CHAPTER 3—NURSERY DESIGN AND LAYOUT

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INTRODUCTION

An intensive soil survey and an accurate topographic map of the nursery site provide the basis for a detailed development plan. The USDA Soil Conservation Service will provide a soil map that will delineate soil types to within approximately 1 acre. The topographic map should show contours at 1-foot intervals on a scale in which 1 inch equals 100 feet. Primary points to be considered in making the plan are: size and shape of the production area, amount of clearing and land leveling needed, drainage and road network, layout of the irrigation system, fences and windbreaks, and location and types of buildings.

PRODUCTION AREA

The production area of a nursery includes both the seedbed and cover crop areas. Before the 1970's, most nurseries were operated on a 1:1 rotation, i.e., 1 year in seedlings and 1 year in a cover crop. The organic matter content was maintained by the use of additives such as peat moss, straw, manure, sawdust, bark, shavings or comparable materials. These materials have become increasingly difficult to find. The alternative is to grow more cover crops or green manure crops. Since about 1970, some of the new nursery sites are large enough to provide 1:2, 1:3, or other rotations that will provide more organic matter. The reason for the change is that continual production of forest tree seedlings subjects the soil to harsh treatment. The entire plant, except for a few small roots, is removed and usually under the most unfavorable conditions, i.e., when the soil is wet and cold. Also the accumulative effects of seedbed preparation, equipment operation during the growing season, and the harvesting operation often result in a loss of soil structure and, therefore, reduced productive capacity.

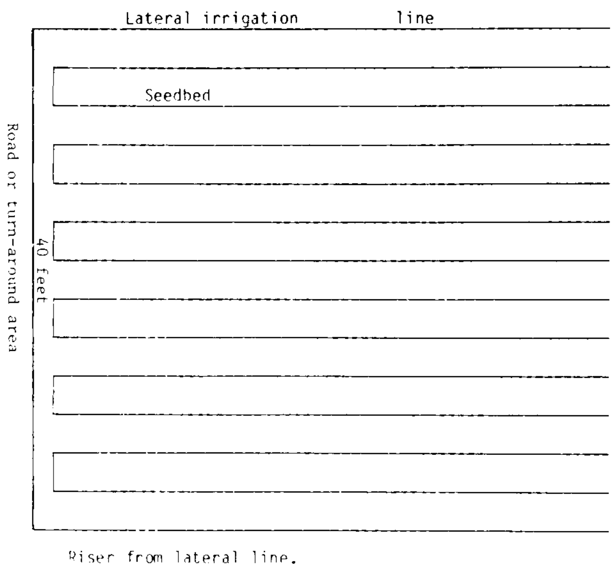

Figure 3-1.—Seedbed layout with lateral irrigation lines spaced 40 feet apart. The first riser can be placed either at the beginning of the line or at 20 feet.

Not all of the seedbed area is in seedlings. Between seedbeds there are paths or alleys for equipment and drainage. In southern nurseries, the standard practice is to install seedbeds 4 feet wide and the paths 2 feet wide. Sets of six or nine seedbeds are separated by lateral irrigation lines, which can be spaced 40 to 58 feet apart. This spacing provides a 2-foot path on each side of the lateral irrigation line (figure 3-1).

In actual operations, the beds are built 56 inches wide and the alleys are 16 inches wide. Most standard machinery is well adapted to this combination and most special machinery has been designed to fit it. During the growing season the extra width of the bed shoulders sloughs off because of erosion and equipment travel in the alleys. A few nurseries space lateral sprinkler lines 60 feet apart with a 3-foot alley on each side of the line.

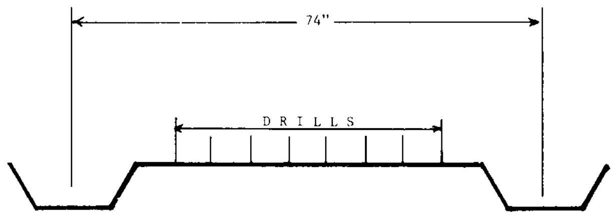

Figure 3-2.—Diagram of a seedbed with 74 inch spacing from alley centers.

