CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD

LAHONTAN REGION

STAFF REPORT

ON

SEPTIC TANKS IN THE VICTOR VALLEY

MAY 1987

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The Victor Valley, which consists of the communities of Adelanto, Apple Valley, Hesperia, Oak Hills, Phelan, Victorville and other small communities, has experienced tremendous growth within the last few years with most of the growth is occurring in the unsewered portions of the Valley. This increase in wastewater discharges from septic tank/subsurface disposal systems, especially in areas of high density development, can be expected to contribute to accelerated pollution of the groundwater basin in the Victor Valley area.

PROBLEM STATEMENT

The Victor Valley's unsewered communities pose a threat to the area's drinking water source. A 20-mile section of the upper portion of the Mojave River flows through the center of the Valley. Domestic water supply wells are scattered throughout the Valley among high density developments served by septic tank-seepage pit wastewater disposal systems. The use of seepage pits is particularly troublesome because wastewater is introduced 20 to 40 feet below ground surface where evapotranspiration is minimized.

The population growth of the Valley has changed the area from a desert hub area to a large-scale urban fringe. This transformation began in the mid 1970's, with the most dramatic growth occurring between 1983 and 1986 (from a population of 76,500 to 137,400). This increase puts the present unsewered population at between 90,000 and 100,000. The subsurface discharge from this development ranges from 9 to 12 million gallons per day of partially treated liquid sewage. At the present growth rate, the population will double the existing level by 1990 (Figure 1).

Domestic, commercial and industrial sewage discharged to the soil through septic tank/subsurface disposal systems, contains a number of constituents which contribute to deterioration of groundwater quality. These constituents include pathogens (bacteria and virus), phosphorous, detergents, trace organics (household products including pharmaceuticals, disinfectants, deodorants, polishing agents, cleaning materials, cosmetics, paint and pesticide products) and nitrogen. Of these, nitrogen is the most likely to affect the groundwater first. Nitrogen combines with oxygen to form nitrate, which is extremely soluble in water and essentially conservative under these conditions. The average values reported for septic tank effluent range from about 35 to 45 mg/l total nitrogen measured as nitrogen. The State drinking water limit for nitrate as nitrogen is 10 mg/l. Approximately 15 percent of the recharge to this basin is septic tank system effluent. Based on these values, the average recharge to the entire groundwater basin contains approximately 5 to 7 mg/l nitrogen.

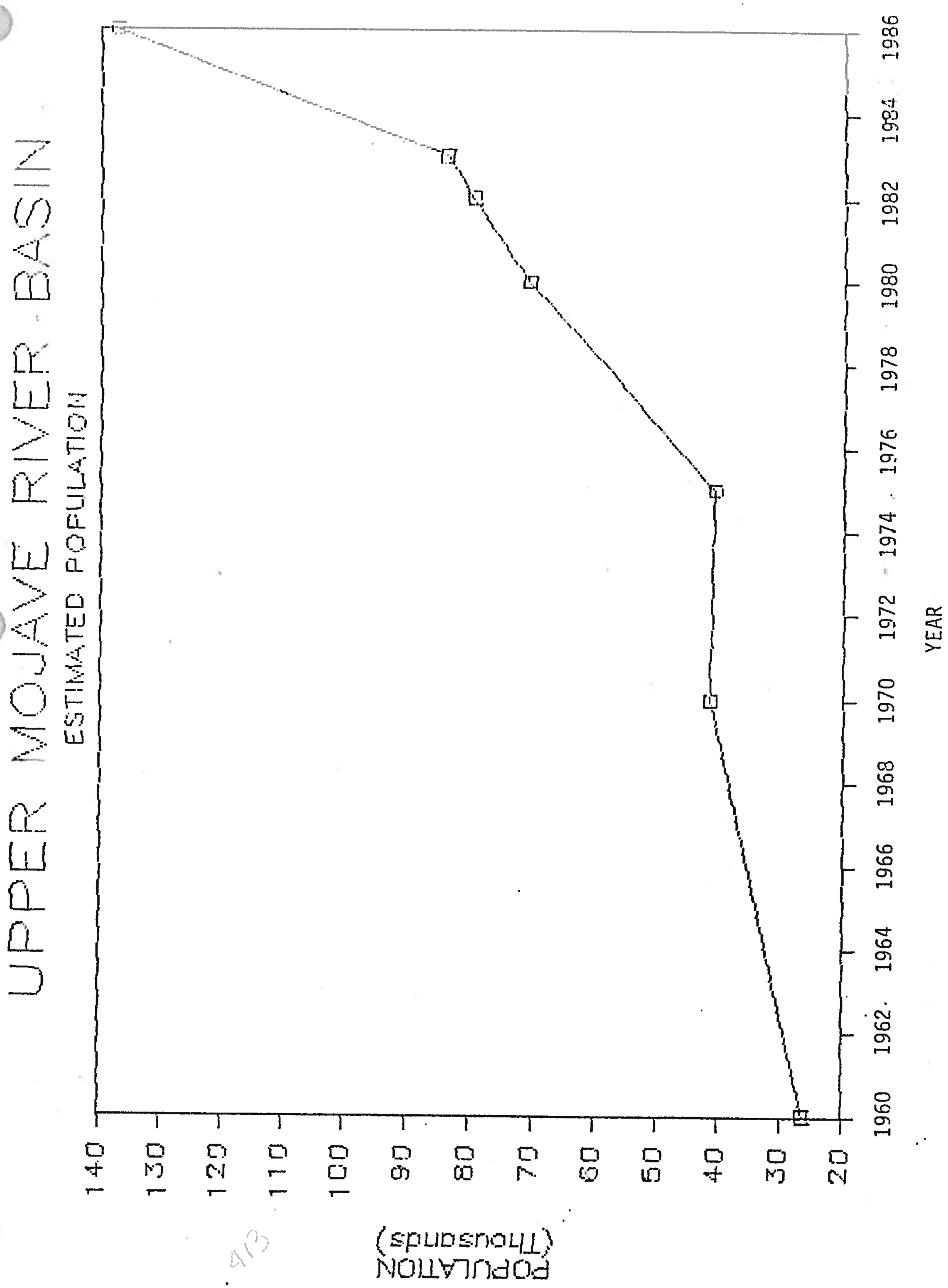


Figure 1

18000 = .413
5000 =

The Victor Valley Wastewater Reclamation Authority (VVWRA) treatment plant was constructed in 1981 to treat sewage generated within the Valley and discharge it downstream of the water supply wells that serve the area. The sewer systems connected to the treatment plant serve only a very small portion of the Valley. Sewerage systems have not been expanded to serve all of the needed areas. The VVWRA now faces having to pay back grant funds for under utilization of interceptor sewers.

