Chapter 5
Monitoring Well Installation

5-1. General

A monitoring well is a device designed for the acquisition of groundwater samples that represent the chemical quality of the aquifer adjacent to the screened interval, unbiased by the well materials and installation process, and which provides access to measure the potentiometric surface for that screened interval. The screened interval consists of that portion of the device that is directly open (e.g., horizontally adjacent) to the host aquifer by way of openings in the well casing (hereafter called the "screen") AND indirectly open (e.g., vertically adjacent) to the aquifer by way of the filter pack (or other permeable material) extending below and/or above the screen. While the maximum length of the screened interval is fixed for a given well (by the length of the filter pack), the effective or functional length may vary with water table fluctuations or sampling techniques. Additional guidance on monitoring well installation may be found in ASTM D 5092.

5-2. Well Clusters

Each monitoring well is a mechanism through which to obtain a representative sample of groundwater and, to measure the potentiometric surface in that well. To help ensure this representation in the case of well clusters, each well of a cluster should be installed in a separate boring. Multiple well placements in a single boring are too difficult for effective execution and evaluation to warrant single hole usage.

5-3. Well Screen Usage

Each overburden well should have a screen, as per Figure 5-1, 5-2, or 5-3 (or of a technically equivalent construction as in ASTM D 5092). Under normal conditions, the extra effort for screen installation in bedrock wells can be more than offset by the assurance of an unobstructed opening to the required depth during repeated usage. When conditions permit, and when allowed by state or local law, an open, unscreened well may be constructed in firm stable bedrock. However, well integrity and consistent access to the original sampled interval during prolonged monitoring must be maintained.

5-4. Beginning Well Installation

a. The installation of each monitoring well should begin within 12 hours of boring completion for holes uncased or partially cased with temporary drill casing. Installation should begin within 48 hours in holes fully cased with temporary drill casing. Once installation has begun, no breaks in the installation process should be made until the well has been grouted and drill casing removed. Anticipated exceptions should be requested in writing by the FDO to the FA prior to drilling. Data to include in this request are:

(1) Well(s) in question;

(2) Circumstances; and

(3) Recommendations and alternatives.

b. In cases of unscheduled delay such as personal injury, equipment breakdowns, or sudden inclement weather or scheduled delays such as borehole geophysics, no advance approval of delayed well installation should be needed. In those cases, resume installation as soon as practicable. However, partially completed borings should be properly secured during periods of drilling inactivity to preclude the entry of foreign materials or unauthorized personnel to the boring. In cases where a partially cased hole into bedrock is to be partially developed prior to well insertion, the well installation should begin within 12 hours after this initial development.

c. Temporary casing and hollow stem augers may be withdrawn from the boring prior to well installation if the potential for cross-contamination is not likely and if the borehole walls will not slough during the time required for well installation. This procedure is usually successful in firm clays and in bedrock that is not intensely fractured or highly weathered.

d. If the borehole will not remain stable long enough to complete placement of all necessary well materials in their proper position, it may be necessary to install some or all of the well materials prior to removal of the casing or hollow stem augers. In this situation, the hollow stem augers or casing should have an inside diameter sufficient to allow the installation of the prescribed diameter screen and casing plus annular space for a pipe through which to place the filter pack and grout.

e. Any materials, especially soils, blocking the bottom of the drill casing or hollow stem auger should be dislodged and removed from the casing prior to well insertion. This action both reduces the potential for cross--contamination and makes well installation easier.

