WATER & SOIL MISCELLANEOUS PUBLICATION NUMBER 99

A Guide to Groundwater Sampling Techniques

National Water and Soil Conservation Authority

Water & soil miscellaneous publication no. 99 (1986)

ISSN 0110-4705

WATER & SOIL MISCELLANEOUS PUBLICATION No. 99

A GUIDE TO GROUNDWATER SAMPLING TECHNIQUES

L. W. SINTON

Hydrology Centre
Ministry of Works and Development
CHRISTCHURCH

WELLINGTON 1986

A Guide to Groundwater Sampling Techniques

L. W. Sinton, Hydrology Centre, MWD, Christchurch

Water & Soil Miscellaneous Publication No. 99, 1986, 24p, ISSN 0110-4705

This publication deals with techniques and equipment for groundwater sampling, principally the sampling of springs, point sampling of shallow groundwater, and sampling of pumped and unpumped wells. The handling of groundwater samples is briefly discussed and some additional sources of information are suggested.

National Library of New Zealand
Cataloguing-in-Publication data

SINTON, L. W. (Lester W.), 1949-
A guide to groundwater sampling techniques / L.W. Sinton. - Wellington, N.Z. : Published for the National Water and Soil Conservation Authority by the Water and Soil Directorate, Ministry of Works and Development, 1986. - 1 v. - (Water & soil miscellaneous publication, 0110-4705 ; no. 99)
628.1140287
1. Water, Underground--Sampling. I. New Zealand. Water and Soil Directorate. II. National Water and Soil Conservation Authority (N.Z.). III. Title. IV. Series: Water & soil miscellaneous publication ; no. 99.

COVER: A simple suction lift sampling system, using a hand-operated car tyre pump (modified for suction).
L. W. Sinton, photo.

Published for the National Water and Soil Conservation Authority
by the Water and Soil Directorate, Ministry of Works and Development,
P.O. Box 12-041, Wellington North, New Zealand.

Contents

1. Introduction

Although groundwater is part of the hydrologic cycle, compared to surface water it is relatively remote and inaccessible. Thus, there are costs, constraints and uncertainties involved in groundwater sampling that are not encountered with surface waters. There are also important differences in the behaviour of contaminants in surface and groundwater systems which affect the selection of water quality determinands and the strategies and equipment employed in sample collection.

The most fundamental constraint in the collection of groundwater samples is usually the availability of sampling sites. In extensive groundwater quality surveys, most samples are collected from existing pumped wells, the density of which will range from > 500 per km^2 in communities without a reticulated water supply to < 1 per km^2 in open farmland. Where available, springs may also be used for groundwater collection. The cost of specially installed groundwater monitoring wells is usually only justified in intensive groundwater pollution investigations or to facilitate long term monitoring of an otherwise inaccessible aquifer.

Although different techniques are required in sampling ground- and surface-waters, the objectives are the same: to obtain a sample that is representative of the water body from which it is extracted, and to ensure that it arrives on the laboratory bench correctly identified and without having being contaminated or altered in any way. Many of the strategies and precautions necessary to achieve these objectives are essentially the same for ground and surface waters and are covered in other manuals (e.g., Kingsford *et al.* 1977). This publication deals only with techniques and equipment that relate specifically to groundwater sampling, principally the sampling of springs, point sampling of shallow groundwater, and sampling of pumped and unpumped wells. The handling of groundwater samples is briefly discussed and some additional sources of information are suggested.

2. Sampling Springs

Natural springs (fissure springs and seeps) may provide suitable groundwater sampling sites. They have the advantage of being a flowing groundwater source, but the type or depth of strata from which the water originates is usually unknown.

Both surface and well water sampling techniques may be required for sampling springs. With all types of spring, it is important to avoid collecting water that has been altered by contact with surface waters, sediments, soils or biota.

2.1 Fissure springs

For groundwater sampling, the ideal fissure spring flows directly from bedrock and has little vegetation growing near the orifice. The possibility of sample contamination may be reduced by the insertion of a sampling tube into the spring fissure.

2.2 Seeps

A seep is more difficult to sample than a fissure spring and there is a greater possibility that it may yield a sample that is unrepresentative of the groundwater from which it originates. Seeps have slower discharge rates and therefore tend to represent a smaller part of the source groundwater system and to be more affected by evaporation. Also they tend to flow through soil zones prior to discharge and the seepage area is frequently densely vegetated. They are therefore likely to be affected by plant transpiration, root respiration and chemical or microbiological processes in the soil (Claasen, 1982). Slow passage of water through the seep may allow reaeration of deoxygenated water. Precipitation of iron and manganese hydroxides in the seep zone is usually indicative of this process.

Seeps may be developed (i.e., their flow increased or channelled) to eliminate or lessen some of the above effects. This may be accomplished by removal of the soil zone in the seep area, but a simpler method involves driving a sampling tube into the subsoil (USEPA, 1974). Pumping of the sampling tube may be necessary in a vertical seep.

3. Point Sampling of Shallow Groundwater

In areas where shallow groundwater is found in fine-grained strata, it may be possible to obtain samples for water quality analysis using portable, small diameter point samplers. Typically, these are made up of a series of stainless steel tubes (Figure 1) with outside and inside diameters of about 16 and 10 mm, respectively. The tubes are approximately 750 mm long and are joined by internal threads to reduce friction during penetration. A weighted driver is used to force the point through the soil.

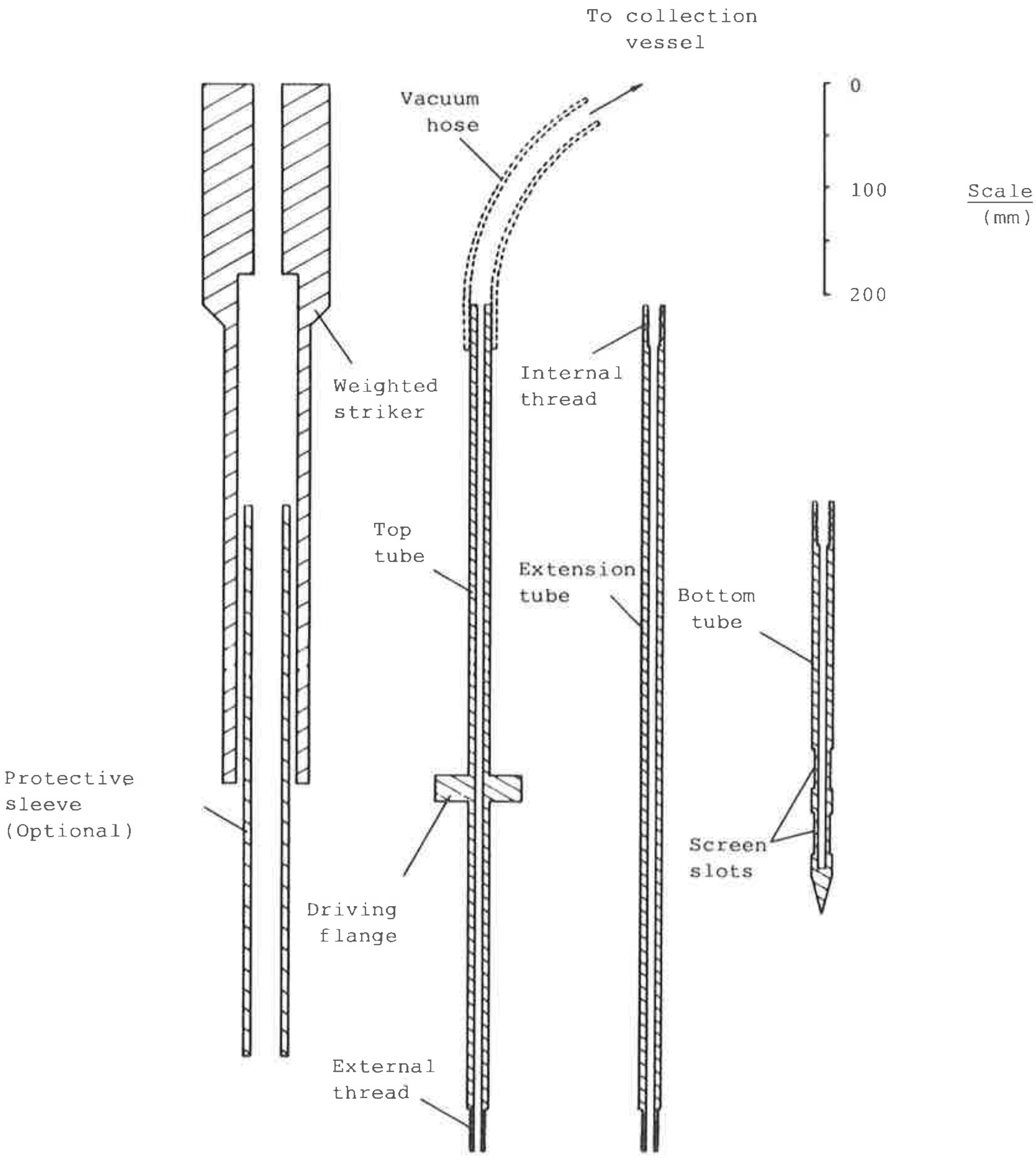

Figure 1: A small diameter, hand-driven point sampler (based on the design by Kerfoot, 1984).

Inset 1

The screen design on the bottom tube will depend on the nature of the groundwater-bearing material. Narrow (< 1 mm) vertical slots are suitable for sands and fine gravels. However, for clays and silts, Kerfoot (1984) recommends a special pointed shield which exposes a porous screen upon withdrawal of the shaft. Replacement tips or alternative screens can easily be fitted to point samplers.

