuum sweepers, except that they have a larger pickup head, and the air is recycled. Advanced high efficiency sweepers are used in industrial applications and are designed to remove the smaller particles.

Tandem street sweeping offers an opportunity to exploit the strengths of both mechanical and vacuum type sweepers. Tandem operations involve the combined use of mechanical and vacuum sweepers in successive cleaning passes. A new type of vacuum-assisted dry sweeper also has been developed that provides the important components of tandem sweeping in a single unit.

Chemical constituent, litter and sediment removal rates are also directly related to frequency of sweeping (particularly vacuum sweeping), the rate at which sediment and other debris accumulates on paved surfaces, and the average interval between storms. The rate at which sediment accumulates depends on a number of factors, including traffic count, adjacent land use, and site design. Sediment is also continuously being removed by wind and traffic-generated turbulence. Consequently, the maximum accumulation (equilibrium between accumulation and removal) can occur in just a few days on highways lacking curbs or other roadside barriers. Structures that help retain sediment on shoulders and the road surface such as concrete guardrails or curbs allow more material to accumulate; therefore, the maximum accumulation might not occur for several weeks.

Detecting and reducing illicit connections and discharges. Illicit connections of sanitary sewers, industrial discharges, commercial floor drains, sump pumps, and basement drains greatly contribute to water quality problems caused by runoff. These often serve as conduits that introduce solvents, oils, and even toxic materials into runoff. The EPA may require that NPDES stormwater runoff permit holders develop and implement an illicit discharge detection and elimination program. This would require the operator to develop and implement a plan to detect and address illicit discharges (including illegal dumping) to the system. Local governments should conduct regular investigations (i.e., smoke tests, dye tests, dry weather flow sampling) to detect and eliminate illicit discharges. These informational actions could include storm drain stenciling; a program to promote, publicize, and facilitate public reporting of illicit connections or discharges; and distribution of outreach materials. Recycling and other public outreach programs could be developed to address potential sources of illicit discharges, including used motor oil, antifreeze, pesticides, herbicides, and fertilizers.

Public outreach decreases the occurrence of and increases the reporting of illicit discharges. A public education program should inform citizens about the legal, health and environmental risks of discharging toxic materials into storm sewers or dumping on roadsides. This information can be disseminated through various media as well as storm drain stenciling programs. Use of volunteers involved in stream and outfall monitoring programs can significantly enhance an agency's inspection and reporting capabilities at nominal cost. Young, et al. (1996) recommend that the public should be informed of:

- The implications of illicit discharges.
- The indications of illicit discharges.
- Who to contact and how to reach that office/person to report a suspected discharge.
- The availability of waste oil, paint, and hazardous household chemical disposal/recycling facilities and proper disposal procedures.

Proper handling, use, and disposal of fertilizers and pesticides. Controlling the rate, timing, and method of chemical applications can minimize use and limit runoff contamination in a watershed. Many state agricultural agencies provide educational materials on the proper type and amount of fertilizers needed for a particular landscape. U.S. Department of Agriculture agencies provide fertilizer and pesticide management guidance in selecting the most environmentally safe chemical and minimum effective dosage. In addition, Austin, San Antonio, the Lower Colorado River Authority and the TCEQ operate household hazardous waste collection programs for the disposal of household chemicals such as pesticides.

Proper handling, use, and disposal of household chemicals. A wide variety of cleansers, oils, solvents, paints, and other household materials pose certain risks to the environment. Some wastes are legally defined as hazardous or toxic and must be disposed of using stringent procedures imposed by federal, state, or local laws. Some states have established programs such as amnesty days that encourage citizens to safely and freely dispose of potentially hazardous household wastes. Citizens need to know how to safely use and dispose of many household materials including antifreeze, gasoline, waste motor oil, car batteries, old tires, floor or furniture polish, most cleaning products, chlorine bleach, paints, paint thinners, turpentine, mineral spirits, wood preservatives, weed killers, and roach and ant killers.

Proper solid waste management. Historically, efforts to control the accumulation of litter were focused on health and aesthetic concerns. In recent years, the impact of this debris on stormwater quality and stormwater management system maintenance has become an equal, if not greater, concern. Solid wastes and litter that accumulate on the land are easily transported by runoff. An effective litter and debris control program should include source controls as well as debris removal and disposal. Appropriate placement of waste receptacles should be considered during the project design phase. Regularly scheduled maintenance of these receptacles and signage (such as for pet waste or litter pickup) can encourage their use.

Source controls consist primarily of public education efforts to inform the public of the impacts of litter on the environment. An example of a successful public education effort is one funded by the Texas Department of Transportation. TxDOT has produced a continuing series of critically acclaimed public service announcements featuring prominent Texas musicians with the theme “Don’t mess with Texas” (Levitt, 1998). Properly collecting and disposing of solid wastes – and recycling appropriate materials – can greatly reduce runoff pollutant loads. Additional efforts to reduce litter might include:

- Publicize and enforce litter laws.
- Educate the public and maintenance workers regarding the legal, financial, and environmental implications of litter and illegal dumping.
- Provide and encourage use of litter receptacles.
- Provide litterbags for use by motorists.

Proper disposal of pet wastes. The wastes our pets leave behind can be a major source of bacterial loading to our waters. Requiring owners to collect and properly dispose of animal wastes can help reduce these loads and keep our waters open to recreation.

Recycling used waste oil. Many gallons of waste oil are dumped into storm sewers for disposal. However, this oil can be recycled and used for many activities. Many states, local governments, and private companies have established used-oil recycling programs and centers. In addition, most automobile oil change businesses will accept waste oil from the public.

Organic debris disposal. As laws limiting the landfill disposal of yard wastes become more common, the proper management of grass, leaves, pruned branches, and other debris becomes increasingly important. Composting by homeowners or at collection centers reduces organic debris and associated pollutants from the runoff waste stream. Additional benefits include increased soil organic matter, resulting in improved water and nutrient holding capacity, and nutrients, which reduce the need for fertilizers.

