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PROCEEDINGS OF THE TWENTIETH ANNUAL NEW MEXICO WATER CONFERENCE

Theme: Water for Energy

April 3-4, 1975

New Mexico Water Resources Research Institute

New Mexico State University • Telephone (505) 646-4337 • Box 3167, Las Cruces, New Mexico 88003

WATER FOR ENERGY

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NEW MEXICO STATE UNIVERSITY

LAS CRUCES, NEW MEXICO

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WELCOME TO THE UNIVERSITY

Gerald W. Thomas

Formally, it is my pleasure to welcome you here today to the Twentieth Annual Water Conference and to welcome you to the Physical Science Laboratory. This tremendous facility, named after Clinton P. Anderson, handles most of our national defence research. New Mexico State University now is twelfth in the nation among the universities in national defence work. This work is primarily through NASA, the Air Force, the Army, and the Navy. We presently have students and faculty located in twelve countries around the world as a result of the operations here at P.S.L.

You have certainly chosen an appropriate theme for this conference, Water for Energy Development. It is certainly aimed at one of the most critical problems facing the world. Energy and the interrelationships between energy and food are just beginning to be realized.

I had the privilege of participating in the World Food Conference in Rome. At this conference it was obvious that the food problem was tied to the energy problem and was furthermore tied to irrigated agriculture and to water for energy development and to water for other uses. I have written editorials for three scientific journals about the World Food Conference. I would be pleased to send copies of these observations to any of you who would like to have them. As one comment made by Secretary Kissinger at the World Food Conference, "we are here to confront the problem and not each other". Secretary Kissinger emphasized that the world food problem could not be solved without adequate consideration of energy and without adequate consideration of irrigated agriculture. As I see these problems developing and as these interrelationships become more and more realized it is apparent to me that food will emerge during the next decade or two as the big problem. We now have a short-fall of ten million metric tons of grain and this short-fall for food production world wide could reach eighty-five to one hundred million metric tons by 1985 or 1990. Certainly these food needs will place more pressure on water resources. We will also see more and more talk about the interrelationship between food and water and energy.

I hope that this conference will help all of us improve our understandings of these interrelationships but the problem of communication between and among peoples is always difficult. You can imagine, with 130 nations gathered in Rome to talk about food and with the many languages and many problems of interpretation that took place, how difficult it was for people to communicate. Even in this room, though we all speak the same language, we will not always be talking about the same thing or interpreting the same words in the same way.

I am reminded of a cartoon in "Dagwood and Blondie" recently. Blondie came into the house and told Dagwood that she had just returned from the garden club meeting where Mabel had indicated some dissatisfaction because her hydrangeas were drooping. Dagwood said, "You know, if she would buy clothes that fit she would not have that problem." Even in the same household and even when we speak the same language we don't always do a good job of communicating.

We hope as a result of this conference that you will have an improved appreciation of water and an improved understanding of the important role of water in the economy of this state, the nation, and indeed of the world.

I have the special assignment at this time to introduce a very special quest to the group, Gilbert Stamm, who is the Commissioner of Reclamation appointed in May, 1973.

PRESENTATION OF THE BUREAU OF RECLAMATION'S CITIZEN AWARD

Gilbert G. Stamm

Stephen E. Reynolds, State Engineer of New Mexico, was presented the Bureau of Reclamation's Citizen Award by the Commissioner of Reclamation Gilbert G. Stamm at the New Mexico Water Conference on the campus of New Mexico State University in Las Cruces. "Mr. Reynolds has provided outstanding leadership and counsel in the support of sound water development projects throughout the State of New Mexico, and his efforts have greatly assisted in the progress of his State," said Stamm. "It is this dedication that prompted presentation of the Bureau's Citizen Award to Mr. Reynolds," the Commissioner added.

The award recognizes beneficial contributions provided by private and public citizens in the interest of achieving Bureau of Reclamation objectives and programs for water resource development. Commissioner Stamm presented the award consisting of a certificate and plaque.

This is the official news release, by the United States Department of the Interior, Bureau of Reclamation, Southwest Region, Amarillo, Texas, April 3, 1975.

Reynolds has served as State Engineer since 1955. He is secretary to the New Mexico Interstate Stream Commission, New Mexico Commissioner to the La Plata River Compact, the Canadian River Compact, and the Rio Grande Compact Commissions, and is also an engineering advisor to the Pecos River and the Upper Colorado River Commissions. He has been a consultant to the President's Advisory Committee on Weather Modification and a member of the National Science Foundation's Panel on Weather Modification as well as chairman of the United States Panel of Scientists and Engineers.

Mr. Reynolds has supported many Bureau of Reclamation projects including Navajo Dam, Hammond Project, and the Rio Grande Project rehabilitation and betterment and often has helped secure appropriations for construction. He has been very active in seeking authorization and funding for other projects such as Navajo Indian Irrigation, San Juan-Chama, Pecos River Basin Water Salvage, Brantley Dam, Hooker Dam as part of the Central Arizona Project, Animas-La Plata, and the Colorado River Salinity Study.

Commissioner Stamm said, "It is only with the assistance, knowledge, and perseverance of public citizens such as Steve Reynolds that Reclamation is able to accomplish its missions and goals. I commend him for his dedication to the people of New Mexico and the nation."

KEYNOTE ADDRESS

WATER DEMANDS FOR EXPANDING ENERGY DEVELOPMENT

George H. Davis

Introduction - Much concern has been expressed recently as to whether water supplies will be sufficient to support accelerated energy development foreseen in Project Independence. Taking the U.S. as a whole, water supplies are ample for energy growth, but locally, as in the Colorado Basin, limited supplies will dictate economies in water consumption and will affect plant siting.

The objective of this presentation is to put water demands for energy growth in proper perspective. The energy processes under discussion exhibit wide demand flexibility depending upon cost of water, and exhibit marked flexibility regarding siting. It will be important to take maximum advantage of economic trade offs in order to avoid serious conflicts with competing water uses.

Water is required in most aspects of energy production -- mining and reclamation of mined lands, on-site processing, transportation, refining, and conversion to other forms of energy. Water supply is generally adequate for energy growth in the East, the South, and along the seacoasts. Most water-supply problems will be in the arid parts of the West, and especially in areas

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where annual rainfall is less than 10 inches -- the lower limit for establishing vegetation without irrigation.

Extraction -- Coal mining demands are generally modest and include water for dust control, fire protection, and coal washing. In most locals these demands are nominal and quality is not a serious limiting factor. The U.S. Bureau of Mines (PIB) recently estimated average water use at 15 GPT in underground mining, compared to 4 GPT in surface mining, and 8 GPT for waste disposal in each. The greater water requirement for underground mining relates to greater need for dust control below ground, and higher demand for washing in the East where underground mining predominates. Little of the water used in coal mining would return to surface streams except a part of the waste disposal requirements. Using a current approximation of 600,000,000 tons annual production of which 50% is surface mined, we arrive at annual water demand nation-wide of 21,000 acre-feet for underground mining and 11,000 acre-feet for surface mining. In addition, in arid areas we must also count water required for revegetation of surface-mine waste. A NAS-NAE study group considering this problem concluded that application of 1/2 to 3/4 of an acre-foot per acre should be sufficient to establish seedlings that would survive without further irrigation. Of course, the area disturbed per ton of coal produced varies greatly with the thickness of the bed mined. Thick beds in Wyoming yield as much as 80,000 tons per acre. In comparable deposits the water needed for revegetation would amount to 2 to 3 gallons per ton over and above other requirements. Of course, the average thickness of stripable coals is less and the water requirements for revegetation are proportionately higher. Dreyfus estimates that at 500MT per year production the water requirement for Western revegetation would not exceed 24,000 acre-feet per year, or about 16 gallons per ton. This water must be of reasonably good quality (say less than 2,000mgl) to sustain plant growth. In most places these demands would be rated as small, but in parts of the arid zone of the Southwest even these nominal amounts of water raise serious questions as to plant siting and the practicability of mining.

Slide 1 shows the Colstrip Mine in E. Mountana production (A) 5,000,000 tons per year. Note regrading of waste. Rainfall here generally is sufficient to grow grass without irrigation, although it is the practice here to give the grass a single irrigation to assure a good start.

Uranimum mining has similar water needs to coal mining for dust control, ore beneficiation, and revegetation as appropriate. However, because the energy production from uranium is orders of magnitude greater than a comparable weight of coal, the use of water on-site is only about 1/10 that of coal for comparable energy yield. The AEC estimates that annualized uranium mining to supply a 1,000 mw Nuclear Reactor would disturb only 17 acres. Water used at the mine site is modest and is mostly consumed as evaporation from mill tailings ponds. Indeed, at the Highland Mine in the Powder River Basin in Wyoming (precipitation @ 14 inches) drainage from the open pit mine supplies water demand of the mine and mill except in dry summer months.

Oil-shale mining is expected to become a major industry in several areas underlain by the Green River Formation in Colorado, Utah, and Wyoming. Shale will be extracted by surface mining, underground mining, and as an adjunct to in-situ underground retorting. Retorting of extracted shale will be done on or near the mine site, because of the low oil content (20-40 gallons per ton), and large volumes of loose burnt shale will be produced. Indeed, one of the largest water demands in the entire process is for compaction and revegetation of retort plant waste, which comprises 40% of the total water use. This water is consumed by evaporation or is permanently bound with the waste, which sets up like a low-grade concrete. Estimates of water needs of an oil-shale industry range from 121,000 to 189,000 af/yr at a production level of 1,000,000 bbls/day or 2-1/2 to 4 gallons of water per gallon of oil produced. When considering a production level of 1,000,000 bbls/day it should be kept in mind that this would require mining 1,000,000 tons/day of high-grade shale -- a rate equal to more than 1/2 the tonnage of coal presently mined in the U.S. -- so it will not come about suddenly.

Petroleum production is the other energy extraction activity using significant amounts of water. Drilling currently requires about 50,000 af/yr (16 X 10^9 gallons) nation-wide, but as this is distributed over a wide area and is a single-time use, supply poses no serious problem. Where water flooding is enployed for secondary recovery larger volumes of water are needed. Salt water is used as available, but is supplemented with fresh water as needed. The nation-wide fresh water demand for this use is estimated at 175,000 af/yr currently (57 X 10^9 gallons).

Transport -- Turning now to transport, the main water demand in this field is for coal slurry lines, which is one of the economic trade offs rapidly coming to the fore. The outstanding operating example is the 278-mile line from the Black Mesa Mine in N.E. Arizona to the Mojave Power Plant on the Colorado River in Nevada. This line moves 4.8 million tons of coal in a 48% water slurry to supply a 1,500 MW Power Plant. The 3,200 acre-feet annual water requirement is mined from a deep aquifer system that should support this pumpage for the life of the coal resource. The slurry line supply is only 1/7 the cooling water requirement of the plant and the slurry water is largely reclaimed for power plant use. As the weight of water used in cooling is 3 times the total weight of water and coal moved in the slurry, the advantage clearly lies in transporting fuel rather than water in most cases.

Slide 2 shows the Mojave Plant. The main water consumption is by the 6 banks of forced draft cooling towers extending to the right of the plant. The prominent evaporation ponds dispose of plant blowdown, normally about 20% of makeup water supply, which is too poor in quality to return to the Colorado River.

Slide 3 shows the route and profile of the Mojave slurry line. In this case a slurry pipeline was preferred over rail transport because of the rugged terrain to be crossed. This is a good example of the option of siting a power plant where water is available rather than at the mine or the load center.

The total water consumption of the plant is 23,000 af/yr of which the slurry line furnishes one-seventh. A much larger slurry line (ETSI) is in planning stages to carry 25 million tons of coal per year from E. Wyoming 1,000 miles to Little Rock, Arkansas. This 48-inch pipeline would require some 15,000 acre-feet of water annually. Large scale lines such as this pose some difficult institutional problems, however, because they commonly involve interstate export of water from deficient areas to places where disposal of the waste water poses problems.

<u>Refining</u> - Energy fuel refining processes of particular interest with respect to water consumption are oil refining and uranium processing.

Oil refining, which consumes water mainly in cooling processes, requires about 10 gallons of water per gallon of oil processed. Of this, from 1 to 2 1/2 gallons is consumed, the higher figure applying to the more modern complex processes. It is estimated that consumptive use in oil refining is currently 740 thousand af/yr (241 X 10^9 gallons) (PIB est.). As this use is mainly in established industrial areas and is partly met by saline estuarine waters, it does not pose a major supply problem.

If we look now at the annualized uranium fuel cycle of a 1,000 MW nuclear Plant, we find a total consumption of 500 af/yr (165 X 10^6 gallons). As noted earlier 40% (65 mg) of this was used around the mine and mill. 90 mg (55%) is used for cooling at the uranium enrichment plant. An additional 8 mg is used mainly in uranium hexafluoride production and fuel-rod processing. To round out the total picture, we should add another 500 acre-feet of water consumed by power plants supplying electricity for the enrichment plant. If this sounds like a lot of water and energy for a 1,000 MW Plant, keep in mind that the energy produced is 22 times the energy consumed to produce the nuclear fuel.

<u>Conversion</u> - Having examined extraction, transport, and refining, lets look now at the really big consumers of water in the energy industry--conversion processes. Of special importance in the drive for self-sufficiency are coal gasification, coal liquefaction, oil shale retorting, use of geothermal energy for electric generation, and increased use of coal burning and nuclear reactors for electric generation. In each mode considerable flexibility is possible in process employed, plant design, location of processing facility with respect to extraction site, source and use of water, and location of market. With such flexibility it is impossible to assign rigid water requirements to any single development, but ranges of water demand are a useful first approximation for planning purposes. Moreover, in steam-electric power plant operation the economic need for high fuel efficiency generally dictates water use within close limits, hence unit values of water consumption can be estimated with considerable confidence.

Steam Electric Generation -- The most efficient method of meeting large steady electric demand (base load) is by use of a steam turbine to drive a generator. The steam may be produced from geothermal wells, by burning coal, oil, or gas, or by heat given off by nuclear fission. The power output of a steam turbine is greatly increased by reducing the pressure on the outlet side of the turbine. This is done by use of a condenser, which lowers the temperature of the exhaust steam, causing condensation and thus significantly reducing the pressure. The cooling capacity needed for the condensation phase accounts for the greatest consumption of water in the entire energy-production process.

Various systems are used for condenser cooling--once-through circulation, cooling ponds, sprayers, wet cooling towers, dry cooling towers, and combinations of the preceding systems. Once-through cooling commonly is used where the plant is near an abundant source of water, such as the sea, a large lake, or large river. As the name suggests, water from an infinite (for practical purposes) source is circulated through the condenser and carries the waste heat away to a point of discharge elsewhere on the water body. The heat is dissipated mainly through increased evaporation from the slightly warmer water body and by conduction to the atmosphere.

Where no large water body is available a natural or artifical pond may be used for storage and as a heat sink. In this mode, heat is dissipated mainly through surface evaporation from the warmed pond. Where the cooling capacity of the pond is inadequate, sprayers may be used to increase evaporation. Sprayers may also be used together with canals in once-through-systems to reduce the impact of heated discharge on fish and other aquatic biota.

Slide 4 shows the San Onofre Nuclear Power Plant, S. California. Rated at 700 MW. Cooling water is withdrawn from and returned to the Pacific Ocean.

Slide 5 shows the Rancho Seco Nuclear Power Plant near Sacramento, California. Rated at 2000 MW. A closed cycle cooling system obtains makeup from the Folsom South Canal of USBR. Condenser cooling is provided by the two natural draft hyperbolic towers. At 40 stories height they are the tallest structures in the Central Valley.

Where water is in short supply or discharge of heated water is unacceptable, and ponds are not practicable, cooling towers generally are employed. In wet cooling towers some of the warm water evaporates through contact with an air draft, either naturally induced or driven by fans, thus cooling the remaining water. Dry cooling towers dissipate heat directly to an air draft in a fashion similar to an automobile radiator. Although dry cooling towers are effective in reducing water consumption, their capital cost greatly exceeds that of wet cooling processes, and their use results in a loss of thermal efficiency as well. They find their greatest use in cold climates and to date have seen little use in the United States in steam-electric power generation.

Various combinations of these cooling techniques are applied to achieve maximum economy in combination with acceptable environmental effects. The cooling system is quite independent of the type of fuel; rather, it depends mainly on local factors such as availability of water, terrain features, and potential environmental impacts.

Slide 6 shows the heat and water balance of a typical 1,000 MW coal-fueled electric plant. Of the 9 X 10^9 btu/hr (billion) energy fuel input, 10% leaves as waste heat thru the stack, 5% is accounted for as miscellaneous in-plant losses, 38% leaves as electric energy, and the remaining 47% waste heat from the condenser circuit, must be disposed of through the evaporative cooling tower shown on the right. This particular plant operating 80% of the time would consume 15,000 af/yr (4.8 X 10^9 gallons) or as much water each year as would be used in mining 400,000,000 tons of coal from surface mines-- more than the present U.S. production. If wet flue gas scrubbers are required to meet air quality regulations on sulfur emissions, an additional consumptive use of 3,000 af/yr must be accommodated.

Considerably more detail is given in USGS Cir. 703, so I will not go into the reasons for variation in water consumption, which is closely rated to thermal efficiency of the process employed. In general the most water-thrifty systems of steam-electric generation are fossil-fueled plants at @ 40% TE, followed by nuclear plants at about 31% TE, and geothermal at 14% TE. Water consumption is roughly in inverse proportion to efficiency as will be shown on a slide later. The evaporative consumptive demand in gallons per Kwh is 0.5 for fossil-fuel, 0.8 for nuclear, and 1.8 for geothermal. This poor water efficiency for geothermal is due to inherently low temperature and pressure of natural fluids which precludes high thermal efficiency.

In terms of water withdrawals, steam-electric power is now the largest single use of water in the U.S. having passed irrigation withdrawals in 1965.

Slide 7 illustrates the rapid growth of withdrawals for thermal electric power in recent years (in billions of gallons per day). In comparing power with irrigation, it should be remembered that the power withdrawals are mainly for once-through cooling systems which consume much less of the water than do irrigation withdrawals.

Slide 8 shows annual withdrawal of water in acre-feet vs. power generated in Kwh X 10^9. Mean annual discharge of the Mississippi at St. Louis is shown for a yardstick. The flattening of the curve in recent years is due to increasing thermal efficiency and greater use of closed cooling systems.

Coal Gasification -- As there are no modern-design coal-gasification plants of commercial scale in the United States, estimates of water demand must be based on research operations, foreign experience, and design data of projected plants. One of the chief sources of information is an engineering report of the El Paso Natural Gas Co. Burnham I Coal Gasification Complex planned for a site near Farmington, New Mexico. The processes being considered for that complex, designed to produce 288 million scp (standard cubic feet) per day of pipeline-quality gas (954 Btu per ft^3), include coal gasification by the Lurgi process followed by shift conversion, gas cooling, gas purification, and methane synthesis. In simple terms, the Lurgi Process produces a low Btu product (about 400 Btu per ft^3) which is upgraded by methane synthesis to pipeline quality. In various stages water is consumed in the chemical reaction; cooling requirements contribute additionally to the overall water demand. Because water is scarce in the region of the plant, recycling will be used to the maximum, and air cooling will be used insofar as practicable. The water input will consist of about 7,000 gpm divided from the San Juan River plus 765 gpm of moisture in the coal input, and 630 gpm produced by the

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Slide 9 is a highly simplified diagram of the water flow to the Burnham Complex. Places where water enters the process are identified in blue, while water consumptions are identified in red. The colored figures represent percentages of inflows and consumption.

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methane-synthesis reaction. Of this total input, some 26% will react to form gas, 17% will be piped to the coal mine and other offsite users, 11% will evaporate from waste ponds, 2% will leave as wet ash, and 35% will evaporate in the cooling system. This represents an extreme case of water conservation as the plant is engineered so that only 15% of gross cooling requirement is met by evaporative cooling. In other areas and under other conditions, water consumption might be considerably higher. In terms of annual consumption at an assumed load factor of 91%, the above estimates indicate total water consumption of 14,000 acre-feet per year of which about 2,500 is supplied to the mine and other offsite uses, leaving a consumptive demand for the plant of about 11,500 acre-feet per year.

To summarize, water consumption in coal gasification plants producing pipeline gas of 250 million scf per day capacity can be expected to range from about 10,000 acre-feet per year where water is at a premium to 45,000 acre-feet per year where abundant but poor-quality water is used for cooling. The principal differences are in evaporative cooling requirement and relate to the extent to which air cooling is employed and greater waste-water disposal where input water is of low quality.

Production of low Btu gas for power-plant consumption onsite rather than high Btu pipeline-quality gas is considered feasible in many situations. This can be accomplished in essentially the way planned at the Burnham Complex except that the methane-synthesis process is omitted. As the methane synthesis does not play a major role in water consumption, it appears that this alternative mode of gas production would have little bearing on consumptive demand for comparable Btu outputs.

Coal Liquefaction -- Water demand in coal liquefaction processes is poorly known because there are no commercial plants operating and numerous rival processes are presently under study. Unit water consumption estimates range from 0.2 to 1.3 acre-feet/year/bpd capacity. Until better data becomes available, projecting water requirements has little meaning.

Slide 10 is a synthesis of unit values of water consumption in the main water-consuming energy processes expressed in common units of gallons of water consumed per million Btu energy output. In the three upper bars for steam-electric power and the two bottom bars both refining, average values are shown because variability is small. On the other three processess, none of which are yet commercial, maximum and minimum values are shown as a measure of our ignorance. Other water uses described were too low to plot. It can readily be seen that steam-electric generation far exceeds other energy processes in terms of unit water use.

Using average values of unit consumptive use we have plotted net water consumption of the several processes in 1970 and as projected by AEC to 1985 under the assumption of energy self-sufficiency. Some other scenarios would show greater growth of coal electric power relative to nuclear. but otherwise the totals differ only slightly.

Slide 11 shows growth of water consumption in various classes of electric generation from about 2-1/4 million acre-feet in 1970 to about 6 million acre-feet in 1985. Projections for coal gasification indicate consumption by coal gasification of about 500,000 acre-feet by 1985. Recent deferrals of construction programs in the current capital crunch will have the effect of stretching out these projections, but more authoritative forecasts are not yet available.

Now then what does all this mean in terms of water demand for energy development in the West. There has been considerable concern expressed, especially on the banks of the Potomac, as to whether sufficient water is available for projected western energy development. Regretably, much discussion has been ill-informed. A common source of confusion is failure to distinguish between withdrawal and consumption of water. Still another is the tacit assumption that energy development necessarily involves large water consumption at the site of extraction. This latter, of course, overlooks the alternative of transporting the energy fuel off-site for conversion.

Slide 12 - let us look at current and future energy diagrams. On the left are energy fuel sources with amounts normalized to BOPDE X 10^6. Domestic oil and gas production are the largest sources of energy. The largest use group is industrial (9.9 BPOE) followed closely by transportation, residential and commercial, and electric generation. On the right is shown used vs. lost energy indicating about 50% overall thermal efficiency. It is noteworthy that electric generation and transport constitute most of the waste because of inherent low thermal efficiencies of steam turbines and internal combustion engines.

Slide 13 - If we turn now to a "business-as-usual" projection for 1990, we find significant trends that will have major impacts in the West. We find a threefold increase in electric generation supplied almost wholly by nuclear and coal. The increased coal and uranium production to accomodate this would be largely from western mines. Gas and oil go to their highest economic uses for space and process heat, and transportation. The high ratio of imported oil has implications that have received much attention in the past 1-1/2 years. A notable feature of this projection is that accompanying a more than doubling of energy consumption is a slippage in thermal efficiency from 50.5% to 44% due to proportionally larger increases in low-thermal efficiency electric generation and transport. Keep in mind that this picture is only one of many projections and much current legislation aims to correct the big oil import deficiency. Presumably this would be accomplished by reducing demand for oil and by substitution of coal insofar as possible.

Now lets examine the implications with respect to water use in the West.

1. Nuclear power represents a large consumptive use of water. By far the greatest consumptive use is for evaporative cooling at the nuclear power plant. For the forseeable future we can expect power plants to be sited close to major power markets in the Eastern states and water supply will dictate the specific plant location in most cases. In any event, the impact on water deficient areas in the West should be limited to the increased water demand related to mining except for power plants serving markets in the West, such as in Central Arizona, Central California, and Southern California.

2. Domestic natural gas production is shown as declining somewhat so one would not expect an additional impact of water supplies in the area. In any event water consumption in natural gas processing is a rather small demand.

3. Increased coal production is shown as going largely to electric production, which will represent a large water consumption at the power plant. However, it does not follow that this consumption necessarily will be in the coal producing areas. Currently, much western coal is going by rail to power plants at Midwestern electric load centers, and the economic realities will dictate that much future generating capacity be sited near load centers.

Indeed, minemouth plants such as the Four Corners and San Juan Plants are the exceptions rather than the rule, and are economically desirable because they can serve several widely separated load centers through interties. Indeed, if coal slurry transportation can overcome legal and institutional constraints that presently obstruct development, this may become the preferred method of conveying large amounts of energy over long distances to meet large electrical demands.

In the area of coal gasification the preferred sites are at mine mouth due to the low cost of gas transmission by pipeline, however, there appears to be some flexibility in plant siting through moving the fuel to a source of water via rail or slurry. Moreover, in the projection shown only 0.9 MBPOE of coal gasification is envisioned for 1990, a relatively small portion of the total.

4. In the oil sector we find a small decline in domestic production and a huge increase in imports. Presumably on-site water demand for water flooding would change very little; water demand for refining would increase in proportion to total production, but as at present this would be concentrated chiefly in Gulf Coast and Eastern refining centers.

   Water demand for oil shale production is tied to the mine site because the large volumes of material handled require retorting close to the mine and much of the water demand is for disposal of the waste shale. The projection for 1990 is 0.8 MBPOE, all in the Upper Colorado Basin. However, this is within water rights available to the states involved -- Colorado and Utah.

Summarizing, the major consumption of water in energy production is and will continue to be for steam-electric condenser cooling. The approximately 8 million acre-feet of water to be consumed nation-wide in energy processes under self-sufficiency assumptions is about the annual flow of the Colorado River thru Grand Canyon or about 1/15 of the annual flow of the Mississippi at St. Louis. Thus, at the national level there is no reason to suggest that water would be a limiting factor in energy development. Even in water deficient areas of the West the provision of water for energy development is simply a planning problem. Where costs or social or legal constraints prove insurmountable for mine mouth development, in most energy fuels, transportation of fuel to point of use generally provides a ready alternative.

NEW MEXICO WATER RESOURCES
UPPER COLORADO RIVER SYSTEM

S. E. Reynolds

The San Juan River and its tributaries constitute the Upper Colorado River System in New Mexico. The availability of water from the San Juan River System for beneficial consumptive use in New Mexico is founded on the Colorado River Compacts.

The Colorado River Compact of 1922 apportioned the consumptive use of 8.5 million acre-feet of the waters of the Colorado River System to the Lower Basin States of California, Arizona, Nevada, Utah and New Mexico. The compact apportioned the consumptive use of 7.5 million acre-feet of the waters of the System to the Upper Basin. Article III (d) provides that the states of the Upper Division will not cause the flow of the river at Lee Ferry to be depleted below an aggregate of 75 million acre-feet in any period of ten consecutive years.

The Upper Colorado River Basin Compact of 1948 divided the 7.5 million acre-feet of consumptive use apportioned to the Upper Basin by the 1922 Compact among the Upper Basin States. It was agreed that Arizona should have 50,000 acre-feet annually and that the balance would be divided among the other four states. New Mexico's share is set at 11.25% of that balance. If the full

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amount of 7.5 million acre-feet is available to the Upper Basin, New Mexico is allowed to make uses that would deplete the flow of the river at Lee Ferry by 838,000 acre-feet annually. Since 1922, it has become clear that the Colorado River at Lee Ferry may be as much as a million acre-feet short of the 15 million acre-feet presumed to be divided by the 1922 Compact. It does not appear that 7.5 million acre-feet annually will remain available for consumptive use in the Upper Basin after delivering to the Lower Basin 75 million acre-feet in each period of ten consecutive years. Using conservative estimates of runoff, it now appears that even with the nearly complete regulation of the river provided by the storage units of the Colorado River Storage Project, the Upper Basin may be able to use only about 6.3 million acre-feet of the 7.5 million acre-feet allocated to it. Current estimates indicate that we will be able to consume at sites of use in New Mexico, about 730,000 acre-feet per year.

The 1922 Compact ensured the rights of the Upper Basin States against the imminent early development in the Lower Basin that, under the law of the West, could have deprived the Upper Basin States of all but the minimal quantities already put to use by a few pioneers. But definitive plans for the use of the Upper Basin's entitlement necessarily awaited consummation of the Upper Basin Compact of 1948. As of 1948 New Mexico was consuming only about 70,000 acre-feet annually from the San Juan River system, nearly all of it for irrigation. New Mexico acted decisively, working closely with the Bureau of Reclamation to complete plans for the use of her share of the Colorado River. The projects settled on included Navajo Dam and Reservoir, one of the storage units of the Colorado River Storage Project; the small Hammond Irrigation Project which furnishes water for 3900 acres; the San Juan-Chama Project to export an average of 110,000 acre-feet annually from the San Juan River System to the Rio Grande System; the Navajo Indian Irrigation Project for the irrigation of 110,630 acres by Navajo Indians; and the Animas-La Plata Project in New Mexico and Colorado for irrigation and municipal and industrial purposes which would consume about 34,000 acre-feet of New Mexico's allocation. All of these developments have been authorized and all but the Animas-La Plata Project are completed or under construction. Total cost of these projects is now estimated at about $475 million. These commitments of water apportioned to New Mexico and the commitment to rights existing before the authorizations described, left a consumptive use of about 100,000 acre feet annually available for municipal and industrial purposes.

Before the developments I have outlined were authorized New Mexico had already made a substantial commitment of water resources to energy development in the San Juan Basin. In February of 1955 Utah Construction Company made application for 139,000 acre-feet annually for the operation of coal-fired electric generators to be fueled from a large coal surface mining project and for the use of industries expected to locate in the area to take advantage of cheap electric energy. The permit ultimately granted was limited to use in coal mining and power generation for the reason that it was inappropriate under our law to grant water rights for uses as yet ill-defined and uncertain. Under the permit the diversion is limited to an average of 55,000 acre-feet annually and consumptive use is limited to 39,000 acre-feet annually. The water is now being used for the operation of five units with a total generating capacity of 2,075 megawatts; the mine and the generating units are located on the Navajo Indian Reservation. It may be of some interest that this permit is prior in time and therefore prior in right to the water rights granted to the Secretary of the therefore prior in right to the water rights granted to the Secretary of the Interior by the State for the developments that I outlined earlier.

In an unusual, if not unique, provision the law authorizing the San Juan-Chama and Navajo Projects in 1962 (Public Law 87-483) prohibits the Secretary of the Interior from entering any contract for water from Navajo Reservoir for municipal and industrial purposes until the Secretary has determined by hydrologic investigation that sufficient water is available in New Mexico's allocation to fulfill the contract and until Congress has approved the contract. This provision is in some respects cumbersome but it has had the desirable effect of assuring us a considerable voice in determining the purposes for which the water available for municipal and industrial purposes is contracted; it is doubtful that the Secretary would propose or the Congress would approve a contract not supported by the State.

At the insistence of the State, the Secretary of the Interior made a hydrologic investigation and in November of 1963 reported that there is available, under the Secretary's rights in the San Juan River System in New Mexico, sufficient water for contracts allowing a depletion of 100,000 acre-feet annually, provided that the terms of the contracts are limited to the year 2005. The most difficult problem confronting the Secretary in his investigation was the determination of what part, in any, of the 1944 Mexican Treaty obligation would have to be met by releases from the Upper Basin in excess of the 75 million acre-feet in each period of ten consecutive years required by Article III (d) of the 1922 Compact. Article III (c) of the compact was prospective; it provided that if the United States should recognize in Mexico any right to the use of the waters of the Colorado River System, the waters would be supplied from waters over and above the aggregate of the Article III (a) and Article III (b) apportionments to the Lower Basin and the Upper Basin. Article III (c) further provided that if the surplus proved insufficient, then the burden of the deficiency would be equally borne by the Upper Basin and the Lower Basin, and the states of the Upper Division would deliver at Lee Ferry water to supply one-half of the deficiency, in addition to the amount required to be delivered by Article III (d).

The Secretary was able to avoid, or at least defer, an interpretation of the provisions of the Compact dealing with the Mexican Treaty obligation. This was done by determining from projections of future development in the Upper Basin that there would be water in excess of total Upper Basin requirements plus one-half of the Treaty obligation until at least the year 2005. This excess was found sufficient to support consumptive uses of 100,000 acre-feet annually in New Mexico under municipal and industrial contracts terminating in 2005.

The New Mexico Interstate Stream Commission concurred in the 2005 term for contracts so long as it did not inhibit the development and use of New Mexico's water resources. It is New Mexico's position that the full amount of 100,000 acre-feet will be available for the contracts in perpetuity. Interstate Stream Commission studies show that under the terms of the 1922 Compact and reasonable projections of stream flow, it will not be necessary for the Upper Basin to make deliveries in excess of 75 million acre-feet in each period of ten consecutive years to meet any part of the United States obligation to deliver 1.5 million acre-feet annually to Mexico. Studies show that with an average annual delivery of 7.5 million acre-feet from the Upper Basin water available from the main stream and tributaries in the Lower Basin is sufficient to furnish the 8.5 million acre-feet apportioned to the Lower Basin and, in addition, the 1.5 million acre-feet required for delivery to Mexico.

With the support of the State, the Congress in 1968 (Public Law 90-272) authorized the Secretary to enter a contract with Southern Union Gas Company for 50 acre-feet annually for cooling in a compressor station; a contract with the Public Service Company of New Mexico for the diversion of 20,200 acre-feet of water, a part of which is not being used for the operation of the company's San Juan plant near the Four Corners; and a contract with Utah Construction and Mining Company for a diversion of 44,000 acre-feet annually. It now appears that water under this latter contract will be used for coal gasification units with a total capacity of 1 billion cubic feet per day.

In September of 1972 the New Mexico Interstate Stream Commission recommended to Governor King that the state support a contract with El Paso Natural Gas Company for 28,250 acre-feet for the operation of a coal gasification complex with a total capacity of 785 million cubic feet per day. The Governor did this by a letter to Secretary of the Interior dated September 12, 1972, and by letters to the members of the New Mexico Congressional delegation. Public hearings on the draft environmental impact statement on the proposed contract were held in Window Rock and Farmington last week. Contract negotiations were completed sometime ago and the Secretary of the Interior has had his determination on the availability of water for the contract under active consideration for a number months. We expect a favorable determination at an early date and hope to have the opportunity to support Congressional authorization of the contract in the current session.

The contracts already authorized and the proposed contract with El Paso Natural Gas Company would commit all but 7500 acre-feet of the 100,000 acre-feet of water estimated by the Secretary to be available for contract for municipal and industrial purposes. It is the position of the Interstate Stream Commission that this residual amount should be tentatively reserved for possible use by the City of Gallup through a project now under investigation by the Bureau of Reclamation.

The 100,000 acre-feet of consumptive use found by the Secretary to be available for municipal industrial contracts does not necessarily represent the ultimate limit on water from the San Juan River System in New Mexico for municipal and industrial purposes. The original design of the Animas-La Plata Project would have provided 13,500 acre-feet of water annually for municipal and industrial use in New Mexico. Studies for the definite plan report on the project indicate that this amount may be considerably higher for the reason that some of the new lands originally planned to be irrigated may not be suitable.