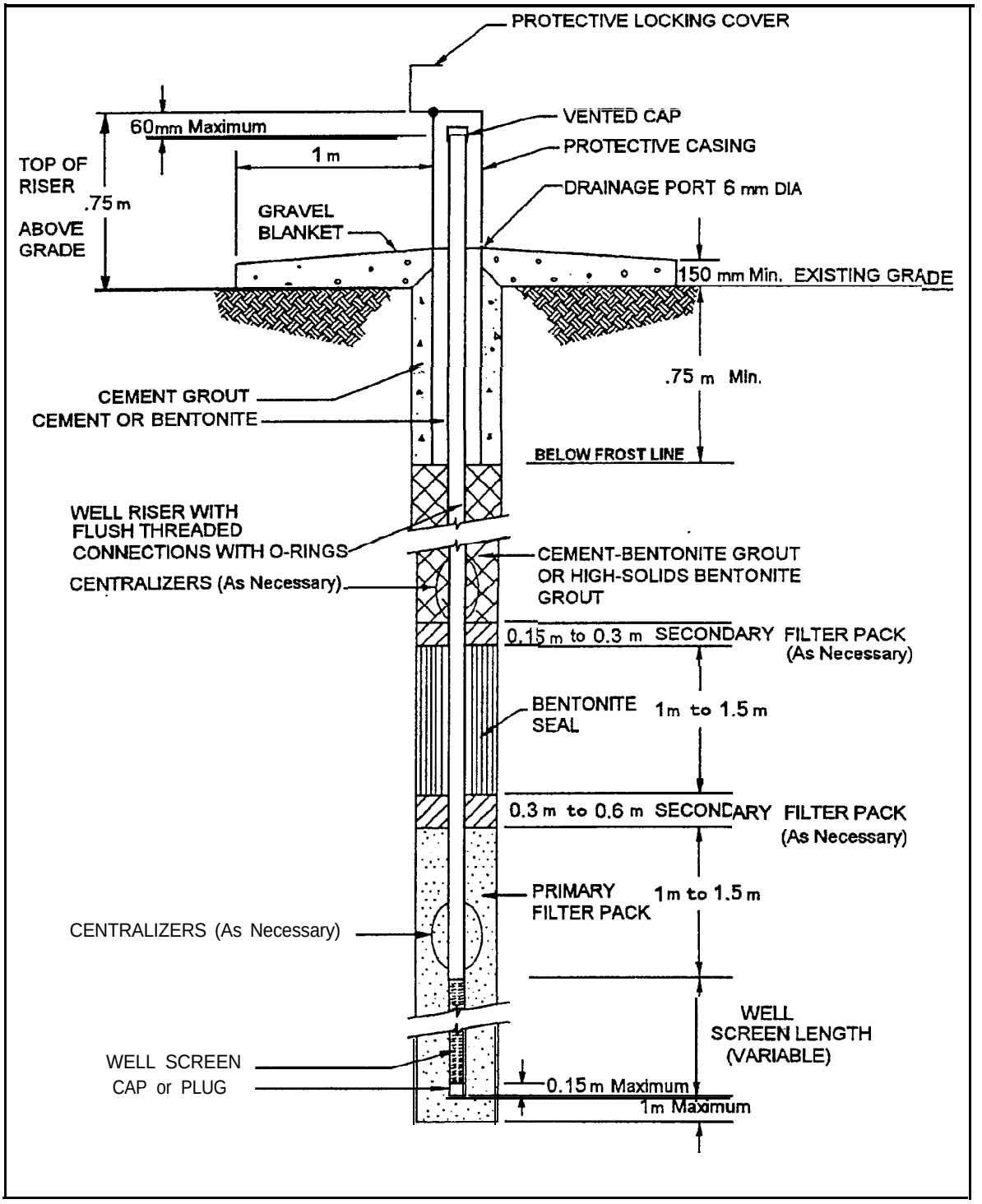

Figure 5-1. Schematic construction of single-cased well with gravel blanket

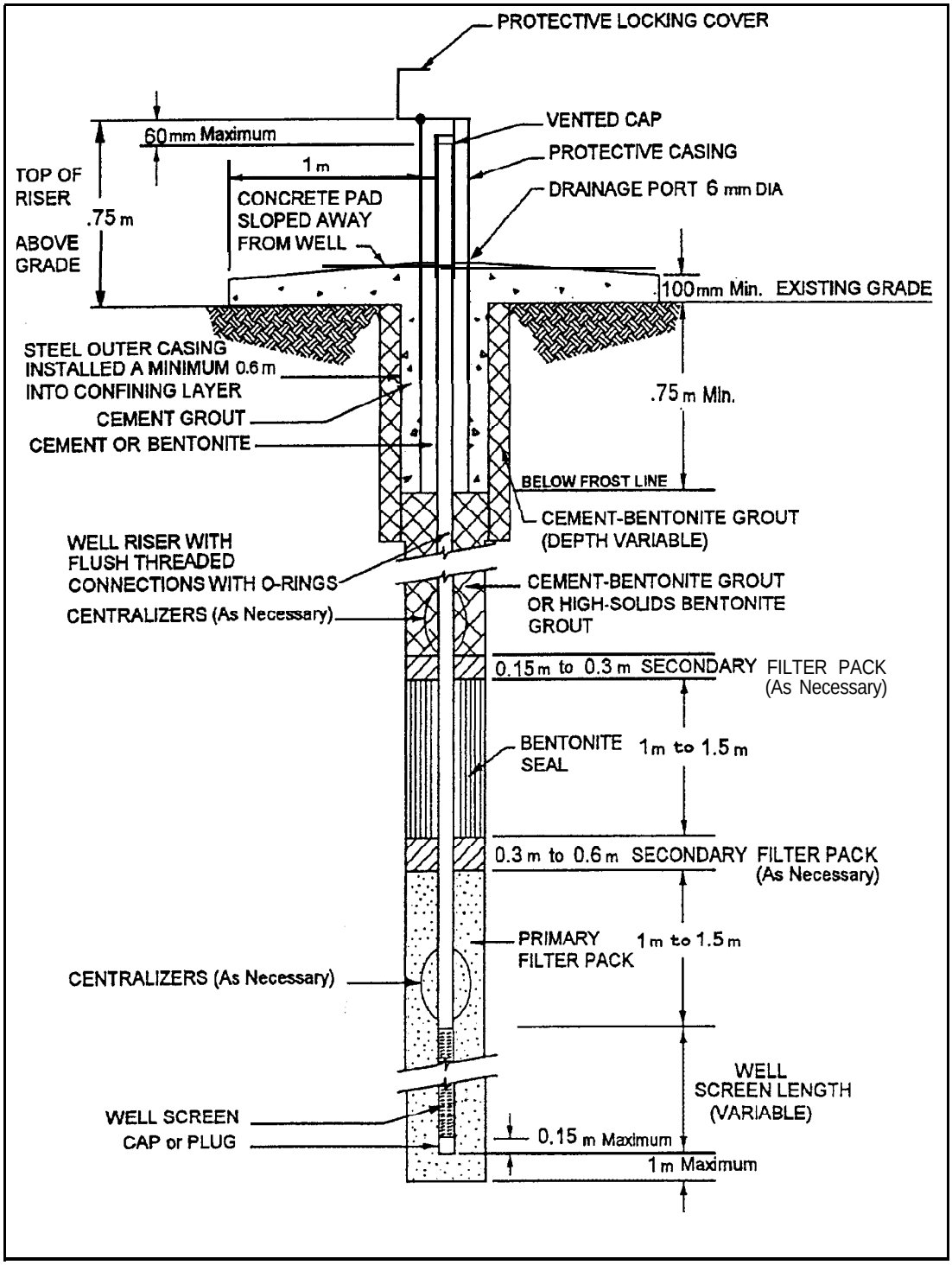

Figure 5-2. Schematic construction of multi-cased well with concrete pad

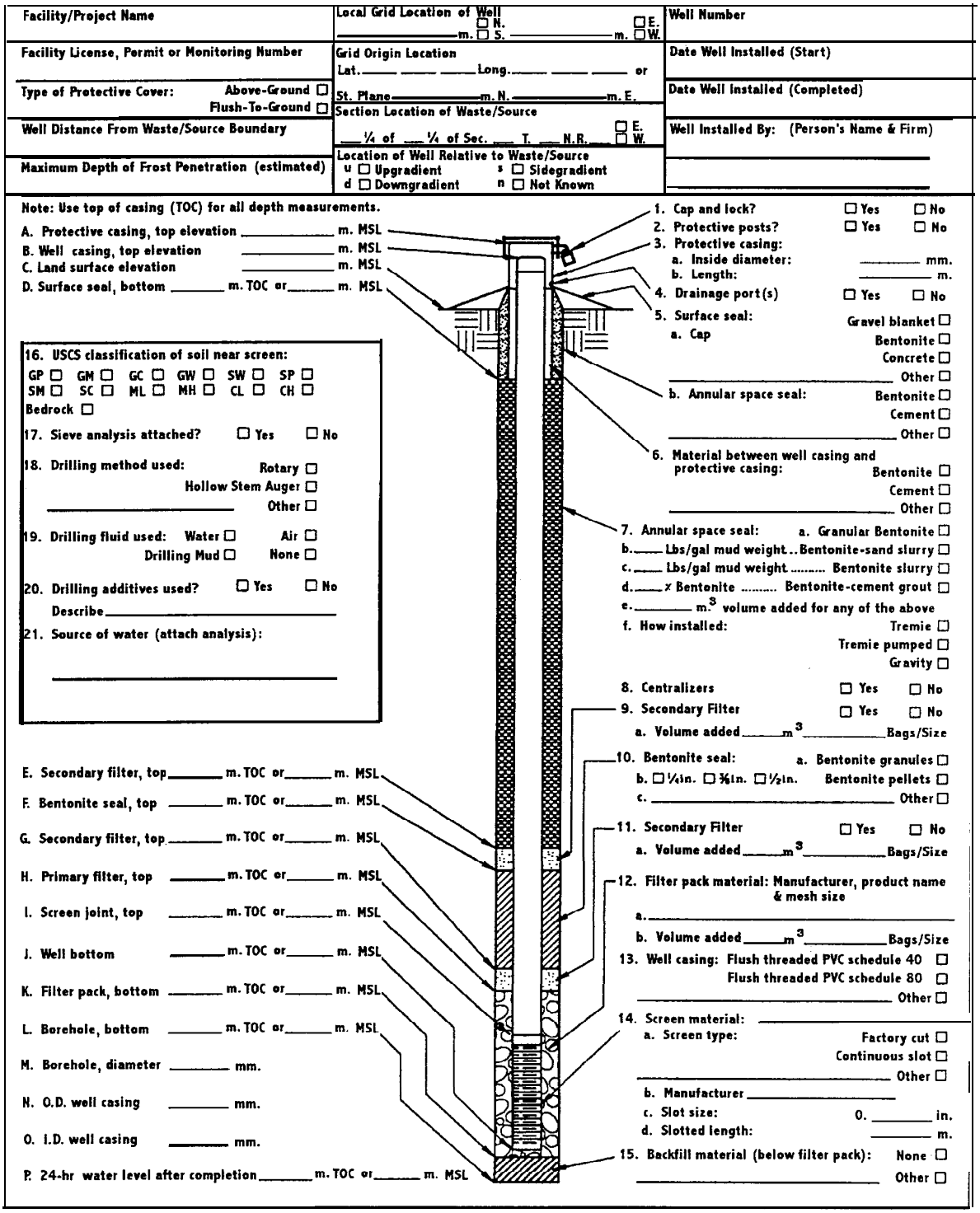

Figure 5-3. Schematic construction diagram of monitoring well

f. Once begun, well installation should not be interrupted due to the end of the driller's work shift, darkness, weekend, or holiday.

g. If possible, the FDO should ensure that all materials and equipment for drilling and installing a given well are available and onsite prior to drilling that well. The FDO should have all equipment and materials onsite prior to drilling and installing any well if the total well drilling and installation effort is scheduled to take 14 days or less. For longer schedules, the FDO should ensure that the above-mentioned materials needed for at least 14 days of operation are onsite prior to well drilling. The balance of materials should be in transit prior to well drilling. Any site-specific factors that preclude the availability of needed secure storage areas should be identified and resolved in the drilling plan.

