2800 OPERATING INSTRUCTIONS

Guelph Permeameter **December 2012**

The Guelph Permeameter is an easy to use instrument to quickly and accurately measure in-situ hydraulic conductivity. Accurate evaluation of soil hydraulic conductivity, soil sorptivity, and matrix flux potential can be made in all types of soils. The equipment can be transported, assembled, and operated easily by one person. Measurements can be made in 1/2 to 2 hours, depending on soil type, and require only about 2.5 liters of water.

Measurements can be made in the range of 15 to 75 cm below the soil surface. The Guelph Permeameter comes as a complete Kit consisting of the permeameter, field tripod, borehole auger, borehole preparation and cleanup tools, collapsible water container, and vacuum test hand pump, all in a durable carrying case. Accessory attachments are available to extend the measurement capability of the permeameter. Depth attachments increase the depth of operation by 80 cm. The maximum practical operating depth is 315 cm. Ring attachments allow ring infiltrometers measurements with 10 cm and 20 cm diameter rings. A tension adapter allows measurements to be made under tensional and very low tension (negative head) conditions.

Fig. 1. Guelph Permeameter Assembled.

Fig. 2 Guelph Permeameter Carrying Case.

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UNPACKING

The Model 2800K1 was thoroughly tested before shipment. When packed, it was in perfect working order. Unpack with care being sure to remove all packing material. Follow the instructions carefully in order to assure long, trouble-free service.

Any damage found upon receipt should be reported immediately to the transport carrier for claim. It is important to save the shipping container and all evidence to support your claim. Be sure to read all operating instructions thoroughly before operating the unit.

CAUTIONS & WARNINGS

- It is highly recommended that users read this instruction manual thoroughly and familiarize themselves with the General Procedure and Generalized Calculations as well as the assembly of the Permeameter before beginning formal field investigations.

- Although very little water is required for each measurement, it is necessary to make provisions for obtaining or bringing water on site.

WARRANTY & LIABILITY

Soilmoisture Equipment Corp. (SEC) warrants all products manufactured by SEC to be free from defects in materials and workmanship under normal use and service for twelve (12) months from the date of invoice provided the section below has been met.

Soilmoisture Equipment Corp. (SEC) is not liable for any damages, actual or inferred, caused by misuse or improper handling of its products. SEC products are designed to be used solely as described in these product operating instructions by a prudent individual under normal operating conditions in applications intended for use by this product.

THEORY OF OPERATION

The Guelph Permeameter is an in-hole Constant-Head Permeameter, employing the Marriotte Principle. The method involves measuring the steady-state rate of water recharge into unsaturated soil from a cylindrical well hole, in which a constant depth (head) of water is maintained.

A constant head level in the well hole is established and maintained at the level of the bottom of the air tube by regulating the position of the bottom of the Air Tube, which is located in the center of the Permeameter (Fig. 3). As the water level in the reservoir falls, a vacuum is created in the air space above the water. The vacuum can only be relieved when air of ambient atmosphere pressure, which enters at the top of the Air Tube, bubbles out of the Air Inlet Tip and rises to the top of the reservoir. Whenever the water level in the well begins to drop below the Air Inlet Tip, air bubbles emerge from the tip and rise into the reservoir air space. The vacuum is then partially relieved and water from the reservoir replenishes water in the well. The size of opening and geometry of the Air Inlet Tip is designed to control the size of air bubbles in order to prevent the well water level from fluctuating.

When a constant well height of water is established in a bored hole in the soil, a “bulb” of saturated soil with specific dimensions is rather quickly established (Fig. 4). This “bulb” is very stable and its shape depends on the type of soil, the radius of the well and head of water in the well. The shape of the “bulb” is included in the value of the C factor (*Reynolds et al., Groundwater Monitoring Review 6:1:84-95, 1986*) used in the calculations.

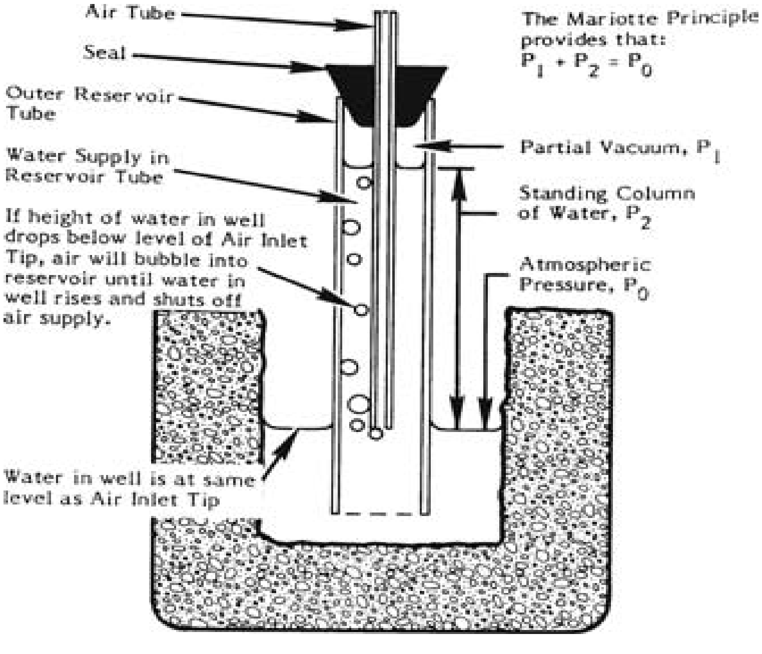


Fig. 3. In-hole constant-head permeameter setup

Once the unique "bulb" shape is established, the outflow of water from the well reaches a steady-state flow rate, which can be measured. The rate of this constant outflow of water, together with the diameter of the well, and height of water in the well can be used to accurately determine the field saturated conductivity, matric flux potential, α* parameter and sorptivity of the soil.

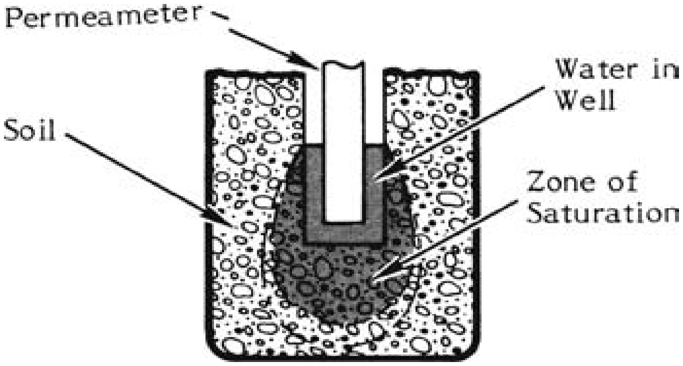


Fig. 4. Saturated zone around borehole (saturation bulb).

AQUAINT YOURSELF WITH THE PARTS

Fig. 5. Guelph Permeameter Kit (2800K1) components in Carrying Case.

1. Water Container and Tube
2. Support Kit (*See Fig. 6 below*)
3. Sizing Auger
4. Soil Auger
5. Tripod Base Tripod Bushing
6. Well Prep Brush
7. Reservoir Assembly
8. Well Head Scale & Upper Air Tube
9. Vacuum Test Hand Pump
10. Support Tube & Lower Air Tube
11. Auger Handle Assembly
12. Tripod Legs
13. Carrying Case

Auxiliary Tools

The Guelph Permeameter Kit includes a Soil Auger for excavating a well, a Sizing Auger, a Well Prep Brush, a Vacuum Hand Pump for pulling a vacuum in the reservoir, and a collapsible Water Container for carrying water to the field (Fig. 5). The Well Prep Brush is included to assist in removing any smear layer that exists in the augered well hole that may create a barrier to the natural flow of water out of the well into surrounding soil. Note that in some cases the brush may not be effective in removing the smear layer. In difficult situations an ice pick (or similar tool) or a spiked roller may be more effective in removing the smear layer (Reynolds et al., 2002). The Soil Auger, Sizing Auger, and Well Prep Brush are all equipped with quick connect fittings for use on the same auger shaft.

1. GP Tube Assembly
2. Silicon Grease
3. Well Head Indicator
4. Clamping Ring
5. Water Outlet Tip
6. Air Tube Coupling Clamp
7. Reservoir Cap O-Ring Seal
8. Air Tube Coupling
9. Air Inlet Tip
10. Reservoir Cap Fill Plug
11. Slip Joint Pliers

Fig. 6. Guelph Permeameter Support Kit.

The Guelph Permeameter is broken down into four basic sections for easy storage and transportability. These four sections are: 1) the Tripod Assembly; 2) the Support Tube and Lower Air Tube Fittings; 3) the Reservoir Assembly; and 4) the Well Head Scale and Upper Air Tube Fittings.

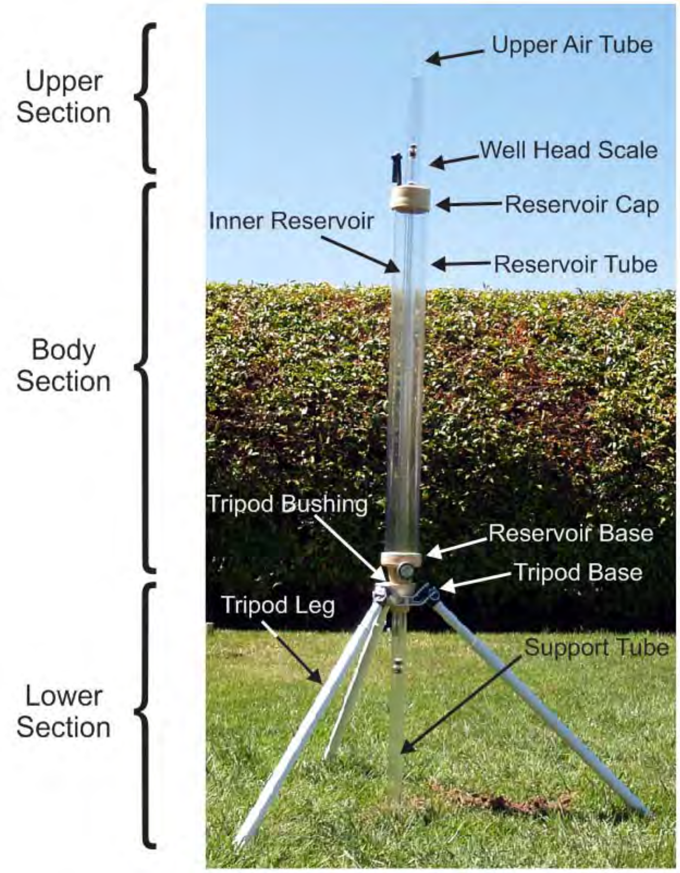


Fig. 7. Guelph Permeameter main components.

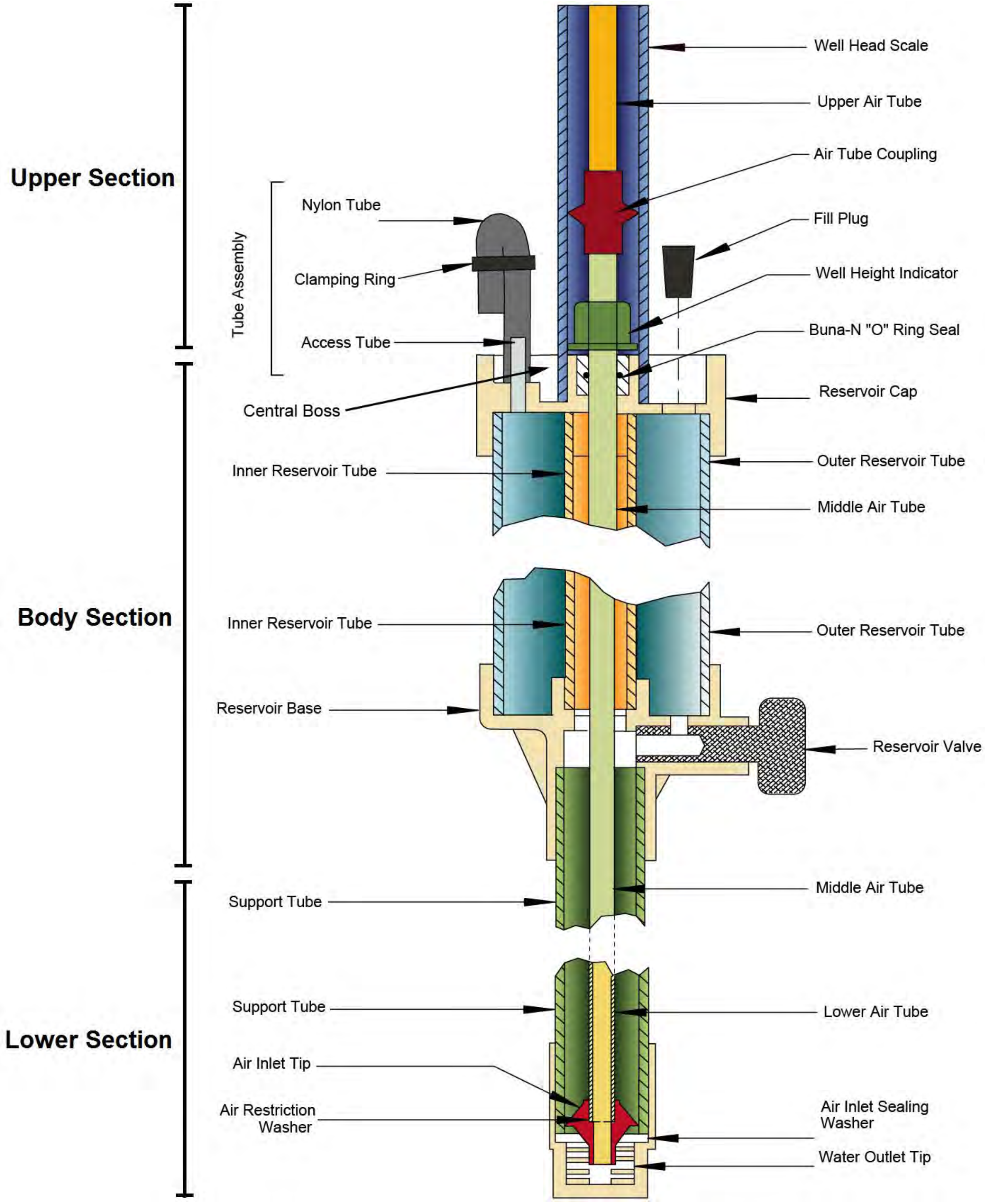
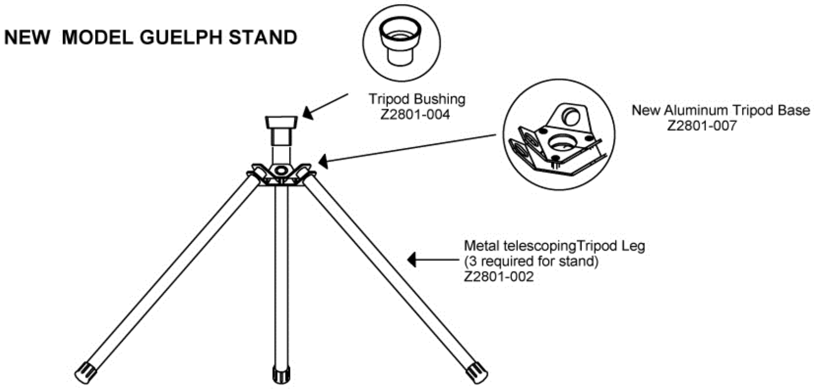


Fig. 8. Guelph Components (detailed)



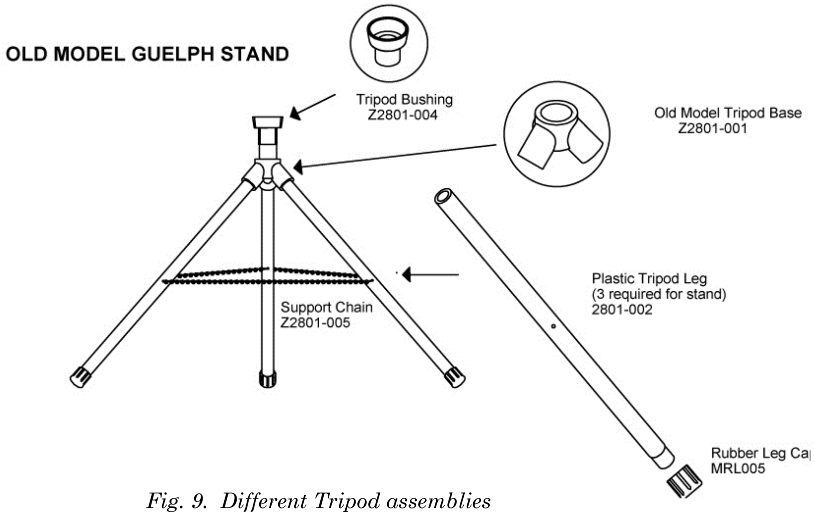


Fig. 9. Different Tripod assemblies

Tripod Assembly

In addition, auxiliary tools are included to provide a complete, self-contained kit that can be easily transported as luggage for making field measurements in most soils. Measurements in slowly permeable soils such as unstructured clays and compacted clay liners can be obtained using early-time measurements with the Guelph Pressure Infiltrometer.

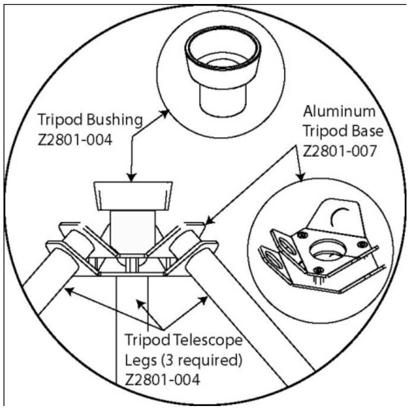


Fig. 10. Tripod Assembly

The Tripod Assembly consists of a Tripod Base with moveable Tripod Bushing and 3 detachable telescoping Tripod Legs complete with end tips. The Tripod Base has 3 leg sockets into which the Tripod Legs are inserted (Fig. 10). The telescoping legs allow a vertical hold on an inclined landscape. To adjust the length of the leg(s) simply twist the leg counterclockwise; to secure that height tighten the leg by turning it clockwise. A Heavy Duty Guelph Stand (2806K1) is also available to firmly secure and stabilize the GP.

Support Tube and Lower Air Tube Fitting

These are the fittings that conduct water from the Reservoir Assembly into the borehole and provide the means for establishing and maintaining a constant head in the borehole.

The Support Tube supports the Reservoir Assembly over the well hole and conducts water from the Reservoir to the Water Outlet Tip.

The Water Outlet Tip serves as a base for the Permeameter and disperses the energy of the out-flowing water through the ribbed vents at the bottom of the tip to minimize erosion of soil in the well hole. The Air Tip Seating Washer rests on the inside step of the Water Outlet Tip and is the seat for the Air Inlet Tip. When the Air Inlet Tip is fully seated against the Air Tip Seating Washer, air cannot move up the Support Tube and there is no flow of water out of the reservoir.

The Air Inlet Tip is connected to the bottom of the Lower Air Tube and is used to regulate the water head height in the borehole. The Air Restriction Washer is located inside the Air Inlet Tip and regulates airflow to provide a constant, non-fluctuating head in the well (Fig 12). The Guelph Permeameter employs the Mariotte Principle to maintain a constant well head and this is described in further detail in the "*Theory of Operation*" section.

