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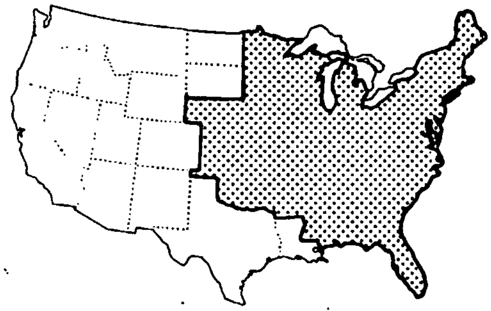
Geothermal Energy And The Eastern U.S.

A Framework for a Site Prospectus for Geothermal Energy Development

DELMARVA PENINSULA

Prepared by: APPLIED PHYSICS LABORATORY
THE JOHNS HOPKINS UNIVERSITY

For the: RESOURCE APPLIED APPLICATIONS
U.S. DEPARTMENT OF ENERGY



THE JOHNS HOPKINS UNIVERSITY ■ APPLIED PHYSICS LABORATORY

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A PROSPECTUS FOR THE DEVELOPMENT OF GEOTHERMAL ENERGY ON THE DELMARVA PENINSULA

The approach utilized in this, the most recent, site-specific prospectus (scenario), done for the Delmarva Peninsula, has evolved from early scenarios which were designed strictly as planning tools for the Department of Energy. The Delmarva prospectus tutorial narrative aimed at providing interested local parties and agencies with enough background to facilitate their actions in developing an economic and environmentally acceptable resource in an efficient manner. Technical, environmental, legal, economic, and institutional information and obstacles to development are discussed. Since development initiative must stem from the local level, the prospectus has been written in conjunction with state and local authorities. It is hoped that the resulting report serves as a useful instrument since it illustrates the relationship of the time phasing of their development plans with Federal programs to define the resource and thereby identifies the required initiatives to be taken at the state and local levels.

I. INTRODUCTION

This prospectus (scenario) has been prepared in order to assist the economic and environmentally acceptable development of geothermal energy on the Delmarva Peninsula. It has been written by the staff of the Applied Physics Laboratory of The Johns Hopkins University (APL/JHU) in their role as the Eastern U.S. Regional Operations Research Contractor for the Department of Energy's Division of Geothermal Energy (DOE/DGE). The format used has evolved from earlier regional scenarios which were designed strictly as planning tools for federal efforts. The present report is a tutorial narrative aimed at providing interested local and state agencies with enough background information to facilitate their actions in developing their local geothermal resources.

The prospectus identifies potential users, obstacles to development, sources of funding and initiatives to be taken at all levels of government. A basic understanding of the technical aspects of the resource, energy extraction and utilization engineering, as well as economic considerations and the developmental process is provided. This report will be updated in all these areas as more information becomes available.

Since the potential resources are restricted in extent, the development initiatives must necessarily stem from the individual resource areas, and this prospectus has been developed in conjunction with concerned state and local authorities. They have, in part, taken the initiative to locate users with suitable applications and have conducted information exchange workshops. This process has produced the grass roots involvement and government cooperation which is necessary for smoothing the future geothermal developments in the area. Thus the resulting report is a more useful instrument for those individuals and agencies interested in development since it illustrates the time phasing relationship between local development plans and the Federal program to better define the resource and in turn identifies the required initiatives to be taken at the federal, state and local levels.

Please forward any comments and suggestions that may help improve the utility of this scenario to F. C. Paddison or J. E. Tillman (301/953-7100, ext. 591) of the APL/JHU.

II. DESCRIPTION OF THE RESOURCE

The resource area is here defined as the southern two counties of Delaware (Kent and Sussex Counties), and the counties in Maryland and Virginia that lie on the Delmarva Peninsula south of Kent County Maryland. This entire area belongs to the Atlantic Coastal Plain Physiographic Province and is underlain by a wedge of water-rich, largely unconsolidated sediments. These Cretaceous and younger sediments were deposited upon the seaward sloping erosional surface of the Piedmont-type basement complex of crystalline (metamorphic and igneous) rock and local basins of Triassic-Jurassic sedimentary rock. This wedge of sediments which pinches out along a line connecting Washington and Philadelphia (Fall Zone) attains a thickness greater than 7700 ft deep beneath Ocean City, Maryland. Basement contours trend approximately NS to NE-SW and the crystalline surface is locally disrupted by faults with up to 200 ft of dip-slip offset. Figure II-1 is a basement map of the Delmarva Peninsula published by the Maryland Geologic Survey (Hansen, 1978) which also shows the deep wells which have been drilled on Delmarva.

The earth's heat is the resource that is to be tapped beneath the Delmarva Peninsula. Water is the convenient heat exchange medium to extract this heat from the earth. Therefore, the geothermal resource that is the easiest to utilize in the near future consists of the hot water within the sedimentary sequence. Water can be most easily extracted from unconsolidated sand horizons which have good primary permeabilities and thus are good aquifers. At shallow depths beneath Delmarva (less than 1000-

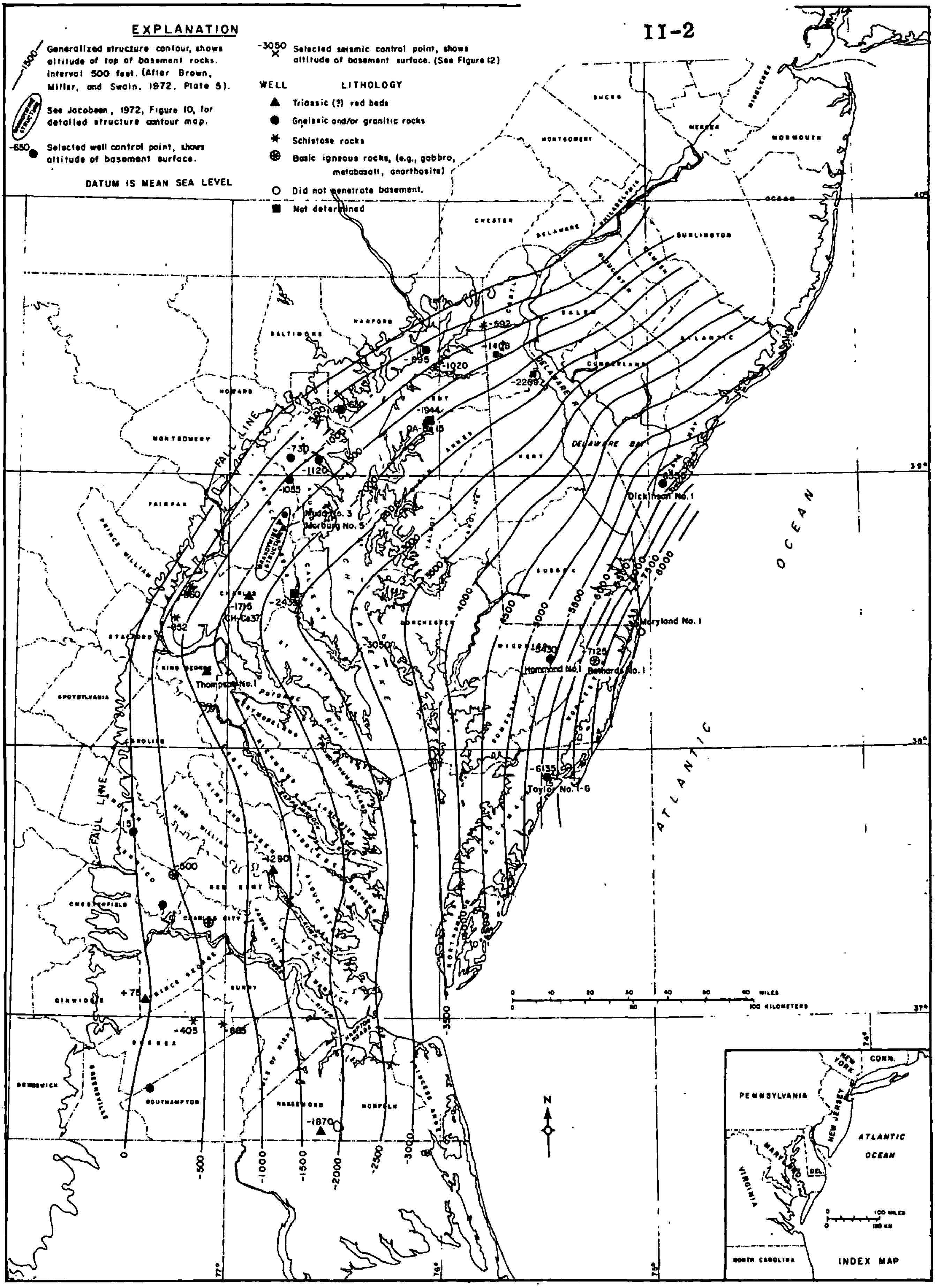


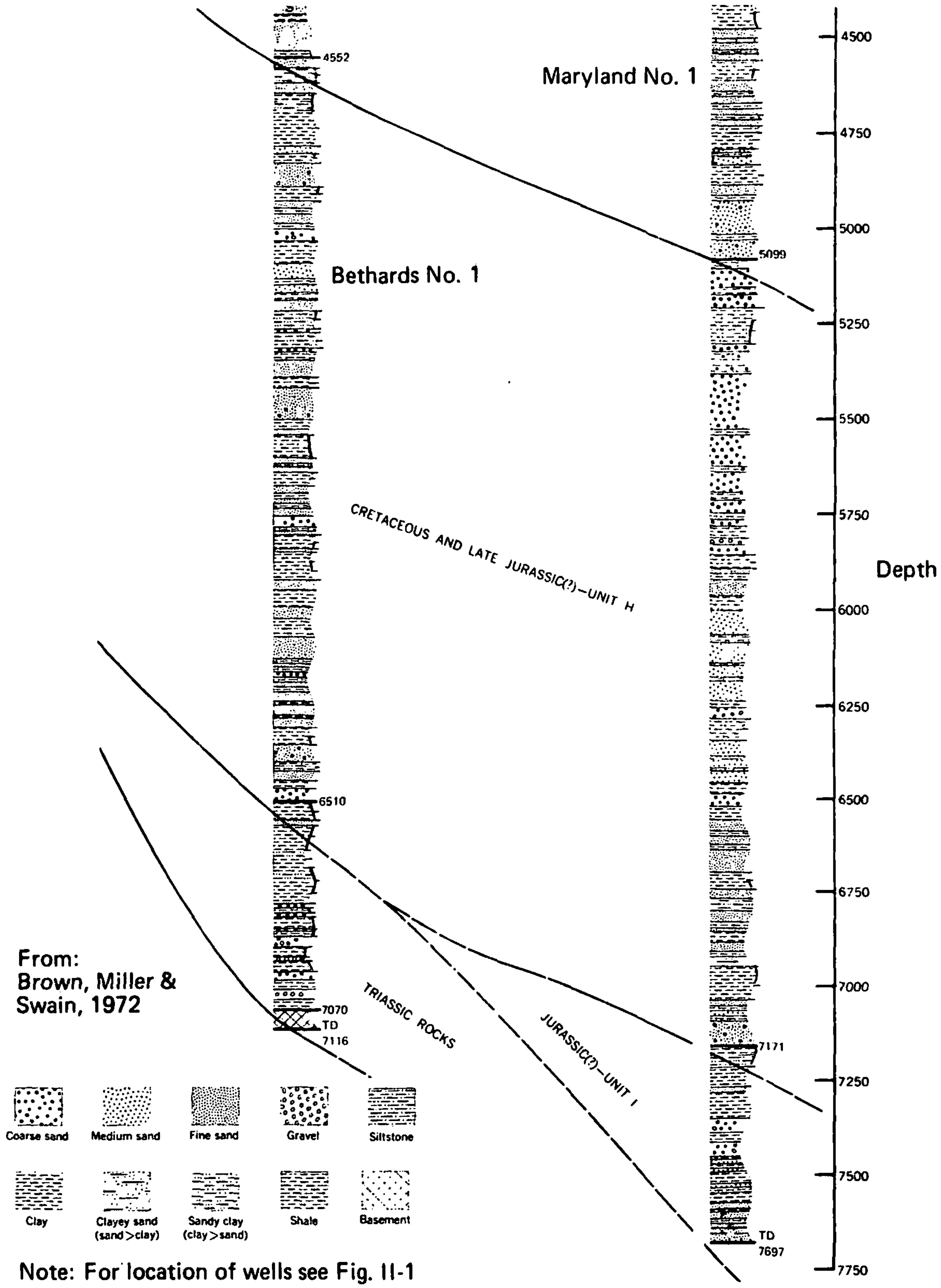
Figure II-1 Generalized structure contour map on top-of-basement surface beneath middle Atlantic Coastal Plain and location of selected deep test holes (modified after Brown, Miller, and Swain, 1972, pl. 5)

(From: H. J. Hansen, 1978)

2000 ft in general) fresh but cold water (≈55°F) has infiltrated the open pore spaces in between the sand grains and is easily extractable with water well technology. Many private, municipal and commercial wells are pumping this fresh water from the shallow aquifers for drinking agricultural, industrial and domestic water supplies. This fresh water resource is owned and regulated by the individual states. The Department of Natural Resources in each state in a joint program with the U.S. Geological Survey's Water Resources Division (USGS/WRD) manage this cold water resource.

The waters in the deeper aquifers, which are warmer because the temperature in the earth increases with depth, become more and more saline and may contain as much as 50,000 to 200,000 ppm of dissolved solids (Ref. Manheim and Horn, 1968) makeing them impotable and potentially harmful to the surface environment and plumbing equipment. In additon, the porosities and permeabilities of the aquifers decrease with depth as a result of compaction due to the increasing weight of the overburden resulting in less water in the aquifer. Due to these less attractive conditions, and the expense of deep drilling, water wells have not been drilled to great depths and little is known about the temperature, quality and quantity of water in the lower parts of the sedimentary wedge. Well data from other parts of the Atlantic Coastal Plain (Ref. Brown and Reid, 1976) indicate that water does exist at these depths but in aquifers of low to moderate permeabilities.

A thick sequence of sands, silts and clays overlie basement. Representative stratigraphic columns from two oil exploration wells are shown on Figure II-2 (Brown, et. al., 1973).



From:
Brown, Miller &
Swain, 1972

Note: For location of wells see Fig. II-1

Fig. II-2 Stratigraphic Units of the Cretaceous and Late Jurassic Sections

The thick Cretaceous and Late Jurassic (?) sediments shown on this figure contain several coarse sand horizons which could probably serve as good aquifers. These sediments, designated as Unit H by Brown (1973) underlie most of Delmarva as shown by the isopach contours on Figure II-3. The depth required to drill to reach these sand units at any location in Delmarva is shown on Figure II-4. However, the hottest water will be obtained at the greatest depths and thus the top of basement shown on Figure II-1 offers the best estimate of depth to the resource.

In addition to the presence of extractable water, an attractive resource must have water at a high enough temperature to be useful in an energy consuming process at the surface. Sediments in this area, and the enclosed fluids, generally increase in temperature with depth at a rate of between 1.5° to 2.5° F/100 ft. Therefore, even for thermal gradients of 1.5° F/100 ft, at depths of 5,000 ft, the temperature of the water will be about 140°F (55°F is average surface temperature plus 75°F increase due to this gradient). It is therefore possible to drill anywhere in Delmarva where the sedimentary wedge is greater than 5,600 ft thick and reach high temperatures. However, it is most advantageous to drill in areas of higher than normal geothermal gradient and where water is expected to occur at depth in order to:

1) obtain high temperatures at a shallower and thus more economic depth, and
2) use the naturally occurring water as the free heat exchange medium.

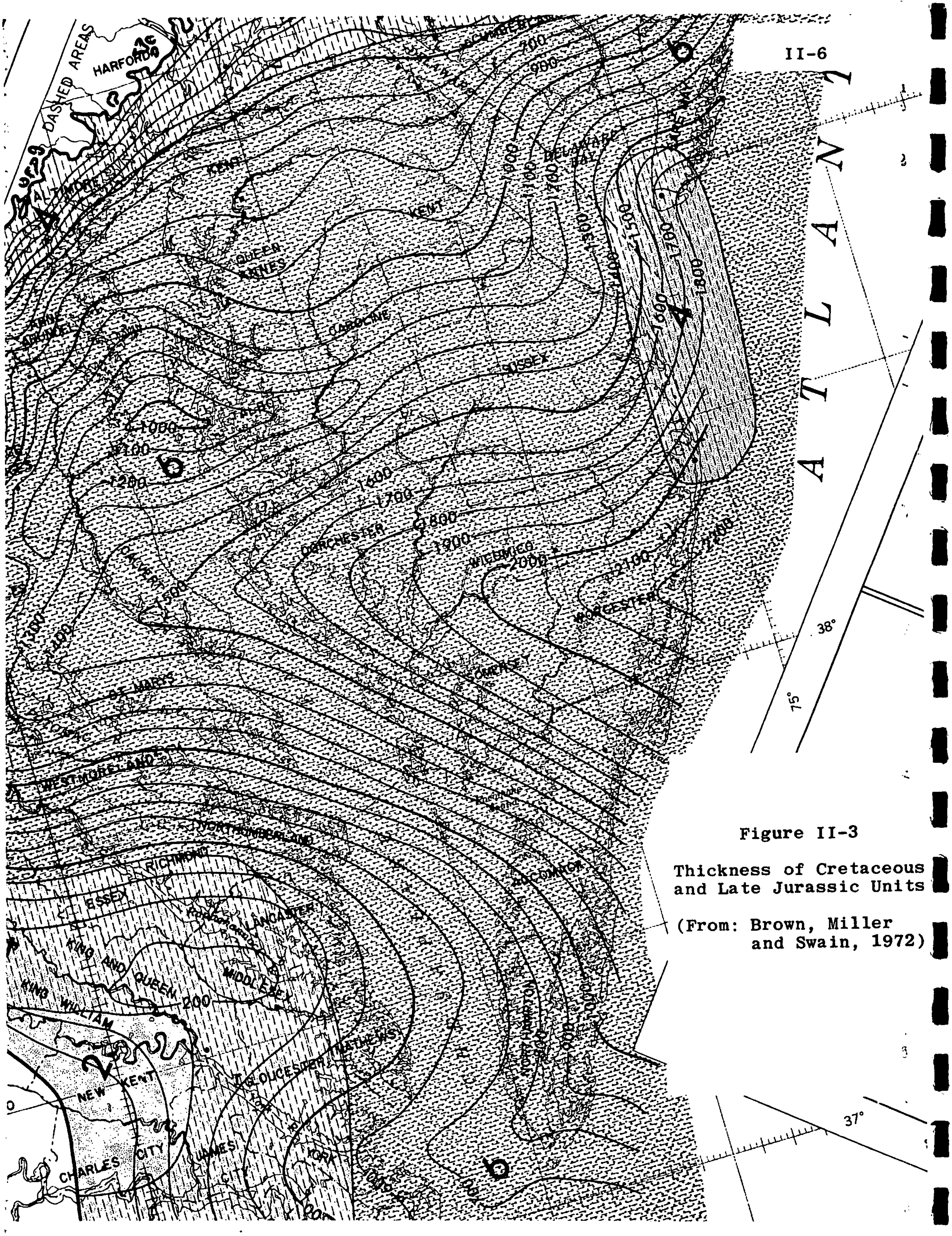


Figure II-3

Thickness of Cretaceous and Late Jurassic Units

(From: Brown, Miller and Swain, 1972)

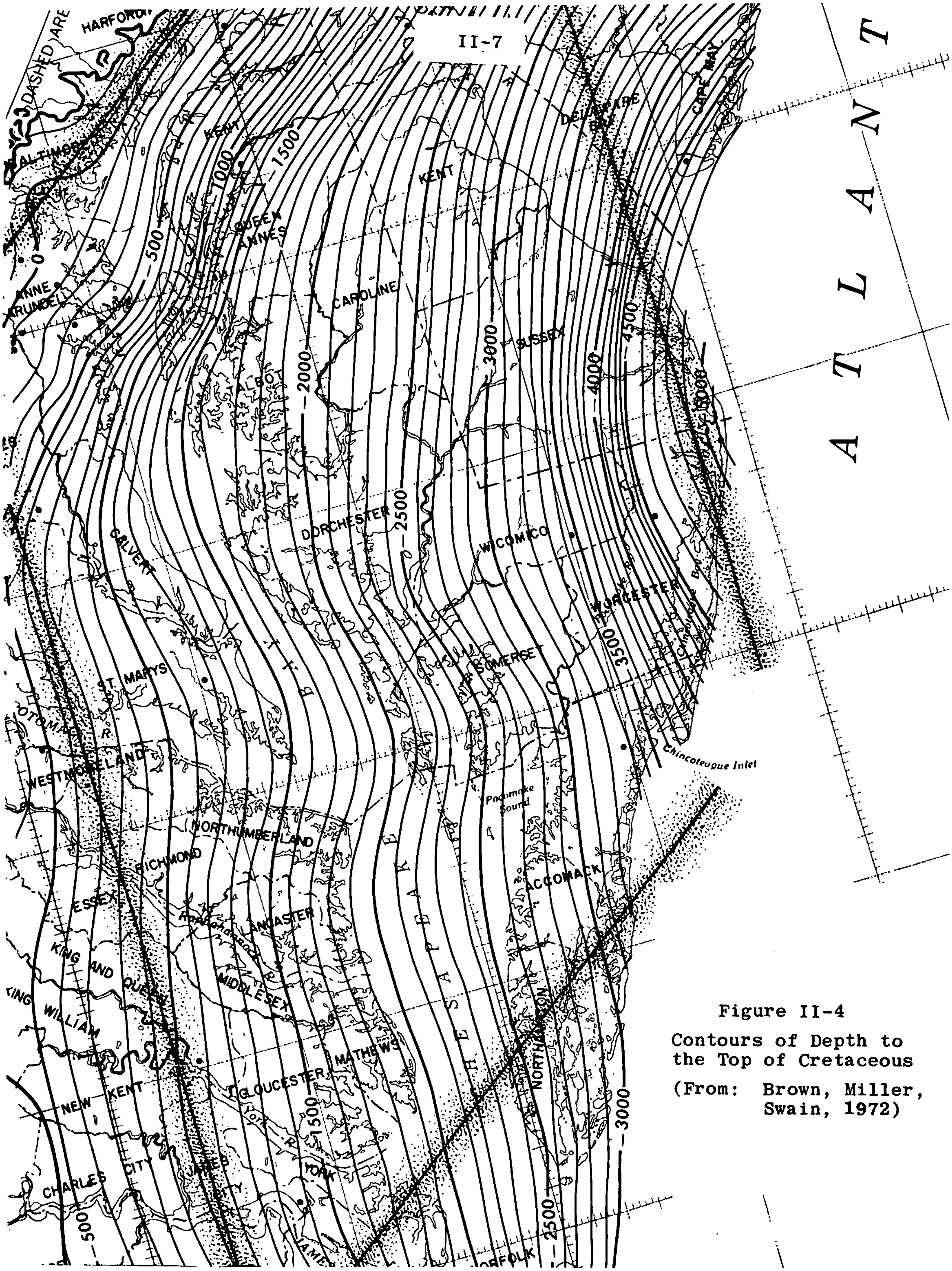


Figure II-4

Contours of Depth to the Top of Cretaceous

(From: Brown, Miller, Swain, 1972)

Regions of higher than normal thermal gradients in the Coastal Plain sediments may be due to one or both of the following conditions existing in the basement beneath the sedimentary wedge:

1) the decaying of local concentrations of radioactive elements (e.g. in a syn- or post-tectonic "granitic" pluton), or
2) adiabatic circulation of waters along a deep, high-angle fault zone.

