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GEOHYDROLOGY OF THE MADERA GROUP, WESTERN ESTANCIA BASIN, NEW MEXICO

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INTRODUCTION

The Madera Group of Pennsylvanian age crops out or is present near the surface in over 1,036 km' (400 mi ') of the western Estancia basin in Bernalillo, Santa Fe, and Torrance counties. In much of this area, the Madera Group is the only potentially water-bearing unit available for domestic, industrial, and municipal water-supply purposes. The scenic quality of the area and easy accessibility to jobs and other urban amenities in Albuquerque due to the completion of 1-40 led to a population boom in the western Estancia basin during the 1970's. One of the centers of this population boom is the Edgewood area, southwestern Santa Fe County, where more building permits are being granted and more lot-splits are being approved than any other area in that county. Approved subdivisions, plus others in various stages of planning, include thousands of lots as small as 1 ha (ha hectare; 2.5 acres). Many smaller lots, approved under older, less-strict regulations, or not approved at all, are present. Water supplied to these developments by individual on-site domestic wells or by community water systems must come from the Madera Group. Typically, liquid-waste disposal is by on-site septic tanks; although, cesspools are common.

The Madera Group is a highly anisotropic, multi-porosity media with three-dimensional flow systems disrupted by structural and stratigraphic features. Ground water from the Madera Group is known to discharge to the Rio Grande and to the Estancia basin. Other discharge areas may exist. The use of ground water in the Madera Group is administered as part of the Estancia, Rio Grande, and Sandia declared underground water basins. The Sandia basin straddles the Tijeras Canyon—Monte Largo structural zone and contributes ground water by underflow to each of the other basins. This paper is concerned primarily with the geohydrology of the Madera Group of the western Estancia basin. The geohydrology of the Madera Group of the Sandia Mountains has been described by Titus (1980).

GENERAL GEOLOGY AND GEOHYDROLOGY OF THE MADERA GROUP OF THE ESTANCIA BASIN

Geology and Factors which Influence Ground-water Availability

Myers and McKay (1976) raised the Madera Formation to group status and divided the Madera Group into a lower unit called the Los Moyos Limestone and an upper unit called the Wild Cow Formation (see Myers, this guidebook). The Los Moyos is described as a cliff-forming, cherty limestone with interbedded shale, siltstone, and channel deposits which are conglomerate or sandstone. The Wild Cow Formation is described as a rhythmically bedded sequence of conglomerate, sandstone, siltstone, shale, and limestone. The upper member of the Wild Cow is arkosic, more conglomeratic, and also more colorful (containing red, green, and yellow shales and mudstones) than the the gray and black shales found in the lower unit (Kelley and Northrop, 1975). The thickness of the Madera Group ranges from 396 to 427 m (1,300 to 1,400 ft) in the Sandia Mountains (Kelley and Northrop, 1975), thickening eastward to about 610 m (2,000 ft) (Titus, 1980). An oil-test hole drilled in 1933 a few kilometers north of Edgewood (SW 1/4, sec. 6, T1ON, R7E), penetrated 823 m (2,700 ft) of Madera Group before being "abandoned in schist" of Precambrian age. Madera Group unconformably overlies rocks of Precambrian age or conformably overlies the Sandia Formation of Pennsylvanian age where the latter is present.

The Madera Group is overlain by the Abo Formation of Permian age or by Quaternary alluvium which partially fills the Estancia basin (see Bachhuber, this guidebook). Titus (1969) mapped and described the Abo as a broad band of strata running the length of the basin beneath the alluvium and connecting outcrops at the northern and southern ends. The Abo consists of interbedded sandstone and claystone which do not readily yield water to wells. The alluvium consists of sand, gravel, silt, and clay eroded from the surrounding highlands, which is overlain by lacustrine sediments in the central valley (Smith, 1957; Titus, 1969; Bachhuber, this guidebook). The lake beds confine ground water in the underlying alluvium. The geology and geohydrology of the central basin have been described by Smith (1957), Titus (1969), and DeBrine (1971).