The Air Tube Coupling joins the Lower Air Tube to the Middle Air Tube and is designed with stabilizing fins to center and prevent bowing of the air tube inside the Support Tube (Fig 11).

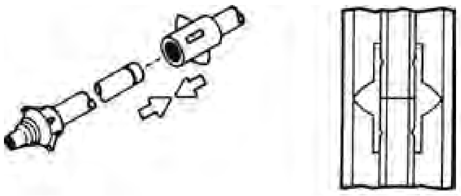


Fig. 11. Air Tube Coupling

Reservoir Assembly

The Reservoir Assembly provides a means of storing water and measuring the outflow rate while the Guelph Permeameter is in use. For studies in low permeability soils for example, some clays, use of the inner reservoir *only* is required to provide adequate resolution of outflow rate when making a reading. When working in moderate to high permeability soils for example, sands and structured loams, the reservoir combination is used. A scale, delineated in centimeters, is stamped on the Inner Reservoir Tube for measuring the rate of fall of water out of the reservoir in both situations. Fittings are located at the top and bottom of the reservoirs to allow filling and selection of the proper reservoir.

The Guelph Permeameter, in Fig 12 Left, shows the closed or sealed state with the Air Inlet Tip sealed against the Air Tip Seating Washer. As illustrated in Fig. 12 Right, upon uplift of the Air Tube with accompanying Air Inlet Tip and Well Height Indicator, water flows from the reservoir down the inside of the Support Tube through the Water Outlet Tip and into the well.

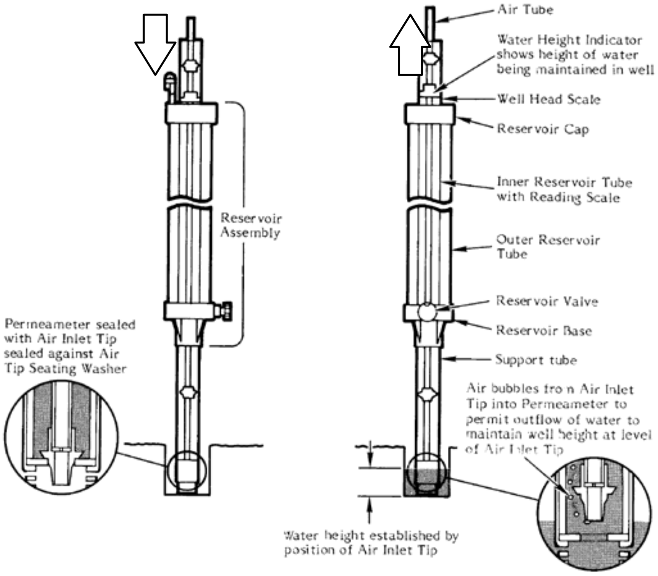


Fig. 12. Illustration of Air Inlet status.
Left: closed/sealed state (push the Air Inlet Tube all-the-way down).
Right: open/operating state (pull the Air Inlet Tube to the desired water head height).

Reservoir Base

The water height in the well is established by the height of the Air Inlet Tip. This water height in the borehole can be set and read using the Well Height Indicator in conjunction with the Well Head Scale (Fig 8).

The Reservoir Base supports the Reservoir Valve and connects and seals the Inner and Outer Reservoir Tubes to the Support Tube (Fig 8).

In use, water flow is controlled by the notched Reservoir Valve. When the notch is pointing straight up, or in the 12 o'clock position, both reservoirs supply water to the borehole. When the notch is pointing straight down or in the 6 o'clock position, only the Inner Reservoir supplies water to the well hole (Fig 13).

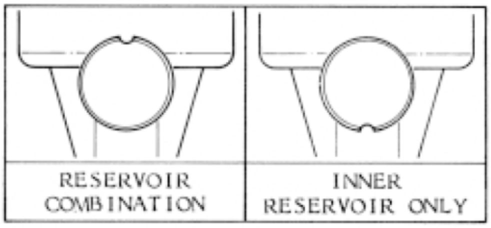


Fig. 13. Different Reservoir Valve positions.

Reservoir Cap

The Reservoir Cap includes a Fill Plug (#1 Stopper) and Vacuum Tube connections. The Reservoir Cap provides an airtight cover for the top of the reservoir, a seal for the Air Tube, and supports the Well Head Scale on the central "boss" (Fig 8).

The 2800K1 Guelph Permeameter comes equipped with an airtight seal as part of the Reservoir Cap. As shown in the sketch below, the Reservoir Cap includes a removable O-Ring Seal (Fig. 14).

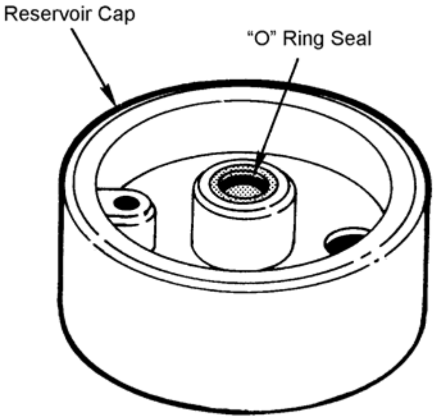


Fig. 14. Illustration of Reservoir Cap and O-Ring position.

Should it become necessary to replace the O-Ring Seal, a wooden toothpick or similar implement should be used to remove the old O-Ring and replace it with a new one (Fig. 15). Sharp, pointed metal implements are not recommended for use when removing the O-Ring, because the O-Ring or more importantly the O-Ring <u>seat</u>, could be damaged.

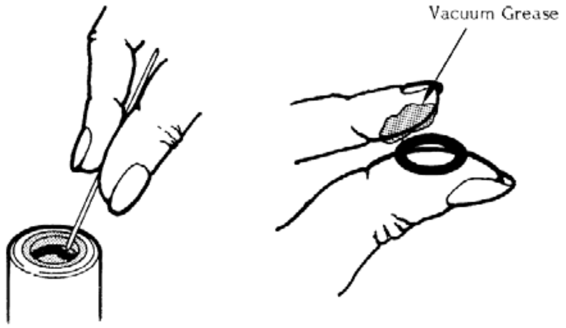


Fig. 15. Left: taking out O-ring using a toothpick. Right: putting vacuum grease on O-ring.

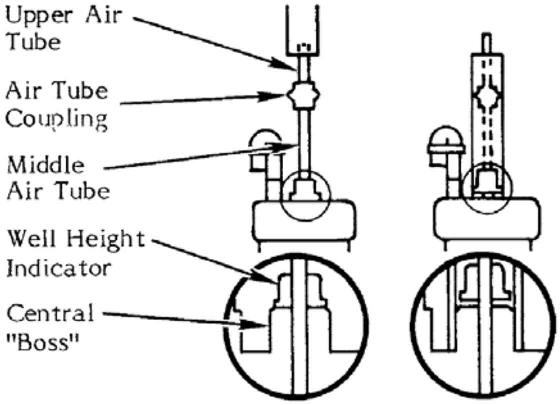
A thin film of vacuum grease should be applied to the O-Ring to ensure an airtight seal (Fig. 15 Right). The Middle Air Tube is located inside the Inner Reservoir Tube and slides through an airtight seal in the Reservoir Cap. The Well Height Indicator (water head height indicator) slides over the Middle Air Tube above the Reservoir Cap and indicates on the Well Head Scale the head of water being maintained in the borehole (Fig 8).

Two ports are located in the Reservoir Cap. The reservoirs are filled through the Fill Port and sealed with a Fill Plug (#1 Stopper). The Vacuum Port consists of an Access Tube, Neoprene Tube, and Clamping Ring. The Vacuum Port facilitates pulling a vacuum if necessary in low permeability soils when the Reservoirs are not initially completely filled, (section "*Making a Reading with Limited Water Supply*"). After a vacuum is created, the Neoprene Tube is bent over and closed off with the Clamping Ring.

Well Head Scale and Upper Air Tube Fitting

The Upper Air Tube is connected to the Middle Air Tube with an Air Tube Coupling. The Upper Air Tube serves as an extension to facilitate setting the well head after the Well Head Scale is put in place. The Well Head Scale is numbered in centimeters and graduated in millimeters. The Well Head Scale fits snugly over the central "Boss" on the Reservoir Cap (Fig. 8). Once the Air Inlet Tip at the bottom of the Permeameter is seated and sealed, the Well Height Indicator is pushed down the Air Tube until it rests against the "Boss" on the Reservoir Cap, as shown in Fig 16. Next the Well Head Scale is mounted. The Air Tube is then pulled up, raising the Well Height Indicator to the height desired. The height is read on the Well Head Scale. A check on the well height can easily be made using a ruler or a wettable paper strip.

Fig. 16. Illustration of Well Height Indicator positioning. When the Air Tip is sealed against Water Outlet Tip, the Well Height Indicator should touch the "Boss".



GENERAL SPECIFICATIONS

Auger Cutting Diameter: 6.0 cm (2-3/8 inches)

Well Height Range: 2.5 cm to 25 cm

Hydraulic Conductivity Range: 10^{-4} to 10^{-7} m/sec (10^{-2} to 10^{-5} cm/sec)

Collapsible Water container Capacity: 11.36 liters (3.0 gallons)

Maximum Permeameter Capacity: 3.18 liters (0.84 gallons)

Overall Carrying Case Size: 132.08 cm (50 inches) long by 44.45 cm (17.5 inches) wide by 15.24 cm (6 inches) deep

Overall Carrying Case Weight: 11 kg (25 lbs)

Depth Range, Standard Unit: 15 to 75 cm (Note: with Extension Tubes, measuring depths can be increased)

Combined Reservoir cross-sectional area (X value): 35.22 cm^2 (±0.18 cm^2 standard deviation)

Inner Reservoir cross-sectional area (Y value): 2.16 cm^2 (±0.04 cm^2 standard deviation)

REQUIREMENTS PRIOR TO USE

The Guelph Permeameter is designed to be installed in a borehole in soil profile down to 80 cm (31.50 inches) deep (for deeper measurements see section *"Making a Reading in Deep Wells"*). Therefore before installing the Guelph Permeameter, one needs to dig and prepare a borehole. All of the tools required to bore a hole are included in the Kit.

Site and Soil Evaluation

Before making a measurement with the Guelph Permeameter in the field, it is necessary to perform a site and soil evaluation, prepare a well hole, assemble the Permeameter, fill the Reservoirs, and place the Permeameter in the well hole. Upon arrival at the site, the user must evaluate the site with regard to topography, general soil appearance, intended application, and select the number and location of areas that are representative of the soils under study. At each site use Table 1 to determine the appropriate value for $\alpha*$. If the computer program is used, then the value for C (one-head analysis) or the values for C_1 and C_2 (two-head analysis) will automatically be determined.

Well Preparation

The implements needed for excavating and preparing a well borehole are included in the Guelph Permeameter Kit. They consist of a two-piece handle, which is assembled as shown in Fig. 17 below, and three interchangeable auxiliary tools, which are connected to the handle by means of the quick connect fitting.

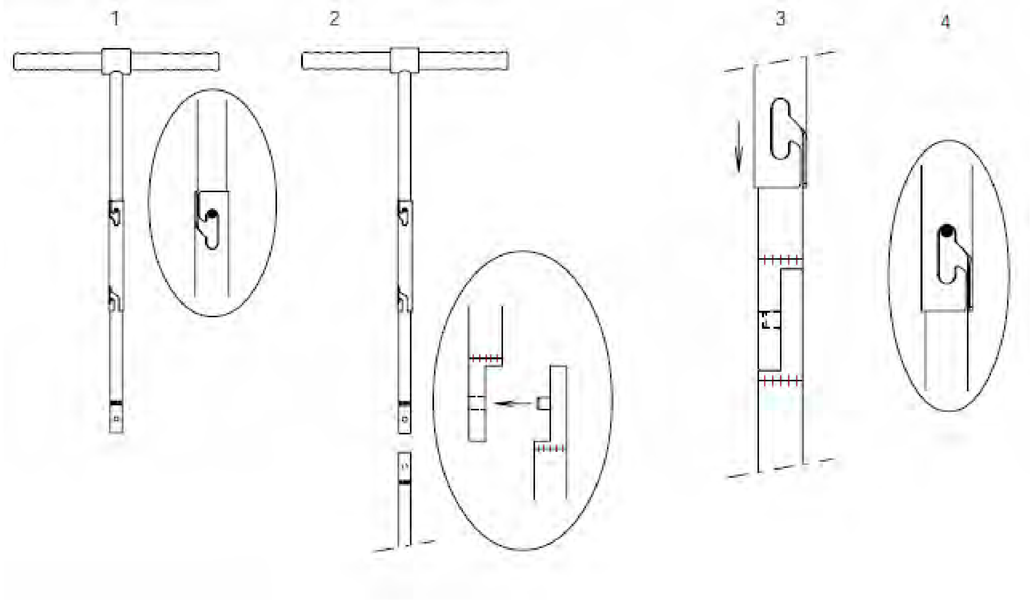


Fig. 17

1. Screw the handle into the upper part. Select the appropriate auger. The Edelman combination type auger or the sizing auger.
2. Connect the auger parts bayonet male into the handle bayonet female (see Fig. 17-2 above).
3. Hold the coupling sleeve in the middle and slide it across the connection and click it onto the sleeve stop. The sleeve is locked when it cannot be rotated. Hold the coupling sleeve in the middle, this will prevent you from catching the skin of your hands between the parts while (dis)connecting them.

The Soil Auger, shown in Fig. 18 below, is used to remove bulk amounts of soil. Auger the well hole by rotating the handle in a clockwise direction applying steady, but somewhat firm, downward pressure on the handle as shown. When the auger body is full, lift the auger out of the hole and push the collected sample out of the auger body. When augering, be careful to keep the shaft of the auger handle vertical to avoid excessive enlargement of the well hole.

Soil Auger and Sizing Auger

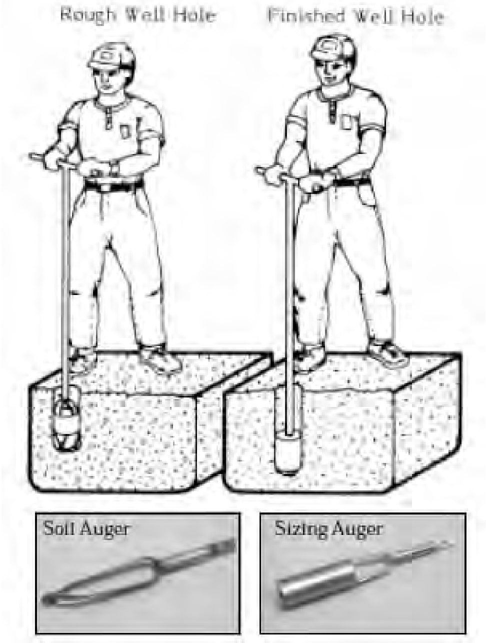


Fig. 18

The Sizing Auger, shown in Fig. 18, is used as a finishing tool to produce a proper sized well hole uniform geometry, meeting the size and shape requirements of the model, and to clean debris off the bottom of the well hole. The Sizing Auger is designed to produce a hole that is uniformly 6 cm in diameter with a flat bottom. It is also important to keep the blade sharpened to a knife-blade edge in order to minimize smearing.

Generally, the preferred procedure is to use the Soil Auger to excavate the well hole down to a depth of 15 cm less than that desired for the final well hole. The last 15 cm can then be excavated using the Sizing Auger to produce a debris-free well hole of uniform geometry. In rocky or gravely soils, it may be necessary to use the Soil Auger to excavate all the way to the bottom of the well hole. The Sizing Auger is then used afterwards to clean loose debris off the bottom of the well hole.

In medium-textured soils of good tilth that are rock free, the well hole is started with the Soil Auger to a shallow depth and then the Sizing Auger alone can be used to excavate the well hole. Apply light downward pressure and take only small bites with the auger (two finger, two turn rule) when augering within the measurement zone. Variations of the procedures for excavating the well hole that are recommended above can be used as soil conditions dictate. The soil and site evaluation is an ongoing process. Soil textural and structural stratification should be identified while augering the hole. A record of this information is an important part of measuring and reporting the hydraulic properties of soil materials. In moist soils, and particularly in medium to fine-textured soils, the process of augering a hole may create a smear layer which can block the natural flow of water out of the well into the surrounding soil. In order to obtain reliable and representative results using the Guelph Permeameter, this smear layer must be removed. The Well Prep Brush is provided for this purpose. The Well Prep Brush is designed to use in the standard 5 cm diameter well hole, and has an outside diameter that is somewhat greater than the diameter of the well. In fine textured soils the brush may not be effective and alternative techniques such as an ice pick or spiked roller should be used (Reynolds et al., 2002).


Fig. 19

Attach the Well Prep Brush (Fig. 19) to the auger shaft using the quick-connect fitting. Push the Well Prep Brush into the well hole and all the way to the bottom. Next, quickly and evenly pull the Well Prep Brush straight up and out of the well hole (Fig. 20). When the direction of the brush is reversed, the bristles will dig into the sides of the well hole, roughen the surface and scour the smear layer. This operation should not be done more than once or twice, since each operation removes a layer of soil. Repeated operations will enlarge the hole diameter beyond the desirable limits needed to obtain accurate results.

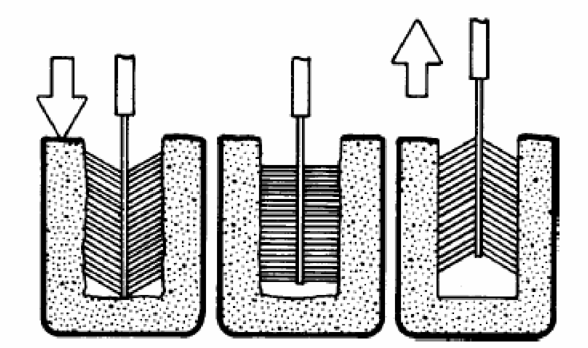


Fig. 20

Typically, the difficulty of removing the smear layer increases with increasing wetness of the soil and in finer textured soils. It is recommended that fine textured soils not be augered when they are in a very wet state.

Borehole Casing

In the case that there is a chance of collapsing of borehole wall, use a perforated pipe with proper diameter and length for supporting borehole wall. Note that the shape and dimensions of borehole can affect the accuracy and reliability of results.

Soil Water Status

Readings made by any type of Permeameter is valid only if it has been made when soil around the borehole is saturated with water and Saturation Bulb has been established (see Fig 4). In order to get the best results in a relatively short time, saturate the soil abound borehole before installing Guelph Permeameter and making the actual readings. Fill up borehole with water and let water percolate completely through soil profile. Depending on soil texture and borehole dimensions it may take several minutes to a day or even more. If the soil is heavy (contains a lot of clay) fill up the borehole with water 24 hours earlier. At the time of reading and before installing Guelph Permeameter the borehole should be empty of water. Evacuate water from borehole if needed before installing Guelph Permeameter (the tools needed for evacuating water from borehole are not included in Guelph Permeameter Kit).

Another way is to install Guelph Permeameter and start readings in an unsaturated soil. The readings continue until soil becomes saturated. In a saturated soil, readings values do not change over time (Steady State). Steady State is explained with more details later in "*Determine the Steady-State Rate of Fall*" section.