Due to the slow downward migration of effluent through soil, the adverse impacts of septic tank systems to the area groundwater may not be known until groundwater degradation has already occurred. However, once the contaminants are introduced into the ground, their effects will continue to be felt for many years to come.

Considering the number and location of existing septic tank/seepage pit systems, in the Victor Valley, it is highly probable that there will exist:

1. Small pockets of groundwater underlying densely developed areas (individual lot sizes of less than half acre) with nitrate concentrations exceeding 10 mg/l as nitrogen.
2. Large pockets of groundwater underlying large areas of medium density (individual lot sizes of between half acre and five acres) with nitrate concentrations in excess of background levels.

AREA DESCRIPTION

The Victor Valley area encompasses approximately 600 square miles, bounded on the south by the San Bernardino Mountains; on the east by Lucerne Valley and the Granite and Sidewinder Mountains; on the west by a topographic high which forms a drainage divide between the Upper Mojave Subunit and the adjacent El Mirage Basin; and to the northeast and north by Shadow Mountain, Helendale Fault, and a low-lying drainage divide southerly of Buckhorn Wash. The population is concentrated along the Mojave River, which bisects the basin from south to north (1).

The Victor Valley area is primarily a high desert environment. Typical of this kind of environment is low rainfall and high evapotransipiration. The average rainfall in Victorville is approximately 5.0 inches per year with evapotransipiration ranging around 70 inches per year.

AREA GEOLOGY

For the purpose of a brief geologic description of the Victor Valley area, this report will divide the geologic units into two broad categories: non-water bearing and waterbearing.

The waterbearing unit is of major concern to the people of the Victor Valley. This geologic unit consists of semiconsolidated to unconsolidated continental and lacustrine deposits which underlie the basin between the mountain boundaries. These deposits range from coarse gravels to clays, with gravels and sand being predominant. These waterbearing formations were deposited from erosion of adjacent highlands, forming a large alluvial apron. These fan deposits are interrupted by the Mojave River which cuts a channel through both the coarse and fine grained sediments (1). The channel is filled with coarse grained, permeable river deposits. Much of the waterbearing unit has a subsurface caliche zone several feet below the surface. Caliche is formed by calcium being carried by rain water several feet below the surface, the water then evaporates, leaving a calcium precipitate. This forms an impermeable subsurface zone in the soil which prevents the deep percolation of the minimal amount of rainfall which does fall.

Because of the high evaporation rate, the low rainfall, and the impermeable caliche zone; the main water recharge for the basin comes in the form of runoff from the surrounding mountains. Very little deep percolation of rain water occurs . The total average yearly recharge for the basin is 78,710 acre-ft, with 76,360 acre-feet coming by way of surface flows from the Mojave Forks area (Figure 2). The remaining recharge is 850 acre-ft from the Sheep Creek Watershed, 500 acre-ft from the Lucerne Valley area and 1,000 acre-ft from Summit Valley (Figure 2) (1). The outflow from the Upper Mojave River Basin at the Helendale Fault is approximately 37,400 acre-feet (1).

Depth to groundwater in the area ranges from zero feet near the Mojave River to several hundred feet in some outlying areas. In general, depth to groundwater changes with local changes in topography and increases with increased distance from the river.

DOMESTIC WASTEWATER SUBSURFACE DISCHARGE, VICTOR VALLEY

In the Victor Valley, the two most common onsite wastewater subsurface disposal methods are seepage pits and leach trenches. The use of seepage pits predominate because they penetrate through the impermeable caliche zone and require little surface area. The trench systems that are used in the Victor Valley tend to be located near the Mojave River where the caliche has not formed because the groundwater is near the surface, and the calcium is not allowed to precipitate out in the soil.

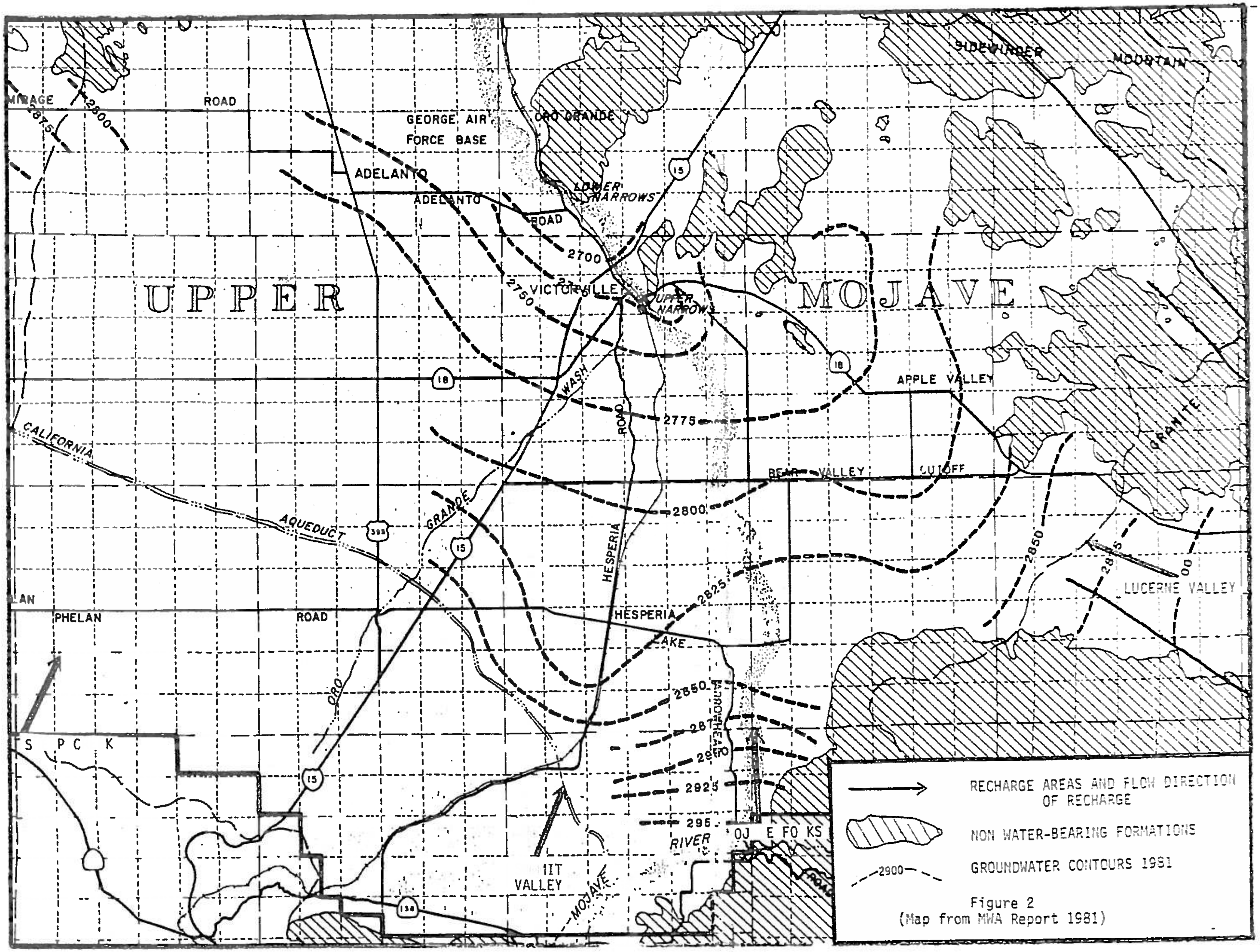


Figure 2
(Map from MWA Report 1981)