Roofing or otherwise enclosing areas. Loading docks, storage areas for raw materials, wastes or final products, and equipment maintenance and storage areas are likely pollutant sources carried in runoff. Roofing or enclosing these areas so they are no longer exposed to rainfall or runoff will prevent oil, gasoline, fuels, solvents, hydraulic fluids, sediment, organics, nutrients, and other pollutants from entering runoff.

2.5 Landscaping and Vegetative Practices

Vegetation of any sort provides several advantages in stormwater management. By increasing the roughness of the surface over which the runoff flows on its way to drainage courses, vegetation helps control quantity as well as quality of stormwater. Preservation of existing vegetation in the catchment areas of recharge features and in riparian corridors provide numerous environmental and water quality benefits.

Selection of low maintenance plants suited to site conditions, use of natural vegetative and drainage features, construction of vegetated drainage systems, and landscape planning and design can be used to incorporate vegetative BMPs in new developments. Typically, vegetative measures alone will not be sufficient to serve all stormwater management purposes on a site, but such practices can be incorporated into a stormwater “treatment train” (Horner et al., 1994). Vegetative practices are effective methods for pretreatment of runoff to reduce the size and cost as well as improve the operation and maintenance of other BMPs.

Vegetation diminishes the impact of precipitation and slows runoff, thereby reducing soil erosion. This also increases water retention over the surface, which allows greater infiltration and evapotranspiration, reduces the volume of stormwater runoff, and, thus, reduces peak discharge during flood events.

Vegetation is an effective filter for removing sediments by reducing runoff velocity, and removing nutrients and heavy metals through plant adsorption and uptake. Surface runoff must pass slowly through the vegetative filter to allow sufficient contact time for these mechanisms to function effectively. Vegetation also provides various wildlife habitats.

In addition to the structural vegetative measures described in Chapter 4, other less technical practices that can enhance stormwater management include (Young et al., 1996):

- Tree Protection
- Stormwater basin landscaping
- Xeriscape programs
- Lawn/turf grass management
- Preservation of critical areas, and natural vegetation and drainage features.

2.5.1 Tree Protection

Estimates indicate that forested areas may produce 30 to 50 percent less runoff than grassed lawns. This results from the canopy intercepting rainfall prior to it reaching the ground, and from enhanced infiltration of precipitation that does reach the ground through the spongy organic matter that accumulates beneath the plants. Forested areas

also provide some pollutant removal potential. Trees planted in the riparian zone serve to stabilize stream banks and minimize erosion. They also absorb noise, provide shade, screen scenery, and provide wind breaks. Trees also moderate local air and water temperatures, the latter serving to protect aquatic habitats. The mixture of trees and shrubs selected must be suited to growing conditions on the site, such as soil texture, moisture, fertility, exposure, and sunlight (Schueler, 1987).

It is advantageous to promote the survival of desirable trees where they will be effective for erosion and sediment control, watershed protection, landscape beautification, dust and pollution control, noise reduction, shade and other environmental benefits while the land is being converted from forest to urban-type uses. The following guidelines were modified from those developed by the VA Dept of Conservation (1992).

New development often takes place on tracts of forested land. In fact, building sites are often selected because of the presence of mature trees. However, unless sufficient care is taken and planning done in the interval between buying the property and completing construction, much of this resource is likely to be destroyed. It takes 20 to 30 years for newly planted trees to provide the aesthetics and ecological functions and benefits of a mature tree stand.

Trees may appear to be inanimate objects, but they are living organisms that are constantly involved in the process of respiration, food processing, and growth. Construction activities expose trees to a variety of stresses resulting in injury ranging from superficial wounds to death. An understanding of these stresses is helpful in planning for tree protection.

Natural and man-related forces exerted on the tree above the ground can cause significant damage to trees. Removal of some trees from groups will expose those remaining to greater wind velocities. Trees tend to develop anchorage where it is most needed. Isolated trees develop anchorage rather equally all around, with stronger root development on the side of the prevailing winds. The more a tree is protected from the wind, the less secure is its anchorage. The result of improper thinning is often wind-thrown trees.

Unprotected trees are often “topped” or carelessly pruned to prevent interference with utility wires or buildings. If too many branches are cut, the tree may not be able to sustain itself. If the pruning is done without considering the growth habit, the tree may lose all visual appeal. If the branches are not pruned correctly, decay may set in. Tree trunks are often nicked or scarred by trucks and construction equipment. Such superficial wounds provide access to insects and disease.

Disturbing the delicate relationship between soil, roots, and the rest of the tree can damage or kill a tree. The roots of an existing tree are established in an area where essential materials (water, oxygen, and nutrients) are present. The mass of the root system is the correct size to balance the intake of water from the soil with the transpiration of water from the leaves.

Raising the grade as little as 6 inches can retard the normal exchange of air and gases. Roots may suffocate due to lack of oxygen, or be damaged by toxic gases and chemicals released by soil bacteria. Raising the grade may also elevate the water table. This can cause drowning of the deeper roots.

Lowering the grade is not usually as damaging as raising it. However, even shallow cuts of 6 to 8 inches will remove most of the topsoil, removing some feeder roots and exposing the rest to drying and freezing. Deep cuts may sever a large portion of the root system, depriving the tree of water and increasing the chance of wind-throw.

Lowering the grade may lower the water table, inducing drought. This is a problem in large roadway cuts or underdrain installations. Trenching or excavating through a tree's root zone can eliminate as much as 40 percent of the root system. Trees suffering such damage usually die within 2 to 5 years.

Compaction of the soil within the drip line (even a few feet beyond the drip line) of a tree by equipment operation, materials storage, or paving can block off air and water from roots. Construction chemicals or refuse disposed of in the soil can change soil chemistry or be toxic to trees. Most damage to trees from construction activities is due to the invisible root zone stresses.