The strippable low-sulfur coal resources of the San Juan Basin in New Mexico have been estimated at about 3 billion tons with an overburden of less than 150 feet, and another 3 billion tons with an overburden of 150 to

250 feet.[1] The State of New Mexico has committed, or supported the commitment of, 131,500 acre-feet of its allocation of Colorado River System water to the use of these coal resources ot a rate of about 80 million tons per year.

It is noteworthy that over 111,000 acre-feet of this amount is committed for use on the Navajo Reservation. In 1972, the Vice-Chairman of the Navajo Tribal Council reported that the unemployment rate for the Navajo Trive is 65 percent. The proposed El Paso Natural Gas Company contract for 28,250 acre-feet would provide the water needed for the operation of two coal gasification units on the Navajo Reservation. These two units would be capable of producing a total of 785 million cubic feet per day of synthetic gas. The two units, the last of which would be completed in 1981 will process about 77,000 tons of Navajo coal per day; royalties to the tribe are conservatively estimated at about $11 million per year. Jobs made available in the construction phase of the development would peak at 4,100 in 1979. About 3,000 employees would be required in the plant operation after 1982; services to support operation of the plants after 1982 will provide an estimated additional 5,700 jobs. The terms of the proposed water contract require that Navajo Indians be given preference in employment for the operation of the mine and gasification facilities. To comprehend the full impact of the proposed gasification of Navajo coal, it should be remembered that WESCO proposes to develop another gasification complex capable of producing 1 billion cubic feet per day of synthetic gas, a complex slightly larger than that proposed by El Paso Natural Gas Company.

The development and use of the coal and water resources of northwestern New Mexico can make a substantial contribution to the achievement of energy self-sufficiency for the United States. But there is legitimate concern that the development of energy resources will siphon off water that otherwise could be used for irrigation to help meet current and prospective world-wide food shortages. I believe it is fair to say that there is a reasonable balance in the water commitments New Mexico has made to these two objectives. At full development, in about 1986, the 110,630 acre Navajo Irrigation Project will consume about 230,000 acre-feet of New Mexico's entitlement; these lands promise to be some of the most productive in New Mexico.

In passing I should point out that full development of the Navajo Project and the gasification units will bring the use of San Juan River water on the Navajo Reservation to about 375,000 acre-feet annually, or a little more than one-half of New Mexico's entitlement under the Compacts.

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1. Memoir 25, New Mexico State Bureau of Mines and Mineral Resources, "Strippable low-sulphur coal resources of the San Juan Basin in New Mexico and Colorado", 1971.

Most of the electrical energy that is being generated and the energy in the form of electricity and gas that will be generated from the coal in the Four Corners area in New Mexico has been, and will be, transmitted for use in other states; a large share of the total will be used in southern California. A current and recurring suggestion is that New Mexico withhold its water from gas production unless and until an agreement is reached under which the water used to produce the gas would be charged against the compact entitlements of the downstream states such as California, where some of the gas is to be used. Obviously, such a suggestion is appealing to the New Mexico State Engineer and I have explored it carefully. However, there is reason to believe that such an agreement could not be negotiated; and the time lost through an effort to negotiate it could so shorten the amortization period as to make the contemplated development infeasible under a water contract terminating in 2005.

Under the Upper Basin Compact of 1948 (Article VII), any water used in New Mexico, on or off an Indian Reservation, is chargeable against New Mexico's apportionment whether the diversion from the stream is made in New Mexico or in some other state. For us to acquire rights to the use of water to which California is entitled under the compact for the manufacture of gas to be used in California, Article III (d) of the 1922 Compact, which requires the delivery of an average of 7.5 million acre-feet per year at Lee Ferry, would have to be amended. All seven states of the Colorado River Basin would have to agree to the amendment by a legislative ratification and the Congress would have to give its consent to the amendment. The first necessary step, of course, would be to persuade those in California having rights to Colorado River water to give up their rights to New Mexico in order that the needs of gas users in California could be met. You can probably best appraise this obstacle by imagining a similar circumstance in New Mexico.

Assuming that the Colorado River Compact of 1922 could be amended, the next step would be the amendment of the Upper Colorado River Basin Compact of 1948. By Article XIV of the Upper Basin Compact Colorado agrees to deliver to New Mexico from the San Juan River and its tributaries a quantity of water sufficient to enable New Mexico to make full use of the water apportioned to us by the Compact. In order for New Mexico to manufacture gas with water that California would otherwise be entitled to it would be necessary to amend the Upper Basin Compact to require Colorado to leave more San Juan River water for use in New Mexico, thus forcing Colorado to take a larger share of its entitlement from other Colorado River tributaries. I can see no incentive for Colorado to so agree and it can reasonably be expected that residents of the San Juan River Basin in Colorado would resist an amendment which would have the effect of transferring water from their area to other tributaries in Colorado. Again, I invite you to imagine a similar circumstance in New Mexico.

Any amendment of the Upper Basin Compact would require ratification by the legislatures of the States of Arizona, Colorado, Utah, New Mexico and Wyoming and the Congress of the United States.

I believe that what I have said supports the view that, while it is theoretically possible to use California water for the manufacture of gas in New Mexico, such an arrangement is not practicable.

I am not aware of any early opportunities to put New Mexico's Colorado River System water to beneficial uses other than energy development projects such as proposed by the El Paso Natural Gas Company. If putting our water to beneficial use is delayed by unpromising negotiations, the water will continue to run downhill and California will have it for use, even if she doesn't have gas.

THE NATIONAL SAFE DRINKING WATER ACT

Dr. John W. Hernandez

A. Purpose of the Legislation

President Ford signed the National Safe Drinking Water Act on December 16, 1974. The purpose of the legislation is to assure that water supply systems serving the public meet minimum national standards for the protection of public health. The Act is designed to achieve uniform safety and quality of drinking water in the U.S. by identifying contaminants and establishing maximum acceptable levels. Prior to this Act, the Environmental Protection Agency was authorized to prescribe Federal drinking water standards only for water supplies used by interstate carriers. In contrast, this bill permits EPA to establish Federal standards to control the levels of all harmful contaminants in the drinking water supplied by all public water systems. It also establishes a joint Federal-State system for assuring compliance with these standards. The major provisions of the Act are:

1. the establishment of primary regulations for the protection of the public health;
2. the establishment of secondary regulations that are related to taste, odor and appearance of drinking water;
3. the establishment of regulations to protective underground drinking water sources;
4. the initiation of research on health, economic and technological problems related to drinking water supplies;
5. the initiation of a survey of rural water supplies; and
6. the allocation of funds to states in improving their drinking water programs through technical assistance, training of personnel and grant support.

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B. Applicability

1. The Act applies to:

   a. all public water supplies, both municipal and investor-owned; and

   b. Federal agencies having jurisdiction over Federally-owned or maintained public water systems, except under waiver of compliance in the interest of national security.

2. The Act does not apply to a system if:

   a. it consists solely of distribution and storage;

   b. it obtains water from, but is not owned or operated by a public water system (e.g., hotels);

   c. it does not sell water to any person (e.g., captive industrial supplies); and

   d. it does not convey water to passengers in interstate commerce.

C. Definitions

1. A Public Water System is one that:

   a. provides water piped to the public for human consumption and serves 15 or more service connections; or

   b. regularly serves 25 or more persons per day during a period of at least 3 months per year; and

   c. includes:

      (1) any collection, treatment, storage, and distribution facilities under control of an operator and used in such a system; and

      (2) any collection or pretreatment storage facilities used in such a system.

2. Contaminant is any physical, chemical, biological, or radiological substance or matter in water.

3. Maximum Contaminant Level is the maximum concentration of a contaminant allowable in water delivered to a user.

4. Effective Date of the Act is the date from which the adoption of both State and Federal regulations under the Act occurs after December 16, 1974.

D. National Primary Drinking Water Regulations

The Act directs EPA to adopt national drinking water regulations related to public health that are applicable to all public water supplies and that may be enforced by either or both Federal and State governments. The following subsections review the applicability and enforcement of these primary drinking water regulations. There are provisions for exceptions and variances, for notification of violations and for monitoring and reporting under these regulations.

1. General considerations are:

   a. these regulations are to protect health to the extent feasible, using technology, treatment techniques, and other means generally available when costs are taken into consideration;

   b. proposed Interim Primary Drinking Water Regulations were published in the Federal Resiger on March 14, 1975, and are subject to comment by any person until May 15, 1975;

   c. revised Interim Regulations are to be promulgated by June 16, 1975;

   d. modified Interim Regulations take effect on December 17, 1976;

   e. after submission on December 17, 1977 of a study by the National Academy of Science on the Primary Drinking Water Regulations, EPA will publish its Revised National Primary Drinking Water Regulations; and

   f. the effective date for the Revised Primary Regulations will be September 29, 1979.

2. Specific considerations of Primary Regulations are that these regulations:

   a. apply to all public water systems;

   b. specify contaminants that may have any adverse effects on the health of persons;

   c. specify for each contaminant either:

      (1) a maximum contaminant level, if it is economically and technologically feasible to determine that level in water; or

      (2) if it is not feasible to determine that contaminant level, they specify each known treatment technique that will reduce the contaminant concentration to a level that will meet the Regulations; and

   d. contain criteria and procedures to ensure that a supply will dependably comply with the allowable contaminant levels, including:

      (1) quality control and testing procedures to ensure proper operation and maintenance of a system, and

      (2) requirements as to:

         (a) minimum quality of water that may be taken into the system, and

(b) siting for new facilities; but

e. may not require the addition of any substance for preventive health care purposes unrelated to contamination of drinking water.

3. Revision to Primary Regulations

The Act provides for a review of the health aspects of the regulations by the National Academy of Science (NAS). Based on results of NAS study, EPA may specify additional contaminants with adverse health effects, it may establish new maximum contaminant levels, it may prescribe a list of known water treatment techniques which will reduce the concentration of any contaminant for which no maximum contaminant level is established (e.g., viruses, organics, asbestos), or it may establish requirements for operation and maintenance. These regulations:

a. shall be amended whenever changes in technology, treatment techniques and other means permit greater protection of the health of persons; and

b. must be reviewed once every three years, for possible revision.

4. Variances and Exemptions from Primary Regulations

The Act provides for a system of either state or EPA issued variances and exemptions that allow at least temporary, conditional use of a water supply that fails to meet a Primary Regulation. Because of the incorporation of compliance schedules in all variances and exemptions, it is anticipated that eventually virtually all public water will comply with the Primary Regulations. Some exceptions under the variance provisions may be possible so that a system may never have to come into compliance if certain conditions exist (e.g., adequate technology is not available).

a. Exemptions

(1) By state approval, one or more exemptions may be obtained for any supply either with respect to meeting maximum contaminant level regulations, or a treatment requirement that is specified in a Primary Regulation.

(2) The reason for granting an exemption for systems that were in operation at the time that a Primary Regulation became effective is:

(a) that compelling factors such as economics prevent a public water supply system from meeting either a

(a) (continued)

maximum contaminant level, or a treatment technique requirement; and

(b) that granting an exemption will not result in an unreasonable risk to health.

(3) Exemptions are relatively short-termed, depending on financing, construction, and other factors, and have finite deadlines for discontinuance. The conditions for granting an exemption to a public water supply are:

(a) that within one year after granting an exemption, a state must issue a schedule of compliance that contains deadlines for increments of progress for each element in the Primary Regulations not met;

(b) that any control measures specified by the state as a condition must be implemented;

(c) that the state provides notice and opportunity for public hearing because a schedule of compliance is ordered; and

(d) that the public water supply meet the compliance schedule to lift the exemption, as expeditiously as practicable, but certainly by the specific deadlines.

(4) Specific deadlines for exemptions are:

(a) for those based on the Interim Primary Regulations, all single public water systems must be in compliance by January 1, 1981; and

(b) for those based on Revised Primary Regulations, seven years after the final version becomes effective (about September 27, 1979).

(5) EPA and a state must act on an application for exemption within a reasonable period of time after it is submitted.

(6) EPA has the responsibility for granting exemptions if a state does not have primary responsibility for enforcement under provisions of the Act.

(7) Enforcement of an exemption compliance schedule is to be under state law, or by EPA if a state does not qualify for enforcement responsibility.

b. Variances

(1) The reasons for granting a variance are:

(a) that the available sources of raw water have characteristics that cannot meet requirements respecting maximum allowable contaminant levels, despite the application of best available technology, treatment techniques, or other means, taking costs into the consideration and

(a) (continued)

that unreasonable risk to public health will not result; or

(b) that a public water system demonstrates to the state's satisfaction that a treatment process specified by the Regulations is not necessary to protect the health of the persons, because of the nature of the raw water source of such a system. (Such a variance is conditioned on monitoring or other requirements as EPA may prescribe).

(2) The conditions for granting variances are that:

(a) before a proposed variance may take effect, a state must provide notice and opportunity for public hearing;

(b) if a state grants a variance, it must, within one year, provide a schedule for compliance including increments of progress and the system must implement any control measure that the state may require;

(c) before a state-prescribed schedule may take effect, it must provide notice and hold a public hearing on granting the variance subject to the prescribed compliance schedule;

(d) if a variance is granted, the water supplier must undertake to meet the compliance schedule as expeditiously as practicable as the state determines may reasonably be achieved; and

(e) a varience must be conditioned on compliance by the public water system with the prescribed time-table in the schedule.

(3) The Act provides for procedures for EPA approval, review and revocation of a state issued variance.

(4) EPA has the responsibility for granting variances if a state does not have a primary responsibility for enforcement of the Act.

(5) There are no absolute deadlines for revocation of a variance. Except as subject to the requirements of a schedule of complicance, a variance may be continued indefinitely. Variances are to be reviewed every three years, but will not be revoked or rescinded unless there is a definite change in the technology available.

5. Notification of Violations of the Regulations

The Act requires public water supply systems to give notice to the users of their system and to the general public of a failure to comply with various regulations and requirements of the Act.

5. (continued)

Bi-lingual notices may be required in certain places.

a. Public notice must be given where a water system:

(1) fails to comply with a maximum contaminant level regulation;

(2) fails to comply when "best treatment techniques" are required;

(3) fails to adopt prescribed testing procedures;

(4) fails to perform required monitoring; or

(5) fails to meet a schedule of compliance issued as part of a variance or exemption.

b. Public notice of any of these violations must be given in each of the following ways:

(1) via public media such a radio, television and newspaper press-releases once every three months;

(2) by publication in local newspaper, as soon as practicable after discovery of the violation, and at least once every three months thereafter as long as the violation exists; and

(3) notice is to be included in water bills if they are mailed every three months; if the consumer is billed more often than every three months, the notice must be included in each bill.

c. Willful failure to comply with these requirements for notification may result in the imposition of a fine up to $5000.00.

E. Proposed Interim Primary Regulations

In Part II of Volume 40 of the Federal Register of March 14, 1975, EPA published proposed Interim Primary Drinking Water Regulations for all public water supply systems. A summary of the maximum contaminant levels established in these regulations is provided in subsections 1. through 6. below. The requirements for chemical and biological analyses and reports associated with complicance with these Interim Primary Regulations are also included (subsection 7.). The Interim Regulations differentiate between a public water system and a community system in a number of places. A community system is one where 70% of those served are residents. There are also some references to the time period during which various analysis must be accomplished; these periods of time are after the effective date of the Interim Regulations (about December 17, 1976).

The maximum contaminant levels for arsenic, barium, cadmium, chromium,

E. (continued)

cyanide, fluoride, lead, selenium and silver are the same as those in the 1962 Public Health Service Drinking Water Standards. With the exception of nitrates, all of the maximum contaminant levels of inorganic chemicals are based upon possible health effects that may occur after a lifetime of exposure of approximately two liters of water per day. Pesticide contaminants were not contained in the 1962 Standards. The maximum contaminant levels for pesticides have been derived from the recent data on effects of acute and chronic exposure to both organochlorine and chlorophenoxy pesticides. In settling specific limits for chemical constituents, the total lifetime environmental exposure of man to the specific toxicant has been taken into consideration. The limits have been determined with a factor of safety included to minimize the amount of toxicant contributed by water when other sources (milk, food, or air) are known to represent additional sources of exposure to man. On this basis maximum contaminant levels should not be regarded as fine lines between safe and dangerous concentrations.

The interim standards have a limit for turbidity because turbidity interferes with disinfection efficiency and because high turbidity often signals the presence of other health hazards. The growth of microorganisms in a distribution system is often stimulated if excessive particulate or organic matter is present. The maximum levels for microbiological contaminants are in terms of the surrogate coliform bacteria, although the purpose of the standard is to protect against disease-causing bacteria, viruses, protozoa, worms, and fungi. The analytical procedures for direct detection of these microorganisms are not well enough developed nor practicable for widespread application at this time. Total coliform counts have been used for nearly 100 years as indicators because the organisms are present in large quantity in the intestinal tracts of humans and other warm-blooded animals, thus the number remaining in a water supply provides a good correlation with sanitary significance.

1. Maximum Contaminant Levels for Inorganic Chemicals

Contaminant	Level (mg/l)
Arsenic	0.05
Barium	1.00
Cadmium	0.010
Chromium	0.05
Cyanide	0.2
Lead	0.05
Mercury	0.002
Nitrate	10.00
Selenium	0.01
Silver	0.05

2. Fluorides

When the annual average of the maximum daily air temperatures for the location in which the public water system is situated is the following, the corresponding concentration of fluoride shall not be exceeded.

Temperature (in ° F)	Level (mg/l)
50.0 - 53.7	2.4
53.8 - 58.3	2.2
58.4 - 63.8	2.0
63.9 - 70.6	1.8
70.7 - 79.2	1.6
79.3 - 90.5	1.4

3. Maximum Contaminant Levels for Organic Chemicals

The maximum contaminant level for the total concentration of organic chemicals is 0.7 mg/l.

4. Maximum Contaminant Levels for Pesticides

Chlorinated Hydrocarbons	Level (mg/l)
Chlordane	0.003
Endrin	0.0002
Heptachlor	0.0001
Heptachlor Epoxide	0.0001
Lindane	0.004
Methoxychlor	0.1
Toxaphene	0.005
Chlorophenoxys	
2, 4-D	0.1
2,4, 5-TP Silvex	0.01

5. Maximum Microbiological Contaminant Levels

Two methods are used to describe the maximum coliform levels that

5. (continued)

must be met and the parameters used to judge compliance with these levels.

a. When the membrane filter technique is used, coliform densities shall not exceed one per 100 milliliters as an arithmetic mean of all samples examined per month; and either,

   (1) four per 100 milliliters in more than one standard sample when less than 20 are examined per month; or

   (2) four per 100 milliliters in more than 5% of the standard samples when 20 or more are examined per month.

b. When the fermentation tube method is used and when

   (1) 10 milliliter standard portions are analyzed, coliforms shall not be present in more than 10% of the portions in any month; and either,

      (a) three or more portions in one sample when less than 20 samples are examined per month; or

      (b) three or more portions in more than 5% of the samples if 20 or more samples are examined per month; or

   (2) when 100 milliliter standard portions are analyzed, coliforms shall not be present in more than 60% of the portions in any month; and either

      (a) five or more portions in more than one sample when less than five samples are examined; or

      (b) five or more portions in more than 20% of samples when five samples or more are examined.

c. If a standard bacterial plate count is used, there must be no more than 500 organisms per one milliliter.

6. Maximum Contaminant Level of Turbidity

The level of turbidity at representative entry point(s) into the distribution system is one turbidity unit (1TU). A maximum of five turbidity units (5TU) may be allowed if the supplier can demonstrate to the state that this higher turbidity does not:

a. interfere with disinfection;

b. prevent maintenance of an effective disinfectant agent through the distribution system; and

c. interfere with microbiological determinations.

7. Water Facility Siting Provisions

The Act and the Interim Primary Regulations both include provisions to require notice before a new water supply is developed or an existing

7. (continued)

supply modified. The purpose of this provision is to avoid problems associated with poor facility location choices. Before a water supplier may enter into a financial commitment for, or initiate construction of a new public water system or increase the capacity of an existing public water system, he must notify the state. To the extent practicable, a supplier should avoid locating the new or expanded facility at a site which is subject to earthquakes, floods, fires, or other man-made disasters which could cause breakdown of the public water system. Normally facilities should not be located within the floodplain of a 100 year flood.

8. Sampling and Analytical Requirements

a. Coliforn Density

(1) Basic sampling requirements

Samples for microbiological analyses are to be taken at regular intervals throughout the month proportional to the population served by the system as shown below. Samples should be collected from representative locations throughout the system.

Population served	Minimum number of samples per month
25 to 2,500	2
2,501 to 3,330	3
3,301 to 4,100	4
4,101 to 4,900	5
4,901 to 5,800	6
5,801 to 6,700	7
6,701 to 7,600	8
7,601 to 8,500	9
8,501 to 9,400	10
9,401 to 10,300	11
10,301 to 11,100	12
11,101 to 12,000	13
12,001 to 12,900	14
12,901 to 13,700	15
13,701 to 14,600	16
14,601 to 15,500	17
15,501 to 16,300	18
16,301 to 17,200	19
17,201 to 18,100	20
18,101 to 18,900	21
18,901 to 19,800	22
19,801 to 20,700	23
20,701 to 21,500	24

(1) (continued)

Population served	Minimum number of samples per month
21,501 to 22,300	25
22,301 to 23,200	26
23,201 to 24,000	27
24,001 to 24,900	28
24,901 to 25,000	29
25,001 to 28,000	30
28,001 to 33,000	35
33,001 to 37,000	40
37,001 to 41,000	45
41,001 to 46,000	50
46,001 to 50,000	55
50,001 to 54,000	60
54,001 to 59,000	65
59,001 to 64,000	70
64,001 to 70,000	75
70,001 to 76,000	80
76,001 to 83,000	85
83,001 to 90,000	90
90,001 to 96,000	95
96,001 to 111,000	100
111,001 to 130,000	110
130,001 to 160,000	120
160,001 to 190,000	130
190,001 to 220,000	140
220,001 to 250,000	150
250,001 to 290,000	160
290,001 to 320,000	170

(2) Check-sample requirements

When the coliform colonies in a single standard sample exceed four per 100 milliliters, additional daily samples must be collected and examined from the same sampling point until the results obtained from at least two consecutive samples show less than one coliform per 100 milliliters. When organisms of the coliform group occur in three or more 10 ml portions of a single standard sample, daily samples must be collected from the same sampling point until the results obtained from at least two consecutive samples show no positive tubes. When organisms of the coliform group occur in all five of the 100 ml portions of a single standard sample, daily samples must be collected from the same sampling point until the results obtained from at least two consecutive samples snow no positive tubes. The location at which a check sample is taken must not be eliminated from future sampling because of a history of questionable water quality. Check-samples are not included in calculating the total number of samples to be taken by a public supplier

(2) (continued)

each month. When a particular sampling point has been confirmed by a check-sample to be in non-compliance with the maximum contaminant levels specified, the supplier of water must notify the state and make reports required by the regulations.

b. Substitution of Residual Chlorine for Coliform Measurements

A supplier may, with the approval of the state, substitute the use of chlorine residual monitoring for up to 75% of the coliform samples required for the system. The supplier of water must take chlorine residual samples at points which are representative of the conditions within the distribution system at a frequency of at least four chlorine residuals for each substituted microbiological sample. There must be at least daily determinations of chlorine residual if a supplier exercises this option and he must maintain no less than 0.2 mg/l free chlorine in the water distribution system. Public water systems serving 4,900 or fewer persons may, with the approval of the state, make a total substitution of chlorine residual measurement for the samples required for coliform measurement. Chlorine residual samples should be taken at points which are representative of the conditions within the distribution system at the rate of one per day for each microbiological sample required. When a supplier exercises this option, he must maintain no less than 0.3 mg/l free chlorine in the water distribution system.

c. Turbidity Sampling and Analysis

For turbidity monitoring, samples must be taken at a representative entry point to the water distribution system at least once per day for surface water systems and at least once per month for supplies obtained from underground sources. This requirement applies only to community water systems. In the event that a measurement indicates that the maximum allowable limit has been exceeded, the sampling and measurement must be repeated within one hour. The results of the two measurements are averaged and, if the average confirms that the maximum allowable has been exceeded, this average is reported. If the monthly average of all samples exceeds the maximum allowable limit, this fact must be reported to the state.

d. Inorganic Chemical Sampling and Analysis

To establish an initial record of water quality, an analysis of substances to determine compliance with the maximum contaminant levels specified in the regulations must be completed for all community water systems utilizing surface water sources within one year after the effective date of the regulations. These analyses are to be repeated at yearly intervals. For community water systems using ground water sources, chemical analysis of the supply must be completed within two years and this analysis repeated at

d. (continued)

three-year intervals. Analysis for public water systems, other than community water systems, whether supplied by surface or ground water sources must be completed within six years and these analyses are to be repeated at five-year intervals.

If a water supplier determines or has been informed by the state, that the level of any contaminant is 75% or more of the maximum contaminant level, he must analyze for the presence and quantity of that contaminant at least once per month following the initial analysis or information. If after conducting monthly testing for a period of at least one year, the supplier of water demonstrates to the satisfaction of the state that the level of such contaminant is stable and due to a natural condition of the water source, he may reduce the frequency of analysis.

If a supplier finds, or has been informed by the state that the level of any contaminant exceeds the maximum contaminant level for the substance, he must confirm the information by sampling the source within 24 hours following the initial information and then analysis must be made on samples taken at least at weekly intervals during the period of time the maximum contaminant level for the substance is exceeded. The results of such repetitive testing must be averaged and reported. To determine compliance of a public water system with the maximum contaminant levels, averages of data will be used and rounded to the same number of significancy figures as the maximum contaminant level for the substance in question.

e. Pesticide and Organic Chemical Sampling and Analysis

To establish an initial record of water quality with respect to these substances, an analysis must be completed for all community water systems utilizing surface water sources within one year after the effective date of the regulations. This analysis is to be repeated at one-year intervals. An analysis for community water systems utilizing ground water sources must be completed within two years and this analysis repeated at three-year intervals. Analyses for public water systems other than community water systems must be completed within six years and repeated at five-year intervals.

f. Reports

Public water suppliers must report the results of these various analyses to the state within 40 days following the test, measurement or analysis. When a supplier determines that his system has failed to meet a particular maximum contaminant level, he must report this failure to meet the standards within 36 hours, including any failure to comply with monitoring requirements. Federal agencies make such reports to EPA. All violations must be reported. A violation occurs when adequate monitoring is not maintained, when an inorganic or pesticide maximum level is exceeded on a monthly average, when the average of two samples for turbidity,

f. (continued)

nitrates and carbon extractables exceed the limit or when a violation of the coliform standards is confirmed.

F. National Secondary Drinking Water Regulations

The National Safe Drinking Water Act also provides for the establishment of an additional set of standards that are to prescribe maximum limits for contaminants that tend to make water disagreeable to use, but that do not have any particular adverse public health effect. These are anticipated to be organics that result in color and odor, inorganics such as iron and manganese that cause color and turbidity, and other chemicals that impart a noticeable and disagreeable taste. These standards for esthetic quality are to be incorporated in the Secondary Drinking Water Regulations.

1. A Secondary Drinking Water Regulation is one that:
    a. applies to all public water systems;
    b. specifies maximum contaminant levels necessary to protect the public welfare, if these contaminants
        (1) adversely affect the odor or the appearance of water causing a substantial number of persons to discontinue its use, or
        (2) adversely affects the public welfare in some other way; and
    c. is not enforceable by EPA, but may be enforced by a state and that may vary according to geographic and other circumstances.
2. The Secondary Drinking Water Regulations are to be promulgated by EPA by September 17, 1975 with a review period to last until their adoption on December 17, 1975. An opportunity for public hearings must be provided in the establishment of these regulations.
3. If within a reasonable time after promulgation of the Secondary Regulations, EPA determines that a state has not enforced these regulations and that a number of public systems have failed to comply with these regulations, then EPA may take action to ensure compliance by notifying the state that it is not taking reasonable action with respect to these regulations.

G. Enforcement of the Act

The Act clearly contemplates that the states will be responsible for enforcing the requirements of the law and the various regulations adopted by EPA. To help the states administer the Act, funds are allocated to

G. (continued)

each although there is a requirement for states to provide matching funds equal to 25% of the Federal funds received. A state need not take over administration of all of the elements of the Act, but can be designated by EPA to only enforce certain regulations. A state may also choose to accept responsibility for operation of the Act over a period of years.

1. Primary enforcement responsibility rests with a state providing that:
    a. the state adopts drinking water regulations to no less stringest than the Interim or Revised Primary Regulations, whichever are in effect;
    b. the state has adopted and is implementing adequate procedures for enforcement of the Regulations, including monitoring and insepc-tions as may be required by EPA;
    c. the state keeps records and reports to EPA as may be requested;
    d. the state will not issue variances and exemptions that are less stringent than those called for by the Act and the regulations;
    e. the state has adopted and can implement an adequate plan for pro-vision of safe drinking water under emergency conditions; and
    f. the state requests that it be delegated this authority.
2. Financial grants are given only to states that:
    a. have programs for enforcing drinking water regulations;
    b. have established (or will establish within one year of a grant) a public water system supervision program; and
    c. will assume primary enforcement responsibility for public water supply systems within the state.
3. By June 17, 1975, EPA must prescribe the manner in which a state may apply for designation and authority to enforce the Act. The states have until September 17, 1975 to apply to EPA for approval of their enforcement plans and programs. EPA approval of state's program will be based on the following:
    a. the period for which that approval will apply;
    b. EPA's determination that the state enforcement program is adequate; and
    c. public hearings held on the state enforcement program.
4. EPA may find that a state is failing to enforce the Act. The procedure in such a case is as follows:
    a. if EPA finds that a state is not enforcing compliance of the various regulations for any system, it will notify the state and offer to

a. (continued)

provide advice and technical assistance that may be needed to bring the system into compliance;

b. if after such a notice the failure to comply extends more than 30 days EPA will:

   (1) give public notice of its finding; and

   (2) give the state 15 days to report on steps taken to bring the system into compliance, including reasons;

c. if the state does not obtain compliance after more than 60 days and if a state fails to submit a report, or if the report is unacceptable to EPA, then EPA may determine that the state has abused its discretion in carrying out its enforcement responsibility; and

d. EPA may commence a civil action to obtain compliance.

5. In a state without primary enforcement responsibility, EPA may find that a system is in noncompliance. It may then commence a civil action against the public water supply in U.S. District Court. The Court may enter a judgement against the water system and impose a fine of up to $5000 per day of noncompliance. If a suit is brought and judgment rendered, the public water supply system must notify all of its customers.

6. In a state that has primary enforcement responsibility and the state makes a finding of noncompliance with the Act, on the part of a public system, it will proceed as follows:

   a. the state may petition EPA for assistance;

   b. the state may hold public hearings to gather technical information and to determine methods of obtaining compliance;

   c. EPA may issue recommendations based on such hearings;

   d. the state should determine ways to bring a system into compliance in the earliest possible time; and

   e. the state will establish the best means for maximum feasible protection of public health.

7. Citizen Suits in U.S. District Court

   The Act permits citizen suits in order to give the public an opportunity to force the states and EPA to obtain compliance with the Act and the various regulations. The conditions for such suits are as follows:

a. a suit may be brought by any person on his own behalf (no class action suits) against:

   (1) any person or water system,

   (2) the U.S. Government,

   (3) any governmental instrumentality, or

   (4) EPA;

b. the limitations on a citizen suit are that:

   (1) no suit against a public water supply may be instituted between December 17, 1975 and February 1, 1978;

   (2) no civil action may be commenced until 60 days after the plaintiff has notified EPA, the alleged violator, and the state in which violation occurred;

   (3) no civil action may be commenced if EPA, the Attorney General or the state has commenced action to require compliance; and

   (4) no person may commence a civil action on a variance or exemption, unless he shows that a state has failed to prescribe compliance schedules in a substantial number of cases.

H. Regulations to Protect Ground Water Sources

The Act provides that each state should adopt regulations to prevent pollution of ground water sources by controlling underground injections. Congress did not intend for individual septic tanks to be controlled by these regulations, but it did intend to include those from multiple dwellings and to include industrial and municipal wastewaters that may be injected into the ground. This section of the Act uses the term "underground injection" which means the subsurface emplacement of fluids by well injection. The term "well" may be interpreted broadly and the scope of these regulations will be determined by EPA in its proposed regulations. An underground injection will endanger a drinking water source if the injected fluid increases contaminant levels in water used as a supply source to the extent that water will not comply with the Primary Drinking Water Regulations, or if the water may otherwise adversely affect the health of persons.

1. Regulations for state underground control programs will be developed as follows:

   a. by June 17, 1975, EPA must publish a set of proposed regulations;

   b. EPA must then hold public hearings before a set of revised regulations are published; and

c. by December 17, 1975, EPA must publish revised regulations.

2. For a state underground injection control program to be approved by EPA it must include:

   a. minimum requirements to prevent underground injections that would endanger drinking water supplies;

   b. prohibit injection after December 17, 1978, unless by special permit;

   c. provide for permits for underground injection only when the applicant can prove that injection will not endanger drinking water sources;

   d. provide for inspection, monitoring, record keeping, and reporting to EPA; and

   e. no requirements that interfere with underground injection in oil or gas production or injection for secondary or tertiary oil recovery.

3. A state may provide a temporary permit system when:

   a. EPA authorizes a state to issue temporary permits;

   b. a system of reasonable notice and public hearings on particular injection locations is provided; and

   c. a temporary permit is valid only until December 17, 1979.

4. For temporary permits to be issued a state must show:

   a. that technology to permit safe injection is not available at time of the application;

   b. that injection is less harmful to health than other disposal methods;

   c. that available technology has been used to the fullest extent to reduce volume, toxicity, and potential health hazard of injected fluid;

   d. that the state can not process all applications before December 17, 1978;

   e. that the adverse effect on the environment of temporary permits is of no consequence;

   f. that permits are to be issued only for existing injection systems; and

   g. that adequate safeguards are provided.

5. State responsibility for the enforcement of underground injection regulations will be determined as follows:

   a. by June 17, 1975, EPA must list all states where underground injection control programs are necessary; and

   b. each of these states must apply to EPA for approval of its program

b. (continued)

within 270 days after EPA publishes regulations on underground injection and show that:

(1) the state has given public notice and held hearings;

(2) the state has adopted and will implement a control program; and

(3) the state will keep records and make reports as EPA may require;

c. within 90 days after a state's application, EPA may approve or disapprove the state program in whole or in part;

d. if EPA approved, the state has primary enforcement responsibility, until EPA revokes approval; and

e. if EPA reviews and revokes approval for cause it has 90 days in which to rescind the disapproval or prescribe revised conditions.

6. If EPA modifies its underground injection regulations, a state must submit a notice to EPA within 270 days showing that its control program meets the revised or added requirements.

7. EPA may find that a state has failed to enforce its underground injection control program. The procedure in such a case is the following:

a. if EPA finds that the state program does not measure up to, or if there is a violation of EPA regulations, then EPA will notify the state;

b. if the violation lasts more than 30 days after the notification, EPA must give public notice and request the state to report within 15 days on steps being taken to comply with regulations; and

c. if the failure to comply lasts more than 60 days after notice or if the state's report is not satisfactory, EPA may begin civil action against the persons who are in violation of the regulations.

8. If a state does not have primary enforcement responsibility for the underground injection regulations, EPA may bring civil action against any person thought to be in violation of a regulation. Violators are subject to fines of $5000 per day of violation, or if such violation is willful, the penalty may be $10,000 per day.

I. Guaranteed Loans

The Act makes some funds available for loans to small public systems, but limits the amount of indebtedness for each system to $50,000. The aggregate amount of indebtedness can not exceed $50 million for such

I. (continued)

systems. EPA is authorized to guarantee loans to small public systems in FY 75 and 76 if:

1. improvements are necessary to meet primary drinking water regulations;
2. the system can not obtain financial assistance in any other manner; and
3. the system has limited revenue collecting capacity.