Seepage pits are deep excavations used for subsurface disposal of wastewater. Covered, porous-walled chambers are placed in the excavation and surrounded by gravel or crushed rock (Figure 3) (2). Wastewater enters the chamber where it is stored until it seeps out through the chamber wall and infiltrates the sidewalls of the excavation. The size of the pit varies according to the anticipated discharge. Typically, they are 20 to 40 feet deep with a diameter of 2 to 5 feet.

Trench systems are normally the most common method of onsite wastewater disposal in other parts of the country. Trenches are shallow, level excavations, usually one to five feet deep and one to three feet wide (Figure 3). The bottom six inches or more are filled with washed crushed rock or gravel. Lain on top of this rock or gravel is a single line of perforated distribution piping. Crushed rock is placed over the pipe. Finally, a suitable, semi-permeable barrier is placed on top of the crushed rock to prevent backfill from penetrating the rock. The bottom and sidewall of the trench are the infiltrative surfaces (2). These systems may differ in size and the number of distribution pipes placed in the trench.

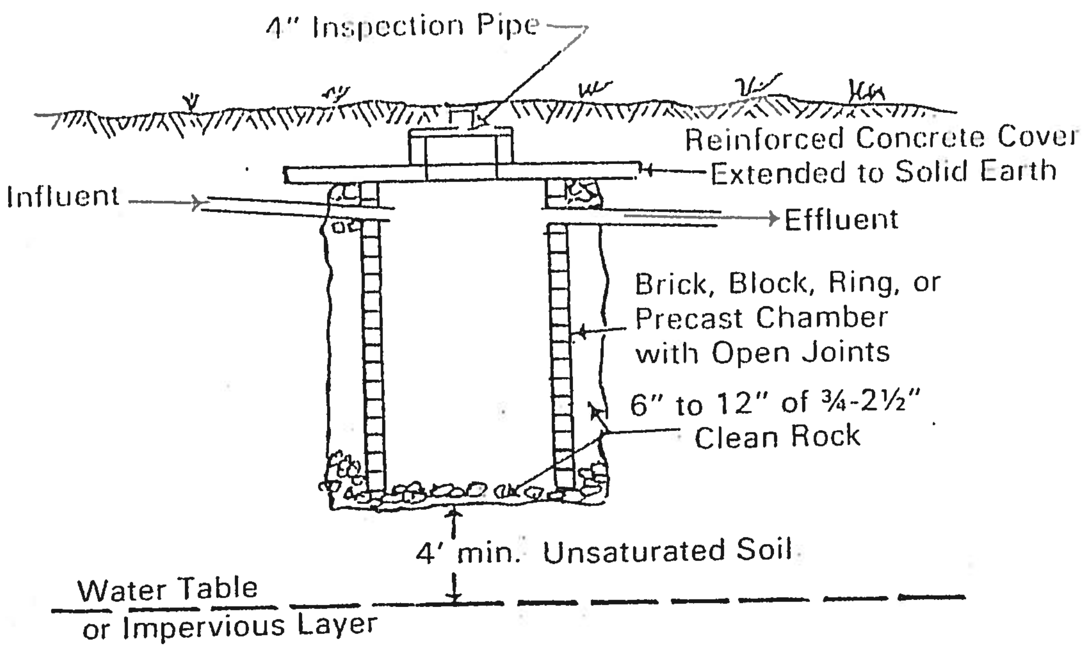
SEPTIC TANK/DISPOSAL SYSTEM CONTAMINANT TRANSPORT

Nitrogen

Nitrogen and other contaminants are introduced into the septic tank in the form of organic material (human waste, garbage, etc.) (Figure 4). Much of the nitrogen stays in the septic tank, bound up with other organic matter, as sludge which is ultimately pumped out and disposed of at landfills. Some of the nitrogen, 45 mg/l on the average; mostly in the form of ammonia (NH_3), is transported with the wastewater from the septic tank to the seepage pit (3, 4, 5, 6, and 7). In the seepage pit itself, and within the top few feet of soil below the seepage pit, the unstable ammonia nitrogen is converted to stable and highly soluble nitrate. Nitrogen is not taken up into plant matter when seepage pits are used because the wastewater is introduced below the root zone.

The nitrogen concentration in septic tank effluent remains at about 45 mg/l (as N) on the average (3, 4, 5, 6, 7 and 8). Once the nitrate is in the soil, it will remain substantially unchanged and unaffected (3, 6 and 7). This is especially true for the sandy-gravelly loose grain soils normally encountered in the Victor Valley area (3, 4, 5 and 9). In some applications of septic tank/leachfield disposal systems significant nitrate can be removed by the denitrification process. This would most likely occur in tight clayey soils. Under these conditions an organic mat will develop under the leachfield. The mat brings together an anaerobic environment and the necessary nutrients to facilitate the denitrification process. This would not likely occur under the conditions which exist in the Victor Valley.