5-5. Screens, Casings, and Fittings

a. All well screens and well casings should be free of foreign matter (e.g., adhesive tape, labels, soil, grease, etc.) and washed with approved water prior to use. Prewashing may not be necessary if the materials have been packaged by the manufacturer and have their packaging intact up to the time of installation. Pipe nomenclature stamped or stenciled directly on the well screen and/or blank casing within and below the bentonite seal should be removed by means of SANDING, unless removable in approved water. Solvents, except approved water, should NOT be used for removal of marking. Washed screens and casings should be stored in plastic sheeting until immediately prior to insertion into the borehole.

b. Bottoms of well screens should be placed no more than 1 m (3 ft) above the bottom of the drilled borehole. If significant overdrilling is required (as for determining stratigraphy), a pilot boring should be used. The intent here is to narrow the interval of aquifer being sampled, limit the potential for stagnant or no-flow areas near the screen, and preclude unwanted backfill materials (e.g., grout or bentonite) from entering or passing through the interval to be screened and sampled. The casing/screen should be suspended from the surface and should not rest on the bottom of the borehole during installation of the filter pack and annular seal.

c. All screen bottoms should be securely fitted with a threaded cap or plug of the same composition as the screen. This cap/plug should be within 150 mm (0.5 ft) of the open portion of the screen. No solvents or glues should be permitted for attachment.

d. Silt or sediment traps (also called cellars, tail pipes, or sumps) should NOT be used. A silt trap is a blank length of casing attached to and below the screen. Trap usage fosters a stagnant, turbid environment which could influence analytical results for trace concentrations.

e. The top of each well should be level such that the difference in elevation between the highest and lowest points on the top of the well casing or riser should be less than or equal to 6 mm (0.02 ft).

f. The borehole should be of sufficient diameter to permit at least 50 mm (2 in.) of annular space between the borehole wall and all sides of the well (centered riser and screen). When telescoping casings (one casing within another), the full 50 mm (2-in.) annulus may not be practical or functional. In this case, a smaller spacing may be acceptable, depending on site specifics.

g. Well screen lengths may be a function of hydrostratigraphy, temporal considerations, environmental setting, analytes of concern, and/or regulatory mandate. Screen lengths should be specified in the drilling plan.

h. The actual inside diameter of a nominally sized well is a function of screen construction and the wall thickness/schedule of both the screen and casing. In the case of continuously wound screens, their interior supporting rods may reduce the full inside diameter. This consideration is critical when planning the sizes for pumps, bailers, surge devices, etc.

i. When physical or biological screen clogging is anticipated, the larger open-area per unit length of continuously wound screens has an advantage over the slotted variety.

5-6. Granular Filter Pack

a. When artificial filter packs are used, a tremie pipe for filter pack placement is recommended, especially when the boring contains drilling fluid or mud. A record should be maintained of the amount of water used to place the filter pack, which should be added to the volume of water to be removed during well development.

b. The filter pack should extend from the bottom of the boring to 1 to 1.5 m (3 to 5 ft) above the top of the screen unless otherwise specified in the drilling plan. This extra filter allows for settlement (from infiltration and compaction) of the filter pack during development and repeated sampling events. The additional filter helps to

maintain a separation between the bentonite seal and well screen.

c. Sometimes, depending on the gradation of the primary filter pack and the potential for grout intrusion into the primary filter pack, a secondary filter pack may be installed above the primary filter pack to prevent the intrusion of the bentonite grout seal into the primary filter pack. To be effective, the secondary filter should extend 0.3 to 0.6 m (1 to 2 ft) above the primary filter pack.

d. The final depth to the top of the granular filter should be directly measured (by tape or rod) and recorded. Final depths should not be estimated, for example, as based on volumetric measurements of placed filter.

5-7. Bentonite Seals

a. Bentonite seals, especially those set in water, should typically be composed of commercially available pellets. Pellet seals should be 1 to 1.5 m (3 to 5 ft) thick as measured immediately after placement without allowance for swelling. Granular bentonite may be an alternate if the seal is set in a dry condition. Tremie pipes are not recommended.

6. Slurry seals can be used when the seal location is too far below water to allow for pellet or containerized-bentonite placement or within a narrow well-borehole annulus. Typically, the specific gravity of cement grout placed atop the slurry seal will be greater than that of the slurry. Therefore, the intent to use a slurry seal should be detailed in the drilling plan, and details should include a discussion of how the grout will be precluded from migrating through the slurry. Slurry seals should have a thick, batter-like (high viscosity) consistency with a placement thickness of 1 to 1.5 m (3 to 5 ft). Typically, only high-solids bentonite grouts are used that consist of a blend of powdered bentonite and fresh water mixed to a minimum 20 percent solids by weight of pumpable slurry with a density of 9.4 pounds per gallon or greater.

c. In wells designed to monitor possible contamination in firm bedrock, the bottom of the bentonite seal should be located at least 1 m (3 ft) below the top of firm bedrock, as determined by drilling. "Firm bedrock" refers to that portion of solid or relatively solid, moderately to unweathered bedrock where the frequency of loose and fractured rock is markedly less than in the overlying, highly weathered bedrock. Special designs will be needed to monitor contamination in fractured bedrock. Guidance on design of ground-water monitoring systems in karst and fractured-rock aquifers may be found in ASTM D 5717.

d. The final depth to the top of the bentonite seal should be directly measured (by tape or rod) and recorded. Final depths should not be estimated, as, for example, based on volumetric measurements of placed bentonite.