The proper development of a wooded site requires completion of a plan for tree preservation before clearing and construction begins. Trees should be identified by species, and located on a topographical map, either as stands or as individuals, depending on the density and value of the trees. Base decisions on which trees to save on the following considerations:

- (1) Life expectancy and present age: Preference should be given to trees with a long life span, such as oak and elm. Long-lived specimens that are past their prime may succumb to the stresses of construction, so smaller, younger trees of desirable species are preferred; they are more resilient and will last longer. However, if the cost of preservation is greater than the cost of replacement with a specimen of the same age and size, replacement may be preferred.
- (2) Health and disease susceptibility: Check for scarring caused by fire or lightning, insect or disease damage, and rotted or broken trunks or limbs. Pest- and pollution-resistant trees are preferred.
- (3) Structure: Check for structural defects that indicate weakness or reduce the aesthetic value of a tree: trees growing from old stumps, large trees with overhanging limbs that endanger property, trees with brittle wood, misshapen trunks or crowns, and small crowns at the top of tall trunks. Open grown trees often have better form than those grown in the woods. Trees with strong tap or fibrous root systems are preferred to trees with weak rooting habits.
- (4) Cleanliness: Some trees are notoriously "dirty", dropping twigs, bark, fruit, or plant exudates. A clean tree is worth more than a dirty one. Trees which seed

prolifically (such as hackberry) or sucker profusely are generally less desirable in urban areas. Thornless varieties are preferred.

- (5) Aesthetic values: Handsome bark and leaves, neat growth habit, fine fall color, and attractive flowers and fruit are desirable characteristics. Trees that provide interest during several seasons of the year enhance the value of the site.
- (6) Comfort: Trees help relieve the heat of summer and buffer strong winds throughout the year. Summer temperatures may be 10 degrees cooler under hardwoods than under conifers. Deciduous trees drop their leaves in winter, allowing the sun to warm buildings and soil. Evergreens are more effective wind buffers.
- (7) Wildlife: Preference should be given to trees that provide food, cover, and nesting sites for birds and game.
- (8) Adaptability to the proposed development: Consider the mature height and spread of trees; they may interfere with proposed structures and overhead utilities. Roots may interfere with walls, walks, driveways, patios, and other paved surfaces; or water lines, septic tanks, and underground drainage. Trees must be appropriate to the proposed use of the development; select trees which are pollution-tolerant for high-traffic and industrial areas, screen and buffer trees for noise or objectionable views. Determine the effect of proposed grading on the water table. Grading should not take place within the drip line of any tree to be saved.
- (9) Survival needs of the tree: Chosen trees must have enough room to develop naturally. They will be subject to injury from increased exposure to sunlight, heat radiated from buildings and pavement, and wind. It is best to retain groups of trees rather than individuals. As trees mature, they can be thinned gradually.
- (10) Relationship to other trees: Individual species should be evaluated in relation to other species on the site. A species with low value when growing among hardwoods will increase in value if it is the only species present. Trees standing alone generally have higher landscape value than those in a wooded situation. However, tree groups are much more effective in preventing erosion and excess stormwater runoff.

Site Planning for Tree Protection

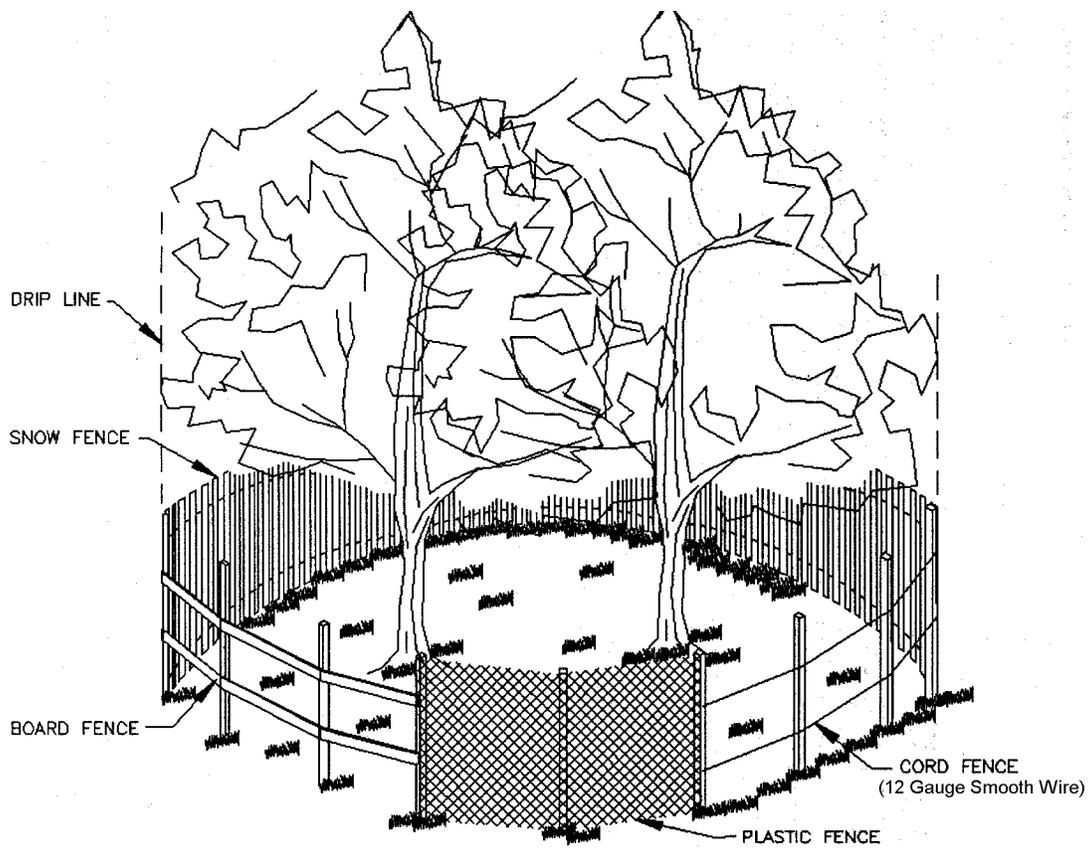
- (1) If lot size allows, select trees to be saved before siting the building. No tree should be destroyed or altered until the design of buildings and utility systems is final.
- (2) Critical areas, such as flood plains, steep slopes, and wetlands, should be left in their natural condition or only partially developed as open space.
- (3) Locate roadways to cause the least damage to valuable stands. Follow original contours, where feasible, to minimize cuts and fills.