SEEPAGE PIT CROSS SECTION



TYPICAL TRENCH SYSTEM

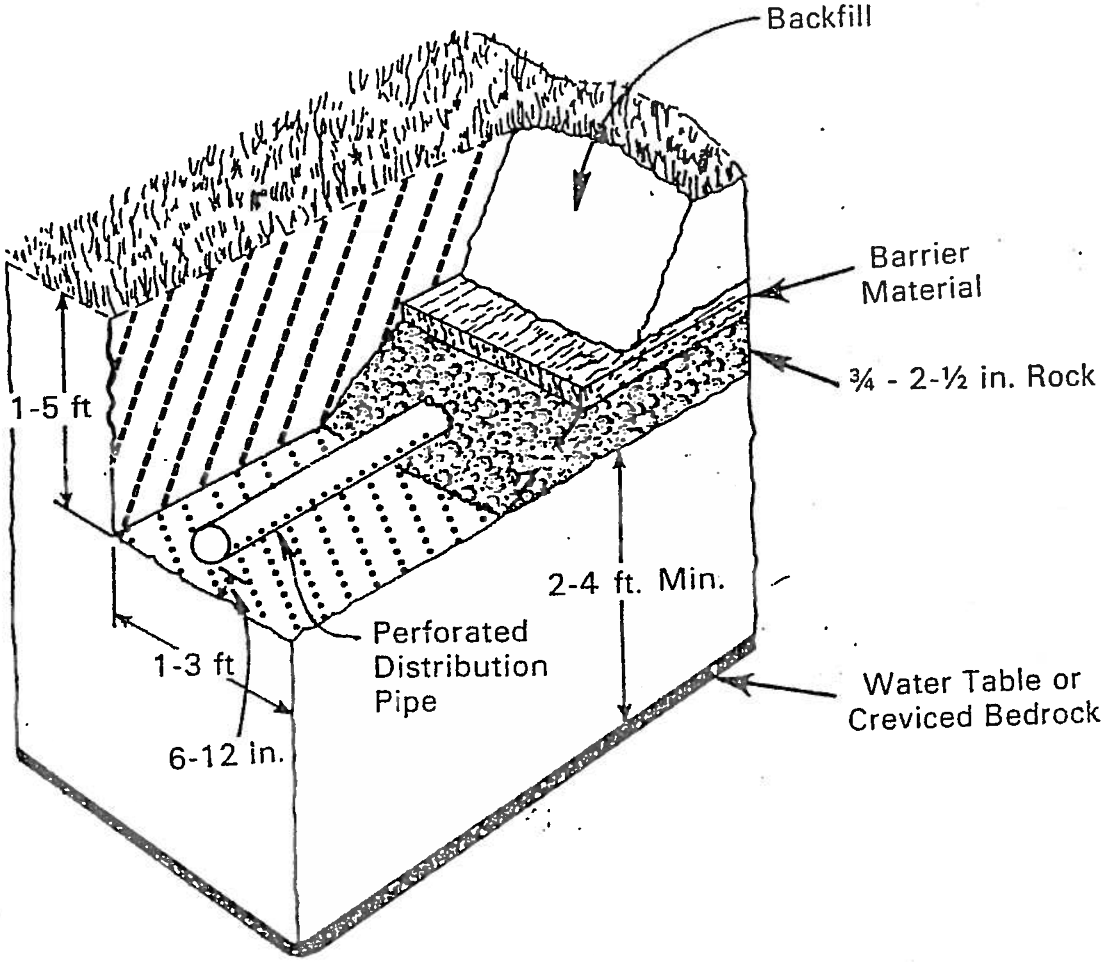


Figure 3
(From EPA Design Manual on "Onsite Wastewater
Treatment and Disposal Systems," October 1980)

FATE OF NITROGEN WITH SUBSURFACE DISPOSAL

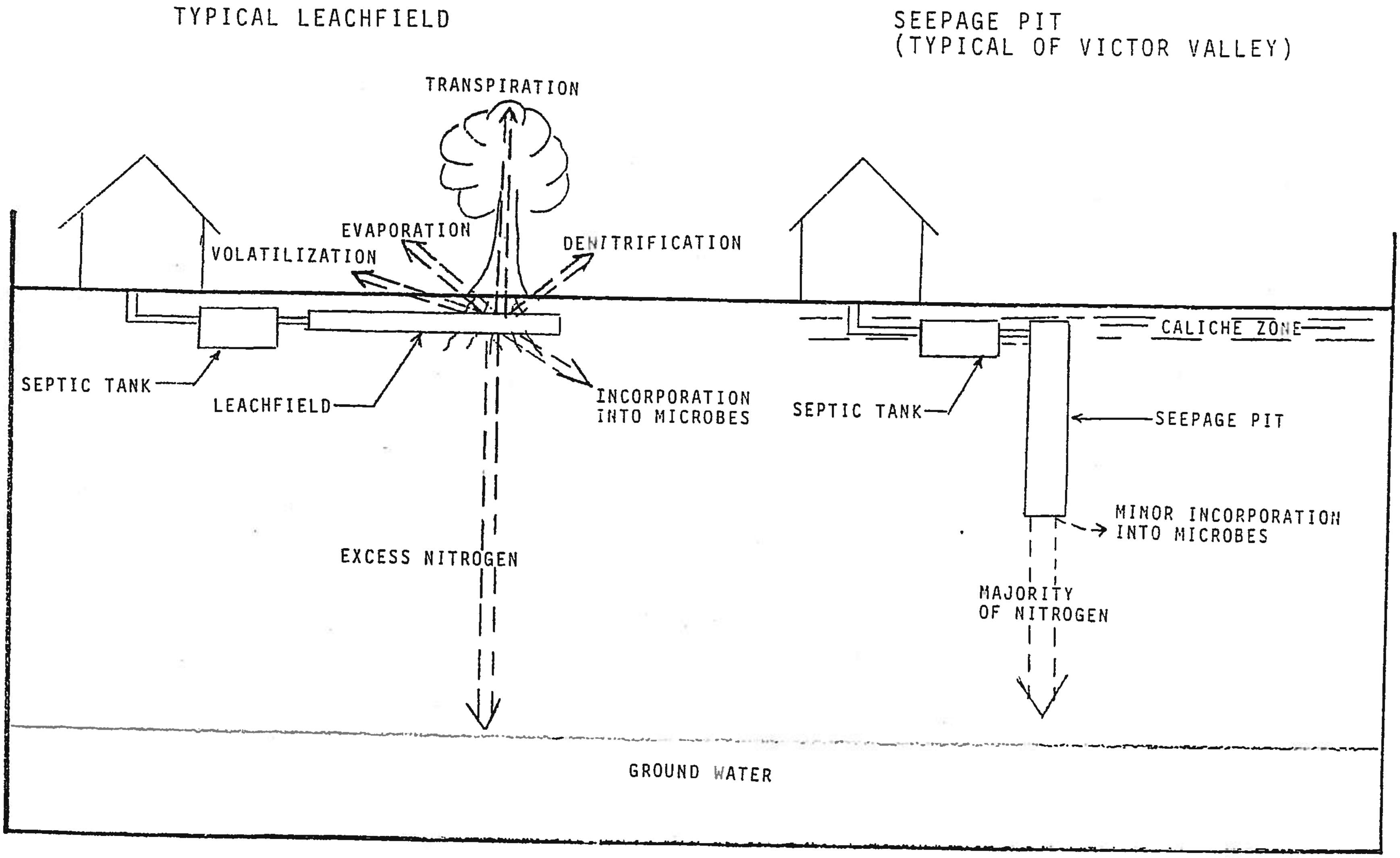


Figure 4

Nitrate moves down through the soil and ultimately ends up in the groundwater. This is known to occur from our past experience with nitrate contamination from specific agricultural and domestic sources here and around the country (3, 4, 5, 6, 7, 8, 9, 10 and 11). Nitrate travels to the groundwater at essentially the same rate as the discharged wastewater. The rate at which the wastewater travels depends primarily upon two things, hydraulic driving force (the amount of wastewater discharged to a specific size area) and soil transmissivity (the rate at which water can flow through a given soil). The discharge from a large apartment complex to a few closely spaced seepage pits will create a large hydraulic driving force which causes contaminants to reach groundwater quickly.