HOW TO USE AND/OR OPERATE UNIT

Permeameter Assembly

The Guelph Permeameter Kit is shipped with its component parts disassembled to provide convenient storage in its hard-shell carrying case and for portability to field sites. The Permeameter is easily assembled. See steps below:

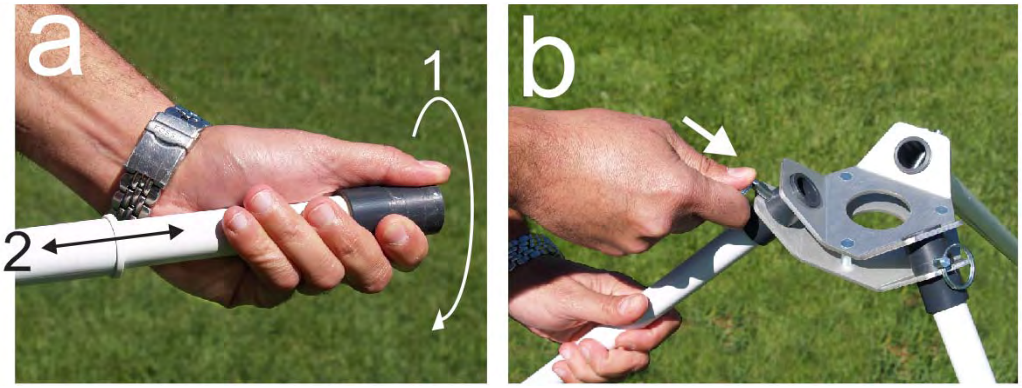


Fig. 21. Assembling the Tripod.

Connect the Legs to Tripod Base (Fig 21). When working on slopes, the telescopic feature of the Tripod Base allows the angle of the Tripod Legs to be adjusted as needed. On a level soil surface there is no need to extend the legs.

Remove the Reservoir Assembly and the Lower Air Tube from the case. The Lower Air Tube is stored inside the Support Tube.

Connect the Lower Air Tube to the Middle Air Tube at the Reservoir Base using the Air Tube Coupling as shown in Fig 22. Firmly push the Lower Air Tube into the Coupling until the ridge on the inside of the coupling snaps into the groove on the end of the Lower Air Tube.

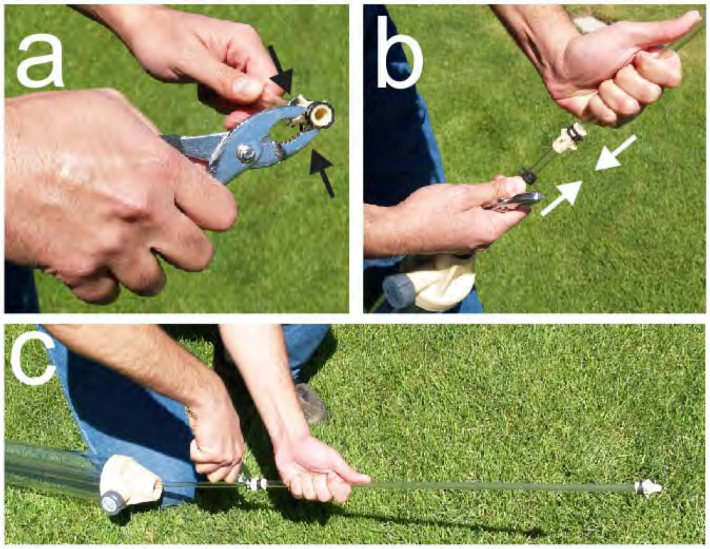


Fig. 22. Connecting the Lower Air Tubing to the Middle Air Tubing using the Air Tube Coupling.

Remove the Tripod Bushing and Support Tube from the case. Slide the Tripod Bushing, with the wide end oriented UP, over the outside of the Support Tube (Fig. 23a). Then, with the Tripod Bushing in place, slide the Support Tube over the Air Tube and connect it firmly into the recess in the bottom of the Reservoir Base, as shown in Fig. 23b. This is an airtight friction fitting and it is important that the Support Tube be seated completely into the Reservoir Base.

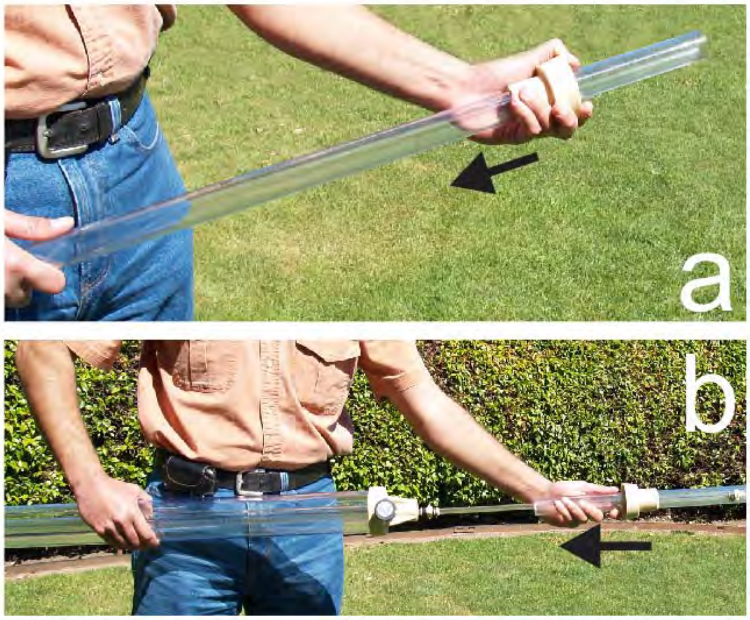


Fig. 23. Assembling the Tripod Bushing and Support Tube.

Lower the Support Tube into the Tripod, as shown in Fig. 24 left. To support and stabilize the Permeameter, push the Tripod Bushing downward fully into the Tripod Base, as shown in Fig. 24 right.

Fig. 24. Left: lowering GP into Tripod and Borehole.
Right: GP is stabilized by pushing the Tripod Bushing into Tripod Base.

Additional support may be required in windy conditions, on sloping soils, or perhaps under other conditions. A steel rod driven into the soil near to the hole and clamped to the Reservoir may be sufficient to support the Permeameter. If the bottom tip of the GP appears to sink into the base of the well, independent support of the GP body is important. Our Heavy Duty Tripod Guelph Stand (2806F1) is another option to consider.

Remove the Upper Air Tube from its storage inside the Well Head Scale, as shown (Fig. 25).

Fig. 25. Removing Upper Air Tube from Well Head Scale.

Make sure that the Well Height Indicator is in place before connecting the Upper Air Tube to the Middle Air Tube (Fig. 26 left). The Upper Air Tube is connected to the top of the Middle Air Tube with an Air Tube Coupling. Again, when connecting the Air Tube sections, be sure that the ridges on the inside of the coupling fully snap into the grooves on the ends of the Air Tube sections (Fig. 26 right).

Fig. 26. Connecting Upper Air Tube to Middle Air Tube.

Fully seat the Air Inlet Tip into the Air Tip Seating Washer by pushing down on the Upper Air Tube. Once the Air Inlet Tip is seated, lower and seat the Well Height Indicator flush against the Reservoir Cap, as shown in Fig. 26, right.

Lower the Well Head Scale over the Upper Air Inlet Tube and fully seat it against the bottom of the recess in the Reservoir Cap (Fig. 27 left). The counter bore in the Well Head Scale fits snugly onto the central “boss” of the Reservoir Cap. The “mm” mark at the top of the scale should be oriented up. The Well Head Scale is properly mounted when the “0” reading of the Well Head Scale is 5 mm below the top of the Reservoir Cap, and the bottom of the Well Height Indicator lines up with the 5 mm mark on the Well Head Scale (see Fig. 27 right).

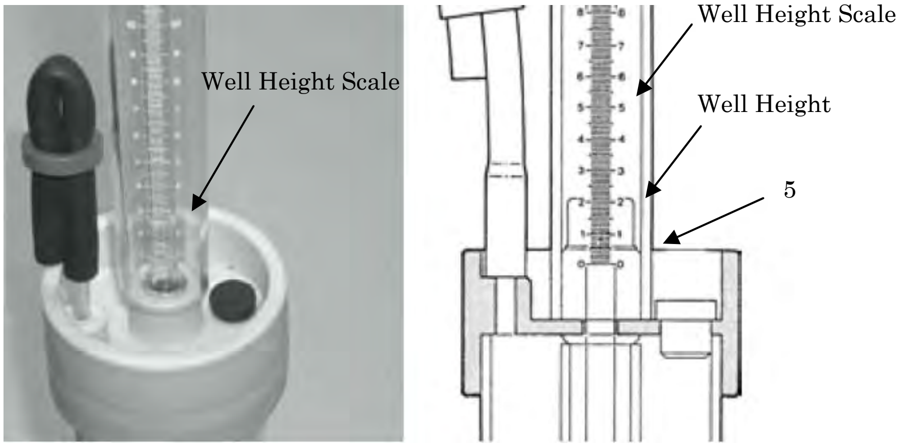


Fig. 27. Connecting the Well Head Scale to the Reservoir Cap

Water Filling

Fig. 28 - Filling the Reservoir with water using the collapsible water reservoir.

After the Permeameter is assembled and mounted in the Tripod, it can be easily filled with water. Remove the Fill Plug in the Reservoir Cap, see Fig. 28a, and adjust the Reservoir Valve so that the notch is in the up, or 12 o'clock position (Fig. 28b). The Inner and Outer Reservoirs are now connected and ready for filling. Pour water into the recess on the Reservoir Top Cap. For convenience, the Tube Assembly can be connected to the plastic water container, and foot pressure can be used to pump water to the Permeameter, as shown in Fig. 28c. Alternatively, small amounts of water may be added consecutively in order to fill the reservoir. The recess prevents water from splashing and spilling over. It is important to fill the reservoir until no air bubbles readily emerge from the fill hole. When only limited quantities of water are available and the reservoir cannot be filled completely, follow the procedure on section "*Making a Reading with Limited Water Supply*". After filling, replace and fully seat the Fill Plug in the fill hole, make sure that the Neoprene Tube from the Vacuum Port is folded over and closed with the Clamping Ring. As a precaution, water can be added to the recess area to ensure that there are no leaks.

Placement of Permeameter

Simply center the Tripod over the well hole and slowly lower the Permeameter so that the Support Tube enters the well hole, being careful not to knock debris off the sides of the well into the borehole bottom (Fig. 29 left). Flexibility in the Tripod Base allows the angle of the Tripod Legs to be adjusted to accommodate variation in slope of the land. The Tripod is used to support the Permeameter in wells down to approximately 38 cm (15 inches) in depth.

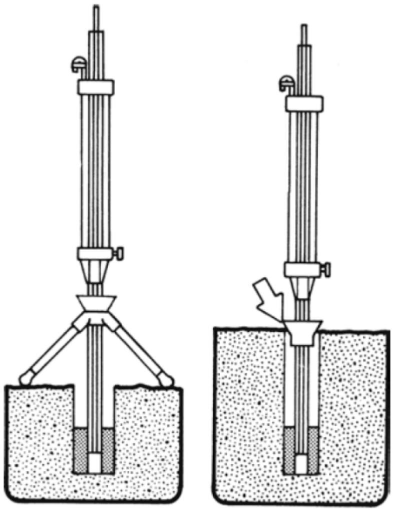


Fig. 29. Filling the Reservoir with water

For use in wells deeper than 38 cm (15 inches), the Tripod Bushing alone provides the functions of centering and stabilizing the Permeameter. Lift the Tripod Bushing from its position in the Permeameter base. The entire Permeameter can then be lifted clear of the Tripod. Lower the Permeameter slowly into the well hole until the Water Outlet Tip rests on the well bottom. Again, care should be taken to avoid knocking debris from the sides of the well into the bottom. Once the Permeameter is in place, center and stabilize it by lowering the Tripod Bushing into the top of the well hole. Secure the Tripod Bushing with a firm push into the soil, as shown in Fig. 29 right.

In unstable soils, pea gravel or coarse sand can be used to backfill around the Permeameter tip to the top of the measurement zone. At times it may be necessary to tape the Water Outlet Tube to the Support Tube to prevent the Tip from being pulled off by the backfill material when the Permeameter is removed from the well. Be careful to not cause debris to fall into the well.

For deep well boreholes where the weight of the water column/reservoir assembly may cause the Water Outlet Tip to “sink” into the saturated soil, it is recommended that our accessory Heavy-Duty Guelph Stand be used to support the water column securely at the height of the bottom of the borehole (See Accessories List). Make certain that adequate water is available to perform the number of measurements required for your particular field investigation. After the Permeameter has been assembled, filled, and placed in the prepared well hole, the following procedure should be followed for making measurements.

Making a Reading

Verify both Reservoirs are connected. The Reservoirs are connected when the notch on the Reservoir Valve is pointing up.

Verify that the Well Height Indicator and the Well Head Scale are seated down flush against the top of the Reservoir Cap. This is described under the "*Permeameter Assembly*" section.

The Fill Plug must be fully seated against the Reservoir Cap (see Fig. 30).

The Vacuum Tube must be closed off with the Clamping Ring (see Fig. 30).

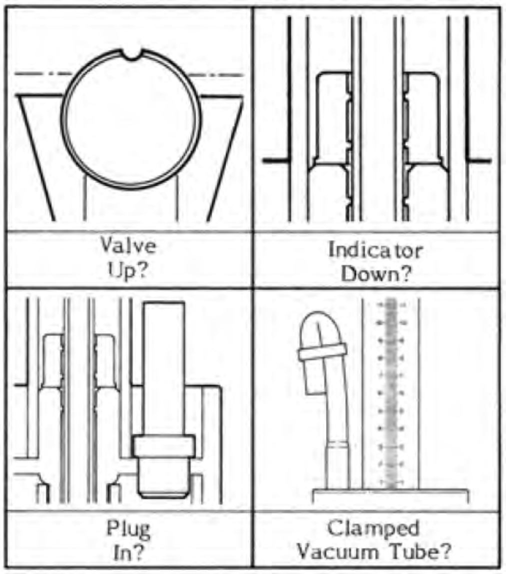
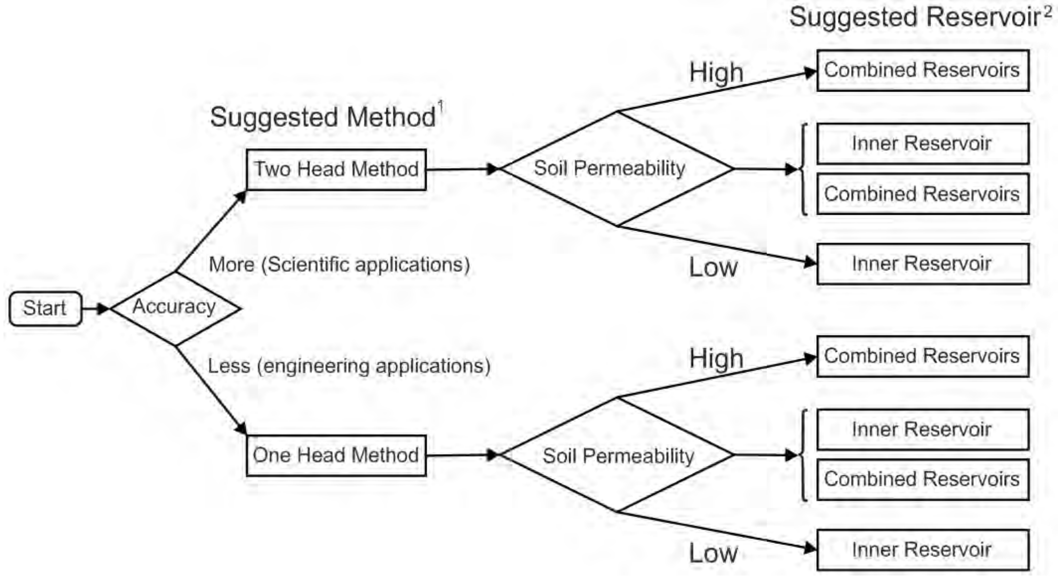


Fig. 30. Double check these items before each reading



[1] The one-head procedure is simpler, but may be less accurate than the two-head procedure. One advantage of the one-head procedure, however, is that it will always give a positive result. The single-head procedure is for applications where the saturated hydraulic conductivity, K_{fs} need only be known within a factor of 2 or less. For many applied engineering applications, this level of accuracy is probably sufficient. The two-head procedure is more research-oriented and is preferred when a higher level of accuracy is required. The two-head approach also provides data for two one-head analyses and the results can be averaged.

[2] Based on the site evaluation you may have selected either the combination or inner reservoir. If difficult to evaluate, then choose the combination reservoir (valve up). Observe the rate of fall of the water level in the reservoir. If it is too slow to easily distinguish the drop in level between consecutive readings, usually a 2-minute interval, then turn the Reservoir Valve so that the notch is pointing down in the 6 o'clock position. Water will then be supplied only from the small diameter Inner Reservoir which will result in a much greater drop in water level between readings.

Fig. 31 Guelph Permeameter method selection flow chart.
The selected method is based on desired level of accuracy and the level of soil permeability.

Decide on whether the one or two-head procedure is to be used (see Fig. 31 above). The one-head procedure is simpler, but may be less accurate than the two-head procedure. One advantage of the one-head procedure, however, is that it will always give a positive result. The one-head procedure is for applications where the saturated hydraulic conductivity (K_{fs}) needs only be known within a factor of 2 or less. For many applied engineering applications, this level of accuracy is probably sufficient. The two-head procedure is more research-oriented and is preferred when a higher level of accuracy is required. The two-head approach also provides data for two one-head analyses and the results can be averaged.

Decide whether the Inner Reservoir or the Combined Reservoir is to be used. The reservoir combination is used in soil of moderate to high permeability. Soils that fit into this category typically have some degree of structure, medium to coarse texture, and little to no cementation or compaction. The Inner Reservoir only is used for work in soils of low permeability. Soils that fit into this category are typically fine textured, structure-less, or are significantly cemented or compacted. If difficult to evaluate, then choose the combination reservoir (valve up). Observe the rate of fall of the water level in the reservoir. If it is too slow to easily distinguish the drop in level between consecutive readings, usually a 2-minute interval, then turn the Reservoir Valve so that the notch is pointing down in the 6 o'clock position. Water will then be supplied only from the small diameter Inner Reservoir which will result in a much greater drop in water level between readings, see Fig. 32. Please note that once the appropriate reservoir is selected, do not change the reservoir valve.

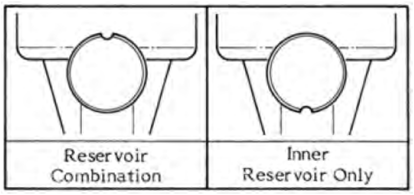


Fig. 32. Selecting Inner or Combination Reservoir.

Establish a Well Head Height (H_1) Note that this is the only head required if the one-head procedure is used.

Slowly raise the Air Inlet Tip (Fig. 33 left), by grasping the Upper Air Tube to establish the first well head height. Note that raising the Air Tube too quickly can cause turbulence and erosion in the well and a potential surging effect that could cause the well to temporarily overfill. Raise the Air Tube until the well height H_1 is established, as indicated by reading the lower edge of the Well Height Indicator against the Well Head Scale (Fig. 33 right). In permeable soils select the combination reservoir and set H_1 between 5 and 10 cm. In slowly permeable soils select the inner reservoir and set H_1 between 10 to 25 cm depending on the R value obtained.