J. Emergency Powers

EPA may take whatever action is necessary when a contaminant is present in, or is likely to enter a public water system such as to pose an imminent and substantial endangerment to public health when the appropriate state and local authorities have not acted. EPA must consult with state and local authorities if practicable.

The author has paraphrased limited sections of a number of EPA text in addition to the Act and the Interior Primary Regulations. Any errors in the author's interpretation of these materials are the responsibility of the author.

THE BURNHAM COAL GASIFICATION COMPLEX

J. P. Musick, Jr.

At the outset, may I express the appreciation of all of us at El Paso for your gracious invitation to share with you some of the details of what we consider to be a most significant and worthwhile project.

As many of you here today are aware, El Paso announced several years ago that it plans to construct the world's first commercial plant for the conversion of coal into a synthetic high BTU gas suitable for pipeline transmission. This announcement stated that the complex would be located in New Mexico near El Paso's existing pipeline system.

On November 15 of 1972 El Paso filed an application with the Federal Power Commission for approval to construct the Burnham Coal Gasification Complex, some 35 miles south of Farmington, New Mexico, on the Navajo Indian Reservation. That application is now under consideration by the FPC.

Today I wish to further explain to you this historic facility, and to discuss its significance to the United States.

J. P. Musick, Jr. is manager of Community Services, Services Department, El Paso Energy Resources Company, El Paso, Texas.

I do not plan today to belabor the very serious energy, and more particularly, natural gas shortage faced by this nation before a group such as this. Someone said recently that if all the energy consumed in making energy studies could be diverted to other uses, there wouldn't be an energy shortage. And indeed it does seem that way.

However, the very sobering facts of the energy shortage have prompted El Paso to investigate other sources of gas supply in recent years, for example: Increased conventional exploration efforts, both foreign and domestic; the development of underground nuclear stimulation technology; a proposal to bring base load supplies of liquified natural gas into the east coast of the U. S. from Algeria; and a feasibility study, now underway, to build a pipeline across the State of Alaska to its southern coast.

In recent years El Paso has acquired substantial reserves of low-sulfur coal in the West. The idea of coal gasification is, of course, not new. El Paso has conducted research in the field since the early 1950's. But only recently has the national energy situation become such that the public interest requires a decision to move forward with building the commercial-sized coal gasification complex you will hear about today.

El Paso purchased in 1968 a 40,286 acre coal lease from the Navajo Indian tribe. The lease is located in San Juan County, New Mexico approximately 35 miles south of the City of Farmington. An extensive evaluation program has been completed. The coal underlying this lease is sub-bituminous and comes from the Fruitland Formation. It is Upper-Cretaceous in age. Four principal coal seams have been ascertained and mapped, ranging in depth from less than 20 feet of overburden to over 200 feet of cover. In addition to the four main seams, numerous other less consistent and thinner seams are present in many areas of the lease. On this lease there are more than 700 million tons of recoverable coal under less than 150 feet of cover. These are all proven reserves. They do not include additional reserves which are inferred but not proven. These coal deposits can be readily surface mined.

The coal is adaptable to gasification processes and can thus be used both to contribute to the Western economy and to aid in solving the nation's environmental problems. Of considerable economic and environmental significance is the fact that there are three existing El Paso Pipelines--two 24-inch and one 34-inch -- situated on or adjacent to the coal lease.

The gasification complex itself is designed to produce 288 million cubic feet per day of 954 Btu per cubic foot gas.

Conventional natural gas now delivered by El Paso is almost wholly methane. The product of the coal gasification complex will also be primarily methane and will be interchangeable with conventional natural gas.

Only one commercially proven high-pressure process exists today of converting coal to synthetic gas. This is a process developed by a West German Firm, Lurgi Mineroeltechik GmbH and referred to as the "Lurgi Process." It has been utilized in some 16 plants around the world and is the process El Paso will use. No such commercial gasification facility exists in the United States today, although several processes are under study. All of these processes under study in this country involve essentially the same chemical principle.

Basic coal gasification involves adding oxygen and steam to coal under conditions of heat and pressure to form a synthesis gas composed of hydrogen, carbon oxides, methane, and various sulfur compounds. The carbon dioxide and sulfur compounds are then removed, leaving a usable gaseous fuel having a low Btu content. This gas is sometimes referred to as "town gas." To this process El Paso will add a further step, methanation, which will increase the heating value of the gas from about 415 Btu to 954 Btu per standard cubic foot. This process will be accomplished by catalytically reacting the carbon monoxide and hydrogen to produce methane and water. The gasification complex will be located on the lease and near El Paso's pipeline system. The main complex area will cover about 960 acres. It will be modern, attractive, and esthetically sound.

The coal mine will be one of the largest in the United States. The Gasification Complex, when fully operational will process over 32,000 tons of coal per day, or about 10 million tons per year. The proposed mining plan is quite similar to that being employed successfully in numerous surface mines throughout the world.

After FPC approval, about 3 years will be needed to construct the complex.

In addition to engineering studies currently underway, extensive environmental investigations are in progress. Substantial amounts of water will be necessary in order to gasify the presently proven, recoverable coal reserves on this lease. The acquisition of dependable, long-range supplies of water is vital to such a project. The energy output of the proposed complex is large - equivalent to that of a 3,300 megawatt electric generating plant, but requiring less than 1/4 of the water required by such a plant. As stated before, the lease contains conservatively, some 700 million tons of recoverable coal. To gasify this much coal will require 28,250 acre-feet per year. Negotiations are currently underway with the Bureau of Reclamation to purchase water from the Navajo Reservoir, at a diversion point downstream of the reservoir in the San Juan River North of the complex site. For this first gasification complex, producing 288 million CFPD of pipeline quality gas, approximately 10,000 acre-feet of water per year will be required.

We are well aware that a project of this magnitude and duration will have an impact on the environment. This has been carefully considered from the beginning of our planning, and it will continue to receive foremost consideration in the construction and operation of both the gasification complex and mine.

Our investigations indicate that the project will have minimal adverse effect on the environment.

Air and water pollution are not expected to be problem.

Both the plan for mining the coal and the plan for restoration of the mined area are subject to approval by the Navajo Tribe, the Department of the

Interior and the Bureau of Indian Affairs. The project must also comply with applicable laws of the State of New Mexico, as well as Federal regulations resulting from the National Environmental Policy Act, to assure that all operations are in the public interest. In addition, at least three federal governmental agencies will review the project plans. These agencies include the Federal Power Commission, the Department of the Interior, and the Department of Transportation.

The mined area will be reclaimed as a part of the mining operation. The planned reclamation activities include burial of the ash generated by the Gasification Complex, grading of overburden, reseeding of graded areas and controlled utilization of the reclaimed and revegetated areas until seeded vegetative cover is established. The mined land will be returned to productive use, in consultation with the Navajo Tribe, Federal, State and Private agencies. Where soil conditions and topography will permit, surface runoff water will be directed into constructed lakes and stock-watering ponds for use by resident ranchers and sheep grazers.

We plan to take every reasonable step to guarantee that no part of the project will adversely affect the environment. In this matter, may I add one personal note:

For some 25 years El Paso has carried on its business in the Four Corners Area. The Company has the reputation of being a good citizen, good neighbor, and a good housekeeper in all its operations. We intend to continue these practices.

The project will provide benefits of major significance, not only to the Navajo Tribe, to the State of New Mexico, and to the adjoining area, but to the entire country.

(1) The project will supply substantial amounts of much-needed energy in the form of a fuel which when burned produces virtually no pollution. This new technology could have far-reaching effects on the energy shortage of the country, perhaps far beyond the imagination of most of us here today.

(2) The economic and social impact on the State of New Mexico, the Navajo Tribe and this general area will be immediate, substantial and will make a continuing contribution to the business, and more important, the well-being of many of the people who live and work there.

The Construction Phase of the complex will require up to 3,500 employees for a period of 3 years, with a peak annual payroll of $70 million.

The Operational Phase of the completed gasification complex and coal mine will provide approximately 1,234 new jobs, with an annual payroll estimated to be $16 million. In addition to these employees, the complex will supply indirect support of 1,850 service jobs in the area. New people will be absorbed into the existing communities in the area, although many employees will live nearby on the Reservation. It is El Paso's intent to train and employ a maximum number of personnel from the Navajo Tribe.

In addition to such employment, the Tribe should realize annual royalty and rental payments in excess of $5 million annually.

Taxes payable to Federal, State, and local entities will amount to an estimated $20 million annually.

Of equal importance - perhaps greater importance - are the social, educational, and cultural benefits which can be provided for many citizens of this area and their families. It is impossible to place a value on such things, and yet, in the final analysis, they are perhaps the most valuable of all.

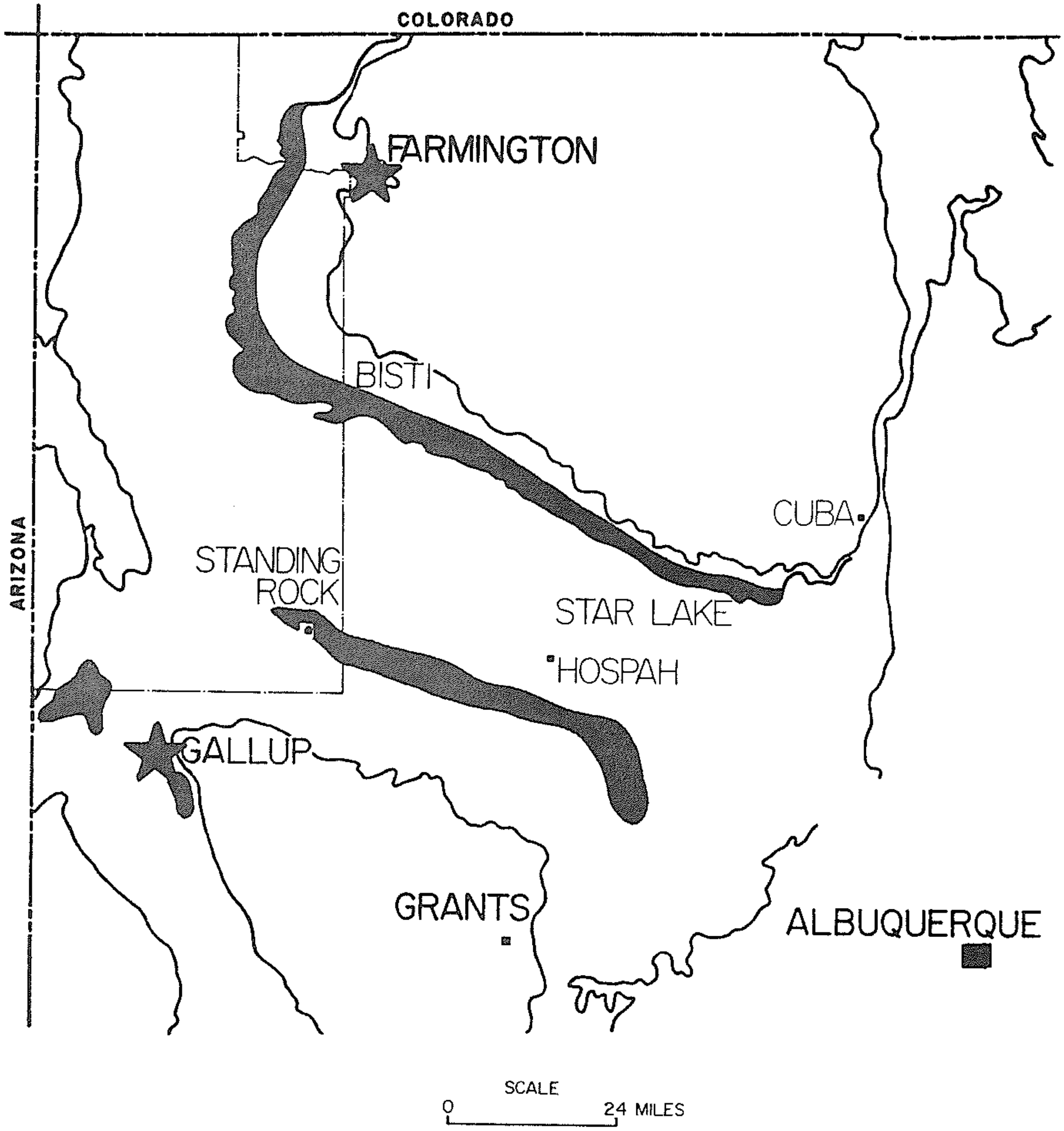

FIGURE 4. AREA OF SURFACE-MINABLE COAL, NORTHWESTERN NEW MEXICO

The Menefee has not been extensively explored, but it is known to contain several large areas of thick coal at depth, and some extensive barren areas. Some of the strippable areas are of economic size.

The principal undeveloped area lies north of Grants, and is owned in large part by a subsidiary of Santa Fe Industires. The area has been explored in detail. A reserve estimate made by the State Bureau of Mines in 1971 of 60 to 75 million tones is certainly far too low. West of it, near Standing Rock on the Navajo Reservation, drill holes have revealed more strippable coal. This area was estimated to contain at least 64 million tons, and probably contains far more. It is currently being examined again, relying on surface mapping only. The coal in these areas is mostly of high-volatile bituminous C rank and contains 0.5 to 1.1 percent sulfur.

Small strippable reserves have also been found just south of Cuba, near Lake Valley south of Bisti Trading Post, and near Newcomb, north of Gallup. None of these appear to be economic at present; only the last-mentioned appears to contain more than 75 million tons.

The only important production now from the Menefee (and the related Crevasse Canyon Formation) is from two strippable areas near Gallup. Northwest of Gallup, partly on the Navajo Reservation is a block estimated to contain 358 million tons or more of strippable coal. A much smaller reserve is being worked just southeast of Gallup. The coals of these areas are also of high-volatile C bituminous rank, with sulfur content around 0.5 percent.

The Menefee has also been estimated to contain on the order of 34.3 thousand million tons of deep coal; current work being done by the State Bureau of Mines indicates that this figure may be low.

One body of Menefee coal which has recently been described alone contains on the order of 22 thousand million tons. It is a zome composed of many individual beds. The trend is 92 miles long and up to 12 miles wide, running from Torreon School on the southeast to Hogback Mountain on the northwest. Virtually all of the coal is well beyond stripping depth, but is appears to be well suited to more futuristic extractive processes such as in-place gasification or solvent mining.

The State Bureau of Mines is beginning a small drilling program to verify the presence of this body of coal, which so far has been described only from the logs of oil and gas tests.

One point worth mentioning is that the coals of our region were laid down in a succession of grand advances and retreats of the ancient sea, themselves made up of countless small ins and outs; the coal is thus disposed in rather small irregular lenses. This habit of southwestern Cretaceous coals of occurring in overlapping lenses of irregular size, shape, and thickness is in profound contrast with the extensive, uniform seams of the eastern United States. In the San Juan Basin it is often difficult to correlate coal beds in drill holes a quarter of a mile apart, while back east the Pittsburgh and Kittanning seams can be traced over thousands of square miles.

It is the Fruitland Formation that contains the San Juan Basin's really major coal reserves. Figure 4, the upper solid dark-shaded band represents the Fruitland Formation strippable areas. Within the band, the entire area is underlain by both deep Fruitland and deep Menefee coal. On the Navajo Reservation, (west of the dashed line) and to the north of the San Juan River, strippable reserves have been well-explored, and are under lease and committed to various development plans. I'll discuss these further on.

From the Colorado line southward to Bisti (almost on the eastern boundary of the Reservation), there is a total of some 1.1 thousand million tons beneath less than 150 feet of over-burden, and another 1.4 thousand million tons from 150 feet down to 250. Most of this is on the Navajo Reservation.

From the Navajo Reservation eastward, there is another 1.3 thousand million or more tons above 150 feet and 1.2 thousand million more between 150 and 250. Much of this is under lands belonging to the Federal Government, and has been fairly extensively explored. I'll describe some plans for some of this coal a little further on too.

Beyond a depth of 250 feet, the Fruitland contains a staggering amount of coal. An estimate by Fassett and Hinds of the U.S. Geological Survey indicates a total of some 154.2 thousand million tons.

A word about the land situation in the basin might be of interest; aside from the Navajo Tribe, most of whose coal is committed, most of the mineral ownership is either state, federal, or Santa Fe Pacific Railroad Co., a subsidiary of Santa Fe Industries and sister of AT&SF Railway. The Santa Fe is finishing exploration of its coal lands, has published a reserve figure of 370 million tons, and is working toward development.

The State of New Mexico has eagerly leased its scattered tracts, which rarely amount to more than four isolated sections per township.

The United States Goverment's Bureau of Land Management, the big coal owner, however, has put a virtual moratorium on coal development. Prospecting permits which allowed a qualified operator to spend his own money exploring federal lands and then lease them on the Government's terms if he liked the looks of the coal, have not been issued since January 1, 1971; permit applications made since then were summarily rejected, and no more can be filed. Officially, the BLM is willing to lease coal to qualified operators but in fact it will not do so. Several large tracts have been explored thoroughly and are ready to mine; markets are lined up for the coal. These tracts were explored under prospecting permits which guaranteed the right to a lease, but the permits are now expired and the BLM has not acted to issue leases. The operators are qualified--one is Peabody Coal, the largest in the country.

The last federal prospecting permit was issued in January of 1971, and the very last lease in New Mexico was issued in January of 1970--well over 5 years ago. What says there is an energy shortage?

In the San Juan Basin alone, there were permit applications totalling over 270,000 acres when all the applications were rejected. There are three thoughts on this mess that you might consider:

1. There is a very prevalent attitude among us these days that big coal companies already control vast acreages of federal coal lands that they have little investment in and no immediate market for. As far as New Mexico is concerned, this is utterly erroneous; there isn't any federal coal acreage claimed by private interests from which the economically minable coal wouldn't be sold tomorrow, and there's no shortage of utilities that desperately need it to fulfill long-term commitments.

2. Some say that coal can't possibly meet our rapidly increasing short-term needs. That is a true statement, but only because the Government has systematically stymied coal development, and because the Government's non-policy has made it impossible for equipment suppliers and mining and engineering schools to prepare to provide the machinery and trained people that rapid coal development will need. The manufacture of equipment and training of personnel take a long lead time, and suppliers and schools need to be confident of long-term policy before committing themselves.

3. Before very long, it is going to be popular to say "private enterprise has failed to provide the energy we need", so we will see lots of crash programs in which the Government will attempt to develop coal. Those who so far have succeeded in keeping coal development in abeyance because of fear of "rip-offs" by large corporations, and of damage to the environment, are in for a damned rude shock when they see the BLM, the USGS, the EPA, the USBM, the MESA, and who knows what other agencies stumbling over each other trying to produce coal and regulate each other at the same time.

From inside the industry it seems obvious that we Americans are afraid of each other; only the Government is considered trustworthy enough to develop our coal resources, and I expect we will soon see an American counterpart of Britain's National Coal Board. I don't know your feelings on that kind of thing, but I'm apprehensive about it.

I would like now to turn to the position of New Mexico coal in the nation-wide market picture, or in simple words, to answer the question "why us?" Figure 5 shows the general distribution of coal resources, both strippable and deep, in light shading, and the country's major population centers as dark circles proportioned to population. At first glance several things seem obvious: (1) the heavily-populated east has plenty of coal of its own, (2) the population centers of the west have coal resources closer than ours to draw upon, and (3) the vast resources of Wyoming, Montana, and North Dakota seem well situated to fill demands from the north-central and northeastern parts of the country.

There are several complications, however. Eastern coals are at a great disadvantage in the market because they include a large amount of deep coal and have, in general, high sulfur contents. Surface mining is effectively banned in several states. Arizona and Utah appear to be geographically well-situated to supply the southern California market, but the Utah coals are almost entirely deep and the only major reserve in Arizona--Black Mesa--is already committed. Northern Arizona and southern Utah are not served by rail transportation either. Montana and Wyoming coals are flowing into distant markets; for example, San Antonio, Texas is now converting to Wyoming coal for electricity generation.

FIGURE 5. COAL AREAS AND POPULATION CENTERS IN UNITED STATES

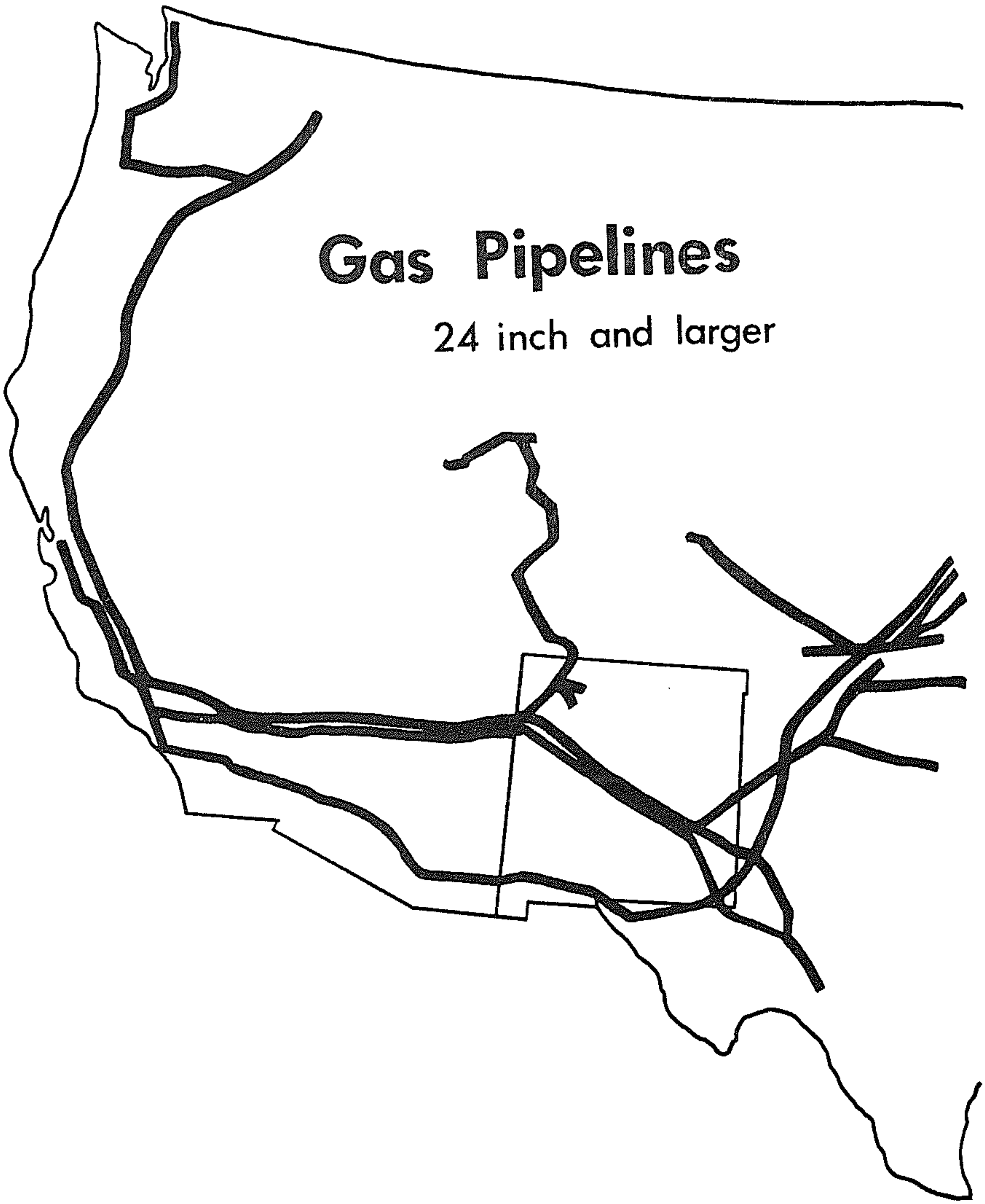

FIGURE 6. GAS PIPELINES IN WESTERN UNITED STATES

Another important factor is illustrated here on Figure 6. New Mexico is a major gas producing state and is on the trans-continental pipeline routes, so we are very well placed to supply synthetic gas made from coal into the gas distribution network. The San Juan Basin, which as I have pointed out contains almost 6 thousand million tons of strippable coal, also is the home of the country's second largest gas field. Gas production has peaked and synthetic gas could pick up the load and carry on very smoothly.

The map of the San Juan Basin and surrounding areas (Figure 7) shows existing and planned coal developments. Triangles are strip mines, boxes are power plants with associated strip mines, and circles represent gasification plants with associated mines.

The two squares just west of Farmington are the Four Corners power plant south of the river and the San Juan generating station north of the river. The Four Corners plant is owned by a consortium including Arizona Public Service Co., Southern California Edison Co., El Paso Electric Co., Tucson Gas and Electric, the Salt River Project, and New Mexico Public Service Co.

This plant is rated at 2,085 megawatts, and is now using between six and seven million tons of coal per year. Coal is supplied by the Navajo Mine of Utah International. This has been the largest coal mine in the United States since 1971. The combined payroll of mine and power plant is about 4.5 million dollars, much of it to members of the Navajo Tribe.

The San Juan Generating Station, north of the river, which belongs to Public Service Company of New Mexico and Tucson Gas and Electric, will have an ultimate capacity of 1,660 megawatts. Coal will be furnished from a mine at the plant owned by Western Coal Co. and operated by Utah International.

The McKinley mine, of Pittsburg and Midway Coal Mining Co. is located northwest of Gallup. It is partly on the Navajo Reservation and partly off. Its production--463,000 tons in 1973--is shipped by rail to the Arizona Public Service Co. Cholla Plant at Joseph City. The McKinley is planning a roughly ten-fold expansion by the early 1980's.

The two gasification complexes in the planning stages are close together on the Navajo Reservation. One is being planned by El Paso Natural Gas Co. near Bisti; it would ultimately consist of two units, together producing 785 million cubic feet of pipeline--quality gas per day from some 73,000 tons of coal. The coal would be mined at the site. It is estimated that the complex will eventually employ 2,800 people with a combined payroll of over 35 million dollars per year. In addition, well over 5 million dollars would go to the Navajo Tribe in the form of royalties would be over six million dollars yearly.

In the next decade coal production on the Reservation alone could reach over 70 million tons per year, a gross value of perhaps 300 million dollars; this would represent several thousand good jobs, and some 18 million dollars in royalty payments.

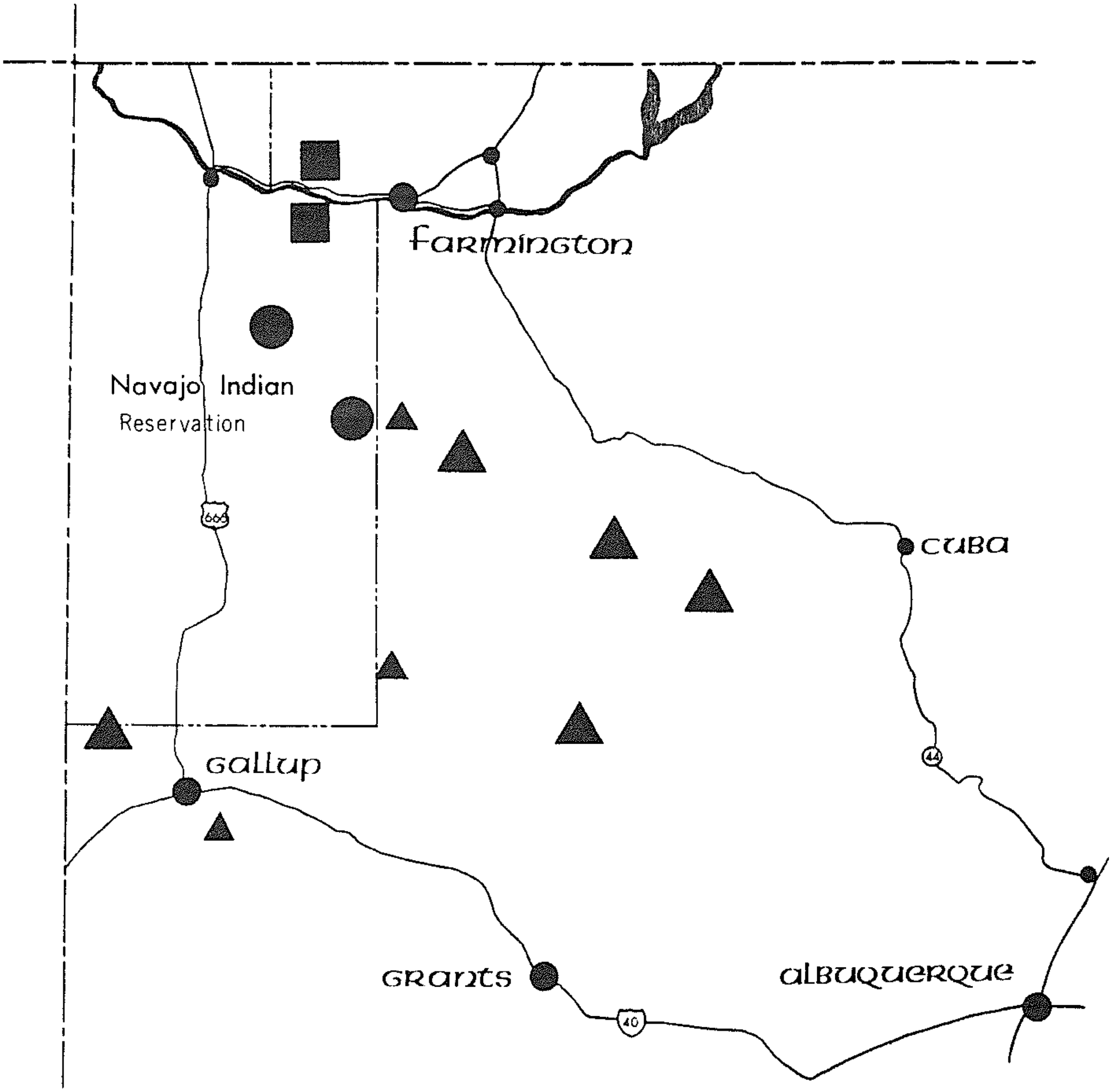

FIGURE 7. EXISTING AND PLANNED COAL DEVELOPMENTS, NORTHWESTERN NEW MEXICO

The triangles east of the Reservation some on federal acreage and some off, represent my guesses as to where new strip mines would be located. Coal from these mines would probably be shipped out of the basin by rail, or perhaps be utilized in air-cooled electrical generating plants. There is no foreseeable source of water on a scale suitable for conventional gasification or water--cooled electricity generation. Rail connection to the eastern part of the basin (where the triangles are) has been a subject of speculation for some years.

AN OVERVIEW OF NEW MEXICO'S COAL INDUSTRY

John W. Shomaker

My principal intent in preparing this paper is to give a general feeling for the coal business in New Mexico, what it is now, where it is taking place, and what its future may be.

Figure 1 is intended only to make the point that within the limits imposed by today's commercial technology and today's market economics, coal is the largest source of accessible energy. In this connection, I am thinking of coal as a stop-gap energy source to buy some time. We need that time for orderly development of obviously better sources of energy and I leave to you the decision as to the ideal energy source. The transition back and forth among fossil fuels is relatively easy, so we can rely more and more upon coal for the near term, while we make the much more fundamental shift to more suitable energy sources for the long term.

I would like to see us eventually turn to coal for petro-chemical feedstock only, and build a New Mexico coal industry based on underground mining or in-place extraction. We would ship a far more valuable product, and benefit from the returns on the additional capital, in the forms of both money and labor, invested in it. But enough of philosophy.

John W. Shomaker is a consulting geologist, Albuquerque, New Mexico.

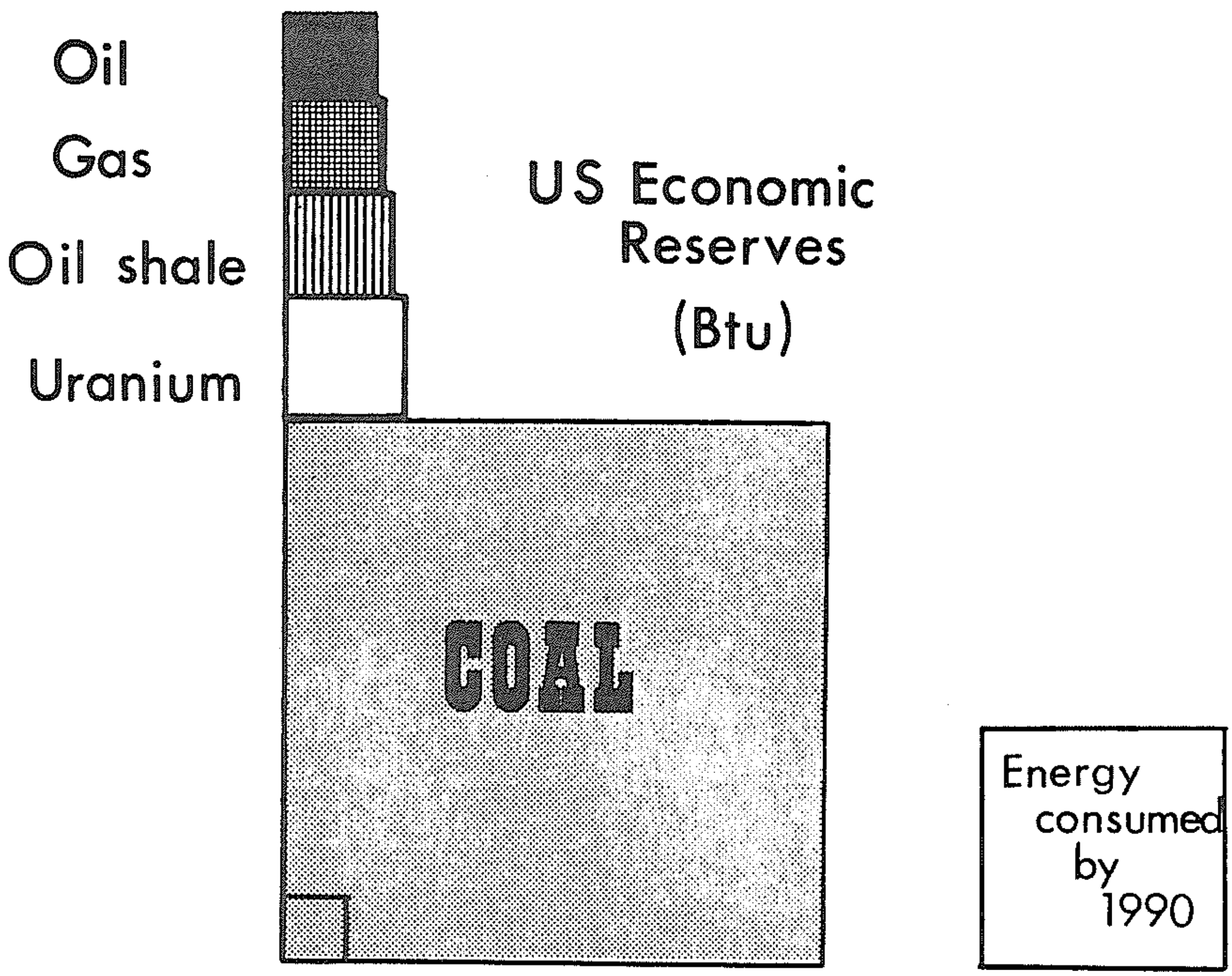

FIGURE 1. COMPARISON OF UNITED STATES ECONOMIC ENERGY RESERVES

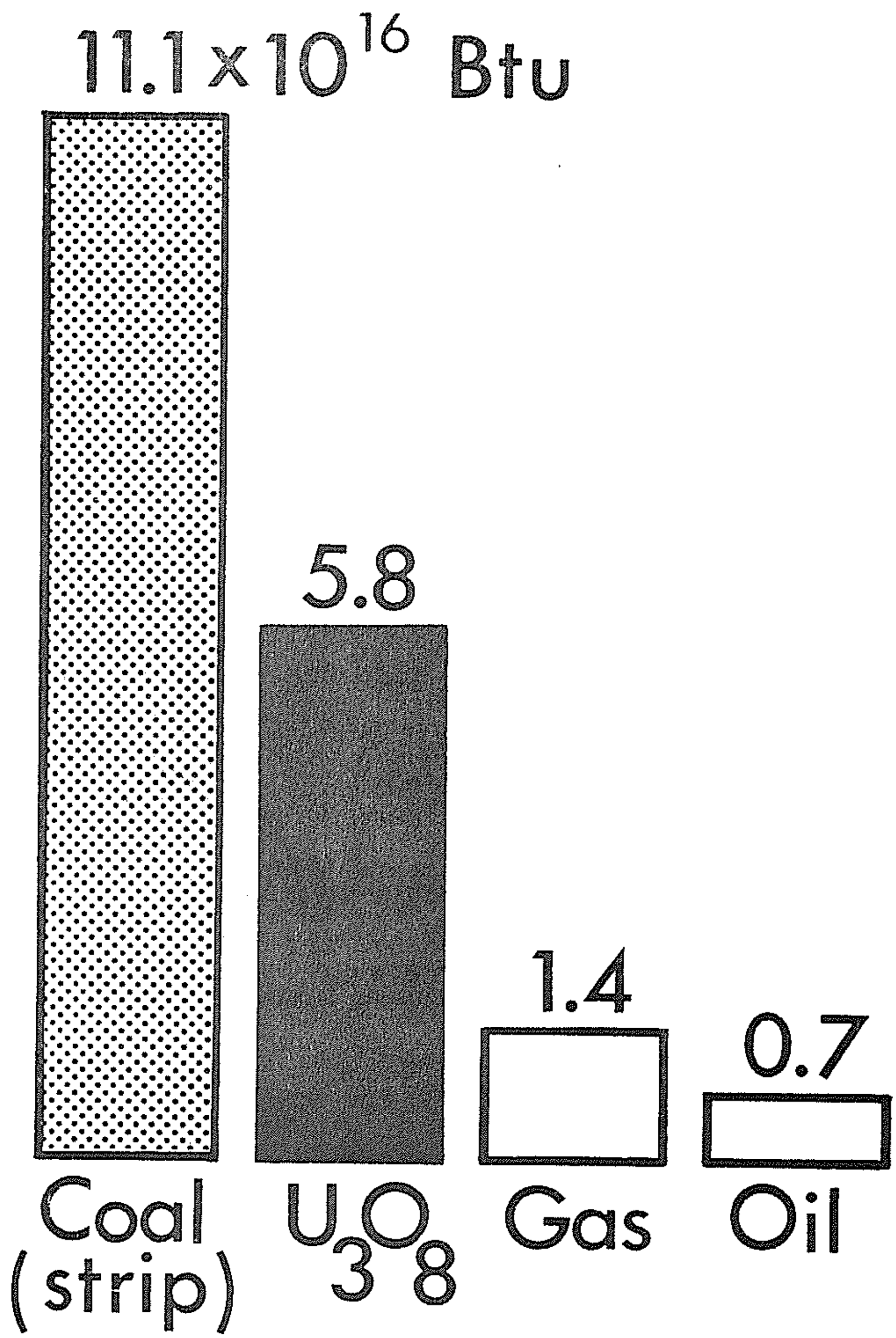

FIGURE 2. COMPARISON OF NEW MEXICO'S ECONOMIC ENERGY RESERVES

New Mexico has quite a bit of coal, on the order of 280,000 million tons. That figure is of course only an educated guess, since only a tiny fraction of the resource is explored in any more than reconnaissance detail. It is also important to note early in the game that only about 6,600 million tons-- about 2.4 percent of the total--is minable by today's economic standards. Figure 2 then represents our energy resources in perspective, including only presently-minable coal, projected oil and gas reserves, and uranium reserves assuming current mining costs and methods of utilization.

