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AN INVESTIGATION INTO THE ROLE OF SITE AND SOIL CHARACTERISTICS IN ON-SITE SEWAGE TREATMENT

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Abstract

The on-site treatment of sewage is common in all rural and regional areas of the world. Due to the public health and environmental risks that these treatment systems pose, the need for adopting performance based management strategies is gaining increasing recognition. This demands the establishment of performance objectives for on-site sewage treatment and disposal which are based on stringent scientific analysis. A research project was undertaken to identify and investigate the role of influential site and soil characteristics in the treatment performance of subsurface effluent disposal areas. The treatment performances of a number of septic systems on a range of site and soil conditions were investigated together with detailed soil analysis. The changes to soil physico-chemical characteristics of the disposal area due to effluent application and its effluent renovation capacity were found to be directly related to the subsurface drainage characteristics. Significant changes to exchangeable cations and chemical parameters such as pH, electrical conductivity and cation exchange capacity (CEC) can result due to subsurface effluent application. A relationship exists between chemical parameters such as exchangeable Na and Ca:Mg ratio and CEC. A strong correlation also exists between the depth to the restrictive subsurface horizon and observed treatment performance. The study confirmed that soil chemistry can be a valuable predictive tool for evaluating the long-term performance of sewage effluent disposal systems particularly in poorly drained sites.

Keywords: On-site sewage, Soil chemistry, Treatment, Effluent, Australia

Introduction

A significant proportion of the population in any country relies wholly on on-site systems for the treatment and disposal of domestic sewage. As an example, approximately 13% of the Australian population, or more than two million people, do not have reticulated sewerage facilities (Thomas and others 1997). In the United States this percentage is even higher and is in the region of about 25% (Siegrist 2001). Septic tanks are by far the most common form of on-site sewage treatment and the associated subsurface effluent disposal area is a crucial part of the treatment train. It forms the 'last line of defence' along with buffer zones to prevent the contamination of surface and groundwater resources by sewage. Figure 1 shows a typical septic tank/subsurface effluent disposal system (Standards Australia 2000).

Despite the seemingly low technology of septic systems, failure is common. In many cases this can lead to adverse public health and environmental impacts (DeBorde and others 1998; DeWalle and Schaff 1980; Lipp and others 2001; Paul and others 2000; Scandura and Sobsey 1997). A primary factor that contributes to failure is the inadequate consideration of site and soil characteristics in the design of the subsurface effluent disposal area (Martens and Geary 1999; Siegrist and others 2000; Whitehead and Geary 2000).

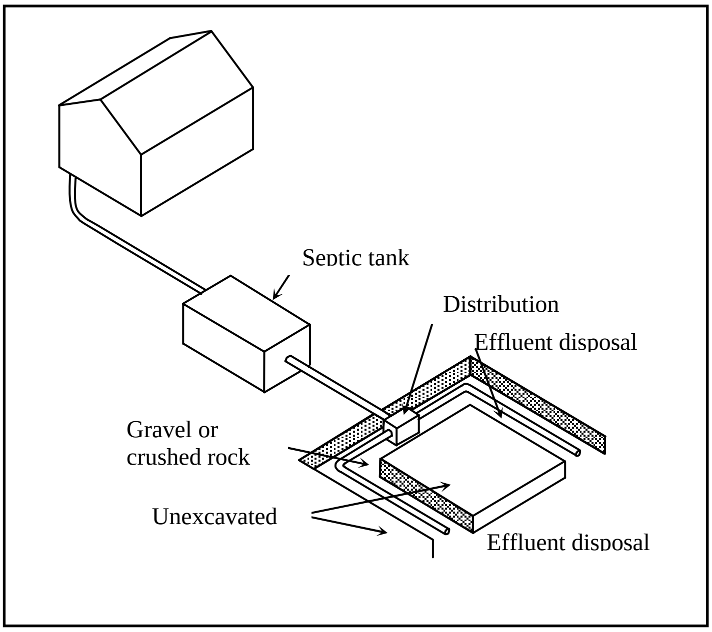


Figure 1 Typical septic tank-effluent disposal area layout

Due to the serious public health and environmental risks that these treatment systems pose, the need for adopting performance based management strategies is gaining increasing recognition. This translates to a paradigm shift from the commonly adopted prescriptive design practices. Consequently, the design of the subsurface effluent disposal area requires a comprehensive understanding of the factors that influence treatment performance and the development of a predictive strategy for performance evaluation.

Soil is as an excellent medium for the removal of contaminants in sewage effluent. However researchers such as Brouwer and Bugeja (1983); Levine and others (1980); Schipper and others (1996); Siegrist (2001); Van Cuyk and others (2001); Whitehead and Geary (2000), have identified the lack of in-depth knowledge of the effluent renovation processes taking place within the soil matrix and the nature of the influence exerted by site conditions as major limitations which inhibit the adoption of performance based design approaches.

Materials and methods

The research project

The research project was undertaken in the Brisbane City urban fringe in the State of Queensland, Australia. A representative sample of 16 study sites having septic tanks and subsurface effluent disposal areas was selected for investigation. The site selection was based on the proportionate area of urban development in the Brisbane region within different soil types and to obtain a mix of system ages. Background details relating to the study sites are given in Table 1 and Figure 2 shows their locations.

Table 1 Disposal area details

Site No.	System age (yr)	Australian Soil Classification[a]	Soil Texture	Soil Drainage[b,c]	Depth from surface to restrictive soil horizon (m)[d]
1	4	Red Chromosol	Sandy loam	Moderately well drained	0.6
2	8	Red Chromosol	Sandy clay loam	Moderately well drained	0.5
3	5	Brown Chromosol	Sandy loam	Imperfectly drained	0.5
4	3	Brown Chromosol	Sandy loam	Imperfectly drained	0.6
5	1	Brown Chromosol	Sandy clay loam	Imperfectly drained	0.3
6	11	Red Dermosol	Sandy clay	Poorly drained	0.2
7	2.5	Red Chromosol	Sandy loam	Moderately well drained	0.7
8	4	Red Sodosol	Sandy clay to clay	Poorly drained	0.3
9	17	Grey Sodosol	Clay	Poorly drained	0.3
10	14	Red Kandosol	Sandy loam	Moderately well drained	0.4 (Rock Ledge)
11	4.5	Red Kandosol	Sandy loam	Well drained	0.7
12	19	Brown Kurosol	Loamy sand	Moderately well drained	0.7
13	16	Brown Kurosol	Loamy sand	Imperfectly drained	0.5
14	14	Brown Chromosol	Clay loam	Moderately well drained	0.7
15	3	Red Ferrosol	Sandy clay loam	Moderately well drained	0.7
16	4	Red Ferrosol	Clay loam	Poorly drained	0.4

a Australian Soil Classification after Isbell (1996)
b based on the position of the site in the landscape catena (Refer Figure 8).
c the classification used complies with AS/NZS 1547:2000 (Standards Australia 2000).
d based on soil profile description measured in the field