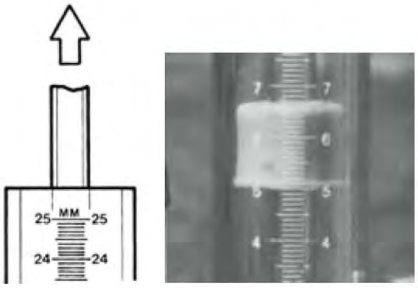


Fig. 33. Raise the Air Inlet Tip by slowly pulling up the Upper Air Tube.

Record the water level in the selected reservoir as read against the scale stamped on the Inner Reservoir Tube. Readings should be made at regular time intervals. As a suggested procedure, try one- or two-minute intervals between readings. When investigating slow permeable soils, situations may arise where the rate of fall of water is so slow that a two-minute time interval may not be long enough to detect a measurable change in the water level in the reservoir. In these cases, a longer time interval is more appropriate. Increase the time interval as needed for measurement of the rate of fall of water in the reservoir, perhaps 15-minute intervals, or longer. On the other hand, in situations where the rate of fall of water is very fast, such as in sandy soils, a time interval as short as 15 seconds may be more appropriate. Make sure the calculation for R is based on the actual time interval selected. In heavy clay soils, where the hydraulic conductivity is very low, the Permeameter can be left in place for a long period of time while other tasks are being performed. Under these circumstances, periodic readings can be made at convenient intervals until the rate of fall reaches a steady-state value (see the next step).

Determine the "Steady-State Rate of Fall". For each reading, calculate the rate of fall of water. The difference of readings at consecutive intervals, divided by the time interval, equals the rate of fall of water, R, in the reservoir.

For example, at time = 0 minutes, assume the level of water in the reservoir is at 5.9 cm as read on the Reservoir Scale. After the elapse of the first time interval, time = 2 minutes, the level of water is at 6.5 cm. The rate of fall, R, of water in the reservoir, is calculated as the change in the level of the water, in centimeters, divided by the time interval for the change, expressed in seconds. The calculation is shown below:

$$R = (6.5\ \text{cm} - 5.9\ \text{cm}) / (2\ \text{min}) = .005\ \text{cm/sec}$$

Continue monitoring the rate of fall of water in the reservoir until the rate of fall does not significantly change in three consecutive time intervals. This rate is called $\bar{R}_1$, and is defined as the "Steady-State Rate of Fall" of water in the reservoir at H_1 (the first well height established see

Table 1, section 2). At this stage soil is saturated with water and a Saturation Bulb has been established (see "*Requirements Prior to Use*" for more details).

In very slow permeable soils, the measurement of these very slow flow rates may not be accurate and different procedures may have to be used (see Elrick and Reynolds, 2003).

Note: In case that you are using the two-head method, **do not** disturb the Permeameter in any manner after completing the outflow measurements and proceed immediately to the next step.

Refill the Inner Reservoir if Needed. Note that continuous measurements are required and do not refill the reservoir at this time. It may be possible when using the small reservoir to partially refill the small reservoir with water from the large reservoir during the switch-over from H_1 to H_2. Partially turn the reservoir valve. This connects the two reservoirs and slowly refills the small reservoir at the same time as the air tube is being raised from H_1 to H_2. This reduces the chance of running out of water in the small reservoir during the H_2 measurements and also prevents over-filling the well at H_2. Turn the Valve to its previous position when the water levels in both reservoirs.

Establish the second Well Head Height (H_2) if the Two-Head Procedure is being used, slowly raise the Air Tube until the well height H_2 is established, as indicated by reading the lower edge of the Well Height Indicator against the Well Head Scale (see Fig. 34). In permeable soils keep the combination reservoir and raise H_2 to between 10 to 20 cm, depending on the R value obtained. In slow permeable soils keep the inner reservoir and raise H_2 to between 20 to 25 cm, again depending on the R value obtained. In most cases set $H_2 > 2H_1$.

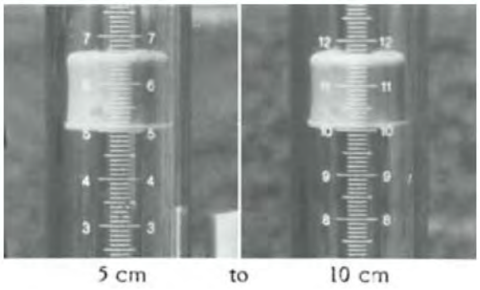
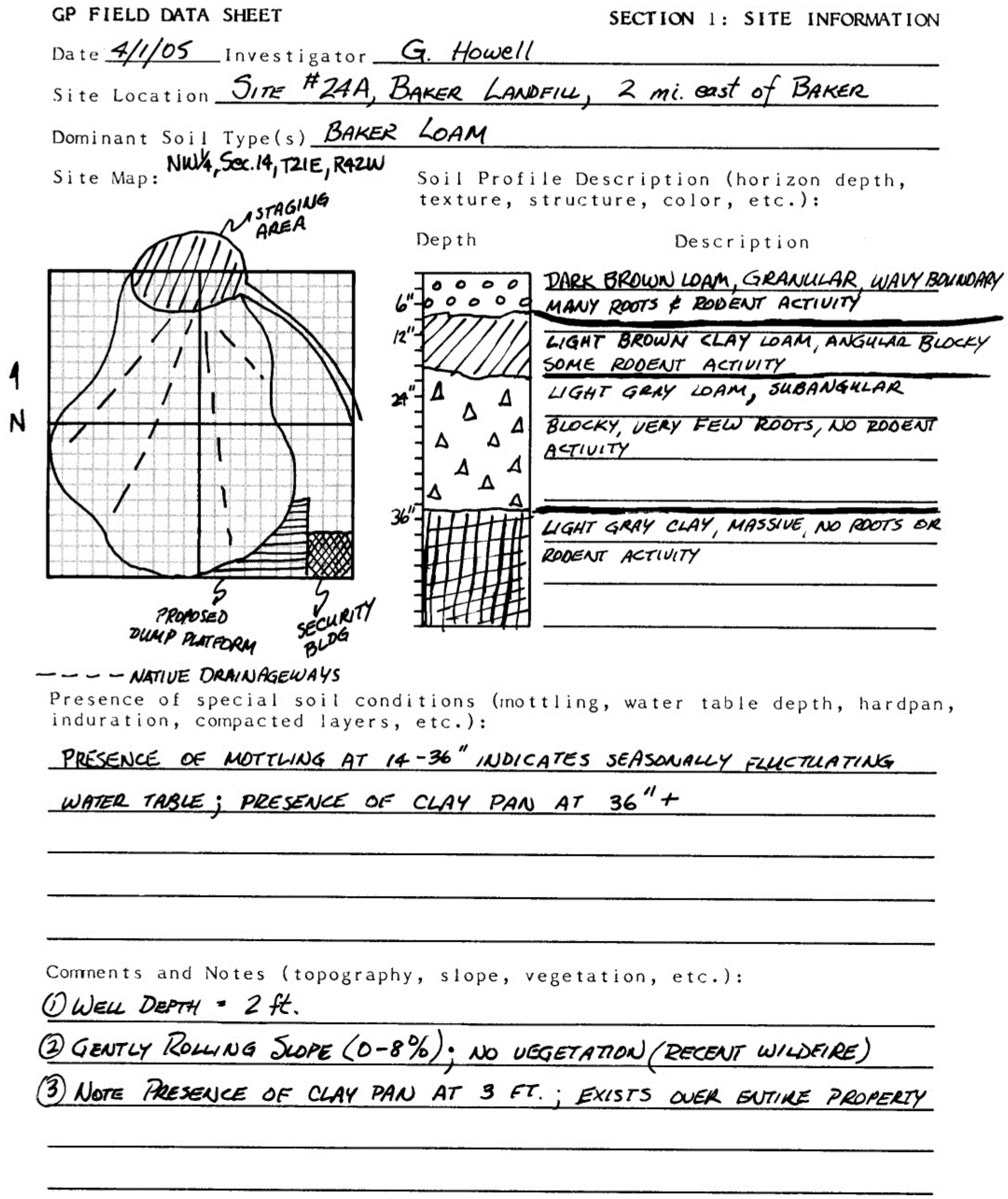


Fig. 34 - The position of Well Height Indicator against the Well Head Scale.

Record the water level in the selected reservoir as read against the scale stamped on the Inner Reservoir Tube similar to what you did in H_1.

Determine the "Steady-State Rate of Fall" similar to what you did for H_1. The steady-state flow rate at H_2 is called $\bar{R}_2$ (see Table 1, section 2).

Table 1. A sample data sheet for the Guelph Permeameter.



GP FIELD DATA SHEET **SECTION 1: SITE INFORMATION**

Date 4/1/05 Investigator G. Howell

Site Location SITE #24A, BAKER LANDFILL, 2 mi. east of BAKER

Dominant Soil Type(s) BAKER LOAM

Site Map: NW¼, Sec. 14, T21E, R42W

Soil Profile Description (horizon depth, texture, structure, color, etc.):

Depth	Description
6"	DARK BROWN LOAM, GRANULAR, WAVY BOUNDARY MANY ROOTS & RODENT ACTIVITY
12"	LIGHT BROWN CLAY LOAM, ANGULAR BLOCKY SOME RODENT ACTIVITY
24"	LIGHT GRAY LOAM, SUBANGULAR BLOCKY, VERY FEW ROOTS, NO RODENT ACTIVITY
36"	LIGHT GRAY CLAY, MASSIVE, NO ROOTS OR RODENT ACTIVITY

Presence of special soil conditions (mottling, water table depth, hardpan, induration, compacted layers, etc.):

PRESENCE OF MOTTLING AT 14-36" INDICATES SEASONALLY FLUCTUATING WATER TABLE; PRESENCE OF CLAY PAN AT 36"+

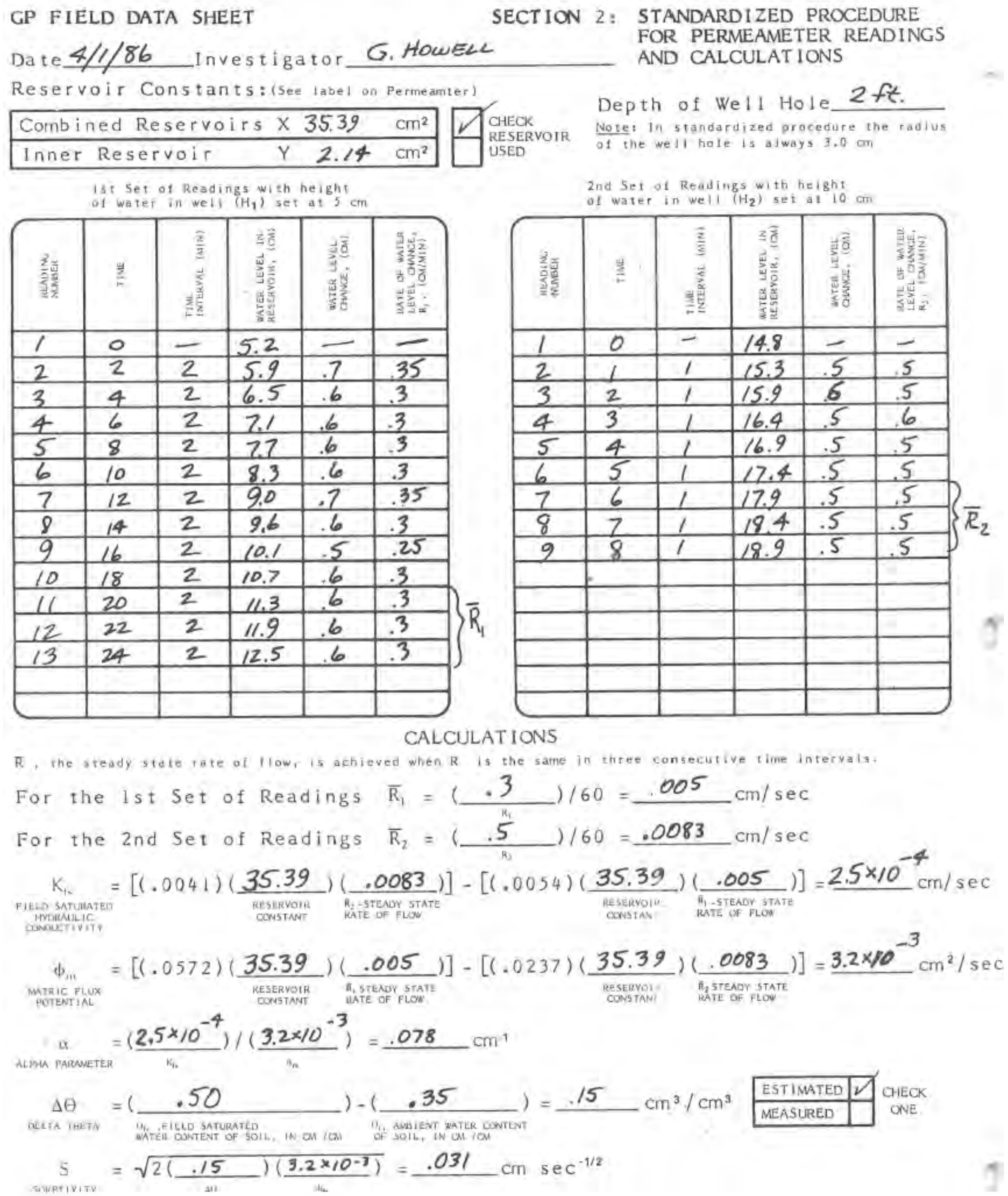
Comments and Notes (topography, slope, vegetation, etc.):

① WELL DEPTH = 2 ft.

② GENTLY ROLLING SLOPE (0-8%); NO VEGETATION (RECENT WILDFIRE)

③ NOTE PRESENCE OF CLAY PAN AT 3 FT.; EXISTS OVER ENTIRE PROPERTY

Table 1 (continued):



GP FIELD DATA SHEET

SECTION 2: STANDARDIZED PROCEDURE FOR PERMEAMETER READINGS AND CALCULATIONS

Date 4/1/86 Investigator G. HOWELL

Reservoir Constants: (See label on Permeamter)

Combined Reservoirs	X	35.39	cm²
Inner Reservoir	Y	2.14	cm²

☑ ☐ CHECK RESERVOIR USED

Depth of Well Hole 2 ft.

Note: In standardized procedure the radius of the well hole is always 3.0 cm

1st Set of Readings with height of water in well (H_1) set at 5 cm

READING NUMBER	TIME	TIME INTERVAL (MIN)	WATER LEVEL IN RESERVOIR, (CM)	WATER LEVEL CHANGE, (CM)	RATE OF WATER LEVEL CHANGE, R_1, (CM/MIN)	
1	0	—	5.2	—	—	
2	2	2	5.9	.7	.35	
3	4	2	6.5	.6	.3	
4	6	2	7.1	.6	.3	
5	8	2	7.7	.6	.3	
6	10	2	8.3	.6	.3	
7	12	2	9.0	.7	.35	
8	14	2	9.6	.6	.3	
9	16	2	10.1	.5	.25	
10	18	2	10.7	.6	.3	
11	20	2	11.3	.6	.3	}
12	22	2	11.9	.6	.3	} $\overline{R}_1$
13	24	2	12.5	.6	.3	}

2nd Set of Readings with height of water in well (H_2) set at 10 cm

READING NUMBER	TIME	TIME INTERVAL (MIN)	WATER LEVEL IN RESERVOIR, (CM)	WATER LEVEL CHANGE, (CM)	RATE OF WATER LEVEL CHANGE, R_2, (CM/MIN)	
1	0	—	14.8	—	—	
2	1	1	15.3	.5	.5	
3	2	1	15.9	.6	.5	
4	3	1	16.4	.5	.6	
5	4	1	16.9	.5	.5	
6	5	1	17.4	.5	.5	
7	6	1	17.9	.5	.5	}
8	7	1	18.4	.5	.5	} $\overline{R}_2$
9	8	1	18.9	.5	.5	}

CALCULATIONS

$\overline{R}$, the steady state rate of flow, is achieved when R is the same in three consecutive time intervals.

For the 1st Set of Readings $\overline{R}_1 = (\underset{R_1}{.3})/60 = .005$ cm/sec

For the 2nd Set of Readings $\overline{R}_2 = (\underset{R_2}{.5})/60 = .0083$ cm/sec

$$\underset{\text{FIELD SATURATED HYDRAULIC CONDUCTIVITY}}{K_{fs}} = [(.0041)(\underset{\text{RESERVOIR CONSTANT}}{35.39})(\underset{\overline{R}_2\text{ -STEADY STATE RATE OF FLOW}}{.0083})] - [(.0054)(\underset{\text{RESERVOIR CONSTANT}}{35.39})(\underset{\overline{R}_1\text{ -STEADY STATE RATE OF FLOW}}{.005})] = 2.5\times10^{-4}\text{ cm/sec}$$

$$\underset{\text{MATRIC FLUX POTENTIAL}}{\Phi_m} = [(.0572)(\underset{\text{RESERVOIR CONSTANT}}{35.39})(\underset{\overline{R}_1\text{ STEADY STATE RATE OF FLOW}}{.005})] - [(.0237)(\underset{\text{RESERVOIR CONSTANT}}{35.39})(\underset{\overline{R}_2\text{ STEADY STATE RATE OF FLOW}}{.0083})] = 3.2\times10^{-3}\text{ cm}^2/\text{sec}$$

$$\underset{\text{ALPHA PARAMETER}}{\alpha} = (\underset{K_{fs}}{2.5\times10^{-4}})/(\underset{\Phi_m}{3.2\times10^{-3}}) = .078\text{ cm}^{-1}$$

$$\underset{\text{DELTA THETA}}{\Delta\Theta} = (\underset{\Theta_{fs}\text{ ,FIELD SATURATED WATER CONTENT OF SOIL, IN CM/CM}}{.50}) - (\underset{\Theta_i\text{, AMBIENT WATER CONTENT OF SOIL, IN CM/CM}}{.35}) = .15\text{ cm}^3/\text{cm}^3$$

ESTIMATED ☑ MEASURED ☐ CHECK ONE

$$\underset{\text{SORPTIVITY}}{S} = \sqrt{2(\underset{\Delta\Theta}{.15})(\underset{\Phi_m}{3.2\times10^{-3}})} = .031\text{ cm sec}^{-1/2}$$

In most natural unsaturated soils we can assume that α is equal to α^*. Therefore if invalid (negative) values of α are obtained (either K_{fs} or Φ_m will also be negative in value) or when α values are obtained that lie outside the realistic range of $0.01 \leq \alpha \leq 0.5$ cm^{-1} , then the One-Head Analysis should be applied to each of the two heads and the resulting values for K_{fs} and Φ_m averaged.

Macroscopic capillary length parameter, α^* represents the ratio of gravity to capillary forces during infiltration or drainage. Large α^* values indicate dominance of gravity over capillarity, which occurs primarily in coarse textured and/or highly structured porous media. Small α^* on the other hand, indicate dominance of capillarity over gravity, which occurs primarily in fine textured and/or unstructured porous media. Although, K_{fs} and φ_m can individually range over many orders of magnitude in a porous medium, α^* generally varies from about 0.01 cm^{-1} to 0.5 cm^{-1}.

Making a Reading in Deep Wells

Extension tubes and couplings are available for the Support Tube, Air Tube, and Auger for use in making measurements at extended depths. The Guelph Permeameter can theoretically be used to considerable depths below the surface soil, to approximately 6 meters (20 ft.), when extension tubes are utilized. The procedure is essentially the same as that for use without extension tubes. Some notes are important regarding preparations for making a measurement in deep well holes.