Water samples may be withdrawn from the screen area through narrow plastic hoses. Alternatively, provided the joints are airtight and the screen is totally immersed in groundwater, the sampler itself can act as the delivery tube, with a hose fitted over the top of the shaft (Figure 1) leading to a vacuum flask/hand pump system.

The weight of the striker is approximately 8kg. Its force is applied to the flange on the top tube via an optional protective sleeve. As each tube is driven into the ground, an extension tube is inserted between it and the flanged top tube. An aperture through the centre of the striker enables it to be used for striking the bottom of the flange when removing the sampler from tight material.

Small-diameter point samplers are a particularly cost-effective method of tracking the movement of septic tank leachate plumes from shallow soakage tiles. When disassembled, the entire sampler can be autoclaved. However, some contamination from surface material may occur as the point is driven downwards. For repetitive use in the field, Kerfoot (1984) recommends rinsing the sampler in distilled water between each insertion, or, if organics analysis is important, in a 10% solution of methanol. Additional precautions, such as washing in 70% ethanol, may be advisable for microbiological investigations. Narrow Teflon tubing inserted down the sampler to the screen area is recommended for the extraction of samples for organics analysis.

The depth to which a point sampler may be driven will depend on soil/subsoil type, but the maximum depth is likely to be around 4 m. The sampler may be driven through clays, silts, sands and fine gravels, but not through coarse gravels or rocky subsoil material.

4. Sampling Pumped Wells

Pumped wells are likely to be the most common sampling sites in groundwater quality surveys. They include wells used for domestic supply, stock watering, irrigation and industry. Legal access to pumped wells may need to be obtained. Where possible, screen details and well logs should be obtained from the owner, well driller or regional water board to assist with the interpretation of water quality data.

Sampling from existing pumped wells limits the precautions an investigator can take to obtain a non-contaminated sample, and sampling techniques may sometimes need to be compromised in order to minimise inconvenience to the owner. The age and condition of the well casings, pumps and plumbing systems are likely to vary markedly and, even with a properly maintained system, there is a risk of collecting an unrepresentative sample, i.e., plumbing water instead of groundwater. A typical domestic well consists of a pump connected to a header tank or a pressure tank. The pump is usually either a reciprocating type with an electric motor at the well head or a submersible type. Retention times in these systems vary markedly from less than a minute for a small pressure tank to several days for a large header tank.

When sampling pumped wells, the investigator should:

(1) Avoid disused systems, or those in a poor state of repair. Where their use is essential, additional care should be taken to ensure the collection a representative, uncontaminated sample.

(2) Collect samples as close as possible to the pump. A sample collected after passing through a large header tank will probably not adequately represent groundwater quality. Even in small pressure tanks, accretions and sediment may alter the quality of water in transit. Therefore, wherever possible, samples

should be collected between the pump and the header or pressure tank. If frequent use of the well for groundwater sampling is envisaged, it may be possible, with the owner's consent, to install a sampling tap between the pump and the tank.

(3) Avoid collecting samples from taps that leak around the spindle. If collection from these taps is unavoidable, an "S-bend" hose (Figure 2) can prevent the water flowing down the outside of the tap from entering the collection bottle. The hose should be cleaned and sterilised according to the procedures outlined in APHA (1985) and the water run to waste for 15—20 seconds after hose insertion to remove any deposits dislodged from the interior of the tap nozzle. Except where it is important to maintain the original dissolved oxygen level, the hose should not be inserted inside the sample bottle. Each hose should be used only once before re-cleaning and sterilising.

Some authorities (e.g, Ministry of Housing and Local Government, 1969) recommend sterilizing the the mouth of a sampling tap by flaming before collecting samples for microbiological analysis. However, this is frequently impracticable, particularly if the tap is inside a private dwelling. In these situations, use of a sterile S-bend hose (see Figure 2) should also be considered.

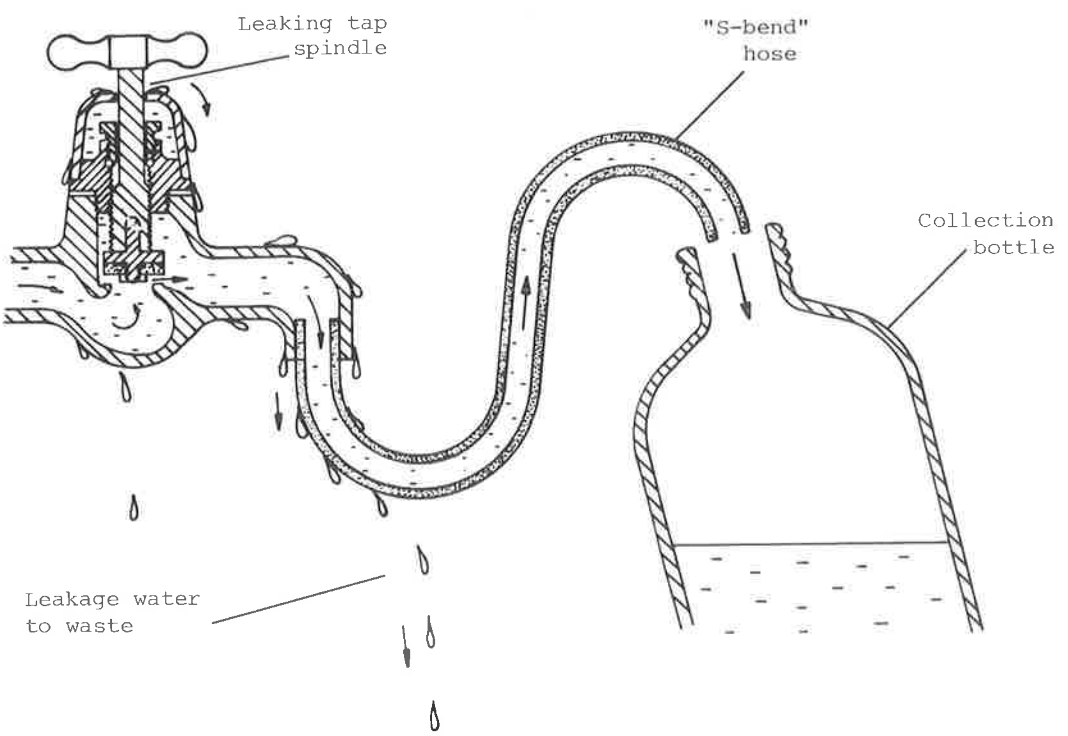

Figure 2: Collection of uncontaminated samples from taps leaking from around the spindle.

(4) Run the water to waste until a constant (groundwater) temperature is reached. Where the pump has not been operated for some time, it is advisable to also monitor pH. When both determinand values stabilise, it is probable that little or no water from casing, tank or plumbing water storage is being pumped (Gibb *et al.*, 1984). Significant quantities of waste water may be produced during sampling, particularly in systems with long retention times. If the sampling point is an outside tap, a length of hose should be carried in order to discharge this water into the nearest gully trap or drain.

Inset 1*

If the above precautions are taken, pumped wells are usually suitable for sampling groundwater for the measurement of most common chemical and microbial water quality determinands. However, they may not be suitable for sample collection for determining dissolved oxygen levels and/or redox potential, or for the analysis of low levels of some organics and metals. Where measurement of these determinands is essential, it may be possible to bypass a suspect pumping system and/or lower special sampling equipment down the well. If not, installation of special monitoring wells may be necessary.

5. Sampling Unpumped Wells

5.1 General considerations

Unpumped wells are normally installed specifically to investigate groundwater quality or hydrology. Bores installed for geologic exploration may also be suitable for groundwater sampling provided they are screened over the required depths. Disused wells, from which the pumping mechanism has been removed, are probably best avoided. If sampling them is essential, the condition of the casing and screen should if possible be checked and the reason for abandonment ascertained.

Because monitoring wells are used less frequently than pumped water supply wells and draw-off is much lower, sampling artifacts associated with stagnant well water are more significant. The most common problems are associated with anoxic groundwaters, which may occur in confined aquifers and near waste disposal sites and can contain high concentrations of dissolved iron. When standing well water is exposed to air, reoxygenation occurs and the dissolved iron (mainly as the ferrous ion) will be oxidised to insoluble ferric hydroxide, which will precipitate in the well. Ferric hydroxide is an efficient scavenger for a wide variety of chemicals and can reduce concentrations in the well relative to those in the surrounding groundwater. Because this process may be exacerbated if the well casing is of iron, plastic (PVC) is generally considered superior for monitoring well construction. However, trace organics can sometimes leach from PVC wells, either directly from the pipe or from jointing solvents and glues.

To eliminate or reduce the effect of artifacts associated with standing water, it is necessary to establish the length of time (i.e., how many well-volumes) for which the monitoring well needs to be pumped before a representative sample is collected. Continuous monitoring (until stable) of temperature and pH will usually indicate when groundwater rather than well water is being pumped. Up to 10 well-volumes may be required, depending on aquifer transmissivity and casing dimensions, (Scalf *et al.*, 1981). The procedure may be unnecessary in wells installed in permeable gravel aquifers where there is a high flow through the well.

Changes in water composition may also occur as a result of contamination by the sampling device, contact with sampler materials, and the sampling procedure. The sampler may be contaminated before it enters the well water, either during handling at the well head or through contact with the well casing. Contamination may also occur within the well water, from either extraneous debris floating on the surface or polluted layers higher in the water column.