The approach adopted in this research involved obtaining field information including site conditions of existing operating on-site sewage treatment systems. This was to determine to what extent contact with effluent has altered the properties of the soil along with the travel distance of pollutants from the subsurface disposal trenches. Soil sampling and monitoring data at established subsurface effluent disposal systems were used as a convenient method for evaluating renovation efficiency and to obtain an insight into renovation mechanisms. The advantage of using soil parameters as indicators is that they are not weather dependent and samples can be taken at any time. In conjunction with soil sampling, a comparison of quality parameters for soil water and effluent samples collected at the soil interface would indicate the degree of change in quality experienced by the effluent moving through the soil.

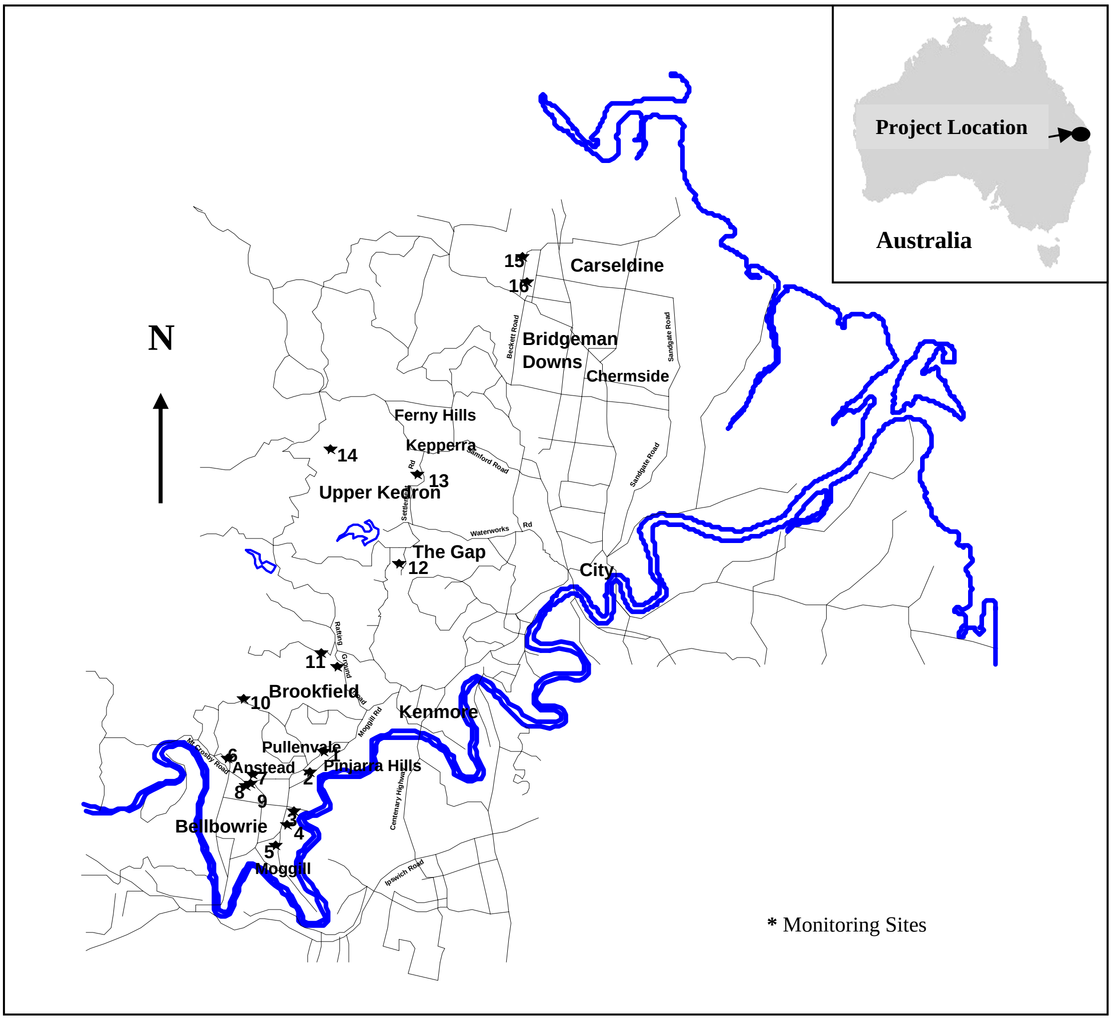


Figure 2 Project location

Analytical program

The investigations undertaken involved the analysis of selected soil profiles for their physical and chemical properties. The results obtained were interpreted and employed as quantitative information for confirmation and to support the field observations. The soil parameter selection was based on the suite of tests generally carried out in land resource evaluation (Rayment and Higginson 1992). These tests have been developed through extensive agricultural research and are designed to distinguish between deficient, adequate and toxic supply of elements in soil and between degraded and non-degraded soil conditions.

Data derived from soil water samples collected during wet and dry periods was used to evaluate the change in chemical properties of the effluent due to movement through the soil. The chloride concentration in soil water was employed as an indicator of effluent movement. Chloride is highly mobile in soil systems and undergoes limited soil adsorption and no biochemical transformation (Monnett and others 1996; Mote and others 1995). The approach adopted provided a convenient method for evaluating effluent renovation efficiency and to obtain an understanding of the renovation mechanisms.

Sampling program

The soil and soil water sampling strategy was specifically formulated to focus on the 'zone of influence' of a subsurface effluent disposal field. Detailed soil evaluation was undertaken directly downstream of the disposal field in order to investigate the extent of effluent travel and the ability of the soil to remove pollutants contained in the effluent by adsorption and/or nutrient uptake. The downstream location was determined on the basis of slope and observed soil water flow. Soil descriptions such as texture, structure and moisture regime were used to determine the effect of movement of water into and through the soil and to qualitatively assess the hydrology of the soil profile. These were obtained from the control sites and the downstream piezometer sites. Valuable information for characterising soil capability for sewage effluent renovation can be derived from terrain evaluation and geomorphologic features that are significant in relation to subsurface drainage. The more important parameters in regard to subsurface effluent disposal include, the position of perched and true water tables and duration of saturation (Cresswell and others 1999). These factors are discussed further under Field data collection.