These mechanisms can produce elevated temperatures at the surface of the basement and an increased gradient within the overlying sedimentary sequence since the water-rich sediments act as an insulating blanket above the basement (due to their low average thermal conductivities). In the Delmarva Peninsula Resource Area the most promising aquifer will therefore be the deepest thick sand unit that overlies an area of abnormally high heat production. The DOE program used to target areas of high heat flow is described in Appendix A. The results to date indicate that a large area of the Chesapeake Bay and much of the central Delmarva Peninsula exhibits an above average thermal gradient. A deep pump test at Crisfield, Maryland, will test the aquifer performance temperature and near the bottom of the sedimentary sequence.

III. POTENTIAL ENERGY CONTENT OF THE SEDIMENTARY SEQUENCE BENEATH DELMARVA

This section offers an estimate of the amount of energy that exists in the deep, hot, water-rich sediments beneath the Delmarva Peninsula. A conservative approach is taken in approximating the value of many of the parameters, however, the product is considered as realistic an estimate as is possible with the presently limited data.

In performing the calculation a series of assumptions had to be made. They are:

1) Water does exist in the deep sandstone aquifers at temperatues that are high enough to be useable for energy extraction,
2) A certain percentage of this water can be extracted, and this amount is dependent on the physical characteristics of the aquifer, its natural recharge rate, and the extraction and reinjection techniques of the geothermal plant.
3) A large number of wells will be required for the total utilization of the resources.
4) Only the most promising areas will be developed.
5) Average yearly surface temperature of 55° F.

6) The volume of extractable hot water will be estimated as follows:

a) That part of the sedimentary sequence above economic basement (middle Cretaceous and younger) whose maximum temperature is greater than 140°F: areal extent $\approx$2400 sq. miles.

b) The high permeability aquifers have a total thickness of 625 ft.

c) The average temperature of the waters in these aquifers is 135°F.

d) The porosity of the high permeability (sand) aquifers is 10%.

e) Upon extraction, heat will be extracted from the water to the extent that the water temperature is reduced to 100°F ($\Delta T = 35^\circ F$).

Then the volume of water bearing aquifer is

$$6.64 \times 10^{10} \text{ ft}^2 \times 625 = 4.18 \times 10^{13} \text{ cu. ft.}$$

and the volume of water is

$$0.10 \times 4.18 \times 10^{13} = 4.18 \times 10^{12} \text{ ft}^3 \text{ of water}$$

and the weight of water is

$$62.4 \times 4.18 \times 10^{12} = 2.61 \times 10^{14} \text{ lbs.}$$

For $\Delta T = 35^\circ F$, the energy that can be extracted is

$$2.61 \times 10^{14} \times 35 = 9.13 \times 10^{15} \text{ Btu}$$
$$= 9.13 \text{ quad}$$

More energy is available in the rock (defined by its specific heat capacity) and in the water contained in the adjacent units. During production, cooler water will probably recharge the aquifer either naturally or due to reinjection of production water and with sufficient time this water will be heated up by the rock. Thus it is likely that over the long term, more heat can be extracted from the resource than estimated.

A maximum value of the thermal energy stored in the water and rock can be obtained by adding the figure derived above for the thermal content of the water to the heat stored in the rock and an estimate of recharged water. It is not reasonable that all this heat can be extracted. The number given for the thermal content of the water is offered as a ball park figure for the amount of extractable energy.

IV. Geothermal Reservoir Parameters for Energy Retrieval

In the last chapter, an estimate was made of the energy content of the deep water bearing aquifers of the Delmarva Peninsula if certain assumptions were made about the extent, depth, porosity, and temperatures of those aquifers. In general, geothermal waters with temperatures of less than 302°F (150°C) are not considered economic for the production of electricity. Thus for Delmarva, where deep waters temperatures of less 212°F (100°C) are expected, the energy utilization will be restricted to those uses which can directly utilize waters of these lower temperatures such as space heating and food, agriculture, and industrial processing. Since the transport of geothermal waters over any significant distance (of the order of a mile or more) becomes an appreciable cost item, the location of the extraction well near the point of use is an important consideration. Therefore, to the prospective user, the local characteristic of the water bearing aquifer and of the water it contains, is of crucial importance.

The water and aquifer characteristics that are of interest to the geothermal developer are as follows:

1. Water temperature.

The temperature of the water that can be extracted determines the use that can be made of it and the amount of energy that can be extracted from the water is proportional to the difference between the temperature at the top of the well and the lowest temperature allowed for the process under consideration. Thus, for domestic space heating of living space, using present acceptable criteria, no useful heat can be extracted from water at temperatures of less than 65°F and in practice, the temperature at which the useful energy can be extracted will be somewhat higher. As an example, if the temperature of the hot geothermal water, $T_1 = 185°F$ and useful heat can be extracted down to $T_2 = 85°F$, then $\Delta T = T_1 - T_2 = 100°F$ multiplied by the number of pounds of water that can be circulated is the measure in British Thermal Units (Btu) of the energy that can be utilized from the well.

2. Availability of Water.

The quantity of water that can be extracted from an aquifer depends upon its permeability and its thickness. The permeability is a measure of the fluid flow across a unit area for a given pressure gradient and fluid viscosity. For a given aquifer, the transmissibility is defined as the product of its permeability and its thickness. The amount of water stored in an aquifer depends upon its porosity. If water is removed from an aquifer by pumping from a well, then in the steady state, the amount that can be pumped depends not only upon how fast the water moves through it (i.e., the transmissibility) but how and where the aquifer is recharged. As will be shown in the next chapter, practical considerations limit deep well diameters to a rather narrow range (8 to 12 inches) but in any case, the amount of water that can be extracted is relatively insensitive to well diameter and very sensitive to aquifer parameters.

3. Static Head and Drawdown

The static head is defined as the depth of water level in the well, measured from the surface, when the well is not pumped. This level can be anywhere from the aquifer level itself to a point above the ground level if the well is artesian. The static head is a measure of the water pressure in the aquifer. Drawdown is the lowering of the water level in the well for a given pumping rate. The static head plus the drawdown (that is, the dynamic water level) determines the depth at which the pump must be placed for a given water extraction rate. Since the deeper the pump must be placed, the greater the cost of installation, and the higher the water must be raised to the top of the well, the greater the operating costs, the dynamic water level is an important economic factor for a geothermal well. The static head and dynamic water levels are properties of the aquifer itself provided the well is so designed that it has adequate access to the waters in the aquifer.

4. Water Quality.

The relatively hot waters in deep aquifers can be expected to contain relatively large quantities of dissolved solids. These presumably impotable brines will not be directly useful because of the corrosive effects on the distribution system, and for many users, the water quality itself. Thus it is probable that, at the well head, a heat exchanger must be used to transfer the heat from the geothermal waters to water that can be circulated in standard plumbing and, if required, used for typical industrial applications or food processing. This heat exchanger must be designed to withstand the effects of the hot geothermal brines and to permit the required cleaning and servicing. A further effect of the chemistry of the geothermal water will be upon the aquifer itself. As the aquifer is pumped, chemical as well as temperature and mechanical effects can change the permeability of the aquifer and possibly affect the amount of water that can be extracted.

The four aquifer and water characteristics listed above are unknown quantities for the Delmarva Peninsula until a deep hole is drilled. By the summer of 1979, the well to be sunk at Crisfield, Maryland should provide information on the thickness and physical characteristics of the deep aquifers, the water temperature and chemistry, and on the possible water availability for that region of Delmarva. This information will make it possible to estimate, using the principles outlined in Chapter VI, the economic factors for the utilization of the geothermal waters. This economic factor includes not only the distribution to and the heat transfer apparatus at the point of use (which are independent of the aquifer and water characteristics) but also the well installation which consists of the heat exchanger, deep well pump, water monitoring equipment and the disposal method for the geothermal waters. The cost and complexity of this well head installation does depend upon the aquifer and water characteristics discussed above.

V. Geothermal Wells and Well Pumping Systems

The geothermal well is the most expensive single item in a geothermal installation. On the Delmarva Peninsula, the depths required for hot water are expected to be about 5000 ft. and, as will be shown in the next chapter, to be economical, the well must produce several hundred gallons per minute. It is probable that once the heat has been removed from the hot geothermal water, it must be reinjected into the ground by means of a second well drilled into another deep aquifer. As a rough estimate, the well cost alone is expected to be of the order of 1 million dollars. Therefore, it is important for the developer or user of geothermal energy to be aware of the problems presented by the well itself and pumps that must be installed to bring the hot geothermal water to the surface.

It will be assumed for the purpose of this discussion that the hot geothermal water exists in an aquifer several hundred feet thick at depths of typically 5000 ft. It will further be assumed that the aquifer is "confined;" that is, it is between strata that are relatively impermeable to water flow. For such a well, the water yield, Q, in gallons per minute is given by

$$1. \quad Q = \frac{Ts}{528 \log R/r}$$

where T = coefficient of transmissibility in gallons per day per foot (gpd/ft)

s = drawdown in feet

R = radius of influence in feet

r = well radius in feet

R, the radius of influence is the distance from the well where a pressure gradient is produced by the extraction of water. For confined aquifer, this distance is several thousand feet and typical values of log R/r are from 4 to 5. This means that the yield of the well is not a sensitive function of well diameter: if r is changed from 4 to 8 inches, the yield of the well is increased by 5 or 6 percent. Therefore, the well diameter is determined not so much by yield as by the properties of standard deep well drilling rigs and the minimum diameter required by the pump that must be placed in the well.

The transmissibility T is given by the product of the permeability K and the thickness of the aquifer z;

2. $T = Kz$

For equation 2, z is measured in feet and unit of permeability is the U.S. Geological Survey unit, the Meinzer in units of gallons per day per square feet. In oil field work the unit of permeability is the Darcy, k. The relationship between the two is

3. $1 \text{ Darcy} = 18.2 \text{ Meinzer} \quad \frac{u(60°F)}{u(T)}$

where u(T) is the viscosity of water at the temperature T and u(60°F) is viscosity of water at 60°F. For water at 185°F, the ratio u(60°F)/u 185°F is about 3.

From Eq 1, if the transmissibility of the aquifer is known, it is possible to calculate the drawdown of the well for a given rate of water removal. If a permeability of 100 millidarcy or 5.4 gpd/ft (at 185°F) is chosen and aquifer thickness of 100 ft., then T = 540 gpd/ft and for a water flow of 500 gal per minute, the drawdown is 2350 ft. Thus if the static level in the well is 75 ft. below the surface, the pump must be placed at least 2425 ft. below the surface. If the aquifer is 5000 ft. below the surface, Eq 1 is still valid (that is, the dynamic water level is above the aquifer), but the magnitude of the pumping problem can be appreciated. To lift 500 gal/min to the surface will require about 450 horsepower and the electrical power required is about 340 kilowatts. If energy can be removed from the water over a range of 100°F (say from 185°F to 85°F), then the gross energy output will be 7,330 kWh at a cost of 340 kWh of electrical energy.

Deep well pumps are submersible units consisting of multistage centrifugal pumps mounted above an electric motor. Motors and pumps of the capacity discussed here require an 8 5/8 inch exterior diameter well casing. The lifetime of such pumps for geothermal uses is not firmly established but will probably average 2 years. Thus provisions must be made at the well head to pull and rebuild the pump. The estimated cost and operational expenses of the deep well pump are discussed in the next chapter.

The deep hydrothermal well must be cased its entire length to maintain the integrity of the walls, to prevent contamination of fresh water aquifer and to prohibit cold waters from the upper aquifers entering the well. The plumbing to the pump must be able to withstand the corrosive effects of the geothermal waters and so mounted that it can accommodate the thermal expansion effects of cutting on and off the flow of hot water.

At the present time, the physical character of the deep aquifers on Delmarva are unknown. But in addition to the permeability, which as shown above, determines the water yield, the physical character of the water bearing stratum determines the method of well completion. That is, the casing through the water bearing aquifer must allow the water to flow into the well, but prevent the entrance of sand and gravel that could destroy the pump or plug the well. How the well completion must be handled depends upon a detailed knowledge of the aquifer for that can only be obtained by drilling.

The life expectancy of a well is crucial to the economics. In the next chapter, it is assumed that a well has a 25 year production lifetime. To insure that lifetime can be obtained, assuming the aquifer can support it at the required pumping rate, it will be necessary to monitor water quality and ground subsidence. A program of well management must be instituted to insure that chemical and mechanical effects do not permanently damage the aquifer and it may be necessary to limit the water pump rate to a level that guarantees the lifetime of the well.

It is probable, at least in most locations, that the thermally depleted geothermal waters must be reinjected into the ground. This will require another well and pumping system. If the water is reinjected into the same aquifer from which it was withdrawn, the problem of cooling the aquifer must be considered. If reinjected into another (presumably higher) aquifer, the problem of pumping the water into it and of possible chemical incompatibility exists. The engineering problems of injection, like the engineering problems of extraction, can only be precisely stated and evaluated when the natures of the deep laying aquifer have been determined.

VI. APPLICATIONS ENGINEERING AND ECONOMICS

I. INTRODUCTION

This chapter discusses the economics of applicationsof geothermal energy, as found in the eastern United States, to meet moderate-temperature energy demands. Life-cycle costs for any complicated system require detailed engineering data. In the case of geothermal energy, such data are not as yet available on either the resource or the equipment required to extract the thermal energy. Accordingly, we only estimate the life-cycle costs based on reasonable estimates of the resource and proposed application system parameters. The geothermal costs are compared with costs incurred when using more conventional, i.e., fossil, fuels. The resources assumed here are deep hydrothermal resources with higher-than-normal temperature increase with depth. It is too early to estimate costs for lower-than-normal gradient resources or for the exploitation of hot dry rock (HDR).

II. THE USE OF MODERATE TEMPERATURE GEOTHERMAL ENERGY

There follows a discussion of the application of moderate temperature geothermal water to space heating and a brief listing of other possible uses in the eastern U.S. The sytem required for each application and its costs vary and, accordingly, this chapter limits itself to consideration of a newly constructed residential space heating system. This is not to say that this is the best or the least costly application.

1. Space Heating with Geothermal Water

a. System Block Diagram

The use of geothermally heated water for space heating may incorporate several supply wells depending on the needs of the community and considering the costs. To focus on these costs, we present the case of a single well system and the varying conditions and costs under which it serves different markets and demand areas. The temperature of the resource and the usage density are both important parameters which have a pronounced effect on the cost of geothermal energy. To illustrate these points, seven different resource temperatures and three residential densities will be used in the calculations. Table I defines the residential densities assumed.

Table I

Density of Communities for Geothermal Space Heating

Type of Community	Density Residences/ 200 x 400 Block	 Residences/ sq mi
Suburban	7	2,535
Town Houses	30	10,140
Garden Apartments	51	17,000

Figure VI-1 illustrates a geothermal community heating system. Here the geothermal water goes through a central heat exchanger and then, depending on the quality of the water and the locale of the system, to some form of surface or subsurface disposal.

The water on the other side of the heat exchanger circulates through the community in a closed system where water chemistry and corrosive properties can be controlled. The system that is posed in this paper may require a topping subsystem after the heat exchanger depending on whether housing units heating demand is completely satisfied by the geothermal resource or if it needs to be supplemented.

The individual residence accepts the heated circulating water and either circulates it directly through radiators or it goes through a small individual heat exchanger, delivering the heat to circulating air. The cost of this latter type of system is estimated.

b. The Wellhead Heat Exchanger

The wellhead heat exchanger is used to transfer the thermal energy from the geothermal water to the local water that will carry the energy to the community. Like many physical devices, its efficiency may be improved through a more expensive design. Since the correct balance between economic efficiency and engineering efficiency is project specific, the heat exchanger costs and performance figures in this report are a compromise.

The variable which best illustrates performance is the differential temperature (ΔT) between the input and output on the community side of the heat exchanger or between the input and exit on the geothermal well side of the heat exchanger, see Table II.

Table II

Definition of Differential Temperatures (ΔT) to Community

	Geothermal Water Temperatures		Circulating Water Temperature	
Differential Temperature	Top of Well Input to Central Heat Exchanger	Exit from Heat Exchanger	Output of Heat Exchanger	Input to Heat Exchanger
ΔT °F	°F	°F	°F	°F
110	195	85	190	80
100	185	85	180	80
90	175	85	170	80
80	165	85	160	80
70	155	85	150	80
60	145	85	140	80
50	135	85	130	80

Given varying ΔT's the cost of the central heat exchanger for the above performance with a maximum flow rate of 500 gallon per minute through the exchanger has been calculated and is presented in Table III.

Table III

Cost of Central Heat Exchanger

Sized to Requirements of Table II at 500 gallons per minute

ΔT °F	Cost ($)	Btu per Min Delivered
110	118,000	459,000
100	107,000	417,000
90	96,000	376,000
80	86,000	334,000
70	75,000	276,000
60	64,000	250,000
50	54,000	209,000

c. The Peaking System

The topping plant plays a most significant role in a community heating system during the peak heating period. This plant, fired most probably by fossil fuel, provides a small increment of temperature to the circulating hot water. The topping system must be capable of large heating rates to augment the geothermal system for the very short duration when outside temperatures are below the design point, which occurs typically less than 10% of the heating season. The presence of the peaking system allows the system designer to increase the number of residences that can be served by a given well. This is achieved by selecting some moderate design ambient temperature and allocating the geothermal energy available to as many houses as can be served by the well's output. For the short duration of time when the outside temperature is lower than this design point, then the peaking system increases the circulating water temperature accordingly. The result is that the utilization of the geothermal well is increased and the resultant savings in capital debt service on a per million Btu basis more than compensates for the cost of the peaking plant and its fuel. A minimum cost per million Btu exists and its character is illustrated later.

The peaking system has several other advantages. These are: it provides a method of matching very moderate temperature resources to many user requirements; it serves as a limited emergency backup, if required, particularly when and if the geothermal well or associated equipment require maintenance during the heating season.

The cost of peaking systems with the peak thermal capacities discussed in this analysis is assumed to be $26,000 per million Btu per hour heating rate. This cost includes boilers, building, controls, and plumbing. The life expectancy of a peaking system at this cost is 15 years for 50% utilization and more than double that (30 years) for the utilization factors assumed here.

d. Home Heat Exchanger

As has been previously mentioned, the home heat exchanger is assumed to be a circulating hot water to air exchanger. The detailed design of the exchanger and costs must be done when specific temperatures and heat loads are known. For this paper, a cost of $100 to $350 appears reasonable to handle the maximum heat loads for an average house at the temperatures supplied by the geothermal and peaking plant.

e. Space Heating System Requirements

The heating and refrigeration industry has developed rules of thumb for estimating the peak heating load and the total annual energy required for a typical residence. These are as follows for a reasonable insulated single story home of 1800 sq ft (Ref. 3).

Peak Energy Demand

The peak energy demand occurs during the coldest period of the year, and the size of the peak may be estimated using local historical data available from Ref. 6. The peak energy demand in Btu per hour is the difference between 65° F, the point at which heat may first be supplied, and the selected design ambient temperature, multiplied by 1200 or:

$$\text{Peak Btu per hour} = 1200 \times (65 - \text{design ambient temperature}).$$

The geothermal resource may be designed to meet 100% of this peak, or, as is suggested in this paper to meet some higher temperature, which allows the resource to be shared by additional residences. The difference between the peak demand and the design ambient temperature demand would be supplied by a peaking system.