However, in actual field practice the beds extend into much of this alley space when additional bed width is needed to prevent outside drill loss that would occur from bed shoulder erosion. Wider beds are created by setting the bed-opening plows out from the standard 72 inches to 74 inches (figure 3-2). The level space on each bed should be increased from 3 to 4 inches by this widening. The additional space is also conveniently used by the

Table 3-1. — Net area per acre in seedbeds and paths (alleys).

Land Use	Distance Between Sprinkler Lines			
	Area: 40 or 60 Feet 1/		Area: 58 Feet	
	square feet	% of area	square feet	% of area
Seedbeds	26,136	60	27,007	62
Paths	17,424	40	16,553	38

1/Area is same for 40- and 60-foot spacings.

equipment operator to prepare a full width bed even after an error has been made by over-running the row marker lines. The additional bed space also reduces loss of mulch spread over into the bed alleys. The net area per acre in seedbeds is given in table 3-1.

The total number of seedlings that can be grown on an acre depends on seedling density in the seedbeds and the space occupied by alleys. Seedling densities range from about 12 per square foot for longleaf pine, to about 30 per square foot for other species (table 3-2).

Table 3-2. — Total number of seedlings per acre for different seedling densities and spacings.

Density per square foot	Distance between sprinkler lines: 40 or 60 feet — plants per acre	40 or 60 feet — acres per 1,000,000 seedlings	58 feet — plants per acre
12	313,632	3.2	324,084
15	392,040	2.6	405,105
20	522,720	1.9	540,140
25	653,400	1.5	675,175
28	731,888	1.4	756,196
30	784,080	1.3	810,210
32	836,352	1.2	864,224

NURSERY LAYOUT

Utmost care must be taken to plan and lay out seedbeds, roads, drainage and water mains correctly when the nursery is established. Any changes made later to improve drainage, control erosion or for other reasons may require beds to be put across former alleys or roads where the soil has been firmly packed and made unproductive. The maximum length of seedbeds depends on topography, surface and subsurface drainage, erodibility of the soil and economy of sprinkler line construction. The longer the seedbeds the more efficiently they can be made, sown, mulched, sprayed and the seedlings lifted by mechanical harvesters. Five hundred feet is considered a practical maximum length. Beyond that length there are increasing problems. Even with gentle slopes (e.g., 0.5 percent) the run becomes long enough and the drop sufficient (2.5 feet) for erosion to become a problem.

Where drainage and other conditions permit, run beds and sprinkler lines at right angles to the prevailing direction of the wind during germination or the driest weeks of the growing season. This arrangement fosters optimum distribution of water from the sprinklers and a minimum water loss on ends of beds.

On sites with poor infiltration or poor subsurface drainage, there will be heavy runoff even from light precipitation and irrigation. The slope along the direction of the beds should be about 0.5 to 1 percent to allow for movement of water. Even on sites with good infiltration and adequate subsoil drainage, there should be enough gradient for runoff of surface water. Usually, water movement across seedbeds should be prevented, but on some sites cross-bed drainage may be needed.

The ideal nursery is either square or rectangular, with square or rectangular blocks (figure 3-3). However, the topography is likely to become more irregular with an increase in the size of the nursery, resulting in odd shapes and sizes of blocks. The optimum length of seedbeds considering all factors, is about 500 feet, with minimum and maximum lengths of 200 to 800 feet.

Clearing and Leveling

Farm lands were cleared and generally leveled during many decades of use. Forest lands that are level or gently sloping will usually have a wide diversity in microtopography, which is aggravated by clearing and stump removal. Preparation of a forested site includes removal of all large woody stems, burning of residual debris, removal of stumps and root-raking to remove large and medium size roots. Leveling and grading and the establishment of a cover crop should precede the first seedling crop. Large piles of stumps, logs, limbs and other debris should not be burned on the seedbed area, as the residual effects of the ash will continue for many years. The cost of clearing new ground is generally close to the cost of acquiring comparable farm lands. Current costs of clearing new land may exceed $1,000 per acre (1980 costs).