- (4) Minimize trenching by locating several utilities in the same trench. Excavations for basements and utilities should be kept away from the drip line of trees.
- (5) Construction material storage areas and worker parking should be noted on the site plan, and located where they will not cause compaction over roots.
- (6) When retaining existing trees in parking areas, leave enough ground ungraded beyond the drip line of the tree to allow for its survival.
- (7) Locate erosion and sediment control measures at the limits of clearing and not in wooded areas, to prevent deposition of sediment within the drip line of trees being preserved. Sediment basins should be constructed in the natural terrain, if possible, rather than in locations where extensive grading and tree removal will be required.
- (8) It is best to minimize cut and fill in the vicinity of protected trees. Placement of fill covering the root collar flare may promote root collar rot that can girdle the tree, eventually causing death.
- (9) If design constraints require encroachment on the critical root zone of a tree, then at least 50% of the root zone should be preserved at natural grade.

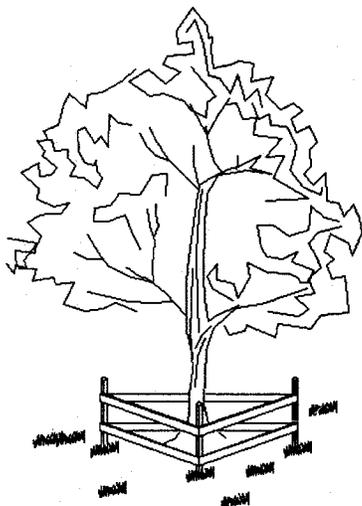
General Guidelines

- (1) Groups of trees and individual trees selected for retention should be accurately located on the plan and designated as “tree(s) to be saved.” Individual specimens that are not part of a tree group should also have their species and diameter noted on the plan.
- (2) At a minimum, the limits of clearing should be located outside the drip line of any tree to be retained and, in no case, closer than 5 feet to the trunk of any tree.
- (3) Before the preconstruction conference, individual trees and stands of trees to be retained within the limits of clearing should be marked at a height visible to equipment operators. A surveyor’s ribbon or a similar material applied at a reasonable height encircling the tree will normally suffice.
- (4) During any preconstruction conference, tree preservation and protection measures should be reviewed with the contractor as they apply to that specific project.
- (5) Heavy equipment, vehicular traffic, or stockpiles of any construction materials (including topsoil) should not be permitted within the drip line of any tree to be retained. Despite the high heat during the summer months, parking of cars in the shade of trees by contractors and their employees should not be permitted. Trees being removed should not be felled, pushed or pulled into trees being retained. Equipment operators should not clean any part of their equipment by slamming it against the trunks of trees to be retained.

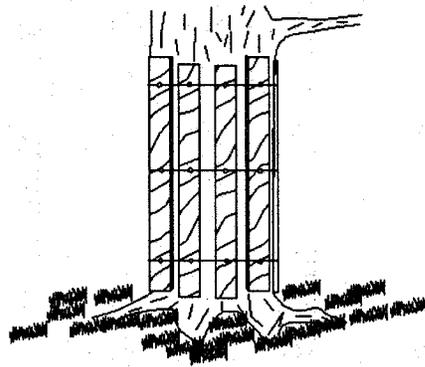
- (6) Fires should not be permitted within 100 feet of the drip line of any trees to be retained. Fires should be limited in size to prevent adverse effects on trees, and kept under surveillance.
- (7) No toxic materials should be stored closer than 100 feet to the drip line of any trees to be retained. Paint, acid, nails, gypsum board, wire, chemicals, fuels, and lubricants should be disposed of in such a way as to not injure vegetation.
- (8) Trees to be retained within 40 feet of a proposed building or excavation should be protected by fencing. Personnel should be instructed to honor protective devices. There are many types of fencing which are appropriate as is shown in Figure 2-1. Probably the most common is 40-inch high “international orange” plastic (polyethylene) web fencing secured to conventional metal ‘T’ or ‘U’ posts installed at the limits of clearing. The web fencing is often not adequate to prevent damage, so chain link fencing is preferred.
- (9) Additional trees may be left standing as protection between the trunks of the trees to be retained and the limits of clearing. However, in order for this alternative to be used, the trunks of the trees in the buffer must be no more than 6 feet apart to prevent passage of equipment and material through the buffer. These additional trees should be reexamined prior to the completion of construction and either be given sufficient treatment to ensure survival or be removed.
- (10) Fencing and armoring devices should be in place before any excavation or grading is begun, should be kept in good repair for the duration of construction activities, and should be the last items removed during the final cleanup after the completion of the project.



CORRECT METHODS OF TREE FENCING



TRIANGULAR BOARD FENCE



CORRECT TRUNK ARMORING

Figure 2-1 Examples of Tree Fencing (VA Dept of Conservation, 1992)

- (11) Should a tree intended and marked to be retained be damaged seriously enough that survival and normal growth are not possible, the tree should be removed. If replacement is desirable and/or required, the replacement tree should be of the same or similar species, 2-inch to 2½-inch (minimum) caliper balled and burlapped nursery stock.
- (12) Cleanup after a construction project can be a critical time for tree damage. Trees protected throughout the development operation are often destroyed by carelessness during the final cleanup and landscaping. Fences and barriers should be removed last, after everything else is cleaned up and carried away.