Table IV lists the peak Btus required and the percent utilization of the geothermal resource as a function of the design ambient temperature for the Delaware area. Two degrees Fahrenheit is assumed to be the lowest temperature. Note that at a design ambient temperature of 35° F afforded by the use of a peaking system, the utilization of the geothermal well is doubled from the approximate 22% if it were used without a peaking system to heat a smaller community.

Annual Energy Demand

Figure VI-2 shows the annual ambient temperature versus duration for the Delaware area. These data are 10-year averages for 5° F temperature increments. The energy demand is determined from the difference between 65° F the point at which heat may first be supplied, and the selected design ambient temperature, as has been discussed. The total annual energy requirements are the integration of these demands over the heating season. This value is frequently expressed as Degree Days. In the case of the Delaware area shown in Fig. VI-2, there are 4983 Degree Days on the average. To obtain the total annual number of Btu's for a 1800 sq ft residence, multiply the number of Degree Days by the constant 28,800, which comes to 143 million Btu's per residence per annum, Ref. 6.

f. System Performance

The Number of Residences That Can Be Heated by One Geothermal Well

Table IV shows the maximum heating rate that must be supplied by the community heating system to each residence as a function of design ambient temperature. If the maximum delivery rate of the geothermal well were used to supply the peak heat rate, then it could supply fewer residences than if it were used to supply the lower peak rate of a higher design ambient temperature, the difference being supplied by the peaking system. The thermal output of the well is equal to the flow in gallons per minute Q times the thermal content per gallon. The latter is equal to the specific heat (unity) times the temperature differential times the number of pounds per gallon (i.e., Btu's per minute = Q x 8.4 x ΔT). Table IV lists the number of residences that can be supplied for different design ambient temperatures and geothermal well differential temperatures.

Table IV

The peak heating rate, number of residences in the Delaware area that can be supplied by 500 gallon per minute geothermal well, and the utilization factor of the geothermal well as function of design ambient temperature.

Outside Design Ambient Temperature	Peak Heat Rate Demanded	Number of Residences Supplied for a Differential Temperature Available from Well ΔT 110	90	70	50	Utilization of Well
°F	Btu/hour					Percent
2	75,000	363	298	231	165	22
10	66,000	416	340	265	189	25
15	60,000	458	375	291	208	27
20	54,000	509	416	324	231	30
25	48,000	573	468	364	260	34
30	42,000	654	535	416	297	39
35	36,000	763	625	486	347	46

2. Other Uses

In addition to residential space heating, there are the following other potential uses of geothermal energy on the Atlantic Coastal Plain. Each of these has its own unique temperature requirement, annual energy demand cycle and economics, as indicated in Fig. VI-3.

Although not discussed in this paper, community domestic hot water heated from the geothermal waters is practical for high density communities.

Space Cooling

In addition to space and water heating, space cooling can be performed wherever the geothermal resource is hot enough. Absorptive air-conditioning equipment powered by heat is not advertised to operate efficiently below 180° F-200° F. It is possible that in time these systems, or variations of these systems, may be driven by lower temperature geothermal heat and will be able to supply space cooling in addition to space heating, increasing the annual usage of the geothermal resource.

Poultry Industry

The year-round space conditioning of poultry brooding houses is a future potential if sufficient numbers of brooding houses can be located near a resource. In addition, poultry eviscerating plants use large quantities of water in the 125° F-180° F range year 'round, and thus offer a prime potential use of moderate temperature geothermal water.

Agricultural Use

The food-processing industry uses large volumes of water in the 120° F-200° F range for pasteurization, crop cleaning, vegetable peeling, blanching, and cooking. While many of these are seasonal, most large plants have several product lines which allows them to operate year 'round.

Greenhouses, growing either vegetables, cut flowers, or bedding plants, are currently a small industry on the Coastal Plain; however, reliable moderate cost energy for space heating would promise growth of that industry.

The drying of lumber, grain, and tobacco are all additional potential users of geothermal.

This list is not intended to be all-encompassing or complete but rather to illustrate those applications receiving study by DOE and industry groups.

III. THE COST OF GEOTHERMAL ENERGY USED FOR COMMUNITY SPACE HEATING

The cost of geothermal energy used for space heating of a new community is determined by: 1) the costs associated with the geologic assessment of the resource and the determination of the engineering parameters for the specific geothermal resource under consideration; 2) the cost of drilling, casing and completing the well; 3) the costs of the geothermal well down-hole-pump used to deliver water to the surface, the wellhead heat exchanger; 4) drilling and completion of the reinjection well; and 5) the distribution system, the peaking subsystem, and the home radiators or heat exchangers.

The following sections discuss, first, the costs of the geothermal energy delivered at the wellhead heat exchanger. It is assumed that the prospective user is co-located with the geothermal well. In succeeding sections, the cost of geothermal energy delivered to the individual residence is shown. Finally, costs of available energy alternatives are listed.

1. Resource Assessment and Engineering

The costs associated with the definition of the size, character and engineering properties of a geothermal resource can be substantial, and, since they are so variable as a function of resource type and vary from area-to-area, no attempt is made to detail them here. In Europe and to some extent here in the U.S. the government does much of the resource assessment in developing the methodology and tools for reservoir engineering and management. In the case of the Atlantic Coastal Plain, the DOE/DGE is assessing the extent of the resource from New Jersey to Southern Georgia and will develop reservoir engineering data on some, if not most, of the promising areas on the Plain. These costs are not included in this paper.

2. Cost of One Million Btu of Thermal Energy Delivered at the Wellhead

The cost of one million Btu of energy delivered by the heat exchanger to the circulating water used for residential space heating involves both initial capital and recurring costs. For this paper it is assumed that the geothermal water must be reinjected by a second well and pump to an intermediate depth of 2000-3000 ft.

Initial Costs of a Geothermal Well

a. The cost of a 7500-ft geothermal well, completely equipped, in the Atlantic Coastal Plain is estimated to be approximately $475,000.

b. The reinjection well = $200,000

c. The heat exchanger = $125,000

d. The down-hole pump including cable and all additional equipment = $125,000

e. The costs of plumbing between wells and heat exchanger, the circulating pump and reinjection pump are all considered to be relatively insignificant and are not included here.

The total cost for this phase, therefore is $925,000. In the analysis, a capital recovery factor, using a 10% interest rate and amortization over 25 years, is 11%.

Operating Cost of a Geothermal Well

The cost of operating the down-hole pump and its maintenance is substantial.

For 100-percent operation, the cost of a 817 horsepower down-hole pump requiring an input power of 780 kilowatts amounts to $313,000 per year, assuming electrical power at $0.04/kw-hr.

The down-hole pumps have a finite life, after which time they must be removed and reworked. The average life for continuous operations in the expected down-hole environment of the Coastal Plain is approximately three years. The cost of removal and rework is 70% of the original cost. The pump cables and in-well equipment are assumed to be completely replaced every six years of continuous service.

This represents an additional operating cost which is hard to quantify at this point. It is not included in the following cost estimates because it probably will amount to less than 10% of the annual operating cost.

The wellhead cost of one million Btu's of geothermal energy is the annual cost of capital plus the operating costs divided by the number of millions of Btu's available annually from the geothermal well. The number of Btu's available varies with the differential temperature available at the wellhead. Table V lists the annual thermal output of the well for a flow of 500 gallons per minute. Figure VI-4 shows the cost, in dollars per million Btu's, as delivered from the wellhead heat exchanger as a function of utilization.

Table V

Differential Temperature ΔT °F	Total Btu's
110	2.42×10^{11}
90	1.98 " "
70	1.54 " "
50	1.10 " "

3. The Total Cost of One Million Btu's of Geothermal Energy Delivered to an Individual User

The total cost of geothermal space heating as presented here is the sum of the wellhead costs per million Btu's and the cost per million Btu's of the system to deliver the energy to the individual residence, i.e., the hot water distribution system, the peaking plant and the fossil fuel as required. The distribution system and peaking plant are considered capital costs and a capital recovery factor, using a 10% interest and amortization of 25 years, is 11%. The fossil fuel is an added annual operating cost.

Table VI shows the total cost of one million Btu's of energy delivered to an individual user in one of three community heating systems as a function of the design ambient temperature and the differential temperature. All homes were assumed to be of the same size, i.e., 1800 sq ft with reasonable insulation. The costs include the purchase of fuel oil for the peaking plant at 100,000 Btu per gallon net and at a cost of $20 per barrel.

Figure VI-5 shows the cost as a function of design ambient temperature for the three different density communities and the hottest geothermal well, viz., ΔT = 110° F. The lowest cost is for a design ambient temperature of 5° F; however the curve is so flat that other considerations other than cost will probably decide design point. Figure VI-6 shows the same curve for the lowest temperature geothermal well, viz., ΔT = 50° F. Here the lowest cost is at a design ambient temperature of 20° F. Figure VI-7 shows the cost as a function of design ambient temperature for all assumed well temperatures, i.e., ΔT = 110° F to 50° F for the garden-type of high density community.

Table VI

Total cost of geothermal heat per residence
Delaware area. Cost in dollars per million Btu

```
DEL.T= 110.0 DEG F
 DESN TEMP      0.0     5.0    10.0    15.0    20.0    25.0    30.0    35.0
 GARDEN APT   3.415   3.385   3.363   3.354   3.360   3.393   3.536   3.827
 TOWNHOUSE    4.228   4.197   4.176   4.167   4.172   4.205   4.348   4.639
 SUBURBAN     5.842   5.811   5.790   5.781   5.787   5.819   5.962   6.254

DEL.T= 100.0 DEG F
 DESN TEMP      0.0     5.0    10.0    15.0    20.0    25.0    30.0    35.0
 GARDEN APT   3.736   3.690   3.653   3.630   3.621   3.640   3.771   4.052
 TOWNHOUSE    4.548   4.502   4.466   4.442   4.434   4.452   4.583   4.865
 SUBURBAN     6.162   6.116   6.080   6.056   6.048   6.066   6.197   6.479

DEL.T=  90.0 DEG F
 DESN TEMP      0.0     5.0    10.0    15.0    20.0    25.0    30.0    35.0
 GARDEN APT   4.127   4.062   4.008   3.966   3.940   3.942   4.058   4.328
 TOWNHOUSE    4.939   4.875   4.820   4.779   4.753   4.754   4.871   5.140
 SUBURBAN     6.553   6.489   6.434   6.393   6.367   6.368   6.485   6.754

DEL.T=  80.0 DEG F
 DESN TEMP      0.0     5.0    10.0    15.0    20.0    25.0    30.0    35.0
 GARDEN APT   4.616   4.528   4.451   4.387   4.339   4.319   4.417   4.672
 TOWNHOUSE    5.428   5.341   5.263   5.200   5.151   5.131   5.230   5.484
 SUBURBAN     7.042   6.955   6.877   6.814   6.765   6.745   6.844   7.099

DEL.T=  70.0 DEG F
 DESN TEMP      0.0     5.0    10.0    15.0    20.0    25.0    30.0    35.0
 GARDEN APT   5.244   5.127   5.021   4.928   4.852   4.804   4.879   5.115
 TOWNHOUSE    6.057   5.939   5.833   5.741   5.664   5.617   5.692   5.927
 SUBURBAN     7.671   7.554   7.447   7.355   7.278   7.231   7.306   7.541

DEL.T=  60.0 DEG F
 DESN TEMP      0.0     5.0    10.0    15.0    20.0    25.0    30.0    35.0
 GARDEN APT   6.083   5.926   5.780   5.649   5.535   5.451   5.495   5.705
 TOWNHOUSE    6.895   6.738   6.593   6.462   6.348   6.264   6.307   6.517
 SUBURBAN     8.509   8.352   8.207   8.076   7.962   7.878   7.921   8.131

DEL.T=  50.0 DEG F
 DESN TEMP      0.0     5.0    10.0    15.0    20.0    25.0    30.0    35.0
 GARDEN APT   7.256   7.044   6.844   6.659   6.493   6.357   6.357   6.531
 TOWNHOUSE    8.069   7.856   7.656   7.472   7.305   7.170   7.169   7.343
 SUBURBAN     9.683   9.470   9.270   9.086   8.919   8.784   8.783   8.958
```

4. Traditional Alternatives

One important method of estimating the economic prospects for geothermal-based space heating is to compare it with other traditional fuels. In Appendix VI-A, using available data, such as the published rate schedules for electricity and gas, we estimate typical per million Btu costs. These are as follows:

Oil	$5.00/million Btu's
Gas	$4.00/million Btu's
Electric space heating	$11.00/million Btu's

Even though we worked with published tariffs, the block structure of the tariff required that we choose typical consumption in order to arrive at per million Btu cost. We did this and our estimates are in agreement with other estimates calculated from national averages.

The conclusion one may reach is that geothermal, under suitable conditions, can match and even beat the prices of traditional fuels.

IV. CONCLUSION

The role of geothermal energy in accommodating the demands for space heating and cooling water heating, and moderate temperature industrial processes is quite promising for the following reasons. 1) The reliability of supply is relatively high; these are natural processes and all that remains is to find where nature has been especially generous. 2) Since the resource, itself is in many ways somewhat inexhaustable, the future delivered price will depend only on the direct price of recovery. In the case of fossil fuels, the future price will depend on the price of recovery, the rising cost of discovery, and cartel arrangements. 3) The environmental effects can be controlled through reinjection of the geothermal well water. 4) This source of energy will replace some of the need for conventional sources of energy which in turn implies that the environmental dangers associated with these fuels will decrease commensurately. 5) While geothermal energy of the variety we have been discussing is not as convenient in handling and use as some fossil fuels, it is no less convenient when used in stationary processes such as space heating or industrial processes. 6) Perhaps the most compelling argument in support of geothermal applications comes from the cost analysis. Using standard life cycle costing methods, we have shown that under favorable circumstances, which consist of no more than reasonably warm water and medium-to-high density housing, geothermal energy is less expensive than traditional fuels for satisfying moderate temperature energy demands. While the present picture is favorable we do not yet have a complete picture. While the major system design variables have been considered in this chapter, there are many more which must be considered in a full system design. In addition, there are several problems which act as barriers to the full development of the geothermal resource. The properties and extent of the geophysical resource must be assessed as well as the detailed cost of recovery. The legal question of resource ownership has not been resolved in most of the eastern states. Finally, a public or private corporation or authority must have an interest, outside its traditional product line or service supply, in developing a geothermal system. These problems will be discussed in the following chapters.

APPENDIX VI-A

THE COST OF ENERGY FROM TRADITIONAL FUELS

Fuel Oil

Fuel oil with a heat capacity of approximately 135,000 Btu per gallon costs approximately $0.50 per gallon today. In residential furnaces used for space heating the net energy delivered is probably less than 100,000 Btu per gallon, leading to a cost of $5.00 per million Btu's.

Natural Gas

Natural gas with a heat capacity of 1000 Btu per standard cubic foot sells at the following rates in the Delaware area in the winter of 1978-79.

First 300 cu ft = $0.9556/100 cu ft
Next 1200 cu ft = $0.3976/100 cu ft
Next 1500 cu ft = $0.3226/100 cu ft

The conversion of the gas in residential furnaces is probably less than 80% efficient on the average; therefore, the eventual slope of the curve is approximately $4.00 per million Btu.

Electric Resistive Heat

Electric energy is sold to different customers at different rates. In the Delaware area the cost of electric energy for electric heated homes is calculated as follows.

Monthly costs for winter of 1978-79

Cost = $5.85 + 0.04635 (kilowatt hours used during highest month of summer 1978) + 0.02585 (kilowatt hours in excess of peak 1978 summer month).

For the average all electric home, this represents a cost during the coldest winter months of $10.00 to $11.00 per million Btu's.

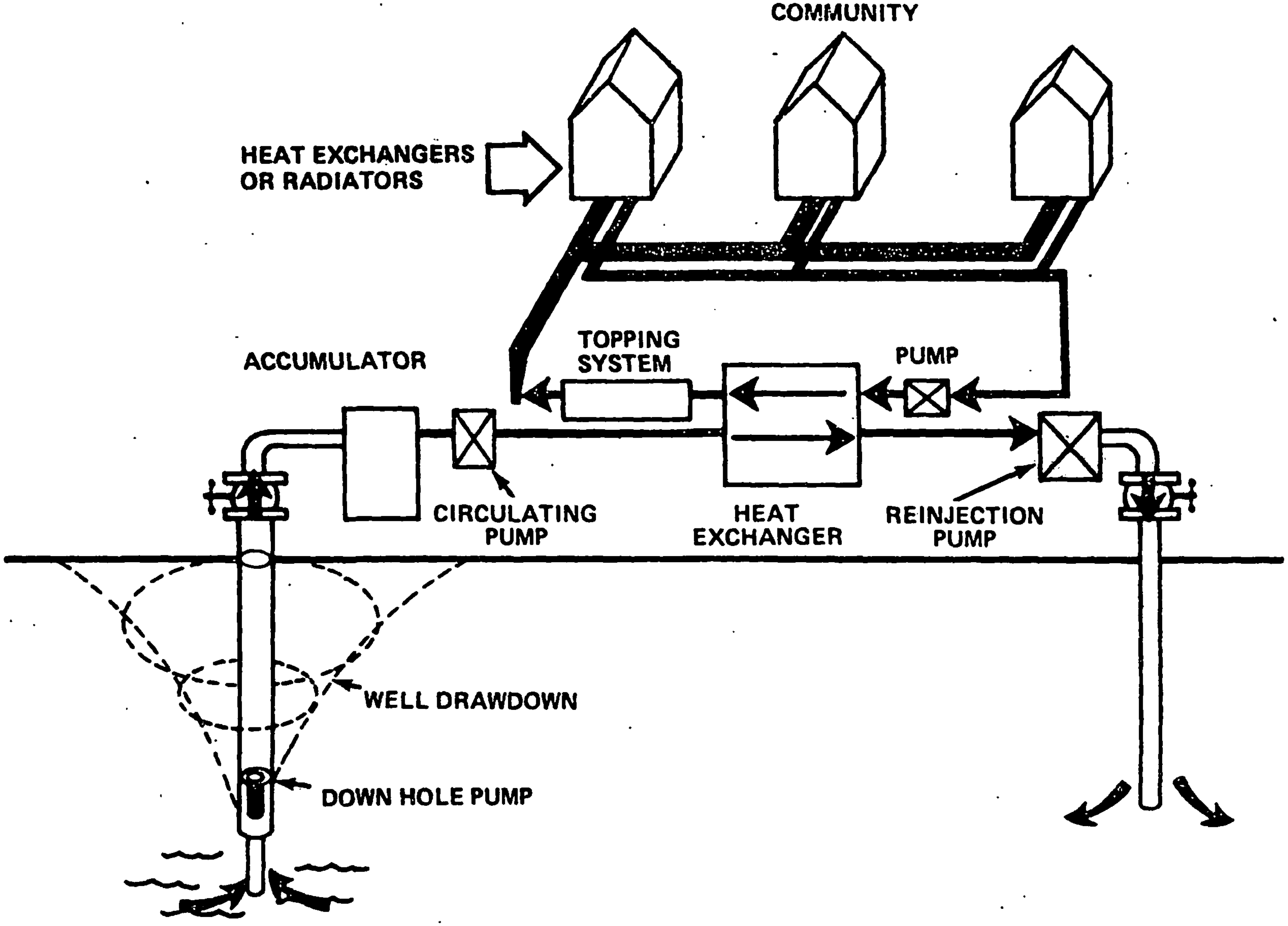


Fig. VI-1 - Illustration of Community Heating — Hydrothermal resource

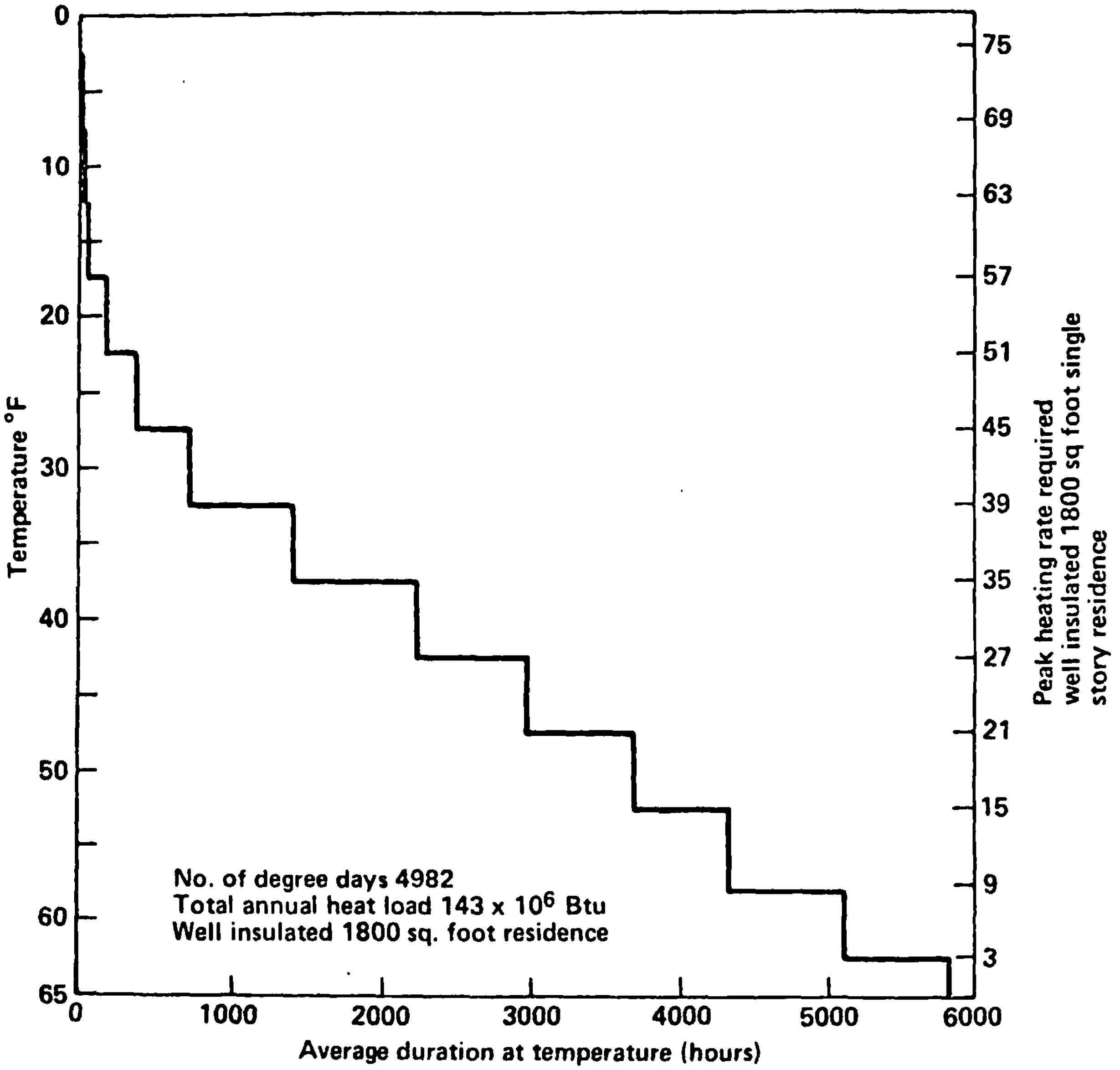


Fig. VI-2 - Annualized Frequency of Hourly Temperatures Delaware Area, 1951 – 1960 Period