To minimise sampler contamination, the same procedures that are used for cleaning sample bottles should be used for the sampler. Thus, sampler materials should resist dilute acid washing (for inorganic chemical analyses) and/or autoclaving (for microbial analyses). Samplers should be transported from the laboratory to the well head in suitable containers, which have also been chemically cleaned and/or sterilised. Samplers should be lifted directly from the container into the well head aperture without touching the ground or well head structures. Avoid touching the sampler with bare hands (use pre-cleaned and/or sterilised gloves). Contamination from contact with the well casing and from other depths in the water column can be minimised if the sampler is designed to open and/or close at, or pump water from, a specific depth in the well.

The materials from which the sampling device is constructed should not alter the collected sample in any way. Particular care should be taken to avoid contamination by pump components or lubricants. Where trace organics are under investigation, only glass or Teflon components should be used in sampler construction (Dunlap *et al.*, 1977; Tomson *et al.*, 1980; Pettyjohn *et al.*, 1981).

The mode of operation of some sampling devices (see Section 5.2) can alter the composition of the water. For example, air lift systems tend to aerate the water sample and may precipitate ferric hydroxide. Gas lift systems can change the pH of the sample by altering the CO_2 partial pressure in the water. Even inert gases used in gas lift samplers may scrub pollutants from the sample and volatile organic losses from some forms of mechanical sampler may be high (Lee and Jones, 1983).

A wide range of sampling devices have been employed in sampling unpumped wells. Many of the devices used in surface waters are suitable for groundwater use but, in addition to the consideration of appropriate component materials, there are two further design constraints which are not usually encountered in the surface environment. Firstly, sampler size and method of operation will be determined by well diameter (typically 30–100 mm). Secondly, suction-only devices will not operate where static well water level is more than about 7 m below ground level. Thus, if continuous sample delivery is required, more elaborate pumping systems may be required to raise the sample to the well head. Overall, the selection of the sampling device will depend on the sampling objectives, the determinands under investigation and the time for which the monitoring well needs to be pumped before a representative sample is collected.

The following list of groundwater samplers concentrates on simple, economical, easily fabricated and portable systems, and gives the principal advantages associated with each type. This information is summarised in Section 7 and Table 1.

5.2 Types of sampler

5.2.1 Bailers

These are the oldest and simplest devices for sampling unpumped wells. Simplest of all are weighted bottles (Figure 3). The lid on bottle 3 (a) contains two staggered 3 mm diameter holes which facilitate the slow filling of the bottle. Thus, if the bottle is lowered rapidly and the sampling depth is less than 5 m below water level, less than 5% contamination by water above this depth should occur. The deeper the sampling depth, the greater the percentage contamination. In bottle 3 (b), a rubber bung, from which the sampler is suspended, is inserted just firmly enough to support the weight of the bottle. At the required depth, the line is jerked to remove the bung and the weight of the bottle is transferred to a 'safety cord'. Hydrostatic pressure makes this difficult to achieve at depths greater than about 20 m below the water table. Sampler 3 (c) suffers similar depth limitations although bung removal pressures can be more finely adjusted. Samplers 3 (a), 3 (b) and 3 (c) share the disadvantage of remaining open during ascent, thereby subjecting the collected sample to possible contamination by shallower well water. Sampler 3 (d) overcomes this problem by having a positive opening and closing action, the maximum operating depth being determined by the maximum practicable length of the "brake cable" system (10–15 m).

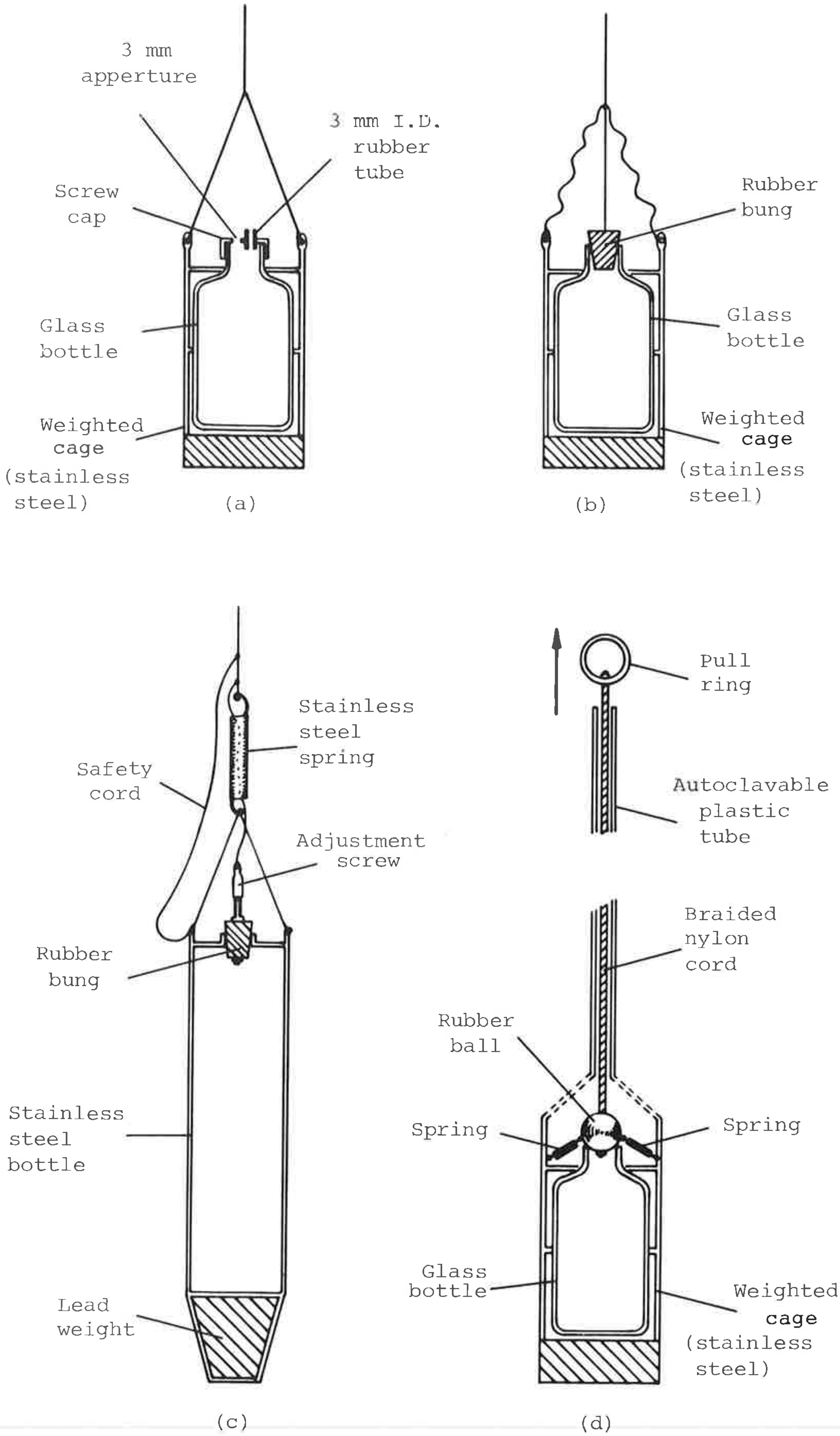

Figure 3: Some bottle-type groundwater sampling bailers.

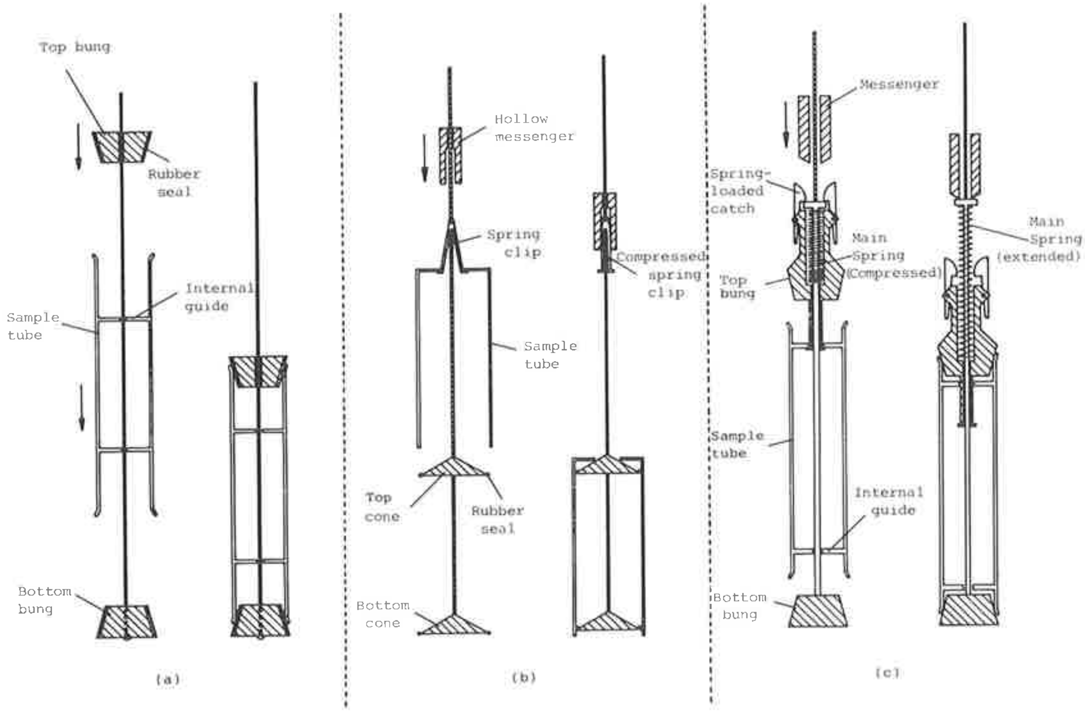

Figure 4: Some tubular groundwater sampling bailers.