Because standing water or wet spots must not exist in the nursery, most new fields must be shaped and most existing farm lands must be renovated. A computer program for land forming permits the nursery manager to develop the land shape that best fits the site (Shih, Sowell and Kriz 1975; Davey 1976). Major steps are:

1. Determine the best location and shape of each block or field.
2. Determine the best bed directions.
3. Establish grade stakes in the field on a 100-foot grid parallel to the bed direction.
4. Determine the elevation of each station to the nearest 0.1 foot.
5. Determine the thickness of the topsoil at each station.

Agricultural engineers with the Soil Conservation Service will usually handle steps 3, 4, and 5.

The computer analysis and printout can be obtained at most land-grant universities. The three solutions most useful for designing nursery fields have the following design characteristics:

1. Uniform slope both in row (in the bed direction) and across rows (perpendicular to the bed direction).
2. Uniform slope in row and variable slope across row with drainage.
3. Uniform slope in row and variable slope across rows without drainage.

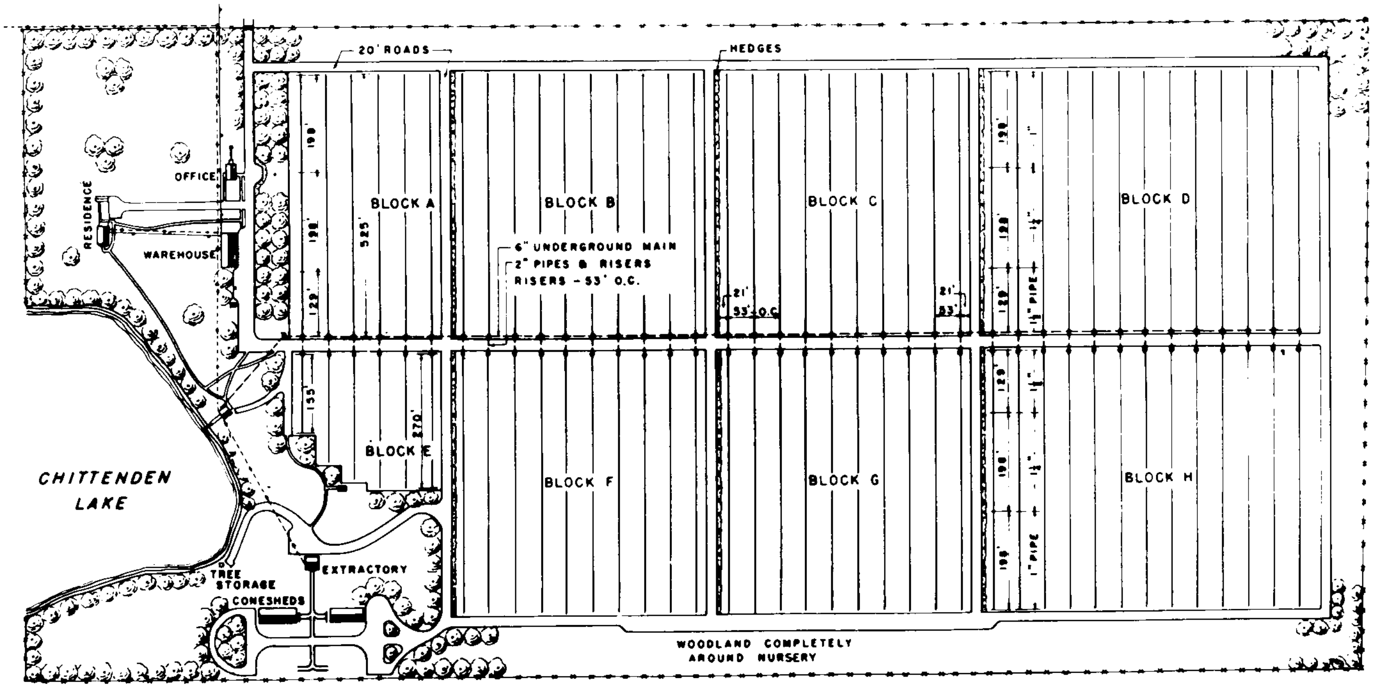

Figure 3-3.—Layout of roads and main and lateral irrigation lines. From: Stoeckeler and Jones 1959.