Soil samples were obtained from the two downstream piezometer sites along with control samples to the same depth and located away from the influence of the disposal field. The control site was needed to determine background soil parameters and had to be undisturbed from landscaping and not contaminated with sewage effluent.

The soil chemical parameters measured were exchangeable cations, Ca:Mg ratio, pH, electrical conductivity (EC), concentration of chlorides and nitrates and phosphorus sorption. Additionally, parameters such as exchangeable sodium percentage (ESP), cation exchange capacity (CEC) and effective cation exchange capacity (ECEC) were derived from the data obtained. In neutral to alkaline soils, the total CEC equals the sum of the exchangeable cations. However in the case of acidic soils which occupy most of the Brisbane area, it is ECEC that is relevant where the summation also includes the exchangeable acidity (Peverill and others 1999). ECEC is defined as:

$$\begin{aligned} \text{ECEC} &= \text{exchangeable cations} + \text{exchangeable acidity} \\ &= \text{Exchangeable } (Ca + Mg + Na + K) + \text{Exchangeable } (Al + H) \end{aligned}$$

Soil water samples were collected using piezometers installed 1 and 3m downstream from the edge of the subsurface disposal area. A typical piezometer installation is shown in Figure 3 and Figure 4 shows a typical site layout. The piezometers were installed to a maximum depth of 1.5m or to a clay layer of low permeability. These consisted of a 90mm diameter perforated plastic pipe wrapped with geofabric (Type 12 Bidum). The geofabric was used to reduce the ingress of particulate matter while allowing the uninterrupted movement of water through the soil profile and into the piezometer. The pipe was capped at both ends and the annular space between the soil profile and the piezometer tube was filled with gravel to facilitate the percolation of effluent into the piezometer and at the same time to prevent the clogging of the slots in the pipe. During the installation of the piezometers, the soil profile was catalogued using a checklist.

In addition to soil and soil water sampling, effluent samples were also analysed. Effluent samples were collected from the distribution box to determine the quality of the wastewater input to the disposal field. The effluent parameters measured and relevant to the current discussion included, EC, chloride concentration, total dissolved solids (TDS), total organic carbon (TOC) and total nitrogen (TN) (APHA 1995).