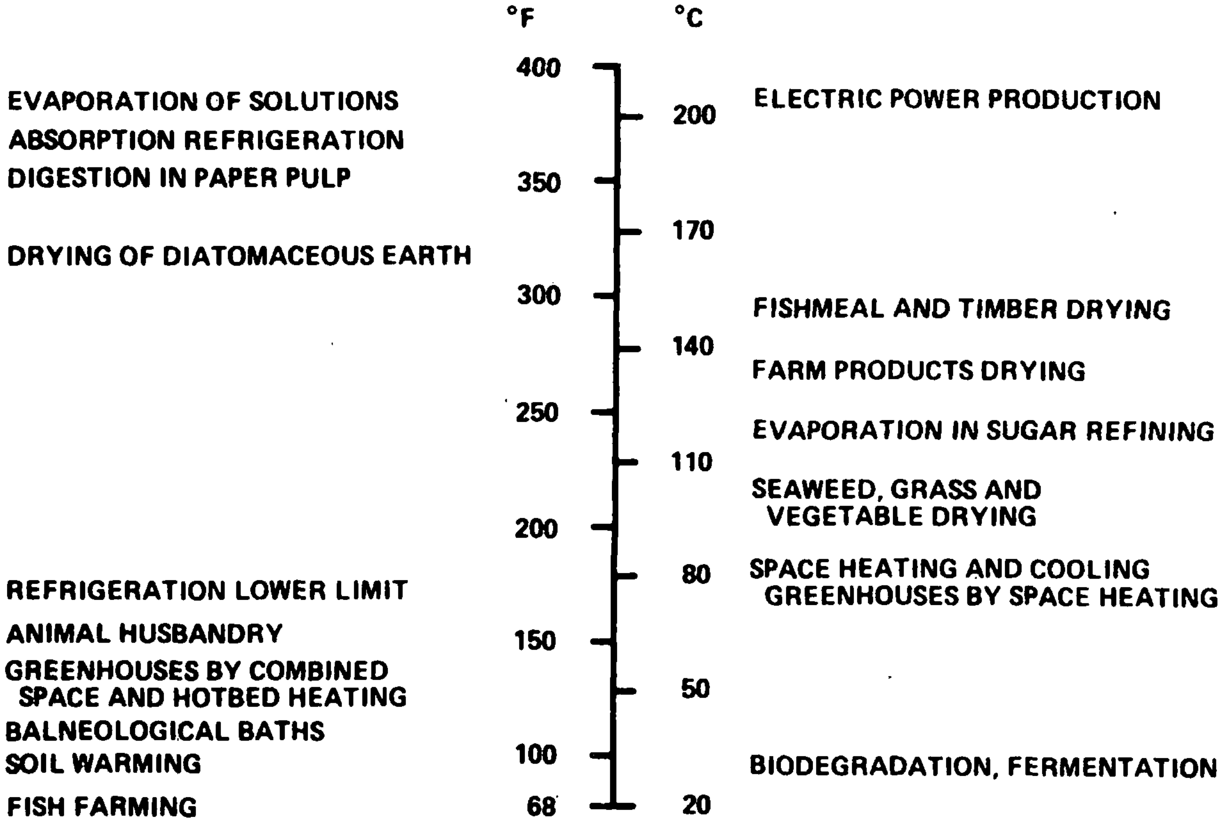


Fig. VI-3 Required Temperatures for Various Processes

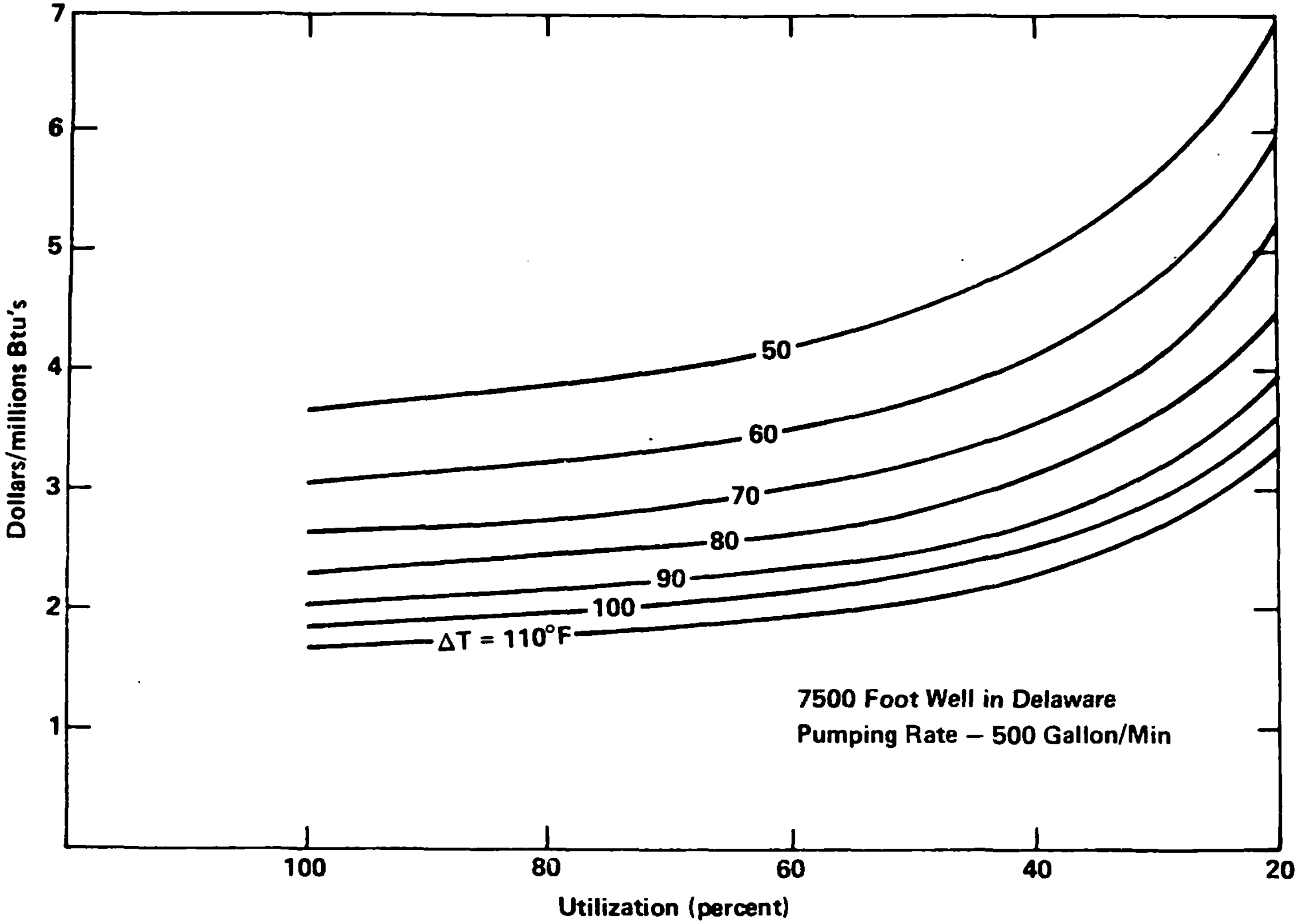


Fig. VI-4 **Well-Head Costs of Geothermal Water**

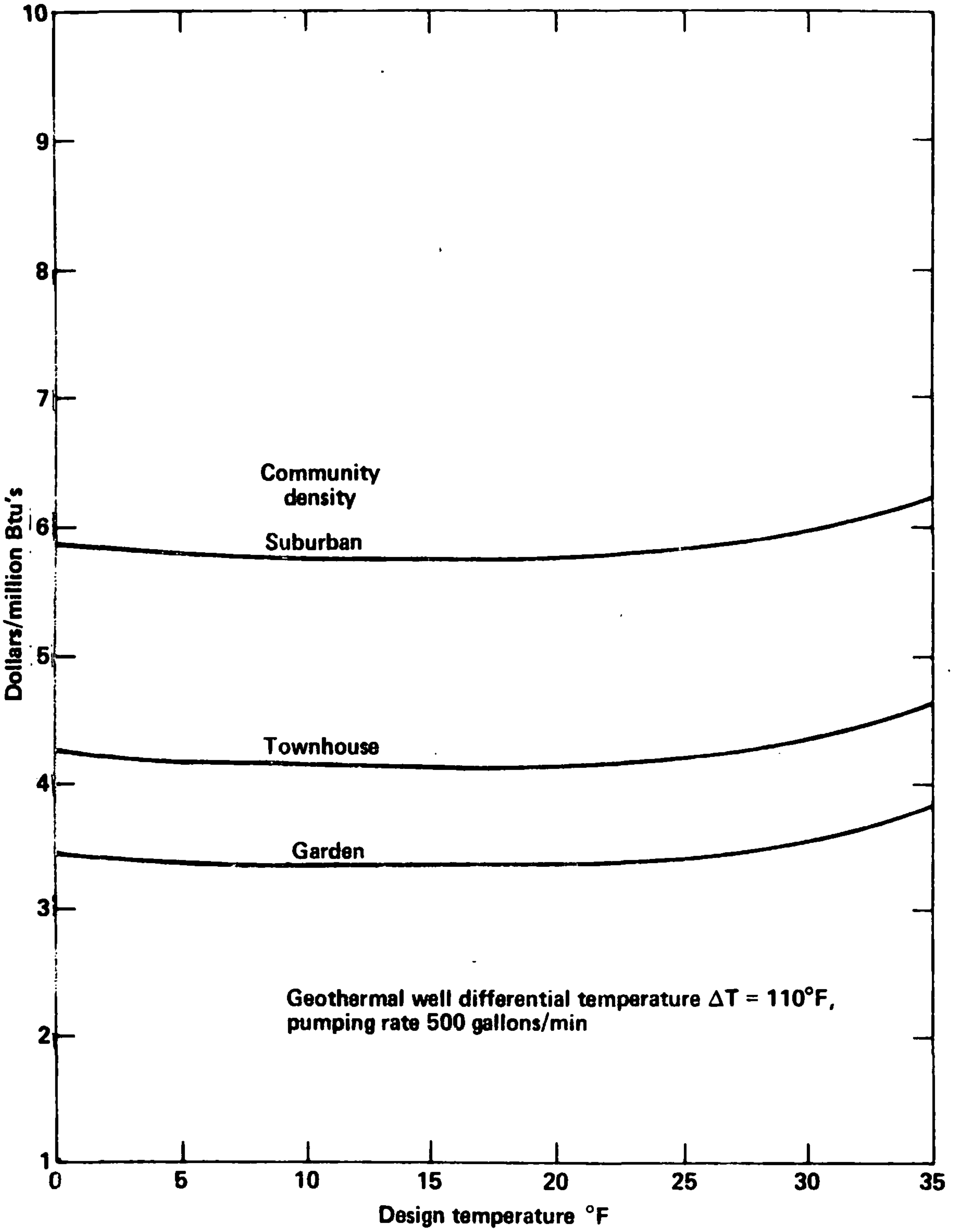


Fig. VI-5 Cost of geothermal energy – Atlantic Coastal Plain, Delaware.

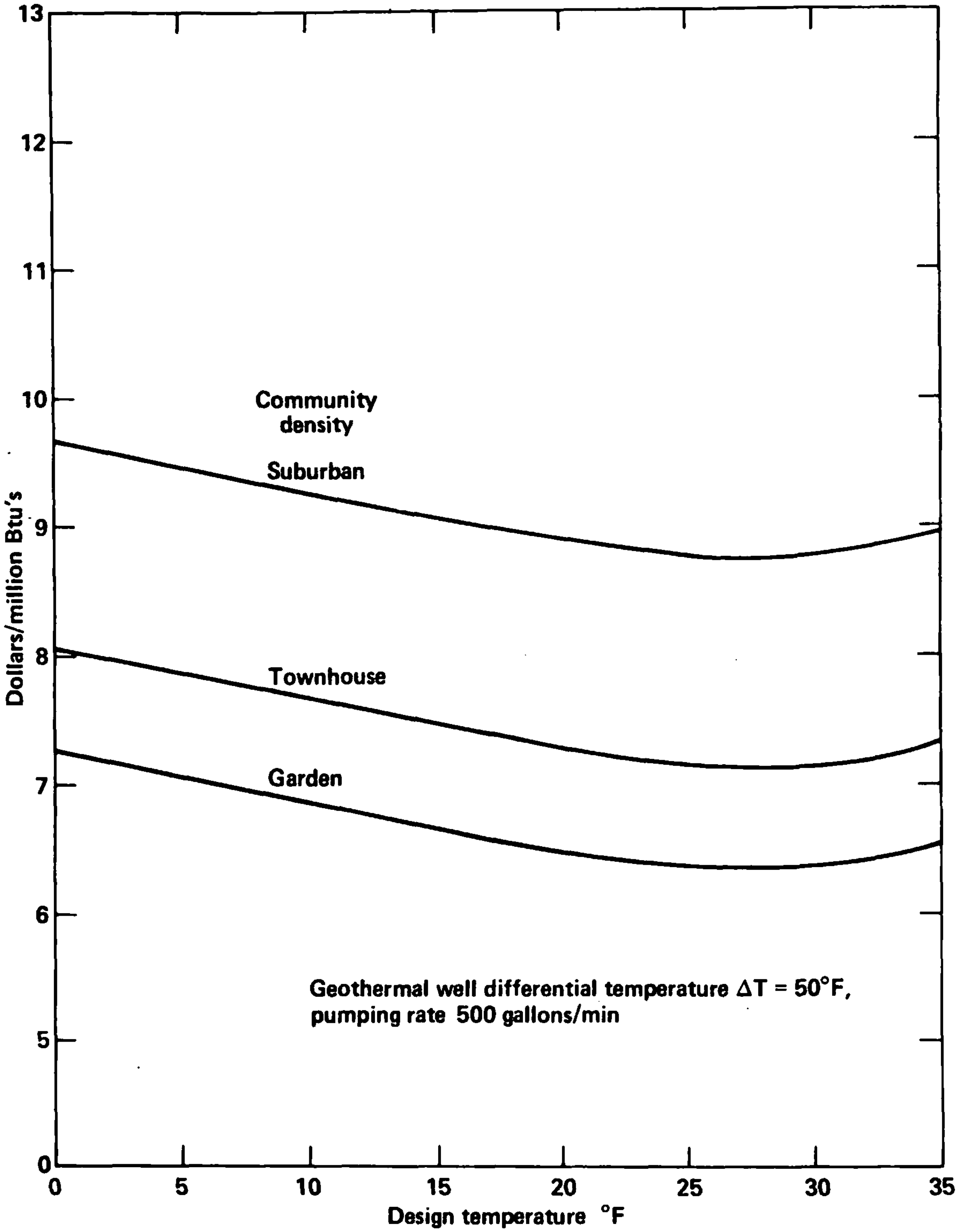


Fig. VI-6 Cost of geothermal energy – Atlantic Coastal Plain, Delaware.

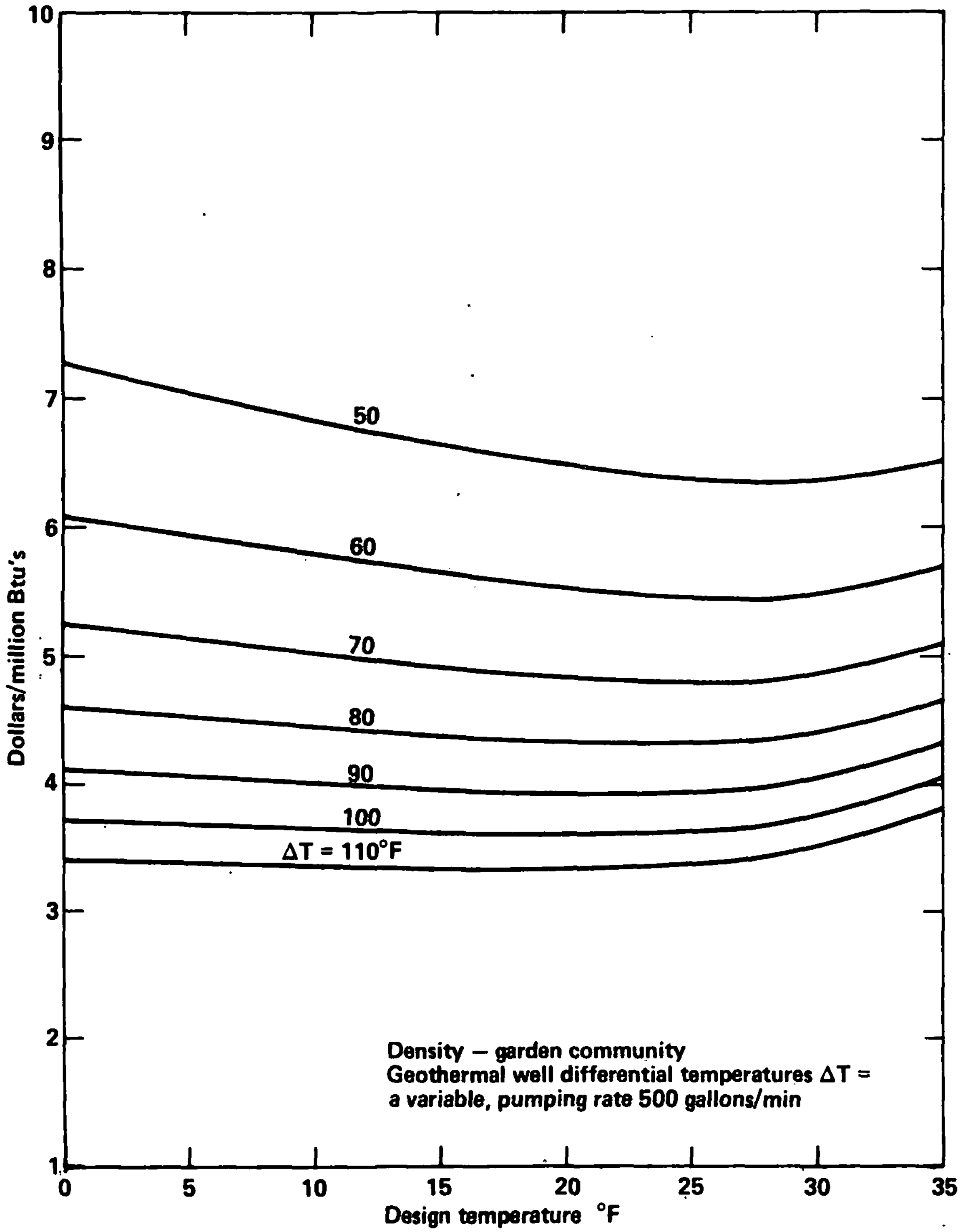


Fig. VI-7 **Cost of geothermal energy — Atlantic Coastal Plain, Delaware.**

Chapter VII DEVELOPMENTAL PROCESS

The following table lists the steps which are necessary for an individual to take in order to develop a geothermal resource on the Delmarva Peninsula in Maryland. Many of these steps have associated with them local, state, and federal regulations which will have to be complied with in most instances. These regulations are necessary in order to protect the other natural resources of the state and the rights of the citizens in Maryland. The rationale and framework for the environmental regulations are discussed in more detail in Chapter VIII, Part 1. The legal and financial issues are also discussed in more detail in Chapter VIII. A list of sample permit forms are included in Appendix D.

A short discussion of similar regulations in Delaware is found in Appendix B.