With deep sands, cuts and fills can be made without stockpiling the top soil. This operation may create some problems: Some areas will have thick horizons with adequate nutrients and organic matter, while other areas will be extremely deficient in both. In areas with fine-textured subsoils, remove a uniform thickness of the topsoil and stockpile it. After the required cuts and fills in the subsoil are completed, the topsoil is returned to the area in a uniform thickness.

On all sites where heavy equipment has been operated it is advisable to subsoil to alleviate compaction. A subsoiler foot or mole pulled through the soil at an 18- to 24-inch depth on 4-foot centers, in perpendicular directions, should improve internal drainage, and reduce soil compaction and pan formation.

Small depressions in old farms frequently have a loamy soil that may be 1 to 3 feet deep. These depressions are usually fill areas, and should receive special treatment. Otherwise they may become poorly drained areas that can tolerate little traffic. Tile drainage is sometimes needed.

When only a small amount of soil is to be removed, the job can be handled by the nursery workers using 3 1/2 to 5 cubic yards pans. Contractors with heavy equipment should be hired where there are deep cuts and fills and large quantities of soil must be moved.

The cost of leveling is high, ranging from about $300 to considerably more than $1,000 per acre (1980 costs). However, the results are essential for efficient field operations and high quality seedlings.

Roads and Drainage

An adequate road and drainage system, carefully planned and constantly maintained, is essential to the efficient operation of the nursery. An all-weather, hard surface road should connect the administrative site to a paved highway.

Exterior and interior roads should be permanent and stable. Frequently, roads within the seedbed area also serve as drainage channels. Therefore, they should: (1) provide access to the seedbeds for equipment and (2) drain the surface water rapidly, but at a low velocity by spreading it over a larger drainage area, in contrast to the conventional road ditch and culvert system. Roads or channels at ends of beds should be 50 feet wide or wider to enable tractors and attached equipment to turn without damaging seedbeds.

Road surfaces, shoulders, ditches or drainage channels are subjected to heavy abuse by equipment moving to and from seedbeds and by water flowing from the seedbed alleys. A large amount of water runs off seedbeds during or after a flash flood or rainstorm that deposits more than 1 inch of water, Also, any southern nursery can expect a 5- to 10-inch rainfall during a 12-hour storm sometime during the year. This water must move continuously so that there will be no standing water over any part of the seedbeds or in the alleys. Either the road or wide ditches between the road and the seedbeds must serve as a drainage channel. The traditional road design is a convex surface with drainage ditches on each side (figure 3-4).

The design shown in figure 3-4 provides a dry road surface. However, elevated surfaces create problems as equipment leaves the seedbed. As an alternative, a concave road surface will handle large storms and equipment turning, but it tends to be a bit wetter than the traditional design. The gradient of the road or adjacent ditches must provide for a continuing flow of water with a minimum of erosion from the seedbeds and the land surface. Water barriers or shallow dams can reduce the rate of flow on grades steeper than 2 percent. Outlets or culverts must be large enough and set deeply enough to move the water and prevent any ponding.

Two successful techniques for moving water under or across roads are: (1) Lower the top of the culvert about 12 inches below the ditch grade and build a well-like entrance around the mouth of the culvert and up to the ditch grade, (2) cut a wide drainage channel across the road and floor with 3-inch concrete slabs. Burlap bags filled with a 2 1/2:1 mixture of sand and cement are easy to use at the entrance of culverts and in ditches or channels.

There is no simple or easy way to stabilize roads and drainage channels in a nursery. A surface of gravel, crushed stone or asphalt is usually effective, but expensive. Perennial vegetation such as bahiagrass, fescuegrass and ryegrass may provide a semipermanent cover for road shoulders and channels, but it must be mowed to prevent seed production. Woven mats, straw, or wood fiber mulch can be used to help establish a grass cover.