Wastewater that reaches groundwater will tend to exhibit groundwater mounding and laminar flow (Figure 5) (14 and 15). As a result, under high density development we are likely to see pockets near the groundwater surface with nitrate concentrations exceeding 10 mg/l as nitrogen. Under large areas of medium density development (0.5 to 5 acre lots) we would see slow diffusion of contaminated wastewater into the groundwater, which, given the strength and quantity of the wastewater, would result in large areas of groundwater contamination in excess of background levels (3, 4, 7, 8, 9 and 10). As groundwater moves horizontally, under natural and artificial forces an area wide general degradation of the groundwater could result (7, 8, 9 and 10).

Phosphorus

The total phosphorus in influent wastewater to septic tank systems serving single household units averages 25 mg/l (3). Eighty-five percent of this influent phosphorus is converted to water soluble organophosphate which is discharged to the seepage pit (3). Septic tank systems are not efficient in removing phosphorus from the wastewater.

Although phosphorus can migrate through the soil and into the groundwater, this is not a common occurrence because phosphorus is most likely retained in underlying soils due to chemical changes and absorption. In a study by Jones et al (1977) (16), it was confirmed that phosphorus from septic tank effluent is not usually transported through the soil to the groundwater. Therefore, phosphorus contamination of the groundwater aquifer is not a major concern where sufficient soil of optimum particle sizes exist.

FATE OF SEEPAGE PIT EFFLUENT
FROM
HIGH DENSITY DEVELOPMENTS

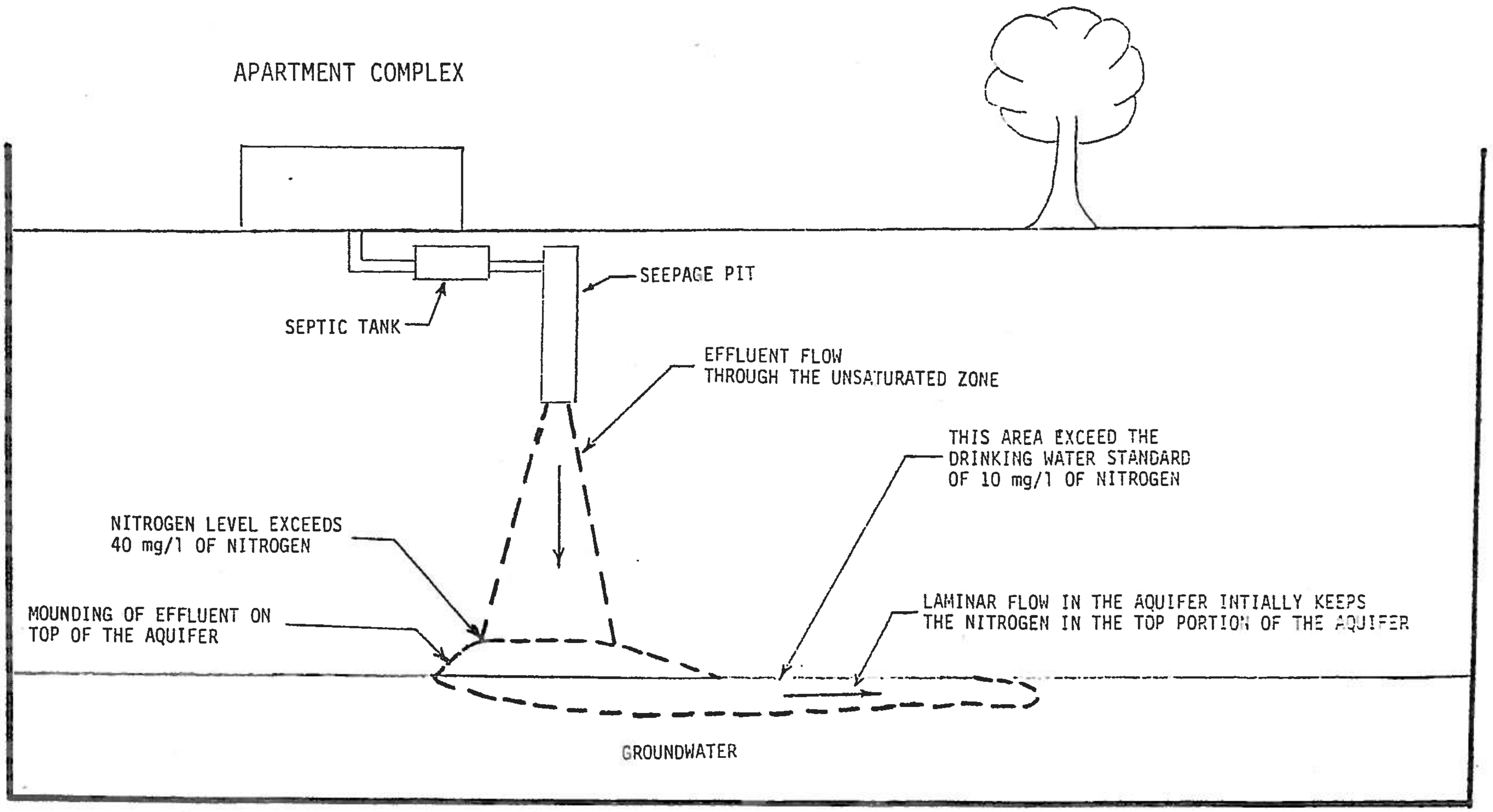


FIGURE 5

Chloride

Chloride is a natural constituent in surface and ground water. It is also found in large quantities in domestic wastewater. Septic tanks and conventional community wastewater systems are ineffective in removing chloride. Due to chloride's negative ionic charge, the mobility of this element in water is extremely high. The transport of chloride through the unsaturated zone to the ground water is likely. Chloride concentrations vary in septic tank effluent and depend on the natural quality of the water supply. This variation ranges from 37 to 101 mg/l (3), which is well below the secondary drinking water standard for chloride of 250 mg/l.

Metals and Other Inorganic Contaminants

Metallic contaminants are quite common in septic tank systems. Arsenic, iron, lead, mercury, manganese, cadmium, copper and zinc are found in domestic wastewater (3). Cadmium and lead are probably found because of the corrosion of antiquated plumbing in older houses (not common in the Victor Valley).

The four major reactions that metals may be involved in with soils are absorption, ion exchange, chemical precipitation and complexation with organic substances. Of these four, absorption seems to be the most important for fixation of heavy metals (positively charged heavy metals are attracted to negatively charged soils).