For very deep well holes, it is preferable to place Extension Tubes and Air Tubes down the well hole before connecting them to the Reservoir assembly. To avoid loss of equipment in deep well holes, it may be desirable to use hose clamps on each end of the support tube coupling; the weight of the extended support tube column may separate the coupling from the support tube. It is advisable to use the Heavy-Duty Tripod to support the extended column.

In loose single grain textures, it may be extremely difficult to make measurements at extended depths due to the ease of dislodging soil material from the upper horizons and partially filling the well hole. In such cases, a 3-inch auger hole is prepared to a depth of 15 cm. A 3-inch PVC casing is inserted to the bottom of borehole, then the 2-inch Well Prep Auger may be used to prep a clean well hole without additional debris in the well. The remaining steps are the same. Please remember to prepare the well so that K_{fs} at 5 cm and 10 cm depths can be measured (H_1 and H_2).

The procedure for adding Air Tubes and Support Tube Extensions is illustrated in Fig. 35. Connect the first Air Tube Extension, using an Air Tube Coupling, to the Lower Air Tube. Slide the coupled Air Tube into the Support Tube and make sure the Air Inlet Tip is seated in the Air Tip Seat. Slide the Support Tube Extension with connected Support Tube Coupling over the Air Tube and couple the Support Tubes. Add additional tubing in the same fashion until sufficient for the desired depth, adding Air Tube Extensions first and then Support Tube Extensions.

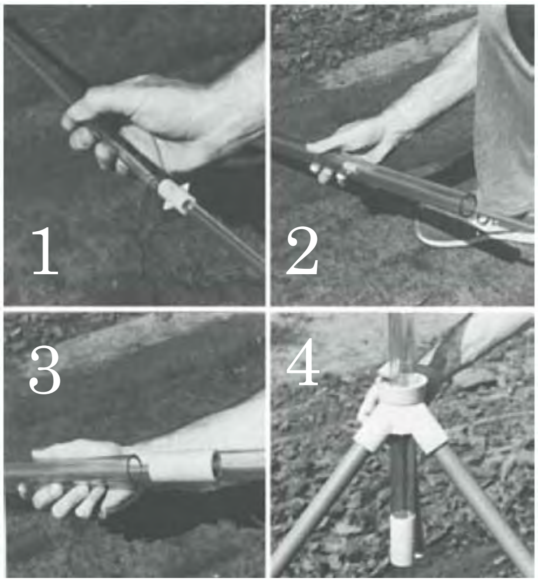


Fig. 35 - Adding Air Tubes and Support Tube Extensions.

Slide the Tripod, with Tripod Bushing in place, over the last Support Tube Extension that is added. If the Reservoir Base will be closer than 38 cm (15 inches) to the soil surface, omit the Tripod and use the Tripod Bushing alone to center and stabilize the Permeameter in the well hole. Use of the Tripod Bushing alone is described more completely under the "*Placement of Permeameter*" section.

Fill the reservoir as described under the "*Water Filling*" section. Make sure that the reservoir is filled close to the top with only a small air space remaining. On deep measurements, an initial vacuum should be created in the reservoir before setting the well height. See the "*Making a Reading with Limited Water Supplies*" section for details. After the Permeameter is placed in the well hole and the reservoir is filled, follow the procedure for "*Making a Reading*" section.

Making a Reading with Limited Water Supply

When sufficient water is not available to completely fill the Permeameter, readings can still be made, but there are additional procedures that must be followed in order to do so. To prevent overfilling of water into the well when establishing the well head and to insure proper operation, an initial vacuum may be created in the air space above the water in the reservoir.

After making sure that the Air Inlet Tip is fully seated, remove the Clamping Ring and attach the Vacuum Hand Pump to the Vacuum Tube located in the Reservoir Cap (Fig. 36, left). Pull a vacuum of 20 centibars, bend the Vacuum Tube over with the Hand Pump still attached, and close it off with the Clamping Ring (36, right). Disconnect the Vacuum Hand Pump and continue with the procedure as described in the "*Making a Reading*" section. Establish the first well height (H_1). When using the Permeameter in deep applications, an additional initial vacuum of about 10 centibars must be applied for each additional extension (80 cm long 2800K2 Extension Kit) that is used.

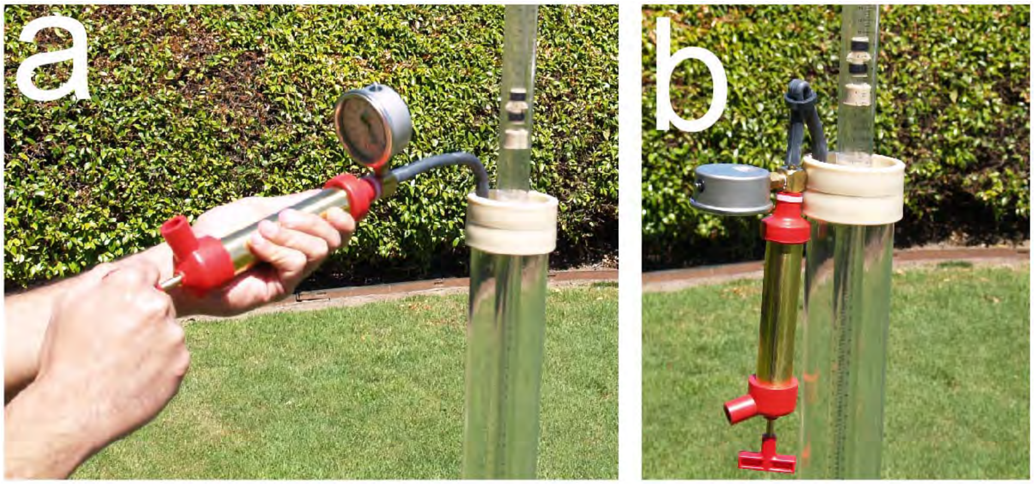


Fig. 36. Applying vacuum to Reservoir.

HELPFUL HINTS DURING NORMAL USE

It is helpful to make readings of R (the rate of fall of water in the reservoir) at specific intervals, as described in the standardized procedure. By using a specified time interval, it is very easy to determine when R (the steady-state rate of fall of water in the reservoir) is obtained.

For shallow use (wells less than 30 inches deep), it is recommended that the reservoir be filled before the Permeameter is placed in the well hole. This enables the operator to verify proper functioning of Permeameter fittings and insure that the Air Inlet Tip is fully seated in the Air Tip Seat. The possibility of an unexpected water spill into the hole is also reduced when the reservoir is filled away from the hole.

When an operator is making measurements in deep wells, it may be necessary to fill the reservoirs after the Permeameter has been placed in the well hole. Care should be taken to ensure that all Air Tube and Support Tube Couplings are tightly fitted to their respective extensions and that the Air Inlet Tip is fully seated in the Air Tip Seat. (See "*Making a Reading in Deep Wells*" section).

Familiarize yourself with the setup, operation, procedure theory, and calculations before going to the field with the Guelph Permeameter. Doing so will facilitate accurate measurements and interpretation of results.

The moveable, molded plastic parts of the Permeameter may exhibit a slight seizing or sticking effect. It is this characteristic of the plastics that assists in obtaining the airtight/watertight seals needed on the Guelph Permeameter. Fittings, such as the Reservoir Valve, may stick a very little bit when first moved. However, they will then move freely.

The Soil Auger included with the Guelph Permeameter is designed for general use. Accessory auger bits are available for use in specialized situations. The Soil Auger is an Edelman auger to increase the ease of operation in sticky, wet soils. It is useful in wet silts and heavy clay soils. The Coarse Sand Auger bits have been specifically shaped for cutting into dry, sandy soils without allowing the contents to escape and refill the augered hole. Ordering information is located in the back of these instructions, under "Accessory Items".

If the Permeameter is taken apart, be sure the tubes are pushed all the way to the bottom of the end caps when reassembled. The Air Tube Coupling has an inner pair of ridges that must seat in the routed tip of the polycarbonate Air Tube. Both Air Tubes on either side of the coupling must seat similarly. The Air Tip and the Water Outlet Tip have a square shouldered seat where the Air Take Coupling must seat.

TROUBLESHOOTING

Problem	Potential Reason
Well Borehole overfills upon initial filling	• Too much air above the water in the reservoirs at beginning of measurement • Fill Plug is not fully seated • Vacuum Line is not shutting off with Clamping Ring
Water leaks at Water Outlet Tip when Permeameter is off.	• Air Inlet Tip is not properly seated against the Air Tip Seat
Well head level falls below that set by Well Head Indicator.	• Air Tube clogged; inspect the Air Restriction Washer
Well Head level rises above that set by Well Head Indicator.	• Too much air above the water in the reservoirs at beginning of measurement • Fill Plug not fully seated • Vacuum Line is not fully shut off with the Clamping Ring
Stable well head level does not correspond with that set by Well Head Indicator.	• Water Outlet Tip is not seated on the Bottom of the well hole • Well Height Indicator was not fully seated Against the Reservoir Cap before raising the Air Inlet Tip • Well Head Scale was not zero height set at reference to the level of the Reservoir Cap Central "Boss" • Well Height Indicator was not fully seated against the top of the Reservoir Cap Central "Boss" when marking .0 cm. Reference with Air Inlet Tip fully seated against the Air Tip Seating Washer.
The calculated K_{fs} value is negative	• Readings in highly heterogeneous soils can lead to negative values. Negative results may be obtained under these circumstances because the GP theory assumes that the soil properties surrounding the base of the permeameter (the measurement zone) are homogeneous. Use of the One-Height Procedure can then be used to obtain valid data.

GENERAL CARE AND MAINTENANCE

A general cleanup is recommended, as soon as practical, after each field use to maintain the transparency of plastic tubes and to prevent clogging, scratching and fouling of the Permeameter fittings by soil or grit. Wipe the Permeameter with a cloth or rinse with clean water to remove soil and grit. Make sure to pay particular attention to small openings where grit can accumulate or soil can cake and dry, such as in the Water Outlet Tip, Air Inlet Tip, Tripod Bushing, and behind the Reservoir Valve. Use a clean, soft cloth to wipe down and dry off the outer surfaces of the Permeameter. Disassemble the Permeameter for a thorough cleaning when necessary using soap and water. **NEVER USE SOLVENTS**!

After cleaning with soap, rinse thoroughly with clean water and dry with a clean cloth. The various flexible plastic fittings used in the Permeameter are all friction fits to various tubes. No cement or other sealant is used. The fittings can be disconnected by carefully “working” them off with your hands. As the Permeameter ages, however, the reservoir end caps may start to leak. This can usually be fixed by tightening with a gear/hose clamp and/or by placing silicone sealant on the seam.

The Reservoir Valve fits into the Reservoir Base by means of a ridge-and-groove friction fitting. To remove for cleaning, place your fingers behind the valve, brace against the Reservoir Base, and pull straight out sharply as shown in Fig. 37. The Reservoir Valve can be lubricated with vacuum grease or Vaseline if it is sticking or seizing excessively.

Fig. 37. Removing Reservoir Valve.

After cleaning the Middle Air Tube, use a toothpick or small wooden implement to remove the O-Ring Seal from the Reservoir Cap for cleaning and to reapply vacuum grease for an airtight seal. Inspect the O-Ring and replace as necessary. The Middle Air Tube should slide easily through the Reservoir Cap and Reservoir Base.

At the positions where vacuum grease or Vaseline has been used, it is particularly important to clean these areas thoroughly with soap and water. Dirt or grit will accumulate at these points and must be removed and re-greased prior to re-assembly.

Clean the carrying case lining regularly to prevent accumulation of soil and grit that can cause scratching of the transparent plastic tubes.

Procedure for Determining Cell Constants (X and Y Values) for the Guelph Permeameter

Combined Reservoir Cell Constant (X-value):
The X-value is, in fact, the cross-sectional area of the Combined Reservoir in cm^2. The exact number of X-value differs slightly (less than 1%) among different GP units. This is because of small variations of the inside and outside diameters of pipe used for making the GP. The average value of Y is 35.22 cm^2 with a standard deviation of 0.18 cm^2. This average can be used for all applications within the GP official application range. However one can measure one's own GP X-value using the following steps.

Set up the GP according to Fig. 38. You will need a digital scale (0.1 g resolution) and a T-handle clamp or a similar clamping tool. Place a Beaker on the Scale on the lab floor and set up the GP tripod over the beaker and scale. Assemble the GP and set it in the Tripod. Secure the GP to the Tripod using a T-handle Clamp to provide enough space for both the Beaker and Scale. Note that the GP assembly should not be in contact with (touching) the Beaker.

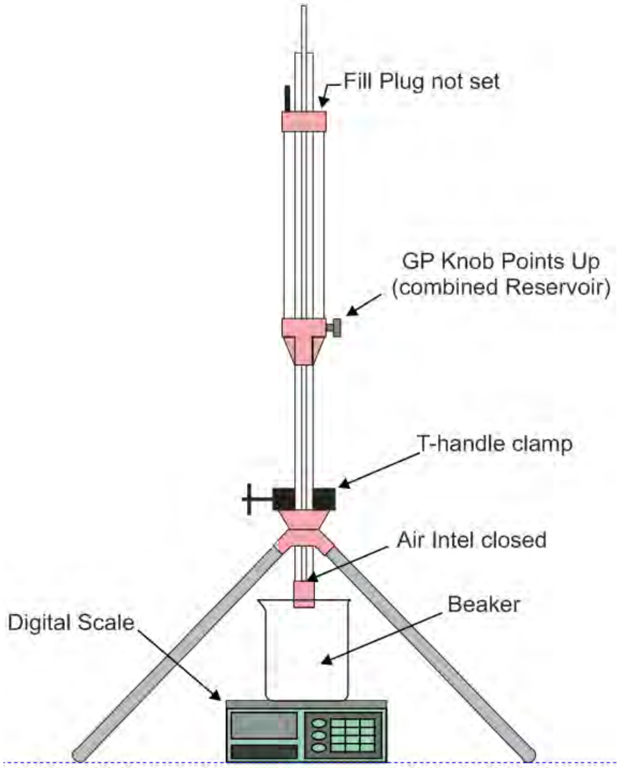


Fig. 38

- **Set the Combined Reservoir Valve to the UP position.**
- **Seal Air Inlet Tip (push the Air Tube all the way down).**
- **Fill Reservoir with water.**
- **Record Water Level (*S* in cm).**
- **Tare (zero) the Digital Scale (Fig. 39).**

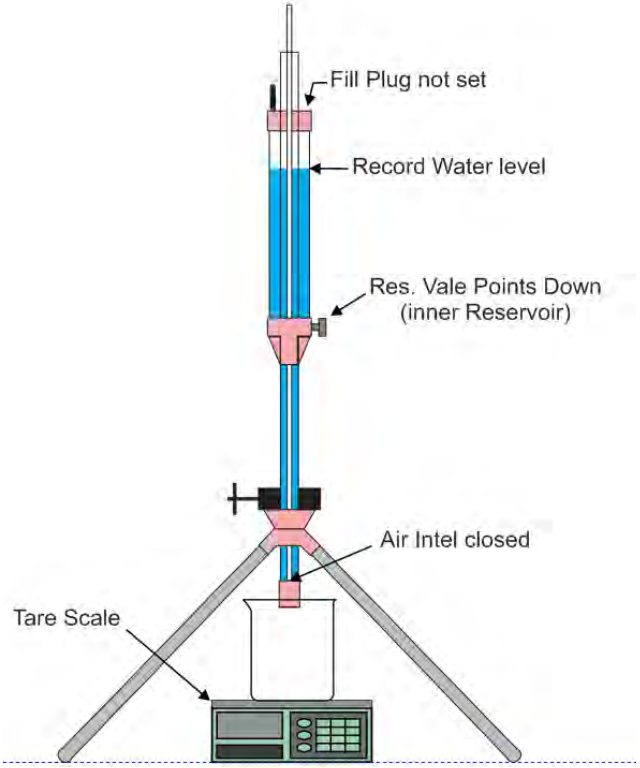


Fig. 39

Pull up the Air Tube very slowly (Fig. 40) to create a slow water flow out of the Water Outlet Tip and into the Beaker. If the water in the Reservoir falls too quickly, push down the Air Tube to decrease the rate of water fall in the Reservoir.

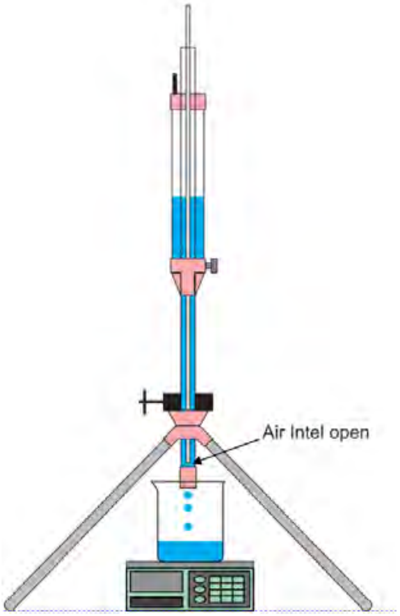


Fig. 40

Push down the Air Tube to seal the Water Outlet Tip when the water level in the Reservoir is close to the bottom (water level about 70 cm). This should stop water flow out of the Water Outlet Tip and also the falling water level in the Reservoir.

Record the water level in the Reservoir (*E* in cm).

Record the water weight (Fig. 41) in the Beaker (*V* in cm^3). Please note that the assumption here is that each gram of water has one cubic centimeter of volume. The volume of water changes slightly due to ambient (room) temperature. Therefore V can be corrected for temperature using the Water Density Table.

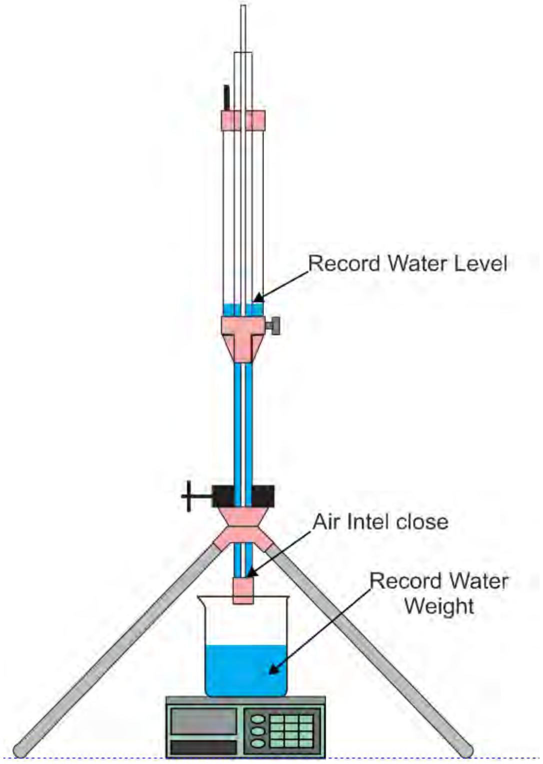


Fig. 41

Calculate the X-value using the following formula:

$$X = \frac{V}{E - S}$$

Where, X is the Combined Cell Constant or Combined Reservoir cross-sectional area in cm^2.