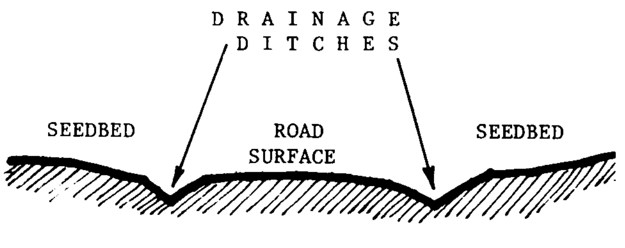

Figure 3-4. – Roads used as drainage channels.

IRRIGATION SYSTEM

Design and installation of an irrigation system includes several stages or phases, each of which requires different kinds of expertise. Some of the planning and development can be handled by the nursery staff. Other phases may require the services of specialists. The agricultural extension service at many land-grant universities has irrigation specialists who can help plan irrigation systems, prepare lists of equipment and materials, and provide the names of suppliers of irrigation equipment. Several well drilling and irrigation companies in the region have competent engineers who can provide advice and assistance.

Mains and Laterals

Consider the location of underground mains and the direction and length of lateral lines when the seedbed production area is prepared. This work is usually handled by the nursery staff.

Source of Water

The actual source of water is determined before final selection of a nursery site. When the source of water is a well or reservoir, services of a specialist are needed. A competent well driller with good equipment should be hired to dig either test wells or production wells. When reservoirs are to be used, engineers with the Soil Conservation Service can provide valuable assistance in selecting a site for the reservoir and determining the size needed. See chapter 2 for water quality considerations and for estimates of water requirements.

Power and Pumps

The water pumping system is one of the major costs in the operation of a nursery; there is no cheap source of power. Electric motors are most frequently used because they are reliable and simple to operate. The cost of electric power is based on a demand charge that is related to the size or capacity of the equipment and the amount of use. The annual cost of electric power may be higher than for gasoline or diesel engine power units. If reservoirs are used, different pumping systems can be used to supply the reservoir and the seedlings.

Vertical multistage turbine type pumps are generally used with deep wells where the required output is large and pumping is continuous for long periods. These units operate on 3-phase, 440 volt current and range from 40 to 75 hp. Smaller electric, motor-driven pumps can be used when the maximum suction lift is about 18 to 22 feet as with streams and reservoirs.

Distribution Lines

Pipe materials changed drastically between 1930 and 1980, moving from cast iron to transite to polyvinyl chloride (PVC) for mains; and from galvanized iron to plastic or aluminum for the lateral lines. The main lines from the source to the seedbeds are generally located along the road between blocks and should be buried 30 to 36 inches deep. Stub lines extend under the road.

The first lateral lines in a block may be placed on the outside edge of the block or about 24 feet inside. The first sprinkler on a lateral line may be placed at the edge of the block adjacent to the road or 20 feet down the alley. Better water coverage is obtained when the first and last lateral lines are on the outside edges of the block and sprinklers are located at the beginning and end of the lateral line (figure 3-2). When lateral lines and sprinklers are placed 20 to 24 feet inside the field, wind may prevent effective irrigation of the areas outside of the sprinklers.

The standard spacing for lateral lines is either 40, 58 or 60 feet with six beds of seedlings between the 40-foot spacings and nine beds between the 58- and 60-foot spacings. The 40- and 58-foot spacings provide for a 4-foot wide path along the lateral line as compared to a 6 foot path for the 60-foot spacing (figure 3-1). In most nurseries, the space along the lateral pipe usually varies from 2 1/2 to 5 feet.

The overhead sprinkler lines (Skinner system) disappeared during the 1950's and were replaced by permanent underground laterals or portable above-ground laterals that use revolving sprinklers. The permanent underground lines eliminated the annual installation of lines at time of sowing and removal at time of harvesting, and reduced the labor requirements. Life of the underground laterals ranges from about 20 to 30 years. The permanent lines limited the use of equipment in leveling, subsoiling, cultivation and fumigation. Risers were frequently knocked down and damaged by field equipment. Permanent laterals require a higher investment for irrigation equipment as they must be installed throughout the entire nursery. However, they provide a means of irrigation for the cover crop, if needed.