Karst features are not well developed in the limestones of the Madera Group, although reports of "honeycomb rock" and bits falling into cavities are common in driller's logs. About 1.6 km (1 mi) of passageways have been mapped in a cave in the N1/2, sec. 22, T1ON, R7E (Trauger, 1974). A sinkhole in sec. 3, T ION, R7E and other depressions in this area have been formed by solution of limestone and piping of the overlying alluvium into the solution-enlarged joints, a process described by Jennings (1971), rather than by collapse as stated by Titus (1980, p. 10). A well drilled in the sinkhole penetrated limestone and shale beds of the Madera Group with no reported cavities and was not as productive as other wells in the area, suggesting that a clay core is forming in the sinkhole and that no large cavities which may be tapped for water are present at this site. However, at another site in the NW 1/4, sec. 35, T7N, R8E, a portion of an irrigated field collapsed into a depression 12 to 18 m (40 to 60 ft) across and 9 m (30 ft) deep (J. T. Everheart, personal commun., 1982; Titus, 1969). The depression was filled with trash and the field was leveled, only to collapse again when runoff from a heavy storm flowed across the field. The development of karst features in the Madera Group is best described as juvenile. However, dissolution processes are active, and the formation of new collapse features can be expected.

Wells in the Madera Group produce water from fractures, joints, and solution cavities in the bedded limestones. The limestones are a fractured media in which nearly all permeability and porosity is the result of secondary processes such as the creation of joints, fractures, and solution cavities. When considered as a hydrologic unit the Madera Group is a multiporosity media with portions of the unit performing specialized hydrologic functions. The low-porosity limestones store little water, but may have open fractures which serve as highly permeable conduits for flow. The conduits are connected hydraulically to sandstones and shales. These units have low permeabilities but have porosities which may be over 30 percent, providing reservoirs for storage of large volumes of water. Where the Madera Group is overlain by saturated alluvium, the same conduit and reservoir relationship exists.

Ground-water Availability and Examples of Well Performance

Titus (1980) summarized the water-producing capability of wells drilled in the Madera Group. Depths of wells drilled for water in the Madera Group range from about 15 to 335 m (50 to 1,100 ft). The performance of wells in the Madera Group is highly variable. The average and median yield of 46 wells drilled in the Madera Group is 0.75 and 0.32 1/s (12 and 5 gpm), respectively. Titus excluded wells with yields of more than 6.3 1/s (100 gpm) from this calculation.

The deepest of 6 wells located in the SW 1/4, sec. 10, T1ON, R6E, at the truck stop along 1-40, was drilled to 305 m (1,000 ft). Reportedly none of these wells yielded more than a few tenths of a gallon per minute. Based on the available records, Titus estimated that one in every five wells drilled in the Madera Group is dry. However, the real percentage of dry holes may be higher because many drillers do not file well records on dry holes. The rig is moved and the permit is simply applied to a different site on the property.

Two zones of high permeability are known to exist in the Madera Group of the western Estancia basin. One zone, which includes T6-8N and R7-8E, may be related to dissolution of limestone by carbon dioxide which was produced commercially in the area until 1942 (Titus, 1980; see discussion at road-log segment 1-B, Stop 2, this guidebook). Bubbles of carbon dioxide occur in water which is produced from some wells in this zone. A well in the NEB/, sec. 1, T7N, R7E reportedly was test pumped at 93 1/s (1,470 gpm).

A second zone of high permeability exists in the Bachelor Draw area, a few kilometers north of Edgewood. A well in the NW 1/4, sec. 23, T1ON, R7E was drilled to 93 m (304 ft) and yielded 35 1/s (560 g/m) for 96 hours with a drawdown of 0.9 m (3 ft) (Trauger, 1974). Recovery was nearly complete 4 minutes after the end of pumping, suggesting that most of the observed drawdown was due to entrance losses in the vicinity of the well rather than drawdown in the aquifer. Nearby, a well in the NE/, sec. 25, T1ON, R7E reportedly had a drawdown of 27 m (90 ft) when pumped 25 1/s (400 g/m) (Smith, 1957). Smith stated that the principal aquifer at this site was the valley fill. However, the performance of the well and the location relative to Bachelor Draw suggest that the Madera Group, hydraulically connected to the alluvium, is the source of water.

Edgewood caverns is located in the Bachelor Draw area, suggesting that solution porosity may be well developed locally. Based on the location of wells reported or observed to have relatively high yields, and on the water-level contours shown by Titus (1980, fig. 4), the high-permeability zone of the Bachelor Draw area is believed to trend in a northwesterly direction between sec. 30, TI IN, R7E and sec. 31, T1ON, R8E. This zone, which is entirely covered by alluvium, may be as much as 3.2 km (2 mi) wide and probably consists of a series of sub-parallel, hydraulically connected fractures. Wells which can produce more than 63 1/s (1,000 gpm) from the Madera Group in the Bachelor Draw area are possible with proper well location and construction.