Figure 3 shows in a very general way the distribution of coal within the state. Dark shading indicates areas with potential for surface-minable coal; these areas are greatly exaggerated, of course, so they can be seen. The total acreage of strippable coal land is estimated at between 300,000 and 400,000 acres, between 0.4 and 0.5 percent of the state's area. This estimate is based on a very conservation estimate of 10 feet for the average thickness of coal. Light shading indicates those areas which are underlain by coal-bearing rocks, regardless of depth.

The map can be broken down into three general groupings of coal areas; the first and most important is the San Juan Basin, marked J. The second is the Raton Basin, marked I; and the third is everything else. It may be that major reserves will be discovered in the Datil Mountain area (H) and in the Sierra Blanca area (D) so we shouldn't write them off too hastily. A major reserve would be no less than 75 million tons, enough to justify a mine-mouth power plant. Smaller reserves, down to only a few million tons, support profitable operations on a spot-market sales basis, and reserves on this order are possible in each of the areas.

The coals of the San Juan Basin are virtually all rather high ash, low sulfur coals, of sub-bituminous A or high-volatile bituminous C rank. They are non-agglomerating, non-coking and so are useless for metallurgical purposes, but are good steam and gasification coals.

The Raton Basin coals are of similar or somewhat better quality, but in contrast are good coking coals. This fact is important in discussion of market position.

The New Mexico part of the Raton Basin is thought to contain, about 715 million tons of currently minable coal, or about 11 percent of the state's total. It is also estimated that on the order of 4 thousand million tons lie beyond current reach. The coal is good metallurgical fuel, and is almost all privately held. Kaiser Steel Corp. controls most of it, and is the only active operator.

The San Juan Basin is in the northwest quarter of New Mexico. Gallup and Farmington are the two black stars on Figure 4. The geologic formations that comprise the basin may be thought of as a stack of shallow, very irregular bowls whose rims are turned up sharply in some areas, but slope only very gently in others. The northern part of the basin is across the line in Colorado, not shown on the map. Two of the bowls are coal-bearing formations: the lower bowl, represented by the southerly band, is the strippable portion of the Menefee Formation, and the upper, represented by the other band is the strippable part of the Fruitland Formation.

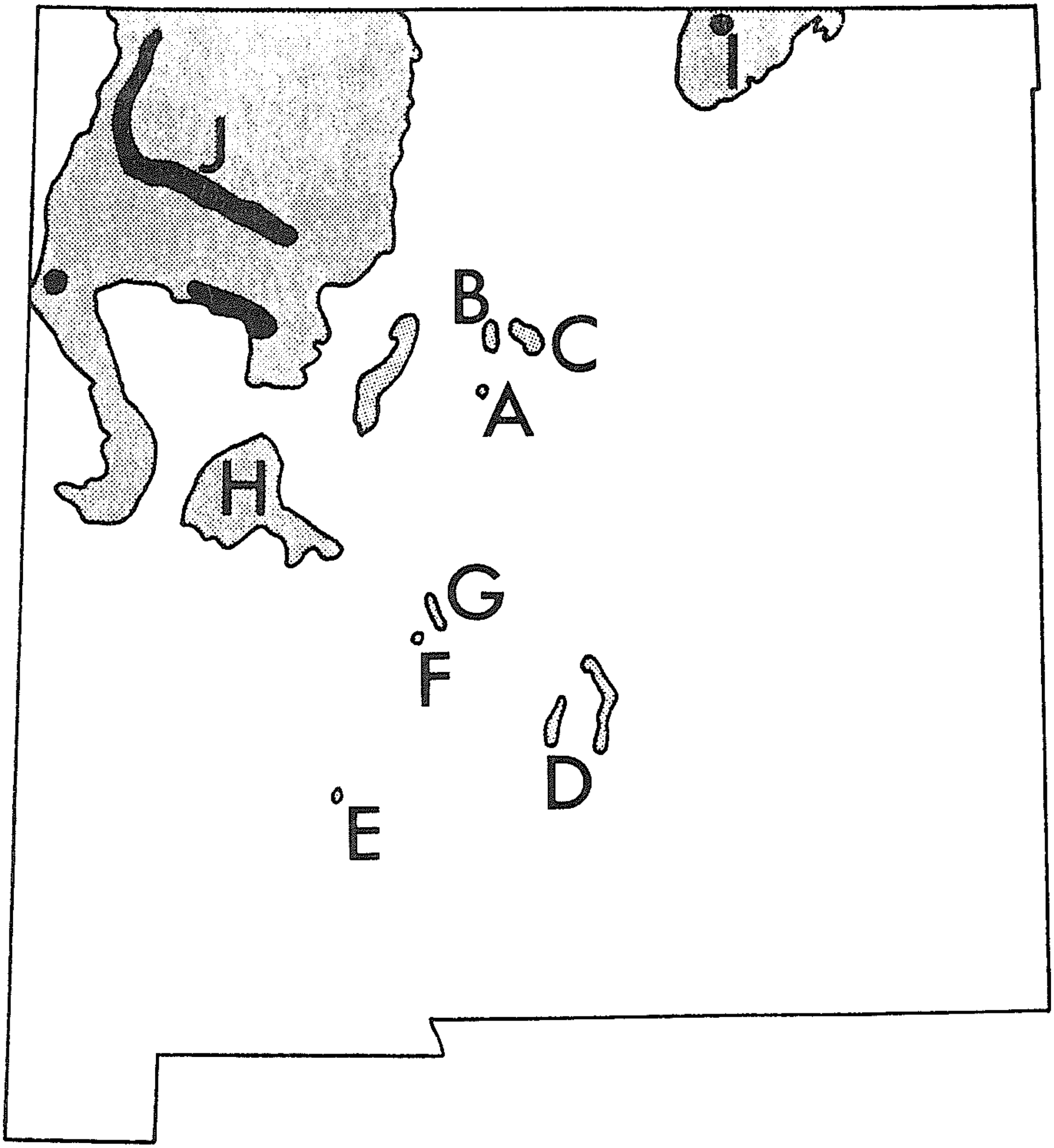

FIGURE 3. NEW MEXICO'S COAL AREAS

GROUND WATER FOR ENERGY DEVELOPMENT, NORTHWESTERN NEW MEXICO

W. J. Stone
and
Tim Kelly

General Statement

Northwestern New Mexico holds a large share of three natural resources used in energy production: petroleum, coal, and uranium. Their development requires water. Virtually all of the surface water in northwestern New Mexico has been appropriated, the largest single claimant being the Navajo Tribe. Thus, water for future industrial or municipal use must either be negotiated surface water or ground water.

Surface water supplies and demands were a central issue at recent environmental-impact hearings in Window Rock and Farmington for the proposed coal-gasification plants in western San Juan county. In addition to the proposed gasification plants, surface water will also be utilized in the Navajo Indian Irrigation Project in northeastern San Juan County. With these heavy demands on the surface water sources--and some have even said there will not be enough for both projects -- the availability of ground water becomes very important.

William J. Stone is a hydrologist with the New Mexico Bureau of Mines and Mineral Resources, Socorro, New Mexico and Tim Kelly is a member of the United States Geological Survey, Water Resources Division, Albuquerque, New Mexico.

Stratigraphic nomenclature used herein is not necessarily that of the U.S. Geological Survey.

According to average annual water uses in the San Juan River Basin, published in 1967, ground water accounts for only 45/100ths of 1% of all water uses! Ground water has been previously ignored for several reasons: surface water is readily available, ground water is often deep and saline, and little is known of the occurrence and availability of suitable supplies.

In an effort to solve this problem, the New Mexico Bureau of Mines and Mineral Resources and the U.S. Geological Survey Water Resources Division, are presently engaged in a cooperative study of the hydrogeology and ground water resources of northwestern New Mexico.

Purpose of Paper

The purpose of our paper today is three-fold:

a) to describe our project,

b) to summarize the regional setting of the study area and

c) to present our preliminary findings.

Location

The study area is located in the northwestern most corner of the state and includes all of San Juan County, northern McKinley County and the western parts of Rio Arriba and Sandoval Counties (Figure 1). The western part of the study area includes the New Mexico portion of the Navajo Nation.

Objectives/Approach

The objectives of our project are to collect and interpret basic hydrogeologic and ground water resource data.

Our approach includes both field and laboratory study. In the field, geologic information is being mapped and water wells are being inventoried. In the lab, rock and water samples are being analyzed and subsurface geologic data from the numberous oil and gas wells in the study area are being compiled in the form of geologic cross-sections.

Agencies Involved/Responsibilities

The principal agencies involved are the New Mexico Bureau of Mines and Mineral Resources and the U.S. Geological Survey. The Bureau is responsible for working out the hydrogeologic setting and the Survey is responsible for collecting and analyzing the basic ground water data. We have, however, tried to contact all other local, state, federal and tribal agencies that may have input or that may ultimately benefit from such a study in order to explain our program, promote cooperation, and gain other perspectives on the problem.

Time Frame/Schedule

The project will take a total of about 5 years and has been divided into 3 parts or phases by area:

1st phase - San Juan County - duration 2 yrs.
2nd phase - Northern McKinley County - duration 1 1/2 yrs.
3rd phase - Wester Rio Arriba, Sandoval Counties - duration 1 yr.

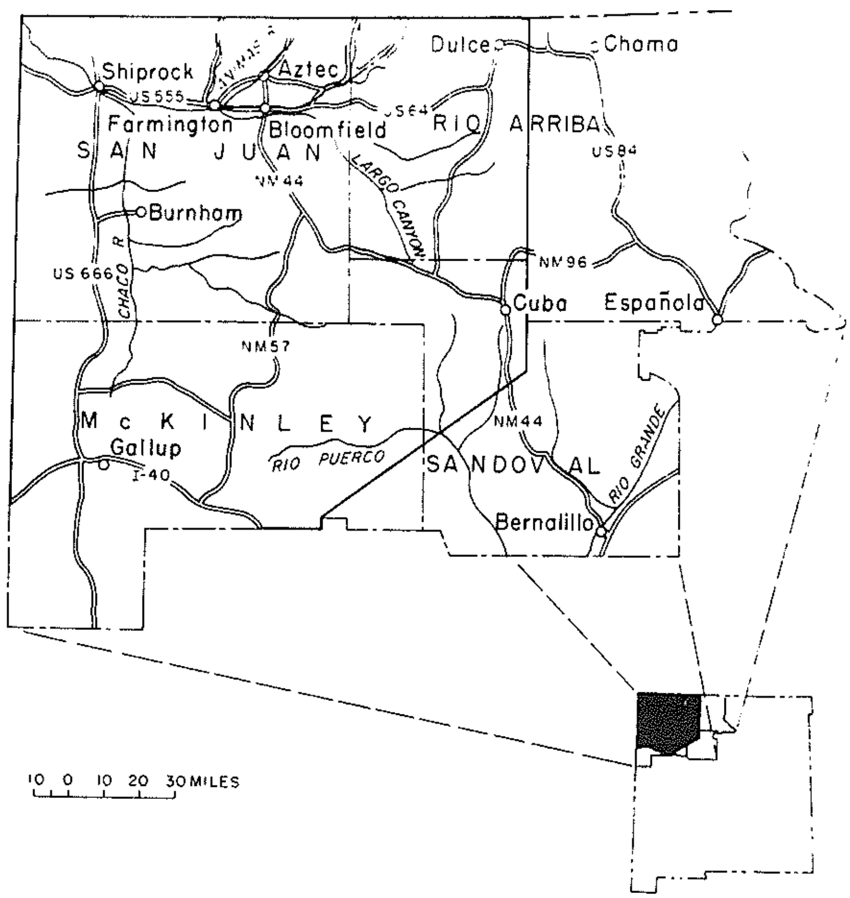

Figure 1. Location of study area.

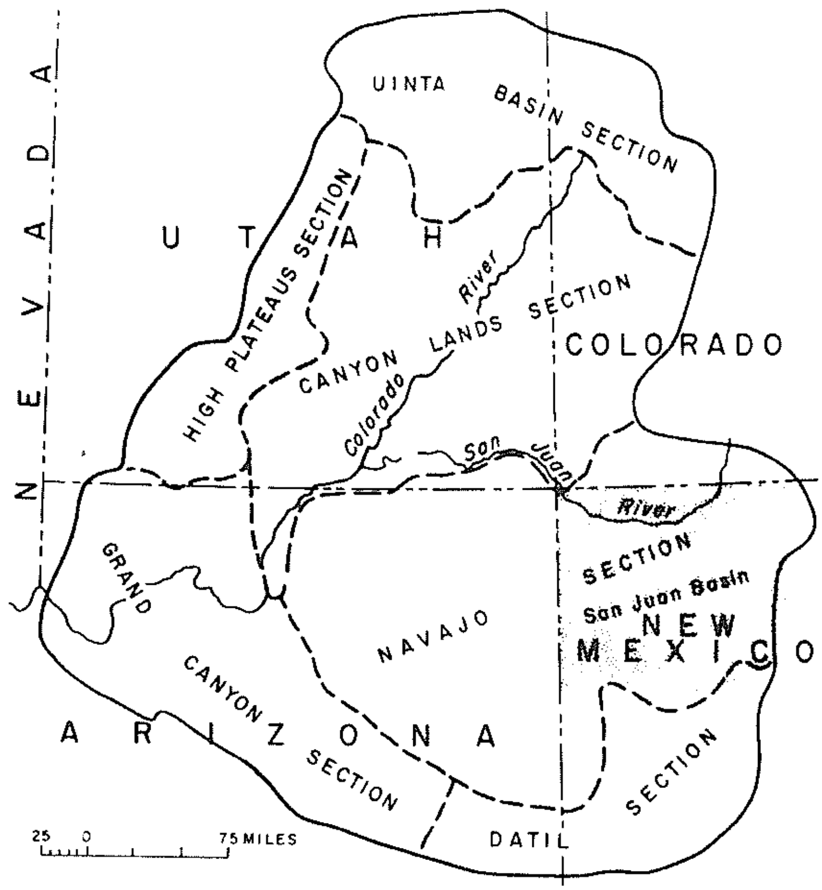

Figure 2. Physiography (Thornbury, 1965).

A separate report will be prepared for each of these 3 areas. We are now involved with Phase I - San Juan County. This area is being done first because of the urgent need for ground water data there in view of the anticipated energy development and growth.

The Study Area

Physiography/Climate

The study area is situated in the Navajo Section of the Colorado Plateau physiographic province, as seen in Figure 2. It has a semi-arid climate with an average annual precipitation of 8 - 10 inches and a pan evaporation rate of 67 inches (based on records for the period 1948 - 1962). The average January temperature is 28°F and the average July temperature is 73°F.

The physiography of the study area is characterized by broad open valleys, mesas, buttes, and hogbacks. Topographic relief is generally low away from the major valleys and canyons. Native vegetation is sparse and shrubby as seen in this slide.

The study area is drained by the San Juan River, which, as shown in Figure 3, is a part of the Colorado River system. The San Juan River is also the only permanent stream in the Navajo Section.

Major tributaries of the San Juan River include the Animas, Chaco, and La Plata Rivers. Examples of average annual discharge of the San Juan River system are shown in Figure 4. Between its inflow point, in Rio Arriba County, and its outflow point, in San Juan County, the San Juan River drops some 1800 ft. in elevation.

Structural Geology

The study area largely coincides with the geologic structure known as the San Juan Basin, which comprises about half of the Navajo Section of the Colorado Plateau. Kelley (1951) recognized several separate structural elements within the basin as shown in Figure 5. Monoclines are the most distinctive type of structure in the Colorado Plateau and several excellent examples occur in the San Juan Basin. This structural depression mainly occupies northwestern New Mexico but also extends into southern Colorado as well. It covers an area of about 10,000 sq. mi. and has about 6000 ft. of structural relief. The deepest well drilled in the Basin is near Gobernador, in northwestern Rio Arriba County, where 14,423 ft. of sedimentary rocks were penetrated without reaching basement.

Surface Geology

The geologic map of the study area (Figure 6) shows a typical basin, that is, distinct curving bands of outcrop with younger rocks in the center and older rocks around the outside. (Notice the stratigraphic succession of rock units in the legend for future reference.) The most prominent

Figure 3. Colorado River Basin (study area stippled).

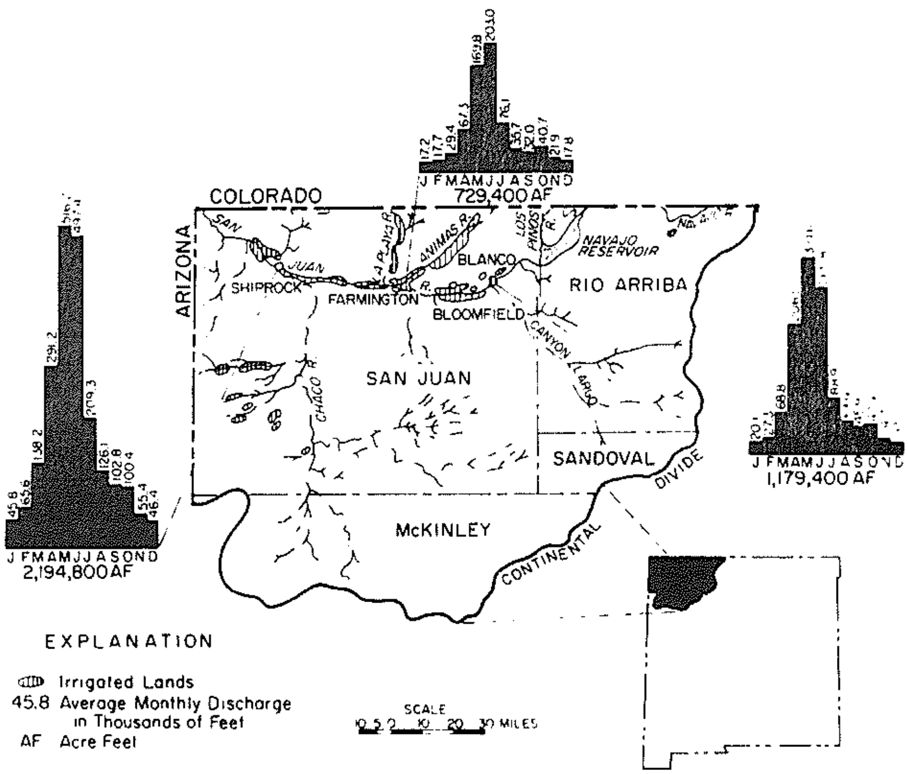

Figure 4. San Juan River Basin (Cooper and Trauger, 1967).

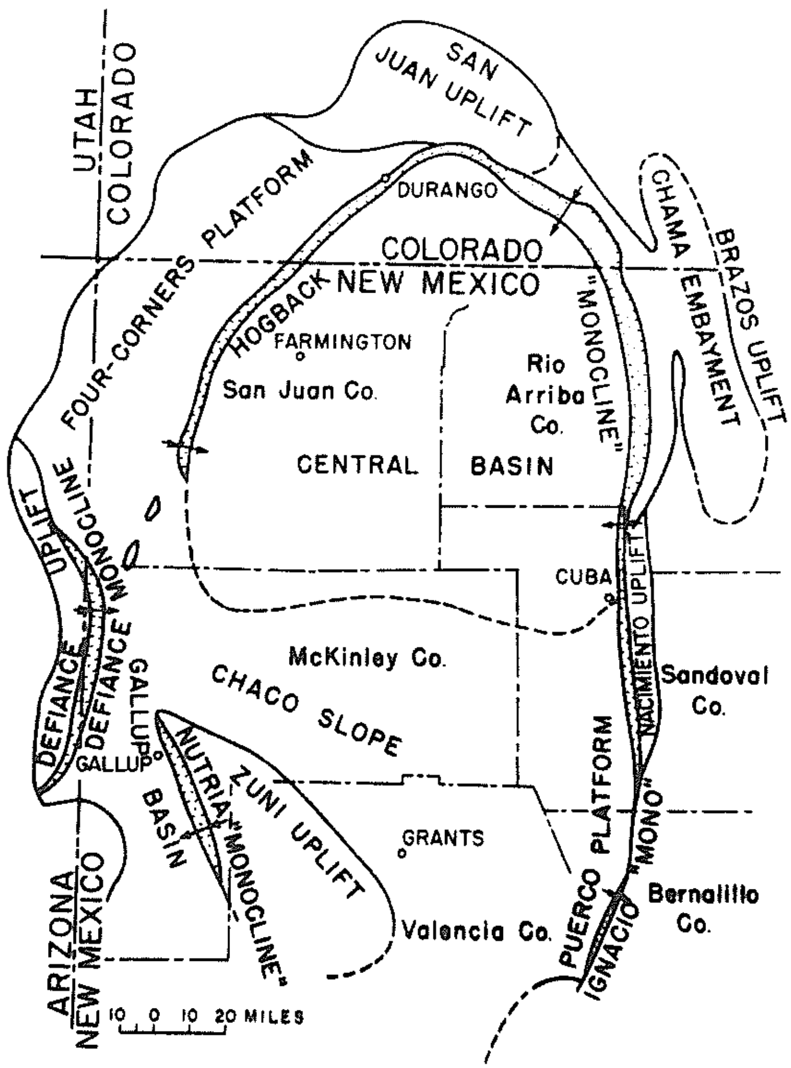

Figure 5. Structural geology (Kelley, 1951).

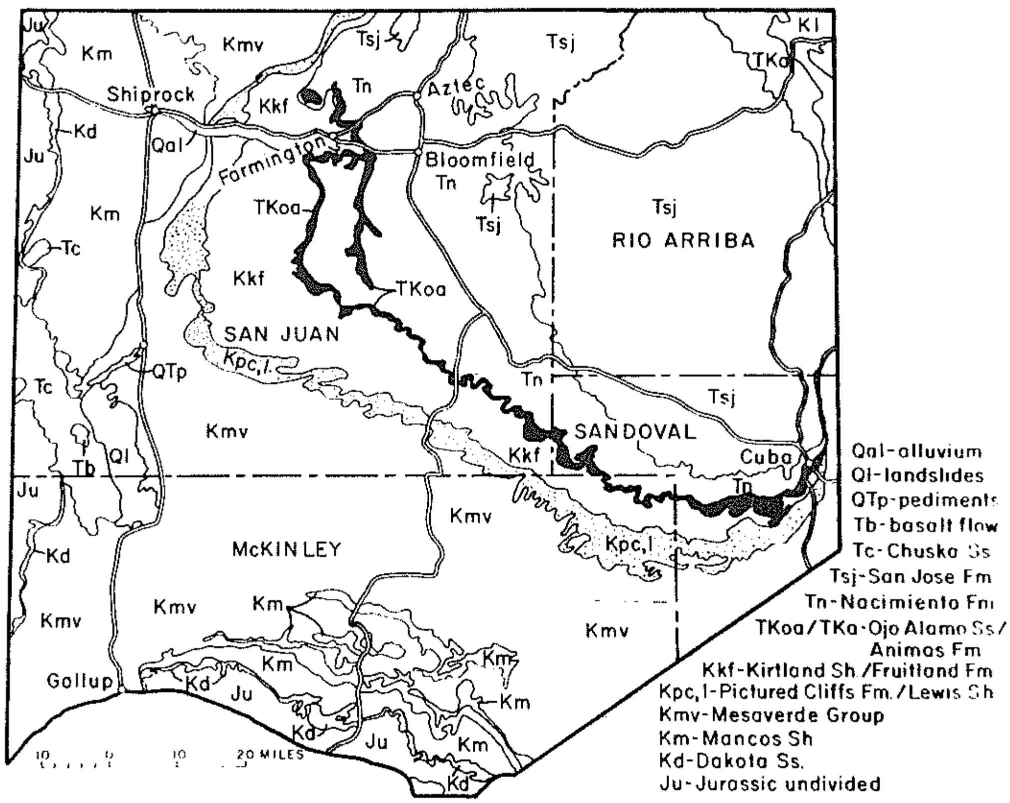

Figure 6. Surface geology (Dane and Bachman, 1965).

outcrops are those associated with the Cretaceous strata which cover much of the area as a broad band lying between the Jurassic and Tertiary aged strata. The North-South trending Hogback Mountain, along the west edge of the study area, consists of Cretaceous rocks dipping steeply eastward. The Ojo Alamo Fm., in part Cretaceous and in part Tertiary crops out in a distinct band as seen in this slide. Rocks of Tertiary age cover the large central portion of the basin. Quaternary deposits occur in stream valleys, along mountain fronts, and atop all other rock units throughout the Basin.

Subsurface Geology

In this study, only Jurassic and younger strata will be considered because older rocks are usually too deep to be economically feasible. The Jurassic rocks record nonmarine or continental deposition extending northward from and adjacent to highlands in the southern part of the region.

The Cretaceous strata represent deposition in and at the margins of the last great sea to invade the continent. In Cretaceous time (about 100 million years ago) the North American continent was divided by a seaway extending from the Arctic Ocean to the Gulf of Mexico. As this Cretaceous Sea lapped on and off the land, a unique rock record of alternating coastal plain carbonaceous shales and coals, shoreline sandstones, and off shore shales was produced (Figure 7).

Where present, continental Tertiary and Quaternary deposits overlie all of the other strata of the Basin and are nearly flat lying. The fact that the Basin is asymmetrical with its deepest part somewhat east of apparent center and has steeper dips on the east than on the west is clearly shown in a cross-section (Figure 8).

Preliminary Results

General Statement

The results are largely restricted to the area of Phase I of our project, San Juan County, and are based on our preliminary compilation of date. In compiling this date, 4 maps were prepared showing the following:

a) the location of outcrops of the aquifers (except in the case of the alluvium which is very widespread),

b) the location of wells penetrating the aquifers, and

c) the direction of deterioration of ground water quality for the wells involved.

In this mapping, the aquifers were grouped more or less geologically -- that is on the basis of age -- but the main consideration was clarity or readibility of the maps. It should be noted here, that the concentrations of wells on these maps are more an indication of local population densities than of ground water availability.

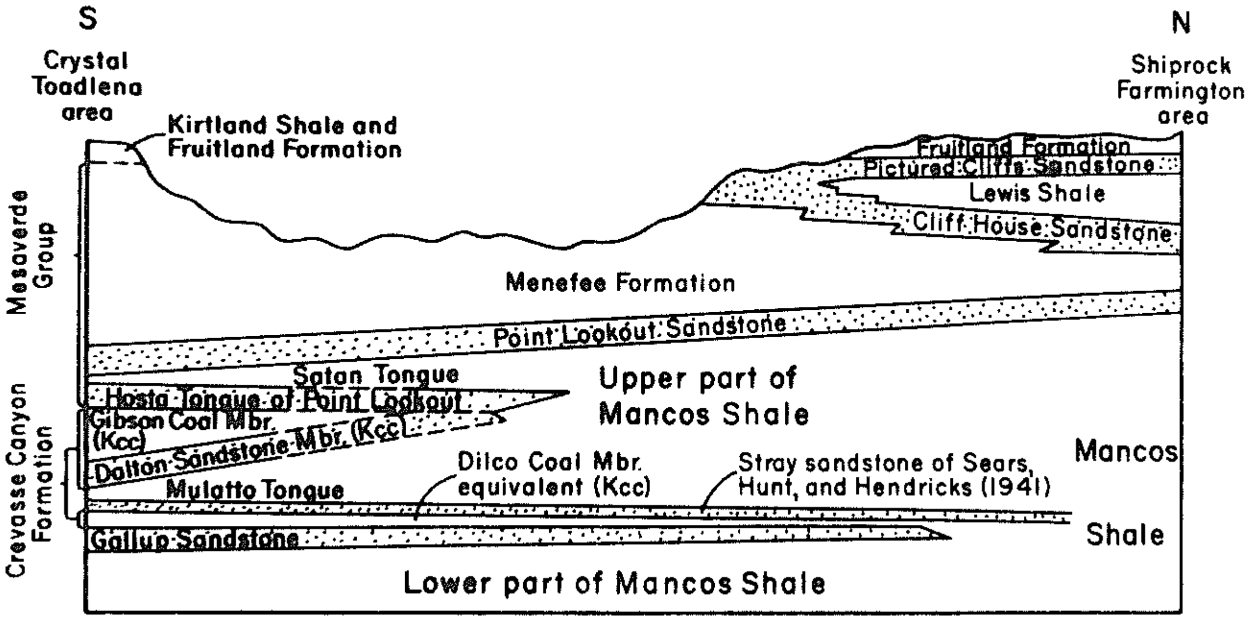

Figure 7. Cretaceous stratigraphy (O'Sullivan and Beikman, 1963).

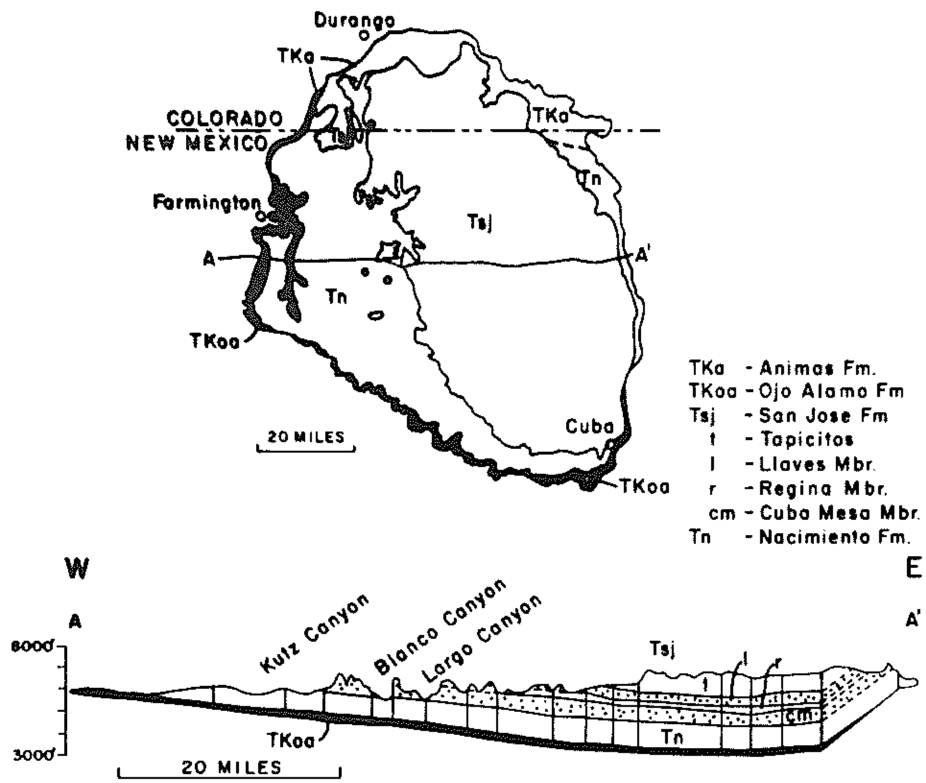

Figure 8. Tertiary stratigraphy (Brimhall, 1973).

Ground water quality will be given in terms of ppm (parts per million, total dissolved solids). For reference I might point out that the recommended drinking water limit is 500 ppm TDS, water with 500-35,000 ppm TDS is termed "saline", and that with greater than 35,000 ppm TDS is termed "brine". Obviously TDS content also effects suitability of ground water for agricultural and industrial uses as well. For example, water with TDS of more than 2000 ppm may be unsuited for long-term irrigation; as regards industrial use, TDS standards for boiler feed waters vary with pressures involved: for pressures ranging from 0 to greater than 400 psi, TDS standards range from 3,000-50 ppm.

The aquifers will be discussed in order of increasing depth (also, therefore, increasing geologic age).