The trend in the 1970's was toward the temporary, portable laterals which can be quickly installed and dismantled. Pipes are in 20- 30- or 40-foot sections and can be easily moved on pipe trailers.

Revolving sprinklers are on risers and may extend from about 18 to 30 inches above the ground. Types of sprinklers and size of nozzles depend on the spacing of sprinklers in lines and between lines, water pressure at the base of the sprinkler, desired rate of application, type of soil and mulch cover (see chapter 11).

OPERATION OF IRRIGATION SYSTEMS

Three types of operations are available: manual, semi-automatic, and completely automatic. An economic analysis of alternative systems should be made when planning the irrigation system. In two systems, nursery staff determine when and how much water to apply at a specific time. The third system is based on the use of soil moisture sensing instruments such as tensiometers or electrical resistance meters and gypsum or similar blocks (chapter 11).

Manual operation.—Each lateral line or group of lateral lines is controlled by hand valve(s), and the pump is operated by a manual switch. This system is used in a majority of nurseries.

Semi-automatic.—An automatic controller can be set for specific time periods for groups or sets of lateral lines. In this system, the manual valves are replaced with electric or hydraulic valves; wire or tubing extends to the valves; and a controller of appropriate design handles the required timing.

Fully automatic.—Computer controls are activated by soil moisture-sensing devices. The controller is programmed to irrigate at the desired time every day. If soil moisture is low enough to require irrigation, a start signal will be sent to the controller. If soil moisture is above a predetermined level, the signal is not transmitted and the system will not be activated. This system is perfect for some crops of very succulent plants and short growing seasons, and for container-grown seedlings in green houses, especially when the moisture level must be maintained close to field capacity. This system does not allow a plant to reach a point of moisture stress.

Nursery workers can use soil moisture-sensing instruments with the first two systems, especially early in the season. After lateral roots are established, southern pines can remain thrifty and grow under higher moisture stress than many other crops in the region.

FENCES AND WINDBREAKS

Nurseries should be fenced if there is potential damage from cattle, hogs, sheep, dogs or people. In areas with strict stock laws, fencing may not be needed except along main roads. Standard fencing will not keep out deer. A deer exclosure fence (8 feet high) may be needed in some nurseries. Such fences are expensive and not always effective. Fences around administrative sites may be needed to protect equipment and buildings from theft or vandalism.

Exterior and interior windbreaks are often needed to reduce the erosion and drying effects of strong winds. Exterior windbreaks can be provided by leaving strips of volunteer trees around the nursery, or by planting of trees. Interior windbreaks can be provided by planting trees in strips at strategic locations throughout the interior of the nursery. They should be located on the windward sides of fields and parallel to the seedbeds. A grid of three to five rows of trees will require a strip from 18 to 30 feet wide.

In the South, most common wind-break species are slash pine, loblolly pine, white pine, Arizona cypress and eastern redcedar. Virginia pine has the potential of a good windbreak species. The species should be selected to avoid the production of volunteer seedlings which may "contaminate" the crop. Windbreaks need periodic maintenance and replacement to provide a wall of foliage because older trees of some species lose lower branches and allow movement of wind over the seedbeds.

ADMINISTRATION AND OPERATIONAL FACILITIES

The number and size of buildings will be influenced by the size of the nursery as well as the financial condition of the owner. Some structures are essential for the efficient operation of the nursery, and two or more functions may be included in the same structure. Floor plans for some nursery facilities are available from the Southern Region, USDA Forest Service, Atlanta, Georgia, 30367, and from the Forest Service's Missoula Equipment Development Center, Ft. Missoula, Montana 59801.

Office, Laboratory, and Working Space

One or more offices are needed for the nursery manager, assistants, secretaries and for records and files. A simple laboratory for seed testing, plant examinations, and handling soil samples is desirable. A large space is needed for the storage of packing or baling material and for grading and baling of seedlings if this operation is not handled in the field. A lunch room, break room, and rest rooms are needed for the crew. A building with 3,000 to 6,000 square feet of floor space is adequate for this complex (figure 3-5). Rest rooms, showers and other critical areas should meet OSHA standards.