Development Process for Industrial Geothermal Use in Maryland

Steps	Regulations and Comments	Further Discussion
0. Financing	a) Development Corporation with insurance	Chapter VIII
1. Well-site Selection	Based on exploration or utilization criteria	Appendix A and C
2. Rights to drill	a) Ownership search	Chapter VIII
	b) Obtain legal right to use surface: lease property if private or letter of agreement if public	
	c) DNR WRA one year exploratory permit plus fee	
	d) DNR WRA construction and Appropriation permit	Requires public notice and opportunity for public hearing
	e) Filing of bond	
3. Environmental Assessment	a) Army Corps of Engineers permit	Chapter VIII
	b) Energy and Coastal Zone Management Permit	
4. Drilling Production and Reinjection wells	a) Engage oil drilling rig	
	b) Master Driller Registration by Maryland State Board of Well Drillers, Bond	
	c) State Highway Permit	
	d) Fuel Tax Permit	
	e) Vehicle Tag Apportionment	
	f) State and County Health Permits	
	g) Well completion reports	
	h) Prepare surface to prevent runoff	

Steps	Regulations and Comments	Further Discussion
5. Logging	a) Data to be filed with Maryland DNR 1) Geological Survey 2) Water Resources Administration	All geophysical logs, drillers log, well history report, water quality, water temperature, cores, hydrologic analysis
6. Pump Testing	a) Liquid Waste Discharge Permit (ACE, MGS)	Chapter VIII
	b) Reinjection (case by case review by DNR)	
7. Surface Plant Construction and Distribution System	a) Prohibited in wetlands	
	b) Local zoning board building permits	
	c) Noise and air pollution laws	
	d) Piping in navigable waters regulated by ACE	
8. Production	a) Utility Charter	Chapter X
	b) Withdrawal reports to DNR WRA biannual	
9. Abandonment	a) Sealing and filling	
	b) Restoration	
	c) Discharge bond	

VIII. DISCUSSION OF CURRENT ENVIRONMENTAL, FINANCIAL AND LEGAL INFRASTRUCTURE

This chapter is divided into three sections and serves as a more detailed backup to items identified in Chapter VII. The first, discusses environmental rules and regulations pertaining to the exploration for and development of geothermal energy in Maryland. The second describes in general terms the potential ways to partially finance geothermal development using government assistance. The third briefly identifies the legal issues to be considered and reproduces the statute as it appears in the Annotated Code of Maryland.

A. Environmental Regulations

1. Introduction

There are two very important natural resources in the Delmarva area which demand that care be exercised in all disruptive activities in order to ensure their future use. Fresh, cold ground water exists in most parts of Delmarva but its abundance is finite and its supply may be critical in certain areas in the near future. Geothermal development, if not properly conducted, could easily chemically and/or thermally contaminate this water. Secondly, the Chesapeake Bay, the Atlantic Ocean and related wetlands are vaulable commercial and recreational resources which must be protected. To this end, state and federal environmental regulations have been written and are listed in Chapter VII. The rationale and framework for these regulations are discussed below.

2. Maryland Water and Geothermal Resources Law

The Geothermal Resources Act was passed by the 1978 Session of the Maryland General Assembly. The Act is patterned after existing statutes on water-well construction and water appropriation. For this reason a brief examination of the appropriation and well construction permit programs is appropriate.

a. Water Well Construction and Water Appropriation Permit Programs

Under the Maryland Annotated Code a well may not be drilled until the Water Resources Administration issues a well construction permit. The permit provides for the collection of basic data on wells drilled in the state as well as for conformance with the well construction standards defined in the groundwater rules and regulations. There are also provisions in the Annotated Code as well as rules and regulations for proper sealing and filling of abandoned and test wells.

With two exceptions water appropriation permits are required for all surface and groundwater appropriations regardless of the amount of withdrawal. The exceptions are water used for domestic and farming purposes. All industrial, municipal, and commercial users do come under the program.

b. Geothermal Resources Act

The objectives of Maryland's Geothermal Resources Act of 1978 are to optimize the productive use of the state's geothermal resources, avoid waste, and protect the environment. The Geothermal Resources Act defines the geothermal resource essentially as the heat of the earth higher than 120°F, the energy available from this heat, the medium containing the heat, and the products (with the exception of hydrocarbons) obtained from the medium containing the heat. Maryland's Geothermal Resources Act does not address the question of resource ownership; however, the Department of Natural Resources is clearly given responsibility for regulating use of the resource. The act requires submission of detailed information on geothermal projects and demonstration that a geothermal appropriation will not be a potential or undue burden on water supplies and will not cause an unreasonable rate of resource exhaustion.

c. Implementation of the Geothermal Resources Act

Specific concerns to be addressed by the Geothermal Resources Act are the protection of fresh-water aquifers and the allocation of water and heat from geothermal producing formations. It is anticipated that the water medium containing the geothermal resource will be highly saline and that there will be no direct contact between geothermal wells and water supply wells. Confining beds overlying the geothermal producing formations should prevent geothermal appropriations from affecting quality or potentiometric heads in overlying fresh-water aquifers. It is important that geothermal well construction regulations be adequate to ensure that water from producing formations will not enter other formations through the properly finished wells themselves. This potential problem also will have to be addressed by regulations that provide for the eventual proper abandonment of all geothermal wells.

The impact of geothermal appropriations on potentiometric heads in a producing formation and therefore on other geothermal appropriators using the same formation may be a future concern. In this respect the review for a geothermal appropriation application will be similar to that for a groundwater appropriation application. It is presently anticipated that the question of whether or not the water produced will have to be injected back into the producing formation will be answered on a case-by-case basis. The primary consideration with surface discharge will be the effect on the quality of surface waters and, therefore, on the surface environment. In addition to environmental benefits it is likely that the injection of geothermal water back into the producing formation (a form of recirculation) will have a lesser impact on the geothermal resource than alternative means and methods of discharge.

No regulations have yet been promulgated for processing the exploratory and appropriation permits. The information gained from the exploratory well which will soon be drilled near Crisfield, Maryland, is expected to provide information on water temperature, quality and availability that will assist in drafting the first set of geothermal regulations. For the interim, applications for geothermal exploration wells and geothermal appropriations have been, and will continue to be, processed according to the intent and guidelines provided in the statute (Geothermal Resources Act). This allows for considerable judgment by the technical staff evaluating the applications. The first set of regulations can be expected to preserve this allowance for technical judgment. More rigid and specific regulations will be adopted as more becomes known about the nature of the resource and the pattern of development.

d. Required Permits and Approvals

Under the Maryland Geothermal Act a Department of Natural Resources permit is required for any geothermal resource exploratory activity. The applicant must have the legal right to use of the surface.

A permit is also required from the Department of Natural Resources for the construction of any plant, building, or structure for use of a geothermal resource. Use must conform with and meet all applicable air, water and noise laws of the state.

Other related regulations are as follows.

The Water Resources Administration (WRA) of the Maryland Department of Natural Resources requires (1) a permit for appropriation of state waters except for domestic and farm uses; (2) a permit for construction and repairs to dams and reservoirs or any changes in cross section or obstruction to the 100-year flood plain of rivers; (3) requires a permit to discharge pollutants into Maryland waters or before constructing any facility capable of pollutant discharge. The latter permit may require discharge treatment before release.

Any project having a significant potential for erosion and sediment damage to lands owned by the state requires approval by the WRA.

Under the Maryland Coastal Facilities Review Act a construction permit from the Maryland Energy and Coastal Zone Administration would be required for major facilities. Major facilities are "various types of oil and gas pipe lines, intermediate production terminals, refineries, storage facilities, operations bases or fabrication yards for off shore activities."

A permit must be obtained from the Maryland Geological Survey before any "excavation appropriation, injury, or destruction may take place on a state-owned archeological site".

A permit is required by the Maryland Department of Health and Mental Hygiene to operate a machine discharging emissions to the air, except for vehicles and certain farm equipment.

No dredging or filling of <u>state or private wetlands</u> is permitted without a license from the Maryland Board of Public Works. The Maryland Department of Natural Resources advises the Board in issuing such licenses. Wetlands are defined as the area adjacent to navigable waters which lie below the mean high tide.

3. Army Corps of Engineers Regulator Role

a. The Army Corps of Engineers regulations instruct district engineers to prepare an "environmental assessment" for all Coastal Zone permit applications in order to determine whether "major Federal action significantly affecting the quality of the human environment" and an Environmental Impact Statement (EIS) is necessary. Few EIS's have been required in Maryland. During 1976, two of 1476 applications requires EIS's and these took approximately 20 months each to complete.

b. The National Environmental Policy Act (NEPA) has directed the Army Corps of Engineers to consider a range of social values prior to granting a Coastal Zone permit. Its regulations direct the district engineers to consider and weigh conservation, economic, aesthetic, historic, navigation, water quality and environmental values. But rather than attempting to reflect all of these values, the Corps circulates permit applications among various other concerned federal, state and local agencies. This procedure is a major strength of the present program. It introduces a healthy eclecticism into the review process. Various reviewers look at the permit request with different emphases; local government -- land use; state natural resource agency -- water quality and wetlands preservation; state economic development agency -- port development; U.S. Fish and Wildlife Service -- fish and wildlife values; and the Environmental Protection Agency -- water quality.

c. Enactment of 1972 amendments to the Federal Water Pollution Control Act (FWPCA) has also had a significant impact on the Corps' territorial jurisdiction. Section 101(a)(1) of the act established as a national goal elimination of the discharge of pollutants in waters by 1985. The principal means for achieving this goal was the National Pollutant Discharge Elimination System (NPDES) established by Section 402 of the Act. Under NPDES, the Environmental Protection Agency (EPA) regulates the discharge of pollutants into waters with a permit system which can be transferred to the states. Pollutants are defined to include various substances, including dredged spoil, rock, sand and cellar dirt as well as sewage, chemical and biological wastes.

There was obviously the potentiality of overlap between the new NPDES and the Corps' traditional jurisdiction under the Rivers and Harbors Act. Filling in navigable waters would have constituted both the discharge of pollutants requiring an NPDES permit and construction activity requiring a Corps permit. To avoid this overlap, Congress included an exception to the overall NPDES program. Section 404 constitutes the Secretary of the Army, acting through the Corps of Engineers, as the exclusive regulator of discharges of dredged or fill material into all waters of the United States. EPA, however, is authorized to adopt guidelines for the specification of disposal sites. And no statutory provision was made for the delegation of the Corps' Section 404 regulatory powers to the states.

4. Maryland Costal Zone Management Program

The federal government passed the Coastal Zone Management Act of 1972 for the purpose of providing financial assistance in the establishment and management of programs which "preserve, protect, develop, and where possible, restore our coastal resources." To qualify for federal financial support for such programs, the states must submit evidence their proposed programs will indeed support the above objectives. Maryland has developed its Coastal Zone Management Program, which is manned by personnel of the Energy and Coastal Zone Administration, part of the Department of Natural Resources of the State of Maryland. The program applies all of Maryland on the Delmarva Peninsula except certain federal lands, which are not subject to program control. The program is based upon the philosophy that no additional Maryland laws are required to meet objectives of the federal act. The Maryland Coastal Zone Management Program coordinates Maryland agency activity in renewing applications for development in the coastal zone and serves to expedite application processing, at the same time attempting to ensure uniform, consistent coastal zone development. But the laws governing the rest of the state are identical except for those regulations which obviously pertain to coastal areas. Hence the section to follow will not distinguish between coastal and non-coastal zones.

Within each county of the Maryland Coastal Zone there is an Area of Focus[1]. The purpose in defining Areas of Focus is to

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[1] Unless stated otherwise material reported herein is taken from Maryland Coastal Zone Management Program, December 1977

allow state and local governments to concentrate their efforts on areas where they are most needed to solve coastal problems. The majority of issues related to the coastal zone arise in the Area of Focus, outside of which only major facilities will be subject to full project evaluation. Major facilities are defined as:

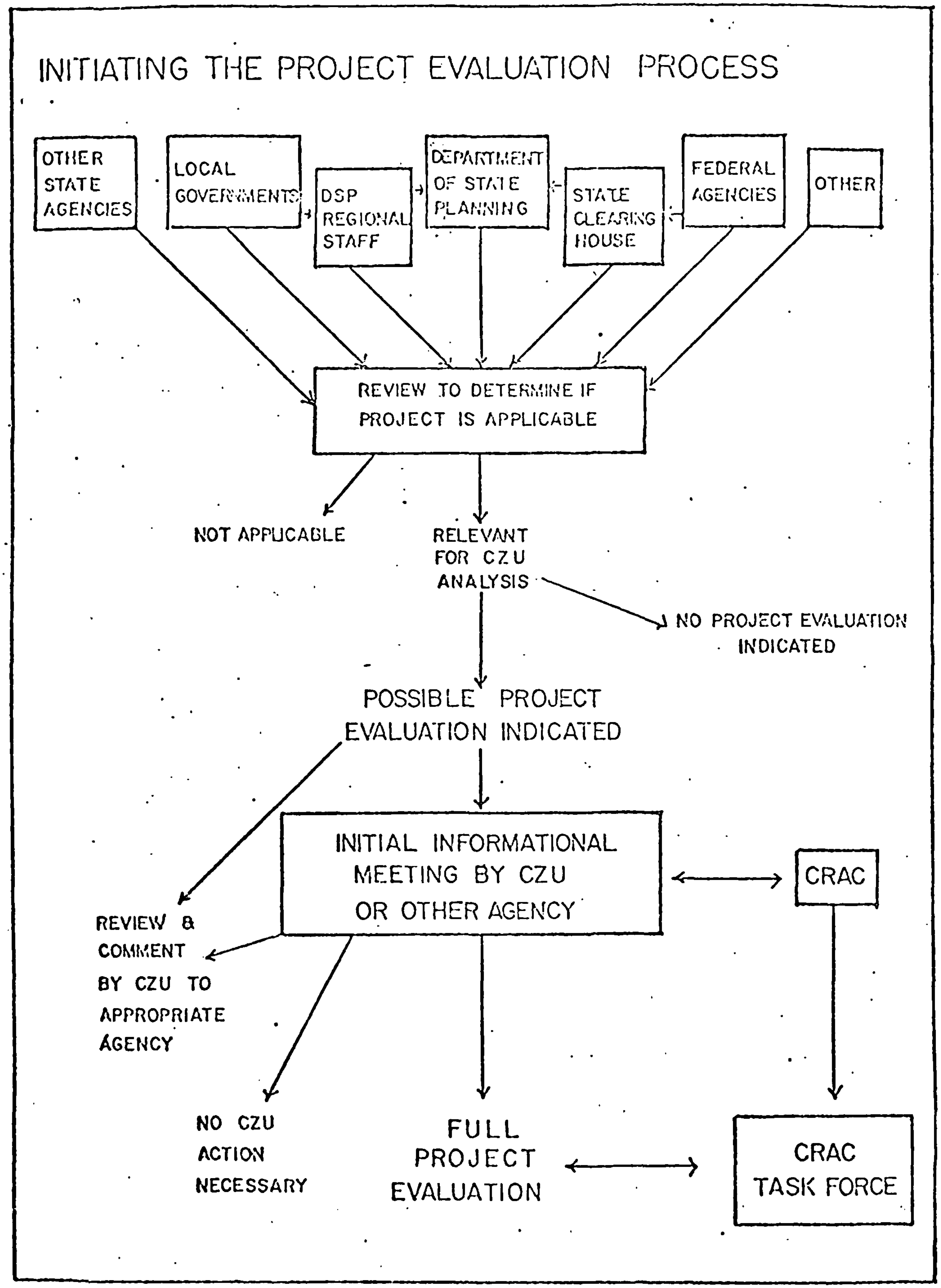
Onshore oil and natural gas facilities
Electric generating facilities
Ports
Industrial parks
Mineral extraction facilities
Large scale residential facilities
Sewage treatment facilities
Land transportation facilities.

The level of involvement of the Maryland Coastal Zone Unit in the evaluation of a project will depend upon the nature of the project and the scope of the existing regulating procedures. As shown in Figure 1, the project evaluation process undertaken by the Coastal Zone Unit will consist of the following steps:

Upon notification of a proposed project, the Coastal Zone Unit will review the project and decide (usually within 30 days) if it is applicable for Coastal Zone Unit consideration.

If it is decided that the project is of Coastal Zone Management concern, the project will be reviewed for possible conflicts with Coastal Zone Management Program objectives or policies.

Figure 1



CZU = Coastal Zone Unit
CRAC = Coastal Resources Advisory Committee

1. Further review of the project and comment to the appropriate regulating agency on the aspects of the proposed project about which the Coastal Zone Unit has relevant information from its studies or from other sources.
2. Convene a meeting of relevant state and local agencies, and/or attend a meeting held by a state or local agency, to obtain more information on the project and to determine if coordination of governmental efforts is needed because of involvement of more than one unit of government. After these meetings, the Coastal Zone Unit may decide that (1) no further involvement is appropriate, (2) comments on certain aspects should be made to the relevant regulating agencies, or (3) a full project evaluation is necessary and the project should be submitted to CRAC, the Coastal Resources Advisory Committee, for its consideration.

The full project evaluation process is described below. This level of evaluation would be automatic for all major facilities as defined above.

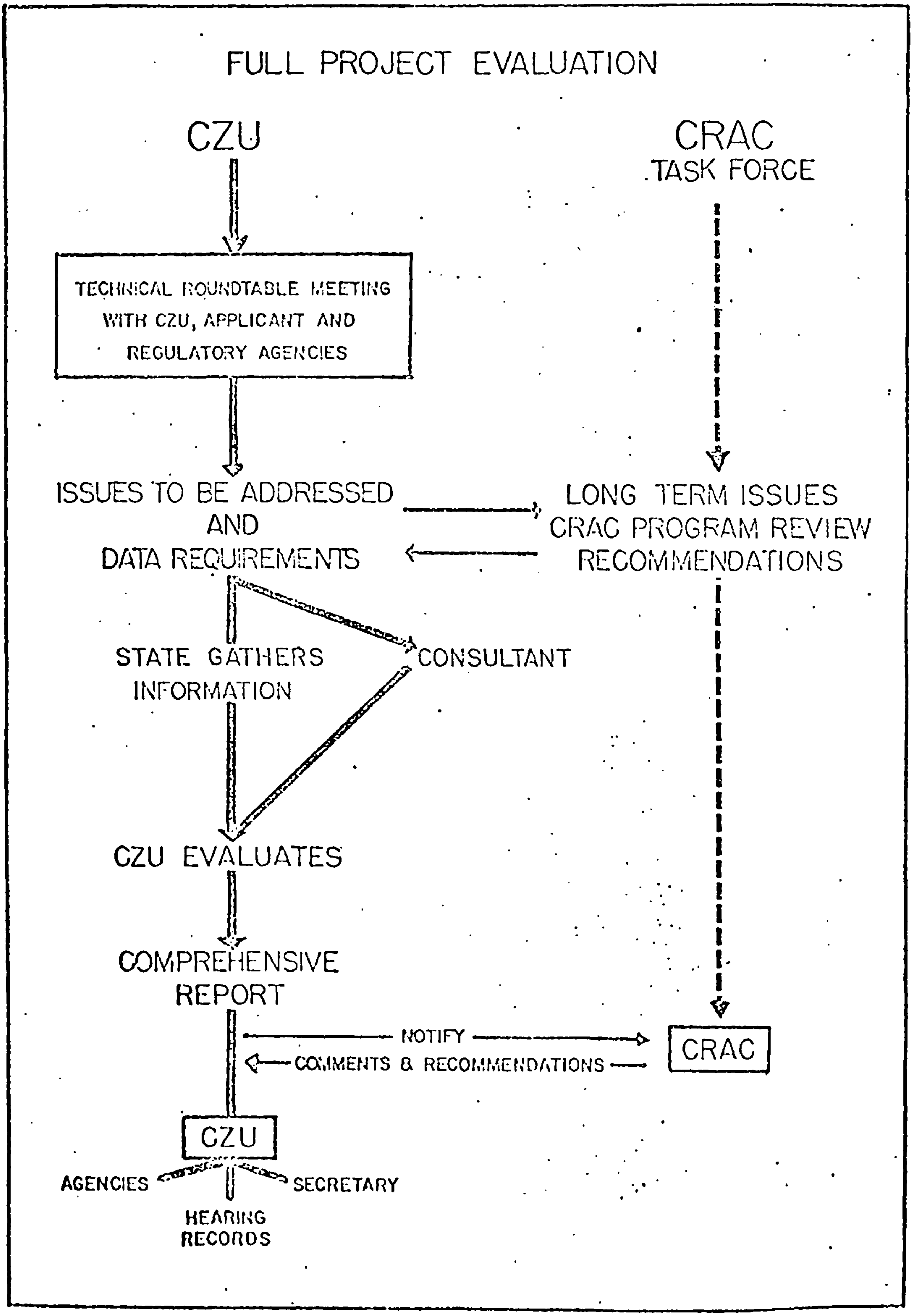
A full project evaluation may be undertaken if requested by other state agencies, local units of government, citizen and interest groups or upon determination by coastal zone unit staff that a full project evaluation is necessary to ensure a comprehensive review of the project to determine its consistency with coastal zone objectives.

Procedures for a Full Project Evaluation (see Figure 2): After notification has been made that a coastal project is proposed and an initial determination has been made by the Coastal Zone Unit that a full project evaluation is warranted, the project will be submitted to CRAC for its consideration. If CRAC indicates that its involvement is warranted, a task force will be established immediately to aid the Coastal Zone Unit in the project evaluation. A meeting of the CRAC task force will then be held on possible issues that should be considered. The Coastal Zone Unit, at appropriate points during the project evaluation, will also meet with the CRAC task force to obtain their comments.