Aquifers

Alluvium (Figure 9)

Distribution - at surface in stream valleys, along mountain fronts

Thickness - 0-50'

Lithology - unconsolidated clay, silt, sand, and gravel

Quality - fresh to slightly saline

Yield - poor to excellent, depending on coarseness and sorting

Remarks - Water from the alluvium generally is adequate and suitable for domestic purposes, however the quality usually reflects the water from nearby outcrops. In the badlands areas, water from alluvium generally is very highly mineralized.

Alluvium is a major source of water along the Chaco River but is only infrequently used along the San Juan and its tributaries.

Water in alluvium would be the first to be affected by strip-mining operations, particularly in the Chaco River alluvium near Burnham, Trading Post.

Chuska Ss. (Figure 10)

Distribution - west side of Chuska Mountains

Thickness - 1,000 ±

Lithology - sandstone with some interbedded shale and siltstone

Quality - fresh to slightly saline

Yield - poor to good, depending on the thickness of interbedded shale, siltstone

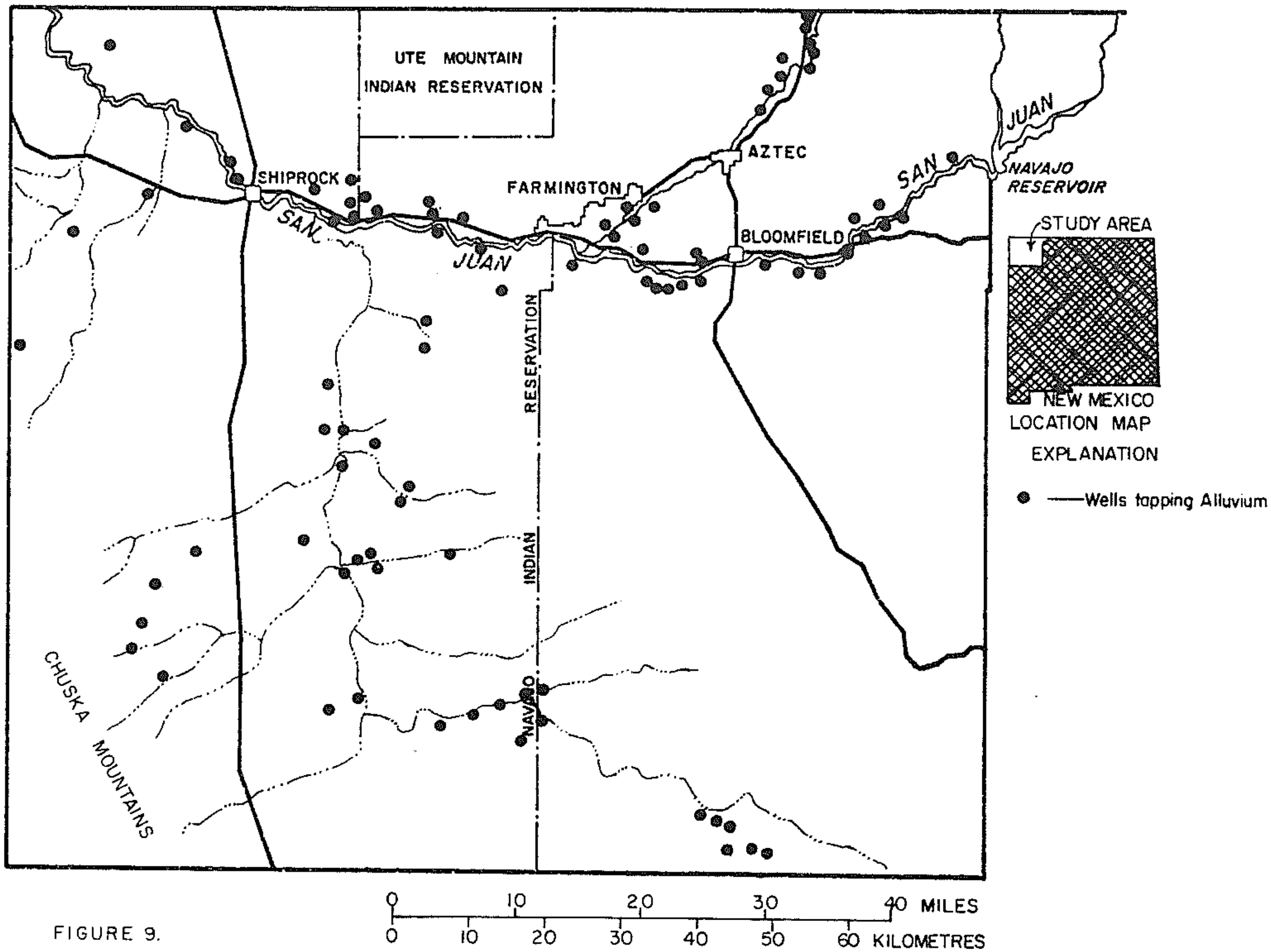

FIGURE 9.

Data collection points from wells and springs tapping alluvium in San Juan County, New Mexico.

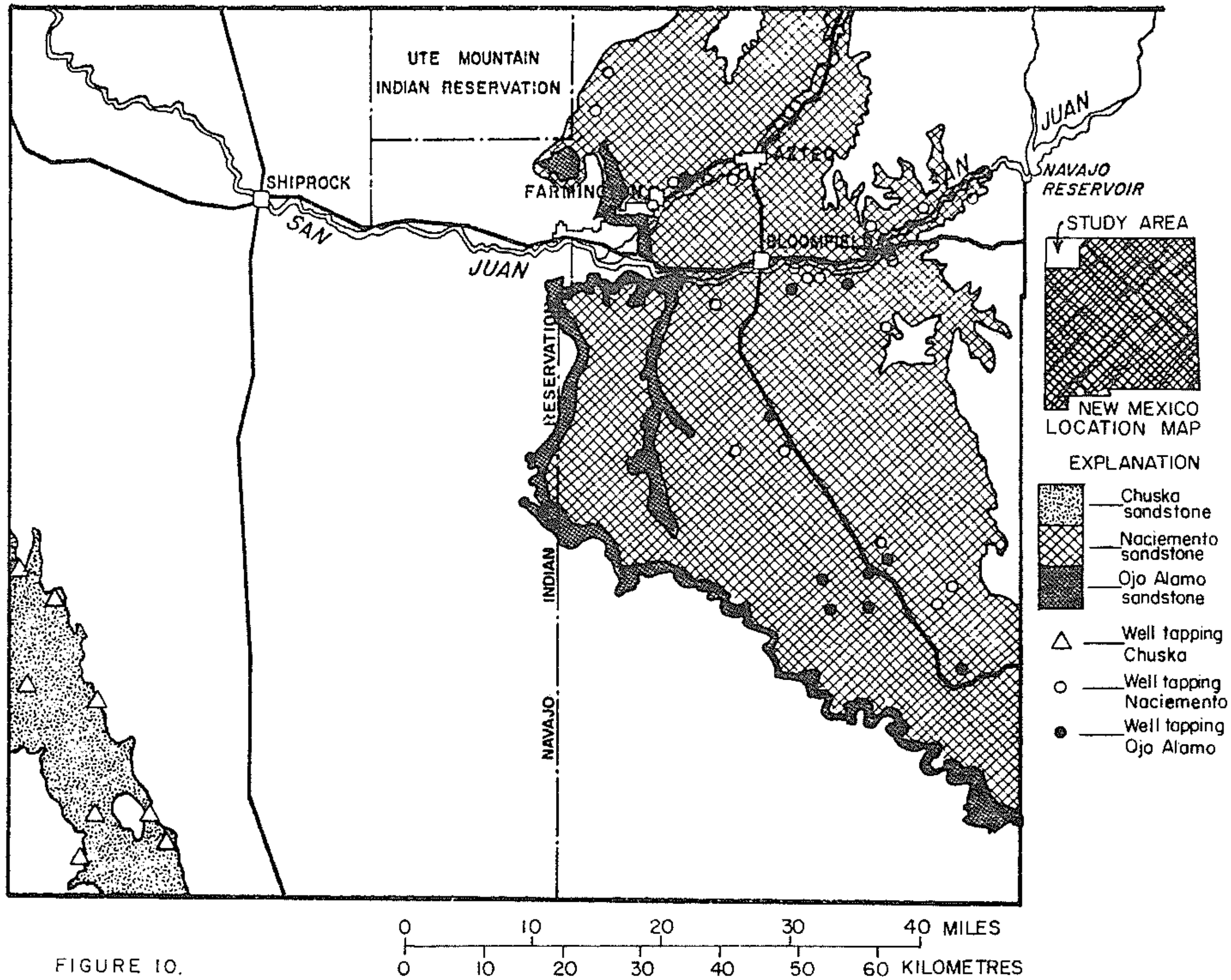

FIGURE 10.
Data collection points from various water-bearing units in San Juan County, New Mexico.

Remarks - Water from the Chuska is used locally for domestic purposes. The quality is excellent. Wells generally have small yields yields, but this may be due to well construction rather than aquifer capabilities. The Chuska is entirely within the Navajo Reservation and is generally untested.

San Juan Fm.

Distribution - not distinguished on the map because of little data for it in San Juan County; covers eastern edge of the area, east of the Nacimiento outcrop.

Thickness - 250 - 2000'

Lithology - sandstone, siltstone, and shale; Llaves and Cuba Mesa Mbrs. are sandstone and potential aquifers

Quality - Brimhall (1973) reported 1,824, ppm TDS - Cuba Mesa Mbr.; fresh to slightly saline generally.

Yield - 36-60 gpm (according to Brimhall, 1973)

Remarks - the sandstone members of the San Juan Fm. may be recharged by the Navajo Reservation and should be investigated further.

Nacimiento Fm.

Distribution - central and eastern half of area

Thickness - 1200 - 3000'

Lithology - shale and siltstone with local conglomeratic sandstone

Quality - 700-1400 ppm TDS (according to Brimhall, 1973); slightly to moderately saline

Yield - 35-200 + gpm

Remarks - The Nacimiento is primarily shale containing thin sandstone units. Shallow wells may provide adequate quantities of water for domestic use. Well yields are small. Water below about 150 feet is usually highly mineralized - in at least one instance exceeding 3,000 ppm.

Ojo Alamo Fm.

Distribution - central and eastern half of the area

Thickness - 50 - 400'

Lithology - coarse sandstone to conglomerate and shale

Quality - 1,000 ppm TDS has been reported near outcrop; generally fresh to slightly saline

Yield - large enough for domestic and stock use

Remarks - The Ojo Alamo is the principal shallow aquifer in eastern San Juan County. Water quality is gemerally good; well yields of up to 100 gallons per minute have been reported. Additional development of the Ojo Alamo should be anticipated. This aquifer possibly will be recharged by the Navajo Indian Irrigation Project.

Kirtland Fm. (Specifically, the Farmington Ss. mbr.) - Map (Figure 11) does not distinguish Kirtland from underlying Fruitland shale.

Distribution - central and eastern part of area; underlies all Tertiary strata

Thickness - 470' ±

Lithology - sandstone

Quality - potable near outcrop; 1,000 to 57,000 ppm TDS in basin

Yield - low

Remarks - The Farmington sandstone is the major water-bearing unit in the Kirtland-Fruitland Fms. Well yields are generally less than 100 gpm. Water quality depends on the proximity of shale to the producing horizon. At depths greater than 700 feet, water quality locally exceeds 8,000 ppm dissolved solids.

Pictured Cliffs Fm.

Distribution - occurs in most of area; underlies Kirtland Fm.

Thickness - 0 - 900'

Lithology - fine-grained sandstone

Quality - 30,200 - 37,800 ppm TDS; highly saline to brine

Yield - low

Cliff House Fm.

Distribution - occurs in most of area

Thickness - 0 - 800'

Lithology - sandstone

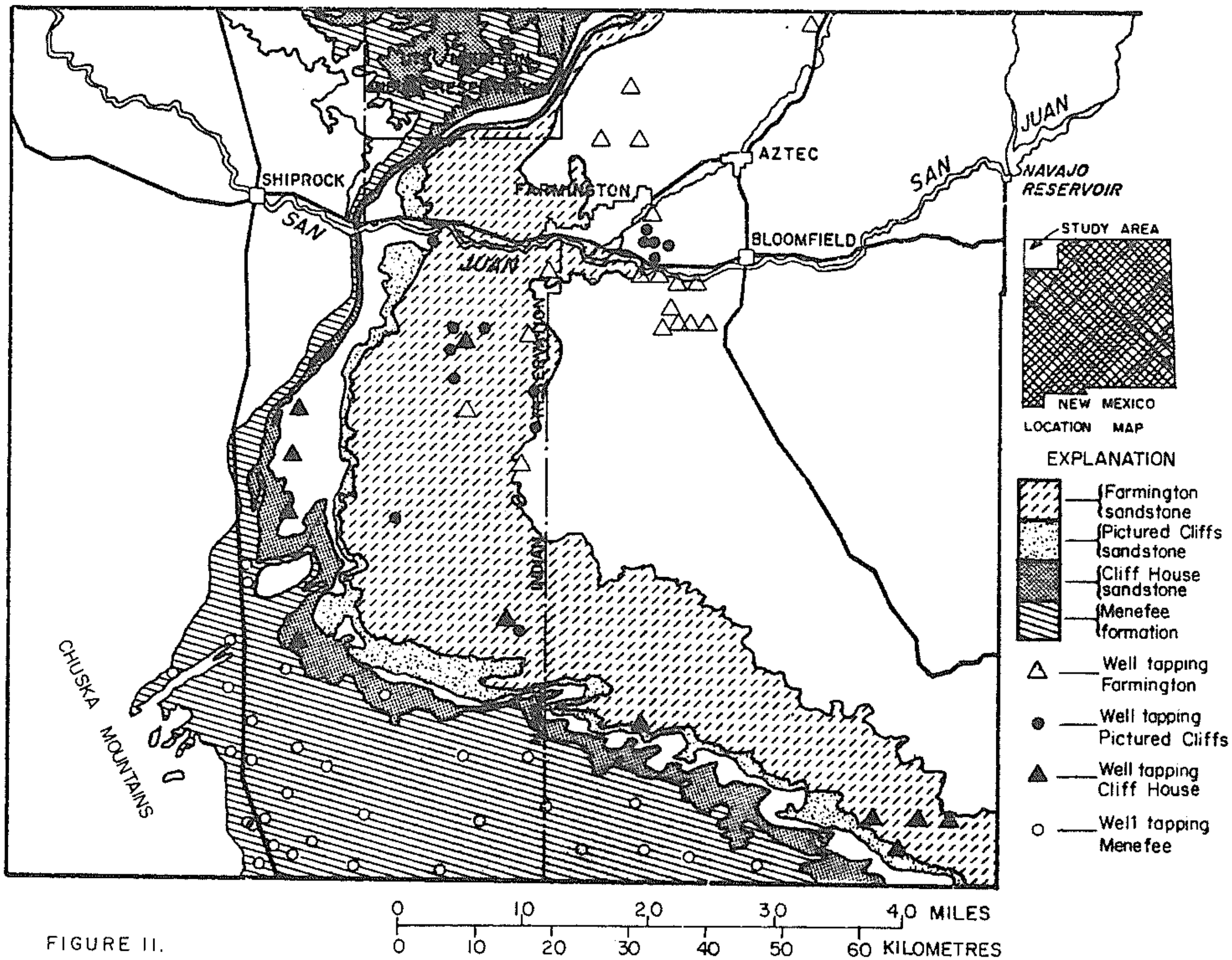

FIGURE II.

Data collection points from various water-bearing units in San Juan County, New Mexico.

Quality - mostly saline

Yield - low

Remarks - The Pictured Cliffs and Cliff House are hydrologically similar. Wells produce small quantities of good quality water near the outcrop belts; elsewhere the water quality deteriorates toward the northeast. These formations might yield sufficient water for industrial development.

Menefee Fm.

Distribution - present in most of the area

Thickness - 400 - 2200'

Lithology - carboaceous shale, sandstone

Quality - poor

Yield - locally sufficient for domestic, stock use

Remarks - The Menefee Fm. is one of the most widely-developed aquifers on the Navajo Reservation where it crops out over a broad area. Numerous stock and domestic wells tap this aquifer. The water quality is quite variable depending on depth and hydrologic conditions. Locally, Menefee wells flow. The The Menefee is generally not considered an aquifer in the sub-surface, that is, where it lies at some depth below the surface, farther out into the Basin.

Gallup Ss. (Figure 12)

Distribution - along the west edge of area

Thickness - 0 - 300'

Lithology - sandstone

Quality - fresh to slighty saline

Yield - fair to moderate

Remarks - The Gallup is a major aquifer in both San Juan and McKinley Counties. Yields of more than 1,000 gpm have been produced; water quality is good to excellent. Water from this unit is highly mineralized in the center of the basin.

Dakota Fm.

Distribution - underlies all of region except extreme western margin

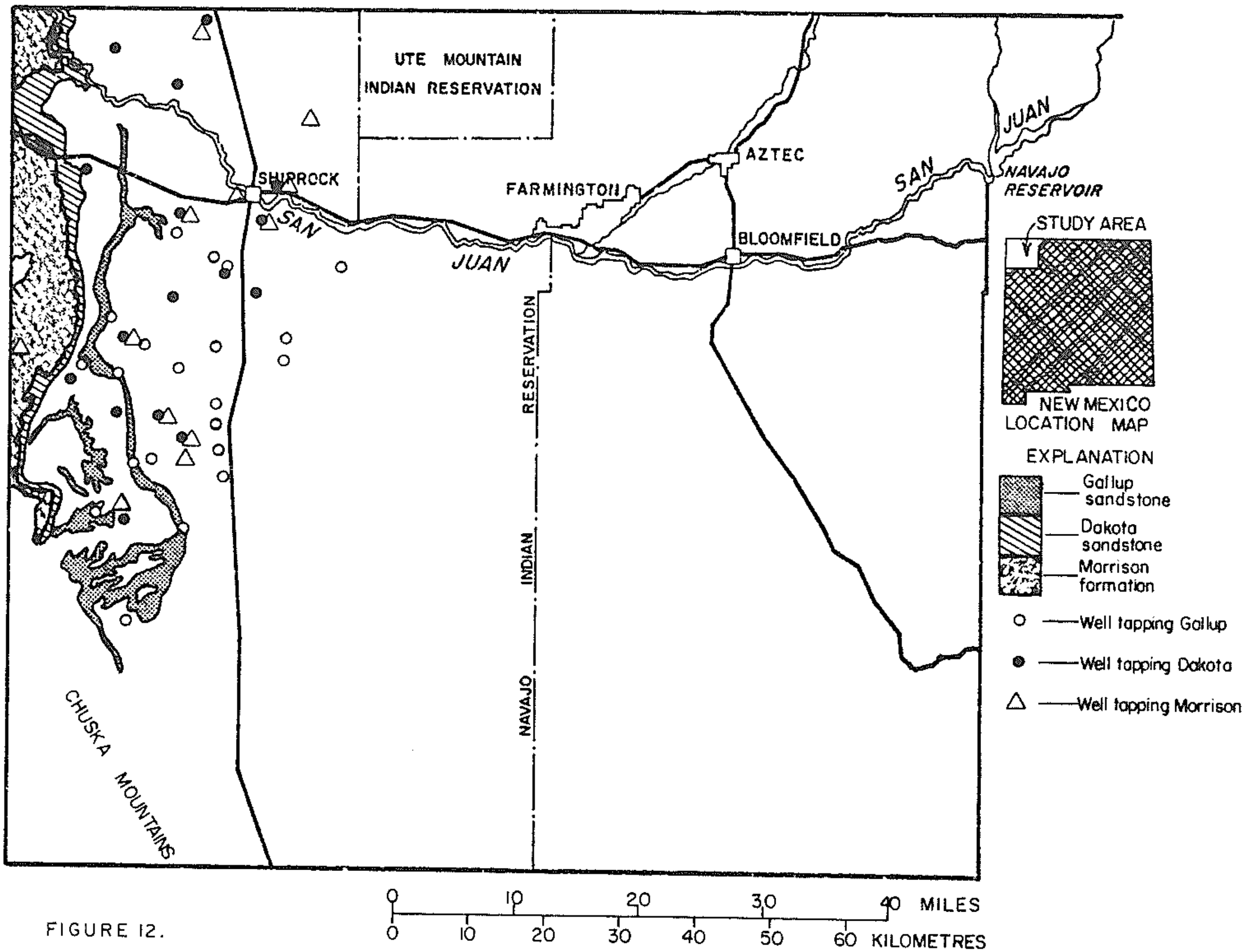

FIGURE 12.

Data collection points from various water-bearing units in San Juan County, New Mexico

Thickness - 150 - 250'

Lithology - sandstone, conglomerate, shale

Quality - fresh to moderately saline

Yield - 10 - 15 gpm

Remarks - The Dakota sandstone generally yields small quantities of water but is a major producer of hydrocarbons. Water quality is good to excellent along the outcrop belts in San Juan and McKinley Counties, more mineralized in the eastern part of the basin.

Morrison Fm.

Distribution - probably underlies most of the area

Thickness - 300 - 600'

Lithology - shale, sandy shale, silty sandstone, sandstone

Quality - slightly saline near outcrops; very saline away from outcrops

Yields - 5 - 800 gpm

Remarks - The Morrison locally produces large quantities of water. Numerous oil tests have been plugged back to this formation and developed as water wells. One such well reportedly flows 800 gom of 95°F water. Numerous wells in McKinley County obtain water from the Westwater Canyon Member of the Morrison which also contains the major uranium mineralization in that area. The Morrison may provide sufficient water for industrialization and should be tested further.

Conclusions

1. Large quantities of ground water with excellent to poor quality are present in a dozen aquifers at depths of less than 2000 feet in much of the p project area.

2. Alluvium in the San Juan River and tributary valleys is generally less than 30 feet thick and probably will not yield adequate supplies for valley communities such as Aztec or Bloomfield.

3. The hydrologic impact of the Navajo Dam is difficult to assess but the reservoir may be an important source of ground water recharge for the San Juan Fm., a potential target for future water resources.

4. The Navajo Indian Irrigation Project may be a source of recharge for the Ojo Alamo sandstone and observation wells should be established to monitor

this system.

5. Adequate quantities of ground water probably exist in the coal-bearing areas, however, its poor quality usually renders it unsuitable for domestic use and undesirable for industrial use.

6. Likewise, adequate quantities of ground water also exist in the Grants uranium belt where the ore body - the Westwater Canyon Mbr. of the Morrison Fm. - is also the principal aquifer.

7. Ground water must be utilized in northwestern New Mexico to a greater extent in the future than at present in view of the already heavy dependence on the surface water supply and anticipated increases in surface water demands.

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REGIONAL ENERGY POLICY FOR THE ROCKY MOUNTAIN STATES

Mally Ribe

I am tempted to thank the Womens' Liberation Movement for joining you here this morning at the early hour, but really I should thank my husband for letting me out on a long leash, and John Clark for letting me in.

This has been a difficult speech to prepare because it is a hot situation. Things are happening all the time, and additions were necessary right up to the last minute.

Jack Campbell has said that conferences are getting to be America's favorite indoor sport. They are indeed. This is my third big conference in two weeks. I attended the ROMCOE "Summit on Coal" with 500 others, on March 20 in Denver. This week I attended the Western Governors Conference on Agriculture in Billings. The subject of that one was, "Energy for Agriculture", and there were 600 people there. Both of these conferences were concerned with the same problems which I will review with you this morning.

Mally Ribe is a member of the League of Women Voters, Los Alamos, New Mexico.

The Federation of Rocky Mountain States (FRMS) is an organization of six states, Montana, Idaho, Wyoming, Utah, Colorado and New Mexico, working together to effectively solve regional problems. It initiates and supports commercial, scientific, economic, civic, cultural and educational activities necessary to the orderly development of the region. It increases communication between the states, business, public and private agencies and the federal government. It gives each member a share in the future of the Rocky Mountain Region. Former Governor Jack M. Campbell is the President.

On September 5, last year, I was in Glacier National Park, attending the 10th Annual Meeting of the FRMS, which was held in the marvelous old Glacier Park Lodge. I had just been appointed by the Governor to this organization's Natural Resource Council. Governor Thomas E. Judge of Montana earned my sincere admiration with his welcoming speech. I was so impressed that I thought that if the FRMS was a group of people as neat as he is, I was indeed in a high powered organization.

Some of Governor Judge's very forceful remarks are worth repeating to you at this conference. "The FRMS plays a vital role by providing a vehicle for leaders of industry, government, and academia to come together to find understanding and solutions to our common problems. Hopefully we will be able to implement land use planning, upgrade our economy, develop our human potential, and conserve our environment for future generations. To do this will require tough decisions. We must develop an intelligent and well thought out land use policy which must be administered at state and local levels... We need a good water conservation policy if our agricultural lands are to continue to meet domestic and world demand for food commodities. As the world looks to our states for a solution to the energy crisis, it is apparent that thousands of acres of farm land will be disturbed by strip mining and oil shale operations. Reclaiming this good agricultural land is vitally necessary for future agricultural production. As agriculture is the basis for civilization, we must develop intelligent policies which guarantee sufficient land and water and technology to meet the demands for food.

The first major decision must be to what extent we want energy development to take place in our region, and how can it be properly controlled? This decision should be made by the people of this region, and NOT by the federal government or by the energy companies. We must know what long term affects this will have on agriculture, water, the environment and on our communities, and the lifestyle of our people. Also, we must know beforehand what the effects on jobs, and revenues to the states will be... We must not let our wealth go elsewhere, or be left with the problems. We must make our voice heard at the federal level... So much energy resource development is anticipated in Montana that the number of applications for industrial water permits for the Yellowstone River Basin, which crosses southeastern Montana, reguired that the Governor ask the Legislature to enact a three-year moritorium on the issuance of any additional industrial permits... Do we want an agricultural or an industrial economy?

The second major decison is whether it is in the best interest of the State to impose restrictions on the use of lands. If we don't make land use choices, out of state developers and special interest groups will make them. There is insufficient water for both energy development and agriculture....

The third major decision regards the allocation of our finite water resources to provide for multiple uses. These questions will be controversial because any conservation program will restrict the use of private property and will determine the role of local government as to how far it should go to protect the public welfare, and to solve community problems. We must make these decisions not with the next few years in mind, but with the destiny of future generations as our underlying concern. Will we be able to avoid the mistakes made by other parts of the country? Will we be able to develop valuable resources in the region and still preserve the unique human and physical environment? We must, for time is running out." ...Thank you, Governor Judge.

A large portion of the conference at Glacier was an exposition of the impact of energy resource development on socio/economic conditions of boom towns or rapid growth areas and on water resources. The Federation of Rocky Mountain States has given priority concern to these problems. The Natural Resource Council, to which I was appointed, met on December 2 in the Federation's Offices in Denver to discuss the many aspects of the current situation. It was apparent that as the oil crisis became more urgent, and as a national policy had not yet been evolved; the energy minerals in the Rocky Mountain Region, (coal, oil, shale, and uranium) would be developed or extracted on a large scale in the near future. We agreed that it was urgent to prepare a position to assert the region's interest at the federal level, before a national policy was set in concrete, to prevent both economic and environmental damage. The 30 people from six states attending this meeting began with the basic framework of a regional energy policy. The first question was, not IF but HOW the mineral development would proceed. The discussion centered around the serious socio/economic impacts on mineral based "new" communities. It was said that new towns are usually not built, but that existing towns just grow, suddenly.

The overnight need for roads, schools, transportation, commercial service, health care, housing, utilities, water and sewage systems, and the resulting human problems caused be dislocation and isolation has made state Governments acutely aware that this new economic boom is no simple blessing. Increased crime, alcoholism, delinquency, divorce, property, and mental illness taxed existing social services beyond their capacities. It is a dismal waste of human resources. The worst effect is felt by the women, who are confined to mobile homes; surrounded by mud; with no work opportunities and no activities; poor services and isolation from families, churches, and friends.

It will be necessary to prevent these problems from occuring in other areas of rapid community growth by planning. Planning and community preparation must be done with "front-end money," or early assistance financing, before tax revenues are available. Special grants and access to established federal funding programs should be sought, especially the revenues from the Mineral Leasing Act of 1920, which provides that 37-1/2% of state revenues be applied to roads and schools. Front-end funding is complicated by local tax schedules and city-county budgeting procedures. It is known that it takes from two to six years for a new city to begin to pay for itself, and that costs for services can be as high as $6-7,000 per capita. Water and sewage facility debts usually run for 25 years. Total public outlay can be as high as $12,000 per job. Towns already affected by rapid growth are Colstrip in Rosebud County, Montana; Rock Springs, Sheridan, and Gillette in Wyoming and Rifle in Colorado.

The road to the town of Colstrip, 29 miles from I-94, is narrow, crooked, and dangerous. The speed limit is strictly enforced to prevent accidents. A pamphlet printed by the Rosebud Protection Association of Forsyth, Montana, states: "construction of mine-mouth conversion facilities in a sparsely populated rural area maximizes the impacts on local residents. Our community does not have the social services that a large number of construction workers and their families do and should expect. The costs of providing additional services have been heavily subsidized by the local residents. While energy companies have maintained that their development will broaden the tax base resulting in lower taxes, we have seen our taxes go up and up. For example, between 1972 and 1974 the total mill levy for Rosebud County rose 13%, the countywide school mill levy increased nearly 42%, and the mill levy for the Colstrip schools increased nearly 118%."etc... The 1974 budget for the Colstrip Schools was almost $100,000, and Montana Power paid only $314,063 in taxes.

In Gillette, the construction costs per capita were $1,635, exclusive of streets and roads. Each mineral related job brought 6.5 people to the community. Wyoming can get 1/3 to 1/2 more taxes from a company after production starts. Debt servicing is 3%. The Federation's staff made a thorough study of the taxes in Wyoming, as their experience has revealed tax inadequacies. At least $850 million will be needed for public facilities.

It is expected that by 1985, 165,000 acres of land will have been disturbed for 50 new communities, with an increase in population of 300 to 600,000 people. The FRMS publication Resource City, Rocky Mountains discusses at length these boom town problems.

The coal producing region needs a sustained funding program to handle development impact problems and it should insist on federal financing assistance in mitigating development impacts.

In addition to these problems, there are environmental problems. Air pollution is multiplied by increased traffic and heavy construction equipment. Montana Power's pollution control equipment, financed by county industrial revenue bonds, will remove only 40% of the sulfur dioxide at its Colstrip power generating station. Large areas of land will be disturbed exposing the dust to wind erosion. Montana has adopted a "strip and ship" policy to avoid air pollution caused by burning coal. Land needed for support services; housing; transportation corridors; and solid waste dumps, whose unpleasant visual impact is the source of anguished protest; contributes to the general degradation if not carefully managed. The impact of mining on water is disruption of aquifer recharge, downstream pollution, and increased erosion and siltation. Other environmental impacts will reduce wildlife habitat and recreational lands, while increased population will demand more recreational facilities. The quality of life will be downgraded.

Competition for scarce water supplies will be intense. Urban and industrial demands for water will exceed the available supply. New allocations of resources will become both a legal and a physical problem. Ground water is being rapidly depleted, drying up livestock wells. Reallocation of irrigation water to a new economic activity reduces the agricultural base and destroys good agricultural land, idling land owners and seasonal workers. Agriculture must compete with other sectors of the economy for energy more than for any other natural resource.

Water needs for energy or coal processing will be 6 to 14.7 gallons per ton for washing and dust control. It it is used for slurry lines it will be exported, which seems absurd because we have been talking about the need to import water for years. The Attorney General in Wyoming has been asked to determine whether slurry lines might be unconstitutional. This brings into focus the need for the states to have accurate information on the available water supply and an objective assessment of the potential for land reclamation. States will also need to coordinate water use planning in advance of resource development.

Obviously water no longer applied to food production reduces the total productivity of the nation. It forces a food producer to become a consumer, and increases his dependence on the rest of the country for food supplies. Food energy and fossil fuel energy must be considered and balanced against each other in long range planning for food production. Some people believe that they can not. All of these problems were acknowledged during the discussion of the proposal for a regional policy.

The major points of agreement in the first FRMS draft were as follows: 1) In response to the urgency of conserving energy (gasoline); major changes in lifestyle will occur in the remote, thinly populated western states, which have no mass transportation and where driving at 55 mph and increasing the price of gasoline are not particularly reasonable, and will only increse poverty. 2) An effort to revise the 37-1/2% of federal royalties from Mineral Leasing Act of 1920 designated to roads and schools to other uses would not be advisable at this time because of political interest in this money. 3) A regional energy policy should be objective, but also specific and positive with reference to the use of water and necessary solutions to the socio/economic effect, to improve the life style and to be financially sound with sustained federal assistance. 5) Tradeoffs between water use and land use and energy must be taken into account, with emphasis on the need for agricultural and water priorities. 6) The major problem of tax imbalances when costs are divided between units of government becomes a political and legal difficulty. 7) The special significance of other renewable resources such as solar, geothermal, and fusion research should be given adequate attention. 8) The problem of energy resources located on Indian lands was not considered an appropriate one for the Federation to address.

On January 27, the Natural Resources Council met again to refine the position, Secretary of the Interior Rogers Morton, in Denver with the eleven western Governors, earlier suggested that they form a regional energy commission which was discussed with interest. It was assumed that this group would be funded by the Four Corners Regional Commission and the Old West Commission, which serves the northern states. Secretary Morton urged increased coal production to help the Nation to be self-sufficient by 1985. He also remined the Governors that President Ford has asked for 192 billion tons of coal per year for the next 10 years, with 250 new coal mines. Secretary Morton assured the Governors that environmental interests would be kept in mind and that their help would be sought in orderly development policy changes.

Governor Judge's response was to oppose exploitation and to ask the rest of the Nation to share in the environmental, social and economic costs of coal development. Governor Herschler of Wyoming asked the Secretary what impact aid would be available and was told that the best way was through royalties.

The need for a regional policy statement was considered still urgent after the meeting. The procedure was to submit our agreement to the six Governors for their consensus, and then to send it to the President and to relevant federal agencies such as the Department of Interior and the FEC. At first we thought that all haste was desirable, but our policy did not ride into Washington on a pure white horse followed by the Washington Post. However, it has attracted considerable interest here in the West and may have important influence in places where it is needed. There is currently a great deal of discussion of this whole problem.

At this point I would like to interject a few questions which have occurred to us : If energy conservation is now understood to mean reducing demand now; how can we continue energy resource development and all its side effects, such as new community construction, which will increase the demand for oil and electricity immediately; in order to produce electricity, at 30% efficiency? Is this fuzzy thinking? What will be the total cost in energy to produce energy? Will there be a net gain? Is this proposed massive resource development really necessary? How much of the energy crisis will coal really resolve? What are our priorities for the available water? Do we really want it allocated to the consumptive uses of gasification plants? Can we meet our responsibilities to the Nation's need and maintain the greatness of open spaces and the beauty of this unique region?

The Federation's final policy proposal includes the following points: The heart of the crisis is the cost and availability of energy. Demand for development of Western energy minerals to meet the Nation's needs brings great pressure on the economic and social life of the people. These activities affect the quality of the region's land, air, and water resources. Therefore, it is important for the states to protect the environment, health, safety, and welfare of the people. It is important that we insure a balanced and equitable approach to energy development. Finally, just as the federal responsibility is to meet national needs, the States' responsibility is to insure a partnership role in energy development decisions that affect the region. The governmental system cannot act properly when one branch attempts to operate independently from the others.

Energy conservation is a necessary long and short term basis for a national policy. The energy growth rate should be less than 2-1/2% per annum, with a reduction of 5 to 7 percent in the next 3 years. There should be better public understanding of and support for these goals.