Guidelines for Raising the Grade around Trees

When the ground level must be raised around an existing tree or tree group, the following considerations should be made and steps taken to adequately care for the affected tree. The preferred option is to create a well around the tree as shown in Figure 2-2. The well should be located slightly beyond the drip line to retain the natural soil in the area of the feeder roots.

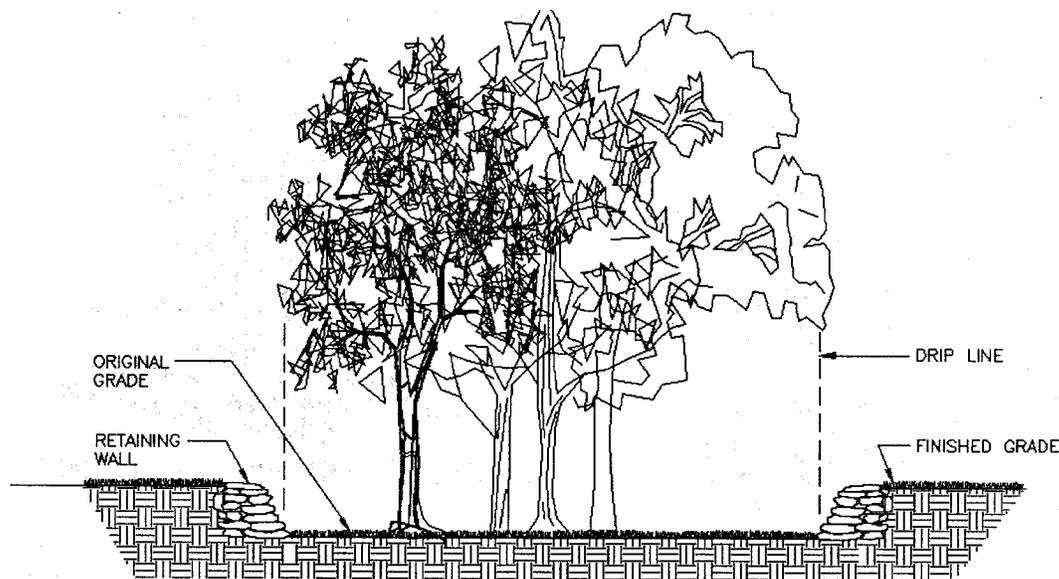


Figure 2-2 Example of a Tree Well (VA Dept of Conservation, 1992)

In the case of an individual tree, when the above alternative is not practical or desirable, the following method is recommended to ensure survival of the tree (Figure 2-3).

- (1) Apply fertilizer in the root area of the tree to be retained or add organic mulch. Overlay with 3 inches of bark mulch.

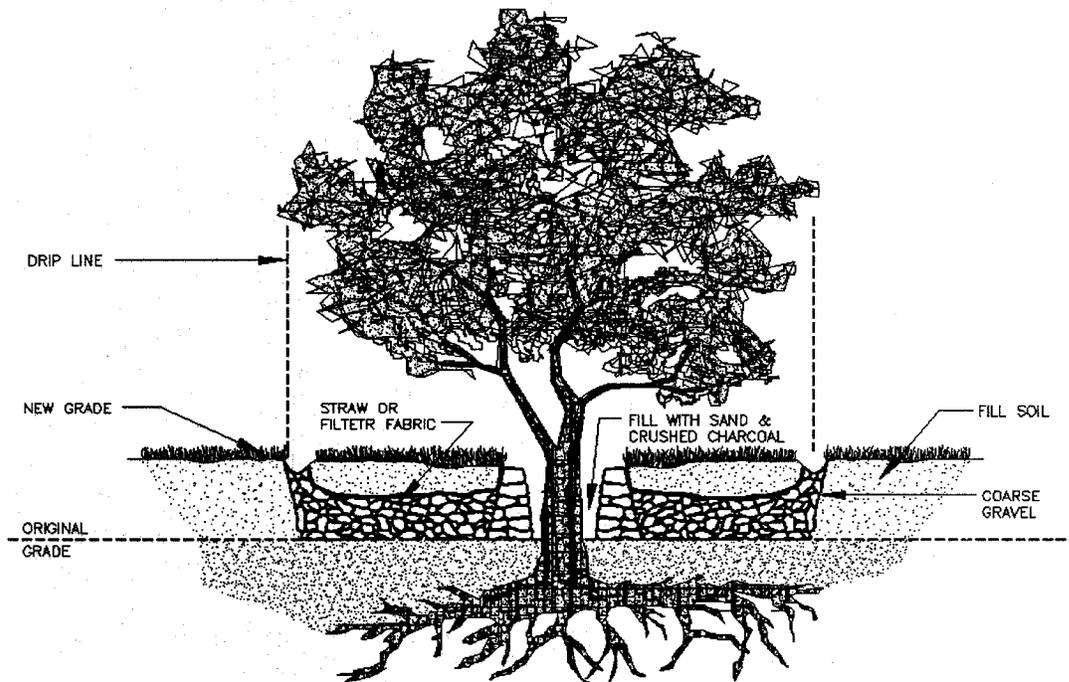


Figure 2-3 Tree Well with Higher Finished Grade (VA Dept of Conservation, 1992)

- (2) The dry well should be constructed so as to allow for tree trunk diameter growth. A space of at least 1 foot between the tree trunk and the well wall is adequate for large, old, slow-growing trees. Clearance for younger trees should be at least 2 feet.
- (3) The well should be high enough to bring the top just above the level of the proposed fill. The well wall should taper slightly away from the tree trunk at a rate of 1 inch per foot of wall height.
- (4) The well wall should be constructed of large stones, brick, building tile, concrete blocks, or cinder blocks, with care being taken to ensure that ample openings are left through the wall of the well to allow for free movement of air and water. Proper drainage of excess moisture is a prime consideration in the design to ensure the survival of the tree. Mortar should only be used near the top of the well and only above the porous fill.
- (5) Stones, crushed rock, or coarse gravel should be placed in the fill so that the upper level of these porous materials slants toward the surface in the vicinity below the drip line. A layer of 2- to 6-inches of stone should be placed over the entire area under the tree from the well outward at least as far as the drip line. For fills up to 2-feet deep, a layer of stone 8- to 12-inches thick should be adequate. A thicker layer of this stone, not to exceed 30 inches, will be needed for deeper fills.