Equipment Shop and Equipment Storage

In many instances, valuable equipment is ruined by neglect and exposure to weather rather than by actual use. A well-equipped shop for maintenance of equipment and storage space for all equipment is essential. These facilities may be included in one or more buildings. The equipment room and the working area should have good lighting, heating and ventilation. The storage portion can be either completely closed or open on one side. A total space of about 2,400 to 4,000 square feet of floor space is usually adequate in a building that serves these purposes. Exterior racks of adequate size and strength are needed for the proper temporary storage of portable aluminum irrigation pipe.

Cold Storage Facilities

Cold storage facilities are required for seed storage, stratification, and storage of seedlings. Seed storage facilities should be adequate to hold a 2-4 year supply of seed at a temperature of 5° to 25°F. A seedling storage facility (34 to 38°F) is needed with a minimum capacity of one to three million trees, depending on the size of the nursery. Custom-made racks are available with a capacity of 30,000 seedlings. These racks are handled with a forklift and can be easily stacked.

Most seed that is stored at a low moisture content will need stratification before sowing. Seedling storage space can be used for stratification at a temperature of 32° to 35°F. All cold storage facilities can be in one structure. They should have an alarm system for protection against power or equipment failures.

Cone Storage and Seed Extraction

These operations may be handled at the nursery or seed orchard, or contracted to a commercial firm. Many organizations extract the seeds at the seed orchard site to avoid shipping cones to the seed cleaning plant. Plans for cone storage and seed extraction, cleaning and testing facilities are available from the Southern Region, USDA Forest Service, Atlanta, Georgia, and the National Tree Seed Laboratory, Dry Branch, Ga.

OTHER FACILITIES

Fertilizers and chemicals require careful storage and should be stored in a separate building. Pesticides require special security and protection from freezing. Usually two or more kinds of fuel are used at a nursery and each of these requires special storage facilities.

Well-designed pumphouses are usually needed to protect pumping equipment. They must be protected from freezing in the winter and overheating in the summer. The domestic water supply may come from the main water source if deep wells are used. Otherwise, a separate source is needed which is usually a shallow well, and consists of a pump and a pressurized water storage tank.

Nursery dwellings are optional, depending on the location of the nursery. Where protection of the nursery depends on a close watch, housing is desirable for at least one of the staff.

Fire protection must be considered for all inflammable buildings. Seed extraction plants, fuel and chemical storage buildings and shops are very hazardous facilities. There should be provision for fire hose hook-ups to both the irrigation system and the domestic water system. Appropriate valves should allow full volume and pressure to be directed into the fire-protection water lines. Seed extraction plants should have a high-temperature alarm system and an automatic cut-off switch.

Nurseries are one of the best public relations arms of an organization so it is desirable to develop a landscape plan that is aesthetically pleasing to visitors. Some nurseries have developed self-guided tours for interested visitors.