Soil composition is the most important factor in all heavy metal fixation reactions. Clay, humus and other organic matter are very important in absorption of metals into the soil, because of their high cation exchange capacity (CEC) (high negative charge).

Soil texture or soil particle size is also important for the fixation of metals by the soil. In general, finely textured soils immobilize heavy metals to a greater extent than coarsely textured soils. Also, fine soils have a greater CEC. Soil texture has been found to influence the transport of mercury, lead, nickel and zinc (17).

Differing pH affects mobility and retention of metals in the soil. The pH is the controlling factor in both absorption-desorption reactions and precipitation-solubilization reactions. One reason this happens is that CEC increases with pH. The degree to which the metal is fixed is a function of pH. Soil pH along with CEC are the major factors in the fixation of lead by soils. Soil pH also influences the retention of zinc, molybdenum, mercury and copper (17).

In conclusion, the soils in the Victor Valley lack clay, humus and organic matter, and in turn have low CEC. However, the pH of the soils is slightly basic which aids in the retention of metals. The overall capability of the soils to retain metals is poor. The only distinct advantage this area has for the retention of metals is distance to groundwater, but most likely all other factors outweigh this advantage.

Transport and Fate of Organic Contaminants

Recent evidence indicates that many areas have been contaminated by organic chemicals. Some of these organic compounds are carcinogenic with some compounds found in septic tank systems. The sludge from septic tank systems in New Jersey was found to contain the following: chloroform, methylene chloride, benzene, toluene, trichloroethylene, ethylbenzene and acetone (10). More studies are needed to understand the movements of these compounds in soils and the potential for organic contamination of groundwater in the Victor Valley.

Contamination of groundwater by organic solvents is a growing concern. One gallon of trichloroethylene (TCE), dumped into a septic tank could result in 16,000,000 gallons of groundwater exceeding the drinking water standard (15). The same gallon of (TCE) dumped in a municipal sewer would be biologically treated and/or air stripped prior to discharge.

Transport and Fate of Biological Contaminants

The potential for biological contamination of ground water by domestic wastewater is high. However, pathogens will not always reach the ground water table under all conditions. There are a multitude of factors which influence the distance biological contaminants may travel. The type of soil, as well as the soil temperature, pH, moisture and organic content can aid or hinder pathogen movement. The distance to the ground water and the hydraulic loading rate from the subsurface disposal system also affect the probability contaminants reach the groundwater, as does the amount of precipitation in an area. Table 1 illustrates the possible distances that bacteria may travel under certain conditions.

Nature of pollution	Organism	Media	Maximum observed distance of travel (ft)	Time of travel (days)
Canal water on percolation beds	E. coli	sand dunes	10	-
Sewage introduced through a perforated pipe	coliforms	fine-grained sands	6	-
Oxidation pond effluent	coliforms	sand-gravel	2,490	-
Secondary sewage effluent on percolation beds	fecal coliforms	fine loamy sand to gravel	30	-
Diluted settled sewage into injection well	coliforms	sand and pea gravel aquifer	100	
Tertiary treated wastewater	coliforms	fine to medium sand	20	-
Tertiary treated wastewater	fecal coliforms and streptococcus	coarse gravel	1,500	2
Lake water and diluted sewage	B. stearothermophilis	crystalline bedrock	94	1.25
Primary and treated sewage effuent	coliforms	fine sandy loam	13	-
Secondary sewage	coliforms	sandy gravels	3	-

Table 1: Movement of Bacteria through Soil (Canter & Knox, 1985)

Perhaps the single most important factor is a pathogen's mortality rate. This varies widely and is dependent on the type of pathogen. Under adverse conditions, eneteric bacteria rarely survive more than ten days, but under more ideal conditions, they can survive more than 42 days (3). High moisture, cool soil and moderate pH favor bacterial survival, while low pH, low organic content of the soil and low moisture increases the death rate. There are two soil mechanisms which may remove bacteria from the soil. The first is physical straining. Straining occurs when bacteria are larger than the pore size of the soil. This prevents further downward movement and the straining in turn cause partial clogging of the soil's pore space with organic particles from the septic tank effluent. Clays and silts, because of their small pore space, are particulary efficient at straining. The second process is absorption (element bonding and chemical interaction).

In the Victor Valley, contamination of the groundwater by bacteria is generally not a concern. This is because the distance to the groundwater table is usually over 100 feet. This results in the travel time to the groundwater to exceed the life span of most bacteria. The only area of concern is the Mojave River channel and adjacent land, because of the short distance to the groundwater and the high permeability of the unsaturated zone. Under these conditions, bacteria survival time may be sufficient for pathogens to reach the water table.

DENSITY OF SEPTIC TANKS

The most important parameter influencing regional groundwater contamination from onsite domestic wastewater disposal systems is the density of these facilities in an area. While geology, depth to groundwater and climate affect the nature and degree of the contamination problem, density is the principal factor. Regional problems are extremely difficult to correct because of the complexity and high cost of eliminating the source and the persistence of some contaminants in the groundwater system, long after the septic tanks are eliminated by replacement with community sewer systems (10, 19).

The potential for groundwater contamination in a region is suggested by the relative density of onsite domestic wastewater disposal systems (10, 19). A calculation of the volume of wastewater discharged to the ground from these units in any particular location does not document the existence or magnitude of a groundwater contamination problem. This cannot be done without field verification which requires consideration of other parameters, such as hydrology, geology and soils. However, the actual volume of domestic wastewater discharged to the underground in high density areas can be an indicator of pending groundwater problems. In the Victor Valley, septic tank effluent represents a significant recharge to the local aquifer (10 to 20% of the total recharge to the Victor Valley groundwater).

A literature search conducted by Regional Board staff indicates that the Victor Valley area has potential groundwater contamination problems. The U.S. Environmental Protection Agency (1980) (10) states that any region with a density greater than 40 units/square mile is a region with potential contamination problems. The unsewered population density over the entire 600 square mile Victor Valley area exceeds 100 units/square mile.

A report by Hantzche presented at the Conference of Directors of Environmental Health, 1986 (8) and research done for California Regional Water Quality Control Board, North Coast Region (6) indicate that large lot sizes may be needed to protect groundwater where septic tanks are utilized.