Holes in the Madera Group which do not penetrate fractures or solution cavities can be expected to yield only small quantities of water (0.03 to 0.06 1/s; 0.5 to 1 gpm) and may be dry. A hole, which was drilled then abandoned in the SW1/4, NE'/, sec. 32, TI IN, R7E due to insufficient yield, probably was drilled south of the high-permeability zone in the Bachelor Draw area.

Hydraulic Coefficients of the Madera Group

Transmissivities reported from well tests in the Madera Group range from about 1.9 to 120,770 m^2/day (20 to 1,300,000 ft^2/day). Almost without exception, reported transmissivities have been determined using the Theis (1935) equation which is not always applicable to fractured rock aquifers. The Theis equation assumes that radial flow occurs toward a pumped well in a homogeneous, isotropic aquifer, assumptions which are not commonly applicable to the Madera Group. Although Madera Group transmissivities determined with the Theis equation are questionable, the broad range of reported transmissivities and the large range in observed well yields show that water availability is site dependent and not entirely predictable. Generalizations which can be made regarding water availability from the Madera Group are presented later in this report.

Jenkins and Prentice (1982) described an aquifer test performed at a well located in the NE1/4, sec. 4, T1ON, R7E and presented a method of analysis applicable to data from fractured rock aquifers under certain conditions. The well, which is located in the high permeability zone of Bachelor Draw, was pumped at 6 1/s (97 gpm) for 96 hours. The drawdown at the end of pumping was about 1.1 m (3.5 ft). Flow in the vicinity of the pumped well and two observation wells was linear toward a fracture rather than radial toward the pumped well, and the response in the observation wells clearly showed that the aquifer is highly anisotropic. The hydraulic diffusivity (T/S) determined from this test was about 15,654 m^2/day (168,500 ft'/day). Although the storage coefficient (S) and transmissivity (T) values cannot be individually determined, the lithology of the Madera Group at the site suggests that the storage coefficient is small (0.005 to 0.01); therefore, the transmissivity at this site is very large. The Madera Group at the test site is covered by a veneer of alluvium. Analysis of the observation well response showed the orientation of the fracture responsible for linear flow to be aboout N20°W. Water form the pumped well was piped 457 m (1,500 ft) and discharged to an arroyo. The depth to water at the discharge site is about 91 m (300 ft). The water level in an observation well near the discharge site began to rise 81 hours after the start of pumping indicating a vertical velocity of about 26 m/day (85 ft/day) and a large vertical hydraulic conductivity in the Madera Group of this area.

THE POTENTIOMETRIC SURFACE IN THE MADERA GROUP

General Description of the Ground-water Flow System in the Madera Group

Ground water in the Madera Group discharges to the Rio Grande drainage basin and toward the Estancia basin. Ground water moves toward San Pedro Creek from the northern Sandia Mountains and toward Tijeras Canyon from the southern portion of the mountains. Both of these streams are tributary to the Rio Grande. Ground water from a portion of the northern Manzano Mountains discharges to Cedro or Tijeras Canyons and then to the Rio Grande. Titus (1980) described the geohydrology of these areas.

The Estancia basin is a closed topographic depression having no external drainage. Recharge by precipitation is the source of all of the water in the Madera Group and in the Estancia basin. Much of this recharge occurs in the Madera Group of the Manzano Mountains. From the recharge area, Smith (1957) suggested that water moves down the potentiometric gradient until it begins to move upward beneath the Estancia basin to discharge to the springs, playas, and salt lakes of the central basin. This describes what is essentially a one-dimensional flow system with water entering at the highest portions of the basin and discharging from the lowest portions. This model may have been adequate to describe the basin prior to development. The development of the ground-water resources of the Madera Group has provided data which suggests that development of a more complex flow model is necessary.