e. Numerous opinions have been expressed regarding bentonite hydration time, bentonite placement procedures under water versus in a dry condition, and the potential installation delays and other consequences caused by these factors. By not allowing sufficient time for the bentonite seal to hydrate and form a low permeable seal, grout material could infiltrate into the bentonite seal and possibly into the filter pack. It is recommended waiting a minimum of 3 to 4 hours for hydration of bentonite pellets, or tablets when cement grout is used above the bentonite seal. If bentonite chips are used, the minimum hydration time could be twice as long. Normally chips should only be used if it is necessary to install a seal in a deep water column. Because of their high moisture content and slow swelling tendencies, chips can be dropped through a water column more readily than a material with a low moisture content, such as pellets or tablets. Bentonite chips should not be placed in the vadose zone. A 1 m (3 ft) minimum bentonite pellet seal must be constructed to protect the screen and filter pack from downhole grout migration. When installing a bentonite seal in the vadose zone (the zone above the water table), water should be added to the bentonite for it to properly hydrate. The amount of water required is dependent on the formation. It is recommended that the bentonite seal be placed in 0.15 to 0.3 m (6 in to 1 ft) lifts, with each lift hydrated for a period of 30 minutes. This method will assure that the bentonite seal is well hydrated and accomplish its intended purpose. A 0.15 to 0.3 m (6 in. to 1 ft) layer of fine to medium sand (secondary filter pack) placed atop the bentonite seal may further enhance barrier resistance to downward grout migration.

5-8. Grouting

All prescribed portions of grout material should be combined in an aboveground rigid container and mechanically (not manually) blended to produce a thick, lump-free mixture throughout the mixing vessel. The mixed grout should be placed around the monitoring well as follows.

a. The grout should be placed from within a rigid side discharge grout pipe located just over the top of the seal. The grout or tremie pipe should be decontaminated prior to use.

b. Prior to exposing any portion of the borehole above the seal by removal of any drill casing (to include hollow-stem augers), the annulus between the drill casing and well

casing should be filled with sufficient grout to allow for planned drill casing removal. The grout should not penetrate the well screen or granular filter pack. Disturbance of the bentonite seal should be minimal.

(1) If all drill casing is to be removed in one operation, the grout should be pumped through the grout pipe until undiluted grout flows from the annulus at ground surface, forming a continuous grout column from the seal to ground surface. The drill casing should then be removed, making certain that borehole exposure to the atmosphere is minimal. During the removal of hollow stem augers, the grout pipe may have to be periodically reinserted for additional grouting to compensate for the larger annular space created by the augers' helical coil.

(2) If drill casing is to be incrementally removed with intermittent grout addition, the grout should be pumped through the grout pipe until it reaches a level that will permit at least 3 m (10 ft) of grout to remain in the well/drill casing annulus AFTER removing the selected length of drill casing. Using this method, at least 6 m (20 ft) of grout should be within the drill casing before removing 3 m (10 ft) of driven casing or considerably more than 6 m (20 ft) of grout for the removal of 3 m (10 ft) of hollow stem auger. With this method, the grout pipe needs only to be reinserted to the base of the casing yet to be removed before repeating the grout insertion process.

c. If the ungrouted portion of the hole is less than 4.5 m (15 ft) deep and without fluids after casing removal, the ungrouted portion may be filled by pouring grout from the surface without a pipe.

d. If drill casing (to include hollow-stem auger) was not used, grouting should proceed to surface in one continuous operation. Care should be taken, however, in deep wells when using cement grout around PVC casing. Extreme heat, commonly known as heat of hydration, can be generated by the cement during hydration and curing. The heat generated can be sufficient enough to soften or weaken PVC casing, resulting in collapse of the casing. Grouting in multiple lifts may be necessary in this situation.

e. Once begun, the grouting process should be continuous until all the drill casing has been removed and all annular spaces are grouted to the ground surface.

f. Protective casing should be installed on the same day as grouting begins.

g. The FDO should check the site for grout settlement and add more grout to fill any depression that day. Repeat this process until firm grout remains at ground surface. This process should be completed within 24 hours of the initial grout placement. Incremental quantities of grout added in this manner should be recorded on the well completion diagram to be submitted to the FA.

h. For grout placement in a dry and open hole less than 4.5 m (15 ft) deep, the grout may be manually mixed and poured in from the surface as long as seal integrity is maintained.

i. No grout should be placed or allowed to migrate below the bentonite seal and into the well screen.

5-9. Well Protection

a. Protective casing should be installed around each monitoring well the same day as initial grout placement. The annulus formed between the outside of the protective casing and borehole should be filled to the ground surface with grout. The annulus between the monitoring well and protective casing should be filled to a minimum of 150 mm (0.5 ft) above the ground surface with cement or bentonite as part of the overall grouting procedure. Specific details of well protection should be approved by the FA. These details and specific elements to be included in the well construction diagrams should be described in the drilling and well installation plan.

b. All protective casing should be steam or hot-water-pressure cleaned prior to placement; free of extraneous openings; and devoid of any asphaltic, bituminous, encrusting, and/or coating materials, except the black paint or primer applied by the manufacturer.

c. Recommended minimum elements of protection design include the following list.

(1) A 1.5 m (5-ft) minimum length new, black iron/steel pipe (protective casing) extending about 0.75 m (2.5 ft) above ground surface and set in grout (see Figures 5-1, 5-2, and 5-4). The bottom of the protective casing should extend below the frost line to preclude damage from frost heave.

(2) A protective casing inside diameter at least 100 mm (4 in.) greater than the nominal diameter of the well riser.

(3) A hinged cover or loose-fitting telescopic slip-joint cap to keep direct precipitation and cap runoff out of

the casing. Threaded covers should be avoided because of the tendency to rust or freeze shut.