- (6) A manufactured filter fabric should be used to prevent soil from clogging the space between stones.
- (7) Filling should be completed with porous soil such as topsoil until the desired grade is reached. This soil should be suitable to sustain specified vegetation.
- (8) To prevent anyone from falling into the dry well and leaves and debris from accumulating there, the area between the trunk and the well wall should either be covered by an iron grate or filled with a 50-50 mixture of crushed charcoal and sand. (This will also prevent rodent infestation and mosquito breeding.)
- (9) Raising the grade on only one side of a tree or group of trees may be accomplished by constructing only half of this system.

Lowering the Grade

Trees should be protected from harmful grade cuts by the construction of a tree wall (Figure 2-4).

- (1) Following excavation, all tree roots that are exposed and/or damaged should be trimmed cleanly, painted with tree paint, and covered with moist peat moss, burlap, or other suitable material to keep them from drying out.
- (2) The wall should be constructed of large stones, brick, building tile, or concrete block or cinder block in accordance with the detail in Figure 2-4.
- (3) Backfill with peat moss or other organic material or with topsoil to retain moisture and aid in root development.
- (4) Apply fertilizer and water thoroughly.
- (5) Prune the tree crown, reducing the leaf surface in proportion to the amount of root loss.
- (6) Provide drainage through the wall so water will not accumulate behind the wall.
- (7) Lowering the grade on only one side of a tree or group of trees may be accomplished by constructing only half of this system.

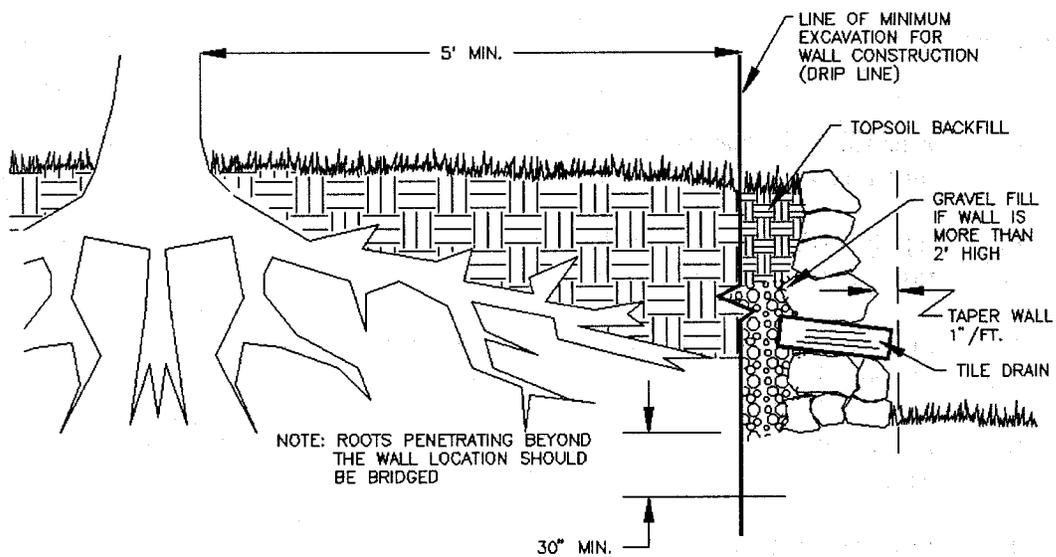
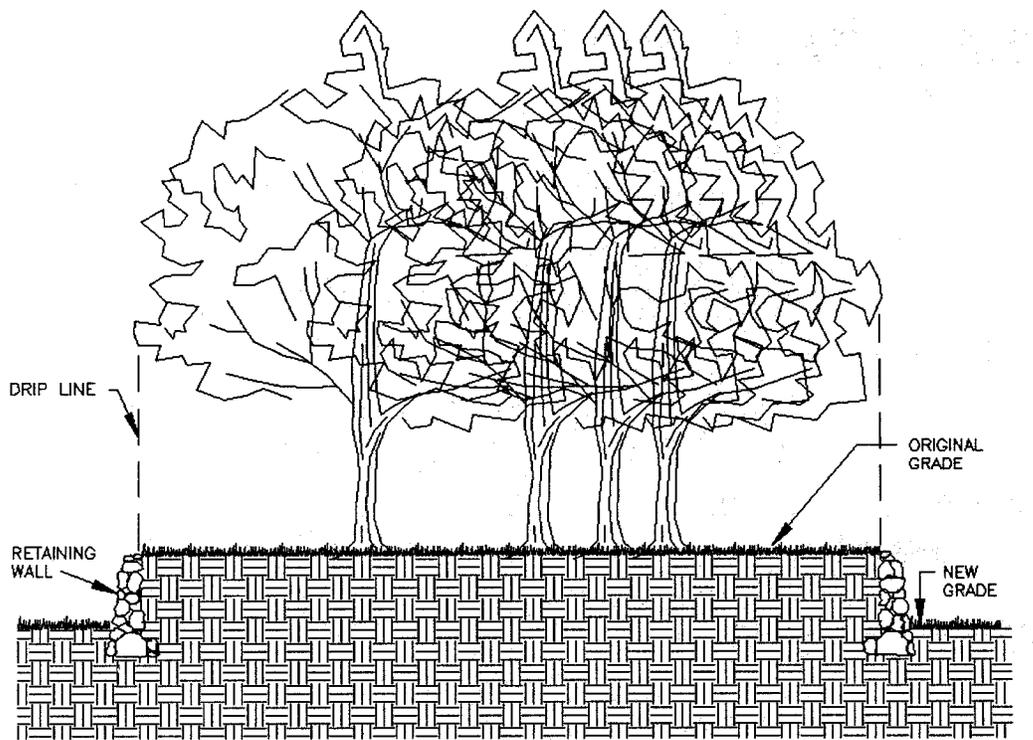
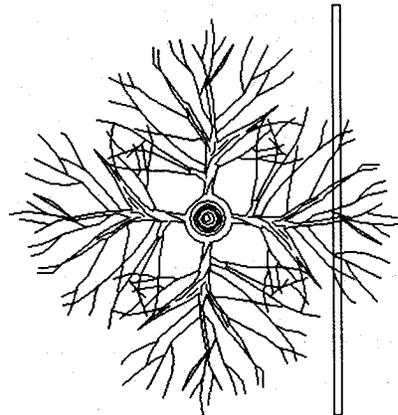
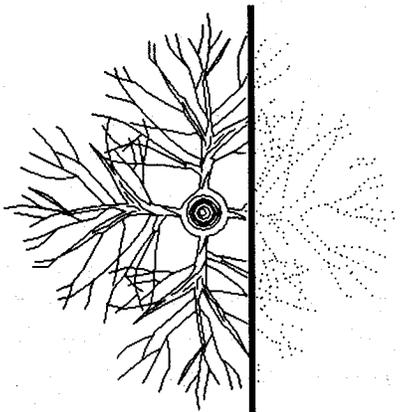
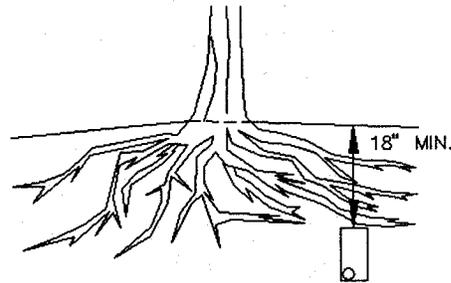
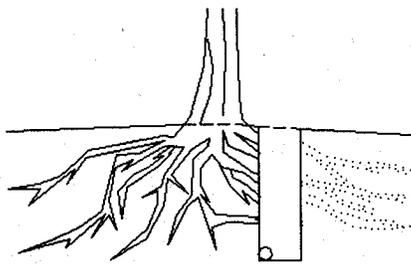