Water-level contour maps showing the potentiometric surface in the Madera Group have been published by Smith (1957) and Titus (1980). Comparison of the water-level contours with the measured water-level elevations reveals many anomalies. Unfortunately, the anomalies are not apparent in the most recently published water-level map of the area (Titus, 1980, fig. 4), because only the water-level contours and total depths of wells are shown on that map. The water-level elevations observed in wells are not shown. Standard two-dimensional techniques of water-table mapping frequently yield unsatisfactory results when applied to fractured rock aquifers. Observed water levels often show large variations within short distances. For example, the elevations of the water level in three wells open to the Madera Group in the SEA, sec. 26, T 1 IN, R6E, are 2,000, 2,029, and 2,054 m (6,563, 6,657, and 6,738 ft) above mean sea level when measured in 1980. The wells are less than 366 m (1,200 ft) apart.

Titus (1974) stated that interpolating water-level altitudes in this area would be difficult and perhaps meaningless. Titus contoured the water-level data by "a rather intuitive averaging of water level altitudes . . ." during which some water-levels were ". . . necessarily ignored. . . ." Titus attributed the hydraulic-head variations to downward movement of ground water in the vicinity of the ground-water divide which separates ground water of the Rio Grande and Estancia basins.

A similarly anomalous situation occurs in wells around the northeastern corner of sec. 32, T1 IN, R7E away from any known ground-water divides and close to the subcrop of the Abo Formation. LeGrande and Stringfield (1971) state that uneven distribution of permeability in solution channels and unfractured rock may cause mounds and valleys in the water table. This explanation must be extended into three-dimensions to explain the extreme water-level variability observed in the Madera Group.

Titus (1980, fig. 18) plotted measured levels versus bottom-hole elevations and showed that a significant vertical hydraulic gradient exists in the area and that water is moving from the upper portions of the aquifer to the lower portions. In an attempt to improve on Titus' intuitive water-level contouring, I plotted water-level elevations and bottom-hole elevations within 1.6 km (1 mi) of east-west cross sections through the Edgewood—Frost Arroyo area. The equipotential lines were contoured on each cross section. The intersections with an inferred water table were then connected between the various cross sections. The exercise was interesting, but the available data were insufficient to result in an interpretation which could be called a significant improvement over the interpretation by Titus. However, a condition of declining head with depth was confirmed in areas away from the ground-water divide identified by Titus, suggesting that deeper wells in other areas of the Madera Group are likely to have deeper water levels than shallower wells in the same area.

The vertical hydraulic gradient might better be defined by using the open interval of the well casing instead of the bottom-hole elevation for the plots or cross sections. However, this would further complicate a cumbersome process. The resulting contours may not be improved significantly, because few wells in the area are perforated over a single small interval. The measured water level in wells open to multiple intervals is an integrated value of the hydraulic head in all of the contributing beds. The water table in the Madera Group is indicated best by the shallowest wells.

Titus (1980) described the limestone ridge, which lies along the Bernalillo—Santa Fe County line just east of the high permeability zone of Bachelor Draw and which forms the eastern boundary of the Barton trough, as a barrier which blocks the eastward flow of ground water from the structural depression in the Barton area. Water-levels in the vicinity of the ridge are contoured to show a water level mound 91 m (300 ft) higher than in adjacent areas. Titus suggests that all ground-water flow leaves the Barton trough through the gap in the northeastern corner of sec. 20, T1ON, R7E, where 1-40 passes through the limestone ridge, and states that a very high value of permeability is required to accommodate the large concentration of flow in the small gap area. The high permeability is assumed to have been created by faulting which shattered the Madera limestones and enhanced the permeability considerably by development of cavernous channels (Titus, 1980, p. 27). One well in the gap having a low water-level elevation and a yield described as adequate is cited as evidence for the high permeability zone. Based on this argument, Titus mapped two faults through the gap, extending into the Edgewood embayment.

Since Titus' work, two wells have been drilled in the gap area but both have been abandoned as dry holes. One of these wells, drilled in 1974 for the State Highway Department along the old highway (U.S. 66; SW 1/4, sec. 20, T1ON, R7E), has a bottom-hole elevation of about 1,948 m (6,390 ft) and may not have been deep enough to reach the water. More importantly, residents report a well was drilled in the eastern half of sec. 19, T1ON, R7E, near the intersection of two faults mapped by Titus. The well was reported to be 155 m (510 ft) deep and dry.