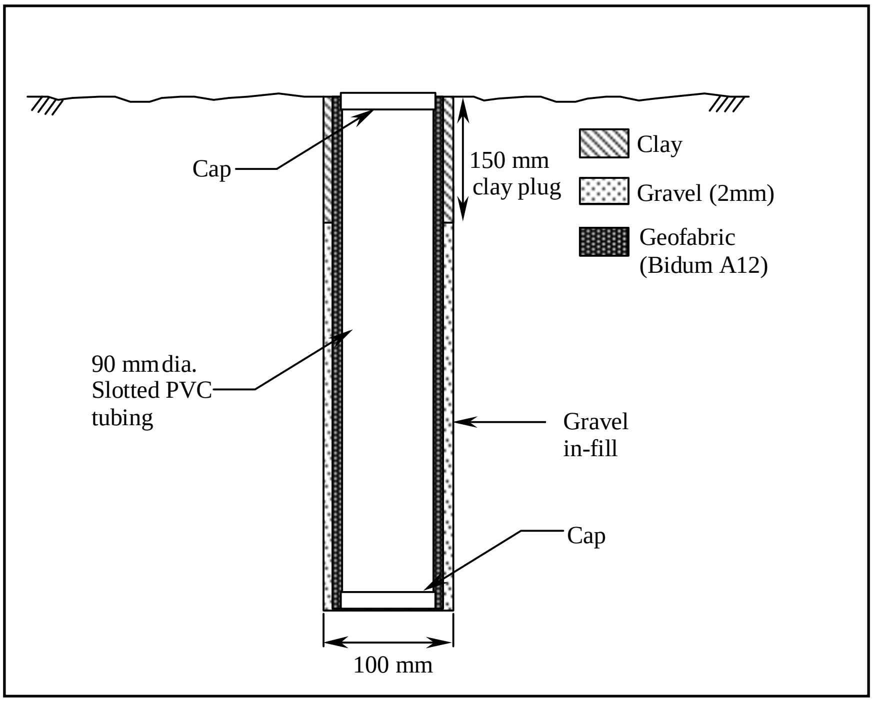


Figure 3 A typical piezometer installation

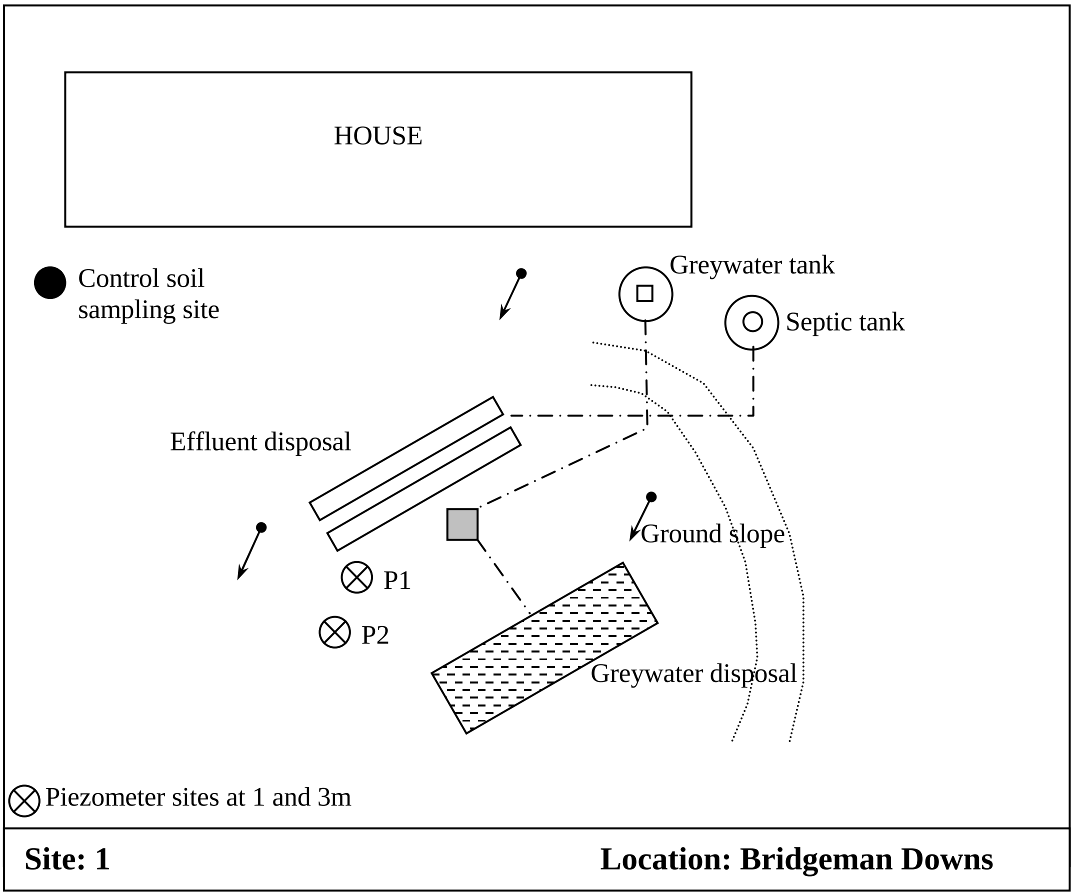


Figure 4 A typical site layout

Field data collection

Soil samples collected were classified, noting features such as parent material and profile description. Soil profile descriptions including colour, texture, structure and biological activity were recorded in depths of 100mm. The soil classification derived is given in Table 1. The dominant soils were Red and Brown Chromosols (Isbell 1996), which generally exhibit a strong texture and contrast between the A and B horizons.

Site conditions such as topography, slope and drainage characteristics were described in detail. Drainage information collected included the presence of preferential flow paths, redoximorphic features, hydraulic conductivity and porosity. Additionally, information on water table depth, presence of effluent flows, depth of soil horizons and depth to the impermeable soil layer were recorded. The location of each site's position within a landscape pattern or catena was identified (White 1997).

Results and discussion

Changes in soil chemical properties

Chemical data such as exchangeable cations, Ca:Mg ratio and ESP were employed as possible indicators to investigate the likely deterioration of the soil structure due to sewage effluent disposal. This deterioration will be in the form of soil dispersion from increased exchangeable Na and thus increased Exchangeable Sodium Percentage (ESP) which will lead to a reduction in soil pore size and consequently a reduced soil hydraulic conductivity. The Ca:Mg ratio in a soil can be employed to indicate cation distribution. Emerson (1977) found that ratios less than 0.5 are associated with soil dispersion. Ca^{2+} ions tend to aid in flocculation of soils while Na^{+} ions and to a reduced extent Mg^{2+} ions will disperse soils. During the study, influential soil parameters were identified and correlations and linkages between these parameters and drainage factors were assessed. These included either cation exchange capacity (CEC), or Effective Cation Exchange Capacity (ECEC), dominance of exchangeable Ca or exchangeable Mg over exchangeable Na concentration, Ca:Mg ratio and dispersiveness (ESP or Emerson test). Soil particle fractions were measured. The sand size particle sizes were determined by sieve analysis and the silt and clay contents were measured by hydrometer analysis and the type of clay was interpreted using published values of CEC (Churchman and others 1993). Cation exchange in soils has significant influence on the nutrient holding capacity of soils (Bell 1993).

The results from the sampling and testing program found the subsurface application of sewage effluent caused appreciable changes in exchangeable cations such as Ca, Mg, Na as well as in parameters such as pH, EC and CEC (or ECEC) compared to the values obtained for the control samples. This is evident from the data given in Table 2. These chemical parameter changes were comparable with other findings relating to New Zealand and Southern Australian soils (Falkiner and Smith 1997; Menneer and others 2001; Speir and others 1999; Stewart and others 1990).

Soils with moderate to high CEC (or ECEC), Ca:Mg >0.5, dominance of exchangeable Ca or exchangeable Mg over exchangeable Na concentration and thus low ESP have the ability to renovate effluent without major soil structure deterioration. In some cases, moderate to high exchangeable Na concentration was offset by the presence of swelling clays and the co-dominance of exchangeable Ca and exchangeable Mg. This characteristic has the ability to aid the adsorption of cations at depth. These conclusions are supported by Curtin and others (1994) in a study on prairie soils in Saskatchewan, Canada.

Soils that exhibit low Ca:Mg ratio (<0.5), imply a high ESP and high exchangeable Na, indicating poor soil conditions for effluent disposal due to possible soil structure breakdown and dispersion. During the study it was noted that the clay content in such soils was generally high. As noted by Sumner (1993), in these cases even low ESP can have a significant impact on soil stability and furthermore even soils with ESP values < 1% can exhibit sodic behaviour.

Table 2 Soil chemistry of disposal areas (selected sites)

Site[a,c,d]	Depth[a] m	pH	EC mS/cm	Cl mg/kg	Exc. Ca meq/100g	Exc. Mg meq/100g	Exc. Na meq/100g	ESP[b] %	ECEC meq/100g
4C	0.2 A	4.5	0.06	<1	1.1	0.85	0.06	NA	4
4C	0.8 B	4.2	0.08	26	0.58	3.2	0.68	4	9
4P1	0.3 A	4.8	0.06	8	0.74	1.0	0.08	NA	3
4P1	0.9 B	4.4	0.17	185	0.12	4.5	1.4	10	14
4P2	0.2 A	4.9	0.07	7	1.2	1.2	0.09	NA	4
4P2	0.8 B	4.5	0.09	70	0.14	4.4	0.84	6	14
12C	0.3 A	4.9	0.12	20	2.2	1.6	0.05	NA	5
12C	0.7 B	4.9	0.13	83	0.1	6.8	1.2	12	10
12P1	0.3 A	4.6	0.09	6	1.0	1.1	0.07	NA	4
12P1	0.9 B	4.9	0.12	35	0.42	7.7	1.6	14	12
12P2	0.2 A	4.6	0.11	13	0.81	1.2	0.06	NA	4
12P2	0.8 B	4.9	0.08	67	0.11	8.5	1.8	15	12
15C	0.3 A	5.3	0.07	17	3.7	2.6	0.04	NA	7
15C	0.6 B	4.8	0.11	12	3.6	2.5	0.09	1	7
15P1	0.2 A	5.0	0.41	17	4.6	1.6	0.02	NA	8
15P1	0.8 B	3.7	0.15	28	3.0	2.1	0.15	2	10
15P2	0.3 A	5.0	0.41	17	5.4	1.8	0.06	NA	8
15P2	0.8 B	3.8	0.12	27	1.2	2.6	0.13	1	9

a A – A horizon; B – B horizon; C – Control soil sample
b NA – Not Analyse
c P1 - Piezometer at 1m, soil sample
d P2 – Piezometer at 3m, soil sample