Tubular bailers (Figure 4), which may theoretically be operated in wells of any depth, are open during descent but closed during ascent. The components of sampler 4 (a) must be of heavy and robust materials for it to operate effectively. The bottom bung is lowered to the required depth, the sample tube is sent down, followed by the top bung. With efficient top and bottom bung seals, sample leakage during ascent can be minimised. The sample tube of sampler 4 (b) is suspended from a spoked or perforated top plate by a spring clip and is released when the clip is compressed by the hollow messenger. Retention of the water sample depends more on the efficiency of the rubber seals than on the weight of the sample tube. Sampler 4 (c) is a Kemmerer-type sampler and has a spring-operated closing action, triggered by a weighted messenger. When combined with a water level sensor, tubular bailers are particularly suitable for sampling and measuring the thickness of layers of material such as oil floating on the groundwater surface.

Ball valve bailers (Figure 5) incorporate features of both bottle and tubular types. The valves open during descent to allow flow-through of water and close during ascent to contain the sample. The sample is released by insertion of a perforated tube into the bottom valve. Ball valve bailers do not aerate the water and, if constructed of Teflon, are particularly suitable for organics sampling. However, the valves may tend to restrict water flow-through, causing some carry down of contaminants from higher layers, and may leak in well waters with a high sediment load.

Bailer samplers are particularly suitable for groundwater tracing experiments or other high intensity sampling programmes because they can be easily cleaned or sterilised after collection of each sample. Some types are economical and convenient enough for a separate bailer to be dedicated to each well to minimise cross contamination. However, some bailers tend to aerate samples and it is usually impractical to use them to evacuate stagnant well water. It may also be necessary, particularly with tubular designs, to install small drain cocks on the top and bottom of the sampler to assist transfer of the water to a sample bottle.

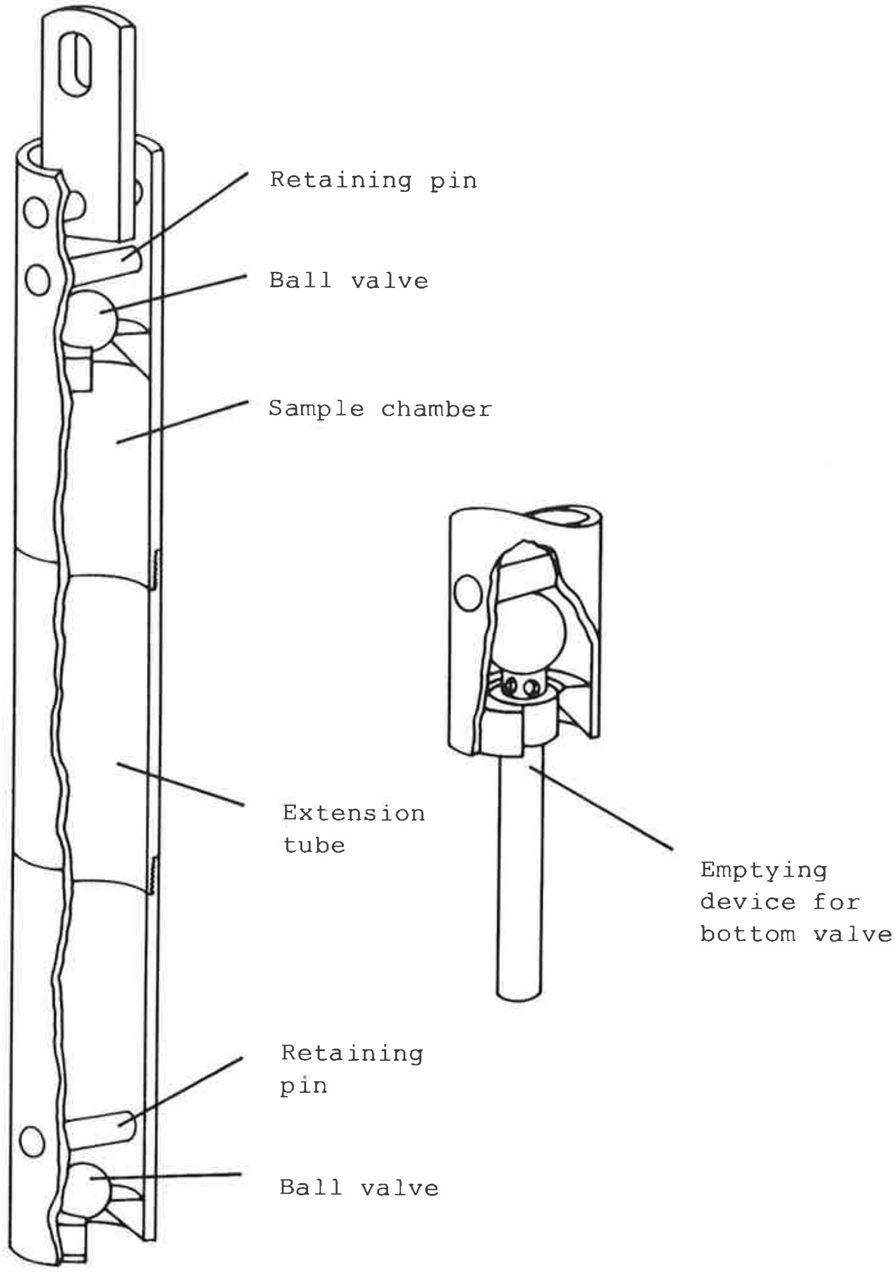

Figure 5: A PVC ball valve sampling bailer.

The cord on which a bailer sampler is suspended is a potential source of contamination, from contact with material around the well head or the water in other wells, particularly where a number of unpumped wells are sampled in quick succession. There are various ways of reducing this problem. One method (described in Sinton, 1980) involves attaching each bailer to a cord of sufficient length to leave about 2 m above the water table when the sampler reaches the required depth. This cord is in turn attached, via a stainless steel spring shackle, to the main cord which is wound on to a rod-and-reel mechanism. Because the main cord never enters the water, cross-contamination of wells is avoided. The rod-and-reel system allows the bailer to be manoeuvred from a clean, sterile container into the well with minimum handling and without touching the ground or well head structures. Where samples are collected more than 1–2 m below the water table, hand-retrieval of the contaminated cord may be necessary to avoid winding it on to the reel.

5.2.2 Suction lift pumps

A variety of pumps may be used if the water table is within suction lift distance, i.e., within about 7 m of the surface. A simple system, using an Erlenmeyer flask, is shown in Figure 6. The high-volume bypass system for flushing out the well may not be necessary in wells with a rapid water flow-through, such as those installed in permeable gravel aquifers. Continuous delivery may be provided by a peristaltic pump, but the flow rate is unlikely to be high enough by itself to flush out a stagnant well. Output may be increased further by using an in-line centrifugal or piston pump, but these increase the possibility of altering sample composition through changes in pressure or contamination by pump components and lubricants.

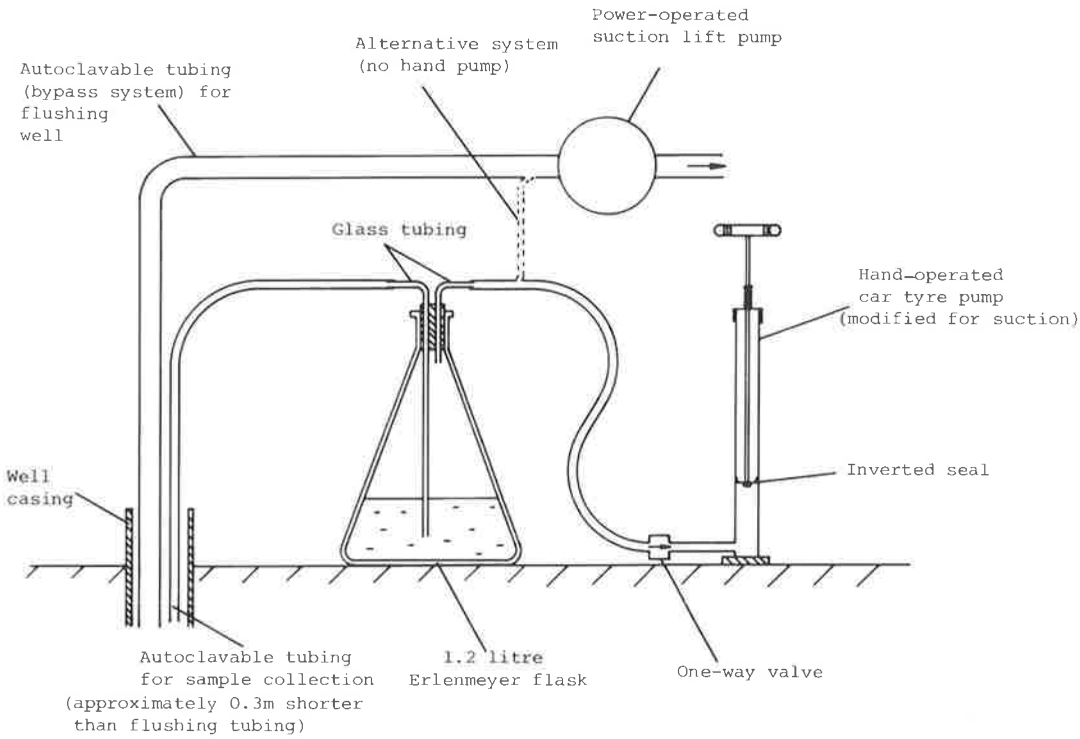

Figure 6: A simple suction lift sampling system.