(4) All protective casing covers/caps secured to the casing by means of a noncorrosive padlock from the date of protective casing installation. All manhole covers should also be lockable.

(5) If practical, have all padlocks at a given site opened by the same key. The FDO should provide four of these keys to an FA-designated representative at the project.

(6) No more than 60 mm (0.2 ft) from the top of the protective casing to the top of the well casing. This, or a smaller spacing, is needed for subsequent water-level determinations by some acoustical equipment which must rest upon the well casing in order to function.

(7) All painting of the protective casing must be done offsite, prior to installation. Only the outside of the casing should be painted. Each well should be identified by a number placed on the outside of the well casing. Various methods of identification have been successfully used such as painting the number on the protective casing with the help of a painting stencil, attaching a metal imprinted noncorrosive metal tag, or imprinting the number directly on the steel protective casing. The color of the casing, the well number and method of application should be specified by the design FA in the drilling and well installation plan, and should be in accordance with the requirements prescribed by the owner and state and local technical regulations. Painting should be completed and dry prior to initially sampling the well.

(8) The erection of protective posts should be considered when physical damage resulting from construction equipment or vehicles is likely. When necessary, steel posts should be erected with a minimum diameter of 80 mm (3 in.). Each post should be radially located a minimum of 1 m (3 ft) from the well and placed 0.6 to 1 m (2 to 3 ft) below ground surface, having 1 m (3 ft) minimally above ground surface. Posts are typically filled with concrete and set in post holes which are backfilled with concrete. The post should be painted orange using a brush. Installation should be completed prior to sampling the well. Flags or barrier markers in areas of high vegetation may be helpful.

(9) When posts are used in conjunction with concrete pads, the posts should be located **OUTSIDE** of the pad. Posts inside of a pad (especially near a comer or edge) may cause the pad to crack, either by normal stress relief or if severely struck as by a vehicle.

(10) The above-mentioned posts should be supplemented with three-strand barbed wire in livestock grazing areas. Post and wire installation should be installed prior to sampling.

(11) Place a 6 mm (l/4 in.) diameter hole (drainage port) in the protective casing centered, no more than 3 mm (l/8 in.) above the grout filled annulus between the monitoring well riser and the protective casing.

(12) The application of at least a 150 mm (0.5 ft) thick coarse gravel 19- to 75-mm (3/4- to 3-in.) particle size pad extending 1 m (3 ft) radially from the protective casing (see Figure 5-4 for layout and dimensions). Prior to placement of this gravel pad, any depression around the well should be backfilled to slightly above the level of the surrounding ground surface with uncontaminated cohesive soil. This will prevent a “bathtub” effect of water collecting in the gravel pad around the well casing. Construction of the gravel pad is suggested prior to development. Some long-term, heavy traffic, or high visibility locations may warrant a concrete pad specially designed for site conditions. Any concrete pad usage, especially in cold climates, should be designed to withstand frost heaving. Frost uplift may adversely affect well and pad integrity. A concrete pad should be at least 100 mm (4 in.) thick and 1 m (3 ft.) square. Round concrete pads are also acceptable.

(13) All elements of well protection should be detailed in the drilling plan. In addition, unique well protection requirements for floodplains, frost heaving, heavy traffic areas, parking lots, as well as wells finished at or below grade, and other special circumstances should also be covered on a case-by-case basis, in the drilling plan. As an example, a suggested well design to minimize the effects of frost heaving is shown in Figure 5-6. An example of a flush-to-ground completion is shown in Figure 5-5. Additional guidance on monitoring well protection may be found in ASTM Standard Practice D 5787.

5-10. Shallow Wells

Shallow, less than 4.5 m (15 ft), well construction may be more problematic than deep. Sufficient depth may not be available to utilize the full lengths of typical well components when the aquifer to be monitored is near the surface. The FA should tailor design criteria to the actual environment and project objectives for appropriate shallow well construction.