Inner Reservoir Cell Constant (Y-value):
The Y-value is, in fact, the cross-sectional area of the Inner Reservoir in cm^2. The exact number of the Y-value differs slightly (less than 2%) among different GP units. This is because of a small variation of inside and outside diameters of pipe used for making the GP. The average value of Y is 2.16 cm^2 with a standard deviation of 0.04 cm^2. This number can be used for all applications within the GP official application range. However one can measure one's own GP Y-value using the following steps.

Set up the GP according to Fig. 42. You will need a digital scale (0.1 g resolution) and a T-handle clamp or a similar clamping tool. Place the Beaker on the Scale on the lab floor and set the GP tripod over the beaker and scale. Assemble the GP and place it in the Tripod. Secure the GP to the Tripod using a T-handle Clamp to provide enough space for both the Beaker and Scale. Note that the GP assembly should not be in contact with (touching) the Beaker.

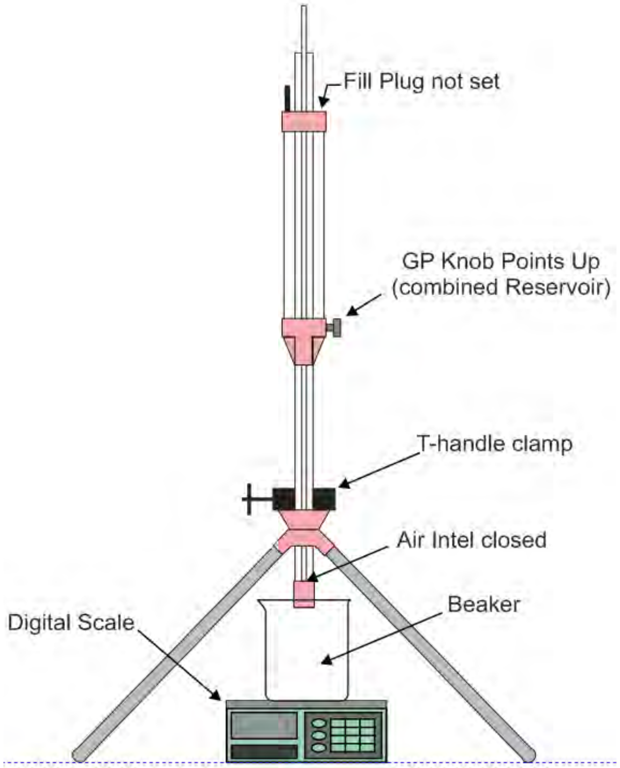
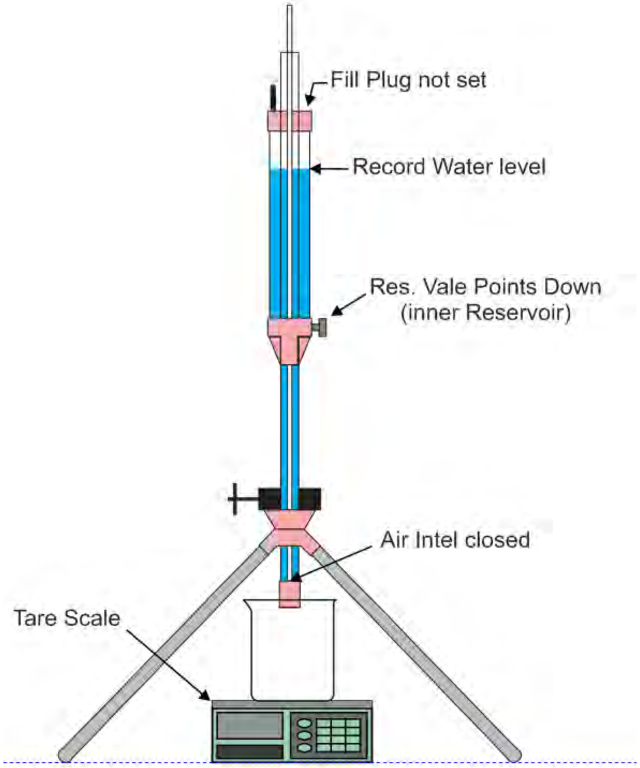


Fig. 42

- **Set the Combined Reservoir Valve to the UP position.**
- **Seal the Air Inlet Tip (push the Air Tube all the way down).**
- **Fill the Reservoir with water.**
- **Set the Inner Reservoir Valve to the DOWN position.**
- **Record the Water Level in the Inner Reservoir (*S* in cm).**
- **Tare (zero) the Digital Scale (Fig. 43).**



(Fig. 43)

Pull up the Air Tube very slowly (Fig. 44) to create a slow water flow out of the Water Outlet Tip and into the Beaker. If water in the Inner Reservoir falls too quickly, push the Air Tube down to decrease the rate of water fall in the Inner Reservoir.

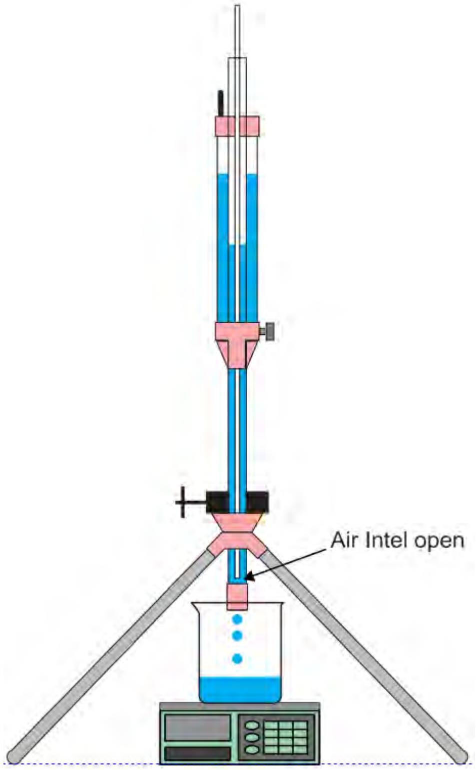


Fig. 44

Push the Air Tube down to seal the Water Outlet Tip when the water level in the Inner Reservoir is close to the bottom (water level about 70 cm). This should stop water flow out of the Water Outlet Tip and also the falling water level in the Inner Reservoir.

Record the water level in the Inner Reservoir (*E* in cm).

Record the water weight (Fig. 45) in the Beaker (*V* in cm^3). Please note that the assumption here is that each gram of water has one cubic centimeter volume. Volume of water changes slightly due to ambient (room) temperature. Therefore *V* can be corrected for temperature using the Water Density Table.

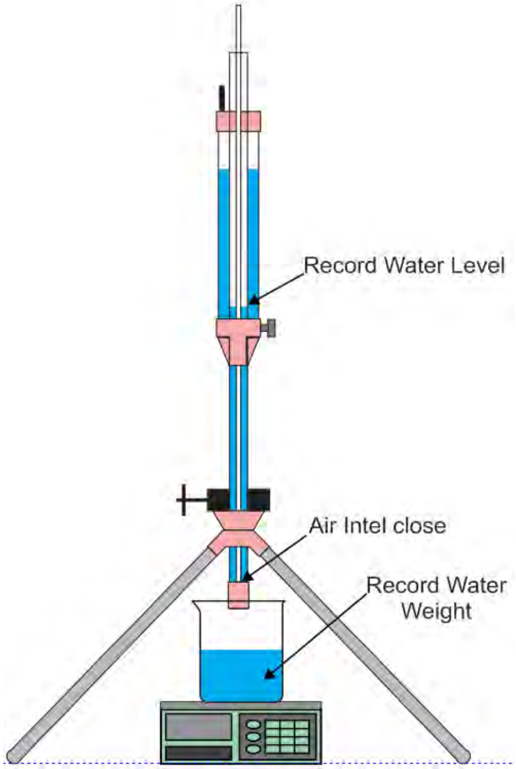


Fig. 45

Calculate the Y-value using the following formula:

$$Y = \frac{V}{E - S}$$

Where, Y is the Inner Cell Constant or Inner Reservoir cross-sectional area in cm^2.

Procedure for Detecting Leakage in the GP

Set up the GP according to Fig. 46. You will need a plastic beaker and a T-handle clamp or a similar clamping tool. Place the Beaker on the lab floor and set the Tripod over it. Assemble the GP and set it in the Tripod. Place the GP Water Outlet Tip on the bottom of Beaker. The Beaker acts like a borehole in soil with zero permeability.

Set the Combined Reservoir Valve to the UP position.

Seal the Air Inlet Tip (push the Air Tube all the way down).

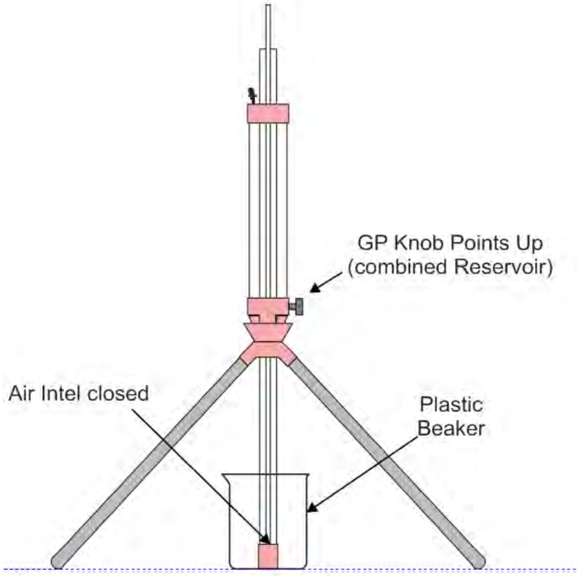


Fig. 46

Fill the Reservoir with water.
Insert the Fill Plug (Fig. 47).

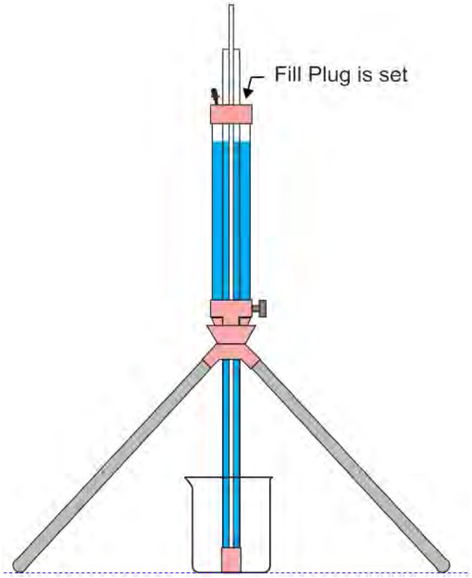


Fig. 47

Pull up the Air Tube very slowly to the 3 cm mark (Fig. 48). This should create bubbles in the Reservoir and establish a 3 cm water head in the Beaker.

Set the Inner Reservoir Valve to the DOWN position for better precision.

Record the water level in the Inner Reservoir.

Mark the water level in the Beaker. It should be 3 cm high.

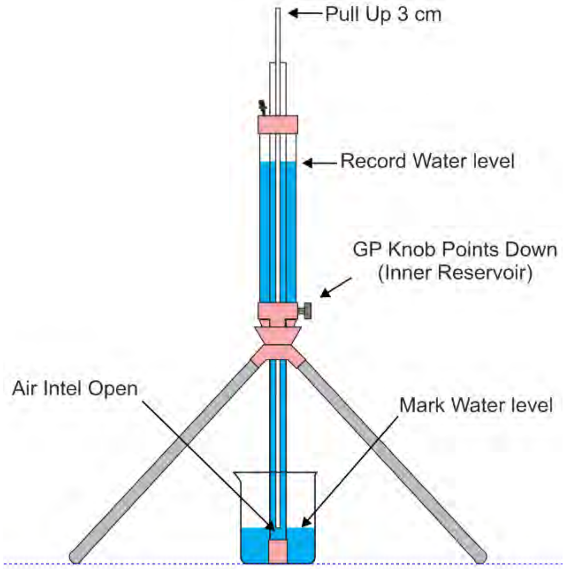


Fig. 48

Check the water level in the Inner Reservoir after approximately one hour. If the system is not leaking, the water level in the inner Reservoir should be the same as recorded previously. Also the water level in the Beaker should not rise.

USE AND APPLICATION OF PRODUCT OPTIONS

The Guelph Permeameter can be used anywhere a hole can be augered in soil. These instructions present a generalized method for determining field-saturated hydraulic conductivity, matric flux potential, and α* parameter.

Because of the practical improvements incorporated in the operation of the Guelph Permeameter and the advanced analysis the theory provides, it is ideally suited for applications involving the design and monitoring of:

- Irrigation Systems
- Drainage Systems
- Canals
- Reservoirs
- Sanitary Landfills
- Land Treatment Facilities
- Tailings Areas
- Hazardous Waste Storage Sites
- Septic Tank systems
- Soil and Hydrologic Studies and Surveys

The Percolation Test

The Percolation Test is commonly used to determine both site suitability and filter field design for on-site wastewater treatment facilities such as septic tank systems. Unfortunately, the "Perc" Test uses a falling head procedure, is empirical in nature and not standardized in many jurisdictions. The GP uses the more accurate constant-head technique to determine K_{fs}. An approximate relationship between the GP steady-state rate of fall R (cm/min) and the "Perc" Test T (min/cm) is available and can be obtained from Soilmoisture Equipment Corporation. An approximate relationship between K_{fs} and T is also available. These relationships are approximate because in many jurisdictions the "Perc" Test in not standardized.

Depth profiling

It is almost always the case that the water transmission properties of soil vary with depth. The Guelph Permeameter can be used to investigate changes in the hydraulic properties of soils with depth. When using the Permeameter for this purpose, it is recommended that the investigator auger a hole at shallow depth first. After making a measurement at the shallow depth, the well hole can be extended by further augering to successive depths and making the respective measurements (Fig. 49).

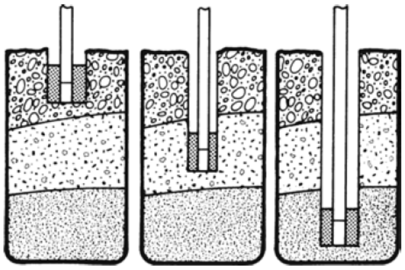


Fig. 49. Investigating changes in the hydraulic properties of soils with depth using the Guelph Permeameter.

Heterogeneous soils

Soils typically have three-dimensional heterogeneity. The Guelph Permeameter method yields essentially a "point" measurement. The size of land under investigation, degree of soil heterogeneity, soil type, and kind of application will dictate the number of measurements needed to adequately characterize a given area and depth of soil.

A soil profile description and soil survey report will greatly enhance the value and understanding of data obtained with the Guelph Permeameter.

Because of the ease and simplicity of the Guelph Permeameter and its depth profiling capability, it is a very useful method for understanding the three-dimensional distributions of the water transmission properties of soils.

CALCULATIONS AND APPLICATIONS

Calculations Using the Guelph Permeameter Excel Spreadsheet

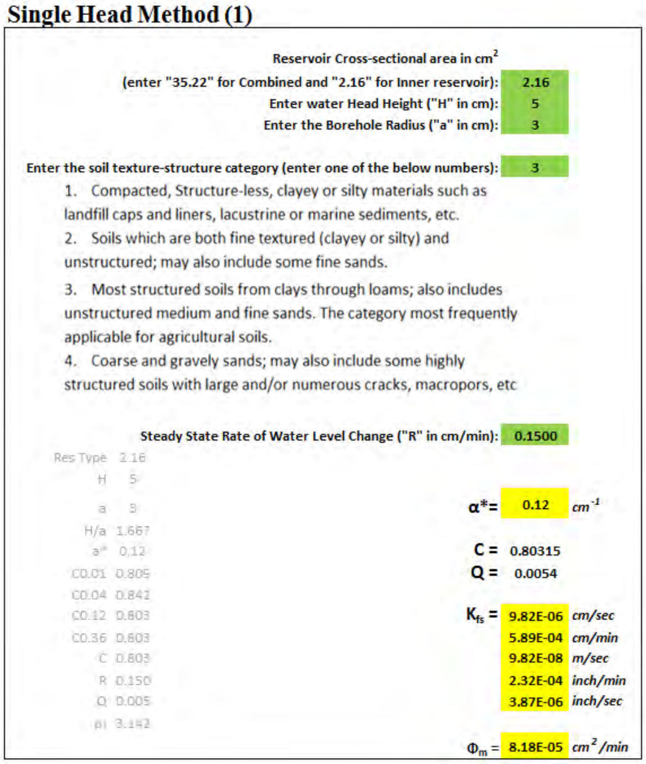
Guelph Permeameter calculations can be easily performed using the “*Guelph Permeameter Calculator*” spreadsheet. The file can be downloaded from Soilmoisture’s website.

Please note that all green cells are for input values and results are shown in yellow calls. Also all tabs are “protected”. Therefore it is not possible to change the contents of cells, only the green cells can be changed. In the case that you need to modify a tab, “unprotect” the sheet first (not recommended).

Please also note that the error handling in this spreadsheet is not comprehensive and it is your responsibility to take special care to enter all the required information correctly. Otherwise you may get incorrect results with no warning.

The file consists of two tabs. The First tab is named “Notes” which consists of general instructions and notes. Please read this tab first.

The next tab is “GP Quick Calculations”. This data sheet provides a quick and convenient way for calculating K value and Matric Flux Potential. The datasheet is divided into four separate areas. The first area is named “Single Head (1)”. It performs the calculations using the “One-Head Method”. Fill the green cells with appropriate numbers and the results will appear in the yellow cells at the lower part of the area:



Single Head Method (1)

Reservoir Cross-sectional area in cm^2
(enter "35.22" for Combined and "2.16" for Inner reservoir): 2.16
Enter water Head Height ("H" in cm): 5
Enter the Borehole Radius ("a" in cm): 3

Enter the soil texture-structure category (enter one of the below numbers): 3

1. Compacted, Structure-less, clayey or silty materials such as landfill caps and liners, lacustrine or marine sediments, etc.
2. Soils which are both fine textured (clayey or silty) and unstructured; may also include some fine sands.
3. Most structured soils from clays through loams; also includes unstructured medium and fine sands. The category most frequently applicable for agricultural soils.
4. Coarse and gravely sands; may also include some highly structured soils with large and/or numerous cracks, macropors, etc

Steady State Rate of Water Level Change ("R" in cm/min): 0.1500

Res Type 2.16
H 5
a 3
H/a 1.667
a* 0.12
C0.01 0.809
C0.04 0.842
C0.12 0.803
C0.36 0.803
C 0.803
R 0.150
Q 0.005
pi 3.142

α^*= 0.12 cm^{-1}

C = 0.80315
Q = 0.0054

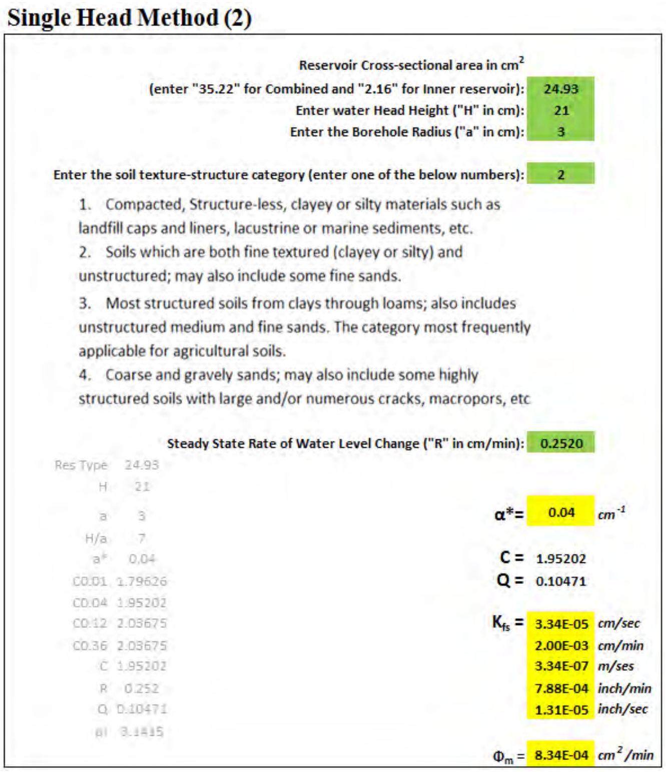
K_{fs} = 9.82E-06 *cm/sec*
5.89E-04 *cm/min*
9.82E-08 *m/sec*
2.32E-04 *inch/min*
3.87E-06 *inch/sec*

Φ_m = 8.18E-05 cm^2/min

The first input cell (green cell) determines Reservoir Cross-sectional Area. Enter “35.22” if you have used Combined Reservoir. If you have used the Inner Reservoir, enter “2.16”.
Please note that the numbers are average and the actual cross-sectional area of each Guelph Permeameter may be slightly different. In almost all applications these average numbers suffice. It is also possible to determine Reservoir cross-sectional area for each individual Guelph Permeameter. For more information please see “Procedure for Determining Cell Constants …” section.