Suction lift pumps are readily available, relatively portable and inexpensive. They may be hand-operated or require a power source. Their major limitation is the need for the water table to be within about 7 m of the surface.

5.2.3 Air/gas lift samplers

Figure 7 shows an air lift sampler, based on the design by Martin (1976). To operate, stopcock (2) is opened and (1) and (3) are closed; the suction pump is operated to draw water into the sampler reservoir; stopcock (3) is opened to equalise the sample chamber and atmospheric pressures; stopcocks (2) and (3) are closed, (1) is opened, and the pressure pump is operated to force the water in the reservoir up the sample delivery tube to the well head. Application of positive pressure to the reservoir while the sampler is being lowered prevents water entry until the required sampling depth. Although it is not necessary to evacuate the sampler chamber in order to facilitate sample entry, vacuum application considerably speeds up water inflow past the bottom one-way valve.

The air lift sampler in Figure 7 is not as convenient to use in the field as a bailer, but it can be constructed of readily available and inexpensive materials, so that separate samplers may be dedicated to individual wells to avoid cross-contamination. Although the PVC components tend to deteriorate with repeated autoclaving, they can be replaced at minimum cost.

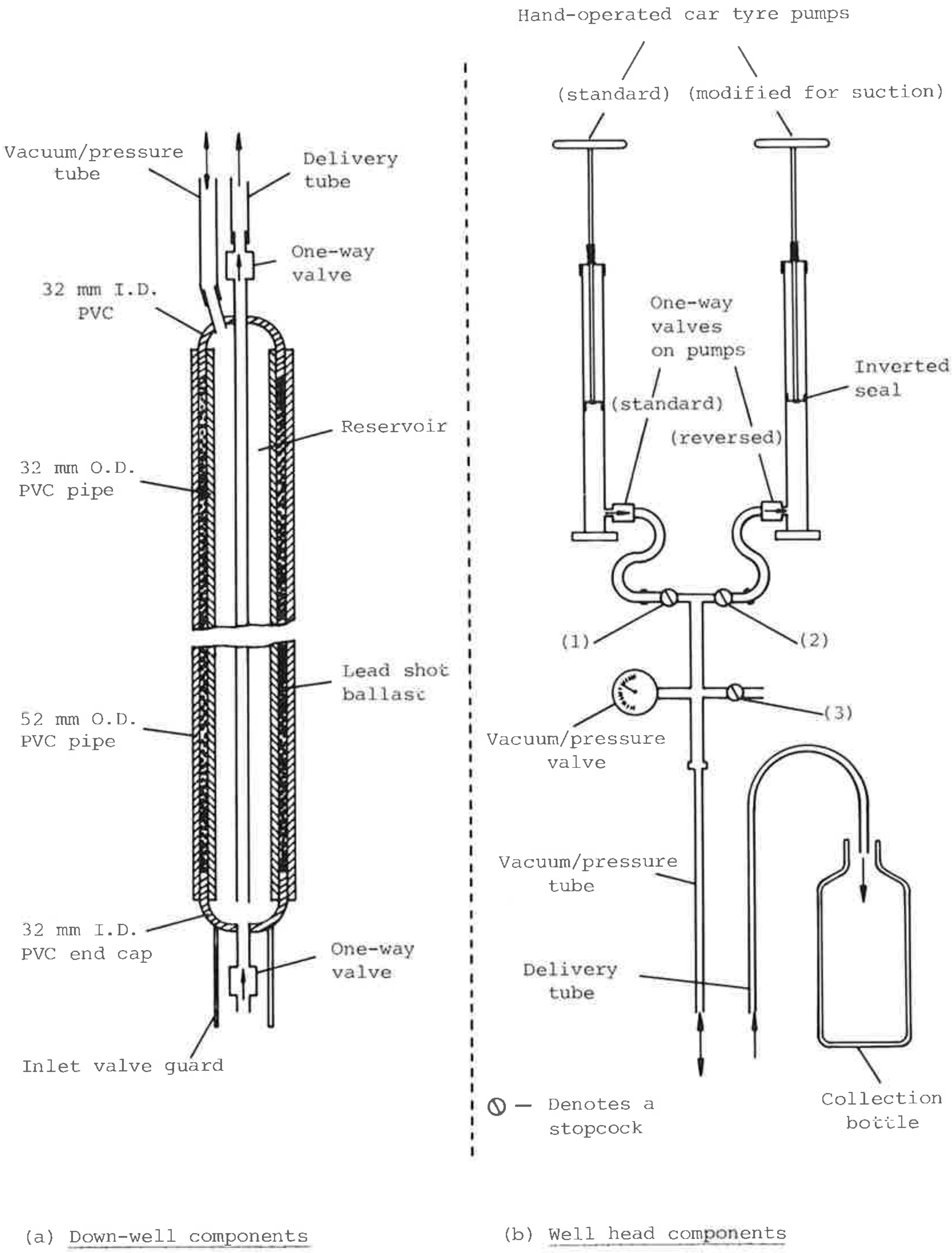

Figure 7: A simple air lift groundwater sampling system.

Figure 8 shows a commercially available air/gas lift sampler which may be constructed of PVC or Teflon. It operates on the same principle as the sampler in Figure 7 but is normally connected to a cylinder of compressed air or gas. Although the air/gas supply tube must be vented to allow the sampler to fill, evacuation of the sampler chamber is normally uneccessary because water flows reasonably readily in through the slots and past the large ball-type one-way (check) valve.

Aeration of the sample is a problem with air lift samplers (see section 5.1). Morrison and Brewer (1981) suggest that aeration may be minimised by using

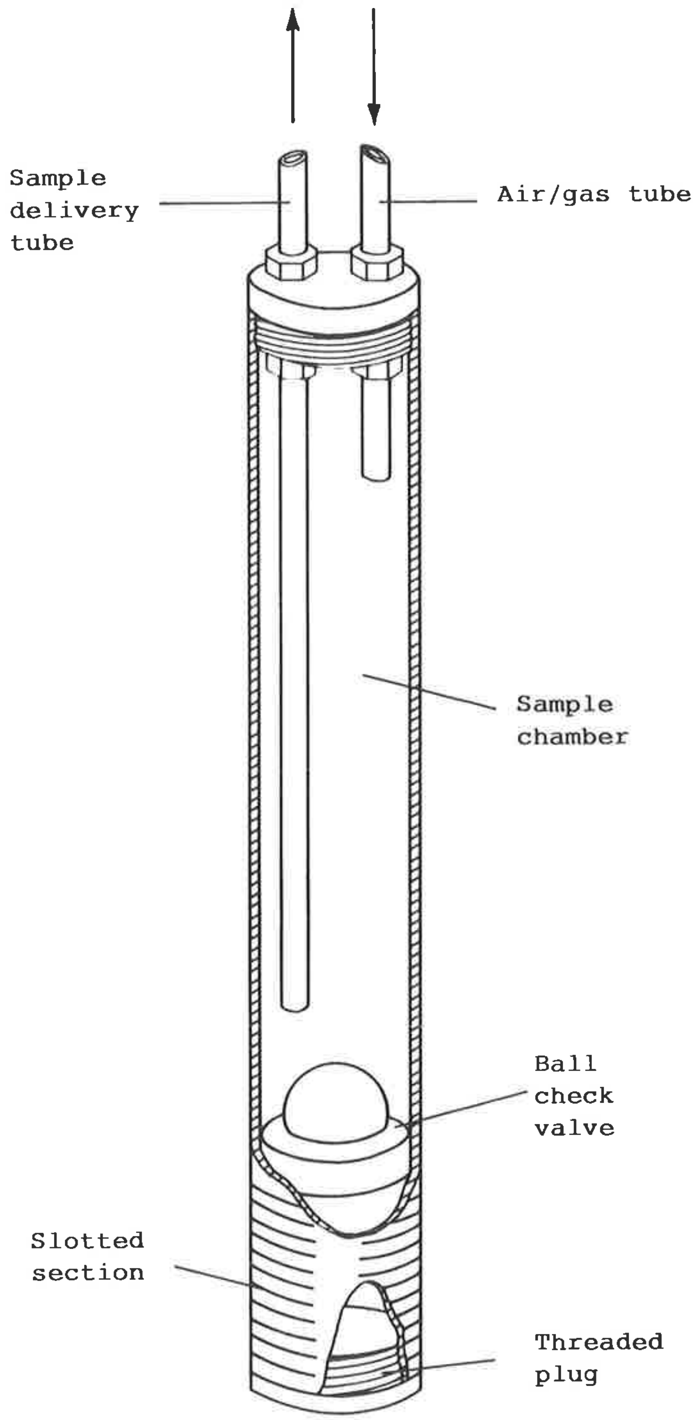

Figure 8: An air/gas lift sampler. (After Morrison and Brewer, 1981).

compressed nitrogen to drive the sample to the surface and by taking care not to overpressurise the sample. Another problem is clogging of the one-way valves with sediment but this may be alleviated by using a fine mesh screen on the intake aperture.