Figure 2-4 Example of a Tree Wall (VA Dept of Conservation, 1992)

Trenching and Tunneling:

- (1) Trenching should be done as far away from the trunks of trees as possible, preferably outside the branches or crown spreads of trees, to reduce the amount of root area damaged, or killed by trenching activities.

- (2) Wherever possible, trenches should avoid large roots or root concentrations. This can be accomplished by curving the trench or by tunneling under large roots and areas of heavy root concentration.
- (3) Tunneling is more expensive initially, but it usually causes less soil disturbance and physiological impact on the root system (Figure 2-5). The extra cost may offset the potential cost of tree removal and replacement should the tree die. Tunneling is almost always preferred over the trenching method. The tunnel should be 18 inches or greater below the ground surface and should not be located under the center of the tree (an off-center tunnel has the least impact on the roots).
- (4) Roots should not be left exposed to the air. They should be covered with soil as soon as possible or protected and kept moistened with wet burlap or peat moss until the trench or tunnel can be filled.
- (5) The ends of damaged and cut roots should be cut off smoothly and protected by painting promptly with a tree-wound dressing.
- (6) Trenches and tunnels should be filled as soon as possible. Air spaces in the soil should be avoided by careful filling and tamping.
- (7) Peat moss or other suitable material should be added to the fill material as an aid to inducing and developing new root growth.
- (8) The tree should be mulched and fertilized to conserve moisture, stimulate new root growth, and enhance general tree vigor.
- (9) If a large amount of the root system has been damaged and killed, the crown leaf surface should be proportionately reduced to balance the reduced root system. This may be accomplished by pruning 20 to 30 percent of the crown foliage. If roots are cut during the winter, pruning should be accomplished before the next growing season. If roots are cut during the growing season, pruning should be done immediately.



DESTRUCTION OF FEEDER ROOTS
WILL PROBABLY KILL THE TREE

TUNNELING UNDER THE TREE WILL
PRESERVE IMPORTANT FEEDER ROOTS

Figure 2-5 Effect of Tunneling and Trenching on Tree Roots

Maintenance:

In spite of precautions, some damage to protected trees may occur. In such cases, the following maintenance guidelines should be followed

- (1) If the soil has become compacted over the root zone of any tree, the ground should be aerated by punching holes with an iron bar. The bar should be driven 1-foot deep and then moved back and forth until the soil is loosened. This procedure should be repeated every 18 inches until all of the compacted soil beneath the crown of the tree has been loosened.
- (2) Any damage to the crown, trunk, or root system of any tree retained on the site should be repaired immediately.
- (3) Whenever major root or bark damage occurs, remove some foliage to reduce the demand for water and nutrients.

- (4) Damaged roots should immediately be cut off cleanly inside the exposed or damaged area. Cut surfaces should be painted with approved tree paint, and moist peat moss, burlap, or topsoil should be spread over the exposed area.
- (5) To treat bark damage, carefully cut away all loosened bark back into the undamaged area, taper the cut at the top and bottom, and provide drainage at the base of the wound.
- (6) All tree limbs damaged during construction or removed for any other reason should be cut off above the collar at the preceding branch junction.
- (7) Care for serious injuries should be prescribed by a forester or a tree specialist.
- (8) Broadleaf trees that have been stressed or damaged should receive a heavy application of fertilizer to aid their recovery. Trees should be fertilized in the late fall (after November 1) or the early spring (until April 1). Fall applications are preferred, as the nutrients will be made available over a longer period of time. Fertilizer should be applied to the soil over the feeder roots. In no case should it be applied closer than 3 feet to the trunk. Fertilizer should be applied using approved fertilization methods and equipment.
- (9) Maintain a ground cover of organic mulch around trees that is adequate to prevent erosion, protect roots, and hold water.