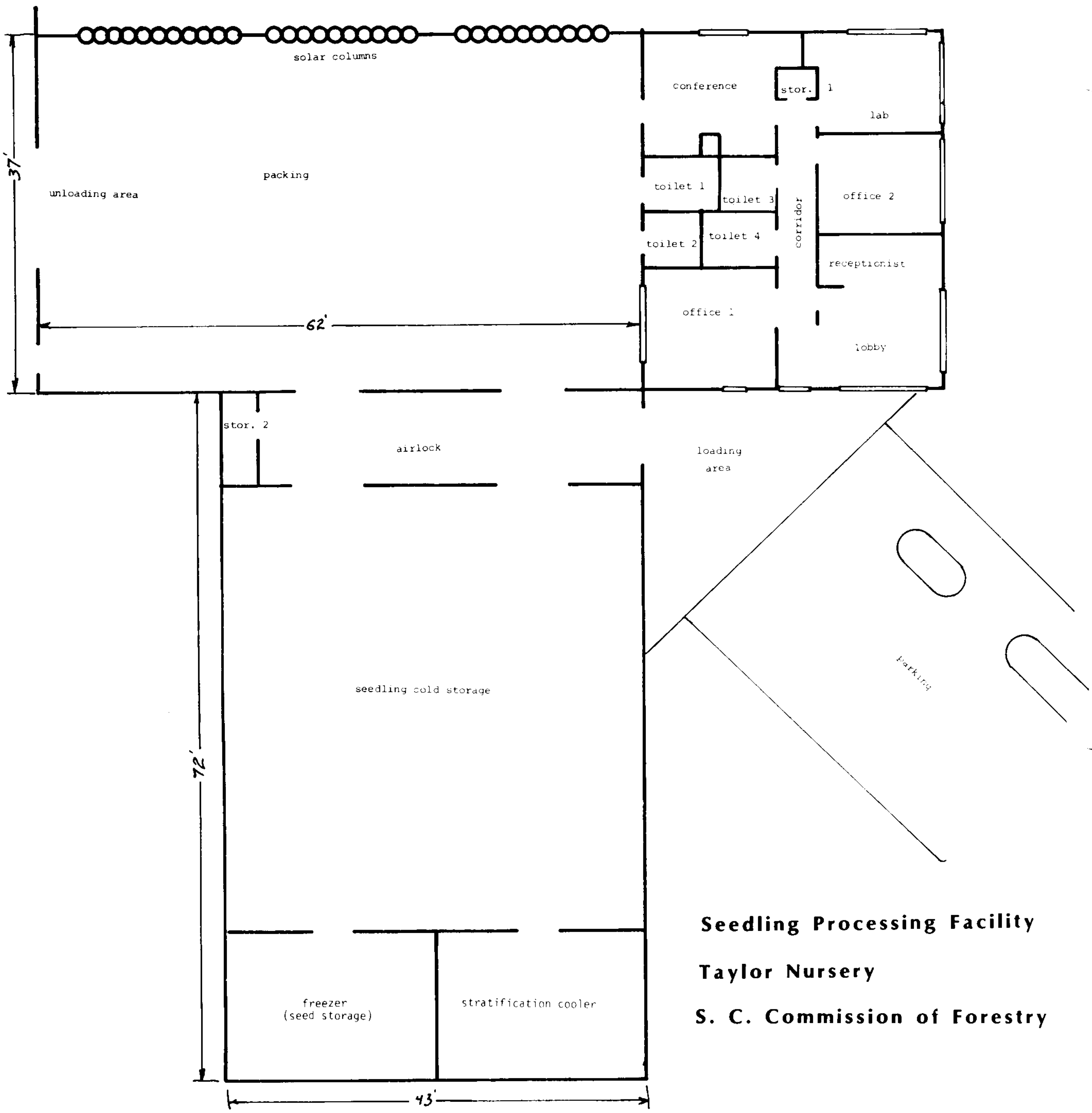

Figure 3-5. — Floor plan of combined office, lab, lounge and work space.

SUMMARY

The economical production of high quality forest tree seedlings requires a skillfully designed nursery with adequate facilities. Primary points to be considered in the design and layout of a forest tree nursery are:

1. Seedbeds should occupy the best sites in the nursery. Level areas with good soil should not be used for administrative sites unless there is a surplus of land.
2. The size and shape of the blocks and the lengths of the seedbeds should be controlled by the soil, topography and drainage.
3. Any southern nursery can expect 5 to 10 inches of rain during a 12-hour period sometime during the year. Seedbeds, drainage channels and roads must be designed to handle these flash storms with a minimum of damage.

4. Irrigation systems should provide an adequate quantity of water at the time needed, and with a minimum of investment and operating costs. Use all available expertise in developing the irrigation system.

5. Administrative and operating facilities including offices, laboratories, shops, working space, storage for equipment, supplies, seed and seedlings and living quarters are relatively standard for all nurseries.

6. The best approach in designing a nursery is to visit several of the better modern nurseries. Nursery staff are very helpful and usually eager to pass on information on the design and construction of their nurseries.

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