5.2.4 Portable submersible pumps

Submersible sampling pumps differ from air lift samplers in that they can provide continuous- or near-continuous delivery. There are three main types:

(1) Electric Pumps

These may be battery or mains operated and are usually suspended on a strong hose to which the power cable is attached. An electric motor sealed in the submerged section operates a piston, gear drive, centrifugal rotor or helical rotor pumping system. A helical rotor pump is shown in Figure 9. Some elaborate systems, mounted on a vehicle equipped with a winch and generator, can operate to depths of 100 m or more (McMillion and Keely, 1968).

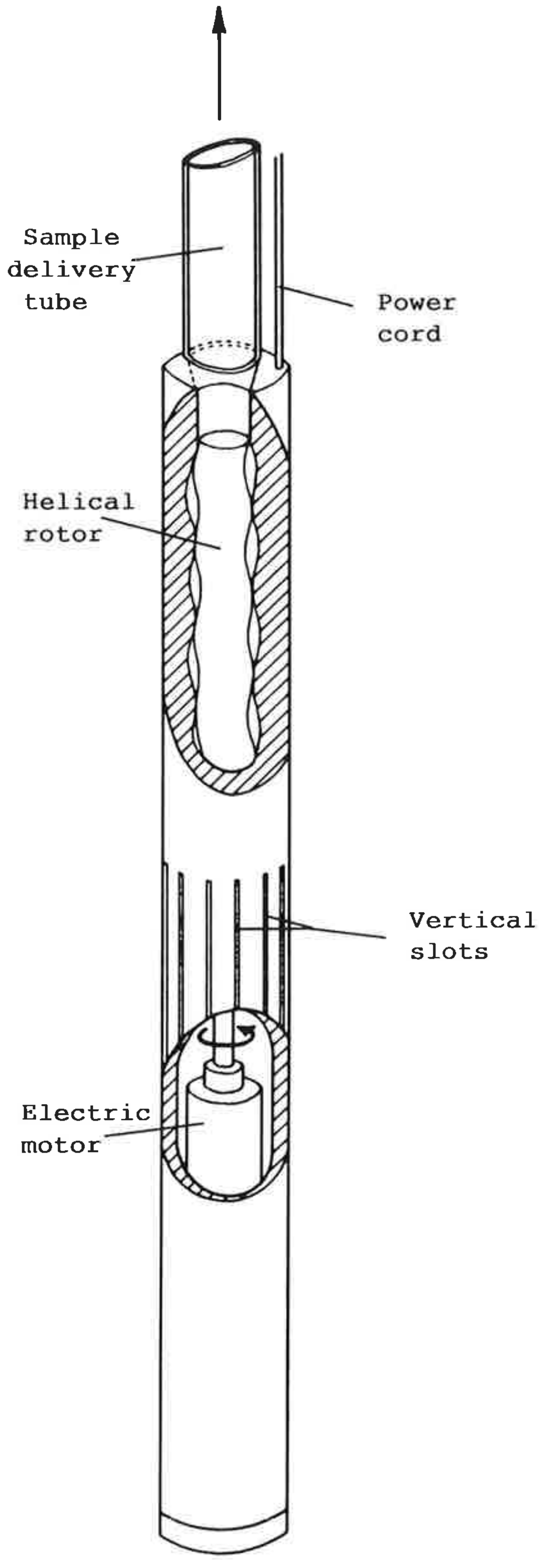

Figure 9: A helical rotor electric submersible pump. (After Morrison, 1983).

Small, battery-operated, centrifugal bilge pumps obtained from boat chandleries may be adapted for well sampling. They are relatively cheap, but vertical lift capability (head) is usually limited to about 10 m.

(2) Pneumatic Pumps

These are operated by compressed air or gas which drives a small piston pump in the submerged probe (e.g., Signor, 1978). They have the advantage of isolating the sample from the operating gas and tend to use compressed gas economically. Scalf *et al.* (1981) report that some can produce a head of over 500 m. However, pumping rates tend to be slow and the mechanism may be inactivated by sediment unless the inflow is filtered.

(3) Bladder or Squeeze Pumps

These are operated by compressed air or gas and consist of a collapsible membrane or bladder inside a rigid housing (Figure 10). The bladder is alternatively inflated and deflated to displace water through ball check valves.

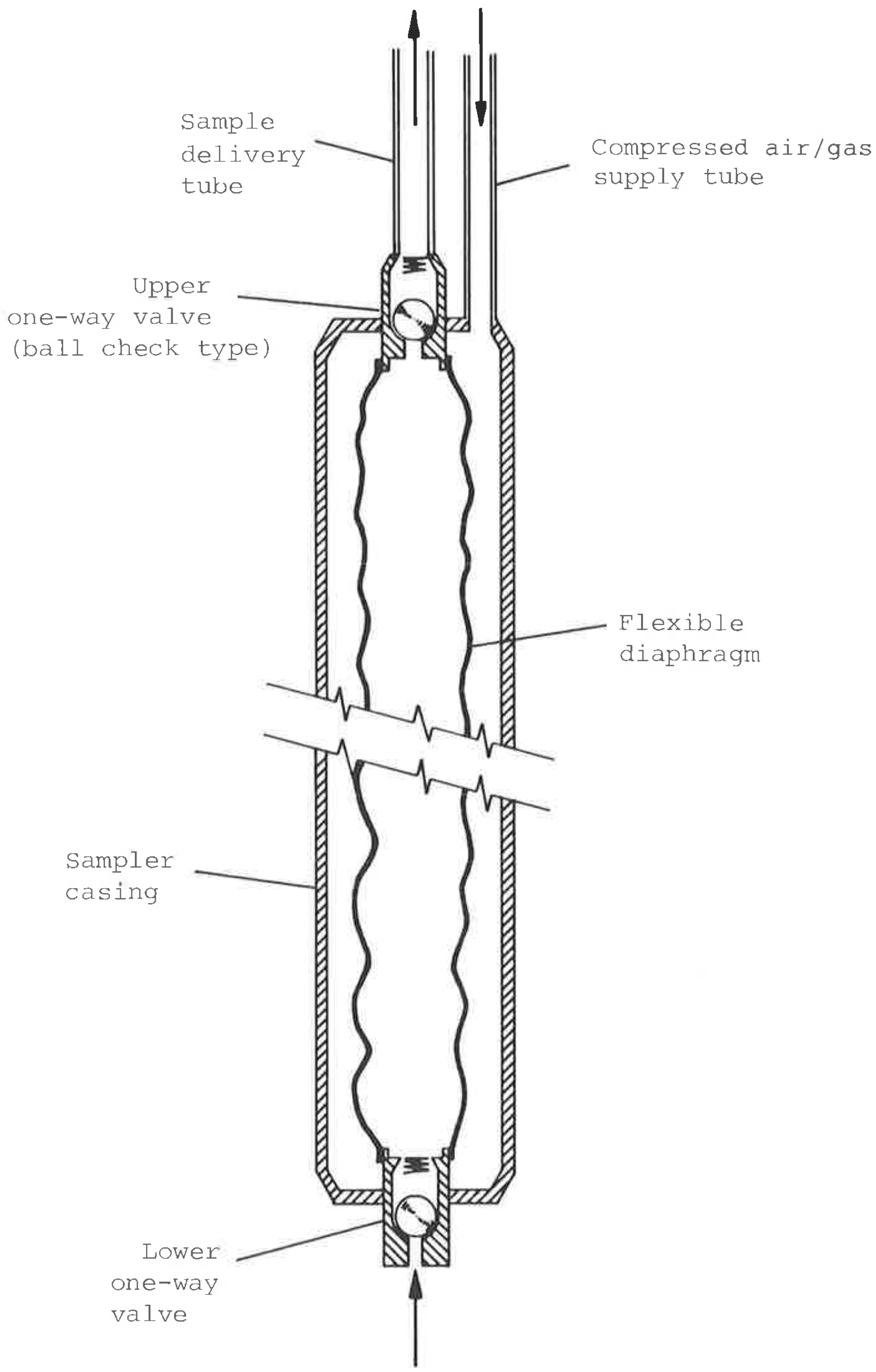

Figure 10: A gas-operated bladder pump.

Bladder pumps provide a reasonable range of pumping rates and may be constructed of a variety of materials. The driving gas does not contact the water sample which eliminates the possibility of contamination or gas stripping. However, large gas volumes and long cycles may be necessary for deep operation.

Portable submersible pumps are reasonably convenient to use and may provide pumping rates large enough to evacuate stagnant wells. Some have diameters as small as 30 mm, which permits the use of narrow and economical monitoring wells. However, many will not withstand autoclaving and, when constructed of conventional materials, are not suitable for obtaining samples for organic analyses. Even for inorganic chemical analyses, sample alteration through pressure changes and contact with pump components or lubricants is possible. The necessity for vehicle mounting of some deep well systems limits field use.