Environmental and social and economic impacts of growth and change give the responsibility to each state to determine the limits of its degradation. An evenhanded policy requires all regions to develop energy resources potential equitably to meet national energy requirements. Differences exist among major regions as to costs, uses, and availability of energy. (Other regions are also asserting their interests.) High clean air and water standards must be preserved. Return of mined lands to productive uses is basic. Anti-degradation options are reserved to the States. States expect to be afforded as much lead time as necessary to determine the need for, and acceptability of proposed development. States must be free to set and enforce standards, and to select among the development options. National policy must insist that impacted states and counties not bear a disproportionate share of the environmental and social cost. The federal government must provide appropriate financial assistance for planning and front-end community development for the benefit of all citizens.

Balanced use of natural resources must be recognized as part of the national policy. The Rocky Mountain region fills a number of national needs; food production, recreation, industry and the way of life. All these are natural resources. Balance of land use, water and energy is necessary to national well being. Economic diversity is the result of careful utilization of scarce water resources. While water is needed for energy development, wholesale shifts which would disrupt the balanced diversity cannot be undertaken. The States must have a voice in water allocation questions. Development of non-renewable resources must keep in mind the needs of future generations and other resource development options. Alternate sources of energy must be developed and the limits to material growth must be recognized.

In January of '75, ten Western Governors attended the National Governors Conference in Washington, and they issued a statement with the following points: 1. The federal coal leasing policy should prohibit the issuance of additional leases until a federal Coal Strip Mining Act is signed. A continuing dialogue with the individual states is vitally needed. 2. Demand for coal is a result of national needs; therefore, there is a national responsibility to insure adequate financial relief for environmental and socio/economic impacts. 3. Energy conservation must be a cornerstone of each alternative source in gaining national self-sufficiency. It is necessary that long range federal guidelines be established, so that each state will be encouraged to develop its own conservation, ethic-tuned to its specific needs. 4. States will not allow federal preemption of any laws which they have the express right to adopt and administer. The Governors are concerned about the present federal proposal to preempt the states' authority to exercise control over the location of energy facilities and the authority to administer clean air and water standards. 5. Present federal policy does not provide adequate funds for development of alternate sources of energy and demonstration projects. It is mandatory that States have significant input into decisions as to where and how funds will be expended. 6. Strip mining regulations are needed to establish broad federal guidelines for coal extraction, as this is the key to eliminating the energy crisis. However, these must not preempt the individual needs of the States for specific legislation.

As I mentioned earlier, Secretary Morton met in Denver on January 25 with ten Western Governors and discussed with them the establishment of a regional energy commission. This was done in March. The governors reiterated the six points I have just read to you. Governor Apodaca of New Mexico is the chairman of this Regional Energy Policy Office, which will have its base in Denver. The FRMS will work closely with this office, and the background studies which the Federation has published will be used.

Governor Lamm of Colorado repeated the desirability of a firm western states impact on national policy to make sure there would be increased communication between states in their own interest on common problems. He too, believes that we must say HOW these resources are developed. He reemphasized importance of the limited amount of water and that agriculture must not be sacrificed to coal power generation. He also said that the consumer has got to pay for the impact of increased population in extracting counties, the "vast aluminum ghettoes with no money to pay for schools and hospitals".

The Los Alamos Laboratory, which is deeply involved in energy research, is now establishing an information processing center. An article in the February issue of the ATOM mentions the vast amounts of water needed to extract fuels, and mentions the basic people problems, which will be the most subtle and complex and unpredictable. The demands of cities for water will conflict with agricultural interests. A study funded by the Bureau of Regional Energy Assessment and the Division of Biomedical and Environmental Research in ERDA, will serve eight western states: Arizona, Colorado, Idaho, Nevada, Montana, Utah, Wyoming and New Mexico. This program will have four parts: data aquisition; program modelling the cost/benefit ratio of projects and their impact, which will be used in approving projects; computer modelling of byproducts and their environmental impacts; and coordination and liaison with numerous agencies and offices. They will cooperate with other regions working with DBER, whose job is to work up a national plan for the orderly development of our resources with acceptable environmental impacts and maximum social benefits. LASL hopes to help find the answers to these diverse problems in the near future.

At the Western Governors Conference on Agriculture in Billings, Montana, Governor Apodaca was a luncheon speaker. He spoke on the Regional Energy Policy as proposed by the Western Governors. He affirmed that when leadership is lacking at the top, it is time for the Governors to step in and provide the leadership. He announced that former Governor William Guy of North Dakota will be the newly appointed director of the Regional Energy Policy Office which will have its office in Denver. Governor Apodaca said that we need federal guidelines so that we won't be left with the pollution, transmission lines, displaced people and sacrificed agriculture. We also need a rational federal leasing policy and federal regulations that do not preempt the states in energy development. We need federal standards for reclamation and air and water quality which do not interfere with the state's rights to determine its own non-degradation. Water is not sufficient for both energy and agriculture. He emphasized that massive front-end funding is needed to make sure that energy cities are decent places for people to live. We must have orderly growth with adequate planning. The ten Governors need to be involved and to be heard early in their role of producer and consumer states to solve the energy problems of the country.

NEW MEXICO THERMAL WATERS

W. K. Summers

PURPOSE AND SCOPE

In our anxiety to generate electricity using the natural heat of the earth, we tend to think about natural thermal waters in two contexts. (1) We look at the known occurrences of warm and hot water in the context of their exploration potential hoping that these surficial occurrences will lead us to a steam field. (2) We project our thoughts forward to a management context... anticipating the problem of the winning, using, and disposing of geothermal fluids.

This paper considers New Mexico's thermal waters in a third context -- their present value. That is what sort of answers evolve if we ask "What are New Mexico's thermal water good for"?

To answer this question we must merge two sorts of data. On the one hand we must know what the thermal waters are like--their occurrences, their physical and chemical properties, and the quantities available. On the other hand, value implies use so we must be aware of the criteria that should be satisfied before a given thermal water can be approved in terms of a given use.

W. K. Summers is a consulting ground water geologist, Socorro, New Mexico.

This paper consists then of three parts: a descriptive survey of New Mexico's thermal waters, a summary of the criteria established for some selected uses and an evaluation of the use potential of the thermal waters in the light of these criteria.

The descriptive survey is derived from a report entitled Catalogue of New Mexico's Thermal Waters, which the New Mexico Bureau of Mines and Mineral Resources is preparing for publication later this year.

Thermal water in New Mexico can be divided into two categories--normal and anomalous. Temperatures generally increase with depth so under normal conditions it's possible to find warm or hot water at some depth in almost any sedimentary basin. For example, temperatures of more than 300° F have been reported from depths in excess of 20,000 feet in the Permian Basin, southeastern New Mexico, and temperatures of more than 100° F are commonly reported in wells in the San Juan Basin.

Anomalous temperatures are those which are distinctly warmer than normal. For New Mexico, water temperatures of 90° F or more to depths of 500 feet are anomalous. For water from depths below 500 feet to be considered anomalous the temperatures (T) must be at least 90° F and larger than $A + 4 + .027\ Z$, where A is the mean annual air temperature and Z is the average depth of the contributing interval of the well.

This paper deals with anomalously warm water.

In this report a thermal area is one in which there is some justification for believing the temperatures between discharge points is continously anomalous, i.e., the Truth or Consequences area. As more information becomes available occurrences counted singularly here will undoubtedly be integrated in the future.

Using these criteria 67 thermal areas have been identified. Of these I have visited 50 and sampled 40. Of the 27 areas I have not sampled 20 are reports from unquestionably reliable sources and 7 are from probably reliable sources.

SUMMARY OF HYDROTHERMAL OCCURRENCES

Thermal water occurs in the mountainous parts of New Mexico and in the intermountain basins. They seem to be related to structural highs that border the state's structural troughs or grabens (i.e. the Rio Grande Valley, the Animas Valley). They occur in areas of volcanism.

Specifically thermal waters were noted in 12 of New Mexico's 32 counties: Catron, Dona Ana, Grant, Hidalgo, Luna, Otero, Sandoval, San Juan, San Miguel, Sierra, Socorro, and Taos.

No thermal waters are likely to be discovered in the following eastern counties: Chaves, Colfax, Curry, DeBaca, Eddy, Guadalupe, Harding, Lea, Quay Roosevelt, or Union.

The prospects for discovering thermal water in the remaining nine counties range from slight (where no warm springs occur) to excellent (where warm springs are numerous).

The frequency of occurrence of thermal areas by drainage basin is as follows:

Basin	No. of areas
Gila River Basin	
Upper Gila Basin	12
Cliff-Gila-Riverside Area	1
Animas Valley	3
San Francisco River Basin	3
	19
Rio Grande Basin	
Upper Rio Grande Basin	5
Jemez River Basin	12
Middle Rio Grande Basin	2
Jornado del Muerto Basin	1
Lower Rio Grande Basin	16
	36
Mimbres River Basin	7
Playas Lake Basin	1
Pecos River Basin	1
Tularosa Basin	1
San Juan River Basin	2
	67

GEOLOGIC AND HYDROLOGIC CHARACTERISTICS OF THERMAL AREAS

Geologic Age

Thermal waters discharge from rocks of all ages, as follows:

Age	Number of Occurrences
1. Precambrian	2
2. Paleozoic	8
3. Mesozoic	2
4. Cenozoic	35
5. Precambrian and Cenozoic	1
6. Paleozoic and Cenozoic	3
7. Precambrian and Paleozoic	1
8. Paleozoic and Mesozoic	1
9. Paleozoic, Mesozoic, and Cenozoic	1
10. Unspecified or unknown	6

The age of the rock, per se, from which the thermal water discharges is apparently of secondary importance. These rocks are not the source of the water nor are they just conduits. They form part of the ground water reservoir. The fact that they contain thermal water merely indicates that hot water moves through them. Both the heat and water originate else-where The head presumably comes from great depths. The water appears to be largely circulating meteoric water.

Lithology

Thermal waters occur in association with various rock types and lithologies. These occurrences are classified as follows:

Rock Type	Number of Occurrences
1. Extrusive igneous rocks (not including areally extensive massive rock)	10
2. Consolidated sedimentary rocks	11
3. Unconsolidated sedimentary rocks	15
4. Massive igneous and metamorphic rocks	8
5. Extrusive igneous and consolidated sedimentary rocks	6
6. Extrusive igneous and unconsolidated sedimentary rocks	1
7. Unconsolidated and consolidated sedimentary rocks	3
8. Unspecified or unknown	6

The arbitrary division of the igneous rocks and the grouping of massive igneous rocks with metamorphic rocks came about for two reasons:

First, hydraulically the massive igneous and metamorphic rocks are similar in that they transmit water almost entirely through fractures, whereas the extrusive igneous rocks include both particulate rocks and fractured rocks.

Second, where massive igneous rocks or metamorphic rocks occur they are fairly extensive and homogeneous, whereas extrusive igneous rocks tend to vary radically in composition and hydraulic character in short distances.

In terms of volume of water discharged, the Magdalena limestone of Pennsylvanian age discharge more thermal water than any other stratigraphic unit.

Many thermal waters are seen only in unconsolidated sedimentary rocks (alluvium, pediment gravels, etc.). Where this condition exists, we have a clear indication that much remains to be learned about the cause and effect of the thermal water at the site.

Geologic structure

Of 50 thermal areas visited, faults were the primary structural feature at only 5; 21 were associated with volcanic structures, including faults; and 23 occurred in situations where (1) distinct structure was lacking or (2) the structural setting was hidden beneath alluvinm or pediment gravels. In a few instances regionally significant faults cut volcanic structures and the thermal waters occurred nearby, so that clear-cut distinctions are not possible.

Faults are probably not important in themselves, but mark zones of fracture and sones in which rock types have been offset. That is to say the old cliche that "Thermal water rises along fault zones" is not universally evident. The waters are associated with fracture systems which in some cases are also related to faults and the exact relation between the thermal waters and the fault is not a singular one.

Similarly the relation of volcanic structures and thermal waters may be extremely complex. The heat and the rock may have originated from a common source, but have done so at widely separated times. Or they may have their origin in two completely separate sources. In all probability, the simultaneous occurrence of relatively young volcanic rocks and thermal water are the product of the same heat source, whereas older volcanic rocks and present-day thermal waters are probably related to differenct heat sources.

The occurrences of thermal water that are most difficult to explain are those where no "volcanics" occur, such as Truth or Consequences thermal water basin, Montezuma Hot Springs, and Ponce de Leon Hot Springs, for in these areas no obvious heat source exists.

Outlets

Thermal water discharges from several distinct outlets. These are:

Type	Number of Occurrences
Fractures	12
Talus slope	5
Interstitial porosity of particulate rocks	5
Calcareous tufa	2
Some combination of the above	7
Wells (including 4 areas with springs)	33

Water discharges from fractures where the rocks have low porosity. These rocks range from granite to breccias. In some places the fractures have been enlarged by the discharging waters; in others they have been partially closed by preceipitated minerals.

Interstitial granular porosity may also be reduced by the disposition of minerals--especially silica as chert and calcite as tufa. Free sulphur occurs at Sulphur Springs and Soda Dam Springs.

Where talus covers the bedrock the exposed lithology suggests that the discharge would be from fractures if the talus were to be removed.

Water discharges directly from calcareous tufa only at Faywood Hot Springs. However, calcareous tufa is an important deposit at Soda Dam Springs and Jemez Hot Springs. It is extensively deposited in the area of the Rio Salado-Jemez River confluence, but not at the rivers.

Some deposits occur in the Socorro thermal area and may mark the location of former thermal springs. Deposits near Ojo Caliente in Taos County probably mark the earliest outlet of the thermal waters there. Similar deposits occur near Truth or Consequences and in the Animas Valley. However, calcareous tufa may form from cooler waters, so its presence does not prove the existence of earlier thermal waters.

Discharge mode

Thermal waters discharge in a variety of ways, which have been subdivided as follows:

Mode of discharge

I. Springs:

A. Above stream

Wells up (boils)

Cascades

Wells up and cascades

B. At stream level

C. No stream near

II. Wells

A. Flowing

B. Pumped

C. Not equipped with operable pump and does not discharge

D. Destroyed

Under ideal effluent conditions ground water discharges to streams. This discharge occurs at springs and seeps along the stream bank and bed.

If the stream bed is very permeable, the individual points at which ground water flows in are not discernible. If the permeability of the stream bed and banks varies, more inflow occurs in the zones of large permeability than occurs along the banks even where the entire reach of the stream contributes to the total flow.

Where permeability contracts are large, the discharge may occur from a valley wall.

Where the rocks involved are fractured and permeability contrasts are related to the fracture pattern and the degree of fracture, the first appearance of the ground water may be a cascade. If the valley wall is steep, a talus cover may hide the actual mode of discharge.

If the discharge is from a low permeability aquifer onto high permeability alluvium, the water from a perennial spring will form an influent stream. In the more arid regions, the discharging spring may be several miles from the nearest perennial stream.

CHEMICAL CHARACTERISTICS OF THERMAL WATER

Dissolved Constituents

For 54 thermal areas 384 chemical analyses from many different laboratories have been assembed. These analyses reveal the following:

(1) Relatively few analyses are complete and the heavy metals have received so little attention that fewer than 20 samples have been analyzed for more than 5 heavy metals.

(2) In 28 areas water discharges from more than one place. In 7 of these areas the water temperature and chemistry vary radically with the source.

(3) The total dissolved solids in thermal water are independent of the temperatures as are most individual constituents. The following tabulation shows the frequency of total dissolved solids for 51 areas. This tabulation is based upon average values and in the 7 areas where concentrations vary upon the maximum values.

Total dissolved solids concentration range (ppm)	No. of areas	Cumulative total	Cumulative percent
0 - 250	8	8	15.7
250 - 500	13	21	41.2
500 - 750	6	27	52.9
750 - 1000	0	27	52.9
1000 - 1500	6	33	64.7
1500 - 2000	0	33	64.7
2000 - 2500	5	3	74.5
2500 - 5000	8	46	90.2
5000 - 10000	2	48	94.1
10000 - 20000	3	51	100.0
?	3	54	

As the preceeding tabulation shows about two-thirds of the thermal water contains 1500 ppm of total dissolved solids.

(4) Most constituents that make up the dissolved solids show no singular relation to the fact that the waters are thermal. The notable exceptions are silica, sodium and potassium, and fluorine. The solubility of silica increases with temperature. So the concentration of silica is generally larger than the average for cooler waters from similar terranes. Sodium and potassium are the dominant cations in thermal waters everywhere regardless of the total mineral content of the water. Fluoride is not unique to thermal but as the following tabulation shows, more than half of New Mexico's 54 thermal water areas contain fluoride concentrations in excess of 3 ppm. The probability that 54 areas chosen on any parameter other than temperature would have such a large concentration is diminishingly small.

Fluoride concentration (ppm)	No. of areas	Cumulative total	Cumulative percent
0 - 1	6	6	12.8
1 - 2	9	15	32.9
2 - 3	4	19	40.4
3 - 4	11	30	63.8
4 - 5	3	33	70.2
5 - 6	2	35	74.5
6 - 7	3	38	80.9
7 - 8	1	39	83.0
8 - 9	1	40	85.1
9 - 10	0	40	85.1
10 - 15	3	43	91.5
15 - 20	3	46	97.9
20 - 25	1	47	100.0
?	7	54	

(5) Boron is usually high only in thermal waters of the Jemez region.

(6) A review of samples from the same sources suggests that the chemistry of the discharging thermal water has not changed enough to measure since 1915.

Associated gases

Only the thermal water of the Jemez River Basin discharges significant volumes of gas. However, most of the thermal springs bubble occasionally. The primary exceptions are those that discharge from beneath a talus slope.

A few springs (Mimbres Hot Springs and Montezuma Hot Springs, for example) give up an occasional odor of hydrogen sulfide. Field tests for hydrogen sulfide however, were negative suggesting that the discharge of hydrogen sulfide was intermittment and of short duration.

Gases associated with thermal water in the Jemez area are:

	CO_2	O_2	H_2O	H_2	N_2	He
	Percent by volume					
Sulphur Springs (Men's)	85.9	1.1	7.1	--	5.9	0
(Alum)	77.9	1.1	20.1	--	.9	0
Soda Dam	82.8	3.3	.0	--	13.9	0
Jemez Spring	91.0	.6	--	2.8	5.2	-
Phillips Springs (Swimming Pool)	70.4	8.3	.0	--	21.3	-
San Ysidro Springs	97.5	.5	.0	--	2.0	0
do	96.3	.6	.0	--	2.7	0

Clearly, the dominant component of the gas associated with the thermal waters of Jemez River Basin is carbon dioxide, with minor amounts of hydrogen sulfide. The other constituents may be contaminants. Duke (1967) obtained similar results for the gas discharges at Mimbres Hot Springs.

Radioactivity

Scott and Barker (1962) reported uranium and radium in groundwater in the United States. They note (p. 15) that thermal waters "...commonly have large amounts of radium..." They also indicate (p.12) an anomaly threshold for both radium and uranium.

Unfortunately only a few samples of thermal water from New Mexico (Table 1) have been analyzed for radio-activity. Of these barely one of six analyzed for radium and only two of seven analyzed for uranium are above the anomaly threshold established by Scott and Barker for the area.

We conclude, therefore, that New Mexico's thermal waters are much like the non-thermal groundwater with respect to radioactivity. Recent work, as yet unpublished, of the U. S. Environmental Protection Agency shows that the radon-222 content of New Mexico's thermal water is also in the same range as normal groundwater (R. Kaufman Personal Communication March 31, 1975).

PRESENT USES OF THERMAL WATER

Currently thermal waters in New Mexico are being used as follows:

Use	No. of areas
Municipal or domestic supply	15
Spas	4
Industrial	2
Space heating	2
Irrigation	1
Stock and wildlife only	22
Destroyed wells--no use possible	7
Wells not in use	6
Steam wells	1

In the past spas operated in at least five other thermal areas. Based on the New Mexico experience a successful spa, based on thermal water, must satisfy these requirements (in addition to good business management):

(1) Easy and convenient access by the public. All existing spas are on or near main highways.

(2) Water temperature in excess of 100°F. Water warmer than 125°F is cooled before it is used. Water cooler than 100° F apparently will not sustain a clientele.

(3) A constant discharge of thermal water of 15 gpm or more.

Table 1.--Radioactivity of thermal water samples from New Mexico

	Beta gamma activity (pc/l)	Radium (pc/l)	Uranium (ppb)	Radon+ 222 (po/l)
Animas Hot Spot	12	.3	.2	---
Soda Dam	--	--	40.0	450
Socorro Thermal Area	11	.2	1.8	520
Gila Hot Springs	12.2	<.1	1.4±.01	640,68
Truth or Consequences (Yucca)	100	7	3.3	1400
Radium Springs	170	.6	1.8	5800
Faywood	19	29	.1	5600
range for region*	--	.1-29	.1-37	---
median for region*	--	.1	1.2	---
anomaly threshold for region*	--	5.9	54	---
maximum observation in Japan**	--	111.1	---	---

*Scott and Barker (1902, p.12)
**Uzumasa (1965, p.116)
+preliminary results of U.S.EPA

POSSIBLE CONVENTIONAL USES OF THERMAL WATER

To determine to what use thermal waters might be put, two facts have to be considered. First, the chemical character of the water as compared to a standard for a use; and second, the amount of water required for that use.

To assay the chemical character of the water as a function of use a table of requirements for specific uses was first compiled. Then the chemical analyses of the thermal water were compared to these requirements.

The possible uses of thermal water were divided into fifteen broad categories:

(1) Domestic water supply. Standards for this category included those for cooking and laundering.

(2) Stock and wildlife supply. Standards for this category included those established for cattle, horses, swine, poultry and rats.

(3) Fish and other aquatic life. This category includes both fresh and sea water when requirements are exceedingly flexible. In general this category considers the requirements of game fish.

(4) Irrigation

(5) Cooling water and air conditioning

(6) Boiler feed water. The quality of water for steam boilers varies with the pressure, only low pressure (150-250 psi) was considered.

(7) Industrial water supply, general. Standards for this category were assembled from standards published from the following specific industries which seem to be essentially the same: ceramic, electroplating, glass manufacture, nitrocellulose production, organic chemical industries paint production, photographic processing, plastic manufacturing, both synthetic and natural rubber manufacturing, soap and steel manufacturing, and tanning.

(8) Textile manufacturing. Standards for this category were compiled from those for textiles in general, bandage manufacturing, cotton manufacturing, dyeing, and wool scouring.

(9) Rayon and synthetic fibers

(10) Dyeing

(11) Pulp and paper making. Standards for this category are a blend of those for alkaline pulps, high grade pulps, low grade pulps, ground wood pulp, fine papers, bleached and unbleached draft paper, and soda and sulfate paper.

(12) Brewing and distilling

(13) Food processing. The standards for this category are those established for food processing in general, plus those for baking, equipment washing, mild and dairy industry, sugar manufacture, and sugar. In general, the water is not a part of the finished product.

(14) Food products. The standard uses in this category are those established for carbonated beverages, fruit juices, and ice manufacture. The water is a part of the product.

(15) Food canning and freezing.

The chemical character of thermal water ranges from suitable for most purposes to unsuitable for any purpose. The most common potential problems are excessive concentrations of iron, manganese, carbonate, bicarbonate, chloride, and sulphate and fluorine. Silica also tends to be high. The pH of many thermal waters tends to fall outside the acceptable range for most uses.

Table 2 summarizes the range of maximum values for these uses. In some cases the range is fairly large because a specific use within a category is sensitive to a particular ion.

Table 3 indicates the potential problem causers in the thermal waters for which some chemical analyses were available. "Potential" problems are specified because (1) a specific use within the catagory may call for substantially lower maximum values than the majority of uses, (2) only one or perhaps a few of several analyses from a source showed values above the "lowest maximum", (3) only one source in a particular area may show above maximum values for a particular constituent.

Three other factors which restrict the use of thermal water for the specified purposes are temperature, discharge rate, and location.

Of the fifteen uses listed, the first five require the water to be cool to some extent, except for laundering. Uses six to fifteen may or may not be sensitive to temperature depending upon specific applications. Temperature of the water is only a minor factor since for many purposes hot water can be cooled to air temperature fairly easily.

Discharge rate is perhaps the most critical factor in determining whether a specific area might lend itself to one of the fifteen possible uses. Discharge rates vary from almost 0.0 gpm at the seep on the Middle Fork of the Gila River (128.14W.2.100) to 1500 gpm at Truth or Consequences. In practice only a few areas can be expected to produce 500 gpm or more of thermal water.

These include:

(1) Hot wells, Animas Valley (25S.19W.7.000)

(2) Flowing wells at Warm Springs (16N.1W.410)

(3) Socorro thermal area

(4) Truth or Consequences (13S.4W.33.400;14S.4W.4.100)

(5) Kennecott Warm Springs

(6) Apache Tejo

Areas, which might be developed to produce 500 gpms or more of thermal water, can only be surmised for there have been no adequate tests to determine potential yield of the groundwater reservoir at these sites. However, experience

TABLE 2.--RANGE OF CONCENTRATION OF PROBLEM CAUSING CONSTITUENTS OF NATURAL WATER AS SPECIFIED FOR SELECTED USES

Constituent	See text for description														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SiO_2									25		20-100	50			
Fe	.3-1				.1-.5		.1	.05	0.0-.2		.3-1		.1-1.0	.2	
Mn	.05-.5	10.0	1.0	.50			00-.5	.2-.25	.0-.03	0.0	0.0-0.5	.1-.2	1.2	.2	.2
As	.05 .01	1.0	1.0	1.0											
Ca	10-200	1000						10.0				200-500	20.0		
Mg	10-150							5.0			12.0	30	10.0		
K	2000														
Se	.01-.1														
HCO_3	60-150	50				0-100	160	200	100			100-200	100	100-300	300
CO_3	20					20-200						60	20-60		
SO_4	200-400	500				1-40		100				250	20-250	250	
Cl	250-600	3000		100			50-75	100			75-200	100			
F	3														
NO_3	45											10.0			
NO_2	2.0											0.0			
B	1.0	20.0		1.0											
DS	500-1500	2500	2000			50-3000	200-1300		200		80-500	500-1500	850	100-850	850
pH	6.0-9.2					8.0-9.6	6.8-7.0		7.9-8.3	q		6.5-7.0			7.5
Zn	5.0-15.0														
Ag	0.05														
NH_3	.5														.5
Cu	.02-1.5	.5-1							5.0					20-20	7.0

Table 3. -- Potential problem causing constituents by use

	USE (THE CORRESPONDING NUMBER IN TEXT)														
LOCATION NO.	1	2	3	4	5		7	8	9	10	11	12	13	14	15
GILA RIVER BASIN															
UPPER GILA RIVER DRAINAGE															
11S.14W.35.409	G	G	G	G	G	G	G	CA	G	G	G	G	G	G	G
12S.13W. 7.340	MN HCO3 PH CA F	G	G	G	G	HCO3 DS PH	MN PH	MN CA	MN SIO2 DS	MN	MN SIO2 DS	MN SIO2 PH	MN	MN DS	MN
12S.13W.31.100	MN HCO3 PH CA F	G	G	G	G	HCO3 DS PH	MN DS CL PH	MN CA	MN SIO2 HCO3 DS	MN	MN SIO2 CL DS	MN SIO2 PH	MN CL	MN DS	MN
12S.13W.30.009	MN HCO3 PH CA F	----	----	----	----	----	----	----	HCO3 SO4 CL DS	----	----	----	----	----	----
13S.13W. 5.241	MN HCO3 PH CA F	G	G	G	MN	HCO3 SO4 DS PH	MN DS CL PH	MN CA	MN SIO2 HCO3 DS	MN	MN SIO2 CL DS	MN SIO2 HCO3 PH	MN SO4 CL	MN DS	MN
13S.13W.10.121	MN HCO3 CL PH CA F	G	G	CL	MN	HCO3 SO4 DS PH	MN DS CL PH	MN CA CL	MN SIO2 HCO3 DS	MN	MN SIO2 CL DS	MN SIO2 HCO3 CL PH	MN CL	MN DS	MN
13S.13W.11.000	MN HCO3 CL PH CA F	G	G	CL	MN	MN HCO3 DS PH	MN DS CL PH	MN CA CL	MN SIO2 HCO3 DS	MN	MN SIO2 CL DS	MN SIO2 HCO3 CL PH	MN CL	MN DS	MN
13S.13W.20.439	CA HCO3 CL DS PH F	G	G	CL	G	HCO3 SO4 DS PH	MN DS CL PH	CA CL	SIO2 HCO3 DS	MN	MN SIO2 CL DS	SIO2 CL PH	CL	DS	G
CLIFF—GILA—RIVERSIDE AREA															
16S.17W. .	FE MN HCO3 PH CA	G	G	G	FE MN	HCO3 SO4 DS PH	FE MN PH	FE MN HCO3	FE MN HCO3 SIO2 DS	MN	FE MN SIO2 CL DS	FE MN HCO3 CA PH	FE MN HCO3 SO4	FE MN DS	FE MN
ANIMAS VALLEY															
25S.19W. 7.000	CA HCO3 SO4 PH DS MN CL	G	G	CL	MN	HCO3 SO4 DS PH	MN FE SO4 CL PH DS	MN CL CA SO4	FE MN SIO2 HCO3 DS	MN	FE MN SIO2 CL DS	MN SIO2 HCO3 CL PH DS	FE MN HCO3 CL SO4 DS	FE MN SO4 DS	FE DS
SAN FRANCISCO RIVER DRAINAGE															
5S.19W.34.200	HCO3 PH	G	G	G	G	DS PH	DS PH	G	SIO2 HCO3 DS PH	G	SIO2 DS	SIO2 PH	G	DS	G
7S.21W.8.442	FE MN HCO3 DS PH	G	MN DS	G	G	HCO3 SO4 DS PH	MN PH	G	MN SIO2 G	E	SIO2 DS	SIO2 PH	G	DS	G
12S.20W.23.120	FE MN HCO3 DS PH	G	G	G	G	HCO3 CL DS PH	FE MN SO4 CL DS PH	FE CL	FE MN HCO3 SIO2 DS	MN	FE MN SIO2 CL DS	MN SIO2 CL HCO3 DS PH	FE MN CL DS	FE CL DS	FE DS
RIO GRANDE BASIN															
UPPER RIO GRANDE DRAINAGE															
26N.11E. 1.009	CA HCO3 CL DS PH	G	G	G	G	HCO3 SO4 DS PH	MN CL DS PH	CA	MN SIO2 HCO3 DS	MN	MN SIO2 DS	SIO2 HCO3 PH	CL HCO3 SO4 DS	HCO3 DS	G
24N.13E. 7.000	MN HCO3 CA PH	G	G	G	G	HCO3 SO4 DS PH	MN CL DS PH	CA	MN SIO2 HCO3 DS	MN	MN SIO2 DS	SIO2 HCO3 PH	SO4 CL	DS	G
24N. 8E.24.100	FE MN HCO3 PH	DS	DS	CL	G	HCO3 SO4 DS PH	MN CL DS PH	MN CA SIO2 HCO3	SIO2 HCO3 DS PH	MN	SIO2 CL DS PH	MN SIO2 HCO3 CL DS PH	SO4 CL	MN HCO3 DS	HCO3
JEMEZ RIVER BASIN															
20N. 4E. 7.000	MN HCO CL DS PH	G	G	G	G	HCO3 SO4 DS PH	MN DS	G	SIO2 HCO3 DS	MN	MN SIO2 DS	SIO2	G	DS	G
20N. 3E.29.000	----	G	G	G	G	HCO3 DS PH	MN	G	SIO2 HCO3 DS	MN	MN SIO2 DS	SIO2 HCO3 PH	G	SIO2 HCO3 PH	G

Table 3.--Potential problem causing constituents by use (cont)

LOCATION NO.	USE (SEE CORRESPONDING NUMBER IN TEXT) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
20N. 3E.35.000	MN HCO3 CA SO4 DS F	DS	DS	CL	FE MN	HCO3 SO4 DS PH	FE MN SIO2 DS	FE MN 6EA CL SO4	MN HCO3 DS	MN	MN CA	FE MN CL HCO3 PH	MN FE DS	SO4 DS	MN HCO3 DS
19N. 3E. 4.000	FE MN DS CL MG SE SO4 DS PH	FE MN SO4 DS	FE MN DS	FE MN	FE DS	SO4 MN PH	FE MN DS PH	FE FE CA MG SO4	SIO2 SIO2 MN PH MG DS	MN SIO2 HCO3 PH MG	MN DS SIO2 HCO3 PH	G	DS	FE MN SO4 DS	FE MN DS PH
19N. 3E.28+32	HCO3	G	G	G	G	DS	FE	G	MN SIO2 HCO3 PH	MN	MN SIO2 DS	SIO2 HCO3 PH	G	DS	G
18N. 2E.14.000	CA HCO3 CL DS F	G	CA HCO3	G	G	CA HCO3 DS PH	CA HCO3	FE CA HCO3	FE SIO2 CA HCO3		FE SIO2 CA	CA HCO3	FE CA HCO3	FE HCO3	FE CA HCO3
18N. 2E.23.000	MN CA HCO3 F	G	CA HCO3	G	G	HCO3 SO4 DS	PH MN	FE MN CA HCO3	MN SIO2 HCO3	MN	MN SIO2 DS	MN SIO2 CA HCO3 DS	CA HCO3 SO4	MN DS	MN
16N. 2E.29.142	FE MN HCO3 PH F	CA HCO3	G	G	FE	CA SO4 PH	FE MN HCO3	FE CA	FE SIO2 HCO3	MN	FE SIO2	FE SIO2 HCO3	FE CA'	FE MN HCO3	FE HCO3
16N. 1W. 1.410	FA CA HCO3 CL SO4 DS F	HCO3 CL SO4 DS	DS	CL	FE	G	FE HCO3 CL SO4 DS	FE CA HCO3 CL SO4	MN SIO2 HCO3 CL SO4 DS	G DS	MN SIO2 CL SO4 DS	FE HCO3 CL SO4 DS	FE CA HCO3 CL SO4 DS	FE HCO3 SO4 DS	FE HCO3 DS
MIDDLE RIO GRANDE DRAINAGE															
10N. 2E.21.343	CA HCO3	---	---	---	---	HCO3 CO3 SO4 DS	PH	CA	SIO2 HCO3	---	SIO2 DS	HCO3 PH	HCO3 CO3 SO4	HCO3 DS	PH
9N. 5W.12.442	HCO3 CL SO4 DS	HCO3 CL SO4 DS	DS	CL	G	HCO3 CL SO4 DS	HCO3 CL SO4 DS	HCO3 CL SO4 DS	HCO3 CL SO4 DS	G	CL	HCO3 CL SO4 DS	HCO3 CL SO4 DS	HCO3 SO4 DS	HCO3 DS
3S. 1W.16+22	FE MN CA	HCO3		G	G	HCO3 CL	FE MN PH	FE MN CA	SIO2 FE MN HCO3 PH	MN	SIO2 MN DS	HCO3 PH	FE CA HCO31	HCO3	HCO3 PH
JORNADO DEL MUERTO															
10S. 1W.25.100	HCO3 SO4 DS	---	---	CL	---	HCO3 SO4	HCO3 DS PH	HCO3 SO4	HCO3 DS PH	---	DS	HCO3 SO4 DS PH	HCO3 SO4 DS	HCO3 SO4 DS	HCO3 SO4 DS PH
LOWER RIO GRANDE DRAINAGE															
13S. 4W. 4.000 14S. 4W. 4.000	FE MN CA HCO3 CL DS F	CL DS	DS	DS	CL	HCO3 SO4 CL DS PH	FE MN DS PH	MN FE CA CL HCO3 SO4 DS	FE MN SIO2 HCO3 CL DS	G	FE MN SIO2 CL DS	FE MN HCO3 CL DS PH	MN FE CA CL HCO3 SO4 DS	FE MN DS	FE HCO3 DS
14S. 5W.25.410	MN CA HCO3 SO4 DS PH F	DS	DS	CL	MN	HCO3 SO4 CL DS PH	FE MN DS PH	MN CA CL DS	FE MN DS	MN	FE MN SIO2 CL DS	MN CA CL DS	MN FE CL DS	MN DS	MN
17S. 4W.29.340	MN CA HCO3 SO4 DS PH	G	G	CL	MN	HCO3 SO4 DS PH	FE MN SIO2 CL DS	FE CA CL SO4	FE MN SIO2 HCO3 DS	MN	FE MN SIO2 HCO3 CL DS	MN SIO2 CL HCO3 DS PH	CL SO4 DS	MN SO4 DS	FE HCO3
19S. 2W. 9.120	FE MN HCO3 DS PH F	G	G	CL	FE	HCO3 SO4 DS PH	FE MN SIO2 CL DS	FE CA CL SO4	FE MN SIO2 HCO3 DS	MN	FE MN SIO2 HCO3 CL DS	FE MN SIO2 CL HCO3 DS PH	SO4 CL DS	FE DS	FE DS
23S. 1W.10.213	MN CA HCO3 CL SO4 DS PH F	CL DS	DS	CL	FE MN	HCO3 CL SO4 DS PH	FE MN SIO2 CL DS	FE MN CA HCO3 CL SO4 DS	FE MN SIO2 CL HCO3 DS	MN	FE MN SIO2 HCO3 CL DS	FE MN SIO2 CL HCO3 DS PH	SO4 CL DS	SO4 DS	FE MN HCO3
23S. 2E.34.000	FE MN CA HCO3 CL SO4 DS PH	G	G	CL	FE MN	HCO3 SO4 DS PH	MN FE HCO3 CL DS PH	FE MN CA HCO3 CL SO4	FE MN SIO2	MN	FE MN SIO2 HCO3 CL DS	FE MN SIO2 HCO3 CL DS PH	FE MN CA HCO3 CL DS	FE MN HCO3	FE MN DS