An issue of concern was the increase in soil sodicity due to effluent disposal. Sites 8 and 9 were poorly drained sodic soils with existing high exchangeable Na levels. The additional loading with sodium rich effluent would cause soil degradation in the long term as the sodium will replace other cations on the soil exchange complex. McIntyre (1979) found that a SAR value above 5 would cause Australian soils to disperse thereby decreasing the infiltration rate and reducing the hydraulic conductivity. Table 3 lists the SAR values obtained for each site. Sites 3, 4, 8, 9 and 16 all exhibit SAR values above 5 and correspond to observed failed sites.

Comparing the soil sampling results at the piezometer locations and the control site, it was evident that during the years of operation of the effluent disposal field, a significant increase in Na concentration had occurred together with a decrease in Ca concentration through the soil profile. The detrimental impact of an increase in Na concentration associated with a reduction in Ca concentration is the increased hazard of clay particle swelling and dispersion (Jnad and others 2001).

Table 3 SAR values from project sites[a]

Site	SAR values for different sampling episodes			
	1	2	3	Average
1	3	4	3	3
3	6	6	7	6
4	4	3	5	4
7	3	3	4	3
8	4	4	5	4
9	5	4	5	5
11	2	2	3	2
12	4	5	4	4
14	2	3	2	2
15	2	2	2	2
16	9	8	7	8

a Samples were taken from the distribution box; Only sites where soil water samples were collected have been included.

Soil pH values in both, the effluent disposal and control areas, were generally found to be low and typical of the acidic leached nature of soils in South East Queensland, Australia. In well drained sites, increases in pH were small or negligible throughout the profile, while in imperfectly to poorly drained sites pH changes of up to 1.5 pH units were observed across most soil types. The data given in Table 4 illustrates this conclusion.

Subsurface effluent travel

In the case of Sites 1, 3 and 8, the 'A' horizon exhibited increased pH levels compared to the control sites indicating that significant lateral movement of effluent was taking place. This was supported by the presence of a highly saturated 'A' horizon at these sites. Also the results of the drainage evaluation indicated saturation zones at the top of a restrictive horizon. The EC data given in Table 5 also indicated the lateral movement of effluent through the more permeable surface layers.

In a number of sites, the 'B' horizon showed signs of redoximorphic features such as free water, presence of mottling and iron accumulation. This indicates a seasonal groundwater table during wet periods (Gross and others 1998). These characteristics point to significant lateral percolation of effluent through the soil profile. It is logical to expect that this phenomenon will be even more pronounced during rainfall periods. Under these circumstances, flow of effluent into surface water bodies is a distinct possibility.

Table 4 pH results for soil samples[a]

Site No.	Drainage Category[b]	$pH^{c}_{control}$	pH_{1metre}	pH_{3metre}
1	MW	5.6 – 7.4	6.6 – 6.7	7.2 – 7.0
3	I	5.3 – 5.0	6.4 – 5.7	6.4 – 5.2
4	I	4.8 – 4.4	4.8 – 4.4	4.9 – 4.5
7	MW	5.7 – 7.7	5.4 – 6.2	5.5 – 7.2
8	P	5.7 – 4.6	6.2 – 6.2	6.2 – 5.8
9	P	6.7 – 5.5	6.4 – 6.1	6.2 – 5.8
11	W	5.4 – 6.0	5.5 – 6.7	6.8 – 7.3
12	MW	4.9 – 4.9	4.6 – 4.9	4.6 – 4.9
14	MW	5.0 – 4.9	6.8 – 6.9	7.1 – 6.6
15	I	4.8 – 4.0	5.0 – 3.7	5.0 – 3.8
16	P	4.6 – 4.0	6.0 – 4.6	5.7 – 5.5

a Not all sites were tested due to insufficient sample collection.
pH values given are an average of duplicate samples and presented as A – B Horizons.
b W - Well Drained; MW – Moderately Well Drained; I – Imperfectly Drained; P – Poorly Drained
c $pH_{control}$, pH_{1metre}, pH_{3metre} refer to the samples collected at the control site and the two piezometers.

Table 5 EC results for soil samples[a]

Site No.	Drainage Category[b]	$EC^{c}_{control}$ mS/cm	EC_{1metre} mS/cm	EC_{3metre} mS/cm
1	MW	0.2 – 0.06	1.41 – 4.35	1.55 – 1.65
3	I	0.12 – 0.05	0.26 – 0.12	0.12 – 0.24
4	I	0.08 – 0.12	0.06 – 0.17	0.07 – 0.09
7	MW	0.17 – 0.22	0.28 – 0.26	0.37 – 0.21
8	P	0.14 – 0.55	1.08 – 0.95	1.79 – 1.12
9	P	0.07 – 0.24	1.16 – 1.36	1.44 – 1.37
11	W	0.3 – 0.08	0.33 – 0.97	0.28 – 0.12
12	MW	0.12 – 0.13	0.09 – 0.12	0.11 – 0.08
14	MW	0.15 – 0.05	2.04 – 5.14	0.75 – 1.70
15	I	0.12 – 0.07	0.41 – 0.15	0.41 – 0.12
16	P	0.20 – 0.09	0.13 – 0.21	0.12 – 0.20

a Not all sites were tested due to insufficient sample collection.
pH values given are an average of duplicate samples and presented as A – B Horizons.
b W - Well Drained; MW – Moderately Well Drained; I – Imperfectly Drained; P – Poorly Drained
c $pH_{control}$, pH_{1metre}, pH_{3metre} refer to the samples collected at the control site and the two piezometers.