A technical round-table meeting to determine information requirements will be convened for technical representatives of relevant governmental units and the applicant (if he desires to participate).

Upon completion of a project evaluation, the CZU findings will be presented to CRAC for its recommendations. The findings and recommendations will be submitted to the Secretary of Natural Resources and the relevant regulatory agencies for action.

Figure 2


FULL PROJECT EVALUATION
CZU
CRAC
TASK FORCE
TECHNICAL ROUNDTABLE MEETING WITH CZU, APPLICANT AND REGULATORY AGENCIES
ISSUES TO BE ADDRESSED AND DATA REQUIREMENTS
LONG TERM ISSUES CRAC PROGRAM REVIEW RECOMMENDATIONS
STATE GATHERS INFORMATION
CONSULTANT
CZU EVALUATES
COMPREHENSIVE REPORT
NOTIFY
COMMENTS & RECOMMENDATIONS
CRAC
CZU
AGENCIES
SECRETARY
HEARING RECORDS

B. Financing Geothermal Projects

For various applications geothermal energy can be cost competitive with other energy forms. However, even when a geothermal resource is well defined, a community, commercial or institutional complex must invest several millions of dollars for installation and maintenance of wells, capital equipment and distirbution system to utilize this form of energy.

Given a defined geothermal resource and given that various utilization projects have been developed and operated successfully, it is envisioned that further projects would be financed by standard means. Thus communities might issue municipal bonds or borrow conventionally. Commercial and institutional entities, normally, would borrow project money by conventional loans. Various forms of financial assistance may be available to these borrowers through departments of the Federal government. Mainly such aid would be in loan guaranty but loan assistance may be available in certain circumstances. These forms of assistance are discussed briefly in B and C below.

The DELMARVA geothermal resource is not as yet fully defined and, therefore, early proposals or projects to employ its energy must be classified as experimental or developmental. Because of the concomitant risk such projects are not expected to attract commercial investors. Therefore, the Federal government maintains several financing programs to aid these early programs in demonstrating the utility of geothermal energy and to interest investors in full commercial development of a resource. These aids are listed in A, below.

The National Energy Act, recently promulgated, and the proposed Onnibus Geothermal Energy Act contain additional assistance items. These are cited in D and E, below.

A. Department of Energy (DOE)

1. Grants and Cost-Sharing Programs

At various times, deemed strategic for stimulating geothermal activity in regions of the country, DOE offers to the public opportunities to submit work proposals which, if selected, receive some level of Federal funding. These requests for proposals are in two categories.

(a) Program Research and Development Announcement (PRDA)

A PRDA is designed to stimulate interest in the development of geothermal energy and does so by soliciting proposals for studies, analyses or projects that will lead to new or improved technology applicable to utilizing this source of energy. Thus PRDAs cover a variety of subjects. For example, one requested proposals for improving down-hole instruments for geophysical measurements; another, testing procedures to gather data in geopressured aquifers so as to further define a resource. A recent PRDA, and one to which several DELMARVA municipal and corporate responses were made, solicited: "--" proposals for engineering and economic studies to determine the feasibility of utilizing purpose for industrial and agricultural processing, mineral extraction, and space/water heating and cooling for commercial and residential buildings. Proposals must be site specific and may be for single or multi-purpose buildings."

PRDAs are issued from the DOE San Francisco Operations Office. State, municipal or nongovernment applicants are chosen on a competitive basis. The Department may support a proposal in whole or in part. To the extent a proposer may benefit independently by participation in a proposed project the Department encourages contractors to share equitably in the project costs.

(b) Program Opportunity Notice (PON)

A PON solicits proposals for geothermal experiments and new applications of geothermal energy in areas where the resource is rather well defined. These proposed projects should demonstrate the adequacy of the reservoir, provide technical and economic data, and address legal, environmental and institutional issues that will be important in assessing the practicability of further resource use.

An example is a 1977 PON that solicited: "--proposals for direct heat utilization or combined electric/direct heat utilization field experiments demonstrating single or multiple usages of geothermal energy for space heating, space cooling, agricultural or aquacultural uses, industrial processing, and/or hot water heating involving the utilization of hydrothermal resources."

PONSs are issued from the San Francisco Operations Office and applicants are selected on a competitive basis. The Department may provide various forms of Federal assistance to and participation in selected proposals. These aids could include cooperative agreements, grants and contracts and the work must be performed on a cost sharing basis.

2. Geothermal Loan Guaranty Program

The primary purpose of this program is to accelerate the commercialization of geothermal energy by guarantying lenders in the private sector against loss of principal or interest on loans for various types of proposed projects. Proposals that indicate early development of geothermal energy are given highest priority. Second priority is given to projects assigned to utilize technical advances or to produce technically advanced components; third to those projects planned to demonstrate commercial development of new resource areas; lowest priority to proposals for exploration or acquisition of land or leases.

Preferential consideration is also given to projects where the lender provides some funds without government guaranty, to those which provide royalties to the Federal government, to those carried out by small public or private utilities and to those carried out by small, independent businesses.

The additional purpose of the loan guaranty program is to develop normal borrower-lender relationships which will remove, ultimately, the need for Federal assistance in developing geothermal resources.

The DOE San Francisco Operations Office has nationwide responsibility for processing all Geothermal Loan Guaranty applications.

B. Department of Agriculture

Although the Department of Agriculture has no current assistance programs specifically oriented toward geothermal energy projects, it does loan money to rural communities for various facility projects and to rural home owners for various improvements. Since the DELMARVA area most likely to have accessible geothermal resources is rural in nature these loans, available through the department's Farmers Home Administration, may be available when the resources are well defined. Only projects for which engineering designs and specifications are completed would be considered.

1. Community Facility Loans

Low interest loans are made to qualifying communities for projects that are to construct, enlarge, extend or otherwise improve community facilities providing essential services to residents of open country, rural towns and villages of not more than 10,000 population. Thus most of the DELMARVA communities would qualify in this respect. Matching funds are not required and loans may be scheduled over a period of up to 40 years. Applications are made through the local Farmers Home Administration County Office.

2. Home Mortgage Loans

Moderate interest loans to home owners are available for various types of improvements. Low interest rates apply to occupants of subsidized housing. As above, loans could only be considered for completely engineered projects. Applications are made through the local Farmers Home Administration County Office.

C. Department of Housing and Urban Development

Block grants are available to towns for well engineered projects to (a) rehabilitate homes and (b) upgrade the quality of a utility. Thus geothermal projects could qualify. A major consideration in awarding grants is the inclusion of low income housing and, so, many of the DELMARVA communities could be considered. It should be noted that any community grant application would be in competition with all other applications within HUD Region 3 which included not only Delaware, Maryland and Virginia but all of Pennsylvania, West Virginia and the District of Columbia.

D. The National Energy Act

The National Energy Act, passed in October 1968, is composed of five bills concerning: (1) National energy conservation policy, (2) powerplant and industrial fuel use, (3) public utilities regulatory policy, (4) natural gas policy and (5) energy taxing policy. The first bill contains provisions relating to energy use in general and the fifth bill has provisions relating to geothermal energy.

(1) Conservation Policy Act

Title III of this act, Public Law 95-619, authorizes grants to states and to public and nonprofit schools and hospitals for identifying energy conservation possibilities and for implementing conservation procedures.

Conservation possibilities are to be determined through energy audits which examine current energy use in buildings and estimate energy savings that could be achieved modification of operations or installation of new measures. A state conservation plan is then submitted to DOE for approval. Approved plans may get Federal assistance up to 50% of the project costs or up to 90% for schools or hospitals if DOE classifies them as in the severe hardship class.

(2) Energy Tax Act

Title I of this act, Public Law 95-618, provides tax credits to residents for specified conservation expenditures and expenditures for using renewable energy sources including geothermal.

Title III contains changes in business investment credits to encourage conversion to new energy technology including geothermal and Title IV includes geothermal resources for depletion allowances and intangible drilling cost deductions.

E. Omnibus Geothermal Act

C. Legal Considerations

The State of Maryland has a geothermal law called the Maryland Geothermal Resources Act of 1978. Rules and regulations to support this law are not yet written, although the main items are discussed earlier in this chapter. The following items are the significant points of the law.

a) Ownership - This is not clearly determined in statute but at present it is interpreted to be owned as well as regulated and managed by the state.

b) Permits - Certain permits and approvals are required by the local, state and federal agencies.

c) Public Hearings - Prior to approval of an appropriation permit public notice and the opportunity for a public hearing must be given.

d) Bonds - A bond must be filed by the applicant and a corporate surety licensed to do business in Maryland prior to development.

Subtitle 8A. Maryland Geothermal Resources Act.

§ 8-8A-01. Definitions.

(a) *In general.* — In this subtitle the following words have the meanings indicated.

(b) *"Construction"* means any clearing, grading, excavation, building, or the commencement of any of these activities.

(c) *"Department"* means the Department of Natural Resources.

(d) *"Exploratory activities"* means any activity involving the drilling of test wells for geothermal resources.

(e) *"Geothermal resources"* means the natural heat of the earth higher than 120 degrees Fahrenheit or 49 degrees centigrade, or the energy, in whatever form, below the surface of the earth present in, resulting from, or created by, or which may be extracted from, this natural heat, the natural or artificial medium containing that heat, and all minerals in solution or other products obtained from naturally heated fluids, brines, associated gases, and steam, in whatever form, found below the surface of the earth, but excluding oil, hydrocarbon gas, and other hydrocarbon substances.

(f) *"Person"* includes corporations, companies, associations, firms, partnerships, joint stock companies, individuals, and government agencies.

(g) *"Well"* means any excavation or other alteration of the earth's surface or crust by means of which geothermal resource may be obtained. (1978, ch. 549.)

Editor's note. — Section 2, ch. 549, Acts 1978, provides that the act shall take effect July 1, 1978.

§ 8-8A-02. Legislative findings and intent.

(a) Geothermal resources are a natural resource in the State which possess great potential value for the State and the nation as a whole.

(b) In exploring and developing geothermal resources maximum possible consideration shall be afforded to avoiding waste and unreasonable use of natural resources and to protecting the environment, and to optimizing the productive use of the resource. (1978, ch. 549.)

§ 8-8A-03. Powers and duties of Department.

(a) The Department shall be responsible for the management and regulation of the geothermal resources in the State.

(b) The Department may contract for research and scientific investigation in order to determine the potential of the geothermal resources in the State.

(c) The Department may conduct and participate in development projects designed to demonstrate the feasibility of utilizing the State's geothermal resources.

(d) The Department may use any funds made available for the purpose of exploring, analyzing, developing and using geothermal resources.

(e) The Department may establish reasonable fees to cover the cost of processing permit applications.

(f) The Department may promulgate rules and regulations necessary to implement this subtitle. (1978, ch. 549.)

§ 8-8A-04. Exploratory permits.

(a) Every person is required to obtain a permit from the Department before conducting any geothermal resource exploratory activities. The applicant for this permit must have the legal right to use the surface. The permit is obtained upon written application to the Department.

(b) The application shall state the intended location of exploration, give assurance of the applicant's right to use the surface for exploration, provide an exploratory work program, and provide any information requested by the Department.

(c) The Department may approve an application if it determines that the applicant is qualified to conduct exploratory work, that the applicant will comply with all applicable laws, and that the applicant's work program provides adequate protection for the natural resources of the State.

(d) The permit required by this section shall be in lieu of any permit required by Title 8, Subtitles 6 and 8. (1978, ch. 549.)

§ 8-8A-05. Permit to appropriate or use geothermal resources.

(a) Every person is required to obtain a permit from the Department to appropriate or use, or to construct any well, plant, building, or structure which may appropriate or use geothermal resources of the State. The permit is obtained upon written application to the Department. The applicant for the permit must have the legal right to use the surface and give assurance of this right.

(b) The application shall be accompanied by the following information and any other information as required by the Department.

(1) A project description specifying:

(i) What is planned to be constructed, its purpose, use, location, estimated cost, and size; and

(ii) The methods of construction, construction schedule, and operation procedure.

(2) A list of licenses, permits, or other approvals required by any government unit.

(3) Detailed information as to the need for the use and facts concerning alternate site locations as may be requested by the Department.

(4) Information providing proof of the discovery of a geothermal resource and an evaluation of the resource.

(c) After public notice and opportunity for public hearing, the Department may issue a permit for the appropriation or use of geothermal resources if it finds that the applicant has demonstrated that the use:

(1) Conforms with and meets all applicable air, water, and noise laws of the State.

(2) Conforms with all applicable State and local plans.

(3) Would have no material adverse effect upon the natural environment of the area, its scenic or natural beauty, rare or irreplaceable resources, or unique historic site.

(4) Would not be so located, constructed, or operated as to have a material adverse effect upon the public health, safety, or welfare.

(5) Would not be a potential or immediate undue burden on the water supply of the site or region.

(6) Would not cause an unreasonable rate of resource exhaustion.

(d) The permit required by this section shall be in lieu of any permit required by Title 8, Subtitles 6 and 8. (1978, ch. 549.)

§ 8-8A-06. Bonds.

After receiving notification from the Department that an application for an exploratory or appropriation permit has been approved, but prior to commencing any construction, the applicant shall file a bond with the Department. The amount of the bond shall be determined by the Department. The bond shall be conditioned that the applicant will faithfully perform every requirement of this subtitle and rules and regulations issued pursuant to this subtitle. The bond shall be executed by the applicant and a corporate surety licensed to do business in this State. The provisions of this section do not apply to the State, political subdivisions, or municipalities. (1978, ch. 549.)

§ 8-8A-07. Judicial review of action on application.

A request for judicial review of the Secretary's action on any application shall be made within 30 days after the decision has been rendered. Proceedings shall be filed in the circuit court or in the Baltimore City Court having jurisdiction in which the facility or any part of it is to be situated. (1978, ch. 549.)

§ 8-8A-08. Violations.

(a) *Injunctions.* — Any person who violates any provision of this subtitle may be enjoined by a court of competent jurisdiction upon application of the Department acting through the Attorney General.

(b) *Penalty.* — Any person who violates any provision of this subtitle or any permit, or order issued thereunder, is liable to a penalty not exceeding $10,000, as well as being subject to being enjoined as provided in subsection (a). The monetary penalty thus provided may be recovered in a civil action by the Department through the Attorney General. (1978, ch. 549.)

§ 8-8A-09. Construction of subtitle.

(a) This subtitle shall be liberally construed to effectuate its intents and purposes.

(b) This subtitle may not be construed to be in derogation of any powers or State laws, but shall be regarded as supplemental and in addition to powers conferred by other laws. (1978, ch. 549.)

from the
1978 Cumulative Supplement
of the
Annotated Code of the Public General Laws of Maryland

IX. GEOTHERMAL DEVELOPMENT INITIATIVES

A. Introduction

The previous chapters have discussed the technical, environmental, legal, institutional and economic problems that apply to the development of geothermal energy on the Delmarva Peninsula insofar as these factors are known or determined at the present time. As shown by the discussion, there are issues for which the areas of ignorance and indeterminacy are large. This chapter attempts to identify the issues that must be addressed by the Federal, state and local governments and by the developer to insure the orderly and expeditious realization of geothermal energy. The first section considers issues of a general nature that are inherent in moderate temperature resource areas of the U.S. The second considers issues of specific importance to the Delmarva Peninsula. Table I attempts to tabulate for some issues the present state of affairs and the initiatives that must be taken.

B. General Issues

1) Commercialization and Financial Risk

Moderate temperature hydrothermal resources are unproven energy sources for most of the U.S. and their exploitation requires a large capital investment (of the order of a million dollars). The private sector or local government will not make such investments without a reasonable expectation of pay-off. The Federal Government must assume the initial risk in a new area, either by funding a demonstration project or by insuring the developer against the failure of the first well. France and Iceland have successfully encouraged geothermal development by use of the latter method. Once the feasibility of geothermal energy is demonstrated, a Federal loan guarantee program and tax incentive program can be used to encourage the development of an energy resource that is in the national interest.

2) Space Cooling and Refrigeration

The high capital cost of geothermal installation requires that, insofar as possible, it be utilized year-round. For many areas, this can best be insured by using geothermal energy in an absorption cycle heat pump for refrigeration or air conditioning. DOE is currently sponsoring some research in this field and DOE/ET and DOE/RA should support this effort to insure that results can be applied to hydrothermal resources with temperatures less than 212°F (100°C).

3) Geothermal Energy and Heat Pumps

Chapter VI concentrated on the direct application of hydrothermal fluids. For moderate temperature resources, the energy market can be extended by using the geothermal fluid as a heat reservoir for a heat pump whose output is a fluid (usually water) at a temperature higher than the geothermal reservoir. The possible economic effect upon the overall cost of the geothermal installation of such heat pumping should be investigated for all cases where a market for the higher temperature energy exists. There is also a possible economic advantage in using cheaper and shallower wells in combination with a heat pump compared to a deep well at higher temperatures. The solution to these economic issues will be site or area specific and must be obtained by the site developer, assisted by general studies by DOE.

4) Exploration of and Proof of the Resource

Most areas in the Eastern U.S. with a suspected geothermal potential require proof that a viable resource exists prior to a local interest in development. The exploration, data collection, and information dissemination for this effort must be performed by DOE.

5) Technical Support

Techniques for providing an entrepreneur with continuing engineering advice are needed. At this stage of the development of geothermal energy in the United States, no established method for doing this exists. The French solution is that the Bureau of Research in Geology and Mines (BRGM) analyzes the geology of each reservoir and determines its engineering. The BRGM is always available for advice and maintains a responsibility in the resource area. A generic plan to provide this continual assistance should be developed which could be adopted by the states and possibly the local USGS/WRD branches.

6) Resource Management

A generic technical monitoring program should be developed which can be adopted by the states to insure the life and quality of the resource, regulate who owns, develops and distributes the resource and to protect the environment. Such a program will help to diminish the number of problems associated with tapping an unknown resource. The developer needs some assurance as to the life and capability of the resource and guidance as to what is required to protect the environment from depletion, subsidence and contamination.

Several computer reservoir models have been developed for other DOE projects. These models should be evaluated and adopted by DOE into a form in which they can assist the local developers of geothermal energy. Those states in which geothermal energy becomes a reality must provide a resource manager to assure that their resources are properly operated.

7) District Heating

District heating, once prevalent in older U.S. cities, has in recent years gone out of favor. Interest in it is lively in Europe and the revival of interest in the U.S. is not limited to concern with geothermal applications. However, as Chapter VI shows, the direct application of moderate temperature geothermal resources requires a district heating concept unless there existed a large concentrated demand. Therefore, for geothermal application, the district heating concept must be studied, not only in its technical and economic aspects, but also from the aspect of the legal and institutional problems of putting such a system on line. Federal programs may offer guidelines and encourage demonstration projects (for example, on large federal installations), but the states and local government must fit such systems into the framework of their laws and regulatory agencies.

C. Issues Specific to Delmarva

1) Well Testing Program

The first geothermal deep well to basement is scheduled to be drilled at Crisfield. This well is being drilled by Gruy Federal as a test well to verify the geothermal energy targeting research program results obtained by VPI/SU. It is incumbent upon DOE/RA, USGS/WRD, the State Geologic Survey and APL/JHU to closely monitor and, if necessary, to affect the test program to determine the potential of the deep Delmarva strata. Water temperature, quality and quantity and aquifer performance data are required by planners, developers and regulatory agencies.

The pump tests are necessary because the amount of water that can be extracted determines the economic feasibility of geothermal application. The optimum well completion methods for the deep Delmarva strata must be determined. This may require water-well technology as opposed to petroleum well methods. The results of the test of this well must be disseminated to the cognizant state and local agencies.

2) Reservoir Engineering

As the results of the core samples for the Crisfield well are obtained, a more precise model of the reservoir will be possible. It is particularly important to calculate the effects of the removal and reinjection fluids upon neighboring aquifers.

3) Extraction Economics and Engineering Design

Once estimates of the temperature, quality and quantity of geothermal fluids can be estimated, the economics of extraction and heat exchangers can be computed, either for the Crisfield well or other Delmarva wells, provided the test well results can be extrapolated.

4) Application Engineering

The possible uses for geothermal energy on the Delmarva Peninsula have been studied in the APL/JHU applications study. Site specific application engineering studies are required for each potential installation. These studies, which will estimate the total cost of geothermal studies for the site selected, together with the extrapolation of the reservoir models, will determine the future sites to be developed.

5) The Environmental Requirements and Legal Factors.

The environmental requirements for the State of Maryland have been discussed in Chapter VII. This chapter also discusses the Maryland Geothermal Resources Act. The Maryland Department of Natural Resources is currently preparing a draft of the Rules and Regulations required to implement that Act.

A summary of the current environmental and legal status and required initiatives for Delmarva are listed in Table I.

Table IX-1

Production Stage (Commercialization)

Processes	Present Regulations	Prerequisite Initiatives
1. General	- New geothermal law in Maryland. - Delaware and Virginia have no law at present. Activities are governed by existing water and geologic regulations.	- Maryland Department of Natural Resources (DNR) will write rules and regulations to back up the new law when R&D stage requires them or when commercialization becomes inevitable. - Delaware and Virginia need to write a law and regulations--with help from the National Conference of State Legislators (NCSL) and using U.S. Geologic Survey publications as guidelines.
2. Analysis of Feasibility and Environmental Impact	- General water and environmental laws apply in part in Delaware and Virginia. Maryland geothermal law	- States will have to set up review procedures for determining long term effect of production on fresh water supply and life of geothermal resource. States will either have to hire a resource manager or depend on local or national technical body for evaluation.
3. Production (Long Term)		- Develop resources management program and long term monitoring program to prevent subsidence and fresh water contaminates and to conserve resource.
a. Drilling	- Water well permit required by DNR in Maryland and Delaware. - Driller registration required by DNR in Maryland and Delaware.	