Table 3.--Potential problem causing constituents by use (cont)

LOCATION NO.	USE (SEE CORRESPONDING NUMBER IN TEXT) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
23S. 2W.36.133	FE MN CA SO4 HCO3 CL PH F	SO4	G	CL	MN	HCO3 SO4 DS PH	MN CL DS PH	MN CL SO4 DS	SIO2 HCO3 DS	MN	MN SIO2 CL DS	MN CL DS PH	MN CL SO4 DS	MN CL SO4 DS	MN
23S. 1W.31.432	FE MN CA HCO3 CL SO4 DS PH	DS	DS	CL	G	HCO3 SO4 DS PH	CL DS	FE CA CL SO4 DS	FE DS	G	CL DS	CL DS	FE CA CL SO4 DS	CL DS	DS
28S. 2W.24.213	HCO3 SO4 CL DS	DS	DS	CL	---	HCO3 SO4 DS	HCO3 CL DS	HCO3 SO4 CL	DS	---	DS	HCO3 SO4 CL DS	HCO3 SO4 CL DS	04 DS	DS
MIMBRES RIVER BASIN															
18S.10W.18.100	FE MN AS SE HCO3 F	HCO3	FE MN	FE	FE MN	HCO3 PH DS	FE MN PH	FE MN	SIO2 FE MN PH	MN	SIO2 FE MN	SIO2 FE MN PH	FE MN	FE MN	MN PH
20S.11W.20.243	FE MN AS CA HCO3 F	HCO3	G	G	FE	HCO3 SO4 DS PH	FE MN HCO3 PH	FE MN CA MG	SIO2 FE MN HCO3 PH	MN	SIO2 FE MN CA DS	SIO2 FE MN HCO3 PH	FE MN HCO3 SO4	FE MN HCO3	SO4 DS MN PH
20S.11W.18.310	MN CA MG HCO3	HCO3	G	G	G	HCO3 SO4 DS	HCO3	FE CA	SIO2 FE MN HCO3 DS PH	MN	SIO2 MN CA MG DS	SIO2 MN HCO3 PH	FE MN CA MG SO4	HCO3 DS	G
19S.12W.19.000	MN CA MG SE HCO3	HCO3	G	G	G	HCO3 SO4	HCO3	MN CA	SIO2 MN HCO3 DS PH	MN	SIO2 MN DS	MN HCO3 PH	MN CA MG SO4	MN HCO3 DS	MN PH
PECOS RIVER BASIN															
GALLINAS RIVER BASIN															
16N.16E. 6.000	FE MN CA HCO3 DS	HCO3	FE	FE	FE	FE HCO3 SO4 DS	FE MN HCO3 DS PH	FE CA	SIO2 FE MN DS PH	MN	SIO2 FE MN DS	SIO2 FE DS PH	FE CA HCO3 SO4	FE DS	PH
TULAROSA BASIN															
18S. 8E. 5.144	FE MN AS CA DS MG HCO3 SO4 CL	HCO3 SO4 CL DS	FE MN DS	FE CL	FE MN	HCO3 SO4 CL DS	FE MN HCO3 SO4 DS	FE MN CA MG HCO3 SO4 CL	SIO2 FE MN HCO3 DS	MN	SIO2 FE MN MG CL DS	FE MN CA MG SO4 CL DS PH	FE MN CA MG SO4 CL DS	FE MN SO4 CL DS	MN DS
SAN JUAN RIVER BASIN															
19N.17W.29.000	HCO3 PH	G	G	G	G	HCO3 SO4 DS PH	HCO3 PH	SO4 HCO3	FE HCO3 DS	G	MN SIO2 DS	MN HCO3 SIO2 DS	SO4 HCO3	G	G

plus observations made during visits suggest the following areas might have production possibilities in excess of 500 gpm.

(1) Gila Hot Springs (13S.13W.5.140)

(2) Lyon Hunting Lodge Hot Springs (13S.13W.10.000)

(3) Cliff-Gila-Riverside area

(4) Lower Frisco Hot Springs (12S.20N.23.120)

(5) The Jemez River drainage

(6) Jornado del Muerto

(7) Las Alturas Subdivision (23S.2W.35.133)

(8) Mimbres Hot Springs (18S.10W.13.110)

(9) Faywood Hot Springs

(10) Garton well (18S.8E.5.144)

(11) Pure oil test Navajo #1 (19N.17W.29.000)

The remaining areas may also one day be made to yield more thermal water than present-day evidence suggests. Without substantial additional testing, we can only say that the geologic setting and known history of discharge suggests that the amount of hot water which can be obtained economically is less than 500 gpm and probably less than 100 gpm.

Access to the thermal water is perhaps the most critical factor of all. Many thermal areas occur in ground water basins which the New Mexico State Engineer has closed to further appropriations. Several are in the Gila National Wilderness area which is closed to any development. Several are in mountainous areas, some distance from existing roads with only limited accessibilities. The majority of the occurrences of thermal water are on privately owned land.

The use of thermal water for irrigation requires special consideration because several factors combine to determine whether a particular water is suitable for irrigation. These include the boron concentration, the sodium adsorption ratio, the per cent sodium and the specific conductance of the water. These data for thermal water show that the bulk of it is not suited for use by irrigators, although particular waters may be so used.

DISCUSSION

From the preceeding discussion two facts are clear. First, much of New Mexico's anomalously thermal water resource is already being used for conventional purposes to the limit of its availability and quality. Second, of the unused portion, either its location, its quality, its probable quantity or cost to obtain preclude its use for space heating, water supply, or other ordinary purposes.

Therefore, I believe that, excepting one or two occurrences, the use of thermal water in New Mexico for prosaic purposes will not be increased by any significant volume in the near future.

As a result of these observations, a third conclusion follows: Future research efforts on anomalously thermal waters should focus on the significance of these waters with respect to exploration for and development of natural thermal waters for generating electricity.

RECOMMENDATIONS FOR FUTURE PROGRAMS

Several research programs on geothermal research are underway; these recommendations are offered in light of these extant programs.

(1) This paper was based on a somewhat arbitraty definition of "anomalous" thermal water. A study of New Mexico's subsurface temperature regime should be conducted to determine with greater precision the distribution of "normal" thermal waters. That is, we should have better criteria for determining when we cross the line that separates normal from anomalous.

(2) The volume of and the feasibility of using "normal" thermal waters should be evaluated. Many "dry" oil wells discharge warm or hot water. In some instances these waters may be warm enough to use for space heating or in a heat exchanger to generate electricity. Today these wells are abandoned as failures.

(3) The anomalous thermal water should be better understood in terms of its role in the hydrologic cycle. A program to measure the stable isotopes in groundwater, including anomalously thermal water, would give insight into a hydrologic regimen. A program to evaluate the trace elements and especially the heavy metals in groundwaters would help us not only to understand the hydrologic regimen of thermal water but also the role of natural waters in the evolution and destruction of ore bodies. Such a program might also lead to the discovery of new ore bodies.

(4) Steam fields, without exception, discharge CO_2 and H_2S. A program should be instituted to learn (a) the nature and volume of the noncondensible gases associated with thermal waters in New Mexico, and (b) the nature and volume of the dissolved gases. This program should include the determination of isotopic content of the gases.

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ECONOMIC IMPACTS OF THE NAVAJO INDIAN IRRIGATION PROJECT AND OTHER WATER RESOURCE DEVELOPMENTS ON THE NAVAJO INDIAN RESERVATION

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In this paper we propose to (1) give a status report on the Navajo Indian Irrigation Project (NIIP), (2) describe the projected economic impacts of the NIIP, and (3) briefly describe the projected economic impacts of the current and proposed coal resource developments in relation to the NIIP, I will discuss the first two issues and my colleague, Dr. Lansford will discuss the latter issue and answer all questions.

For the benefit of those of you who are not familiar with the NIIP, it was authorized by Congress in 1962 as part of a package that also authorized the San Juan-Chama diversion. The project, part of the upper Colorado River Storage Project, will furnish irrigation water to 110,630 acres of Navajo-owned land located generally south of Farmington, New Mexico.

Several years ago the Navajo Tribal Council approved the establishment of the Navajo Agricultural Products Industry (NAPI) to plan and coordinate the agricultural development. The operating plan calls for the establishment of a tribal enterprise agro-industrial type farm development owned and operated by the Tribe, but under the direction of a separate board of directors and hired professional management. All profits are to accrue to the tribal treasury.

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CROP, LIVESTOCK, AND PROCESSING ACTIVITIES
FULLY DEVELOPED NIIP

CROP	ACRES
Alfalfa	25,000
Feedgrain	36,900
Vegetables	19,760
Sugar Beets	13,000
Beans	8,308
Seeds	2,000

LIVESTOCK	NUMBER OF ANIMALS
Dairy	2,200 Cows
Sheep Feedlots	19,000 Head
Beef Feedlots	216,000 Head
Egg Production	600,000 Hens

PROCESSING	UNIT
Sugar Beets	42,000 Tons
Vegetable Cannery	2,000,000 Cases
Livestock Slaughtering	250,000 Head

Present Status

The first block of land of approximately 9,000 net irrigible acres should be ready for farming next year, the 1976 crop year. All construction contracts are let and expected to be completed in time. The second block of land of slightly less than 10,000 acres will not be ready for farming until 1978,

Table 1. Projected Gross Sales, Net Operating Profit and Operating and Capital Requirements[1] Navajo Indian Irrigation Project 1976-1987.

	Gross Sales	Net Operating Profit[2]	Annual Investment Capital	Investment Capital To Date	Annual Operating Capital
			$1,000		
1976	1,340	638	2,477	2,477	959
1978	4,188	953	3,152	5,629	2,968
1979	16,645	2,373	4,892	10,521	9,150
1980	34,717	4,243	6,896	17,417	18,439
1981	64,346	7,900	9,000	26,417	36,957
1982	89,000	14,427	34,643	61,060	54,478
1983	91,388	15,630	3,572	64,632	59,881
1984	108,074	17,645	8,115	72,747	68,569
1985	118,431	18,596	3,194	75,941	74,848
1986	128,889	20,079	10,050	85,991	84,686
1987	129,253	20,613	1,802	87,793	85,328

[1]All profits, income and capital estimates are based on "constant dollars" with 1969-72 as the base period. Projections are based on the cropping plan and livestock and processing activities listed in SWERD Environmental Study.

[2]Net Operating Profit is Gross Income less all expenses except interest.

To allow for startup costs for the first block of land it was assumed that yields would be 70% of the budget expectations and costs would be 130% of budget expectations listed in Costs, Returns, and Capital Requirements of Selected Crops for the Navajo Indian Irrigation Project, Agricultural Experiment Station Reserach Report 256, Las Cruces, New Mexico, May 1973.

Specific information on each crop can be found in Costs, Returns, and Capital Requirements of Selected Crops for the Navajo Indian Irrigation Project, Agricultural Experiment Station Research Report 256, Las Cruces, New Mexico, May 1973 and Special Report on monthly cash budgets.

hence, they will have two years of operating block one before bringing in the second block. If adequate funding is received, an additional block of approximately 10,000 acres will be brought in each year after 1978 with the full 110,630 acres scheduled to be under irrigation by 1987. The project plan also calls for a 23,000-kilowatt hydroelectric plant at the Navajo Dam to provide part of the power needed on the project.

NAPI Preliminary Long Range Plan

NAPI has taken steps toward preparing a preliminary long range development and operating plan. Under current planning about 60 percent of the acres of the fully developed project are expected to be planted in alfalfa and feedgrains. Another 34 percent of the acreage will be planted in sugar beets; and fresh and processed vegetables including potatoes. The remaining six (6) percent is scheduled for beans and seed crops. Livestock activities of dairy, sheep feeding, cattle feeding and egg production are included in the long range plan. Also, fresh vegetable packing sheds, vegetable processing, sugar beet processing, and livestock slaughtering facilities will be developed if economic conditions seem favorable.

The project when fully developed is expected to realize an annual net operating profit of $20.6 million on sales of nearly $130 million (table 1). This figure includes profits from the crops, livestock, and processing and marketing activities contained in the long range plan. It does not include profits from machinery, fertilizer, seeds, transportation or other associated business that will develop. Net operating profit is defined as a net business income before any interest expense is paid. Since the amount and sources of debt capital or equity capital have not been determined, it is not possible to predict net income (profits after interest expense) without making some assumptions.

The project is expected to require nearly $88 million in investment capital for sprinkler systems, machinery and equipment, buildings, and processing and marketing facilities. Annual operating capital needs are estimated at nearly $86 million. The beef feedlot and processing plants are the largest users of operating capitol.

The Navajo Tribe does not have to repay the Federal Government for the cost of bringing the water to the land. The Tribe is also not subject to Federal nor State property or income taxes on profits earned from agricultural activities on the reservation. These conditions provide them with a competitive advantate over non-Indian irrigation developments.

Although the Navajo Tribe is desperately in need of additional income and employment opportunities, they currently do not have the capital available to develop the project along the lines suggested in the long range plan. If the project is properly managed, it should be reasonably profitable and be able to attract some private equity and debt capital. However, it is likely that the Federal Government will have to provide much of the investment and operating capital at least in the early development years, but public investments in creating long run income and employment opportunities for the Indians and other people living or migrating to the project area should be partially compensated through future reductions in public welfare payments.

Employment and Income Impact on the Local Economy

The majority of the economic impacts will accrue to residents (or future residents) of San Juan County, New Mexico with lesser impacts accuring to the Gallup area, McKinley County, New Mexico. Because of the increased economic activity, expenditures for goods and services will also be made in many of the surrounding communities such as Albuquerque, New Mexico and Durango and Cortez, Colorado. Also because of the large size of the project, communities across the United States that manufacture farming and agricultural processing equipment will also benefit.

San Juan County, New Mexico will probably receive the majority of the economic impacts for the following reasons: (1) the project is centrally located in the county, (2) San Juan County had over 52,000 residents in 1970, and with the irrigation project and coal gasification plants (with anticipated direct employment exceeding 8,000) the county should exhibit sufficient growth in population and associated business firms to reduce many of the economic leakages that now occur, and (3) the immediately adjacent communities do not have complete, well developed agricultural service industries, hence these will tend to develop adjacent to the project in San Juan County.

Since the project is for the benefit of the Navajo people and it is not unreasonable to expect that over 90 percent of the jobs created in direct farming, processing, and marketing activities will be filled by Navajos (2). The economy of the Navajo Reservation is not well developed so many of the indirect (services and supplies) jobs created will probably go to non-Navajos. This probable effect could be mitigated somewhat if the Navajo people increase their involvement in service business firms. Because of the undeveloped reservation economy there will be few economic linkages that would enhance the general economy of the entire reservation.

Because of the substantial distance of the Irrigation Project from most areas of the reservation, most employees will probably reside in San Juan County, New Mexico. It is probable that some commuting will develop particularly for individuals closely tied to the Navajo extended family system, but the majority of the Navajo employees will probably reside in the existing communities in San Juan County, or in possible new ones under consideration.

The enterprise farming complex (NAPI) is owned by the Tribe. Presumably this will be a profitable venture and all profits will be available for Tribal investments or support of the many existing tribal programs. To the extent profits are distributed across the reservation, all Navajo people will benefit from the irrigation project.

Estimation of the Economic Multiplier

The economic impact of the irrigation project will not be limited to wage and other payments made to the local community; the income resulting from these payments will be, in part, re-spent within the community and will create additional income and jobs. An economic multiplier is typically used in estimating the total change in the economic variables resulting from the initial change.

The method of estimating the income and employment multiplier is based upon the relation between basic (export) industrial sectors and non-basic (local use) sectors. Basic sectors depend on demand from outside the community. The income resulting from a region's exports provides the demand for outputs of the local sector. Most of the agricultural products produced and processed on the project will be exported to other regions, hence it is a basic industry. Retail trade is a good example of a local service sector.

A comparison of basic and non-basic jobs, using San Juan County 1971 employment figures as a base period, indicated that for every basic job there were 1.4 people employed in non-basic sectors (table 2). If one assumes these relationships hold true in the future then every new job created in the basic sector will result in a total increase in employment of 2.4 people -- the new basic sector job and 1.4 additional jobs created in the remaining sectors of the local economy.

Application of economic base analysis techniques to estimate the economic impact of new employment in an area is not an exact science. They must be interpreted as "rough estimates" subject to substantial error. The economic multiplier that might result in San Juan County in 1987 at the time the irrigation project is expected to be fully developed could easily range from less than two (2) to greater than three (3). The multiplier size will depend upon the change in the amount of leakages in the local economy as the area develops (purchases outside of San Juan County).

An employment multiplier of 2.4 is much larger than one would expect as a result of incremental increases in basic employment in a region the size and population of San Juan County. However, this may be a realistic estimate of the employment impact by 1987 considering the immense size of the irrigation project and the substantial growth that will occur in the energy industries in the county. The combination of these two basic developments should induce considerable expansion in the local economy.

Direct Employment Effects

The project has had and will have direct employment effects resulting from planning and construction activities, and jobs in farming and related activities (table 3). It is estimated that by 1987 and thereafter when the project is scheduled to be fully developed, 2,137 jobs will be created from the irrigation development in the basic industries of agriculture, government, project related construction and processing activities.

Indirect Employment Effects

Employment is forecasted to increase by more than 5,000 in San Juan County by 1986 and thereafter as a result of the irrigation project. This

Table 2. Allocations of San Juan County Employment into Basic and Non-Basic Categories 1971.[1]

Employment Category	Sector Basic	Sector Non-Basic	Total
	number of jobs		
Manufacturing	1,319	0	1,319
Mining	1,410	0	1,410'
Contract Construction[2]	950	719	1,669
Government			
Federal	1,218		1,218
State		244	244
Local		1,724	1,724
Agriculture	532	0	532
Transportation & Public Utilities[2]	938	937	1,875
Wholesale & Retail Trade[2]		2,889	2,889
Finance, Insurance & Real Estate[2]		366	366
Service & Miscellaneous[2]		2,183	2,183
Total[3]	6,367	9,062	15,429

Sources: New Mexico: County Work Force Estimates 1967-73, Prepared by the Research and Analysis Section of the Employment Security Commission of New Mexico.

U. S. Department of Labor, Bureau of Labor Statistics, Employment and Earnings United States, 1909-72, Bulletin 1312-9, 1973.

[1]The category "All other non-agricultural" employment as used by the Research and Analysis Section of the Employment Security Commission of New Mexico, could not be used in this approach because comparable national data was not available. This category includes all self-employed regardless of occupation, unpaid family workers, and private household workers.

[2]Location Quotient technique was used to assign employment as basic or non-basic for these sectors. The assumption method was used for the other sectors.

[3]Determination of Economic base Multiplier: 15,429 ÷ 6,367 = 2.4 i.e., for each additional job added to the basic category, 1.4 jobs are added in the non-basic sectors, for a total of 2.4 jobs created.

Table 3. Estimated Changes in Basic and Non-Basic Employment Resulting from Development of the Navajo Indian Irrigation Project 1967-1987.

Year	Basic Employment: Manufacturing[1]	Agriculture	Construction[2]	Total Basic	Non-Basic[3]	Total Employment
1967			375	375	525	900
1968			320	320	448	768
1969			143	143	200	343
1970			89	89	125	214
1971			229	229	321	550
1972		33	267	300	420	720
1973		39	370	409	573	982
1974	8	40	355	403	564	967
1975	8	45	402	455	637	1,092
1976	8	55	505	568	797	1,365
1977	8	55	505	568	797	1,365
1978	8	137	515	660	924	1,584
1979	8	291	515	814	1,140	1,954
1980	8	485	490	983	1,376	2,359
1981	118	726	350	1,194	1,672	2,866
1982	307	815	390	1,512	2,117	3,629
1983	307	891	400	1,598	2,237	3,835
1984	307	1,061	370	1,738	2,433	4,171
1985	307	1,133	340	1,780	2,492	4,272
1986	585	1,213	320	2,118	2,965	5,083
1987	585	1,241	310	2,137	2,992	5,129

1. Includes employment created in food processing.

2. Construction employment on the project including Bureau of Reclamation Personnel.

3. An employment multiplier of 2.4 was used (1.4 non-basic jobs created for each basic job added, See Table 8).

"best guess" forecast is based on a total employment multiplier of 2.4 (one basic job increase and 1.4 additional jobs created in the non-basic industries). If the local economy does not develop as this employment multiplier would suggest and considerable economic leakage occur, the total employment effect would be somewhat less. If the 2.4 employment multiplier underestimates the effects on the local economy, significantly more than 5,000 jobs may be created. For example a total employment multiplier of 2.0 would predict creation of slightly more than 4,250 jobs, whereas an employment multiplier of 3.0 would indicate creation of more than 6,400 jobs.

Direct Income Effects

There are two sources of direct income effects on the local economy resulting from development of the irrigation project: wages and salaries by NAPI and business profits earned by NAPI spent in the local economy. Wages and salaries for all employees are expected to increase from $600,000 in 1976 to $14,000,000 as the project becomes completely developed in 1987 (table 4).

NAPI is forecasted to earn $10,300,000 in net income in 1987 and years thereafter (assuming they will have to pay an interest expense or 8% on all investment capital and on about 1/2 of their operating capital). Assuming profits are distributed by the Navajo Tribe on a per capita basis relative to total Navajo population, about 20 percent or $2,100,000 would be spent annually in the local area. The other $8,000,000 would be spent in other portions of the reservation. Total direct income (labor plus NAPI profits) spent in the San Juan County area as a result of the irrigation project is forecasted to be about $16,100,000 by 1987.

Indirect and Total Income Effects

Indirect income in the local community created by the irrigation project when fully developed is forecasted at $22,500,000 annually. The employment multiplier discussed earlier was used as an estimate of the indirect income effects.

Total income effects for San Juan County are estimated at $38.6 million annually after 1986 (sum of estimated direct and indirect income).

Navajo Income Effects

The total direct effects from development of the irrigation project on incomes to Navajos is estimated at $23 million annually after the project is fully developed. This estimate is based on the assumption that 90 percent of the basic jobs and labor income will go to Navajos, and the $10,300,000 in NAPI net income will be spent for Tribal programs on the reservation. Since adequate information was not available, no attempt was made to estimate the indirect income effects accruing to the Navajo people. However, unless the economy on the reservation develops rapidly in the next decade, the indirect effects would be very limited.

Table 4. Estimated Annual Income From Wages and Salaries Paid by Navajo Agricultural Products Industry, 1976-86.[1]

Year	Wages and Salaries
	$1,000 dollars
1976	600
1977	1,300
1978	2,600
1979	4,100
1980	6,700
1981	8,800
1982	9,400
1983	10,800
1984	11,300
1985	13,700
1986	14,000

[1]Based on the NAPI Long Range Plan rounded to the nearest $100,000.

Navajo Indian Irrigation Project Water Use

As originally planned the Navajo Indian Irrigation Project would utilize flood irrigation with a gravity distribution system. It was estimated that to irrigate the 110,630 acres there would be required an average annual diversion of 508,000 acre-feet from the river and that about 256,000 acre-feet would return to the San Juan River as return flows thus an average annual depletion of 252,000 acre-feet. By the conversion of the Navajo Indian Project to a sprinkler irrigation system, it is estimated that only 330,000 acre-feet of water would be required to be diverted annually to irrigate 105,000 productive acres, with 226,000 acre-feet depleted annually and loss and return flows averaging 104,000 acre-feet (table 5).

The per acre consumptive irrigation requirement has been estimated by the Bureau of Reclamation to be 1.886 acre-feet based on annual per acre consumptive use of 2,496 acre-feet and an effective precipitation of 0.61 acre-feet.

The average farm irrigation efficiency is estimated to be 75 percent resulting in per acre farm deliveries of 2.516 acre-feet. The project efficiency is estimated to be 60 percent resulting in an additional 0.627 acre-feet losses in canal, lateral, etc., thus resulting in an average annual diversion from Navajo Reservoir to be 3.143 acre-feet per acre.

New Mexico Water Rights from the San Juan River as Part of the Colorado River Compact

In the Reservation area, water in the quantities required for large thermal power units, gasification plants, and major industrial developments must be obtained from surface sources since underground sources are not sufficient. Potential surface sources are limited to Colorado River Basin water currently allotted to New Mexico. Operating under the limitations of the Colorado River Basin Compact, the following annual allotments from storage in the Navajo Reservoir have been: (1) 330,000 acre-feet diversion and 226,000 acre-feet depletion for the Navajo Indian Irrigation Project, (2) Navajo Power Plant 178,000 acre-feet diversion and 28,000 acre-feet depletion, (3) 100,000 acre-feet of depletable municipal and industrial water (M & I), (4) 55,000 acre-feet of diversion and 39,000 acre-feet of depletion to the Utah Construction and Mining Company (now Utah International), and (5) 20,000 acre-feet diversion and 10,000 acre-feet depletion for the Hammond Irrigation Project. The current water allocations and contracted uses including the 100,000 acre-feet of M & I water are summarized in table 6.

The water use projections for the Navajo Indian Irrigation Project, Navajo Power Plant, electrical generation would appear to be reasonable. There are sufficient data available on irrigation water requirements under sprinkler irrigation. The Four Corners Power Plant has been in operation for several years, therefore, the water requirements have been recorded. The Navajo Power Plant located at Navajo Dam has a depletion right of 28,000 acre-feet but only a small portion will be depleted at the Power Plant, thus leaving the remaining amount available for other uses by the Navajo nation.

Table 5. Estimated consumptive use, consumptive irrigation requirements and diversions for the Navajo Indian Irrigation Project in Northwestern, New Mexico.

	Per Acre	Total Irrigation Project (105,000 Productive Acres)
	-------------Acre-Feet-------------	
Consumptive Use	2.496	262,050
Effective Rainfall	(-)0.61	-64,050
Consumptive Irrigation Requirement	1.886	198,000
Farm Loss [1]	(+) .63	66,150
Farm Delivery	2.516	264,150
Canal, Lateral Loss [2]	(+) .627	66,150
Project Delivery	3.143	330,000
Average Project Diversion		330,000
Average Irrigation Requirement		198,000
Average Non-beneficial Uses		28,000
Total Depletions		226,000
Losses and Returns		104,000

[1]Based on 75 percent farm irrigation efficiency.

[2]Based on 60 percent project efficiency.

Table 6. New Mexico Water Use From Storage* in the Navajo Reservoir on the San Juan River.

Water Right	Annual Diversion acre-feet	Net Annual Depletion acre-feet	Use Contracted For	Present Level of Depletion acre-feet	Projected Date For Complete Use
Navajo Indian Irrigation Project	330,000	226,000	irrigation	none	1987
Navajo Power Plant	178,000	28,000	hydro-power	none	1979
Utah International, Inc.[1]	55,000	40,000	thermal power	40,000	completed 1970
Utah International, Inc.[2]**	44,000	44,000	coal gasification	none	1983
El Paso Natural Gas Company[3]	28,250	28,250	coal gasification	none	1983
Public Service Company of New Mexico[4]**	20,200	20,200	thermal power	5,000	1979
Hammond Irrigation Project	20,000	10,000	irrigation	8,000	completed 1962
City of Gallup[5]**	7,500	7,500	municipal	none	unknown
Southern Union Production Company**	50	50	compressor station	50	1970

Sources: New Mexico State Engineer's Office and Appendixes to Re-Evaluation Report Navajo Indian Irrigation Project, New Mexico, August 1966.

[1]This water right permit from SEO is being used by Arizona Public Service Company for cooling for the Four Corners Power Plant at Fruitland, New Mexico.

[2]This water right contract will be used by WESCO in the operation of four gasification plants.

[3]The 28,250 acre-feet depletion right to El Paso Natural Gas Company has been recommended by the Inter-State Streams Commission, and Governor, not approved by U.S. Congress; contract had not been signed as of April 1, 1975.

[4]Contract water-right approved.

[5]No contract has been signed to date.

*Some use may be supplied from return flow.

**Temporary water supply to year 2005, as per Section 11 of Authorizing Act.

Since there has been no experience in the Four Corners area with large-scale coal gasification projects, the water use requirements may or may not be accurate.

Coal Resources in the Area

Coal reserves suitable for strip mining in the San Juan Basin of New Mexico are estimated at nearly 5.8 billion tons (Table 7). The general location of the coal fields is shown in figure 1. Of this total strippable approximately 50 percent is in the San Juan Basin in New Mexico but not on the Reservation (7).

Table 7 presents a summary of reserves considered strippable under criteria designed to include coal within stripping range using current techniques, and a deeper category representing what is expected to be feasible stripping coal in the near future.

The strippable total coal reserves are nearly equally divided between those under less than 150 feet of overburden and those being deeper. Approximately 1.4 billion tons of strippable coal with less than 150 feet of overburden are located on the Reservation. The most important reserve is the Navajo Fruitland coal field being the largest and best known coal field in the San Juan Basin. Utah International, Inc. has two leases on the Navajo Fruitland field. One lease signed in 1957, covers 24,000 acres with royalty arrangements of 15 cents per ton. A second lease immediately south of the first lease covers 6,500 acres with royalty arrangements of 20 cents per ton. The combined leases have estimated reserves of more than one billion tons. One-third of this is committed to use in the Four Corners electrical generating station. Of the remaining two-thirds, about 234 million tons will be allocated initially to the WESCO Coal Gasification Plant (8). It is estimated that a total of 950 million tons of coal will be mined over a period of 25 years to support the 1,000 million cubic feet per day substitute natural gas complex planned by WESCO (9).

El Paso Natural Gas Company and Consolidation Coal Company lease the remaining 40,287 acres of the Navajo Fruitland field along the southern boundary of the Navajo Indian Irrigation Project. The lease contains estimated reserves of nearly 1 billion tons and it is scheduled for use with a 785 million cubic feet per day substitute natural gas complex planned by El Paso Natural Gas Company. Royalty arrangements of 20 cents per ton for coal used on the Reservation and 30 cents per ton for coal exported from the Reservation.

The Pittsburg and Midway Coal Mining Company lease the Gallup field, part of which is on the Navajo Indian Reservation lands about three (3) miles from the Arizona-New Mexico state line above Gallup, New Mexico. The part leased from the Navajo Tribe contains at least 75 million tons of strippable coal and the royalty is tied to the F.O.B. market price and will vary from 25 cents per ton up to 37.5 cents per tons. The Pittsburg and Midway Company provides coal for the Arizona Public Service Company Power Plant at Joseph City, Arizona. The Company mined 385,400 tons in 1970.

The Newcomb coal field is located on the Navajo Reservation and the Standing Rock field located partly on the Reservation, contain an estimated strippable

Table 7. Strippable Coal Reserves of the San Juan Basin in New Mexico.

Coal Field or Area	Depth of Overburden: Less than 150 feet, Known	Less than 150 feet, Inferred[1]	150 feet to 250 feet, Known	150 feet to 250 feet, Inferred[1]
	-------Millions of short tons-			
On or partially on the Navajo Reservation				
Gallup[2]	270.0		88.0	
Newcomb		78.5		6.3
Navajo Fruitland	1,024.7		1,352.8	
Standing Rock[3]		63.5		75.0
Subtotal	1,436.7		1,522.1	
Total on or Partially on Reservation		2,958.8		
Totally off the Navajo Reservation				
Chaco Canyon		31.0		
San Mateo		21.2		
Fruitland	93.0		65.0	
Zuni		6.2		
Crownpoint		15.0		
South Mount Taylor		1.4		
La Ventana		15.0		
Red Mesa		22.0		
Bisti		958.0		
Star Lake		365.0		
Subtotal		1,529.8		1,335.0
Total off Reservation		2,958.0		
Total	2,964.5		2,857.1	
Grand Total		5,821.6		

State Bureau of Mines and Mineral Resources, Strippable Low-Sulphur Coal Resources of the San Juan Basin in New Mexico and Colorado, New Mexico Institute of Mining and Technology, Socorro, New Mexico, 1971.

1 Inferred reserves are based on drill-hole or outcrop measurements more than a mile apart, and involve considerable extrapolation of data and projection of geological evidence. The inferred category encompasses a wide range of reliability, from that in areas in which drilling density is almost one hole per square mile but thickness variations are too great to permit accurate thickness contouring, to that in areas in which the reserve estimate is a speculation based on only a few measurements per township.