The second input cell is the constant water head height at the bottom of borehole in cm. The third input cell is the radius (not diameter) of the Borehole in cm. Enter the proper soil category in the next input cell. You need to enter an integer number from “1” to “4”. Please note that most agricultural soils fall into the third category. If you are not sure about the soil category, enter “3”. The last input cell is the Steady State Water Level Change. This parameter has to be measured using the Guelph Permeameter (see section “*Making a Reading*”).

After entering all the required fields, Soil Hydraulic Conductivity and Water Flux Potential will be reported in the corresponding yellow cells. For the sake of convenience, the K value is presented in several units. Note that the resulting numbers are always in scientific format. The second area of the “GP Quick Calculations” tab is called “Single Head (2)”. In the case that you are using the “Two Head” measurement method, you are able to do the calculations related to the second head in this area. This area is completely identical to the “Single Head (1)”, except that you need to enter the information related to the second head here. The only fields that are different from Single Head (1) are the Head Height and Steady State Flow Rate.



Single Head Method (2)

Reservoir Cross-sectional area in cm^2
(enter "35.22" for Combined and "2.16" for Inner reservoir): 24.93
Enter water Head Height ("H" in cm): 21
Enter the Borehole Radius ("a" in cm): 3

Enter the soil texture-structure category (enter one of the below numbers): 2

1. Compacted, Structure-less, clayey or silty materials such as landfill caps and liners, lacustrine or marine sediments, etc.
2. Soils which are both fine textured (clayey or silty) and unstructured; may also include some fine sands.
3. Most structured soils from clays through loams; also includes unstructured medium and fine sands. The category most frequently applicable for agricultural soils.
4. Coarse and gravely sands; may also include some highly structured soils with large and/or numerous cracks, macropors, etc

Steady State Rate of Water Level Change ("R" in cm/min): 0.2520

Res Type 24.93
H 21
a 3
H/a 7
a* 0.04
C0.01 1.79626
C0.04 1.95202
C0.12 2.03675
C0.36 2.03675
C 1.95202
R 0.252
Q 0.10471
pi 3.1415

α^*= 0.04 cm^{-1}

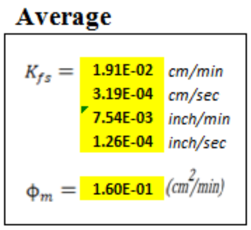
C = 1.95202
Q = 0.10471

K_{fs} = 3.34E-05 cm/sec
2.00E-03 cm/min
3.34E-07 m/ses
7.88E-04 inch/min
1.31E-05 inch/sec

Φ_m = 8.34E-04 cm^2/min

The average of results from Single Head (1) and Single head (2) are presented in "Average" Area. These results are especially useful when the K value from the "Two Head Method" is negative.

When you use "Average" area, please keep in mind that Head Height and Steady State Flow Rate of "Single Head (2)" have to be always greater than Head Height and Steady State Flow Rate in "Single Head (1)" area. Otherwise the results are not valid.



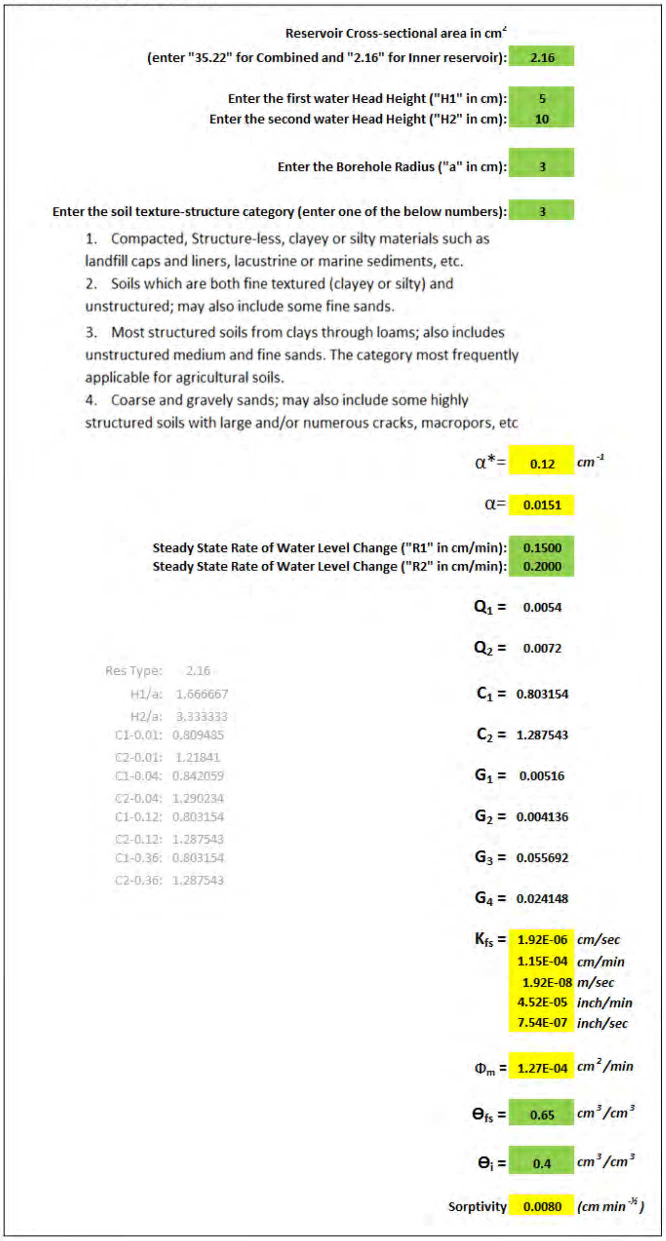
Average

$K_{fs} =$	1.91E-02	cm/min
	3.19E-04	cm/sec
	7.54E-03	inch/min
	1.26E-04	inch/sec
$\Phi_m =$	1.60E-01	(cm^2/min)

The last area is the “Two-Head Method”. All the input fields are similar to the previous fields except that here there are two head heights and two Steady State Rates (one for the first water head and one for the second water head).

If invalid (negative) values of α are obtained (either K_{fs} or Φ_m will also be negative in value) or when α values are obtained that lie outside the realistic range of $0.01 \le \alpha \le 0.5$ cm^{-1}, then the Single-Head Analysis should be applied to each of the two heads and the resulting values for K_{fs} and Φ_m averaged (use K value in "Average" area).

Double Head Method



Reservoir Cross-sectional area in cm^2
(enter "35.22" for Combined and "2.16" for Inner reservoir): 2.16

Enter the first water Head Height ("H1" in cm): 5
Enter the second water Head Height ("H2" in cm): 10

Enter the Borehole Radius ("a" in cm): 3

Enter the soil texture-structure category (enter one of the below numbers): 3

1. Compacted, Structure-less, clayey or silty materials such as landfill caps and liners, lacustrine or marine sediments, etc.
2. Soils which are both fine textured (clayey or silty) and unstructured; may also include some fine sands.
3. Most structured soils from clays through loams; also includes unstructured medium and fine sands. The category most frequently applicable for agricultural soils.
4. Coarse and gravely sands; may also include some highly structured soils with large and/or numerous cracks, macropors, etc

$\alpha^*=$ 0.12 cm^{-1}

$\alpha=$ 0.0151

Steady State Rate of Water Level Change ("R1" in cm/min): 0.1500
Steady State Rate of Water Level Change ("R2" in cm/min): 0.2000

$Q_1 =$ 0.0054

$Q_2 =$ 0.0072

Res Type: 2.16
H1/a: 1.666667
H2/a: 3.333333
C1-0.01: 0.809485
C2-0.01: 1.21841
C1-0.04: 0.842059
C2-0.04: 1.290234
C1-0.12: 0.803154
C2-0.12: 1.287543
C1-0.36: 0.803154
C2-0.36: 1.287543

$C_1 =$ 0.803154

$C_2 =$ 1.287543

$G_1 =$ 0.00516

$G_2 =$ 0.004136

$G_3 =$ 0.055692

$G_4 =$ 0.024148

$K_{fs} =$ 1.92E-06 cm/sec
1.15E-04 cm/min
1.92E-08 m/sec
4.52E-05 inch/min
7.54E-07 inch/sec

$\Phi_m =$ 1.27E-04 cm^2/min

$\Theta_{fs} =$ 0.65 cm^3/cm^3

$\Theta_i =$ 0.4 cm^3/cm^3

Sorptivity 0.0080 (cm min$^{-½}$)

Manual Calculations

Determine α* and Calculate the shape factor (C) for each water head using Table 2. Shape factor is a function of soil type, water height in borehole (H) and borehole radius (a). In the case that you are using two-head method, you need to calculate one C factor for each head height. Note that you may need to use α* in the future steps of calculation. You can always determine α* using Table 2 and based on the soil category.

Table 2. Calculation formulas related to shape factor (*C*). Where H_1 is the first water head height (cm), H_2 is the second water head height (cm), a is borehole radius (cm) and α* is microscopic capillary length factor which is decided according to the soil texture-structure category. For one-head method, only C_1 needs to be calculated while for two-head method, C_1 and C_2 are calculated (Zang et al., 1998).

Soil Texture-Structure Category	**α*(cm^{-1})**	**Shape Factor**
Compacted, Structure-less, clayey or silty materials such as landfill caps and liners, lacustrine or marine sediments, etc.	0.01	$C_1 = \left(\frac{H_2/a}{2.081 + 0.121\left(H_2/a\right)}\right)^{0.672}$
Soils which are both fine textured (clayey or silty) and unstructured; may also include some fine sands.	0.04	$C_1 = \left(\frac{H_1/a}{1.992 + 0.091\left(H_1/a\right)}\right)^{0.683}$ $C_2 = \left(\frac{H_2/a}{1.992 + 0.091\left(H_2/a\right)}\right)^{0.683}$
Most structured soils from clays through loams; also includes unstructured medium and fine sands. The category most frequently applicable for agricultural soils.	0.12	$C_1 = \left(\frac{H_1/a}{2.074 + 0.093\left(H_1/a\right)}\right)^{0.754}$ $C_2 = \left(\frac{H_2/a}{2.074 + 0.093\left(H_2/a\right)}\right)^{0.754}$
Coarse and gravely sands; may also include some highly structured soils with large and/or numerous cracks, macro pores, etc.	0.36	$C_1 = \left(\frac{H_1/a}{2.074 + 0.093\left(H_1/a\right)}\right)^{0.754}$ $C_2 = \left(\frac{H_2/a}{2.074 + 0.093\left(H_2/a\right)}\right)^{0.754}$

Calculate the factor Q for each water head using the steady rate of fall of water ($\bar{R}$) related to each water head (see section "*Making a Reading*"). The formula of Q varies depending on method of measurement (one-head or two-head) and the type of reservoir used in measurement (Inner or Combined). Table 3 contains the Q formulas for all possible combinations of Method and Reservoir type.

Calculate saturated hydraulic conductivity using the formulas in Table 3. Again, the formula changes depending on method used (one-head or two-head) and the type of reservoir used in measurement (Inner or Combined).

Table 3. Calculation formulas related to one-head and two-head methods. Where $\bar{R}$ is steady-state rate of fall of water in reservoir (cm/s), K_{fs} is Soil saturated hydraulic conductivity (cm/s), ϕ_m is Soil matric flux potential (cm^2/s), α^* is Macroscopic capillary length parameter (from Table 2), a is Borehole radius (cm), H_1 is the first head of water established in borehole (cm) , H_2 is the second head of water established in borehole (cm) and C is Shape factor (from Table 2).

One Head, Combined Reservoir	$Q_1 = \bar{R}_1 \times 35.22$	$K_{fs} = \dfrac{C_1 \times Q_1}{2\pi H_1^2 + \pi a^2 C_1 + 2\pi \left(\dfrac{H_1}{\alpha^*}\right)}$ $\phi_m = \dfrac{C_1 \times Q_1}{(2\pi H_1^2 + \pi a^2 C_1)\alpha^* + 2\pi H_1}$
One Head, Inner Reservoir	$Q_1 = \bar{R}_1 \times 2.16$	
Two Head, Combined Reservoir	$Q_1 = \bar{R}_1 \times 35.22$ $Q_2 = \bar{R}_2 \times 35.22$	$G_1 = \dfrac{H_2 C_1}{\pi\left(2H_1H_2(H_2 - H_1) + a^2(H_1C_2 - H_2C_1)\right)}$ $G_2 = \dfrac{H_1 C_2}{\pi\left(2H_1H_2(H_2 - H_1) + a^2(H_1C_2 - H_2C_1)\right)}$ $K_{fs} = G_2Q_2 - G_1Q_1$ $G_3 = \dfrac{(2H_2^2 + a^2C_2)C_1}{2\pi\left(2H_1H_2(H_2 - H_1) + a^2(H_1C_2 - H_2C_1)\right)}$ $G_4 = \dfrac{(2H_1^2 + a^2C_1)C_2}{2\pi\left(2H_1H_2(H_2 - H_1) + a^2(H_1C_2 - H_2C_1)\right)}$ $\phi_m = G_3Q_1 - G_4Q_2$
Two Head, Inner Reservoir	$Q_1 = \bar{R}_1 \times 2.16$ $Q_2 = \bar{R}_2 \times 2.16$	

Calculate α Parameter:

Where α is the slope of the line relating the natural log of K_{fs} (hydraulic conductivity) to Q, the soil water pressure head (cm^{-1}).

$$\alpha = K_{fs}/\phi_m$$

In most natural unsaturated soils we can assume that α is equal to α*. Therefore if invalid (negative) values of α are obtained (either K_{fs} or Φ_m will also be negative in value) or when α values are obtained that lie outside the realistic range of $0.01 \leq \alpha \leq 0.5$ cm^{-1} , then the One-Head Analysis should be applied to each of the two heads and the resulting values for K_{fs} and Φ_m averaged.

Calculate other related parameters:

$$\Delta\theta = \theta_{fs} - \theta_i$$

$$S = \sqrt{2(\Delta\theta \times \phi_m)}$$

Where θ_{fs} is field saturated water content of soil (cm^3 cm^{-3}), θ_i is ambient water content of soil (cm^3 cm^{-3}) and S is soil sorptivity (cm min$^{-½}$).

Bibliography

For further theoretical discussion regarding the use and applicability of the Guelph Permeameter, it is recommended that the user consult the following scientific papers:

W.D. Reynolds and D.E. Elrick. 1986. *A method for simultaneous in-situ measurement in the vadose zone of field-saturated hydraulic conductivity, sorptivity and the conductivity-pressure head relation*ship.

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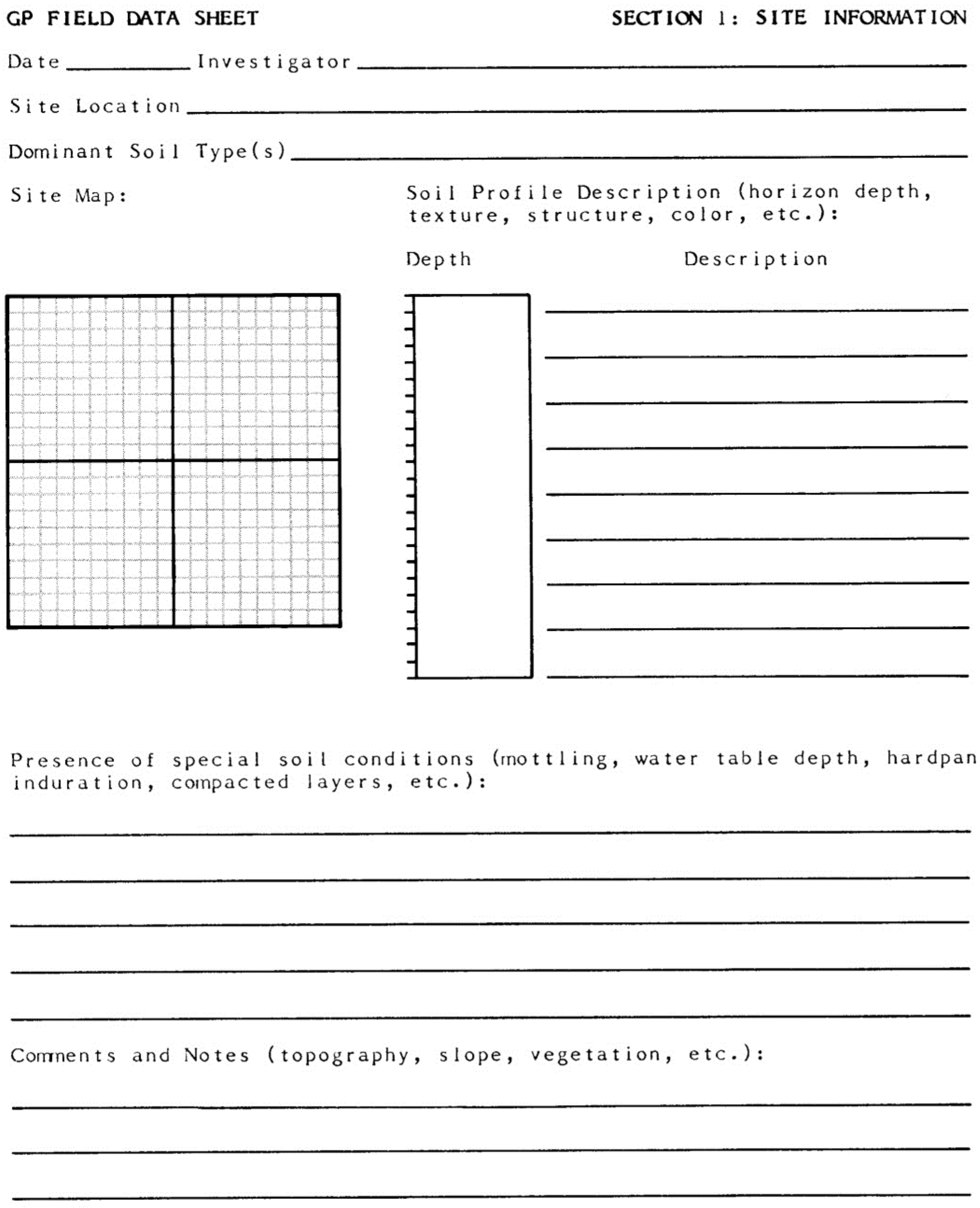
Reynolds,W.D., D.E. Elrick, E.G. Youngs, A. Amoozegar, H.W.G. Booltink,and J. Bouma. 2002. Ch. 3.4, *Saturated and field-saturated water flow parameters*, in Methods of Soil Analysis, Part 4. Physical Methods, J. Dane and C. Topp, ed., p. 797 - 878. SSSA, Madison, WI.