5.2.5 Well packers

Well packers enable the sampling of specific aquifer layers. Although many of the samplers described in section 5 can be opened and/or closed at specific depths in unpumped wells, the collected sample will not represent groundwater quality

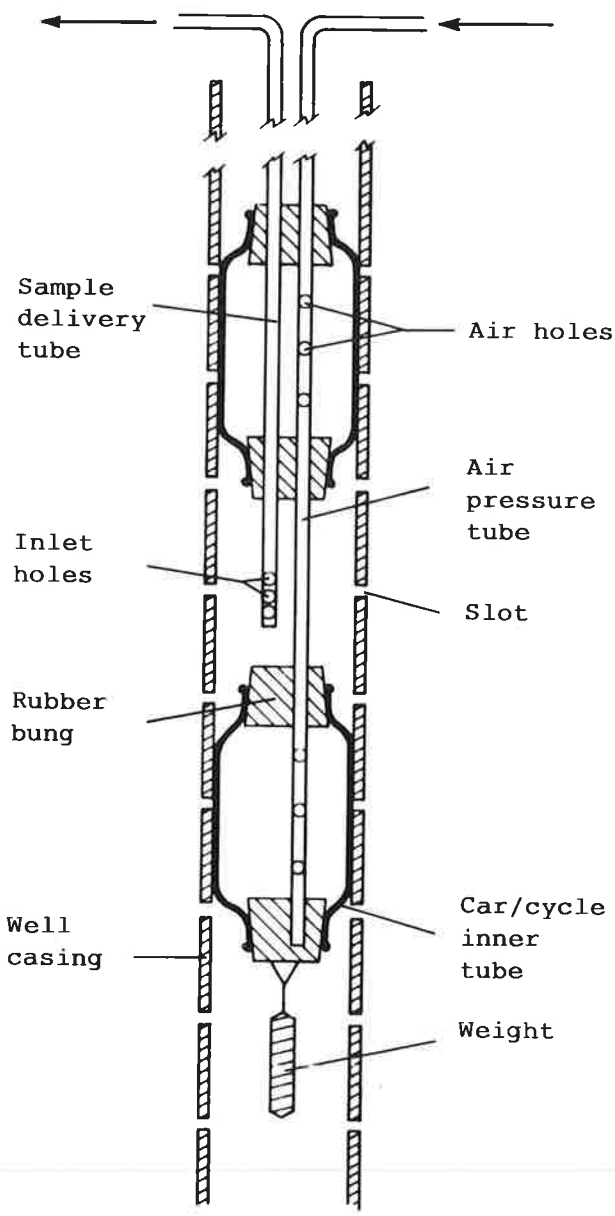

Figure 11: A well packer system coupled with a vacuum pump. (After Galgowski and Wright, 1980).

at that depth outside the well casing if there are vertical currents inside the well. Even in static water, a submersible pump may draw water from other depths in the well more rapidly than through the adjacent well casing. Thus, to obtain a representative specific depth groundwater sample from a monitoring well, the top and bottom of the appropriate section of casing must be sealed off and pumped to waste before sampling. Although well packers are commercially available, they may be readily fabricated from bicycle, motor cycle or car tyres, depending on the diameter of the well (Figure 11). Well packers can be used with suction lift pumps and most types of submersible pump. However, longer packers will be required if the well screen is comprised of vertical slots, and fractured or disturbed material outside the casing could allow entry of water from other depths into the sealed-off area.

5.2.6 Special purpose samplers and pumps

A wide variety of samplers and pumps constructed for specific groundwater sampling tasks have been described in the literature. Examples include a syringe sampler designed to cause minimum change in gas pressure during sampling (Gillham, 1982), multilevel devices (e.g., Pickens *et al.*, 1978), and a nitrogen-powered, continuous delivery glass/Teflon pump for deep sampling of organics (Tomson *et al.*, 1980).

6. Sample Handling

Post-collection handling of groundwater samples is essentially the same as for surface water samples, as described in Bordner *et al.* (1978), USGS (1979), Environment Canada (1979), USEPA (1979), Smith *et al.* (1982) and APHA (1985). Sample handling considerations relating specifically to groundwater have been discussed in detail by Scalf *et al.* (1981).

Before collecting groundwater samples, it is important to fully discuss the intended analyses with the laboratory performing them, to ensure that any special requirements with respect to sample handling, preservation or identification are met. As a guide, the following sections (6.1–6.3) briefly summarise the major precautions required when transferring and transporting groundwater samples.

6.1 Inorganic determinands

Groundwater samples for inorganic chemical analysis should be transferred to chemically cleaned plastic screw-capped bottles. Care should be taken to avoid contaminating the bottle during sample transfer. It is important to note that some determinand concentrations may change very rapidly when a sample is removed from the groundwater environment into an environment with different temperature, pressure, light, substrate or oxygen conditions. Numerous difficulties arise in this respect, but, as discussed in Section 5.1, probably the most common involves aeration of the sample and the consequent effects on the relationship between the redox potential of the water and dissolved iron levels. Thus, sample transfer should be performed with minimum aeration and turbulence. Sample bottles should be kept at low temperatures (packing in ice is usually best) and in the dark for transport to the laboratory. Guidelines for the use of preservatives for some determinands are covered in Environment Canada (1979), USEPA (1979), Scalf *et al.* (1981) and APHA (1985).

6.2 Organic determinands

Groundwater samples for the analysis of organics, particularly highly volatile compounds, should be carefully poured into clean glass vials (Scalf *et al.*, 1981).

Particular care should be taken to avoid turbulence. Generally, the vial should be topped up to exclude an air space, tightly closed with a screw cap lined with a Teflon septum, and packed in ice for transport to the laboratory. However, some laboratories may specify the provision of space in the vial for an extractant. If the analyses are not performed immediately, deep freezing of the samples may be necessary which means that alternatives to glass vials (such as Teflon containers) will need to be considered. Procedures for the collection, preservation and transport of samples for organics analysis are covered in Environment Canada (1979), USEPA (1979), Scalf *et al.* (1981) and APHA (1985).

6.3 Microbiological determinands

Groundwater samples for microbial analysis should be collected in chemically clean and sterile screw-capped glass bottles. Care should be taken to avoid any sources of microbiological contamination during sample collection and transfer. The sample bottles should be packed in ice and held in the dark for transport to the laboratory. Samples should be processed within 6 hours of collection. Procedures for the collection and transport of samples for microbial analyses are covered in Ministry of Housing and Local Government (1969), Bordner *et al.* (1978) and APHA (1985).

7. Selecting a Suitable Technique—A Summary

The sampling techniques and equipment used in a groundwater quality investigation will obviously depend largely on study objectives and be constrained by available finance. However, the capabilities and limitations of both the mechanisms and construction materials used in wells, samplers and pumps should be considered before a particular sampling technique is adopted. These issues have been discussed in detail by Scalf *et al.* (1981), Barcelona *et al.* (1984) and Nielson and Yeates (1985).

Table I summarises the principal considerations relating to the sampling and pumping mechanisms described in the preceding sections. Attributes and limitations of the materials commonly used in sampler construction are summarised below:

Glass: Suitable for micro-organisms, most organics and most major inorganic chemical determinands except phosphorus compounds.

PVC: Suitable for micro-organisms (but deteriorates with repeated autoclaving) and most major chemical determinands, but not some organics.

Stainless steel: Suitable for micro-organisms and most major chemical determinands, including phosphorus compounds, but not some organics.

Teflon: Appears to be suitable for all chemical and microbial determinands.

Polyethylene: Suitable for micro-organisms (although it tends to deteriorate with repeated autoclaving) and most major chemical determinands, but possibly not some organics.

8. Where to Go for More Information

8.1 General

Further information on specific groundwater sampling topics may be obtained from the relevant references in the preceding text. The reader is referred specifically to the "Manual of Ground-water Sampling Procedures" by Scalf *et al.* (1981) and "Ground Water Monitoring Technology" by Morrison (1983). Recent developments in groundwater sampling techniques are covered in the U.S. journal *Ground Water Monitoring Review*, available through the Central Library, Ministry of Works and Development, Wellington.

Table 1: Summary of characteristics of existing pumped wells and portable sampling devices (modified from Nielsen and Yeates, 1985).

Device	Minimum well diameter (mm)	Approximate maximum sampling depth (m)	Potential for chemical alteration of sample	Commercially available?	Approximate cost/sampler*
Point sampler (Figure 1)......................	NA	4	Slight	No	$300-$400
Existing pumped well					
via small pressure tank.	NA	Fixed at depth of existing screen	Moderate-high	NA	NA
via large header tank....	NA	Fixed at depth of existing screen	Severe	NA	NA
Bottle type bailers					
Figure 3 (a)..................	70-100	10-30 below water table	Moderate-high	No	< $100
Figure 3 (b)..................	70-100	20 below water table	Moderate-high	No	< $100
Figure 3 (c)..................	50-100	20 below water table	Moderate-high	Polypropylene version available	$250-$300
Figure 3 (d)..................	70-100	15	Moderate-high	No	$150-$200
Tubular bailers					
Figure 4 (a)..................	50	Unlimited	Minimum-slight	No	$150-$200
Figure 4 (b)..................	50	Unlimited	Minimum-slight	Yes	$700
Figure 4 (c)..................	50	Unlimited	Minimum-slight	Yes	$800
Ball valve bailer (Figure 5)......................	30	Unlimited	Slight	Yes	$150
Suction lift sampler (Figure 6)......................	20-50	7	Moderate-high	No	Wide variation
Air lift sampler (Figure 7)......................	60	50	High	No	< $200
Air/gas lift sampler (Figure 8)......................	30	100	Moderate	Yes	$2,000-$3,000
Portable submersible pumps					
Electric pumps (eg, Figure 9)	50	60	Slight-moderate	Yes	$300-$5,000
Pneumatic pumps.........	30-50	160	Slight-moderate	Yes	$4,000
Bladder pumps (Figure 10)................................	30	120	Minimum-slight	Yes	$3,000-$8,000

NA—Not applicable
*—New Zealand dollars; 1986 prices

8.2 Comparative performance of groundwater samplers

Barcelona *et al.* (1984) have evaluated 14 commercially available groundwater sampling devices in 5 mechanical categories in terms of collection of soluble determinands, dissolved gases and organic compounds. Nielson and Yeates (1985) have also compared a number of sampling mechanisms for narrow unpumped wells.