Although some flow undoubtedly occurs through the gap, there is no reliable evidence for a zone of high permeability and large flows of ground water through the gap between Barton and Edgewood. Further, it seems unlikely that a 91-m (300-ft) high water-level mound could persist in a ridge having an area of only about 10.5 km' (4 mi²). Titus' water-level contours in the Barton area are based on relatively few measurements, and many of the wells on the Barton side of the ridge are relatively deep while Titus' 2,042-m (6,700-ft) contour in the ridge is based on the water level in a single 50.5-m (166-ft) deep well. The anomalous water levels observed in some of these wells may be due to the vertical hydraulic gradient which Titus observed in the Frost Arroyo just a few miles to the north. The deep water levels in the Frost Arroyo area, Barton trough, and the Bachelor Draw area suggest that water moves around the northern end of the ridge, and possibly through the ridge, in some deep permeable beds.

GROUND-WATER DISCHARGE FROM THE MADERA GROUP

The direction of movement for most ground water in the system may be assumed to be from west to east and parallel to bedding, except where open vertical fractures are present. This results from interbedded clays and shales which impede cross-bed movement. The lithology and structure of the Madera Group have combined to make a strongly anisotropic flow system. The lithology of the overlying formations suggest that anisotropic conditions prevail in these units, also. However, water must cross bedding planes to reach the discharge area in the Estancia basin (see Smith, 1957), because the beds of the Madera Group dip beneath the Estancia basin. The dipping beds and vertical hydraulic gradient result in a situation where water that is draining slowly downward is at the same time moving relatively rapidly in the direction of bedding (Titus, 1974). This condition must be reversed as water approaches the discharge area. The hydraulic gradient in the Madera is downward and vertical near the contact with the Abo, suggesting that the primary discharge area is beneath the Madera-Abo contact.

The anisotropy of the Madera Group and overlying units forces speculation regarding the site and mechanism of ground-water discharge from this formation. There are four possibilities for ground-water discharge from the Madera Group.

1. Despite the low transverse-to-bedding permeability, there is sufficient surface area for all outflow from the Madera Group to pass through the overlying formations. Water discharges ultimately to the central basin.

2. The transverse-to-bedding permeability is low, and most ground water discharging from the Madera Group flows over the overlying formations directly to the alluvium at low points along the contact of the Madera with overlying rocks in the sub-alluvium surface. These discharge points are contact springs which have been covered by alluvium.

3. The lithology of the Madera and overlying formations has been disrupted in the central basin, possibly by solution and collapse of limestone beds, creating channels for vertical movement of ground water which permits discharge of deep, saline water to the central basin.

4. The central basin playas are not the ultimate discharge area for all ground water in the Madera Group.

Possibilities 1 and 2 require that ground water in the Madera becomes saline a short distance east of the contact between the Madera and overlying, pre-alluvium rocks, because the rate of ground-water flow in the Madera must diminish greatly beyond this contact. Unfortunately, there is insufficient data on the quality of water in the Madera beneath the alluvium of the central valley. Some wells in the Edgewood area produce fresh water from total depths below the elevation of the salt lakes east of Willard and Estancia, New Mexico, suggesting that if a salt-water/fresh-water interface exists, it is some distance from the Edgewood area. Possibility 2 suggests also that continued development of ground-water resources of the Madera Group will hydraulically isolate the Madera from the Estancia valley when the water-level falls below the discharge points on the sub-alluvium surface.

The difficulty in moving ground water across post-Pennsylvanian rocks into alluvium of the Estancia basin and ultimately to the discharge areas at the central basin playas invites further speculation on alternate discharge areas for ground water in the Madera Group. Little subsurface data is published regarding the Estancia basin. Structural contours on the top of Precambrian rocks (Woodward and others, 1975) suggest the possibility that subsurface discharge from the Madera Group may occur to the Rio Grande basin on the northern side of the Estancia basin, as suggested by Meinzer (1911), and that discharge cannot occur on the eastern and western sides because of the Pedernal and Manzano uplifts. Titus (1969) concluded that ground water from the Estancia valley probably does not discharge across the Abo Formation at the southern end of the basin. Therefore, ground water in the Madera probably does not cross the Abo and overlying formations to discharge to the central valley. The shape of the Precambrian surface suggests that discharge from the Madera on the southern side of the basin may occur in the vicinity of Mountainair, New Mexico. The ultimate discharge area for the Madera Group in the southern Estancia basin may be the Tularosa basin.

The ground-water flow system in the Madera Group is complicated by structural and hydrologic factors. The water-quality and water-level data needed to define the system are limited both in terms of quality and distribution and are insufficient to identify all of the discharge areas.