2 Approximately 50 percent of the acreage of the Gallup field is within the Navajo Reservation boundary.

3 The western portion of the Standing Rock field is within the Navajo reservation boundary.

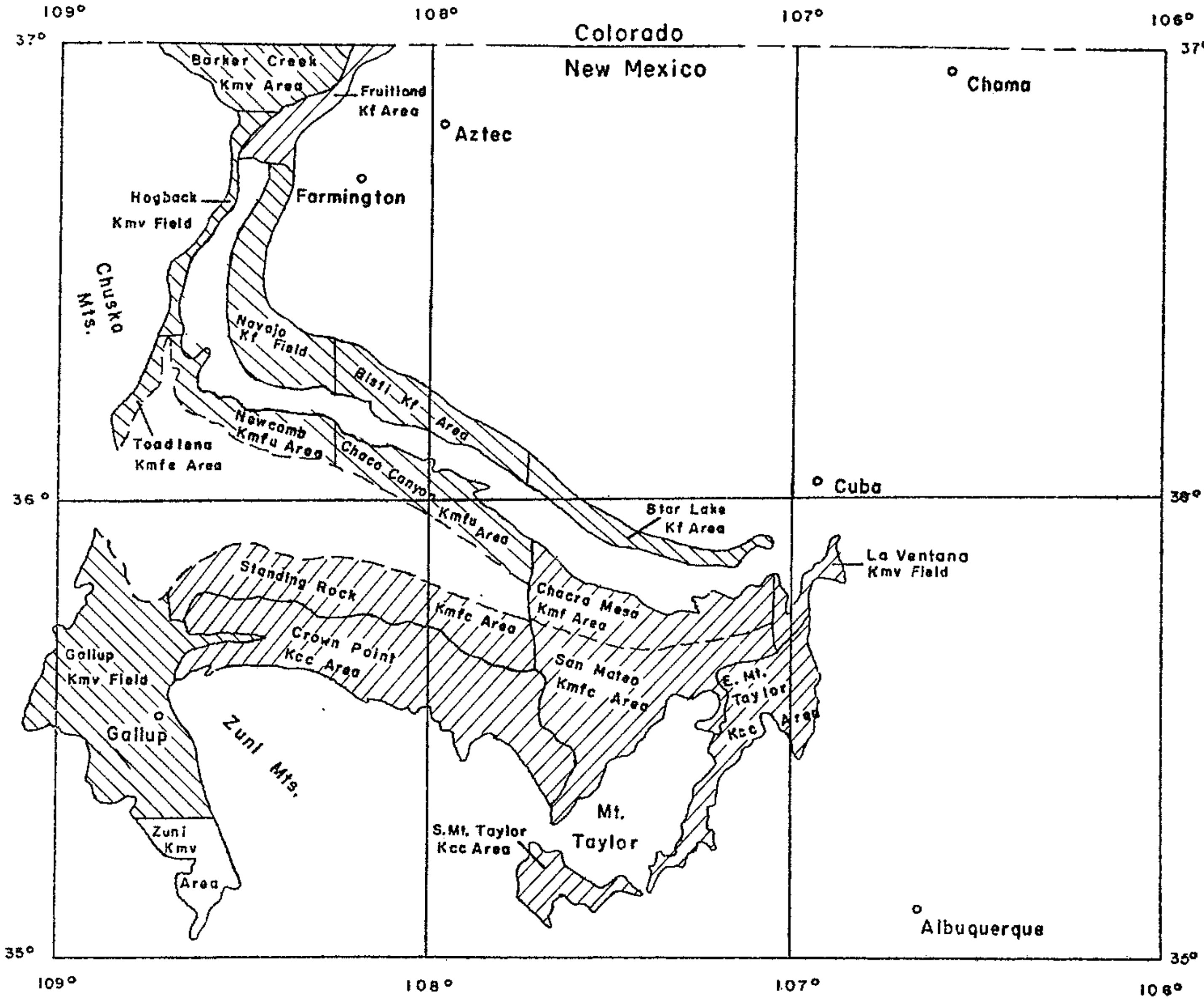

Figure 1: Fields and areas of strippable low-sulfur coal in San Juan Basin.

Source: New Mexico State Bureau of Mines and Mineral Resources reserve of nearly 80 and 138 million tons respectively and have not been leased.

The Western Coal Company has non-Indian coal leases adjacent to the Navajo Reservation in New Mexico. These leases provide coal for the New Mexico San Juan Power Plant located between Farmington and Shiprock.

Bisti and Star Lake are two of the most important coal fields in the San Juan Basin off Navajo Reservation lands. The Bisti field is immediately adjacent to the Navajo Fruitland field on the Reservation. The Bisti and Star Lake fields together contain about 1.3 billion tons at less than 150 feet of overburden and another 1.2 billion tons between 150 and 250 feet.

Existing and Planned Coal Powered Thermal Electrical Generation Plants

The Four Corners Plant located at Fruitland is owned jointly be Arizona Public Service Company (87 percent) and the Public Service Company of New Mexico (13 percent). The Power Plant was completed in 1970 with a capacity of 2,085 million kilowatts. The plant has 39,000 annual acre-feet depletion right (Utah International, Inc.) and would deplete 8.66 million tons of coal annually if operated at 100 percent of capacity.

The plant employs approximately 315 people with an annual payroll of 4.5 million dollars. Another 478 people are employed by Utah International, Inc. in coal mining with an annual payroll of nearly 5 million dollars.

The New Mexico San Juan Power Plant, a joint venture of the Public Service Company of New Mexico and Tucson Gas and Electric, is in the development stage. Unit 2 started operations in September 1973 with a capacity of 341 million kilowatts. Unit 2 will deplete approximately 10,100 acre-feet of water and 1.30 million tons of coal annually. Unit 1 came on line in early 1975, Unit 3 in 1977, and Unit 4 in 1979, with the four unit complex having a capacity of 1,740 million kilowatts.

Unit 2 of the San Juan Plant employs 92 people with an annual payroll of over one million dollars. The four unit plant will employ approximately 180 people and another 444 will be employed in mining activities for a combined payroll exceeding 7.25 million dollars annually.

Planned Coal Gasification Plants

WESCO. Western Gasification Company (WESCO), a joint venture of Texas Eastern Transmission Corporation and Pacific Lighting Corporation, has proposed to construct and operate a coal gasification complex and the necessary support facilities. Two subsidiaries, Transwestern Coal Gasification Company and Pacific Coal Gasification Company, would be responsible for the plant design, construction, and operation. Utah International, Inc. would have the responsibility of providing coal and water resources required for the operation of the gasification plant. WESCO is currently planning for an ultimate producation of 1,000 million cubic feet per day of substitute natural gas (SNG). The SNG production would be achieved over a 12-year period in four increments. The initial complex would produce 250,000 cubic feet of SNG each day in 1977 with the ultimate development to be reached in 1983.

Utah International, Inc. has a water right of 44,000 acre-feet of depletion annually which will be used by the WESCO Plants. Each 250 million cubic foot per day unit with current planning is expected to deplete 11,000 acre-feet of water and 9.13 million tons of coal annually. It is expected to have a combined plant and mine labor force of nearly 1,100 and an annual payroll of over 13 million dollars.

El Paso Natural Gas. The El Paso Natural Gas Company is planning on converting coal from their lease on the Navajo Indian Reservation to substitute natural gas according to the following schedule:

Unit	Date	Total capacity million cubic feet per day	Water depletion acre-feet annually	Coal depletion million tons annually
Burnham 1,				
Phase 1	1978	288	10,358	10.80
Phase 2	1979	325	11,660	12.20
Burnham 2,				
Phase 1	1980	613	22,020	23.06
Phase 2	1981	785	28,250	29.45

The complete complex is expected to provide over 2,000 jobs in plant operations and nearly 800 in mining activities. The combined annual payroll is expected to exceed $35 million when the project is fully operational.

Water Use Relative to Employment and Income Opportunities

Based on information developed by WESCO and El Paso Natural Gas Company, with 1,000 acre-feet of depleted water used for coal gasification, on the average will create 82 jobs and annual wages of 1.25 million (Table 8).[1] Each 1,000 acre-feet of water also yields nearly $187,000 in coal royalties to the Navajo Tribe.

Each 1,000 acre-feet of depleted water used for coal powered thermal electrical generation on the average will create approximately 25 jobs and annual wages and salries of $300,000.[2] Coal royalties to the Tribe would average about $43,000 annually assuming new leases paid a royalty of 20 cents per ton.

Based on the Navajo Agricultural Products Industry long-range plan, each 1,000 acre-feet of water used for irrigation would, on the average, create 9 jobs and annual wages of $55,000. Each 1,000 acre-feet of water used for

[1]Economic information from both companies was grouped and averaged to arrive at this estimate.

[2]See footnote above.

Table 8. Comparison of Estimated Direct Income and Employment Effects of Alternative Uses of Navajo Indian Irrigation Project Water[1]

Use	Direct Employment	Direct Labor Income	Direct Local Business Profits	Navajo Tribal Income
	number	dollars	dollars	dollars
	per 1,000 acre-feet of water depletion annual			
Coal gasification	82	1,250,000	minimal	187,000
Thermal Electrical Generation	25	300,000	minimal	43,000
Irrigation	12	80,000	8,000	35,000

[1]Other alternative uses, such as footloose industries or recharging underground reservoirs, were not included in this analysis because either there was considerable doubt as to their economic feasibility or water was not one of the major resource requirements.

irrigation should also return approximately $35,000 annually in business profits assuming an 8 percent opportunity cost for capital. Each 1,000 acre-feet of water used for irrigation should create about three (3) jobs and about $25,000 in labor income and $8,000 in business profits from purchases of goods and services other than labor in the local community. Coal gasification and electrical power generation industries make very few purchases in the local economy other than labor.

Each acre-foot of water used for coal gasification creates seven (7) times as many jobs and fifteen (15) times greater labor income than water used for irrigated agriculture (Table 8). Benefits paid directly to the Navajo Tribe are estimated at only four (4) times greater.

Water used for thermal electrical generation also has the potential of creating greater employment and income opportunities than if it is used for irrigation. Royalty income received by the Navajo Tribe is estimated at only slightly greater than projected business profits from agriculture.

It appears obvious that if immediate income and employment opportunities are of the greatest concern, and that no other resources (such as coal) are critically limited in supply, water should be diverted from agriculture to energy production uses. This also presumes that capital is available for energy development and a profitable market exists. Both of these conditions appear probable at the present time. However, there are other considerations such as the productive length of the development, depletion of non-renewable Navajo coal resources, and environmental impacts.

The planned gasification plants by WESCO and El Paso Natural Gas Company and the Four Corners Power Plant combined will deplete from 70 to 75 millions tons of coal annually under full production. The reserves on the Reservation under less than 150 feet of overburden are sufficient to support these plants for approximately 25 years. The coal reserves on the Reservation at depth from 150 to 250 feet are sufficient to support this level of mining activity for an additional 20 years. The Bisti and Star Lake fields off the Reservation have sufficient reserves to support this level of activity for another 30 to 35 years. There are presently no surface water rights available for development of the Bisti and Star Lake fields in the near future. The amount of Navajo Indian Irrigation Project waters that could be feasibly transferred to energy uses depends heavily upon the availability of coal reserves and the preferences of the Navajo people.

VIEWS FROM THE NATIONAL SCENE

Senator Pete Domenici

Let me first say that when I was asked to come here and participate with you in this rather historic and tremendously important conference, it was with a little reluctance. Not because I did not know of the significance of it, but because we do have some tremendous experts in this field, right here in this audience, far more expert than I.

They asked me to talk about National and/or Federal overview on the subject matter, water for energy development. That's pretty tough to do because if you want the true facts, the Federal Government is doing little or no thinking about the relationship of water to the concept of energy independence. I need not remind, you who are talking about new ways to meet America's growing energy needs, of the tremendous dilemma that America finds itself in today and why. Nor need I remind you of how hard it is going to be to shift gears.

I believe about 2 or 3 minutes of history would be in order so we can put it into prospective. About 23 years ago, the United States of America made an overt conscious decision to become a petroleum and natural gas oriented economy. At that point in America's history, crude oil could be brought to the surface of America, whether it be in the Permian Basin or in the shallow wells of Kansas, for about $2.65 a barrel. And it was beginning to flow in abundance, but there were some grave limitations. So very consciously America asked it's business people to go and see if they could find that very versatile

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Senator Domenici is a United States Senator from New Mexico.

black crude oil somewhere else in the world, in large quantities, and see if we could figure out a way to tie it into our supply and bring it here. The response was loud and clear and you all know what happened. In short order, the huge crude oil deposits of the Middle East were found and the startling information came fast across the ocean to America's industrial machine that we found it and it cost only 10 cents a barrel. And from that point in time, America went its merry way, with that kind of energy being developed over there and America's crude oil domestically rising from the astronomical amount of $2.65 to $3.25 in 23 years. We matched that 10 cent oil with our supply, and the great American industrial machine moved on. We reached the point where we began, adding natural gas and petroleum together, and became about 77% dependent upon those two commodities to generate the energy to move America ahead. Everything about our economic growth was suddenly tied to oil and gas. Never did we think that the Middle East would dare to take a look and see that we were 30% dependent upon that cheap oil, and then tell us that we could not have any more. Who would ever think that a cartel would be formed to call the great economic bluff. A cartel saying that we will give you some, but that we will charge you whatever we want. And while all that occured, the search for crude oil in America, in particular by its independent develop-ersers and wildcatters, went in reverse of the American growth graph. All of a sudden we find ourselves as the world's greatest industrialized nation, greatest producer of material goods that man-kind has ever seen, and greatest energy consumer, strutting a bit. We wonder how we are going to be able to keep the brisk pace we have in the past. Some say that we are going to have to walk and there are some pessimists who say that's too tough. As I view our national government's effort at moving toward energy indepen-dence, we have done a rather deplorable job in 18 months. Yes, we have created ERDA (Energy Research Development Administration). We are optimistic about it being the focal point for research and development moving toward maximizing alternative sources of energy for the people of America. But, it's not moving very fast. There are many reasons it isn't, but among them are that the jurisdiction in the energy field in the Congress of the United States has historically been spread among four or five committees. There is a great reluctance to put it all into one and get on with the job. I just checked the other day and in the last year of Congress, most energy related bills got referred to three major committees, a number got referred to four and some got referred to five, and that's only in the United States Senate. So I am delighted that here on this campus our best talents come together to talk about something we're not talking about in the Congress. Would you believe that the energy office of America, the one that's doing all the coordinating and predicting, have a statement in the summary of energy independence that says there is not concern about water as it relates to energy independence in America? According to this office, there seems to be no significant shortage, and we will get there with out any significant changes in our national policy. That is quite different from what other people are saying and I don't have to even read much about it or study it much to say that.

There is no doubt that water supply, will be an important consideration in energy development, and an analysis of water needs for future energy development should begin. People knowledgeable about energy matters should begin immediately with the available information to make judgments about water supply problems. In addition, an analysis of the water resources needs for energy development should be undertaken now.

Continued delay in developing a water resource plan for energy development could cause severe economic problems in the future.

ENERGY RESEARCH AND DEVELOPMENT AT NEW MEXICO STATE UNIVERSITY - 1975

Robert L. San Martin

A university is an excellent place for many types of investigation involving energy; for instance, the development of alternative energy sources, the socio/economic impact of the development of sources, environmental impact and also the promotion of conservation of energy. This University becomes involved in many of these fields via its role of teaching, research and service. The campus is a single location where one has a diverse group of people with expertise in many areas available to solve multi-displinary types of problems.

The University in its commitment to solving relevant problems, created in January of 1974, an Energy Research and Development Institute to coordinate energy research on the campus. Currently, approximately 30 major energy projects are in progress at the University. These involve research, development and demonstration projects, and represent almost $3 million of activity. This is a beginning, and it is anticipated that this program will be expanding to best meet the needs of the people of New Mexico, the Southwest, and the Nation.

Support for these programs come from a variety of sources. The 1974 state legislature recognized the necessity of energy research and development and a

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financial committment of $2 million to allow the universities in the state to begin projects. The University receives support from the Water Resources Research Institute, national agencies and private industry. Energy programs throughout the campus involved all the college and research units. Current projects involve the areas of electric power, water for energy, environmental impact of energy developments, energy in agriculture, the use of sewage and refuse as energy sources, geothermal energy, coal energy, wind energy and solar energy.

The area of electric power has been a tradistional area for the departments of Mechanical and Electrical Engineering. The Electrical Engineering Department has for a number of years run an Electric Utilities Management Program. This program is supported by a consortium of electric power companies in the Southwest ranging from Texas to California and into Colorado. Their main effort is analyzing large power systems, work that leads to more efficient and reliable transmission and distribution of electrical energy. The University is cooperating with Los Alamos Scientific Laboratories in the interfacing of the power that one would get from either one of these superconducting transmission lines, or from a possible superconducting storage system and how this would interface with the existing conventional power systems.

Water is an extremely important commodity, especially when one envisions the possible energy developments that will take place in the West, more specifically in the Rocky Mountain region. We've talked about coal, we've talked about geothermal, but there's also solar. We are in a prime solar area in the Southwest, and this along with mineral deposits that exist is going to require considerable water supplies in its development. Mr. Lawrence and Senator Domenici both mentioned the Tularosa Basin project. We're very proud that the initial funding of this project was made to the State Water Resources Research Institute on a study entitled, "The Feasibility Study for the Establishment of an Energy Water Complex in the Tularosa Basin". As initially begun, this is an intradisciplinary intrainstitution type of project. New Mexico State University, Los Alamos Scientific Laboratory, University of New Mexico and New Mexico Institute of Mining Technology are all working jointly on this particular project. It is a boost to this project that it has recently received an additional $100,000 from the Federal Energy Administration. Another project is "A Study into the Optimal Distribution of Energy Industries in New Mexico Relative to the Limited Water Supplies within the Area". This is being undertaken as a interdisciplinary study and the goals are to define the water requirements of industries that may locate here, to predict the secondary growth that would be involved with this type of development and to develop elementary models for the particular basins that would be affected by this development. These will be interrelated and attempts will be made to optimize this type of development through the year 2000. Another study involving the analysis of water characteristics of manufacturing industries and their adaptability to semi-arid regions is in progress. This is a joint study that is being completed with the University of New Mexico. In the area of conservation in use of water, there has been a project involving the trickle irrigation of cotton, for optimizing water use efficiency and energy conservation. The goal of this project is to derive the fruits from the crop and yet use less water in the production.

Environmental considerations in energy must cover all the various energy development fields. A recent project involved the evaluation of New Mexico's environmental regulations on energy costs. This is a joint project with University of New Mexico, attempting to integrate all the various factors involved in water quality, air pollution, solid waste disposal, land use, stripmining, radiation emissions and noise generation, and see how it would effect development. In the area of environmental considerations, we have a project involving the microbial growth in minespoil materials. As spoil materials are returned to the ground what must be done to encourage revegetation, and the rehabilitation of this ground? This project addresses this particular problem.

Another area involves agriculture. There is a large project involving the entire agricultural college in the development of policies for energy use in the food and fiber ecosystem of the Southwest. The first is modelling energy consumption throughout the entire food and fiber system; from the inception, through actual consumption. It is very possible that we may find some processing steps that are great users of energy, and could be modified to minimize the energy use in that particular area resulting in conservation.

Sewage and refuse is an area where there is interest. Our city will be taking more direct steps in evaluating this energy source. The type of activity mentioned here involves ways other than direct combustion that have been proposed for recovering the energy from refuse. A study involving several departments on campus is attempting to use enzyme and microbial generators to convert waste products into primary sugards which could be converted, if desired, into ethyl alcohol or methane for use as an energy source. Projects in the area of geothermal energy, involve investigation into and a careful inventory of New Mexico's thermal springs. Chemical geothermometers are used to assess the base temperatures available in geothermal pools and to determine the hydrological potential of these areas for expanded geothermal development.

An area that has been addressed by many of the speakers today is coal. One thinks of coal as "King Coal" with regards to what will be needed in this country in the very near future. Some of the projects addressing the problems of coal gasification were described by other speakers. There is a project in the chemistry department evaluating molten catalysts for the methanation phase of coal gasification. This is an important step in the total process of gasifying coal. Any improvements will help the efficiency of existing processes. Another project is addressing the use of brackish water, which is plentiful in this state, for use in coal gasification. This particular project is investigating the primary gasification reactions to determine if brackish waters could be used in the process. The socio-economic impact of coal development is a very serious problem, and should be carefully considered. A study of this problem at the University involves the impact on the rural communities of developing New Mexico's coal resources. There is always a possibility of a boom and bust syndrome. The long range impacts of these cycles and how to handle them must be studied. Stripmining in various areas will show that recovery and rehabilitation of coal mined areas are going to be very, very important. A major project is studying rehabilitation in San Juan County. Samples have been taken of the original soils and work is proceeding to determine the best species of plants to be used for revegetation, and to determine the optimum topographic design. As a complementary study, the movement of tract elements is overburden and native sandstone is being followed. The problems of trace elements infiltrating the water table are being anticipated.

One can use low Btu gas in many ways to further develop the coal that is available within New Mexico. A study in the chemical engineering department is investigating how low Btu gas can best be used for the solvent refining of other coals. We can possibly use low Btu gas in metal recovery type processes and in methanol production or in sulfur recovery processes as well.

The area of coal is quite important to the state and to the nation. The Energy Institute at New Mexico State University will be sponsoring a coal symposium on campus Friday, April 18th. There will be a series of invited speakers from throughout the nation. I invite all of you to attend this particular symposium. The topics that will be addressed during the symposium include the geology of coal in New Mexico, the recovery and rehabilitation of stripmine areas, coal liquefaction, coal gasification, coal combustion and power production, and the socio-economic effects of coal developments. The university also has an interest in wind energy, another possible alternative source which requires development. The astronomy department had a need for energy at a very remote location, Blue Mesa Observatory, which is approximately 18 miles from the closest electric power. At this particular location, delicate astronomical equipment is often unattended with automatic devices maintaining temperature levels. Portable fuel, powered generators and bottled gas proved unreliable for heating. A wind powered electric generator was made by refurbishing an old windmill. They have been able to produce electricity, store it in electric batteries and use it on demand. This has been the most reliable source of power for this particular site. This wind turbine is not large enough to supply the entire site, but the possibility of further development of wind power at Blue Mesa is currently being explored.

Solar energy is an area in which this university has been involved in for some time. It is quite natural for this part of the country to be concerned with solar energy because if we look at a map of the United States, the darker area is that region which receives the largest amount of solar energy. The State of New Mexico is virtually unequaled in total solar energy as a large land mass. If we look at the solar energy New Mexico receives and compare it to what is received in the large deserts of the world, the Sahara Desert and the deserts of Australia receive more solar energy than New Mexico, but only 10% more.

(Some of the current projects are listed on the following page.) These slides show three different types of collectors. On the right is one that trickles water down its front surface. On the left is a very conventional type solar collector with a tubular pattern in the metal sheet and fluid circulates through this particular metal. In the center we have a New Mexico State University invention, a thermal trap collector. In this particular application a thick piece of acrylic plastic is placed adjacent to the collector plate and therefore is able to achieve relatively high temperatures. This becomes very important in certain types of solar collector applications. One

GEOTHERMAL

An inventory of the southwestern New Mexico thermal springs is underway. These resources are having chemical geothermometers applied to them to assess their temperature base. Also, a preliminary assessment is being made of the hydrology to estimate the potential of these springs. Another project will assess the geothermal potential of most of Arizona and western New Mexico for its application to the desalination of brackish water.

ELECTRIC POWER

This has been a traditional area of work for several academic departments at NMSU. A program in Electric Utilities Management is supported by a consortium of electric power companies in the southwest and has done considerable work in analyzing large power systems, specifically the areas of transmission and distribution. Another project is addressing the problems of interfacing superconducting transmission and storage devices with a conventional power grid.

WATER

Located at NMSU is the state's Water Resources Research Institute. Most of the water related projects are administered through this institute. Programs in this area have typically been interdisciplinary and intra-institutional. A current one is a feasibility study for the establishment of a water-energy complex in one of the large closed saline water basins in the state. Such a development may be capable of producing several thousand megawatts of electric power and up to one million acre feet of desalted water per year, for several hundred years. Another investigations involve a determination of the optimal distribution of energy industries within the region relative to the limited water resources. Simultaneously, another study is underway which is analyzing the water characteristics of manufacturing industries and their adaptability to semi-arid regions. Likewise, conservation studies are underway such as the development of trickle irrigation methods for water intensive crops such as cotton, as a means of optimizing water use.

ENVIRONMENT

NMSU also houses an Environmental Institute which addresses the broad range of environmental considerations. In more directed work in energy, a study is underway which is evaluating the statewide environmental regulations and their impact on energy costs. Another project is in progress which addresses the problems of microbial establishment in minespoils as a mechanism to enhance the rehabilitation and revegetation of these areas.

> This nation has to prepare for a decade of energy emphasis as shortages continue, alternatives are sought, and lifestyles shift toward lower energy use. Many people are inclined to take a narrow view of the energy situation. Some believe the worst that can happen will be fuel oil in short supply, gasoline rationed again and utility bills higher. The consequences can, and probably will, be much more serious because the cost and availability of energy influences the cost of nearly all consumer products and services. As one of the major energy producing states in the nation, New Mexico, through the research at its universities and federal laboratories, hopes to play a major role in the nation's energy research program.

SOLAR ENERGY

NMSU is fortunate in having over a quarter of a century of experience in solar energy research. During that time the faculty and staff have published over 60 technical papers on the subject. Currently, work is in progress in the areas of solar heating and cooling, solar thermal power and clean fuel production.

In October 1975 New Mexico State University will have on campus the largest building of its kind in the nation to be both solar heated and cooled. This 25,000 sq. ft. building will have 7,000 sq. ft. of solar collectors located on its roof and will house the offices and specialized laboratories of the New Mexico Department of Agriculture. The University is also building a solar demonstration house on the campus, which will be solar heated and cooled. This full-sized laboratory will be used for developing and testing solar heating and cooling equipment. It is a 1,900 sq. ft. 3-bedroom facility and will be operational in the fall of 1975. Work is also in progress on the development and testing of various types of solar collectors.

Another solar energy study is in partnership with Egypt. The goal of this project is the design, construction and evaluation of a 5 kilowatt electrical closed system solar thermal prototype power plant and the design of a 100 kilowatt unit. The first phase of this project will be completed and operational in calendar year 1975.

Basic research is underway on the solar production of hydrogen. The method being investigated is a continuous catalytic process which would produce hydrogen from water through the photochemical trapping of solar energy.

COAL

Current programs include coal gasification, socio-economic impact, and recovery and rehabilitation studies and other coal related technology developments.

Basic studies in the evaluation of molten catalysts for the methanation phase of coal gasification are in progress. The use of brackish water for coal gasification is also being studied. The approach being implemented is an experimental investigation of the primary gasification reactions when brackish waters are used. The socio-economic impact on rural communities of developing coal resources is under investigation.

Restoration of surface-mined land in northwestern New Mexico is being approached by identifying the status of the original soils, what the overburden material will be, determining the best species for revegetation, and an analysis of optimum topographic design needed for revegetation. Simultaneously, a study is underway which identifies the movement of trace elements that one finds in many of the overburden and sandstone materials.

Another project is the development of New Mexico's coal potential via the use of low Btu gas. The aims are to evaluate the use of this gas for the solvent refining of coal, metal recovery in the associated chemical processes, methanol production and sulfur recovery.

OTHER

NMSU has begun a study on the initial development of policies for energy use in the food and fiber ecosystem of the southwest. Such a study would identify the energy consumed by the various steps and processes that are involved in the total food and fiber cycle, and lead to identifying alternatives which could reduce the energy consumption in this overall process.

A project is also ongoing in the conversion of sewage and refuse to energy sources. This study addresses the use of enzyme and microbial generators to convert these products into primary sugars which are then processed, if desired, into ethyl alcohol or methane.

goal here was to develop a solar collector that could operate at relatively high temperatures, 200°F and above, and also be relatively efficient. The work on this thermal trap collector is continuing under a university grant. A comparison of the thermal trap collector to the right collector: It is about half the size, but collects eight times as much energy from the sun on a typical day. This is the type of development needed. These collectors may give us a breakthrough in better collection of the energy at a much higher efficiency. The reason for developing this type of collector is for the application of solar heating and cooling. There are two major projects going on at the University. One involves this particular building, the New Mexico Department of Agriculture Building. It's been in the planning stage for several years and now is under construction. When completed it should be the world's first large solar heated and cooled building. This particular building is over 24,000 sq. ft. It will be heated and cooled by the power from 7,000 sq. ft. of solar collectors located on the roof. In order to have energy for nighttime use and for those periods without sunlight, we will store collected energy from the sun in two large underground tanks, each of 15,000 gallon capacity. The stage of construction may be seen in this slide showing where the ceiling support beams are currently being installed. Construction of this building began in October 1974 and it is expected to be completed in October of this year. This slide shows one of the thermal storage tanks for the building. It will hold pressurized to stop it from boiling at this temperature. Here, the storage tank is having a coating of insulating material applied to the exterior. Each tank has about 3 1/2" of insulating polyurethane foam to retard heat loss. These are the holes that the storage tanks fit into. These are located underneath the building. The two storage tanks are shown in place with one of the construction workers standing next to it to give an idea of the size of each tank. This is the cap of the tank that is inside the instrument room of the building.

Now in designing this building there was concern about many things: 1) Cost, 2) What energy savings could be realized, 3) Will it be possible with the currently available technology to undertake such a project and be successful. After many hours of discussion on all these points, it was decided that we could successfully attempt this type of project. This decision was made almost two years ago. We decided to go ahead with the solar heated and cooled building using a different type device for cooling, an absorption refrigeration cycle. This building will have mechanical refrigeration. Feasibility studies were done to determine the expectations of this system.

It is predicted that the solar heating and cooling system will provide about 80% of the building's heating, cooling and domestic hot water requirements. Why 80%, why not 100%? There are various reasons for this. We could provide 100% of the energy requirement, but we are counting against ourselves the electricity required for pumps and fans to operate the solar system. Also, if you plan for many consecutive days of sunless skies, you would build bigger storage tanks, to store more energy. It you look at covering all of these contingencies, you soon find that the cost of your storage tanks starts to approach the cost of your building, so the decision to go less than 100% solar is an economic decision. You look at the cost of your alternative fuels, what you can use as an auxiliary heat source for the building when you need it, and then you pick the eonomic optimum of all of these to decide what percentage of your system should be solar and what percentage should come from some other energy source. Now an optimum of this sort does not apply throughout the nation. That is the optimum for this area of the country, and the optimum very strongly depends on the cost of your alternative fuel and the climatic environment. For instance, studies have shown that in my home state of Florida, if you were to have a solar heated residence, the economic optimum of operation you would want to have 15% of your heating supplied by the solar system and 85% by your auxiliary. You get some funny turnarounds when you look at developing the economic optimum.

We designed this particular building in conjunction with the senior architects of W.T. Harris & Associates, the mechanical engineering consulting firm is Bridgers & Paxton and the University's own consultants. The project was approached in a slightly different manner than is usual because it is unique. The entire building, including all associated internal equipment, was bid as an individual package with the exception of the solar collectors. The solar collectors for the building are currently in the bid process. We haven't decided on what type of solar collector to use on this building because there are so many people working on collectors and we wanted everyone to have an opportunity to develop the state of the art in that particular component of the building. We have also had some very interesting experiences in going out and trying to bid the solar collectors. No one has ever attempted to look at collectors before in this type of process. We did not want to buy the lowest cost collector; we're liable to come up with a White Elephant. So we're going through a multi-step process.

We received a variety of bids. We selected the five best collectors from these bids and now we're getting ready to comparatively test all of these collectors on the roof of the Physical Science Laboratory. We will pick the collector that best suits the requirements of the new building. This may not be the lowest cost collector.

This slide shows some of the early stages in construction of a test stand that will actually house all the collectors. Here is one of the support brackets to hold the collectors in place. We've found that the people responding to the bids have some very special problems. Legally, the University requires that any bidder post a bid bond and later a performance bond on a particular item. When a firm goes to its insurance company and requests a performance bond for solar collectors, the insurance company often respondes with, "What is a solar collector--we've never done this before--why should we do it this time--maybe it should cost you a little extra money because we're delving into an unknown area." We found that some of the small organizations that tried to respond with bids on this project had great difficulty in being bonded for this non-standard item. These are some of the non-technical problems that have to be addressed before solar developments can be realized in a large portion of this nation.

Concurrent with building a solar University building, we have a solar house under construction. We expect to have about the same amount of the energy provided by the solar system, about 80% of the heating, cooling, and hot water needs of the house. The University retained the architectural firm of Dean and Hunt in Albuquerque for this particular project. Many of you may have noted an architect's model of this house at the entrance to the Physical Science Laboratory Building today. It is a 1900 sq. ft. residence with approximately 750 sq. ft. of solar collectors. It has been receiving a great deal of interest from the people in this area.

The types of solar heating and cooling systems we have been talking about use the arrangements shown in this slide in order to operate. One for heating applications and another for cooling type of applications. As we generated interest in this project, we have had a variety of groups join with us to become partners in this project. They have supplied us with not only information, but also materials and, in some cases, money. The local firm of Builders Block & Supply has donated all our blocks for our project. The New Mexico Sand and Gravel and Readymix Association has donated these supplies to the project. Pittsburgh Plate and Glass out of Pennsylvania is donating all the glass that we require and the Copper Development Association from the New York area is donating all the copper used along with all the solar collectors for the particular project. A cross section through the building indicates the location of the solar collectors, looking at it from the south; in one instance they'll almost reach the ground. There are some burms here that bring the round about three feet higher than the level of the building in this particular area.

The state building inspector is very concerned, as we are, about possible conflects with building codes. There will have to be changes in this area to allow people to use some of these solar systems. We have already seen some of these problems and are working at possibly recommending either changes or new codes that the state might adopt in order to handle these problems.

We picked a sight for the house south of the University golf course, near the Interstate. We hope to develop the landscape in the natural desert style. The home itself is now walled to the roof line. The angle structure you see in this slide will be supporting the solar collectors. The building should be completed in October. We are making provisions for people to take tours not only of the solar house, but, with the help of Dr. Bill Stephens, the Director of the New Mexico Department of Agriculture, of the new Agriculture building as well.

Another area of solar application will be producing electric power, solar thermal power application. We are very fortunate to have the largest solar furnace in the United States at White Sands Missile Range. We are also fortunate that the University has a two year grant from the National Science Foundation for developing the first solar thermal electric power plant. This is being done in partnership with the Egyptian government. This plant is under construction right now just outside of Cairo. The solar collectors for the plant are already available and so is the boiler. We are currently in the process of purchasing the remaining components for the system. Five kilowatts electrical energy is not very much by our standards. That is about half of what you need for a normal household. This plant will be a prototype. We hope to learn how to optimize these systems. Part of the project includes developing second generation design so that larger plants of this type can be built. Some of the decisions that have already been made include changing slightly the type of solar collector system that will be used, and going to a system where we will have planer mirrors that actually reflect the sun's energy to the central boiler itself.

In this area we also have another project going on at the Physical Science Laboratory. One of the critical areas involves providing controls for devices that are used to track the sun. This slide shows a test set up. The decorations are not involved in the overall control loop. This particular set up is developed for accuracy, reduced cost and all of other parameters that you need in solar collector tracking systems, especially of the type that you're going to need for large scale developments for the production of electric power.

In November 1974, this University co-hosted with White Sands Missile Range the nation's international seminar on large scale solar test facilities. We had as guests at this University interested people from France, Japan and Italy, along with many attendees from the United States. The current state of the art in large scale solar power type of applications was discussed. Basically, one of the goals of the conference was to develop preliminary information for our Energy Research and Development Administration agency on the requirements for a five megawatt thermal solar test station for this country. A test station this size would be five times larger than what the world's technology has now produced in large solar installations. This test station was discussed at the conference by a variety of people, including federal representatives. Three sites within the United States were chosen for this type of development. One, the area around China Lake, California another the area around Yuma, Arizona and a third being the area of Southern New Mexico and West Texas. The federal government has announced that they will be building such a facility which will be in the multi-million dollar range. The Energy Institute is currently taking steps to organize people from New Mexico and Texas into a group to work towards locating this facility in the Southern New Mexico and West Texas area.

Another solar application that is being looked at by our chemistry department is how to use the sun's energy to break water into oxygen and hydrogen, considering that we have in the oceans large supplies of water and that hydrogen could become one of our fuels in the future. This project is proceeding and the University has applied for a patent for this particular process.

Senator Domenici mentioned the Solar Energy Research Institute. This project has advanced as far as a definitive proposal outlining what such an institute should do for this nation. This proposal represents a New Mexico consortium of the Governor's Office, the State of New Mexico in total, the New Mexico Technology University, University of New Mexico, New Mexico State University, Sandia Laboratories and Los Alamos Laboratories. Talks are going on right now and I hope that within a few months this consortium will be a multi-state consortium for work towards attracting this national laboratory to an area of ideal solar environment and also an area that has large groups of people involved in solar energy developments. I personally feel that the university structure can make a very definite contribution to our overall problems and their solutions. I think that the University will continue to be involved in this particular area and even though I expect some hard times, times of conservation of not only energy, but many of our resources in the broadest sense, I do believe that we are going to make significant strides in this country to alleviate problems of this sort.