8.3 Commercial suppliers of groundwater sampling equipment

Many suppliers of groundwater sampling equipment advertise in *Groundwater Monitoring Review.* In addition, every year the journal devotes a section of one of their quarterly publications to a "Monitoring Products Buyers Guide" which lists known North American manufacturers and their relevant products. Some New Zealand scientific equipment suppliers are agents for these products as well as other sampling equipment suitable for groundwater applications.

8.4 The design and installation of monitoring wells

Monitoring wells suitable for a wide range of geologic formations have been described by Scalf *et al.* (1981) and guidelines for water well installation and maintenance in New Zealand have been provided by Bowden *et al.* (1983).

8.5 Hydrogeological considerations

The determinands selected in groundwater quality sampling programmes will depend on the study objectives, the nature of any pollution sources and on aquifer hydrogeology. The behaviour of contaminants in groundwater systems in relation to aquifer hydrogeology has been discussed by Walton (1970), Bouwer (1978), Freeze and Cherry (1979), Matthess (1982) and others. The influence of hydrogeology on sampling strategies has been outlined by Scalf *et al.* (1981) and Claasen (1982), and discussed briefly in relation to New Zealand alluvial gravel aquifers by Sinton (1983). Ogilvie (1983) and Sinton (1983) have briefly outlined some determinand selection considerations pertaining to New Zealand groundwater systems.

Acknowledgements

The author wishes to thank staff of the North Canterbury Catchment Board—particularly Dr M. Freeman and Mr R. B. Ayrey, Southland Catchment Board—particularly Mr L. McKenzie, and the Waikato Valley Authority—particularly Mr T. W. Marshall, for their comments on this material. Valuable contributions were also made by Drs J. B. Macaskill, D. G. Smith, R. H. S. McColl and H. R. Thorpe and Mr G. Bryers, Mr M. E. Close and Ms B. Vaile of the Water and Soil Directorate, Ministry of Works and Development. Information on several sampling devices was provided by Scott Technical Instruments Ltd and Smith Biolab Ltd.

References

American Public Health Association, American Water Works Association and Water Pollution Control Federation, 1985: "Standard Methods for the Examination of Waters and Wastewater, 16th Edition." American Public Health Association. 1268 p.

Barcelona, M. J.; Helfrich, J. A.; Garske, E. E.; Gibb, J. P. 1984: A laboratory evaluation of groundwater sampling mechanisms. *Groundwater Monitoring Review, Spring 1984*: 32–41.

Bordner, R. H.; Winter, J. A.; Scarpino, P. 1978; *Microbiological Methods for Monitoring the Environment: Water and Wastes Publication EPA-600/8-78-017.* Ohio: United States Environmental Protection Agency. 357 p.

Bouwer, H. 1978: "Groundwater Hydrology." McGraw-Hill. 480 p.

Bowden, M. J.; Harris, E. V. R.; Thorpe, H. R.; Wilson, D. D. 1983. Commissioning and Maintaining a Water Well in New Zealand: A Guide to Good Practice. *Water and Soil Miscellaneous Publication No. 61.* MWD, Wellington, New Zealand. 26 p.

Claasen, H. C. 1982: Guidelines and Techniques for Obtaining Water Samples that Adequately Represent the Water Chemistry of an Aquifer. *US Geological Survey Open-File Report 82-1024.* 49 p.

Dunlap, W. J.; McNabb, J. F.; Scalf, M. R.; Cosby, R. L. 1977: *Sampling for Organic Chemicals and Microorganisms in the Subsurface. EPA-600/2-77-176, August 1977.* United States Environmental Protection Agency.

Environment Canada. 1979: Analytical Methods Manual. Inland Waters Directorate, Water Quality Branch, Ottawa, Canada. 374 p.

Freeze, R. A.; Cherry, J. A. 1979: "Groundwater." Prentice-Hall. 604 p.

Galgowski, C.; Wright, W. 1980: A variable-depth ground-water sampler. *Soil Science Society of America Journal 44:* 1120–1121.

Gibb, J. R.; Schuller, R. M.; Griffin, R. A. 1984: Monitoring Well Sampling and Sample Preservation Techniques. United States Environmental Protection Agency (In Press).

Gillham, R. W. 1982: Syringe devices for groundwater sampling. *Groundwater Monitoring Review 2 (1):* 36–39.

Kerfoot, W. B. 1984: A portable well point sampler for plume tracking. *Groundwater Monitoring Review, Fall 1984:* 38–42.

Kingsford, M.; Nielsen, J. S.; Pritchard, A. D.; Stevenson, C. D. 1977: Sampling of Surface Waters. *Water and Soil Technical Publication No. 2*, MWD, Wellington, New Zealand. 15 p.

Lee, G. F.; Jones, R. A. 1983: Guidelines for sampling ground water. *Journal of the Water Pollution Control Federation 55 (1):* 92–96.

McMillion, L. G.: Keely, J. W. 1968: Sampling equipment for ground-water investigations. *Groundwater 6 (2):* 9–11.

Martin, G. N. 1976: Water sampling from unpumped wells with static water levels deeper than 10 metres. *Journal of Hydrology (NZ) 15 (1):* 41–45.

Matthess, G. 1982: "The Properties of Groundwater." John Wiley and Sons. 406 p.

Ministry of Housing and Local Government. 1969: *The Bacteriological Examination of Water Supplies.* Department of Health and Social Security, Welsh Office, Reports on Public Health and Medical Subjects No. 71. Her Majesty's Stationery Office, London. 52 p.

Morrison, R. D. 1983: *Ground Water Monitoring Technology: Procedures, Equipment and Applications.* Timco Manufacturing, Prairie du Sac, Wisconsin, USA.

Morrison, R. D.; Brewer, P. E. 1981: Air lift samplers for zone-of-saturation monitoring. *Ground Water Monitoring Review 1 (1): 52–55.*

Nielsen, D. M.; Yeates, G. L. 1985: A comparison of sampling mechanisms available for small diameter groundwater monitoring wells. *Ground Water Monitoring Review Spring 1985:* 83–99.

Ogilvie, D. J. 1983. The use of physical and chemical water quality parameters. *In:* "Design of Water Quality Surveys. Proceedings of a Symposium, Hamilton, 17-18 November 1982." (Edited by R. A. Hoare). *Water and Soil Miscellaneous Publication No. 63.* MWD, Wellington, New Zealand. pp. 41-53.

Pettyjohn, W. A.; Dunlap, W. J.; Cosby, R. Keely, J. C. 1981. Sampling ground water for organic contaminants. *Groundwater 19 (2):* 180–189.

Pickens, J. F.; Cherry, J. A.; Grisak, G. E.; Merrit, W. F.; Risto, B. A. 1978: A multilevel device for ground-water sampling and piezometric monitoring. *Groundwater 16 (5):* 322–327.

Scalf, R. F.; McNabb, J. F.; Dunlap, W. J.; Cosby, R. L.; Fryberger, J. 1981: "Manual of Groundwater Sampling Procedures." Robert S. Kerr Environmental Research Laboratory, USEPA, Ada, Oklahoma, USA. 93 p.

Signor, D. C. 1978. Gas-Driven Pump for Ground Water Samples. *USGS Water Resources Investigation 78–72, Open-File Report, July 1978.*

Sinton, L. W. 1980: Investigations Into the Use of the Bacterial Species *Bacillus stearothermophilus* and *Escherichia coli* (H_2S+) as Tracers of Groundwater Movement. *Water and Soil Technical Publication No. 17*, MWD, Wellington, New Zealand. 24 p.

Sinton, L. W. 1983: Design of groundwater quality surveys: *In:* "Design of Water Quality Surveys. Proceedings of a Symposium, Hamilton, 17–18 November 1982." (Edited by R. A. Hoare). *Water and Soil Miscellaneous Publication No. 63.* MWD, Wellington, New Zealand. pp. 113–129.

Smith, D. G.; Macaskill, J. B.; Stevenson, C. D.; Edgerley, W. H. L. 1982: Physical and Chemical Methods for Water Quality Analysis. *Water and Soil Miscellaneous Publication No. 38.* MWD, Wellington, New Zealand. 119 p.

Tomson, M. B.; Hutchins, S.; King, J. M.; Ward, C. H. 1980: A nitrogen-powered continuous delivery all-glass-teflon pumping system for groundwater sampling from below 10 metres. *Groundwater 18 (5):* 444–446.

U.S. Environmental Protection Agency. 1974. *Manual of Individual Water Supply Systems. EPA-430/9-74-007.* Washington, D.C. 115 p.

U.S. Environmental Protection Agency. 1979: *Methods for Chemical Analysis of Water and Wastes. USEPA. EPA-600 4-79-020.* Environmental Monitoring and Support Laboratory, Office of Research and Development, United States Environmental Protection Agency. 431 p.

U.S. Geological Survey. 1979: *Methods for Determination of Inorganic Substances in Water and Fluvial Sediments. Publication No. 024-001-03177-9.* U.S. Department of the Interior Geological Survey. U.S. Government Printing Office, Washington, D.C. 626 p.

Walton, W. C. 1970: "Groundwater Resource Evaluation". McGraw-Hill. 664 p.

V. R. WARD, GOVERNMENT PRINTER, WELLINGTON, NEW ZEALAND—1986

59557G—86PT

WATER & SOIL MISCELLANEOUS PUBLICATION NUMBER 99

A Guide to Groundwater Sampling Techniques

National Water and Soil Conservation Authority

Water & soil miscellaneous publication no. 99 (1986)

ISSN 0110-4705