POTENTIAL FOR GROUND-WATER DEVELOPMENT

The Madera Group is a heterogeneous, anisotropic, fractured-rock aquifer in which the availability of ground water is site dependent. The yield of wells may vary greatly over short distances, because well yields are directly dependent on penetration by the well of open, saturated fractures which are not evenly distributed throughout the rock. Wells which do not penetrate a sufficient number of fractures obtain water at rates determined by the primary porosity and permeability of the rock which are low. Such wells are often poor producers and are abandoned as dry holes.

Some generalizations can be made which apply to the successful siting of wells in the Madera Group as a whole. Consideration of the following points should maximize the chances of obtaining a water supply from a well adequate for domestic purposes. These points should be considered by potential land owners when contemplating the purchase of a particular piece of property in the area underlain by the Madera Group.

1. The approximate depth to water beneath a given property can be estimated from Titus' (1980) Figure 4 by finding the difference between the land-surface elevation and the elevation of the water surface indicated by the water-level contours. The depth of the well must be deeper than the depth to water.

2. Well yield is related to the number of fractures penetrated. Rock which is extensively fractured is more easily eroded than unfractured rock. Therefore, topography should be considered in selecting a well site. In the Edgewood area and other areas which are relatively high topographically, wells sited along arroyos are more likely to be successful than are wells sited on ridge tops. J. T. Everheart (personal commun., 1982) suggests that in areas which are relatively low topographically, such as the high permeability zone northwest of the town of Estancia, the largest well yields may be obtained on the ridge tops, because the solution cavities developed along the arroyos have been partially filled in by collapse and piping of fine sediments.

3. Surface-drainage patterns often indicate subsurface conditions. The location of many of the larger arroyos, even many in the alluvium near the limestone outcrop, is controlled by faults in the limestone bedrock which is more easily eroded than adjacent, unfaulted rock. Portions of drainages which are fault controlled often can be identified on topographic maps, because they tend to be linear and less sinuous than unfaulted drainages.

In addition to the general guides for locating wells in the Madera Group, more specific statements can be made regarding ground-water availability in the Edgewood area. Interstate-40 and N.M. 344 intersect at Edgewood and divide the area into quadrants which can be used conveniently to describe ground-water conditions. These man-made features do not coincide exactly with geologic controls on water availability, therefore exceptions do occur.

In general, wells located south of 1-40 have a 20 percent or greater chance of being dry holes. Successfully completed wells in this area usually yield only a few gallons per minute. Northeast of Edgewood, the Madera Group is covered by saturated alluvium. Many wells have been drilled in the area and few dry holes have been reported. Most domestic wells are less than 91 m (300 ft) deep. Wells yields of more than 63 1/s (1,000 g/m) are possible in this area with proper well siting and construction. Most of the wells which supply local community water systems are located in this area.

The greatest variability in ground-water conditions in the Edgewood area occurs north of 1-40 between N.M. 344 and the county line. Both dry holes and high yield wells have been reported in this area. The most unfavorable well locations appear to be between the east-west-trending drainages in the limestone ridge which roughly coincides with the county line. The best producing wells lie along projections of these drainages which are fault controlled. The number of successfully completed wells in this area suggests that the chances of drilling a dry hole are less in this area than in the area south of 1-40.

Special consideration should be given to well-drilling methods used on any well drilled for water in the Madera Group. Wells drilled by rotary methods should use clear water for a drilling fluid to the extent possible. The practice of recirculating drill cuttings may cause the water producing pores and fractures to become permanently plugged. The use of a biodegradable drilling mud may be advisable. Use of bentonite, shredded paper, or other materials occasionally used by drillers to maintain circulation should be avoided. In low-yield wells, where no obvious production zone is apparent, well casings should be perforated from the static-water level to the bottom of the hole to maximize production from each bed penetrated in the saturated zone. Holes drilled in the Madera Group will often stand open without casing; however, it may be advisable to install a casing at least to the depth of the lowest probable pump setting.