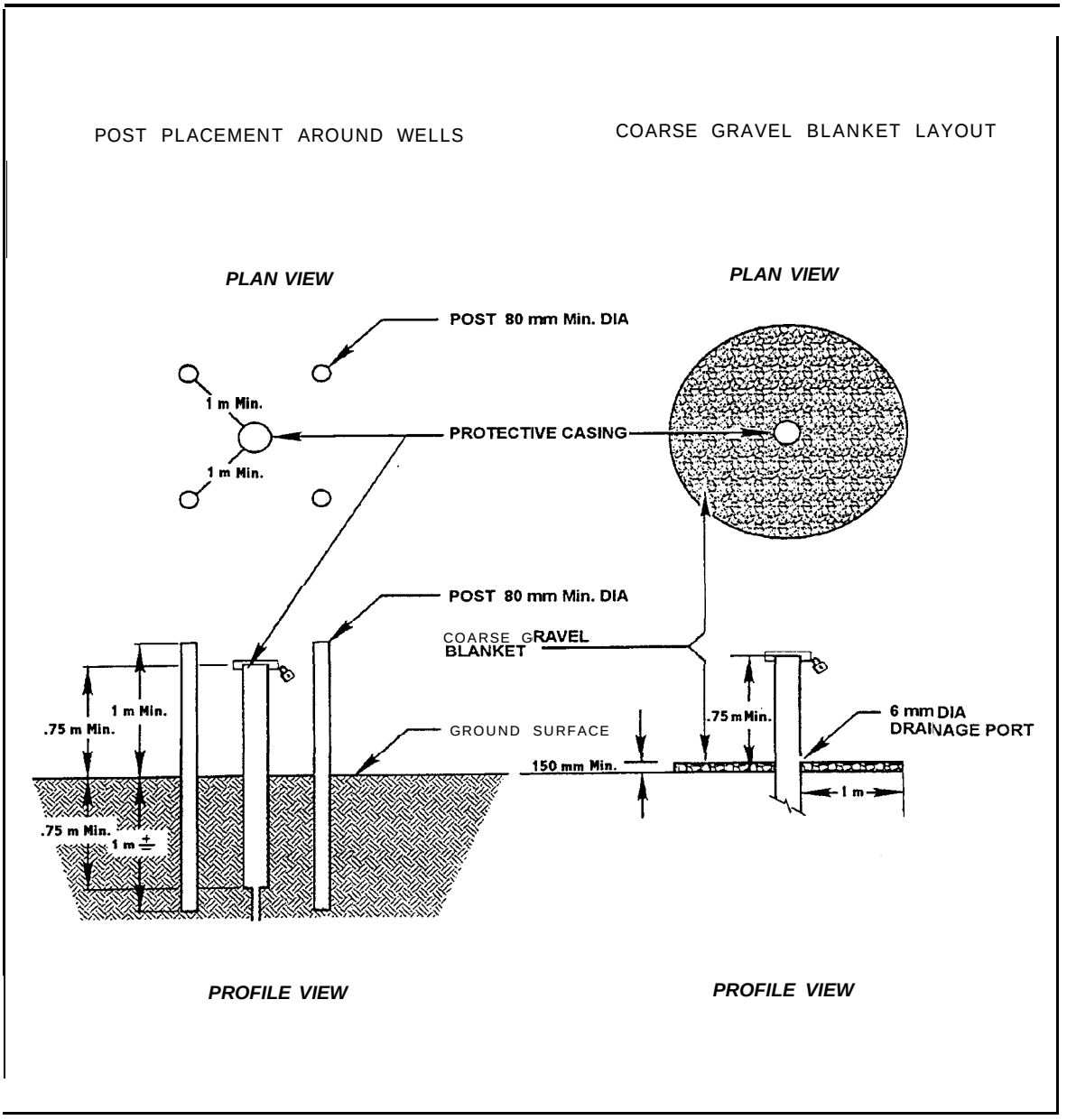

Figure 5-4. Post placement and gravel blanket layout around wells. (Adapted from a figure provided by International Technology Corporation)