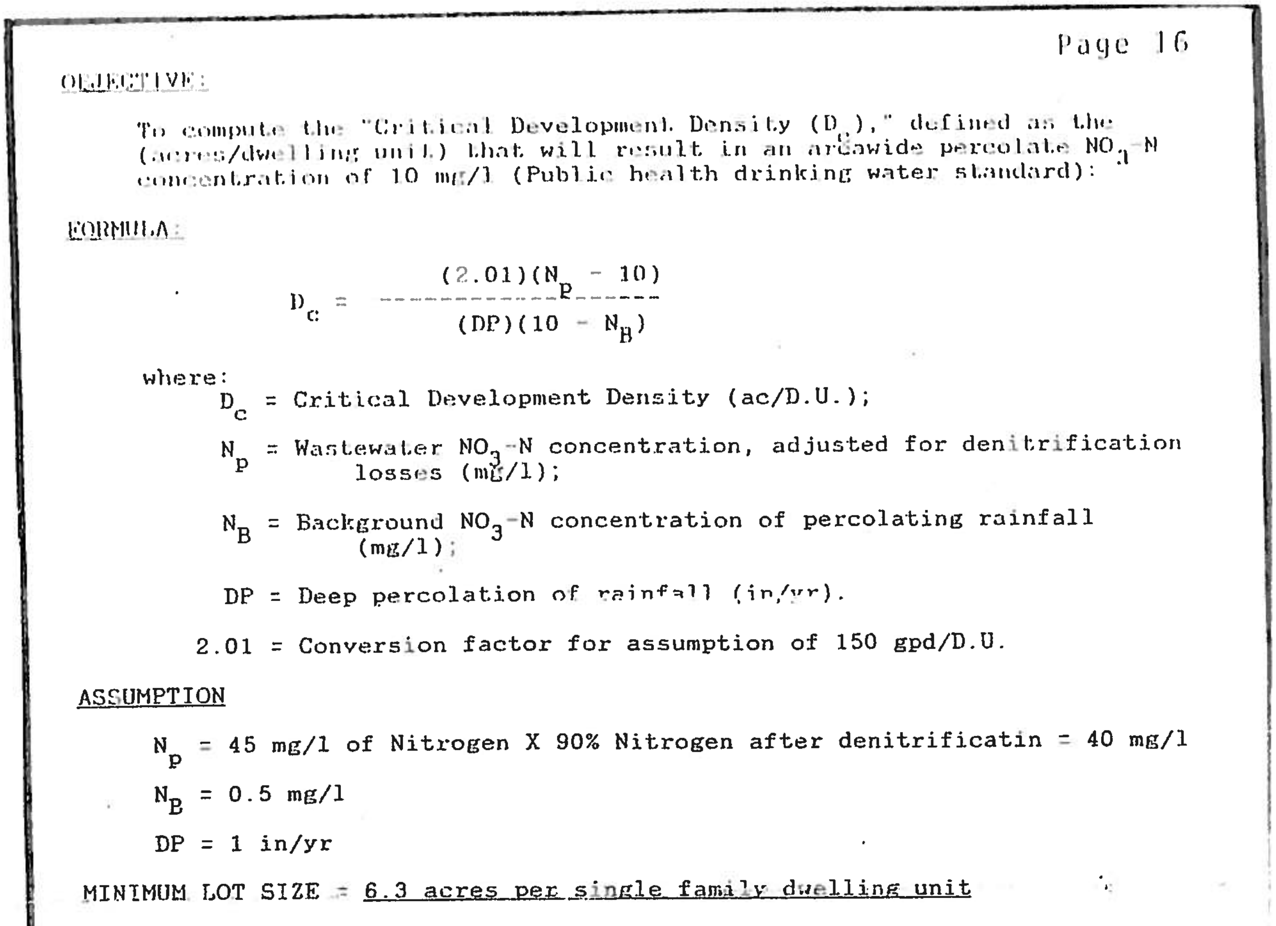
The model takes into consideration local variations in wastewater production per dwelling unit and deep percolation of rainfall. The model can be calibrated based on the level of denitrification which may be estimated based on site specific characteristics of specific disposal systems. The model was calibrated in an area with the following characteristics:

- Depth to groundwater was approximately 10 feet.
- Typical soil type was sandyloam to sand.
- Average annual rainfall was approximately 31 inches.
- Deep percolation of rainfall was estimated to be 14.4 inches/year.
- Wastewater production per household was 130 gpd winter and 240 gpd summer.

Significant variations in the transport mechanisms and biochemical reactions taking place in the soils can occur as the result of changes in the site specific conditions mentioned above. These conditions presented above vary considerably from those in the Victor Valley. Therefore, the model should be field verified under the conditions found in the Victor Valley before any application of the model is attempted.

Figure 6a presents a calculation based on the model presented in these papers which indicates that for the Victor Valley individual lot sizes of 6.3 acres per single family unit may be necessary for long-term groundwater quality protection. When calculating the acreage denity, the optimistic values of one inch of deep percolation of rainfall and 15 percent denitrification were used.

A study called "Preliminary Assessment of Nitrate-Nitrogen Loading Agents and Removal Mechanisms Impacting Local Ground Waters Within the Livermore - Amador Valley of California" (7) has established density criteria for that area. Using a mass balance formula established in the report, an estimate of 7.9 acres per single family unit in Victor Valley may be necessary for long-term protection of groundwater quality (Figure 6b). However, in the study it was stated that "These results should not be viewed as being absolute, but at best, merely reflective of the possible nitrogen situation."



OBJECTIVE:

To compute the "Critical Development Density (D_c)," defined as the (acres/dwelling unit) that will result in an areawide percolate NO_3-N concentration of 10 mg/l (Public health drinking water standard):

FORMULA:

$$D_c = \frac{(2.01)(N_p - 10)}{(DP)(10 - N_B)}$$

where:

D_c = Critical Development Density (ac/D.U.);

N_p = Wastewater NO_3-N concentration, adjusted for denitrification losses (mg/l);

N_B = Background NO_3-N concentration of percolating rainfall (mg/l);

DP = Deep percolation of rainfall (in/yr).

2.01 = Conversion factor for assumption of 150 gpd/D.U.