Processes	Present Regulations	Prerequisite Initiatives
b. Logging and Coring	- Logs and other data if requested must be filed with Maryland Geologic Survey. - Geologist Registration in Delaware.	
c. Pumping Testing	- Appropriation of State Waters requires a permit if amount exceeds > 50,000 gpd in VA > 10,000 gpd in MD	- State laws should require this data from all developers and use data for monitoring developments.
d. Well Stimulation	- None	- Feasibility and techniques should be evaluated by DGE
4. Disposal of Brine (Long Term)	- Discharge off property requires a National Pollution Discharge Elimination System Permit (NPDES). - Virginia law prohibits non-research and development reinjection. - Piping into ocean requires U.S. Army Corps of Engineers Permit.	- Modify state laws (if reasonable) where appropriate. - Establish regulations to protect environment.
a. Ocean Wasting		
b. Surface Wasting		
c. Reinjection		
5. Surface Plant Construction and Distribution System	- Prohibited in wetlands in Delaware and Maryland. - Requires building permits by local zoning boards. - Regulated in navigable waterways by U.S. Army Corps of Engineers. - Construction erosion control regulated by Maryland DNR. - An environmental impact statement may be required in Maryland. No[illegible] and air pollution laws must be [illegible]llo[illegible].	- Develop building codes to incorporate aspects of design specific to geothermal plants (e.g., thermal expansion of plumbing).

X. SOURCES OF ASSISTANCE

Certain information is available to prospective developers. Check the following list for assistance in these areas: resource data, reservoir engineering, reservoir management, drilling and pump testing.

Introduction

1. Applied Physics Laboratory
The Johns Hopkins University
Johns Hopkins Road
Laurel, Maryland 20810
Phone: (301) 953-7100
Contact: Fletcher C. Paddison
Areas of Expertise: Engineering, Reservoir Management, Economics, Design

2. Virginia Polytechnic Institute and State University
Department of Geological Sciences
Blacksburg, Virginia 24061
Phone: (703) 951-6521
Contact: Dr. John K. Costain
Areas of Expertise: Heat Flow; Geophysics; Conducted Atlantic Coastal Plain Exploration Program
Contact: Dr. J. Lambiase - Sedimentology

3. Gruy Federal, Inc.
Consultants in Engineering
2500 Tanglewilde
Suite 150
Houston, Texas 77063
Phone: (713) 785-9200
Contact: Mr. R. N. Lane
Area of Expertise: Drilling; Permitting

4. U.S. Geological Survey
Water Resources Division
Towson, Maryland
Contact: Dr. Ed Otten

U.S. Geological Survey
Water Resources Division
Trenton, New Jersey
Contact: Mr. Harold Meisler

Area of Expertise: Ground Water Hydrology; Stratigraphy; Pump Testing

5. Maryland Geological Survey
   Merryman Hall
   The Johns Hopkins University
   Baltimore, Maryland 21218
   Phone: (301) 235-0771
   Contact: Mr. Kenneth A. Schwarz
   Area of Expertise: Reservoir Engineering, Geology, Hydrology

6. Department of Natural Resources
   Water Resources Administration
   Tawes State Office Building
   Annapolis, Maryland 21401
   Phone: (301) 269-3675
   Contact: Ernest Rebuck
   Area of Expertise: Water Law Regulations

7. Maryland Energy and Coastal Zone Administration
   Tawes State Office Building
   Annapolis, Maryland 21401
   Phone: (301) 269-2261
   Contact:
   Area of Expertise:

8. Maryland Department of State Planning
   Lower Eastern Shore Regional Office
   Salisbury, Maryland 21801
   Phone: (301) 749-4618
   Contact: Mr. William Livingston
   Area of Expertise:

9. U.S. Department of Energy
   Division of Geothermal Energy
   20 Massachusetts Avenue, N.W.
   Washington, D.C. 20545
   Phone: (202) 376-4897
   Contact: Dr. Gerald P. Brophy
   Area of Expertise: Geology, Exploration, DGE Plans

10. U.S. Department of Energy
    Resource Applications
    12th and Pennsylvania Avenue, N.W.
    Washington, D. C. 20461
    Phone: (202) 633-8908
    Contact: Mr. W.L.R. Rice
    Area of Expertise: Eastern U.S. Program

11. LBL (?)

REFERENCES

1. P. M. Brown, J. A. Miller, and F. N. Swain, 1973, Structural and Stratigraphic Framework of the Atlantic Coastal Plain North Carolina to New York, USGS Prof. Paper 796, 79 p.

2. P. M. Brown and M. S. Reid, 1976, Geologic Evaluation of Waste Storage Potential in Selected Segments of the Mesozoic Aquifer System Below the Zone of Fresh Water, Atlantic Coastal Plain, North Carolina to New Jersey, USGS Prof. Paper 881

3. DOE Idaho Operations Office, Idaho Falls, Idaho 83401, "Rules of Thumb and Geothermal Space Heating Publications"

4. H. J. Hansen, 1978, Upper Cretaceous and Palescene Punchouts on the South Flank of the Salisbury Embayment, Maryland, and their Relationship to Antecedent Basement Structures, Maryland Geologic Survey Report of Investigation #29

5. Manheim and Horn

6. NOAA National Climate Center, Asheville, North Carolina 28801, "Frequency of Hourly Temperatures, Period 1951 to 1960 for 138 Cities in the USA"

APPENDIX A

DIVISION OF GEOTHERMAL ENERGY RESOURCE DEFINITION PROGRAM

The Division of Geothermal Energy's on-going and future programs for more precise resource definition consists of the following three parts which will be discussed in some detail below:

1. Development of exploration models
2. Targeting of resource areas of greatest potential
3. Testing of models and resource

The Virginia Polytechnic Institute and State University (VPI&SU), under the direction of Dr. John K. Costain, has developed an exploration model based on the theory that some of the local areas of increased geothermal gradient in the Atlantic Coastal Plain are the results of increased heat flow due to an additional source of heat in the upper crust. The model predicts that certain late Paleozoic, syn- and post-metamorphic granitic plutons have above average heat generation ability. The plutons which have been studied lie in the Appalachian Piedmont west of the adjacent Coastal Plain, but Piedmont type rocks are thought to extend part-way beneath the sedimentary cover of the Coastal Plain. Granitic plutons of all ages characteristically are associated with gravity lows and therefore commonly can be recognized with sufficient gravity data, even under considerable sedimentary cover. The targeting procedure would therefore select all gravity lows that occur in the Coastal Plain and a testing program would determine which areas are associated with high thermal gradients. To assist in better defining gravity lows, VPI&SU and the Delaware Geological Survey are gathering additional gravity data. Once gravity lows were defined, a series of 38 or more shallow (1000 ft - 2000 ft) wells were drilled. These wells were logged and cores collected for thermal conductivity measurements. The wells were allowed to come to thermal equilibrium and a series of thermal gradient tests run. The average gradient and thermal conductivity were then used to estimate the heat flow at that point. Comparison of these data from all the shallow wells were used as part of the evaluation to determine the most promising site for the deep test well. In support of the site selection study for the deep test well, high resolution, seismic reflection surveys were conducted and aeromagnetic data analyzed in order to begin to understand the subsurface structural setting.

The deep test well will be drilled for hydrologic and stratigraphic testing purposes in addition to determining the temperature of the water. Several promising aquifers will be pump tested in order to determine engineering characteristics and economics of extraction. Cores will be extracted to measure thermal conductivity and aquifer performance data. To obtain a complete appraisal of the resource, additional deep wells will be required.

APPENDIX B

DELAWARE GEOTHERMAL REGULATIONS

Delaware has no geothermal law. A permit is required to drill a well and if more than 50,000 gallons of water per day are withdrawn an additional permit must be obtained. Well drillers must, of course, be licensed in the state.

No federal regulations other than environmental are involved in well drilling if federal funds are not involved.

A permit would be required to reinject well water. It would have to be injected into the same aquifer from which it was withdrawn or one with the same water quality.

If water is to be discharged on the surface a permit would have to be obtained and NPDES (National Pollutant Discharge Elimination System) statement for EPA would have to be provided.

Local zoning laws would not impact wells but even a well house would require a building permit.

Delaware has a Coastal Zone Act which further regulates industrial activity in the zone. The following summary is concerned with that act.

The Coastal Zone in Delaware is a coastal strip 12 miles wide at its widest point in the southern part of the state and 1/4 mile wide at its northern extremity.

It follows the 10 ft elevation contour (see attached map).

The Coastal Zone Law prohibits heavy industry, such as steel mills, paper mills, etc. (spelled out in the law). Other <u>manufacturing</u> <u>plants</u> must obtain permits.

In the case of a geothermal plant there is a good possibility the state of Delaware would not classify the plant as a manufacturing operation. In this case no fruther permit would be required. But first the application for "Status Decision" would have to be made if the plant is located in the Coastal Zone, (see map). Information required would include description of product, plant and process, input and output. If the "Status Decision" is that a permit is required an environmental impact statement, would have to be filed together with information regarding expected number of jobs created, expected wages and taxes, highway improvements required, demand for public services.

A reading of the law seems to make it clear that a geothermal plant would not be considered a manufacturing plant, since the Coastal Zone Act regulates only manufacturing plants. Section 7002(d) defines manufacturing as the "mechanical or chemical transformation of organic or inorganic substances into new products, characteristically using power driven machines and materials handling equipment, and including establishments engaged in assembling component parts of manufactured products, provided the new product is not a structure or other fixed improvement."

APPENDIX C

POTENTIAL NEAR-TERM USES FOR GEOTHERMAL ENERGY

This Appendix lists, in abbreviated form, the potential uses of geothermal energy that have been discussed with State and local government agencies and private industry on the Delmarva Peninsula. This list is not meant to be complete nor has an attempt been made to critically evaluate the feasibility of each of the proposed uses. However, the listing does provide a survey of the current planning on Delmarva, gives the status of such planning where available, and in addition, lists possible applications of geothermal energy at existing facilities. It is hoped that this list will be of assistance to other potential users.

1. Indoor Recreation Project, Ocean City, Maryland.

The Mayor and Council of Ocean City, in conjunction with the Coastal Zone Management Coordinator and Maryland Department of Planning, have been evaluating a proposal to establish an indoor recreational complex in Ocean City. The facility, along with a police station and firehouse, would be placed somewhere north of 62nd Street. This facility would be an attraction for the high density condominium area of the city, especially as a year-round facility. The use of geothermal water for space conditioning at a complex involving these combined municipal facilities is appealing to the planners. It is estimated that a study, including the use of geothermal waters for heating and cooling, will be completed in December 1979.

2. Heating of High-Rise Condominiums in Ocean City

The construction of high-rise condominiums peaked in the early 1970s but there is some expectation that the expansion of the facilities of northern Ocean City will resume. Ocean City is interested in encouraging off-season occupancy of its facilities and there is some indication that this is occurring. At present, most high-rises use electrical resistance heating. Of existing structures, so far as we can determine, only a very few use water referenced air conditioners and cooling towers. In these, the plumbing exists for conversion to geothermal heating. However, no economic study of this conversion has been attempted. If and when construction resumes, high rise condominiums and the required expansion of other facilities such as shopping centers offers an attractive concentrated use of geothermal energy both for heating and absorption cycle cooling. Ocean City, so far as known at present, is located over a promising geothermal resource and an economical source of heat would add to the year-round appeal of the resort.

3. Integrated Poultry Industry Complex.

The Delmarva Peninsula has long been a center of the nation's meat producing poultry industry and this industry constitutes a major segment of the area's economy. This industry is a large energy consumer, both in the raising of the chickens and the processing of them for market. Energy is used in the hatching of small chicks and the heating of the houses in which they are grown in cool or cold weather. In processing, energy is used to heat water for the plucking, evisceration and clean-up processes and for the cooling or freezing of the final products. At present, the chicken growing industry is dispersed; some processing plants are located in population centers such as Salisbury, Maryland. The application of geothermal energy to such processing plants is attractive because such plants would use a large portion of the energy produced by an economically feasible well.

The Regional Staff of the Department of State Planning (Maryland) has suggested the development of a fully integrated poultry industry complex on a single site. This complex would include facilities for grain drying and storage, hatching and rearing of chickens, processing and cooling and freezing. From the energy point of view, such a complex would permit an economy of scale. The use of geothermal energy to provide cooling of broiler houses would provide a welcome new dimension to the industry since hot weather losses due to death and lower growth efficiency are substantial.

4. Worcester County (MD) Planned Industrial Park.

The Worcester County Planning Commission has authorized the study for an Industrial Park at the intersection of US Route 113 and Maryland Route 90, east of Ocean City and Ocean Pines and along the main line of the Con Rail system. The initial plans for the area envision the construction of warehouses and light industries to serve the growing areas of Ocean City and Ocean Pines. The prospect of geothermal energy opens the prospect of adding food processing industries to the industrial park. State funds are available for land acquisition and construction loans for such industrial parks; if the plans are submitted to and approved by the county commissioners, it is estimated that development activities can begin in about five years. Thus, there is time for a serious study of geothermal applications with a prospect of obtaining, in the meantime, some confidence in the geothermal potential of the area.

5. Melfa (VA) Industrial Park.

The County of Accomack, Virginia, set up an Industrial Development Authority in 1974 to assume responsibility for the development of an industrial park near the town of Melfa. Phase I of the development plan, funded by over two million dollars of Federal and state funds, is scheduled to begin in 1979. Types of industry sought include leisure businesses, pharmaceuticals, health care products, and food storage container manufacturers. In all, about 1.5 million square feet of heated and cooled building space is planned. The Authority has complete responsibility for the development of the park and sees no problem in its assuming the development, distribution, and management of geothermal energy. Should this source of energy prove feasible, detailed planning should begin before 1983.

6. Seaford (Delaware) Industrial Park.

Seaford, Delaware, is considered one of the fastest growing areas in the State and has recently annexed several hundred acres adjacent to the town for controlled development as an industrial park. An Industrial Feasibility Study has been completed by the 390th Civil Affairs Group of the U.S. Army. In 1979, Seaford expects to conduct further planning with a grant from the Environmenta Protection Agency (EPA). It expects this planning effort to consume one to three years. Seaford, which until recently generated its own electricity and which still maintains and operates the electrical distribution system, would consider the management of a geothermal resource as a municipal utility.

7. Cambridge, Maryland.

Dorchester County and the City of Cambridge are planning to add 300 acres to an existing industrial park. Presently, the county is seeking state and Federal funds to continue planning and justify the need for economic development. If successful in these efforts, active work on permitting may begin in 1981.

8. Ocean Pines Community (MD).

Ocean Pines, located on the western side of Assawoman Bay about six miles west of Ocean City, began as a planned recreational community in the late 1960s by the Boise Cascade Corporation. Boise Cascade is now in the process of selling the land not previously sold to various local development interests. The area was originally planned to accommodate 8000-10,000 dwelling units and a population of 30,000 to 40,000.

Over 6000 lots have been sold and about 1000 homes have been built. The tendency of local developers is to look upon Ocean Pines as a site for year-round housing because of its recreational areas, open spaces and proximity to current and future economic development in Maryland and Delaware. Homes built in the last two years have been heated with air referenced heat pumps, instead of resistance heating. Discussion with a local realtor and developer revealed that heating costs are a prime concern of prospective buyers in

Ocean Pines and that geothermal waters would be a welcome asset for future development. Of the original 3,500 acres, 1200 are yet unsubdivided and available for sale. These areas present a potential market for geothermal energy; however, the slow building rate on lots already sold indicates that the time scale is very uncertain.

9. Crisfield, Maryland.

The first East Coast exploratory geothermal well is being drilled at Crisfield, Maryland by DOE/ET. APL/JHU has consulted with the local authorities and school board and is currently studying the possibility of using this well, once the scientific purpose has been served, to supply heat to the local hospital-nursing home complex and three schools.

Appendix D

Sample Permits - Maryland

Attached are sample copies of the following permit forms required in the State of Maryland.

1) Water Appropriation and Use
    a) Application
    b) Permit
2) Water Well Application Form
3) Well Completion Report
4) Requirements for Hydrogeologic Study

APPLICATION FOR A PERMIT TO APPROPRIATE AND USE WATERS OF THE STATE

Water Resources Administration
Water Supply Section
Tawes Office Building
Annapolis, Maryland 21401

☐ Surface Water ☐ Groundwater ☐ New Application ☐ Change in Existing Permit

Number ____________

APPLICATION

____
(Owner's Name) (Telephone Number)

____
(Owner's Address) (Street) (Town) (State) (Zip Code)

WITHDRAWAL

GROUNDWATER

Appropriate and use a yearly average of

____________ gallons per day,
[total annual use ÷ 365 days]

and ____________ gallons
[highest total monthly use ÷ days in month]

for the average day of the maximum month, from

____________ well(s) having a diameter of
[number]

____________ inches, and a depth of
[estimate]

____________ ft.
[estimate]

SURFACE WATER

Appropriate and use a yearly average of

____________ gallons per
[total annual use ÷ 365 days]

day, and a maximum use of ____________

gallons in any one day, from:

____
[name of stream]

____
[exact location of withdrawal]

PROJECT LOCATION

____
[Location — be specific]

County ____________ Subdivision or town ____________ Phone number ____________

Name and type of business ____________

ALL APPLICATIONS MUST INCLUDE A COPY OF A U.S.G.S. TOPOGRAPHIC OR SIMILAR MAP SHOWING PROJECT

PURPOSE

The water will be used for:

☐ Community Water Supply
☐ Non-Potable supply (sanitary uses, not for drinking water)
☐ Potable Supply (drinking water, etc.)
☐ Cooling Water
☐ Irrigation
☐ Process Water
☐ Other ____________
[explain]

____

WASTEWATER TREATMENT AND DISPOSAL

☐ Public Sewer ____________
[name of system]

☐ Groundwater
  ☐ Subsurface (tilefield, seepage pit, etc.)
  ☐ Spray Irrigation
  ☐ Other, explain ____________

☐ Surface Water ____________
[name of stream]

Discharge Permit # ____________
or applied for ____________

SIGNATURE

Please sign here ➧ ____________
[signature]

____
[please print name, title, and date here]

THIS APPLICATION CANNOT BE PROCESSED WITHOUT SIGNATURE

APPROVAL BY COUNTY HEALTH DEPARTMENT OR DESIGNATED AGENCY

THIS SECTION NOT TO BE COMPLETED BY APPLICANT

Is this Project consistent with the County Water and Sewerage Plan and local planning and zoning?

☐ YES ☐ NO, explain ____________

Signature of county representative ____________
[signature] [title] [date]

STATE OF MARYLAND

DEPARTMENT OF NATURAL RESOURCES
WATER RESOURCES ADMINISTRATION

WATER APPROPRIATION AND USE PERMIT

PERMIT NUMBER:

EFFECTIVE DATE:

EXPIRATION DATE:

FIRST APPROPRIATION:

HEREINAFTER REFERRED TO AS THE "PERMITTEE", IS AUTHORIZED BY THE WATER RESOURCES ADMINISTRATION, HEREINAFTER REFERRED TO AS THE "ADMINISTRATION", PURSUANT TO THE PROVISIONS OF TITLE 8 OF THE NATURAL RESOURCES ARTICLE, ANNOTATED CODE OF MARYLAND (1974 VOLUME) AS AMENDED, TO APPROPRIATE AND USE WATERS OF THE STATE SUBJECT TO THE FOLLOWING CONDITIONS:

1. ALLOCATION - AVERAGE ____________ GALLONS; MAXIMUM ____________ GALLONS. THE AVERAGE IS CALCULATED AS THE TOTAL YEARLY PUMPAGE DIVIDED BY 365 DAYS. THE MAXIMUM IS CALCULATED AS THE AVERAGE DAY OF THE HIGHEST MONTH FOR WELLS AND SPRINGS, AND THE HIGHEST DAILY USE FOR ALL OTHER SOURCES.

2. USE - THE WATER IS TO BE USED FOR ________________________________
   ____.

3. SOURCE - THE WATER SHALL BE WITHDRAWN FROM ________________________
   ____.

4. LOCATION - THE POINT(S) OF WITHDRAWAL SHALL BE LOCATED ____________
   ____
   ____.

CONTINUED ON PAGE TWO

PAGE NUMBER TWO
PERMIT NUMBER

5. RIGHT OF ENTRY - THE PERMITTEE SHALL ALLOW AUTHORIZED REPRESENTATIVES OF THE ADMINISTRATION ENTRY INTO THE PERMITTEE'S FACILITIES TO CONDUCT INSPECTIONS AND EVALUATIONS NECESSARY TO ASSURE COMPLIANCE WITH THE TERMS AND CONDITIONS OF THIS PERMIT. THE PERMITTEE SHALL PROVIDE SUCH ASSISTANCE AS MAY BE NECESSARY TO EFFECTIVELY AND SAFELY CONDUCT SUCH INSPECTIONS AND EVALUATIONS.

6. PERMIT RENEWAL - IN ORDER TO RECEIVE AUTHORIZATION TO CONTINUE OPERATION BEYOND THE EXPIRATION DATE, THE PERMITTEE SHALL REQUEST AN EXTENSION OF THE PERMIT IN WRITING TO THE ADMININSTRATION NO LATER THAN SIX MONTHS PRIOR TO THE EXPIRATION DATE.