Comparing the electrical conductivity and chloride concentration values in the soil at the two piezometer locations, it was found that in some cases the values obtained at the second piezometer (3m from edge of disposal area) were higher than the first (1m from edge of disposal area). Figures 5a and 5b show typical examples of this occurrence (Sites 1 and 14). This was postulated to be due to effluent percolating through the 'A' horizon in dilute pulses from the absorption trenches during periods of saturation. Similar observations were also reported by Brouwer and Bugeja (1983). Saturated conditions would initially form closest to the trench and then the effluent would move through the soil profile forming fronts of elevated parameter levels.

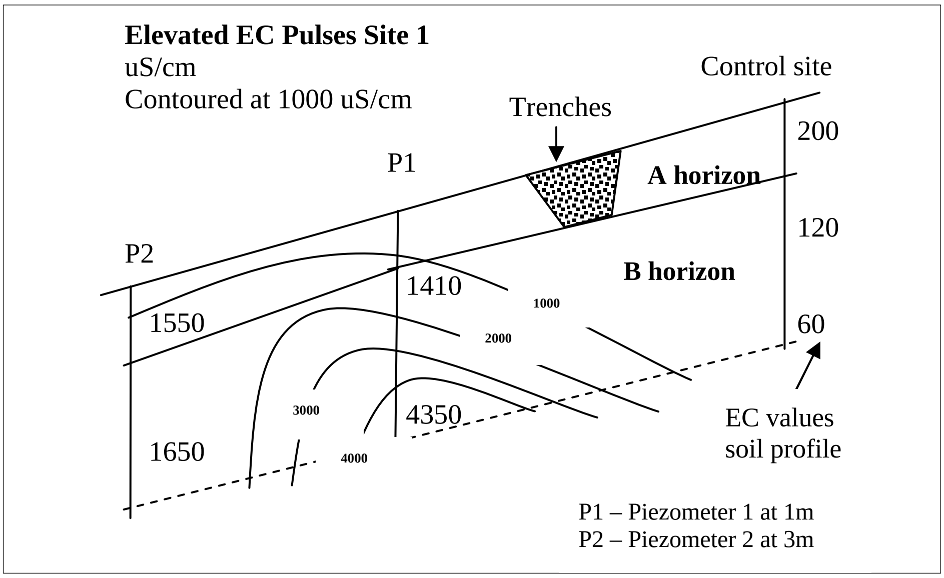


Figure 5a Elevated EC pulses Site 1

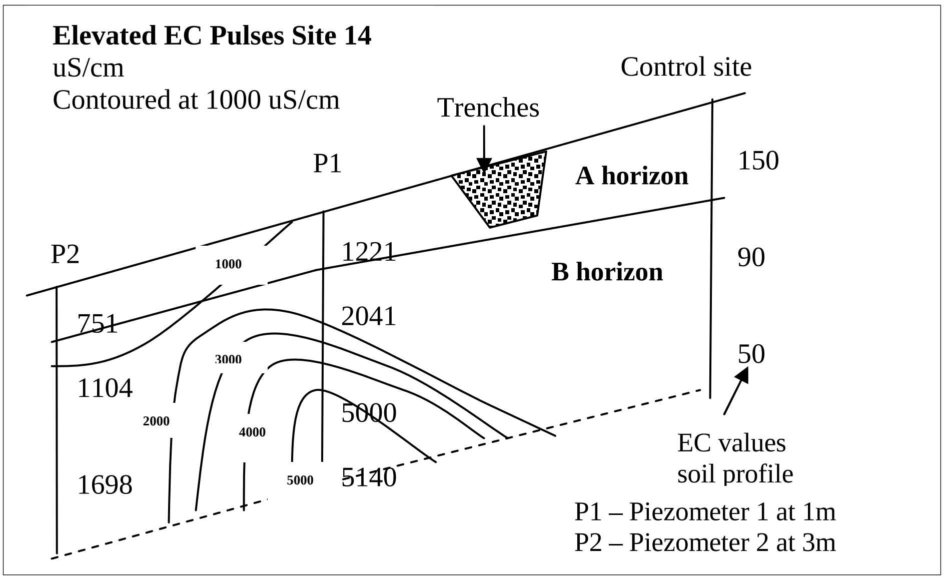
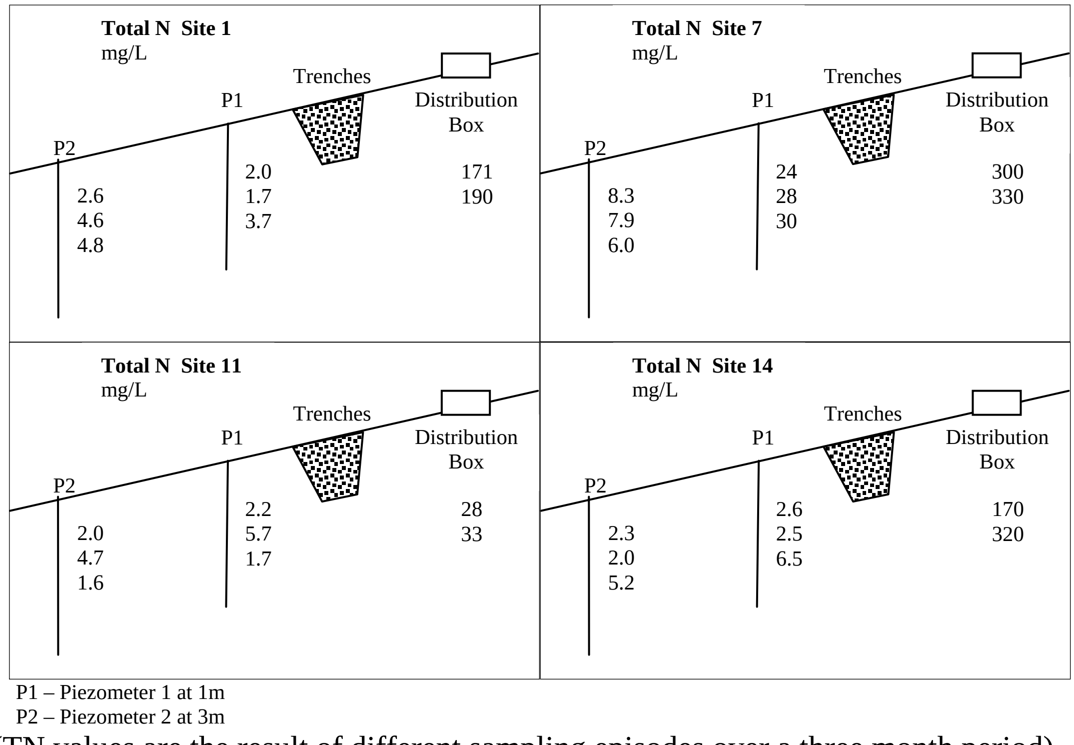