VULNERABILITY OF THE MADERA GROUP TO GROUND-WATER POLLUTION

Home development in the area where the Madera Group crops out typically consists of single family dwellings on lots of various sizes. Water is supplied to each lot by an on-site well, although a number of community water systems exist in the Edgewood area. Septic tanks are the most common method of sewage treatment. However, discharge to open pits and to open-bottomed barrels have been observed. The depth to water is greater than the 3.7-m (12-ft) minimum required by State agencies for drainfield installation at most locations. However, the depth to bedrock required for drainfield installation is insufficient at many locations. Some residents have reported that their drainfield area had to be blasted in order to place the trench bottoms at the required depth below land surface.

The Madera Group is known to contain fractures and solution channels capable of transmitting large amounts of water, in which soil filtration mechanisms such as sedimentation, entrapment, and absorption will not always be effective. The porosity of the limestone is small and the volume of water in storage near a well may not always be sufficient to dilute wastes to a low level. Contaminants, particularly nitrates, bacteria, and virus, can be carried to the water table when contaminated fractures in the unsaturated zone are filled with storm runoff or an unusually large domestic discharge.

No cases of human-caused pollution are known to have occurred, and residents generally do not perceive a pollution problem. However, pollution sources are present, sufficient water is available intermittently to transport contamination to the water table, and open channels are known to be present. Pollution of ground water in the Madera Group appears probable unless existing regulations are strictly enforced. Proper siting of wells and appropriate waste-disposal systems will minimize the extent of pollution. The effects of septic tank discharge on development of karst features are unknown. The localized discharge may accelerate dissolution of the underlying rock, enhancing the ability of particulate contaminants such as bacteria and virus to reach the water table.

GROUND-WATER QUALITY

The quality of water produced from the Madera Group by most wells is suitable for domestic consumption and meets water-quality standards set by County and State agencies. The dissolved-solids content usually is less than 450 ppm and primarily is due to calcium bicarbonate. Titus (1980) reported water from some wells in the Madera Group to be high in magnesium, sodium, potassium, and fluoride, particularly in the vicinity of the Barton trough. Waters high in fluoride were also softer than other waters from the area, and Titus concluded that water softness may be an indicator of high fluoride concentrations. Concentrations of 11 to 14 ppm have been measured in the Barton area.

High fluoride levels in drinking water are not desirable, and the levels reported in the Barton area are capable of producing fluorosis of the bone and blackening of tooth enamel in long-term consumers (McKee and Wolf, 1963). There may be a more pressing danger in consumption of the soft waters of the Madera Group. Residents have reported difficulty in reducing the sodium levels in persons strictly adhering to low sodium diets. Sodium in drinking water may be harmful to persons with cardiac, renal, or circulatory conditions (McKee and Wolf, 1963).

CONCLUSIONS

Ground water is available in sufficient quantities for domestic use from most of the area underlain by limestones of the Madera Group. However, the availability of water at a particular well site depends upon the number of open, saturated fractures penetrated by the well. The primary porosity and permeability of the Madera Group are such that wells which do not penetrate a sufficient number of open, saturated fractures are likely to produce only modest quantities of water and may be dry. Wells drilled in the Madera Group have a 20 percent or greater chance of being dry, although these chances probably can be improved at any site by consideration of geology in selecting a site and by using appropriate drilling methods.

High-yield wells, capable of producing a few tens to 63 l/s (few hundred to over 1,000 gpm) from the Madera Group, are possible in at least two areas. Well-site selection and well construction are critical in obtaining high yields.

The ground-water flow system of the Madera Group is a complex, three-dimensional system which is not completely understood. A large downward gradient exists in much of the Edgewood—Frost Arroyo area, a larger area of the Madera Group than that in which a downward gradient had been documented previously. The downward movement of water in this area suggests the possibility that all ground water from the Madera Group does not discharge to the central playas of the Estancia basin. Continued development of the ground-water resources of the Madera Group hydraulically may isolate the Madera from the Estancia basin. Subsurface discharge from the Estancia basin through beds of the Madera Group may be occurring at the northern and southern ends of the basin.

The development of cavities and solution enlarged fractures, which make high-yield wells possible, enhance the vulnerability of ground water in the Madera Group to pollution. Given present development patterns, the most likely source of pollution is recharge from cesspools and improperly sited or improperly constructed septic-tank drain fields. Development without pollution of the ground-water resources of the Madera Group can be accomplished to any density acceptable to the local population and permitted by the regulations of the appropriate county. Whether development will occur without seriously polluting the aquifer is doubtful. The key lies in selection and application of appropriate, available technology compatible with the natural development limitations placed on a particular site by its geology.

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