7. PERMIT SUSPENSION OR REVOCATION - THIS PERMIT MAY BE SUSPENDED OR REVOKED BY THE ADMINISTRATION IN THE EVENT OF A VIOLATION OF THE TERMS OR CONDITIONS OF THE PERMIT OR REGULATIONS PROMULGATED PURSUANT TO TITLE 8 OF THE NATURAL RESOURCES ARTICLE, ANNOTATED CODE OF MARYLAND (1974 VOLUME) AS AMENDED.

8. CHANGE OF OPERATIONS - ANY ANTICIPATED FACILITY, WHICH MAY RESULT IN A NEW OR DIFFERENT USE OR A CHANGE IN APPROPRIATION OF WATER SHALL BE REPORTED TO THE ADMINISTRATION BY THE PERMITTEE BY SUBMISSION OF A NEW APPLICATION OR BY WRITTEN NOTICE.

9. TRANSFER OF PERMIT - THIS PERMIT MAY BE TRANSFERRED PROVIDED THAT PRIOR TO ANY SUCH TRANSFER, (a) THE PERMITTEE NOTIFIES THE ADMINISTRATION OF THE NAME AND ADDRESS OF THE TRANSFEREE, AND (b) THE TRANSFEREE NOTIFIES THE ADMINISTRATION IN WRITING OF TRANSFEREE'S AGREEMENT TO BE BOUND BY ALL OF THE TERMS AND CONDITIONS OF THE PERMIT.

10. INITIATION OF WITHDRAWAL - THE PERMIT SHALL EXPIRE IF THE PRIVILEGE GRANTED IS NOT EXERCISED WITHIN ONE (1) YEAR FROM THE DATE HEREOF, EXCEPT THAT UPON WRITTEN REQUEST BY THE PERMITTEE PRIOR TO THE EXPIRATION DATE, THIS TIME LIMIT MAY BE EXTENDED FOR GOOD CAUSE AT THE DISCRETION OF THE ADMINISTRATION.

11. FLOW MEASUREMENT - THE PERMITTEE SHALL INSTALL AN ADMINISTRATION APPROVED FLOW METER THAT WILL BE CAPABLE OF MEASURING ALL WATER PUMPED.

12. WITHDRAWAL REPORTS - THE PERMITTEE SHALL SUBMIT TO THE ADMINISTRATION, SEMI-ANNUALLY (JULY-DECEMBER, NO LATER THAN JANUARY 31 & JANUARY-JUNE, NO LATER THAN JULY 31), PUMPING RECORDS. THESE RECORDS SHALL SHOW THE TOTAL QUANTITY OF WATER PUMPED EACH MONTH.

13. WELL CONSTRUCTION REQUIREMENTS - WELLS SHALL HAVE:

A.) PROVISIONS FOR TAPE MEASUREMENTS OF WATER LEVELS DURING PUMPING AND NON-PUMPING PERIODS. OPENINGS FOR TAPE MEASUREMENTS SHALL HAVE A MINIMUM INSIDE DIAMETER OF 0.5 INCHES AND BE SEALED BY A REMOVEABLE CAP OR PLUG.

B.) A TAP, FOR TAKING RAW WATER SAMPLES BEFORE THE WATER ENTERS A TREATMENT FACILITY, PRESSURE TANK, OR STORAGE TANK.

BY AUTHORITY OF THOMAS C. ANDREWS
DIRECTOR, WATER RESOURCES ADMINISTRATION

CHARLES A. WHEELER, CHIEF
WATER SUPPLY PERMITS

DNR-131 (7-77)

EMERGENCY NO. (If any) -

D-6

B 1 ☐	SEQUENCE NO. (WRA USE ONLY)	
1 2 3 (SEQ. NO.) 6		

(THIS NUMBER IS TO BE PUNCHED IN COLS. 3-6 ON ALL CARDS)

STATE OF MARYLAND

WATER RESOURCES ADMINISTRATION

TAWES STATE OFFICE BLDG., ANNAPOLIS, MARYLAND 21401

APPLICATION FOR PERMIT TO DRILL WELL

WRA PERMIT NUMBER

FILL IN THIS FORM COMPLETELY

DATE RECEIVED (WRA USE ONLY)

8-13

OWNER ______ COL 15 LAST NAME FIRST NAME COL. 34

STREET OR RFD ______ COL 36 COL. 55

POST OFFICE ______ COL 57 COL. 76

B 1 CONTINUED — DRILLER INFORMATION

1 2 3 (SEQ. NO.) 6

DATE ______ LICENSE NUMBER ______ 77 80

______ FIRST NAME DRILLER LAST NAME

SIGNATURE ______

B 2 — WELL INFORMATION

1 2 3 (SEQ. NO.) 6

MAXIMUM PUMPING RATE (GALLONS PER MINUTE) ______ 8 12

AVERAGE DAILY QUANTITY NEEDED (GALLONS PER DAY) ______ 14 20

USE FOR WATER (CIRCLE APPROPRIATE BOX)

22

- D HOME (SINGLE OR DOUBLE HOUSEHOLD UNIT ONLY)
- F FARMING, AGRICULTURE, IRRIGATION
- I INDUSTRIAL, COMMERCIAL, STATE AND FEDERAL GOVERNMENT.
- M MUNICIPAL WATER SUPPLY } MUST HAVE STATE HEALTH DEPT. APPROVAL
- P PRIVATE WATER COMPANY } MUST HAVE STATE HEALTH DEPT. APPROVAL
- T TEST

APPROXIMATE DEPTH OF WELL ______ FEET 24 28

APPROXIMATE DIAMETER OF WELL ______ (NEAREST INCH)

METHOD OF DRILLING USED (CIRCLE APPROPRIATE METHOD)

30-37

BORED (OR AUGERED)	JETTED	DRIVEN
AIR-ROTARY	AIR-PERCUSSION	ROTARY (HYDRAULIC ROTARY)
CABLE	REVERSE-ROTARY	DRIVE-POINT

OTHER (DESCRIBE) ______

REPLACEMENT OR DEEPENED WELLS (CIRCLE APPROPRIATE BOX)

39

- N THIS WELL WILL NOT REPLACE AN EXISTING WELL
- Y THIS WELL WILL REPLACE A WELL THAT WILL BE ABANDONED AND SEALED
- S THIS WELL WILL REPLACE A WELL THAT WILL BE USED AS A STANDBY
- D THIS WELL WILL DEEPEN AN EXISTING WELL

PERMIT NUMBER OF WELL TO BE REPLACED OR DEEPENED (IF AVAILABLE)

______ 41 52

B 3 — LOCATION OF WELL

1 2 3 (SEQ. NO.) 6

COUNTY ______ 8 (DO NOT ABBREVIATE COUNTY NAME) 21

SUBDIVISION ______ 23 42

SECTION ______ 44 46 LOT ______ 48 50

NEAREST TOWN ______ 52 71

MILES FROM TOWN (ENTER O IF IN TOWN) ______ 73 76 77 78 M | ..

B 4 — DIRECTION FROM TOWN (CIRCLE APPROPRIATE BOX)

1 2 3 (SEQ. NO.) 6

N NORTH	E EAST	N E NORTHEAST	S E SOUTHEAST
S SOUTH	W WEST	N W NORTHWEST	S W SOUTHWEST
8	8	8 9	8 9

NEAR WHAT ROAD ______ 11 30

ON WHICH SIDE OF ROAD (CIRCLE APPROPRIATE BOX)

NORTH	SOUTH	EAST	WEST
N	S	E	W
32	32	32	32

DISTANCE FROM ROAD (ENTER DISTANCE AND CIRCLE APPROPRIATE BOX) ______ 34 37 F T / M .. 38 39

DRAW A SKETCH BELOW SHOWING LOCATION OF WELL IN RELATION TO NEARBY TOWNS, ROADS AND STREAMS WITH NORTH IN THE DIRECTION OF THE ARROW, AND GIVE DISTANCE FROM WELL TO NEAREST ROAD JUNCTION OR STREAM CROSSING SHOWN ON THE SKETCH. ALSO SHOW, BY MEANS OF AN "X", THE WELL LOCATION IN THE BOX BELOW AND THE BOX NUMBER FROM THE WELL LOCATION MAP.

N

BOX NUMBER E ______ N ______

0/5	5/5
0/0	5/0

NOT TO BE FILLED IN BY DRILLER (WRA USE ONLY)

APPROPRIATION PERMIT NUMBER G A P ☐☐☐☐☐☐☐☐☐☐☐ 54 63 ENGINEER REVIEW DISTRICT NO. ☐ 65

FORCE ☐☐ 67 68 WRITE INITIALS IN BOX

CONDITIONS

A	E	N	S	G	W	Q	C	L	U
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
70	71	72	73	74	75	76	77	78	79

NORTH COORDINATE ☐☐☐☐☐☐ 50 51 52 53 54 55

EAST COORDINATE ☐☐☐☐☐☐☐ 57 58 59 60 61 62 63

ELEVATION AT WELL HEAD (FEET) ☐☐☐☐ 65 66 67 68

B 4 CONTINUED — HEALTH DEPARTMENT APPROVAL

1 2 3 (SEQ. NO.) 6

41 S STATE HEALTH (CIRCLE BOX) ______ COUNTY NAME ______ COUNTY NO.

DATE MO. DAY YR. ☐☐☐☐☐☐ 43 48 ______ APPROVED BY

B 5 ☐ SPECIAL CONDITIONS 8-63 (WRA USE ONLY)

1 2 3 (SEQ. NO.) 6 ☐☐ 8 63

NR-214 (7-77)

C	1	7820

1 2 3 (SEQ. NO.) 6

SEQUENCE NO. (WRA USE ONLY)

THIS NUMBER IS TO BE PUNCHED
N COLS. 3-6 ON ALL CARDS)

STATE OF MARYLAND

WATER RESOURCES ADMINISTRATION

TAWES STATE OFFICE BLDG., ANNAPOLIS, MD. 21401

WELL COMPLETION REPORT

D-7

THIS REPORT MUST BE SUBMITTED WI
IN 30 DAYS AFTER WELL COMPLET

FILL IN THIS FORM COMPLETELY

COUNTY NUMBER

DATE RECEIVED (WRA USE ONLY) 8-13

DATE WELL COMPLETED ☐☐☐☐☐☐ 15 20

DEPTH OF WELL ______ 22 (TO NEAREST FOOT) 26

PERMIT NO. FROM "PERMIT TO DRILL WELL" ☐☐-☐☐-☐☐☐☐ 28 29 30 31 32 33 34 35 36 37

DRILLERS IDENTIFICATION NO. ______

OWNER ______ LAST NAME ______ FIRST NAME

STREET OR RFD ______ POST OFFICE ______

WELL DESCRIPTION

WELL LOG

TATE THE KIND OF FORMATIONS PENETRATED, THEIR OLOR, DEPTH, THICKNESS AND IF WATER BEARING

DESCRIPTION (USE ADDITIONAL SHEETS IF NECESSARY)	FEET FROM	FEET TO	CHECK IF WATER BEARING

GROUTING RECORD

WELL HAS BEEN GROUTED (CIRCLE APPROPRIATE BOX) YES ☐Y 44 NO ☐N 44

TYPE OF GROUTING MATERIAL (CIRCLE BOX)

CEMENT ☐C☐M 45 46 BENTONITE CLAY ☐B☐C 45 46

NO. OF BAGS ______ NO. OF POUNDS ______

GALLONS OF WATER ______

DEPTH OF GROUT SEAL (TO NEAREST FOOT)

FROM ______ FT. 48 52 TO ______ FT. 54 58

(ENTER 0 IF FROM SURFACE)

CASING RECORD

CASING TYPES INSERT APPROPRIATE CODE BELOW

☐S☐T STEEL ☐C☐O CONCRETE

☐P☐L PLASTIC ☐O☐T OTHER

MAIN CASING TYPE ☐☐ 60 61

NOMINAL DIAMETER TOP (MAIN) CASING (NEAREST INCH) ______ 63 64

TOTAL DEPTH OF MAIN CASING (NEAREST FOOT) ______ 66 70

OTHER CASING (IF USED)

EACH CASING

	DIAMETER (INCH)	DEPTH (FEET) FROM	TO
☐☐	______	______	______
☐☐	______	______	______

SCREEN RECORD

SCREEN TYPE OR OPEN HOLE INSERT APPROPRIATE CODE BELOW

☐S☐T STEEL ☐B☐R BRASS OR BRONZE ☐H☐O OPEN HOLE

☐P☐L PLASTIC ☐O☐T OTHER

C	2	

1 2 3 (SEQ. NO.) 6

EACH SCREEN — DEPTH (NEAREST WHOLE FOOT)

	TYPE	FROM	TO
1	☐☐ 8 9	11 ______ 15	17 ______ 21
2	☐☐ 23 24	26 ______ 30	32 ______ 36
3	☐☐ 38 39	41 ______ 45	47 ______ 51

SLOT SIZE 1. ______ 2. ______ 3. ______

DIAMETER OF SCREEN ______ 56 60 (NEAREST INCH)

GRAVEL PACK FROM ______ TO ______

IF WELL DRILLED WAS A FLOWING WELL CIRCLE BOX 68 ☐F

WRA USE ONLY (NOT TO BE FILLED IN BY DRILLER)

70☐ T TELESCOPE CASING

☐ 72 (E.R.O.S.) LOG INDICATOR

☐☐☐ W Q 74 75 76 OTHER DATA AVAILABLE

C	3	

1 2 3 (SEQ. NO.) 6

PUMPING TEST

HOURS PUMPED (TO NEAREST HOUR) ______ 8 9

PUMPING RATE (GALLONS PER MINUTE TO NEAREST GALLON) ______ 11 15

METHOD USED TO MEASURE PUMPING RATE ______

WATER LEVEL: (DISTANCE FROM LAND SURFACE)

BEFORE PUMPING ______ 17 20 (NEAREST FOOT)

WHEN PUMPING ______ 22 25 (NEAREST FOOT)

TYPE OF PUMPED USED (CIRCLE APPROPRIATE BOX) (FOR PUMPING TEST)

☐A AIR 27 ☐P PISTON 27 ☐T TURBINE 27

☐C CENTRIFUGAL 27 ☐R ROTARY 27 ☐O OTHER (DESCRIBE BELOW) 27

☐J JET 27 ☐S SUBMERSIBLE 27

PUMP INSTALLED

TYPE OF PUMP (WRITE APPROPRIATE LETTER IN BOX — SEE ABOVE: A, C, J, P, R, S, T, O) ☐ 29

DRILLER WILL INSTALL PUMP (CIRCLE APPROPRIATE BOX) YES ☐Y NO ☐N

CAPACITY:

GALLONS PER MINUTE (TO NEAREST GALLON) ______ 31 35

PUMP HORSE POWER ______ 37 41

PUMP COLUMN LENGTH (NEAREST FOOT) ______ 43 47

CASING HEIGHT (CIRCLE APPROPRIATE BOX AND ENTER CASING HEIGHT)

☐+ ABOVE
☐− BELOW
49

LAND SURFACE ______ 50 51 (NEAREST FOOT)

LOCATION OF WELL ON LOT

N

SHOW PERMANENT STRUCTURE SUCH AS BUILDINGS, SEPTIC TANKS, AND/OR OTHER LAND MARKS AND INDICATE NOT LESS THAN TWO DISTANCES (MEASUREMENTS TO WELL).

CIRCLE APPROPRIATE BOXES

☐A A WELL WAS ABANDONED AND SEALED WHEN THIS WELL WAS COMPLETED

☐E ELECTRIC LOG OBTAINED

☐P TEST WELL CONVERTED TO PRODUCTION WELL

I HEREBY CERTIFY THAT I HAVE COMPLIED WITH ALL CONDITIONS STATED ON THE ABOVE-CAPTIONED "PERMIT TO DRILL WELL", AND THAT INFORMATION CONTAINED IN THIS REPORT IS TRUE, ACCURATE, AND COMPLETE TO THE BEST OF MY KNOWLEDGE, INFORMATION AND BELIEF.

DRILLERS NAME

(PLEASE PRINT) ______

SIGNATURE ______

Project ______________________________

Date ________________________________

Prepared by __________________________

Requirements For Hydrogeologic Study

Test drilling and aquifer flow testing shall be performed to determine and evaluate the geology and hydrology at the site. The work shall include the installation of test well(s) and observation well(s) as described herein.

The following outline is meant to be a guide in conducting test drilling, aquifer flow tests, and the preparation of comprehensive hydrogeologic studies in a manor acceptable to the Water Resources Administration. Sections of the outline which are not applicable to this project have been deleted.

II Field Testing

A. Well drilling

1. Exploratory test drilling requirements

    a. Test drilling shall be performed to a depth of ____________________.

    b. Accurate lithologic (driller's) log.

    c. Test hole of sufficient diameter (at least __________) to accomodate the probe of geophysical logging equipment.

    d. Samples of formation(s) encountered, collected at __________ foot intervals and at each formation change.

    e. Geophysical well log(s) of the entire depth of test hole to include at least resistivity, spontaneous potential, natural gamma, ____.

    f. Cores of specific formations (the exact depth of cores shall be determined by the Administration after examining the information gathered from the geophysical and lithologic logs.

2. Test well drilling requirements

    a. ____________ test well(s) shall be installed to a depth of ________________________________.

    b. The test well(s) shall be of sufficient diameter to accomodate a ____________________ pump capable of producing no less than ________________ g.p.m.

    c. All formations encountered and not being tested shall be sealed to prevent intermixing of the water.

3. Observation well drilling requirements

    a. _______________ observation well(s) of at least __________ inches in diameter shall be installed.

    b. The observation well(s) shall be screened in the same formation as the test well.

    c. The observation well(s) shall be at least _____________ feet, but no more than _______________ feet from the pumping (test) well.

B. Preparation for pump testing

1. Preparation of observation well(s)

    a. All observation wells shall be pumped and/or cleaned sufficiently to obtain accurate water level measurements.

b. All observation wells shall be observed and "order-of-magnitude" water level changes recorded during preliminary flow testing of the pumping (test) well.

2. Preparation of test well(s)

a. Install a ______________ pump capable of producing no less than __________________ g.p.m.

b. Provision shall be made for water level measurement, using a steel or electric tape, during the pumping test.

(1) Installation of a conductor pipe at least 3/4 inch I.D., shall be required down to the top of the pump intake unless specified otherwise.

(2) Conductor pipe or other measuring points on pumping well shall be positioned so as to be safely accessable for water level readings (i.e. positioned away from diesel engine drive shafts, pump discharge points, etc.)

c. Install an orifice or totalizing flow meter capable of measuring all water pumped.

d. All water being pumped during the pumping test and the preliminary pumping test shall be diverted away from the test site

e. Test well(s) shall be pumped, developed and made ready for flow testing. A short, preliminary pump test shall be run in order to determine the water producing capacity of the well.

3. General preparations for flow testing

a. All measuring points shall be specified and their elevation above or below land surface recorded.

b. Adequate illumination shall be provided during hours of darkness to allow for safety and for accurate water level measurements.

c. Notify the Administration at (301) 269-3675, at least __________________ hours before the start of pumping.

C. Aquifer flow testing (pumping test)

1. Conducting pumping test and recovery test

a. Test well and observation well(s) shall remain idle for at least ______________ hours prior to the start of pumping (During this period, water level measurements shall be made at all wells, at intervals of ____________________ hours.

b. All water level measurements shall be made carefully to at least the nearest 1/4 inch.

c. The time and date of the start of pumping should be recorded.

d. The formation shall be pumped continuously at a uniform rate of not less than _________ g.p.m. for ___________ hours.

e. During the period of pumping, water levels shall be recorded in all wells according to the following schedule

(1) Immediately after the pump starts, water levels shall be measured at ____________ minute intervals for the first _____________ minutes,

(2) Then at _______________ minuintervals for the next ____________ minutes,

(3) Then at ___________ minute intervals for the next _______________ minutes,

(4) And at ____________ minute intervals for the remainder of the test.

f. Flow (g.p.m. or piezometer heights) should be recorded at each water level measurement during the pumping test.

g. During the final hour of pumping, take water samples as described below in section 3.

h. Record the time of pump shut-down.

i. Commencing immediately at pump shut-off, water level measurements shall be taken at the well and observation well(s), in accordance with the measurement schedule set forth in section 1e. above, for _____________ hours.

Procedures to follow in the event of premature pump shut-off

a. Record time of pump shut-off

b. Commencing immediately at pump shut-off, water levels shall be taken at the test well and observation well(s), in accordance with the measurement schedule set forth in section 1 i above.

c. Contact the Administration at (301)-269-3675 as soon as possible

d. Do not attempt to restart the test until Water Resources Administration representatives have been notified.

e. The whole pumping test sequence may have to be repeated unless the Administration determines that the pumping test length and the data obtained were sufficient

3. Water quality investigation procedures

a. Water quality samples (approx. ______ gallons) shall be taken from the well during the last hour of pumping unless specified otherwise by the Administration.

b. Water quality samples shall be collected and transported as directed by the testing laboratory

c. The water quality samples shall be analyzed for the following:

Total Alkalinity
Bicarbonate
Calcium
Carbonate
Chloride
Conductivity
Total Dissolved Solids
Flouride
Total Hardness
Iron
Temperature (deg. C. - temp. of water being discharged to be taken during last hour of pumping)

Magnesium
Manganese
Nitrate
Total Nitrogen
pH (Field)
Potassium
Silica
Sodium
Sulfate