Figure 5b Elevated EC pulses Site 14

Effluent renovation

Effluent renovation refers to the removal and/or assimilation of wastewater pollutants leading to an improving of its quality. The natural soil system offers a medium for not only absorbing pollutants but for treating and utilising waste constituents. The porous nature of soil can provide an ideal media for absorbing and transmitting effluent. A sinuous flow path through soil pores that is neither too rapid nor too slow allows for a variety of natural treatment processes to take place. Purification occurs through physical filtration, chemical treatment through ion exchange, adsorption and transformation, biological decomposition by micro-organisms as well as enrichment of the nutrient pool for uptake by plants.

Based on the soil water sampling results, it could be surmised that the improvement in soil water quality appeared to take place within the initial 1m (piezometer 1) of travel. An appreciable further improvement in quality was not apparent between the 1m to 3m (piezometer 2) distance. This is illustrated in Figure 6 which shows the results for Total Nitrogen on several well-drained sandy loam sites. These sites are typical of the moderate to well-drained sites investigated in the study.



(TN values are the result of different sampling episodes over a three month period)
Figure 6 Soil water sampling for total nitrogen

The improvement in Total Nitrogen was comparable to other similar studies (for example Sherman and Anderson 1991; Gerritse and others 1995). It is important to note that the above conclusions relate only to the degree of quality improvement that is obtained. This does not necessarily mean that the quality that is obtained is satisfactory.

This finding could be interpreted to mean, that while the concentration of pollutants may be expected to decrease with distance of effluent travel due to dilution, the total pollutant quantity percolating into a water course or aquifer will be finite. This amount would be determined by the soil processes taking place in the initial few metres of travel. Therefore, under these circumstances, the most important criteria for preventing the contamination of water resources due to sewage effluent disposal would be the density of treatment systems in a given area. This is based on the premise, that the amount of pollutants removed from sewage effluent will be determined by the soil characteristics while the remainder of the pollutants will eventually percolate into the groundwater. Therefore in a given area, the total quantum of pollutants percolating into the groundwater will be determined by the density of on-site sewage treatment systems. This will be a crucial issue particularly in the case of poor soil conditions or environmentally sensitive groundwater resources.

Subsurface drainage

The subsurface characteristics of the disposal area are among the most important factors governing the performance of effluent treatment processes (Bond 1998; Jenssen and Siegrist 1990). Purification will occur within a minimum depth of unsaturated soil beneath the disposal trenches. In this context, effective depths ranging from 0.6m to 2m have been quoted in research studies (Johnson and Atwater 1988; Mote and others 1995; Siegrist and Van Cuyk 2001).

A strong correlation between the depth to the restrictive horizon measured at a site and observed treatment performance was noted from the study results. Observed performance was defined by field observations, detailed site history obtained from the householder and surface and subsurface site conditions noted during the study. In cases where the restrictive horizon was less than 0.4m from the surface, inadequate purification of effluent was the general outcome.

During the study, sites were categorised, initially by their landscape position along with subsurface drainage, and climate factors. Where the soil profile evaluation supported the drainage characteristics of the site as favourable, no further detailed chemical analysis was warranted. In the case of poor drainage, detailed soil chemistry was a valuable tool in predicting site suitability for long-term effluent disposal. Very poorly drained sites can be deemed unsuitable for on-site sewage disposal, especially in small lot developments even without further investigations. An example was a 'duplex' soil at Site 3, which was thought to be moderately drained based on its position on the landscape. The initial investigations supported this conclusion with the soil being described as sandy loam. However, the detailed soil profile evaluation at the control site revealed the presence of a clay-enriched zone at the top of the 'B' horizon at 0.6m. Subsequent soil chemistry revealed low Ca:Mg ratio and high exchangeable Na, low CEC (or ECEC) and the exchange capacity being dominated by exchangeable Mg. These results indicated that poor soil conditions exist for effluent disposal. Conclusions of this nature could only have been derived from soil chemical analysis. It was subsequently confirmed that the house owner had replaced a failed septic system due to constant overflowing and waterlogging of the disposal trenches. This highlights the importance of detailed site and soil evaluation and confirms the strong site specific nature of effluent renovation.

Satisfactory drainage is crucial even in the case of surface irrigation of treated effluent, due to the possible accumulation of salt on the surface. Where salt is continually added to the soil by the effluent, it is important that there is continuous movement of water for leaching of salt through the profile. Without this continuous leaching, salt can build up to levels that may be harmful to the landscape and vegetation. Figure 7 shows a typical example of this high accumulation of salt at the A/B horizon interface at the two piezometer locations when compared to the salt concentration at the control site.

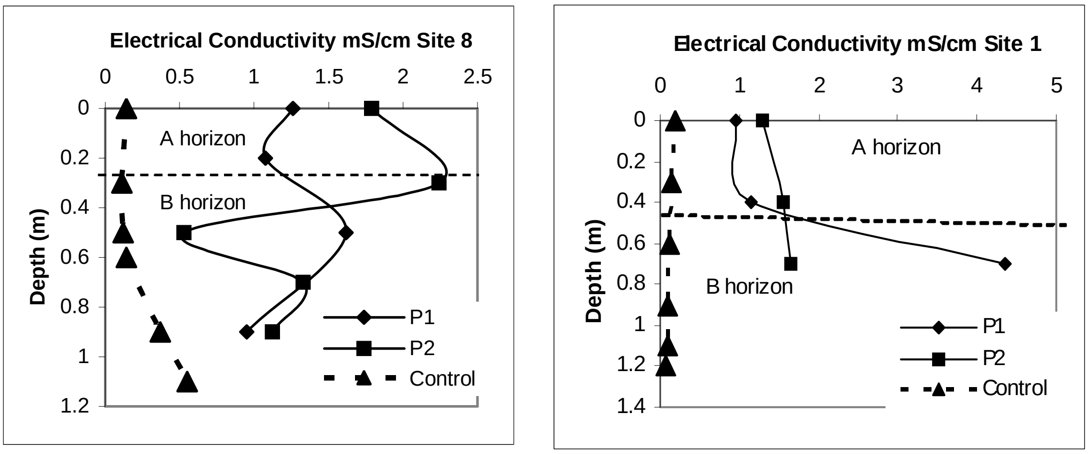


Figure 7 Salt profile after effluent disposal

Landscape factors

A comprehensive site assessment can help to define the limitations of a site for effluent disposal. It should take into consideration factors such as:

1. topography, drainage and aeration of soil and whether there is soil movement downslope;
2. climate such as temperature, rainfall and evaporation as these factors influence profile development through leaching and weathering;
3. parent material which exerts the primary control on soil development;
4. native vegetation which reflects the nutrient status, transpiration and water availability; and
5. biological activity which can impact on infiltration and water storage in the soil.