2.5.2 Stormwater Basin Landscaping

Design of all stormwater management basins or ponds should be accompanied by a landscaping plan. Proper landscaping is essential to stabilize the basin, and will significantly influence its pollutant removal efficiency, appearance, maintenance requirements and habitat value through the life span of the structure. The following should be considered in developing a basin landscape design (Young et al., 1996):

- Do not plant trees with root balls greater than 30 inches on pond embankments, as the large root structures will threaten the structural integrity of the embankment.
- Larger holes must be dug on side slopes and embankments to account for compacted soils that may prevent root penetration.
- Priority should be given to use of native plant species that are adapted to local climate and soil conditions, and therefore will require less maintenance.
- During early establishment of vegetation, constructed basins are exposed to varying weather conditions, therefore selected plants should be tolerant of exposure to sun, winter, wind, etc.

- Provide for additional maintenance requirements during the early years of establishment (watering, weed suppression, fertilizing, pest management, mulching, etc.).

Due to the wide fluctuation of water levels within stormwater basins, varying moisture conditions that support different plant species occur. The vegetative zones that can occur in a basin are described below (Schueler, 1987):

- Deep water pool (wet ponds only) - submerged aquatic plants; enhances pollutant uptake and provides food for waterfowl.
- Shallow water bench (wet ponds and shallow marshes) - emergent aquatic vegetation; enhances nutrient uptake, reduces water velocities, increases local sedimentation rates, stabilizes bottom sediments, provides food and cover for wildlife (waterfowl and shorebirds).
- Shoreline fringe (wet pond and shallow marsh) - plants tolerant of routine inundation but also tolerant of periodic drying; stabilizes shoreline from erosion, conceals water level changes, limits access to pond, provides shade to the surface of the pond to reduce warming, provides food, cover, nesting and loafing areas for waterfowl and wildlife.
- Riparian fringe (extended detention ponds, infiltration basins and dry ponds) - plants tolerant of wet soil conditions and inundation for brief periods; stabilizes basin floor, prevents suspension of deposited sediments, reduces water velocities, conceals and traps trash and debris, maintains soil infiltration capacity through root penetration.
- Floodplain terrace (upper stage of all basins and along stream channels) - native floodplain species tolerant of infrequent inundation and generally moist or slightly wet soils; includes the embankment and side-slopes of the basin (generally between the one- and five-year water-surface elevation), plant selection considerations include:
 - Ground cover to prevent erosion on steep slopes, and requiring minimal mowing.
 - Placement of trees and shrubs to break engineered contours.
 - Species tolerant to exposure and compacted soils with minimal maintenance requirements.
- Upland slopes (buffer areas for all basins) - seldom inundated; species selected based on local soils, exposure and intended use of open space.

2.5.3 Xeriscape Programs

The objective of xeriscaping is to maximize plant cover, conserve water, and reduce landscape maintenance. The concept integrates plants requiring minimal support (watering, fertilizing, and pesticides), and an efficient watering system. Advantages of xeriscape systems include reduced runoff, water loss, soil erosion, mowing requirements, and fertilization. Florida and California have enacted laws requiring xeriscaping and water-efficient landscape requirements for highway and public construction projects. Xeriscaping has also gained popularity in arid regions. This concept lends itself well to highways and related facilities. Specific considerations should include (U. S. EPA, 1993):

- Landscape design, installation and maintenance standards.
- Use of native or adapted plants.
- Selection of controlled plant species and determination of conditions for their use.
- Determination of maximum percentage of impervious and turf ground covers in the xeriscaped area.
- Monitoring and maintenance programs.

Based on site conditions, xeriscaping can reduce landscape maintenance requirements by up to 50 percent and reduce watering requirements by up to 60 percent (U. S. EPA, 1993).

2.5.4 Lawn/Turf/Grass Management

Grassed areas serve to reduce runoff velocities and remove particulates. However, grassed areas (such as lawns) typically are maintained with the use of fertilizers that contribute nutrients to runoff if not properly managed. Key considerations for reducing pollutant runoff and maintenance include (U. S. EPA, 1993):

- Properly apply pesticides and fertilizers (i.e., selection, rate and timing of application).
- Avoid over-watering lawn areas, and utilize lower rate delivery systems that increase infiltration, conserve water, and minimize runoff.
- Incorporate Integrated Pest Management and xeriscaping concepts.
- Use trained and certified individuals for application of chemicals.

- Cut grasses high to maximize mowing intervals, and remove no more than one-third of the total blade height.
- Leave grass cuttings scattered over the lawn area to encourage decomposition and reduce fertilizer requirements.

The use of vegetation designed for erosion control (biorevetment) also is gaining popularity as a desirable and effective approach to slope protection and erosion control. This technology incorporates vegetative plantings or soil bioengineering to establish a dense vegetated cover on exposed soil or erosion-vulnerable channel bottoms and side slopes. In general, vegetative revetment practices are preferred over concrete or rock revetment practices because of their superior aesthetic value and lower cost. The use of vegetative practices is limited, however, if design flow velocities exceed the erosion resistance capability of the selected vegetation. During review of construction plans, hydraulic calculations will be required to support the viability of selected vegetative channel restoration designs. Gray and Sotir (1996) and King County (1993) contain additional guidelines on the use of biorevetment in reports.

2.5.5 Preservation of Riparian Areas

Preservation of riparian corridors offers the following benefits:

- Provides space for structural BMPs that remove pollutants and control flow,
- Serves as the foundation for present or future greenways,
- Increases pollutant removal,
- Increases property values,
- May prevent severe rates of soil erosion,
- Provides effective flood control,
- Helps protect nearby properties from the shifting and widening of the stream channel that occurs over time, and
- Reduces small drainage problems and complaints by residents that are likely to experience backyard flooding.