Table 4. Guelph Permeameter sample data sheet.



GP FIELD DATA SHEET **SECTION 1: SITE INFORMATION**

Date ____________ Investigator ______________________________

Site Location ______________________________

Dominant Soil Type(s) ______________________________

Site Map:

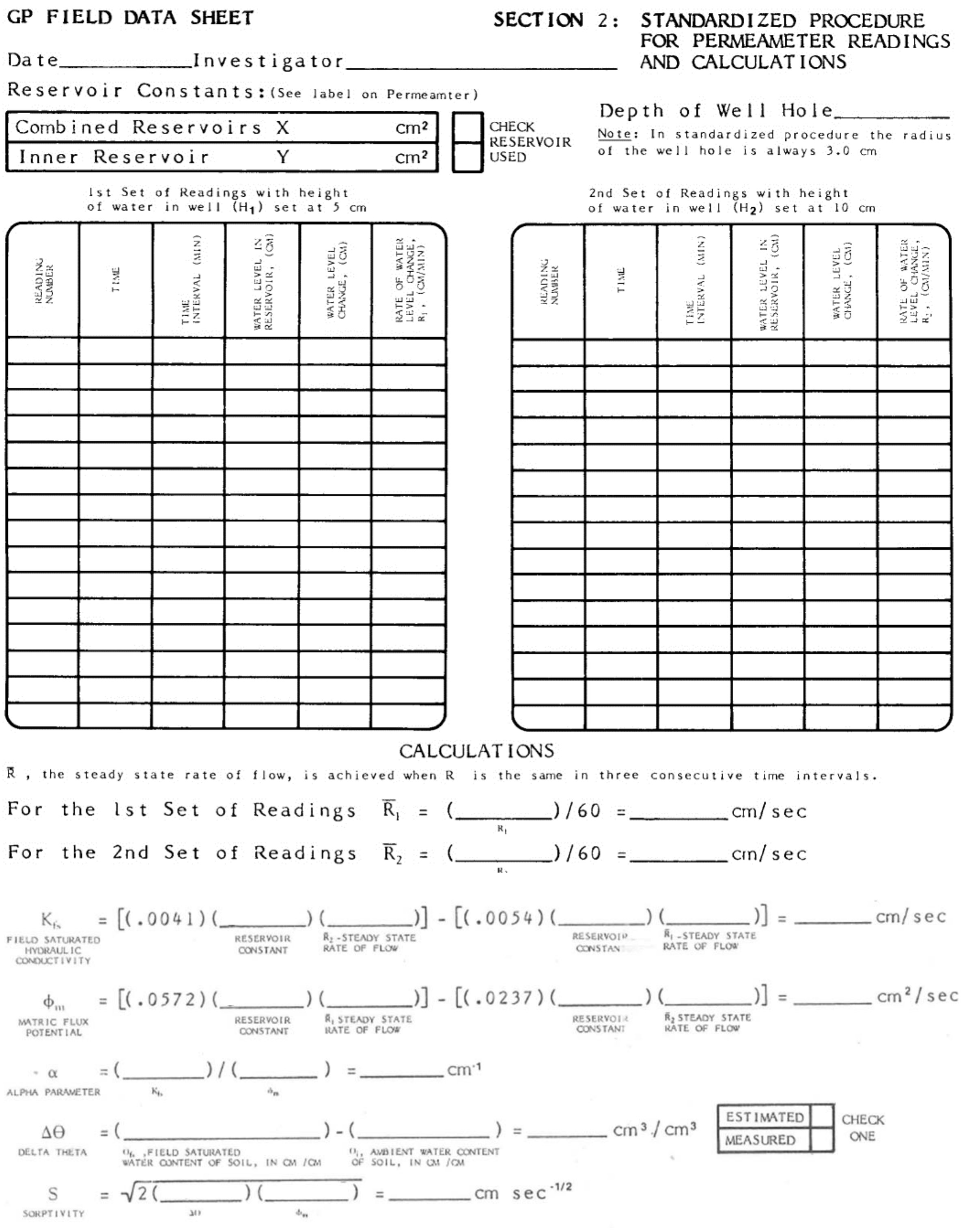
Soil Profile Description (horizon depth, texture, structure, color, etc.):

Depth Description

Presence of special soil conditions (mottling, water table depth, hardpan induration, compacted layers, etc.):

Comments and Notes (topography, slope, vegetation, etc.):

Table 4 (continued):



GP FIELD DATA SHEET

SECTION 2: STANDARDIZED PROCEDURE FOR PERMEAMETER READINGS AND CALCULATIONS

Date____________Investigator________________________

Reservoir Constants: (See label on Permeamter)

Combined Reservoirs X	cm²	☐
Inner Reservoir Y	cm²	☐

CHECK RESERVOIR USED

Depth of Well Hole__________

Note: In standardized procedure the radius of the well hole is always 3.0 cm

1st Set of Readings with height of water in well (H_1) set at 5 cm

READING NUMBER	TIME	TIME INTERVAL (MIN)	WATER LEVEL IN RESERVOIR, (CM)	WATER LEVEL CHANGE, (CM)	RATE OF WATER LEVEL CHANGE, R_1, (CM/MIN)

2nd Set of Readings with height of water in well (H_2) set at 10 cm

READING NUMBER	TIME	TIME INTERVAL (MIN)	WATER LEVEL IN RESERVOIR, (CM)	WATER LEVEL CHANGE, (CM)	RATE OF WATER LEVEL CHANGE, R_2, (CM/MIN)

CALCULATIONS

$\bar{R}$, the steady state rate of flow, is achieved when R is the same in three consecutive time intervals.

For the 1st Set of Readings $\bar{R}_1$ = (________ R_1)/60 = ________ cm/sec

For the 2nd Set of Readings $\bar{R}_2$ = (________ R_2)/60 = ________ cm/sec

K_{fs} FIELD SATURATED HYDRAULIC CONDUCTIVITY = [(.0041)(________ RESERVOIR CONSTANT)(________ $\bar{R}_2$-STEADY STATE RATE OF FLOW)] - [(.0054)(________ RESERVOIR CONSTANT)(________ $\bar{R}_1$-STEADY STATE RATE OF FLOW)] = ________ cm/sec

ϕ_m MATRIC FLUX POTENTIAL = [(.0572)(________ RESERVOIR CONSTANT)(________ $\bar{R}_1$ STEADY STATE RATE OF FLOW)] - [(.0237)(________ RESERVOIR CONSTANT)(________ $\bar{R}_2$ STEADY STATE RATE OF FLOW)] = ________ cm^2/sec

α ALPHA PARAMETER = (________ K_{fs})/(________ ϕ_m) = ________ cm^{-1}

$\Delta\Theta$ DELTA THETA = (________ Θ_{fs}, FIELD SATURATED WATER CONTENT OF SOIL, IN CM /CM) - (________ Θ_i, AMBIENT WATER CONTENT OF SOIL, IN CM /CM) = ________ cm^3/cm^3

ESTIMATED	☐
MEASURED	☐

CHECK ONE

S SORPTIVITY = $\sqrt{2(\_\_\_\_\_\_\_\_ \Delta\theta)(\_\_\_\_\_\_\_\_ \phi_m)}$ = ________ cm $sec^{-1/2}$

REPLACEMENT PARTS LIST

PARTS

0234SHDLB, Handle
2005G2, Vacuum Hand Pump
2031G2, Clamping Rings, 1 dozen
2031G2-001, Clamping Ring, each
2038V3, Water Container (2.5 gal)
2038V3-001, Water Container Tube
2800-014, Knob Label with X and Y value
2804-002, Well Prep Brush
2804-003, Sizing Auger, 6 cm, Bayonet connection
2804-006, Guelph Combination Auger (6 cm diam.)
M802X012PKG05, (O-Ring for Z2800-011)
MFJ012PK, Grease Pack (1/4 oz.)
MRL005, Leg Tip
MSL087, 9/16-inch Spring Hose
MSL087, Spring Clip (for Z2800-002 and Z2800-006)
MSL088, Slip Pliers
MSL099, Water Cap to Hose Spring Clip
Z1900-200-01, Access Tube and Vacuum Tube
Z2080X1, Fill Plug
Z2800-001CR, Water Outlet Tip (includes 2800-001 and Z2800-200)
Z2800-002CR, Air Inlet Tip (includes 2800-002, Z2800-003 and MSL087)
Z2800-003, Air Restriction Washer
Z2800-004, Support Tube
Z2800-005L12, Upper Air Tube
Z2800-005L21, Lower Air Tube
Z2800-005L45, Middle Air Tube
Z2800-006, Air Tube coupling (each includes two MSL087)
Z2800-007, Reservoir Base
Z2800-008, Reservoir Valve
Z2800-009, Outer Reservoir Tube
Z2800-010, Inner Reservoir Tube
Z2800-011CR, Reservoir Cap
Z2800-012, Well Head Scale
Z2800-013, Extension Coupling
Z2800-016, Well Height Indicator
Z2800-100CR, Reservoir Assembly
Z2800-200, Air Tip Seating Washer
Z2800-300, Tube Assembly
Z2801-002, Tripod Leg (Telescoping)
Z2801-004, Tripod Bushing
Z2801-005, Tripod Support Chain (old style)
Z2801-006, Tripod Support Sleeve (old style)
Z2801-007, New Model Tripod Base
Z2803, Carrying Case

ACCESSORIES

2800K2, Extension Kit, 80 cm long
  Consists of:
    Z2800-004, Support Tube
    Z2800-005L31, Air Tube Extension
    Z2800-006, Air Tube Coupling
    Z2800-013, Support Tube Coupling

0234RVD06, Riverside Auger diam. 6 cm

0243SHDLBXL100, Extension, 1 meter (includes coupling)

0234SLB, Coupling Sleeve

2806F1, Heavy Duty Guelph Stand, Improved

2800K4, Guelph Permeameter only (No case)

2800K5, 2800K2 + 0234SHDLBXL100

ATTACHMENTS

2805D10, Pressure Infiltrometer Adapter Kit (require 2800K1 for operation)

2805D20, Pressure Infiltrometer Adapter Kit (require 2800K1 for operation)

2825, Pressure/Tension Infiltrometer Adapter (requires 2800K1 for operation)

2805D10K1, Pressure Infiltrometer Complete Adapter Kit (does not replace 2800K1)

2805D20K1, Pressure Infiltrometer Complete Adapter Kit (does not replace 2800K1)

2825K1, Pressure/Tension Infiltrometer Complete Kit (does not replace 2800K1)

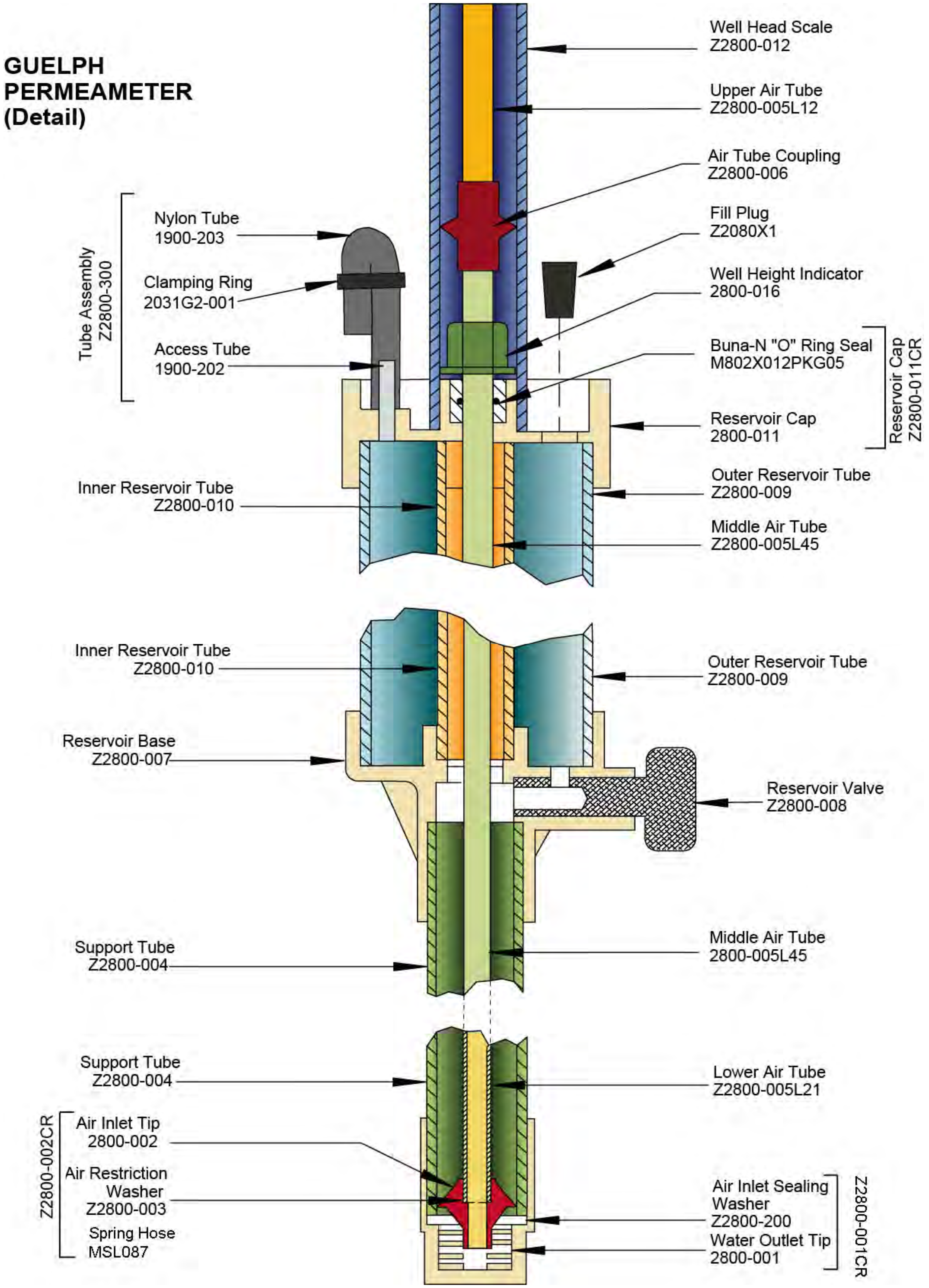


Fig. 50- Guelph Components.

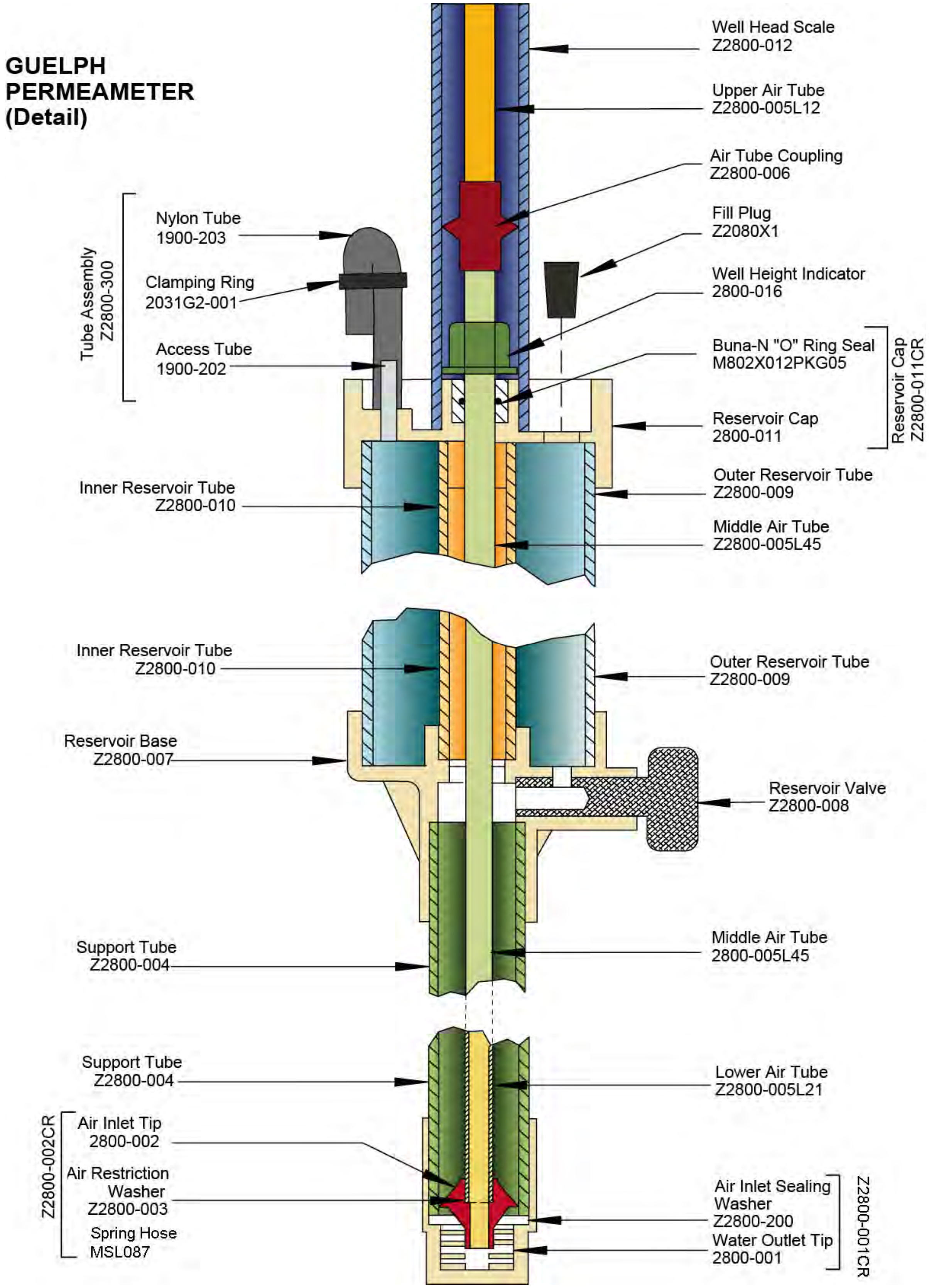


Fig. 50 - Guelph Components (detailed).

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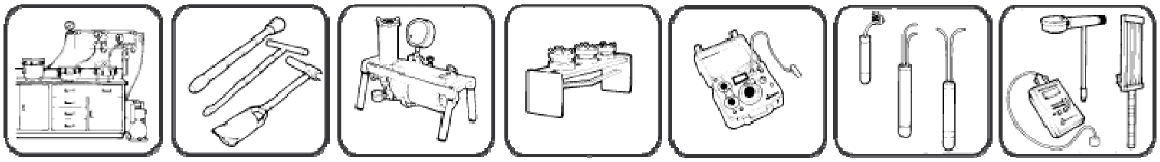

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