(White 1997, McDonald and others 1998; McIntosh and others 2000)

This assessment can be supported by the observation and description of colour, texture and structure of the soil which can be used to qualitatively assess the hydrology of the soil profile while the physico-chemical soil data can provide an insight into soil stability and its ability to absorb applied nutrients (Bridge and Probert 1993; Phillips and Greenway 1998). Many Australian soils have ‘duplex’ profiles. These are soils that have a impermeable ‘B’ horizon and when they occur in an undulating landscape can develop perched water tables, which predisposes to reducing conditions and gleying and mottling in the profile (White 1997). It is sites of this nature that can be problem sites for effective effluent disposal and need characterising carefully by a combination of site factors along with chemical and physical soil criteria.

Generally in undulating landscapes on permeable material, the soils near the top of the slope tend to be free draining with the watertable at depth, while the soils at the valley bottom are poorly drained with the watertable at or near the surface. The succession of soils forming under different drainage conditions on relatively uniform parent material comprises a hydrological sequence. This is illustrated in Figure 8 (from White 1997) and was used to classify sites into drainage classes as given in Table 1. The results of the study undertaken confirmed that by determining the site location, its position in the landscape, slope and other relevant topographic features, that it is possible to determine whether more detailed soil chemical investigations are justified.

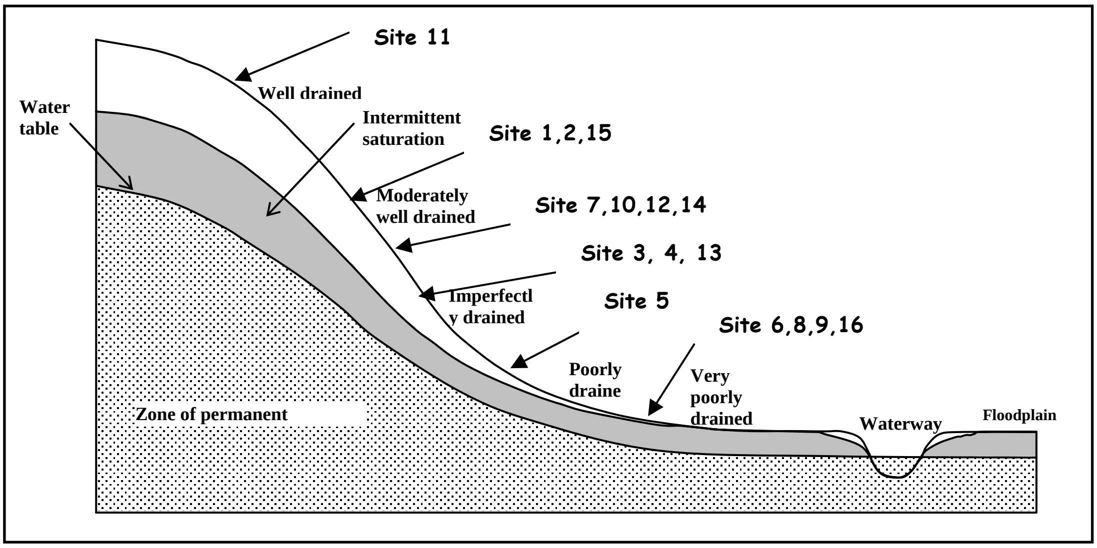


Figure 8 Approximate location of sites in a landscape catena

Summary

The research project undertaken evaluated site and soil parameters influencing the performance of subsurface effluent disposal systems and identified correlations between these parameters and drainage factors. The subsurface characteristics of the disposal area play an important role in governing effluent treatment performance. Appreciable changes in parameters such as exchangeable cations, pH, EC and CEC (or ECEC) due to the subsurface application of sewage effluent were noted. These parameters generally define the ability of soil to renovate sewage effluent. Additionally, there is a strong correlation between the depth to the restrictive soil horizon at a site and the treatment performance. In cases where the depth to restrictive horizon was less than 0.4m, inadequate purification of effluent was the common outcome.

In a majority of the sites investigated, the effluent treatment quality achieved within the initial 1m of travel was close to the final quality. This would mean that while the concentration of pollutants may decrease with distance due to dispersion and dilution, the total pollutant quantity percolating into groundwater is determined by the processes occurring in the initial few metres. Therefore, the most important criteria for preventing the contamination of water resources due to sewage effluent disposal would be to ensure setback distances are maintained and the density of treatment systems is reduced in areas where soils are inadequate for effective effluent treatment. This was compounded by the fact that subsurface soil conditions at a number of sites indicated that significant lateral movement of effluent was a common occurrence. Under these circumstances, flow of effluent into surface water bodies is possible. Saturated conditions would initially form close to the trench and then move through the soil profile forming fronts of elevated pollutant levels.

The above conclusions underlie the importance of a comprehensive site assessment which can assist in defining the limitations of a site with regards to effluent disposal. Factors such as topography, climate, parent material, and biological activity in the soil should be taken into consideration. This assessment can be supported by the observation and description of colour, texture and structure of the soil which can be used to qualitatively assess the hydrology of the soil profile.

Soil chemistry in conjunction with soil physical characteristics and drainage factors was an invaluable predictive tool for evaluating the long-term performance of effluent disposal systems. However, soil chemistry does not necessarily add value to a suitability assessment in the case of a well-drained site on an upper position on a landscape catena. Its greater value is in the case of soils in the lower position in the landscape. These soils generally exhibit poor drainage and need further evaluation and characterisation in terms of soil physical and chemical analysis to assess their suitability for effective effluent disposal. Very poorly drained sites can be deemed unsuitable for subsurface effluent disposal especially in small lot developments even without further analysis.

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