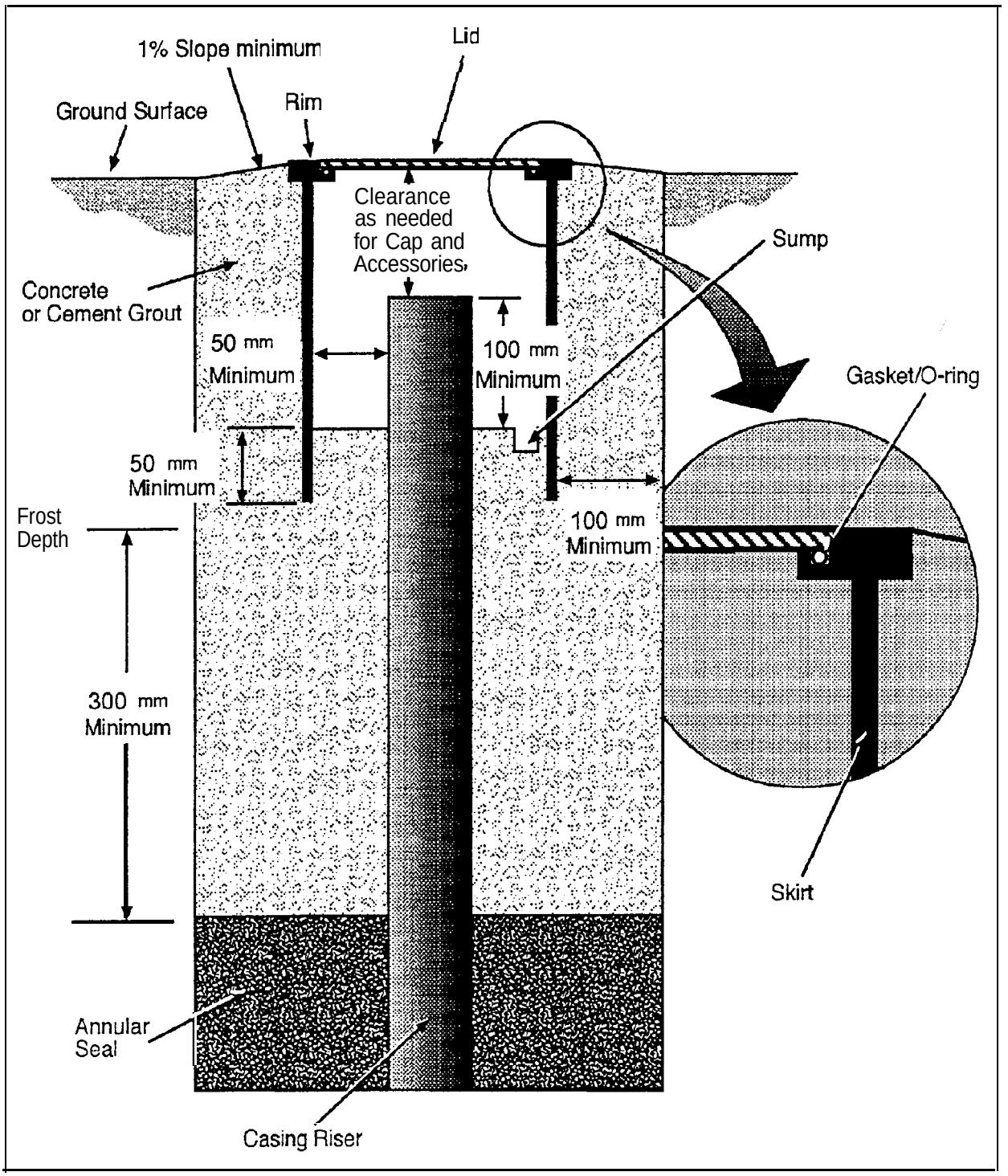

Figure 5-5. Schematic construction of flush-to-ground completion. (Figure provided by Ronald Schalla)

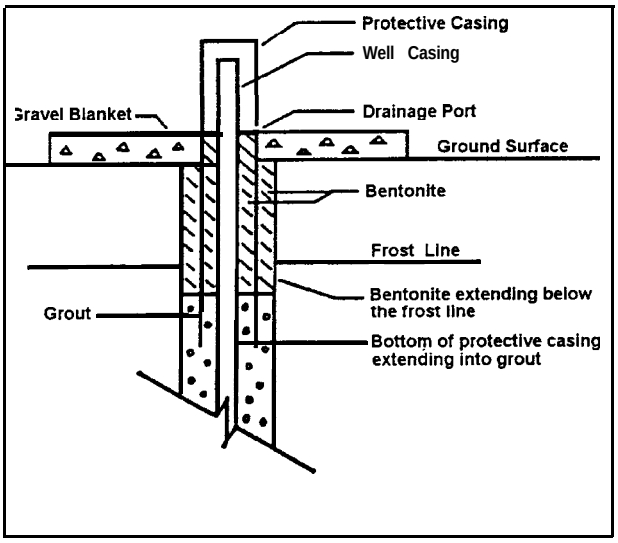

Figure 5-6. Well design parameters to minimize frost heave

5-11. Drilling Fluid Removal

When a borehole, made with or without the use of drilling fluid, contains an excessively thick, particulate-laden fluid that would preclude or hinder the specified well installation, the borehole fluid should be removed or displaced with approved water. This removal is intended to remove or dilute the thick fluid and thus facilitate the proper placement of casing, screen, granular filter, and seal. Fluid losses in this operation should be recorded on the well diagram or boring log and later on the well development record. Any fluid removal prior to well placement should be contingent upon the driller's and the geologist's evaluation of hole stability, e.g., long enough for the desired well and seal placement.

5-12. Drilling Fluid Losses in Bedrock

If large drilling fluid losses occur in bedrock and if the hole is cased to bedrock, the FDO should remove at least three times this volumetric loss prior to well insertion. The intent is to allow the placement of a larger pump in the borehole than otherwise possible in the well casing, thereby reducing subsequent development time and removing the lost water closer to the time of loss. Development of the completed well could then be reduced by a volume equal to that which was removed through the above procedure.

5-13. Well Construction Diagrams

a. Each installed well should be depicted in a well diagram. An example of a well diagram is shown in Figure 5-3. This diagram should be attached to the original bore log for that installation and graphically denote, by depth from ground surface.

(1) The bottom of the boring (that part of the boring most deeply penetrated by drilling and/or sampling) and boring diameter(s).

(2) Screen location.

(3) Joint locations.

(4) Granular filter pack.

(5) Seal.

(6) Grout.

(7) Cave-in.

(8) Centralizers,

(9) Height of riser (stickup) without cap/plug above ground surface.

(10) Protective casing detail.

(a) Height of protective casing without cap/cover, above ground surface.

(b) Bottom of protective casing below ground surface.

(c) Drainage port location and size.

(d) Gravel pad height and extent.

(e) Protective post configuration.

(11) Water level (ASTM D 4750) 24 hours after completion with date and time of measurement.

(12) Estimated maximum depth of frost penetration.

b. Describe the following on the diagram.

(1) The actual quantity and composition of the

grout, bentonite seals, and granular filter pack used for each well.

(2) The screen slot size in millimeters (inches), slot configuration, total open area per meter (foot) of screen, outside diameter, nominal inside diameter, schedule/thickness, composition, and manufacturer.

(3) The material between the bottom of the boring and the bottom of the screen.

(4) The outside diameter, nominal inside diameter, schedule/thickness, composition, and manufacturer of the well casing.

(5) The joint design and composition.

(6) The centralizer design and composition.

(7) The depth and description of any permanent pump or sampling device. For pumps include the voltage, phase requirements, and electrical plug configuration.

(8) The protective casing composition and nominal inside diameter.

(9) Special problems and their resolutions; e.g., grout in wells, lost casing and/or screens, bridging, casing repairs or adjustments, etc.

(10) The dates and times for the start and completion of well installation.

c. Each diagram should be attached to the original boring log and submitted from the field to the FA.

d. Only the original well diagram and boring log should be submitted to the FA. Carbon, typed, or reproduced copies should be retained by the FDO. A legible copy of the well diagram may be used as a base for the supplemental protection diagram.

e. Special abbreviations used on the well completion diagram should be defined on the diagram.