ASSUMPTION

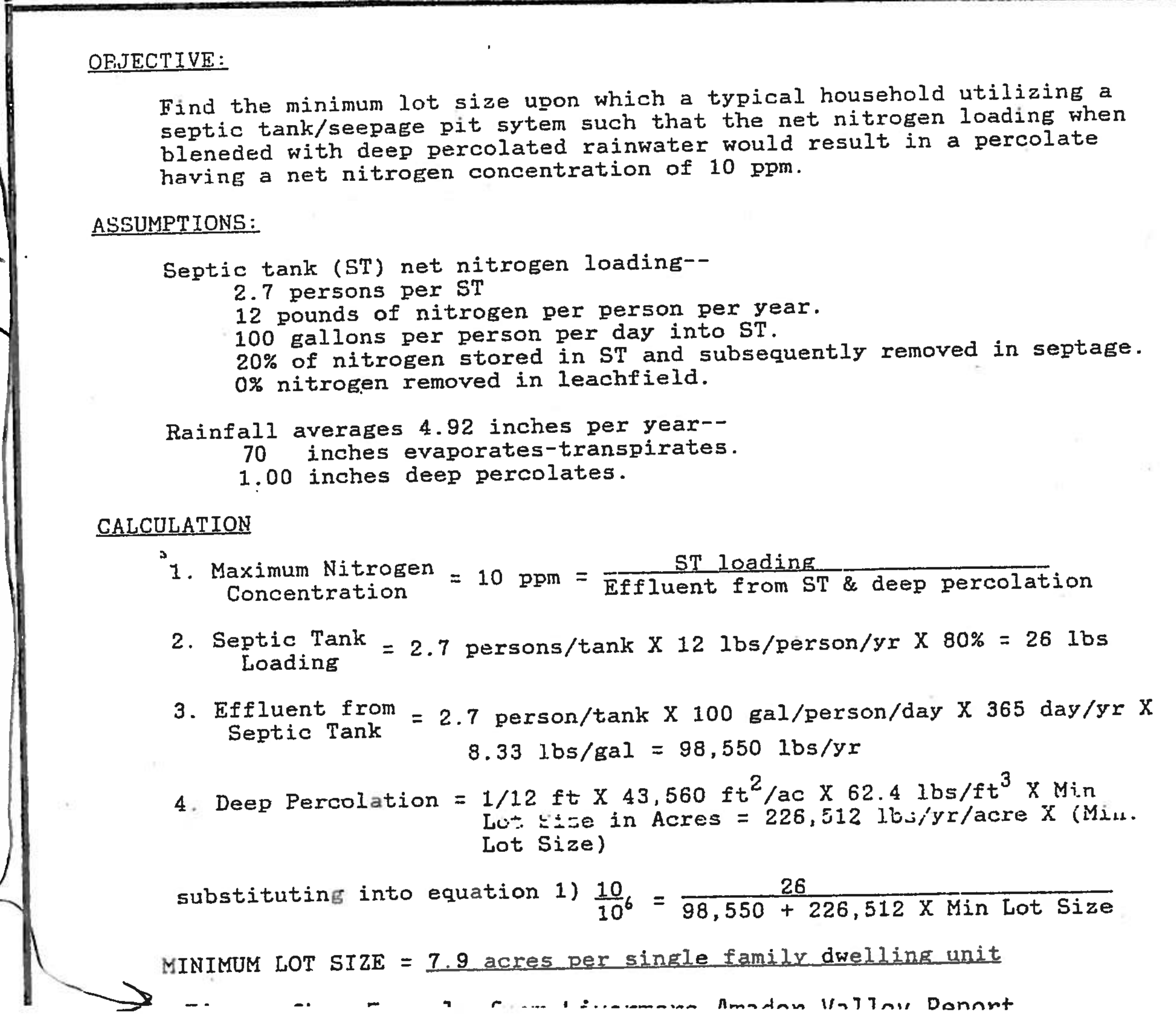
N_p = 45 mg/l of Nitrogen X 90% Nitrogen after denitrificatin = 40 mg/l

N_B = 0.5 mg/l

DP = 1 in/yr

MINIMUM LOT SIZE = 6.3 acres per single family dwelling unit

Figure 6a - Formula from North Coast Region Report



OBJECTIVE:

Find the minimum lot size upon which a typical household utilizing a septic tank/seepage pit sytem such that the net nitrogen loading when bleneded with deep percolated rainwater would result in a percolate having a net nitrogen concentration of 10 ppm.

ASSUMPTIONS:

Septic tank (ST) net nitrogen loading--
2.7 persons per ST
12 pounds of nitrogen per person per year.
100 gallons per person per day into ST.
20% of nitrogen stored in ST and subsequently removed in septage.
0% nitrogen removed in leachfield.

Rainfall averages 4.92 inches per year--
70 inches evaporates-transpirates.
1.00 inches deep percolates.

CALCULATION

1. Maximum Nitrogen Concentration = 10 ppm = $\frac{\text{ST loading}}{\text{Effluent from ST \& deep percolation}}$

2. Septic Tank Loading = 2.7 persons/tank X 12 lbs/person/yr X 80% = 26 lbs

3. Effluent from Septic Tank = 2.7 person/tank X 100 gal/person/day X 365 day/yr X 8.33 lbs/gal = 98,550 lbs/yr

4. Deep Percolation = 1/12 ft X 43,560 ft^2/ac X 62.4 lbs/ft^3 X Min Lot Size in Acres = 226,512 lbs/yr/acre X (Min. Lot Size)

substituting into equation 1) $\frac{10}{10^6} = \frac{26}{98,550 + 226,512 \text{ X Min Lot Size}}$

MINIMUM LOT SIZE = 7.9 acres per single family dwelling unit

Figure 6b - Formula from Livermore-Amador Valley Report

Figure 6b. Formula from Livermore-Amador Valley Report

The literature indicates that densities of less than 1/2 acre/single family dwelling unit are not acceptable for long term water quality protection. No literature has been found that states that any density below 1/2 acre/single family dwelling unit is acceptable, when considering the 10 mg/l nitrate (as N) drinking water standard.

SUMMARY AND CONCLUSION

The information found in the literature uniformly indicates that development density is the major factor related to the potential for groundwater contamination and that nitrate is the contaminant found in sewage that will first exceed the drinking water standard. The literature presents a wide range of critical development densities which can affect the amount of nitrate in the groundwater. Minimum lot sizes for protection of the groundwater from septic tank and sepage pit effluents vary from 0.5 to 7.9 acres per dwelling unit, depending on the transport mechanisms and biochemical reactions taking place in the soil. **In no case did the literature recommend a minimum lot size of less than half an acre per dwelling unit.** Most sources indicate the need for parcels greater than half an acre in size. Many of the models referred to in the literature were developed under different site conditions and need to be verified in the Victor Valley before larger minimum lot sizes are established as a result of their use.

RECOMMENDATION

Regional Board staff has reviewed a large body of the available literature dealing with the impact of septic tank/subsurface disposal systems on groundwater quality. The literature overwhelmingly indicates that pollution and contamination of subsurface water supplies will occur even at a density of two units per acre.

The Victor Valley area has historically been developed on half acre or larger parcels. Only recently has higher density development on subsurface disposal systems been allowed; therefore, the half acre lot size for a single-family home can be implemented with only minor disruption to the community at this time.

Further immediate investigation of the dangers involved in allowing two units or more per acre on subsurface disposal systems should be undertaken and amendments to the Basin Plan should be considered if warranted. Until such time as the Basin Plans are amended or contrary information develops, two units per acre should be the greatest density allowed in the Victor Valley unless the units are sewered.

It is therefore recommended that a maximum density of two dwelling units per acre be allowed in the Victor Valley pending further investigation and possible revision of the Basin Plan if warranted.

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